A Statistical Analysis of Characteristics of Mesoscale Convective System Mountain Initiation Location Clusters in the Arkansas-Red River Basin

By

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Thesis Abstract

Mesoscale Convective Systems (MCSs) are the focus of this analysis since it is the convective weather category which is smallest in number but produces the highest amount of precipitation. Being able to forecast these MCSs will make it easier to anticipate flooding events that can occur with these systems. The multi-sensor precipitation data, a combination of satellite, radar, and rain gage data, was used in Tucker and Li (2009). The MCSs initiating west of 104˚ W in the warm season (April – September) in the years 1996 to 2006 in the Arkansas-Red River Basin were used in this analysis. A cluster analysis was run on this data to group the MCSs to preferred locations. It has been shown that convective weather has preferred locations within the Rocky Mountain chain (Tucker and Crook 2005). The clusters containing 20 or more members are used in this analysis. Data for the surface and upper air variables was gathered from Iowa State's online database (Iowa State 2011) and data for the North American Regional Reanalysis (NARR) data was gathered NOMADS (National Climatic Data Center 2011). Once observations for all the variables were gathered for each MCS cluster, Multiple Linear Regressions (MLRs) and Principal Component Analyses (PCAs) were determined for the six hours prior through the three hours after initiation. The analysis of these model runs could help determine the characteristics needed for MCS mountain initiation within the cluster domain. The results from these analyses can be used to anticipate MCS mountain initiation if the conditions are known.

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1: Introduction

Convective weather systems produce copious amounts of precipitation each year, causing flooding which can lead to destruction of property and loss of life. However, these systems can also provide beneficial precipitation for agriculture and river systems (Doswell et al 1996). These convective weather systems can be divided into three categories: Single cell systems (which for this analysis include supercells), multiple cell systems, and Mesoscale Convective Systems, also known as MCSs. MCSs include a well-known subset called the Mesoscale Convective Complex (MCC). Out of the three categories, MCSs produce the biggest percentage of precipitation overall in the central United States (Tucker and Li 2009) and are the focus of this analysis since they are difficult to forecast.

1.1: Overview

For areas immediately east of the Rocky Mountains, the precipitation produced in the mountains can be of great concern after it reaches the creeks and rivers. Mountain thunderstorms produce most of the precipitation in the Rocky Mountain region. Although relatively rare, thunderstorms that become an MCS can form in the Rocky Mountains and travel out onto the adjacent plains (Banta 1990, Tucker and Crook 1998). The mountain water runoff produced by an MCS (or mountain thunderstorms) will reach the plains, adding to the precipitation already received from the system on the plains. This twofold amount of precipitation can cause flooding or compound any already existing flooding problems. These flooding events are hard to predict. It is important to study the formation and initiation of such major precipitation producers since these systems are prone to causing flooding. These major precipitation producers also provide beneficial precipitation which is important to anticipate as well.

It has been estimated that MCSs produce between 30 and 70 percent of the total warm season precipitation with a much higher percentage of precipitation occurring for MCSs in June through August (Fritsch et al 1986). Fritsch et al (1986) also found that the training (several systems moving over the same area throughout a given time period) of MCSs can produce even more precipitation than hurricanes and therefore is of vital importance to study and understand. MCSs can cause a range of severe weather including flash floods and lightning which can severely affect everyday activities (Banta 1990) and over half of MCCs in the United States form in the Rocky Mountains (Maddox 1980).

1.1.1: Forecasting Difficulties

Forecasting for a flooding event or a heavy precipitation event can be a difficult task. The setup may seem perfect for heavy precipitation to occur but changes may prevent the event from occurring. Conversely, it could appear that a heavy precipitation event setup is not present but the heavy precipitation event still occurs. Even though heavy precipitation occurs, a flooding event may not occur, so the precipitation could be considered beneficial. Some atmospheric conditions could not be seen or changes could occur and this would affect if convection were to actually initiate. If the atmospheric conditions are not seen, it is very difficult to forecast for an event.

Flooding events can be more severe when MCSs train over the same area over a number of days, bringing profuse amounts of precipitation to one area. The soil becomes saturated and the runoff increases, creating an even bigger flooding issue. Forecasting for MCSs is an important step forward in helping people be prepared if a flooding event from an MCS occurs.

1.1.2: Importance

Major precipitation producers such as MCSs can provide precipitation to locations which are in need of water. The importance of studying MCSs is to determine the necessary characteristics needed for initiation. Once these necessary characteristics are known, more accurate forecasts can be obtained and more precise warnings can be issued.

A large portion of these major precipitation producers are considered destructive in nature, but they can also be helpful in providing much needed precipitation for an area experiencing a drought, for agriculture (Maddox 1980), or to replenish depleted reservoirs. Finding an easier, more effective way of forecasting for these types of events is of upmost importance.

1.2: Statement of the Problem

This analysis will focus on the ingredients necessary for MCS mountain initiation (MCSMI) off certain peaks in the Rocky Mountains in Colorado (CO) and New Mexico (NM). Several questions will be answered during the course of this analysis and goals have been set to determine the possible viability of using the following analysis as a first step towards a potential forecasting tool for MCSMI within the Arkansas-Red River Basin domain.

The questions to be answered within this analysis include: Do preferred locations for MCSMI exist within the Rocky Mountain chain? What are the warm-season conditions needed for an MCS to form within the entire global domain and within a general area? Which variables appear most often within a general area? Which variables appear least often within a general area? What is the contribution given with the inclusion of a variable? Are variables utilized the same way in multiple clusters or does the variable's use change from each general area? Are the variables hour dependent, meaning the variable is only used in a few of the model runs but not all of the model runs? These questions will be answered throughout the analysis in each of the 29 clusters being analyzed and the overall model runs being analyzed as well.

In Chapter 2, background for convective weather systems, mountain meteorology, and

MCSs will be discussed. In Chapter 3, the data and the methods used will be discussed. This discussion will include the original Tucker and Li (2009) database and the variables used for each MCS. In Chapter 4, the analysis of the individual clusters will take place, ordered from largest to smallest. In Chapter 5, a discussion of the global results will occur. The figures and tables are included at the end of each cluster discussion in a subsection which makes the figures and tables easily accessible. Chapter 6 is a conclusion of all of the analyses and any remaining questions will be answered.

2: Background

Multiple studies have been performed on MCSs in general as well as those relating to mountain meteorology. A discussion of MCSs and mountain meteorology will be provided. A review of convective weather systems along with general conditions for convection will be conducted in Section 2.1. Mountain meteorology will be discussed in Section 2.2 and MCSs relating to mountain meteorology will be discussed in Section 2.3.

2.1: Review of Convective Systems

There are three types of convective weather systems – single cell systems, multiple cell systems, and MCSs. For convection and Deep Moist Convection (DMC) to occur, three conditions need to be met: a conditionally unstable environmental lapse rate, sufficient moisture, and a lifting process. Once convection initiates, the precipitation rate in one area can be determined by system movement speed, system size, and variations in rainfall intensity (Doswell et al 1996). More organized convection occurs with increasing wind shear and instability. These organized systems occur in clusters, which can be termed multiple cell systems, and lines, which can be termed squall lines (Moller 2001).

The atmosphere needs to be destabilized to the point where convection can occur. This can transpire in a number of ways including either lifting from a front or lifting of an air parcel over topography or forced upward motion. Other preconditioning processes include boundary layer mixing, advective processes, and mesoscale dynamical processes. Mesoscale dynamical processes tend to happen in one location but affect another location through the propagation of gravity waves (Johnson and Mapes 2001). Outflow boundaries can also be used as a lifting mechanism for further development of cells and can help destabilize the atmosphere after the system has initiated (Doswell et al 1996).

Convective Available Potential Energy (CAPE) and Convective Inhibition (CIN) are important to convective initiation in that CIN needs to be overcome for initiation to occur and CAPE provides the buoyant energy needed for the parcel to rise. CIN is typically at its maximum in the morning and will reduce more as daytime heating occurs. CAPE varies widely. An accurate representation is not given with the sounding network because it may show that CAPE is too small for initiation in one area, but the sounding area is so sparse that not every area is covered. Forecasting difficulties arise when trying to apply a sounding at one location to a general region (Johnson and Mapes 2001, Moller 2001).

Each convective weather type needs the above environmental conditions but there are also conditions necessary to only one type of system.

2.1.1: Single Cell Systems and Multiple Cell Systems

Single cell systems occur when there is not enough lift present in the gust front to initiate new cells. Once the downdraft begins to dominate the cell, the cell will dissipate, giving rise to the single cell system. For the purposes of this analysis, supercells are considered single cell systems. A difference between a single cell system and a supercell is that the single cell system's updraft is driven only by buoyancy and the supercell's updraft is driven by a combination of buoyancy and vertical pressure gradient forces (Byers and Braham 1949, Doswell 1985). The precursor environment for single cell systems includes relatively light winds and light vertical wind shear. However, supercells occur in environments with stronger winds and stronger vertical wind shear. The precipitation seen with larger systems is not seen with single cell systems (Chappell 1986, Weisman and Klemp 1984). Single cell systems tend to initiate at the time of maximum daytime heating and CAPE tends to be relatively small (Moller 2001). The transition from a single cell system to a multiple cell system can be determined by observing both the wind shear and the CAPE (Weisman and Klemp 1982, Weisman and Klemp 1984).

Multiple cell systems are formed when there is repeated new cell development along the gust front. These new cells can be considered ordinary and only have a lifetime of 30 to 60 minutes but there is enough new cell development for the system to be considered a multiple cell system. New cells tend to initiate on the downshear flank because of the position of the environmental wind shear and the gust front (Doswell 1985). Multiple cell systems tend to have LIs of less than -8˚C indicating that the air at the initiation location is very unstable. Low-to-moderate vertical wind shear is also present in the precursor environment of multiple cell systems (Chappell 1986).

2.1.2: Mesoscale Convective Systems

In 1980, Maddox wrote the defining paper on MCCs. Zipser (1982) was one of the first to use and coin the term Mesoscale Convective System. The orogenic MCS was first described by Tripoli and Cotton (1989). Tripoli and Cotton (1989) and Tucker and Crook (1998) provide details on the initiation characteristics needed for an MCS to form within the Rocky Mountains.

MCSs cover a broad range of storm types including squall lines, bow echoes, and MCCs. There are several definitions associated with an MCS since there are a wide range of conditions that can initiate the system and several storm types included within the MCS definition. According to Fritsch and Forbes (2001, referred to as FF01), the MCS has a mesoscale circulation with convective processes driving the system and is multicellular. MCSs last for several hours and may last for days if the conditions are right. This convective system will form an anvil due to the persistence of the convection, the updraft strength, and the number of individual cells. This anvil will show up on satellite images which makes the classification of the MCS much easier (Doswell et al 1996). According to Jirak et al (2003), May, June, and July, all have equal chances of producing an MCS with April as the month in which an MCS is least likely to form within the warm season. The larger the system grows, the longer it will last, and the more likely it is to become an MCS (FF01). An MCS is a general term that covers several types of systems including squall lines, bow echoes, and MCCs. A wide variety of initiation conditions occur but there are some environmental aspects which are always present in the precursor environment.

An MCS begins with single-celled systems, typically in the late afternoon/early evening. The single-celled systems evolve into a multicellular structure that eventually produces an anvil/cold cloud shield as the MCS reaches maturity. Due to the nature of the system, severe weather is typically seen early in the MCS lifetime while flash flooding is typically seen later (FF01). This flash flooding is compounded when multiple MCSs train over the same area due to the rainwater that is already present (Doswell et al 1996).

MCSs are more likely to form after a system has been evolving awhile. The outflows from the individual cells merge and create one giant cold pool which initiates new cells easier than the individual cold pools (FF01, Weisman and Rotunno 2004). The large scale environment also plays a role in the initiation of the first cell and the continued formation of new cells. The large scale environment can determine if the system being initiated will eventually become an MCS (Chappell 1986).

Once an MCS forms, it has been shown that it can alter the large-scale environment to the point that it is favorable for cyclogenesis, though this does not occur often (Stensrud 1996). Also, an MCS can alter the large-scale environment through the generation of vorticity. A positive potential vorticity anomaly is created at midlevels and is offset by the generation of a negative potential vorticity anomaly at the tropopause. The anomalies create favorable conditions for future MCS generation. These new MCSs are more likely to train over the same area, leading to more flash flooding (FF01). This training can also lead to an extra inflow of moisture, producing a positive feedback, and is more likely to set off new convection, with more moisture in that convection (Stensrud 1996).

The precursor environment for an MCS includes features at multiple levels. At 850 mb, there is a southerly wind component present prior to initiation for most of the MCSs (Jirak and Cotton 2007, referred to as JC07). This wind level has also been considered, by JC07, as a proxy for the Low-Level Jet (LLJ) which is a recurring feature prior to MCS initiation. It tends to brings in moisture to the region, which is shown by the very moist conditions seen at the surface prior to initiation. According to JC07, other features, such as convergence and warm air advection, are not seen as often in initiation as the LLJ. The convergence of the air can aid initiation since it provides the possibility of rising air. Just because convergence is present, does not mean the air will rise and there has to be a mechanism to force the air to rise. The warm air advection will bring warmer air to the region (JC07). LLJs have been found to be important to convective initiation. They transport heat (temperature advection) and moisture (moisture advection) into the initiation location. It has been suggested that the LLJs and the jet streaks are coupled and not separate entities. Upper tropospheric and lower tropospheric jet streaks work together to create the region of convective instability which tends to occur when the jet axes are orthogonal and advections are maximized (Uccellini and Johnson 1979). The precursor MCS environment has been found to be more unstable in general and wind shear is greater than in widespread convection (JC07). According to JC07, storm relative helicity’s (SRH) best value for MCS initiation is 60 m^2s^{-2}. This value of SRH corresponds to a concentrated group of thunderstorms and was determined by JC07 as the optimal threshold for MCS initiation. JC07 also discussed that the maximum SRH value occurs near the initiation location of an MCS.

According to JC07, MCSs tend to develop slightly upstream of a broad ridge and form in the right entrance of a jet streak. Strong warm air advection at 700 mb is seen prior to convective initiation that will eventually become an MCS. The area where the warmest warm air advection occurs tends to be located at the point of initiation. A strong LLJ is observed from the southwest at 850 mb, bringing moist air into the region. For MCS development, there also tends to be a region of convergence along an east-to-west oriented boundary that sits in unstable air. The point where the LLJ and the boundary intersect is the area most often seen to initiate MCSs (JC07). Different values of wind shear will create different MCSs, for example, large CAPE and strong wind shear tend to create bow echoes. Primarily, MCSs initiate with slightly larger wind shear than is seen with single cell systems and can have very strong wind shear, however, once the wind shear is too large, it becomes a hindrance to convection (Johnson and Mapes 2001).

MCSs have also been observed forming along fronts and other large-scale features. According to JC07, the stationary front is the type of front most likely to start the convection needed for an MCS. Cold fronts are the next most likely feature to start convection. The third most common type of feature in beginning an MCS initiation is the trough. While drylines are favorable for convection, they are not favorable for MCS initiation (JC07). According to Tripoli and Cotton (1989), solenoidal circulations are used to generate the circulation that can lead to MCS Mountain Initiation (MCSMI). These solenoidal circulations occur every day with the heating of the slopes and the formation of upslope and downslope winds.

The temperature profile throughout the atmosphere can affect the potential for convection. The atmosphere tends to be cooler near the tropopause and in the lower troposphere and warmer in the upper half of the troposphere for MCS initiation, according to FF01. While the temperature value at a certain location is important to initiation, the inflow of warmer air is also important. According to JC07, when warm air advection is present at 700 mb it increases the possibility of MCS formation. The maximum of this warm air advection is in the same location as the MCS initiation location.

Once the thunderstorms which will eventually become an MCS have initiated, there has to be a trigger to create new cells. This tends to be outflows for the older cells creating the uplift needed for further cell development. The new cells will have to develop close enough to the older cells to be considered part of the same system. This outflow may eventually reach the point where the uplift provided by the outflow to create the new cells can no longer be obtained. The uplift is gone when the cold pool created by the outflow is too shallow to be of sufficient depth to be of use in helping to raise the parcel to the required height for the initiation of new cells. This shallowness can occur when the cold pool spreads out over a large area. This can occur but there are other ways new cells no longer form (Johnson and Mapes 2001). If the mountain barrier provides too much, or not enough, interference with the outflows, the new cells may not form and an MCS will not be generated. These outflows are also affected by the strength of the thunderstorms themselves and other environmental conditions which can combine to produce stronger outflows (Tucker and Crook 1998).

Ice can also be important to the development of an MCS because it tends to affect the outflow of individual cells. The inclusion of the ice helps create rain drops as the ice particles are used as a nucleus in precipitation formation. The inclusion of ice also affects the outflow by the melting of the ice and the addition of the extra latent heat release. Once the ice is pulled from high in the atmosphere, the particles can be included in the system to help it advance. These MCSs reach high in the atmosphere; this depth of convection can be seen when the anvil begins to form. That anvil indicates that the system has reached the top of the troposphere, which tends to be a very cold place. These ice crystals strengthen the outflow, giving rise to the formation of the MCS (Tucker and Crook 1998).

Wind shear is also important to MCS initiation and needs to be of a certain value to create new cells. The precursor environment for an MCS has large vertical wind shear over multiple depths of the atmosphere (JC07). Depending on how strong and deep the shear, and how it is oriented compared to the cells, it will determine how the system becomes an MCS. If the shear is strong and deep, the MCS is likely to be comprised of supercells rather than ordinary cells. If the shear is oriented 90 degrees to the system, the cells within the system are likely to collide with each other. If the shear is oriented 45 degrees to the system, the new cells tend to move along with the system and not collide with other cells (Rotunno et al 1987, Rotunno et al 1988, FF01, JC07).

2.1.2.1: Categorization of Mesoscale Convective Systems

MCSs are usually subdivided into three categories – squall lines, bow echoes, and MCCs. Squall lines are a linear line of cells. Bow echoes are contained within squall lines. The bow echoes are bow shaped and several can be contained within one squall line. MCCs require that a cold cloud shield is circular along with an area of the cold cloud shield being below a temperature threshold (Maddox 1980).

Since there are MCS types, each one should be described due to the unique characteristics inherent in each category. The following sections discussed the three main types of MCSs – squall lines and bow echoes in section 2.1.2.1.1 and MCCs in section 2.1.2.1.2.

2.1.2.1.1: Squall Lines and Bow Echoes

Squall lines are a fairly common type of convective system. Within the squall line category, there are sub-categories. Squall lines are split into leading stratiform squall lines, parallel stratiform squall lines, and trailing stratiform squall lines. Trailing stratiform squall lines are the most common type at approximately 70 percent. Intense squall lines form in precursor environments that contain large CAPE and low-level wind shear. Once the squall line commences and relatively dry air is present in the lower levels, strong cold pools are favored for development. If the squall line commences and relatively moist air is present in the lower levels, then weaker cold pools are favored for development (Bluestein and Jain 1985, Rotunno et al 1987, Rotunno et al 1988, Weisman and Rotunno 2004, Jirak et al 2003, JC07).

When a system has ends, it is easy to create a bow echo. Bookend vortices initiate and enhance the rear-inflow jet. Bookend vortices are created when vorticity lines are created by a squall line and pulled upward on both sides of the updraft. These vortices enhance the rear-inflow jet (i.e. stronger winds) causing the squall line between them to bow outwards, creating the bow echo. Bow echoes tend to form in large CAPE environments and have strong low-level shear (Weisman 1993, Weisman and Davis 1998, Johnson and Mapes 2001).

2.1.2.1.2: Mesoscale Convective Complexes

MCCs are defined by the size and temperature of the cold cloud shield seen on satellite images. MCCs must maintain a near perfect (eccentricity of 0.7 or greater) circle for at least six hours, 100,000 km^2 or greater size, and a temperature of -32˚C or less. Inside that cold cloud shield is a smaller one at 50,000 km^2 or greater with a temperature of -52˚C or less (Maddox 1980). Since MCCs are defined by the anvil, the radar appearance underneath the anvil can take on many shapes. Therefore squall lines and bow echoes can also be considered MCCs (Doswell et al 1996, FF01). MCCs can be divided into two categories: Type 1 events occur with warm or stationary fronts, and Type 2 events occur with a surface-based cold pool and its interaction with the vertical wind shear (FF01).

Studies relating MCC generation to the Rocky Mountains have been performed to determine if there was a correlation between the two. McAnelly and Cotton (1986) found that MCCs tended to generate along quasi-stationary fronts and that these fronts occurred along the eastern slopes of the Rocky Mountains. They also found that the systems forming along the eastern slopes of the Rocky Mountains tended to create larger MCCs than were originated elsewhere. Pielke and Segal (1986) conclude that the areas of circular convergence, set up by upslope and downslope winds, are prime locations for MCC generation in the Rocky Mountains. They believe this occurs mainly on the Front Range of the Rocky Mountains.

2.2: Convective Initiation in the Rocky Mountains

Systems forming in the Rocky Mountains are more difficult to predict due to the wind flows and moisture availability (Banta and Schaaf 1987, referred to as BS87). Many studies (Cotton et al 1983, BS87, Banta 1990, Tucker and Crook 2001, Tucker and Crook 2005) have examined system formation in the mountains, as well as the initiation locations, and found wind speed, wind direction, and wind flows predict initiation locations. Initiation will only occur off a certain mountain peak if the wind is coming from a preferred wind direction. These wind directions can be influenced by mountain flows including upslope and downslope winds.

2.2.1: Flows Around Topography

Upslope winds occur during the day (Pielke and Segal 1986), are generated by the surface heating, and are fastest once the temperature difference between the sunlit slopes and the valley below is the largest it can be (Banta 1990). These upslope winds, when there is some interaction with the large-scale flow, tend to produce convection (Pielke and Segal 1986). Upslope winds can provide the necessary lift for convection to occur along the mountain ridge.

Downslope winds are generated by the radiative cooling that occurs at night. Once these winds begin it is difficult for convection to start due to the direction of flow, but the winds can be overcome if the right environmental conditions are in place and depending on the size of the mountain barrier. Downslope winds can create convergence which is favorable for convection when downslope winds arrive in one location from multiple directions (Pielke and Segal 1986).

Longer mountain chains block air flow and this can be conducive to convection (Banta 1990). These larger mountain barriers, such as the Rocky Mountains, are more likely to develop the circulation needed for convection. The circulation can arise from the temperature variations (Johnson and Mapes 2001). These long mountain ranges are considered massive thermal sources since one side of the mountain heats more during the day, for midlatitude locations, than the other side. North-south oriented mountain chains, such as the Rocky Mountains, have a massive east facing slope which will heat up extensively in the mornings (Banta 1990).

2.2.2: Mountain Initiation

While mountain barriers play a vital role in convective initiation, large-scale forcing is key to setting up the conditions needed. These large-scale forcings can regulate the atmosphere through suppression, permission, and active forcing. Suppression occurs when a large-scale forcing inhibits the convection, such as a large-scale descent in a high pressure system. Permission occurs when the atmosphere neither fuels nor inhibits convection. Active forcing occurs when an atmospheric phenomenon forces air up and is one of the most common ways for storms to initiate (Banta 1990). While these large-scale forcings determine whether a convective system will initiate, the small-scale forcings determine the exact place and time convection will begin. Small-scale forcings include flows around topography, wind direction, wind speed, and moisture (Banta 1990). Other environmental conditions needed for convective initiation seem to be more related to the type of system being formed. Warm advection at 850 and 700 mb have been found to be important to convective initiation and possible MCS development, therefore, advection is important to initiation of MCSs (Cotton et al 1983).

One study found that there are three general wind regimes most likely to initiate convection. They are southwesterly, northwesterly, or “curving” southerly (BS87). Depending on the placement of the mountain in relation to the entire range, the initiation wind direction will differ. Banta (1990) found that on the east side of a range, southwesterly or northwesterly wind direction is more prominent; while on west side of the range the “curving” southerly wind direction is more prominent. Since moisture is also important to convection, the “curving” southerly wind direction is ideal because it is able to bring moisture into the area more so than the other wind directions (Banta 1990). The northwesterly wind direction tends to be associated with less moisture due to the drier, northern air. Northwesterly winds tend to produce stronger winds, until the winds begin to suppress convection, which can sometimes overcome the drier air to produce convection. Northwest winds are also parallel to the Rocky Mountain terrain (Tucker and Crook 2001, Tucker and Crook 2005).

The stronger the ridgetop winds, the more likely the winds will interact with the wind flows and interfere to the point that convective initiation may not occur (constructive versus destructive interference, Banta 1990). Weaker ridgetop winds tend to help convection (Tucker and Crook 2005). Tucker and Crook (2005) completed simulations of convective initiation with differing wind speeds. It was found that there were fewer initiation sites with stronger wind speeds and more initiation sites with weaker wind speeds.

Enough moisture has to be present in the atmosphere for the clouds to form, especially in the lower levels. This moisture can come from great distances and will be carried by the wind.

The drier regions in mountainous regions need the moisture and the air needs to be brought to saturation for clouds to form. Saturation can be achieved in three ways – an addition of moisture, nonadiabatic cooling, and adiabatic cooling/expansion (Banta 1990). Cotton et al (1983) found that convection initiated once mid-level moisture passed through the location that study was covering. Nonadiabatic cooling includes radiative cooling that happens throughout the night. Adiabatic expansion/cooling includes the lifting of a parcel, while adiabatic warming/compression includes the descent of a parcel (Banta 1990). Once saturation is achieved, MCS development can occur in the preferred locations.

2.2.3: Preferred Locations of Initiation

Most of the ridges within the Rocky Mountains are aligned northwest-southeast. This configuration shows where some preferred initiation locations are positioned (Tucker and Crook 2005), and preferred locations are a focus of this analysis. The preferred wind regimes can be specific to a section of the mountain range. Northwesterly winds are likely to be of importance throughout the entire mountain range, “curving” southerly winds are likely in the southern part of the domain, and southwesterly winds are likely in the northern part of the domain (BS87).

When BS87 examined geosynchronous satellite data, they found some regions where convective initiation occurs often. These places include the Raton Mesa which is inside the Rocky Mountain chain. BS87 noted that the preferred locations in the Raton Mesa could be due to the southern part of the nearby Sangre de Cristo Mountains. In the Sangre de Cristo Mountains, the preferred locations are along the east side of the mountain range. BS87 found when the different wind regimes were considered separately, the preferred locations on the east side of the mountain range were more prominent when a northwesterly wind regime occurs, and more convective clouds form in the southeastern part of the domain. An isolated peak just north of Taos, NM, is known as a significant source of convective initiation; however, it was found to only be active under northwesterly flow. The Wet Mountains, part of the Rocky Mountain chain, are also considered to be a significant source of convective initiation and are located close to Pueblo, CO. The Wet Mountains are active with the “curving” southerly and the southwesterly wind regimes (Banta 1990).

Preferred locations are important to convective initiation. If the conditions are ideal for initiation, the area should be watched for a system to form and could produce a thunderstorm that will eventually become an MCS.

2.3: Mountain Meteorology Relating to Mesoscale Convective Systems

Thunderstorms have been found to have preferred initiation locations within the Rocky Mountains (BS87) but MCSs have not been shown to have preferred initiation locations, which is the focus of this analysis. The development of the convection that leads to an MCS can occur within the Rocky Mountain chain.

Organized convective development occurring throughout the day includes systems forming in elevated terrain – mountain barriers like the Rocky Mountains. This organized convective development can lead to MCSs, though it typically produces only thunderstorms, and tends to be mesoscale in nature. This development is set up throughout the day and continues throughout the night as the systems propagate into unstable air (Trier and Parsons 1993). Several studies (Maddox 1980, Fritsch et al 1986) have found that a portion of the MCCs forming in the United States developed on the eastern slopes of the Rocky Mountains. This area was also shown to be a prominent location for nocturnal MCS initiation. It was concluded that the eastern slopes of the Rocky Mountains form more systems than what would be seen if the formation were totally random. This leads to the conclusion that mountain meteorology has an influence on general convective initiation in the area (Tucker and Crook 1998). Tripoli and Cotton (1989) hypothesized that the moisture needed for MCS initiation in the Rocky Mountains originates from the southwest. Normally the southwest is a dry area except in the monsoon season. The moisture from the monsoon season is advected into the Rocky Mountains and has an effect on the eventual formation of MCSs (Tripoli and Cotton 1989).

MCSMI with preferred locations within the Rocky Mountain chain has yet to be studied in detail but will be done within this analysis. The preferred locations derived within this analysis can be observed for similarities with other preferred locations and with the information contained above. Also, the information contained above will help guide this analysis in determining the variables needed for MCSMI and the analysis types used. The values of the chosen variables can be compared to the information contained within this chapter to determine how closely the values in this analysis compare to the literature.

3: Data and Methods

The data used for this analysis come from many sources including Tucker and Li (2009)'s data from the Arkansas-Red River Basin Forecast Center (ARBFC), NOMADS (NARR data, National Climatic Data Center 2011, Mesinger et al 2006), and Iowa State's online database (Iowa State 2011). Several processes were run on the Tucker and Li (2009) database to obtain the best possible precipitation estimate along with the cases for this analysis. The data gathered from NOMADS (National Climatic Data Center 2011) and Iowa State (Iowa State 2011) were used to record the values of the variables used in looking for MCSMI. These data files and processes will be discussed in the order used in the analysis.

3.1: Data Processing

Radar and rain gage data are used for analysis since they give the best precipitation estimate possible. Several processes are used in data collection from radar before a final product is reached (Smith and Krajewski 1991, Fulton et al 1998, Anagnostou et al 1999, Tucker and Li 2009). Radar precipitation is estimated using a Z-R relationship; however the relationship tends to vary with time and location. Also, there are problems with blocking of the radar beam, distance from the radar determining accuracy and resolution, and sampling limitations. The blocking of the radar beam can occur with changes in topography as seen in mountain ranges. The farther the beam travels from the radar station, the less accurate the radar beam sweeps are and there is poorer resolution on the fringes of the radar coverage area. Sampling limitations occur with the radar beam since it only reaches a certain distance from the station and a full radar sweep takes minutes to occur. This means features may be missed because they occur between the sweeps. Radar's benefits include radar precipitation estimates used frequently for forecasting and warning guidance (Young et al 2000). In addition, the rain gage network is too sparse to give an accurate reading of all the precipitation and it is possible the network does not pick up on locally heavy rainfall because no gage is present. An advantage of rain gages is that a more accurate precipitation estimate can occur within an area of the gage over radar estimates (Young et al 2000). Smith et al (1996) demonstrated rain gage estimates within the ARBFC exceeded radar estimates of the same area by 14 percent to 100 percent. Therefore, rain gage data plays an important role in precipitation estimates, especially in local estimations.

The ARBFC uses hourly digital precipitation reports, estimated using a Z-R relationship, and then gridded over the forecast center area. The rain gage network is used to correct any biases seen in the radar data, then forecasters finish correcting the data to create the final Stage III product (Tucker and Li 2009). These steps show how the forecaster arrives at the final precipitation product.

The multi-sensor precipitation data used in this analysis were developed to give a more accurate representation of the precipitation than the Z-R relationship alone. Radar or rain gage data alone does not give an accurate estimate of precipitation. A combination of these datasets using algorithms is believed to give the best combination for precipitation estimates data (Young et al 2000). This multi-sensor precipitation data was used to remove the biases (discussed above) that occur with all the radar.

There are several processes performed on the radar data. In Stage I, hourly digital precipitation is gathered and a mosaic is produced (Reed and Maidment 1999). In Stage II, the hourly digital precipitation product is merged with rain gage data using the appropriate Z-R relationship. In Stage III, forecasters decide if the gages are giving accurate readings, and if not, the gage value will be altered or a non-existent gage will be added to account for the changes. Once all the gages have been corrected, the analysis is rerun and the final Stage III product is outputted. The Stage III product's biggest strength is revealed when rain gage densities are low and rely on radar data and algorithms to compute the precipitation estimates. The ARBFC was using this through late 1996 (Young et al 2000).

Since late 1996, the ARBFC has used the P1 algorithm to determine precipitation estimates. To make these estimates, a ratio is created between rain gage and radar-only precipitation estimates. Each cell is assigned a value and for those cells not containing a rain gage, a value is extrapolated from the surrounding cells. These ratios are then used with the radar precipitation estimates from Stage III to create the P1 multi-sensor precipitation product. Even though P1 is handled differently than Stage III, there is still influence from a forecaster. This P1 algorithm was created by the ARBFC and is considered to be better at detecting light precipitation than its predecessors and has fewer associated biases (Young et al 2000, Tucker and Li 2009). Currently, the P1 algorithm is considered the best algorithm for detecting precipitation in the Arkansas-Red River Basin (ARM: Climate Research Facility 2011).

The ARBFC also used a coordinate system called the Hydrologic Rainfall Analysis Project (HRAP) instead of a latitude/longitude coordinate system (ARM: Climate Research Facility 2011). This coordinate system was used to produce mosaics of precipitation estimates from multiple radars into a larger map. When the HRAP coordinates were converted to latitude and longitude coordinates, the map projection used was the Polar Stereographic coordinate system. The Polar Stereographic map projection has a standard latitude of 60˚ N and a standard longitude of 105˚ W. Each HRAP cell is approximately five kilometers by five kilometers (resolution of 0.36˚ in latitude and 0.001˚ in longitude, ARM: Climate Research Facility 2011) but there are some distortion issues (Reed and Maidment 1999). This introduced some error into the system, but it is considered negligible.

3.2: Description of Data Used

The multi-sensor precipitation data, which is a combination of satellite, radar, and rain gage data, was used as the basis. The satellite data is not used much in practice but is available if needed. The multi-sensor precipitation data has multiple processes run to give the best precipitation estimate. The ARBFC relied on Stage III algorithm through late 1996 then switched over to the P1 algorithm; however, no discernible change was detected (Tucker and Li 2009).

Approximately 600,000 convective systems were in the original Tucker and Li (2009) database and contained no missing data (no gaps in the multi-sensor precipitation data in the years 1996 to 2006 were present). MCSs account for one percent of the original database and a fraction of this one percent is examined; the MCSs initiating west of 104˚ W in the warm season (April – September) in the years 1996 to 2006 in the Arkansas-Red River Basin are the systems used in this analysis. Figure 3.2.1 is a map showing the coverage of the Arkansas-Red River Basin.

A system in this database is a set of connected precipitation cells. There has to be a minimum amount of precipitation detected in a cell for it to be considered part of a system. Once connected cells were delineated for each hour, any connecting cells from one hour to the next were considered part of the same system. If a system moves so fast that there are no connecting cells, one system would be considered two separate systems. Some of the systems left the domain region before they would have reached the MCS threshold (Tucker and Li 2009).

Criteria had to be set to delineate the systems into different convective weather categories. For a system to be considered a single cell system, the criteria were a duration of less than one hour and a Footprint Size (FP) of 20 cells or less. FP is defined as the number of one system's cells that contain precipitation throughout its duration. For a system to be considered an

MCS, the criteria were a duration of at least six hours and a FP of 21 cells or greater. A multiple cell system was any system that did not meet the criteria for either the single cell system or the MCS. With this delineation, 78 percent of the database was single cell systems, 21 percent of the database was multiple cell systems, and one percent of the database was MCSs (Tucker and Li 2009).

Once the database was downloaded and determined, several computer programs were used in the analysis of all data files. MATLAB was used when a computer code was needed, IDV and GEMPAK were used to gather the variable information, and SPSS was used to run the analyses of the clusters.

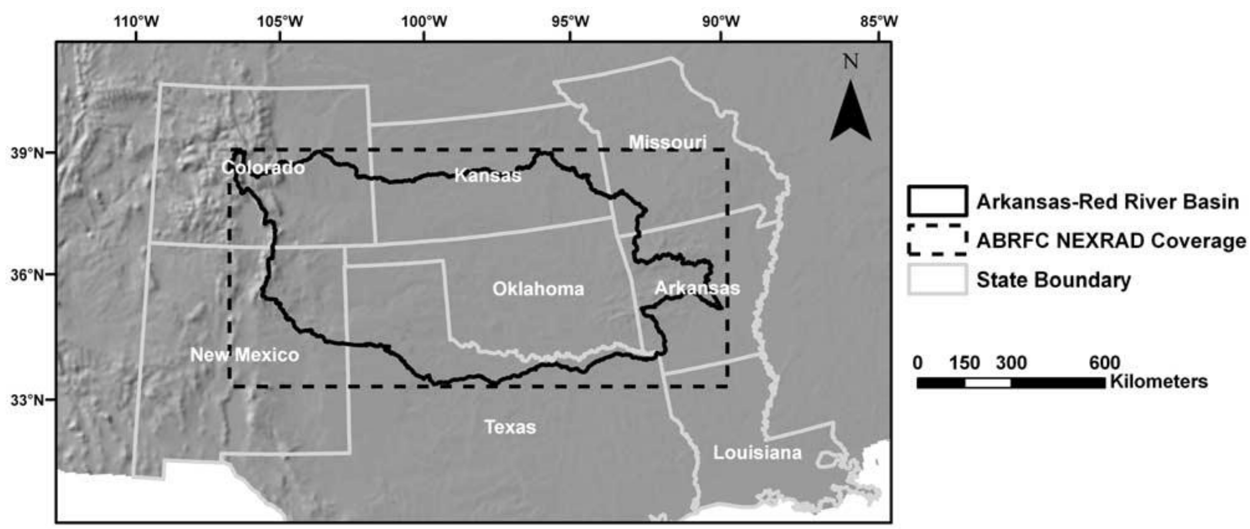


Figure 3.2.1: Map of the Arkansas-Red River Basin. The Arkansas-Red River Basin covers parts of Colorado, New Mexico, Kansas, Texas, Missouri, and Arkansas and all of Oklahoma. The portion of the Arkansas-Red River Basin covered within this analysis is west of 104˚W. This figure is originally from Tucker and Li (2009) and is reproduced with permission from the American Geophysical Union.

3.3: Extraction of Data and Coordinate Transformation

MATLAB was first used to create the subset of MCSs from the original database.

MATLAB code was written to pull all MCSs from the original database. From that any MCS originating west of 104˚ W was further pulled from the subset. Then the MCSs originating in the warm season (April – September) were further pulled from the subset. The resulting subset had an approximate membership of 1,700 MCSs. To determine the initiation location, the coordinate of first precipitation appearance in the multi-sensor precipitation data was used. This is the closest approximation to the initiation location that can be achieved within the database.

3.3.1: Correction of Coordinate System and Time

The original coordinate system employed for this database was the HRAP coordinates (ARM: Climate Research Facility 2011). Using the transformations from the ARM: Climate Research Facility (2011), the Polar Stereographic HRAP coordinates were transformed into latitude and longitude coordinates (Reed and Maidment 1999) to make the cluster analysis performed later more comprehensible and make it easier to gather variable information later. Local time was used in the original database and was transformed to Coordinated Universal Time (UTC) for all cases. This was necessary to be able to gather the variable information from various meteorology sources.

3.3.2: Errors

The only error in this part is not from MATLAB itself but from the database and is the original location of each MCS. It is only the location of first appearance on the multi-sensor precipitation data. This does not include the appearance of clouds. Nothing will be done to correct the error since the initiation of the system is considered to be the first appearance of precipitation.

3.4: Cluster Analysis

SPSS was used for two parts in this analysis. It was first used in performing the cluster analysis on the MCS initiation locations west of 104˚ W in the warm season in the years 1996 to

2006 in the Arkansas-Red River Basin.

The data from MATLAB was loaded into SPSS and a cluster analysis was run on the latitude and longitude coordinates. A cluster analysis was performed using between-groups linkage and Euclidean distance in the Analyze menu as a hierarchical cluster. The between-groups linkage and Euclidean distance gave the best possible combination of clusters. Between-groups linkage is the most common linkage used in cluster analysis and Euclidean distance was used because the distance between the points was small. Seventy-six clusters resulted from the cluster analysis. The map of the MCS cases and the resulting clusters is given in Figure 3.4.1. Membership ranged from clusters containing only two members to a cluster containing 154 members. For the final analysis, only clusters contain 20 or more members were used so that the sample size was large enough to get an accurate representation of the cluster throughout the entire analysis. With that restriction, 29 of the 76 clusters met the criterion of 20 or more members. Clusters with 20 or more members covers approximately 75 percent of the MCSs within the subset from the Tucker and Li (2009) database. Only these 29 were analyzed because if the sample size is too small, accurate model runs will not occur or no model run will occur due to the absence of data. The clusters with higher memberships have initiations that occur more often than ones with smaller sample sizes meaning the initiation characteristics occur more often within the cluster domain. The clusters used in this analysis are given in Table 3.4.1. The names of each cluster give the most prominent feature at the approximate center of the cluster and the membership size is also included. These are the clusters that will be analyzed in Chapter 4.

A second cluster analysis was run on the Elk Mountain, NM cluster using between-groups linkage and Euclidean distance. The variables used for this cluster analysis were the wind directions at 600 and 500 mb instead of the latitude and longitude coordinates used in the first cluster analysis. This analysis was done because there was a bimodal distribution of the wind direction variables.

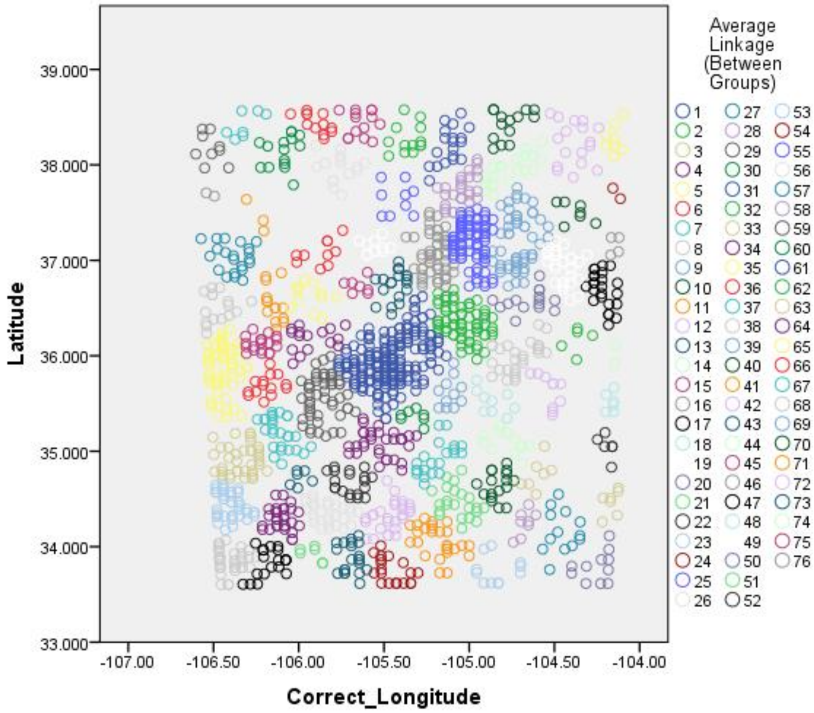


Figure 3.4.1: Map of the Entire Set of Cluster Along with the Location of Each Cluster. The key on the right side of the figure gives the cluster and its associated cluster. The biggest cluster is the one in the center of the map – Elk Mountain, NM cluster (the highest concentration of circles).

Table 3.4.1: Cluster Names and Membership Amount, Listed in Decreasing Membership.

Cluster Name	Membership
Elk Mountain (as part of the Santa Fe Mountains), NM	154
Ute Hills/Pete Hills, CO	90
Rincon Mountains, NM	76
Lookout Peak/Rayado Peak, NM	70
Pajarito Mountain/Cerro Grande, NM	61
Culebra Range/Sangre de Cristo Mountains, CO	56
Shaggy Peak, NM	51
Los Pinos Mountains, NM	43
Mount Washington, NM	38
Wrye Peak, NM	36
Mesa de los Jumanos, NM	34
Jacinto Mesa, NM	32
Bartlett Mesa/Horse Mesa, NM	31
Trinchera Mesa/Valencia Hills/Howard Mountain, NM	31
West Mesa, NM	29
South Mountain (just south of the San Pedro Mountains), NM	28
Badito Cone, CO	27
Bunker Hill, CO	27
Caliente Canyon/Long Canyon, NM	27
Cowboy Mesa, NM	27
Las Mesa Del Conjelon, NM	27
Laughlin Peak, NM	24
Hogback Mountain/Mt. Signal, CO	23
Gacho Hill, NM	22
Argonne Mesa, NM	21
Jicarilla Mountains, NM	21
Neff Mountain/Jarosa Peak, CO	21
Rincon del Cuervo, NM	20
South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM	20

3.5: North American Regional Reanalysis Data

The Integrated Data Viewer (IDV, Murray 2003) was used to get the variable information from the North American Regional Reanalysis (NARR) data. The data probe setting was used to gather the information at the initiation location.

3.5.1: North American Regional Reanalysis Data

NARR data has been extensively studied and multiple papers have been published on the reanalysis data and some of its uses. This information can be gathered from the NOMADS online database (National Climatic Data Center 2011, Mesinger et al 2006). This reanalysis data is run every three hours and goes back several decades. As of this writing, NARR data is available from January 1979 to August 2012 (National Climatic Data Center 2011). NARR data is run on a 32 kilometer horizontal grid spacing with 45 vertical layers. NARR has been found to contain the best possible estimates available for meteorological fields at the time (Mesinger et al 2006).

This NARR data was the only reanalysis (and model) data found that spanned the entire time frame with no missing data. It is run at three-hour intervals rather than the six-hour intervals seen in several other models. NARR was also chosen because of the small grid spacing. Two reanalysis runs before and one after initiation were downloaded. Another reanalysis run was downloaded if initiation occurred on an hour the reanalysis was run (0, 3, 6, 9, 12, 15, 18, 21 UTC). Once the NARR data was gathered, the variables were chosen for analysis. These NARR variables are (quick reference in Table 3.5.1):

- 1000-500 hPa thickness (Thickness) [gpm]. Thickness provides an indication of the temperature of the column. Lower values mean the column contains colder air while higher values mean the column contains warmer air (JC07).
- Precipitable water (PW) [mm]. Precipitable water indicates the amount of water vapor in the atmosphere that can be precipitated out of the system. Since MCSs are such major precipitation producers, it is expected that precipitable water values will be relatively high. McAnelly and Cotton (1986) report the precipitable water needed for MCS initiation needs to be in excess of 30 millimeters.
- Convective Available Potential Energy at surface (CAPE) [J/kg]. The value of CAPE depends on the type of MCS initiated. Large CAPE is associated with bow echoes, for

example (Johnson and Mapes 2001).

- Convective Inhibition at surface (CIN) [J/kg]. The value of CIN depends on the type of convective weather system. CIN should be overcome for convection to occur and is at a minimum, typically, in the heat of the day (Johnson and Mapes 2001).
- Storm relative helicity (SRH) [m^2/s^2]. Also discussed in Chapter 2 is Storm Relative Helicity's (SRH) role in MCS initiation and subsequent formation. JC07 reports a SRH of 60 m^2/s^2 is ideal for MCS initiation. JC07 also reports that the maximum SRH value resides close to the MCS initiation location.
- Geopotential height at 600, 500, 300, 200 mb (GH600, GH500, GH300, GH200) [gpm]. Geopotential height variables provide an indication, as well, of the temperature of the column. MCS typically develop upstream of a broad ridge (JC07).
- Specific humidity at 850, 800, 600, 500, 300, 200 mb (SH850, SH800, SH600, SH500, SH300, SH200) [kg/kg]. Specific humidity was chosen to find moist and dry pockets in the atmosphere. Doswell et al (1996) showed that for convection to occur sufficient moisture is needed and this variable determines if "sufficient" moisture is present.
- U component of the wind at 600, 500, 300, 200 mb (UC600, UC500, UC300, UC200) [m/s]. The winds at 600 and 500 mb were used to observe the ridgetop wind directions and wind speeds since most of the mountain ridgetops will fall between those two values. The winds at 300 and 200 mb were used to look at possible jet stream values. Wind speed determines place and time of initiation (Banta 1990). The value of the wind speed will also determine the number of possible initiation locations in the Rocky Mountains (Tucker and Crook 2005).
- V component of the wind at 600, 500, 300, 200 mb (VC600, VC500, VC300, VC200) [m/s]. See U component of the wind explanation.

- Temperature at 600, 500, 300, 200 mb (T600, T500, T300, T200) [˚C]. The temperature variables were used to see if there was a value necessary for warm-season MCSMI. If the temperatures at one level are all relatively close in value then that value is an indicator for MCS initiation. Warmer temperatures in the upper half of the troposphere and cooler temperatures in the lower troposphere are ideal for MCS initiation according to FF01.

Table 3.5.1: Quick NARR Variable Reference

Variable Name	Description
Thickness	1000-500 hPa Thickness
PW	Precipitable Water
CAPE	Convective Available Potential Energy
CIN	Convective Inhibition
SRH	Storm Relative Helicity
GH600	Geopotential Height at 600 mb
GH500	Geopotential Height at 500 mb
GH300	Geopotential Height at 300 mb
GH200	Geopotential Height at 200 mb
SH850	Specific Humidity at 850 mb
SH800	Specific Humidity at 800 mb
SH600	Specific Humidity at 600 mb
SH500	Specific Humidity at 500 mb
SH300	Specific Humidity at 300 mb
SH200	Specific Humidity at 200 mb
UC600	U component of the wind at 600 mb
UC500	U component of the wind at 500 mb
UC300	U component of the wind at 300 mb
UC200	U component of the wind at 200 mb
VC600	V component of the wind at 600 mb
VC500	V component of the wind at 500 mb
VC300	V component of the wind at 300 mb
VC200	V component of the wind at 200 mb
T600	Temperature at 600 mb
T500	Temperature at 500 mb
T300	Temperature at 300 mb
T200	Temperature at 200 mb

3.5.2: IDV

For each variable collected in IDV, the data probe setting was used to gather the information for the variable at the initiation location, observing a point specific value and not the surrounding point values. While the surrounding point values could contribute to the initiation of an MCS, those values were not observed within this analysis. The data probe setting is fixed so the user can input a latitude and longitude in the chosen coordinate system (in this case, the Polar Stereographic coordinate system), in the chosen sampling mode (weighted average) and a value is shown for that variable at that location. This setting made it easier to observe the conditions necessary for MCSMI at the initiation location rather than some distance away.

A bundle of all the variables gathered in IDV was saved with the data probe setting so the latitude and longitude coordinates only had to be entered in one time for a reanalysis run. This was a time saving measure and proved to be a valuable tool.

3.5.3: Errors

When looking at the variable values, problems with the algorithms used to calculate the variables were noticed. CIN should always be a negative value, but sometimes the value given was positive. When this occurred the value was recorded as zero rather than the positive value. When positive CIN values were given, they were always small values. Therefore, setting CIN to zero at the initiation location at that time does not introduce significant error. There could be issues with the NARR algorithms to calculate other variables, whether in the NARR files or IDV, but this was the most noticeable error.

3.6: Derived Variables

The second MATLAB part of this analysis dealt with calculating wind direction and wind shear. These calculations were a result of the outcomes seen in Callen and Tucker (2012). There were wind shear proxies present in the Multiple Linear Regressions (MLRs) and Principal Component Analyses (PCAs), so wind shears between various levels were calculated. The goal of calculating the wind directions is to see if the MCSs require a specific wind direction to initiate.

3.6.1: Wind Direction and Wind Shear Calculations

Wind direction was calculated at the 600 and 500 mb levels using the U component and V component wind speeds recorded from the NARR data. Since these levels tend to correspond to the ridgetop winds, these were the wind directions most likely to be useful for MCS initiation. These wind direction and wind shear variables are (quick reference in Table 3.6.1):

- Wind direction at 600, 500 mb (WD600, WD500) [˚]. Convective initiation is more likely to occur in the Rocky Mountains with certain wind directions (BS87).
- U component wind shear at 500 mb to surface, 600 to 500 mb, 600 mb to surface (UWSS500, UWS600500, UWSS600) [m/s]. Wind shear was calculated between the surface and 500 mb, between 600 and 500 mb, and between the surface and 600 mb. These wind shears were chosen based on the outcomes from Callen and Tucker (2012). In the MLR, a proxy for wind shear was seen between the U component wind at 500 mb and the U component wind at 600 mb. In the PCA, the proxy for wind shear was seen between the surface winds and the upper level winds (600 and 500 mb). With the addition of these wind shears, the goal is to account for the proxies with the new variables.
- V component wind shear at 500 mb to surface, 600 to 500 mb, 600 mb to surface (VWSS500, VWS600500, VWSS600) [m/s]. See U component wind shear explanation.

Table 3.6.1: Quick Calculated Variable Reference

Variable Name	Description
WD600	Wind Direction at 600 mb
WD500	Wind Direction at 500 mb
UWSS500	U component wind shear at 500 mb to surface
UWS600500	U component wind shear at 500 mb to 600 mb
UWSS600	U component wind shear at 600 mb to surface
VWSS500	V component wind shear at 500 mb to surface
VWS600500	V component wind shear at 500 mb to 600 mb
VWSS600	V component wind shear at 600 mb to surface

3.7: Observed Variables

GEneral Meteorology PAcKage (GEMPAK, DesJardins and Petersen 1986) was used to gather the information from the surface and upper air files. These variables were recorded from the closest reporting weather station at initiation, if possible. If not possible, the data from the next closest reporting weather station was used. This continued until either the data was available or one of the closest reporting weather stations reported data. If this occurred, then the previous time was used for the variable information. Table 3.7.1 lists all of the weather stations and the associated abbreviations used in this analysis.

3.7.1: Surface Data

Surface data was gathered from Iowa State's online database (Iowa State 2011). Surface data was used over NARR data for these variables because it gave the opportunity to use different data sets in this analysis and the variables were present in the Surface data. For each case, the surface data file corresponding to the day of initiation was downloaded. The surface variables used in each case were recorded for the hour of initiation from the closest reporting station whenever possible. Sometimes the closest reporting station did not exist for the time or the station did not record all the variables for that time. Table 3.7.2 lists the surface stations for each cluster. Once the surface stations that were to be used on the clusters were determined, the surface variables were gathered for each case. The surface variables are (quick reference in Table 3.7.3):

- Surface potential temperature in Celsius (STHC). STHC was used to determine if a potential temperature threshold is present for MCSMI. The lowest value of STHC of a cluster can be considered the lower limit of MCSMI for that cluster. Cooler temperatures at the surface are ideal for MCS initiation according to FF01.
- Surface mixing ratio in g/kg (SMXR). The SMXR and SMXS consider moisture at the surface. The closer the SMXR and SMXS values are together, the moister the air. Doswell et al (1996) reports sufficient moisture is needed and these variables are used to determine if sufficient moisture is present at the surface.
- Surface saturated mixing ratio in g/kg (SMXS). See SMXR explanation.
- U component of the wind in m/s (UWND). The U and V component surface winds can play a role in initiation, but the winds are more likely to be greatly influenced by topography. Therefore, the wind direction was not taken at the surface. The initiation place and time are determined by wind speed (Banta 1990).
- V component of the wind in m/s (VWND). See U component of the wind explanation.

3.7.2: Upper Air Data

Upper air data was gathered from Iowa State's online database (Iowa State 2011). Upper Air data was used over NARR data for these variables because it gave the opportunity to use different data sets in this analysis and the variables were present in the Upper Air data. The day of initiation file was downloaded for each case. The closest sounding location and time before initiation was used. This could be up to 11 hours prior to initiation since the atmosphere can change drastically in that time frame. If this was the case, then the recorded variable values were not very representative of what the atmosphere looked like at the initiation hour. There are fewer upper air stations in any given area than surface stations. Only two upper air stations were within the Arkansas-Red River Basin west of 104˚ W domain, located in Denver, CO and Albuquerque, NM. Frequently, one of these stations did not report upper air data for the closest reporting time, so the next closest upper air station was used. If Denver did not report, then the stations used were Grand Junction, CO and Dodge City, Kansas. If Albuquerque did not report, then the stations used were El Paso, Texas and Amarillo, Texas and Flagstaff, Arizona. The upper air stations used for each cluster are given in Table 3.7.2. Once the upper air stations were determined for each cluster, the upper air variables for each case were recorded. These variables were recorded from actual observations rather than interpolated from the NARR data. The upper air variables are (quick reference in Table 3.7.3):

- Lifting Condensation Level (LCL) [mb]. The lower the LCL, the easier it will be for a system to form. The parcel of air has to rise a smaller distance with a lower LCL than it would with a higher LCL and this is more conducive to convective initiation. According to Banta (1990), the location of the cloud base can be determined by the LCL.
- Lifted Index (LI). The LI was used as a stability index for the potential for an MCS to form in that location. The more negative a value of LI, the more likely it is for severe weather to occur and the more unstable the air (JC07). The stability of the atmosphere needs to be determined and a way to do that is by using a stability index (Moller 2001).

3.7.3: Errors

There are no errors directly associated with GEMPAK. The errors are introduced when using the stations, since the stations are not at the initiation locations. The surface stations are much closer to the initiation locations than the upper air stations, but some surface stations double as upper air stations. An error is introduced when the values of the variables are taken at some time before the initiation hour; therefore, the variables are not a true representation of the atmosphere.

3.7.4: Surface Data and Upper Air Data Tables

Table 3.7.1: Stations Used for Surface Data and Upper Air Data. The abbreviations used for each station are listed in the first column. The locations of the stations are listed in the second column.

Abbreviations	Locations
ABQ	Albuquerque, NM (35.05˚N, 106.62˚W)
AEG	Double Eagle Airport, NM (35.14˚N, 106.80˚W)
ALM	Alamogordo, NM (32.83˚N, 106.00˚W)
AMA	Amarillo, TX (35.23˚N, 101.70˚W)
COS	Colorado Springs, CO (38.82˚N, 104.72˚W)
CPW	Pagosa Springs, CO (37.45˚N, 106.80˚W)
CQC	Clines Corners, NM (35.00˚N, 105.55˚W)
DDC	Dodge City, KS (37.77˚N, 99.97˚W)
DEN/DNR	Denver, CO (39.87˚N, 104.67˚W)
EPZ	El Paso, TX (31.80˚N, 106.40˚W)
FCS	Fort Carson, CO (38.68˚N, 104.77˚W)
FGZ	Flagstaff, AZ (35.13˚N, 111.67˚W)
GJT	Grand Junction, CO (39.12˚N, 108.53˚W)
HMN	Holloman Air Force Base, NM (32.85˚N, 106.10˚W)
LVS	Las Vegas, NM (35.66˚N, 105.14˚W)
PUB	Pueblo, CO (38.28˚N, 104.52˚W)
RTN	Raton Airport, NM (36.75˚N, 104.50˚W)
SAF	Santa Fe, NM (35.62˚N, 106.08˚W)
SKX	Taos, NM (36.45˚N, 105.67˚W)
SRR	Ruidoso, NM (33.47˚N, 105.53˚W)
TAD	Trinidad, CO (37.25˚N, 104.33˚W)
VTP	La Veta Mountain, CO (37.50˚N, 105.17˚W)

Table 3.7.2: Stations Used for Each Cluster. In the first column contains the cluster name. In the second column are the surface station names for each cluster. In the third column are the upper air station names for each cluster.

Cluster Name	Surface Stations	Upper Air Stations
Elk Mountain (as part of the Santa Fe Mountains), NM	CQC, SAF, ABQ	ABQ
Ute Hills/Pete Hills, CO	RTN, TAD, PUB, DEN/DNR	DEN/DNR
Rincon Mountains, NM	LVS, CQC, ABQ	ABQ
Lookout Peak/Rayado Peak, NM	LVS, CQC, SAF, ABQ	ABQ
Pajarito Mountain/Cerro Grande, NM	SAF, ABQ	ABQ
Culebra Range/Sangre de Cristo Mountains, CO	VTP, SKX, SAF, ABQ	ABQ
Shaggy Peak, NM	CQC, SAF, ABQ	ABQ
Los Pinos Mountains, NM	ABQ, AEG, SAF	ABQ
Mount Washington, NM	SAF,ABQ	ABQ
Wrye Peak, NM	HMN, ALM, ABQ	ABQ
Mesa de los Jumanos, NM	CQC, SAF, ABQ	ABQ
Jacinto Mesa, NM	CQC, SRR, ABQ	ABQ
Bartlett Mesa/Horse Mesa, NM	RTN, TAD, PUB, DEN/DNR	DEN/DNR
Trinchera Mesa/Valencia Hills/Howard Mountain, NM	CQC, SRR, ABQ	ABQ
West Mesa, NM	CQC, ABQ	ABQ
South Mountain (just south of the San Pedro Mountains), NM	SAF, ABQ	ABQ
Badito Cone, CO	PUB, FCS, DEN/DNR	DEN/DNR
Bunker Hill, CO	RTN, LVS, SAF	DEN/DNR
Caliente Canyon/Long Canyon, NM	RTN, TAD, PUB, DEN/DNR	DEN/DNR
Cowboy Mesa, NM	SRR, CQC, ABQ	ABQ
Las Mesa Del Conjelon, NM	LVS, RTN, PUB, DEN/DNR	DEN/DNR
Laughlin Peak, NM	RTN, TAD, PUB, DEN/DNR	DEN/DNR
Hogback Mountain/Mt. Signal, CO	PUB, FCS, COS, DEN/DNR	DEN/DNR
Gacho Hill, NM	CQC, LVS, ABQ	ABQ
Argonne Mesa, NM	LVS, CQC, ABQ	ABQ
Jicarilla Mountains, NM	SRR, ALM, HMN, ABQ	ABQ
Neff Mountain/Jarosa Peak, CO	CPW, SAF, ABQ	ABQ
Rincon del Cuervo, NM	SAF, SKX, ABQ	ABQ
South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM	SKX, SAF, ABQ	ABQ

Table 3.7.3: Quick Surface and Upper Air Variable Reference

Variable Name	Description
STHC	Surface potential temperature in Celsius
SMXR	Surface mixing ratio in g/kg
SMXS	Surface saturated mixing ratio in g/kg
UWND	U component of the wind
VWND	V component of the wind
LCL	Lifting Condensation Level
LI	Lifted Index

3.8: Analysis Methods

The second part of SPSS was used to run the analysis model runs on each of the clusters. The MLRs and PCAs were run for each of the six hours prior (6HP) to initiation through the three hours after (3HA) initiation. Each case will contribute to specific model runs. For example, if a system initiated at 0000 UTC, the variables would be used in the 6HP, three hours prior (3HP), initiation, and 3HA model runs. Also, if a system initiated at 0100 UTC, the variables would be used in the four hours prior (4HP), one hour prior (1HP), and two hours after (2HA) model runs.

3.8.1: Multiple Linear Regression

MLR was a quick and easy way to determine the necessary ingredients for larger FPs that are attached to MCSMI at different times before and after initiation. The hours following initiation are considered because there may be conditions necessary to grow the cells to MCS size. A MLR is not always the best choice since the fit to the data may not be linear.

In SPSS, a linear regression is run using FP as the dependent variable. FP is used because the larger the FP, the larger the system. Bivariate correlations are run on all of the variables and indicate the dependency of the variables since one assumption of MLR is that the variables are all independent of each other. SPSS can be used to determine if the variables are independent of each other which, if that is not the case, then there are multicollinearity issues present. Multicollinearity issues occur when the variables are not truly independent of each other – the correlations between the variables are too high for independency among the variables. If there are multicollinearity issues present then the MLRs have fit problems. There are expected to be some multicollinearity issues because of the nature of the variables, for example Thickness and GH500 which should be of similar value. Another example of potential multicollinearity issues would be the inclusion of multiple stability parameters – LI and CAPE. The multicollinearity issues will be corrected when using PCA.

The entry method used in this analysis is the stepwise method. The variable with the smallest-associated error below the entry value criterion is added into the equation until no variable meets the entry value criterion. For most of the model runs, the entry value is set at 0.15. When the models would not run with an entry value of 0.15, the entry value was increased to 0.20. Originally, the entry value was set to 0.10 but the model runs that resulted gave small R square values and very few variables included in the equations. With increasing the entry value to 0.15, the R square values increased, indicating a better fit to the data. Increasing the entry value increases associated error as well but this new error is offset by the higher R square values.

The MLRs were run on the variables for the corresponding hour creating ten model runs (6HP to 3HA) for each cluster. The resulting equations, R square values, and multicollinearity issues will be analyzed. Each of the variables' contributions will be discussed.

3.8.2: Principal Component Analysis

PCA was used as a more in-depth tool to determine the necessary ingredients for MCSMI. Every variable is used in every component, so the information that can be gathered from a PCA is much more comprehensive than can be seen in the MLR. The PCA was also done since the fit to the data may not be a linear fit as was seen in the MLR.

In SPSS, the Dimensional Reduction menu was chosen. From that menu, the Factor option was chosen. Within the Factor option, the analysis type was Principal Component Analysis. SPSS is set up to accommodate many different types of analysis; PCA is just one of the analysis option types. This analysis type was chosen because the variables are still considered to be independent of one another but the independency is not as important as it is with MLR.

To have enough of the components present to get an accurate representation of the model without using all, those with eigenvalues greater than one are used. Most of the variance in the variables is considered and the model is useful. The variance considered with those components is significant since most of the overall variance (approximately 90 percent for each model run) has only a small number of components. Using every variable in every component gives a more accurate representation of the variable’s contribution to the overall model.

The variables giving the most contribution to the PCA are analyzed as well as the significance of the components and variance. The loadings of the first two individual components for each model run are also analyzed to determine the contribution of the variables to the PCA. While PCA is the most difficult to comprehend, it gives the most accurate representation of the data and gives the best option for identifying the variables needed for MCSMI. The PCAs were run on all the variables for the corresponding hour creating ten model runs for each cluster (6HP to 3HA). The variables with 90 percent or more variance accounted for, eigenvalues valued one or greater, and the percent of the accounted for variance are discussed as well as some variable contributions.

3.8.3: Errors

An error from this part of the analysis comes from the sample size. While the membership of each cluster is 20 or more, that is not necessarily the case for each hour since the initiation hour varied throughout a cluster. At times the sample size used for a model run may have been too small to give an accurate representation of the data.

Another error from this part of the analysis comes from how some negative valued variables are treated, in particular CIN. An issue with CIN was previously discussed in the section 3.5. CIN was recorded as a negative number or zero for each case. This problem arose when CIN was added negatively into some of the equations and is counterproductive since more CIN means it is harder for initiation. Overall, the value of CIN decreases throughout the day. This problem shows that more negative values of CIN will provide a greater positive contribution which is counterproductive as initiation nears. This is an artifact of how the MLRs and PCAs handle variables being added/loaded into the model runs.

4: Individual Cluster Results

The MLR and PCA results are divided into two chapters. This first chapter discusses the individual cluster results and the next chapter discusses the global results. The individual clusters are discussed first within this chapter, followed by an overall discussion of the individual clusters at the end of this chapter.

4.1: Explanation of Coverage

In this chapter, the clusters with 30 or more members are discussed in detail, and a quick assessment is made of the remaining clusters, listed in Table 3.4.1. Each section in this chapter is concerned with a different cluster and its resulting model runs and will begin with a description of each cluster. Median values are given for each variable for each model run in each section, are used over mean values since median values are not as affected by outliers, and are located in the middle of the data. The median values for the surface and upper air variables are from the closest reporting station and closest reported time before initiation. The NARR variables are for each hour – 6HP to 3HA. Each section covers the MLRs and PCAs run for each of the 6HP through initiation. Discussion of the individual variables is limited to that which pertains to the analysis. Each section includes tables of the MLR equations and the most used variables from the PCAs along with other statistics and pertinent figures. The MLRs are discussed in detail if the R square value is 0.600 or greater. The PCAs are discussed in detail if the variance accounted for is 80 percent or greater. The conclusions drawn from the MLRs and PCAs are specific to the cluster being discussed. The individual cluster discussion highlights the differences and similarities between the clusters. Cluster location maps are included in Appendix A and results from the model runs done after initiation are included in Appendix B.

Composite maps are included at the end of each section and will be discussed in the discussion section for each cluster. The composite maps cover the area of the United States west of the Mississippi River and give most frequently occurring pattern for the chosen variables. The information for the composite maps was gathered from Plymouth State's online database (Plymouth State Weather Center 2012). The initiation times were viewed for the chosen variables. The variables were used in this analysis were compared to the variables listed for viewing in the database. The temperature variables included in both places were STHC, T500, T300, and T200. The moisture variables included in both places were SMXR, SH850, SH500, SH300, and SH200. The geopotential height variables included in both places were GH500, GH300, and GH200. The wind shear variables were calculated from the median values.

The variables chosen for each of the composite maps were chosen because of the MLRs and PCAs. The ones that were chosen were used the most often in the MLRs and PCAs and, therefore, considered the most important. The patterns of the most used variables can show how the atmosphere needs to be conditioned before initiation. The most frequently occurring patterns for each variable over the western United States are plotted on the composite maps. In using the pattern that was observed the most often, the most frequently occurring pattern was determined by observing each most used chosen variable for each case. The composite maps give a general description of the atmosphere pattern.

4.2: Elk Mountain, NM

4.2.1: Description of Entire Cluster

The Elk Mountain, NM cluster is the largest cluster with 154 members and is located north-northwest of Santa Fe, NM. It has been researched previously in Callen and Tucker (2012), but the results will differ since the calculated variables have been added to the analysis. The median values given for the surface variables in Table 4.2.1 show that the potential temperature is hot at 40.610˚C (approximately 105˚F), the air is relatively dry, and the winds are from the southeast. With the potential temperature very warm relatively close to the initiation location, it can be assumed that the potential temperature at the initiation location is warm as well. The median values of SMXR and SMXS show the air is relatively dry at approximately 46 percent relative humidity and show relatively dry air is required for initiation. Relatively dry air at the surface was seen in Tucker and Zentmire (1999, referred to TZ99) as an initiation characteristic of orogenic MCSs. The UWND and VWND give a median wind direction of southeast. BS87 observed that "curving" southerly winds are one of the three prominent wind directions within the Rocky Mountains. The median upper air values given in Table 4.2.1 show a below-ridgetop level LCL and an LI that indicates the air is slightly unstable.

The median NARR values for each of the ten model runs are given in Table 4.2.2. When comparing the Thickness and geopotential height variables at 6HP through 3HA initiation, the only significant change noted is with Thickness. The geopotential height variables change insignificantly throughout the model runs. The Thickness variable increases which indicates that the column of air is warmer at initiation than it was 6HP and there is the potential for a ridge. After initiation, the Thickness value decreases, indicating the column of air is cooling and there is the possibility of a trough. This decrease is likely a direct result of the system initiating. PW does not change significantly between any of the model runs, demonstrating that approximately the same amount of PW is needed throughout the ten hours. CAPE is at its highest median value at five hours prior (5HP) but is small at initiation. CIN decreases slightly from the 6HP value but increases as initiation draws closer and is at its highest median value 2HA. SRH does not show any significant change over the hours. SH850 and SH800 show the air drying out before initiation, but SH600, SH500, SH300, and SH200 indicate the air is becoming moister before initiation. This was also the conclusion drawn from TZ99 – drier air at the surface could be used to increase the strength of the outflow. From initiation to 3HA, the SH850, SH800, SH300, and SH200 are increasing in value, indicating an influx of moisture. The U component winds do not change much from 6HP to initiation but increase in speed after initiation. The V component winds change significantly throughout the model runs, but all wind variables are hour dependent. All the wind shear values change significantly throughout all the model runs. The wind shear values are seen as low to moderate values which is not expected for an MCS. The median upper level temperature values do not change significantly throughout the model runs which indicates that the system does not have a significant impact on the temperature change at any level.

Histograms for the entire Elk Mountain cluster, Figure 4.2.1, were created for the start year, start month, start hour, and Julian Day. The most MCSs occurred in the years 2004 and 2006, but the mean year value was 2001. The start-month histogram indicates July and August were the months when the most MCSs occurred. This is expected since these months tend to have more MCSs initiating according to Jirak et al (2003). The start-hour histogram shows MCSs usually initiating in the late afternoon/early evening in the Rocky Mountains. The late afternoon/early evening conditions seem to be the most conducive for MCS formation which is consistent with FF01's findings. The Julian-Day histogram shows the MCSs tend to form in mid-July to early-August, when the surface temperatures are usually the warmest.

4.2.2: Multiple Linear Regression – Overall

MLRs were run on each of the 6HP through the 3HA initiation on the entire Elk Mountain cluster. The resulting equations and the R square values (1.000 is a perfect fit) are included in Table 4.2.3. These equations provide the variables used to achieve an FP. Each variable included is important and contributes to the possible eventual FP. The results discussed below for the entire Elk Mountain, NM cluster originate from a combination of Table 4.2.1, Table 4.2.2, and Table 4.2.3.

The 6HP and 5HP model runs had R square values less than 0.600; therefore, these model runs will not be discussed in detail but are included in Table 4.2.3.

At 4HP, a better outcome occurred. A stronger U component wind shear between the surface and 500 mb, larger values of CAPE, lower surface saturation mixing ratios, and LIs closer to zero but still in the unstable regime are needed at 6HP within this cluster's domain for larger FPs. Also needed for larger FPs are moist conditions at 200 mb and stronger north-south winds at 500 mb. The fit to the data was acceptable at 0.759, but this is not the best fit out of all the model runs. This proves that though it is not a perfect fit or a linear fit, it can realistically identify the variables needed for the FP. Even though the fit to the data is better than the previous model runs, there are no multicollinearity issues. This is an improvement over Callen and Tucker (2012) which showed multicollinearity issues at 4HP. With the inclusion of the calculated variables, the multicollinearity issues have been dropped.

The 3HP and two hours prior (2HP) model runs have R square values less than 0.600. These are included in Table 4.2.3 but are not discussed.

The 1HP model run was a better fit to the data than the previous model run, but it was still not the best fit. Stronger west-east wind shears between the surface and 500 mb, a moist pocket of air at 600 mb, and colder columns of air between the surface and 200 mb are needed at 1HP to initiation. Also needed for larger FPs are LIs closer to zero, stronger V component winds at 500 mb, and a moist pocket of air at 850 mb. This model run was an acceptable fit (as compared to other model runs for this cluster) at 0.638. The variables are independent of each other which is shown by there being no multicollinearity issues.

The model run at initiation was a poor fit to the data with an R square value of less than 0.600. The equation is still included in Table 4.2.3 and will not be discussed in detail.

Throughout all the MLRs, there were several variables that were never used: PW, GH500, SH500, SH300, UC600, VC600, VC300, VWSS600, and T500. The variables used the most were LCL, LI, UWS600500, and VC200 at four out of ten model runs. The new wind shear variables are used often overall instead of the wind shear proxies used in Callen and Tucker (2012). The separate wind component variables are not used as often as were used in Callen and Tucker (2012). In this cluster, LI indicates that barely negative and not extreme negative values are needed for larger FPs. Most of the variables used in these model runs are only used once, indicating that individual variables are not as important to larger FPs. The upper level temperatures are included much less often in these model runs than expected when comparing to model runs in Callen and Tucker (2012). Overall, the wind variables were used often, while the moisture variables were not used often if at all. The biggest similarity among the equations is the inclusion of the wind shear variables; there is at least one wind shear variable included in almost every model run. They are useful in determining if an MCS, by way of larger FPs, will form and what the size it will be once it does form (consistent with JC07). The biggest difference between the model runs is the use of temperature variables, especially when compared to Callen and Tucker (2012). The upper level temperatures are used much less often indicating that the temperatures at those levels are not as important to larger FPs as other variables.

The Elk Mountain cluster can be broken into two clusters based on wind direction, and this was done to see if the fit to the data would be better and if the multicollinearity and poor fit issues can be corrected. The poor fits seem to be directly related to the wind direction. The results from the cluster analysis and the MLRs from the two wind direction groups are discussed in the sections 4.2.5 and 4.2.8.

4.2.3: Principal Component Analysis – Overall

PCAs were run on each of the 6HP through 3HA initiation on the entire Elk Mountain cluster to solve the fit issues seen in the MLRs, so the PCAs should be a better fit to the data. Included in Table 4.2.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those components. These variables are significant to MCS formation using the PCA as the type of analysis.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. The variables loaded the highest into the first component were Thickness (6HP), geopotential height (6HP, 5HP, 3HP, 1HP, initiation), specific humidity (5HP, 2HP), U component wind shear (5HP, 4HP), and temperature (6HP, 5HP, 4HP, 3HP, 1HP, initiation) variables. All of these variables were loaded in positively. Most of these variables will have greater contributions with positive loadings than with negative loadings. The variables loaded the highest into the second component were the specific humidity (2HP, 1HP), U component wind (3HP, initiation), U component wind shear (initiation), V component wind (6HP, 5HP, 3HP, initiation) and V component wind shear (6HP, initiation) variables. These variables were loaded in positively. No variables were loaded highly into the second component in the 4HP model run. The contribution from wind and wind shear variables depends on the value of the variable. These PCAs did not have variables that were highly loaded into every model run indicating that there could be an issue with the fit to the data.

There were variables that were not included in the most used list and are different from the ones that were not included in the MLRs. These variables are STHC, SMXR, LCL, LI,

SH200, UC200, WD600, WD500, VC200, VWS600500, and T200. According to the PCAs, most of the variables at 200 mb are not important. Most of the surface data and upper air data variables are included. The variables included on every most used list were Thickness, GH500, GH300, UC500, UWSS500, VWSS500, VWSS600, and T500 and are the most important to the possibility of MCSMI for the entire Elk Mountain cluster. Geopotential height and wind variables seem to be the most important which coincides with the above analysis. There are several other variables that were included often but not in every model run. These variables include PW, GH200, SH850, SH800, VC500, T600, and T300. Moist air is the most necessary for formation. The rest of the variables not previously discussed were used rarely in the model runs and are only important at certain times prior to and after initiation.

As previously discussed, the question is the fit to the data – could a better variance be achieved by solving the issue of several prominent wind directions. The cluster analysis performed on the original Elk Mountain cluster gives two wind direction groups. The results from the cluster analysis and the PCAs are discussed in the sections 4.2.6 and 4.2.9.

4.2.4: Description of Wind Direction Group 1 Cluster

The cluster analysis was performed using the same method as the previous cluster analysis. Figure 4.2.2 gives the locations of the two groups which resulted from the cluster analysis. The red circles in Figure 4.2.2 give the locations of the Wind Direction Group 1 cases in the Elk Mountain cluster. The Wind Direction Group 1 cluster is the larger of the two resulting clusters. The median values for the surface and upper air variables are given in Table 4.2.5. The surface potential temperature is very warm at 40.505˚C (approximately 105˚F). The air is relatively dry with the median winds coming out of the southeast at the surface. The relatively dry air (TZ99) and southeast winds (BS87) have been previously researched and shown to be important to initiation. The median values of SMXR and SMXS provide a relative humidity of approximately 46 percent. The relatively dry air at the surface is necessary for the potential for MCS formation within this cluster. The LCL is a midlevel LCL at 625.730 mb which is not too high in the atmosphere as to not be achievable. The median LI value shows the air is slightly unstable.

The NARR variables are included in Table 4.2.6 which shows how the variables change as the time progresses from 6HP to 3HA. Thickness is noticeably smaller at 3HA initiation as compared to the initiation hour. SRH and CAPE have larger values after initiation. Overall, the variables are fairly consistent throughout all the model runs. Wind direction does change throughout the model runs but it stays within a certain overall wind direction. CAPE is highest at 5HP. For this cluster, the time when CAPE is at its highest indicates that processes for MCSMI could start out far in advance of the actual initiation. The specific humidity variables give relatively moist air overall. It is reasonable that the median variable values in the Wind Direction Group 1 cluster will be similar to the information contained in the entire Elk Mountain cluster since the Wind Direction Group 1 cluster is the larger. The wind shear before and after initiation does not change significantly, indicating that the sustained wind shear is a necessary component to MCS formation within this subset of the Elk Mountain cluster.

The histograms containing the time information for the Elk Mountain Wind Direction Group 1 cluster are given in Figure 4.2.3. The most MCSs occurred in 2004, followed by the years 1998 and 2006. The start-month histogram shows that July and August produced an almost equal number of MCSs. The next largest month was June, followed closely by September. The start-hour histogram looks very similar to the histogram for the entire Elk Mountain cluster. The systems initiate at what would be late afternoon/early evening in the Rocky Mountains (consistent with FF01). There are systems that initiate at other times of the day but are rare occurrences. The spike in the Julian-Day histogram that is seen in Figure 4.2.1 is not seen in the Julian-Day histogram in Figure 4.2.3. There is a much more gradual buildup to the Julian Day that contains the most MCSs for this subset than there was overall. This subset contains 114 members of the original 154 members. It is reasonable to assume that with that many members of the original cluster, the histograms and the outcomes of the model runs could be very similar.

4.2.5: Multiple Linear Regression – Wind Direction Group 1

The MLRs were run on the 6HP through the 3HA initiation for the Elk Mountain Wind Direction Group 1 cluster. The resulting equations and the R square values are given in Table 4.2.7. These equations are expected to be similar to the equations given for the entire Elk Mountain cluster. The differences are expected since only a fraction of the original Elk Mountain cluster will be used in this part of the analysis. The goal of the MLRs is to achieve a bigger FP which makes sure the system does reach MCS criteria. These variables given in the MLRs also consider the characteristics needed for larger FPs. The results discussed below for the Elk Mountain, NM Wind Direction Group 1 cluster come from a combination of Table 4.2.5, Table 4.2.6, and Table 4.2.7.

Even though the model runs for the Wind Direction Group 1 are much better fits to the data than the entire Elk Mountain cluster, there were still some fit issues. The 6HP and 5HP model run have low R square values, lower than 0.600. These model runs will not be discussed but are included in Table 4.2.7.

The 4HP model run for the Elk Mountain Wind Direction Group 1 cluster is different from the entire Elk Mountain cluster. There are eight variables present in the equation for the Group 1 cluster as compared to the six variables present in the equation for the entire cluster.

Larger values of CAPE, LIs closer to zero but still negative, warmer temperatures at 300 mb, and colder columns of air between the surface and 200 mb are preferred for initiation in four hours. Stronger east-west winds, SRH values closer to zero, relatively cooler surface potential temperatures, and warmer columns of air between the surface and 300 mb are also needed for larger FPs within this cluster's domain according to this equation. The R square value for this equation was 0.893 which is the highest R square value for all the model runs for this cluster. This equation delivers the best possible combination for the cluster to be used in identifying the variables needed for the FP. There were multicollinearity issues present in this equation.

The 3HP and 2HP model runs also had R square values less than 0.600. The information is included in Table 4.2.7.

The 1HP model run for the Elk Mountain Wind Direction Group 1 cluster is dissimilar to the entire Elk Mountain cluster. Stronger positive wind shears between the surface and 500 mb, a moist pocket of air at 600 mb, warmer temperatures at 200 mb, and SRH values closer to zero will provide the greatest contribution to the FP. Stronger west-east winds at 200 mb, a moist pocket of air at 300 mb, larger negative CIN values, and larger north-south winds at 300 mb are needed for larger FPs within this cluster's domain. Overall, this combination of variables delivers a decent fit to the data at 0.795 which is an improvement over the model run for the entire Elk Mountain cluster. This improved fit is a more accurate representation of the data. There were no multicollinearity issues present.

While the model run at initiation was a better fit to the data than that for the entire Elk Mountain cluster at initiation, the R square value is still lower than 0.600. Therefore, this model run will not be discussed but it still included in Table 4.2.7.

There were variables that were never used in the Elk Mountain Wind Direction Group 1 model runs: SMXS, VWND, PW, GH500, SH850, SH800, UC600, UC500, UWSS600, WD600, VC600, VC500, VWSS600, and T500. If the variable is not important to the FP, it is not included in the model runs. The variable included the most was a wind shear variable, UWS600500, in five out of ten model runs. This is expected since wind shear is crucial to convective initiation and the formation of new cells (from JC07). One specific variable is not usually used more often. There are multiple conditions needed for larger FPs and those change throughout the hours leading up to initiation. The foremost similarity among all the model runs is the inclusion of one of the wind shear variables (from JC07). There is definite improvement over the original Elk Mountain model runs but there are still problems with the fit to the data with some of the runs.

4.2.6: Principal Component Analysis – Wind Direction Group 1

The PCAs were run for each of the 6HP through 3HA in the Elk Mountain Wind Direction Group 1 cluster. The PCAs show a more accurate representation of the variables needed for identifying variables for the MCSMI since it tends to be a better fits to the data than the MLRs. Table 4.2.8 contains the variables with 90 percent or more variance, the number of components that have an eigenvalue greater than one, and the percent of variance accounted for with the components. These PCAs show that multiple variables are important and will be discussed in the analysis.

The 6HP through the initiation model runs have similar variables loaded highly into the first components. The variables loaded the highest into the first component were STHC (5HP), PW (3HP, initiation), geopotential height, specific humidity (6HP, 4HP, 1HP, initiation), U component wind shear (2HP), V component wind shear (2HP), and temperature (5HP, 3HP, 2HP, 1HP, initiation) variables. All of these variables were loaded in positively. The positive inclusion of the specific humidity variables shows that moisture is needed at all levels for the possibility for an MCS to form. The geopotential height variables were also loaded positively which means that the higher values are needed – warmer columns of air. In the second component, the variables loaded in the highest were SMXR (4HP), SMXS (4HP), PW (4HP), geopotential height (6HP, 1HP), U component wind (initiation), V component wind (6HP, 3HP, 2HP, initiation), and V component wind shear (5HP) variables. These variables were loaded in positively with the exception of SMXS (4HP) and geopotential height (6HP, 1HP) variables. The contribution from the wind and wind shear variables depends on the value of the variable. The combination of a positive SMXR loading and a negative SMXS loading shows moister conditions are needed at the surface according to the PCA.

There were only a few variables that were not included in the most used list for any PCA: SRH, UC200, WD600, VWS600500, and T200. These variables are definitely different from the ones that were not included in the MLRs for this cluster. They are not as important as other variables that were included often in the PCAs. The variables included in every model run were: GH500, GH300, UWSS500, VWSS500, and T500. Most of these variables are at least partially related to the 500 mb level. This level is important for identifying the variables needed for MCS formation in this particular cluster. It is possible that the variables at the 500 mb could be observed and used for the identification of variables needed for MCSMI.

4.2.7: Description of Wind Direction Group 2 Cluster

Wind Direction Group 2 is the smaller of the two groups that resulted from the second cluster analysis. The black circles in Figure 4.2.2 delineate the locations of Wind Direction Group 2 cases within the entire Elk Mountain cluster. The median values given for the surface variables, in Table 4.2.9, show that the potential temperature is hot at 42.165˚C (approximately

108˚F), dry air is present at the surface, and the winds are from the southeast. These conditions have been shown to be important in previous discussions (TZ99, BS87). This surface potential temperature is warmer than the previous two clusters, so it has to be warmer at the closest reporting station for this subset than for the entire Elk Mountain cluster. The air is also drier than the entire cluster, at approximately 43 percent relative humidity. The median wind direction is from the southeast – seen through the combination of UWND and VWND. The median values for the upper air variables are also given in Table 4.2.9 showing an acceptable LCL and a slightly unstable LI.

The median NARR variables are given in Table 4.2.10 for each of the 6HP through the 3HA. The Thickness and geopotential height variables show little change from the 6HP to the 3HA. There is fluctuation in the values of these variables but it is minimal overall. CAPE reaches a maximum median value at 1HP but there is a significant amount of CAPE throughout the model runs. CIN reaches a maximum at 3HA. Overall, CIN has relatively low values and would be easily overcome. The specific humidity variables fluctuate very little overall. The SH850 becomes larger just prior to initiation but decreases to its original value at initiation. The wind direction from Elk Mountain Wind Direction Group 1 was from the southwest, whereas the wind direction from Elk Mountain Wind Direction Group 2 was from the southeast. The wind direction fluctuates more in this subset than in the previous subset, but the wind direction remains out of the southeast. There are some noteworthy changes in the wind shear. The V component wind shears in particular get stronger (more negative) from 6HP to the initiation hour. The temperatures variables also stay fairly consistent throughout the model runs.

The histograms for the Elk Mountain Wind Direction Group 2, Figure 4.2.4, cluster were created for the start year, start month, start hour, and Julian Day. The most MCSs initiated in the year 2004, with 2006 second, but the mean year overall was 2002. The start-month histogram shows that the main two months MCSs initiated in this subset were July and August. The month in which the most initiations occurred was July for this subset and August for the previous wind direction group. The start hour is late afternoon/early evening (consistent with FF01). The Julian-Day histogram shows that most of the systems were initiated in July and August. The mean Julian Day is the same for this cluster as it was for the previous cluster. This subset contains 40 of the original 154 members. Since it is a small portion of the original cluster, it is reasonable to assume that there will be differences between the entire Elk Mountain cluster and the Elk Mountain Wind Direction Group 2 cluster.

4.2.8: Multiple Linear Regression – Wind Direction Group 2

The MLRs were run for each of the ten hours between 6HP and 3HA. Table 4.2.11 contains the approximate equations and the associated R square values for each model run. The variables included in the equations provide the best combination for the larger FP at that hour. The results discussed below for the Elk Mountain, NM Wind Direction Group 2 cluster come from a combination of Table 4.2.9, Table 4.2.10, and Table 4.2.11.

The 6HP model run for the Elk Mountain Wind Direction Group 2 cluster has only one variable in common with the entire Elk Mountain cluster at 6HP – UWS600500. Stronger positive wind shears between 600 and 500 mb, warmer temperatures at 200 mb, stronger south-north winds at 600 mb, larger values of CIN, weaker U component wind shears between the surface and 600 mb, and weaker west-east winds are 200 mb are all needed for initiation to occur in six hours for larger FPs according to this analysis. Overall, the fit to the data is almost perfect at 0.936. Even though the equation is a near perfect fit, there are no multicollinearity issues present which demonstrate that the variables included in the equation are not interrelated.

The 5HP model run was also different from the entire Elk Mountain cluster at 5HP - only one variable was similar. LCLs closer to the ground, values closer to zero of the U component surface wind, weaker V component wind shears between the surface and 500 mb, lower surface saturation mixing ratios, and higher surface mixing ratios give the best possible combination of variables to observed for larger FPs within this cluster's domain. The fit to the data is better than it was for the entire Elk Mountain cluster 5HP at 0.825. Since the R square value is relatively high and there are no multicollinearity issues, this is an acceptable equation for this subset at this time prior to initiation.

The 4HP model run only included three variables but it was an almost near perfect fit to the data. Stronger west-east winds at 500 mb, weaker V component wind shears between the surface and 500 mb, and warmer temperatures at 200 mb are needed for larger FPs. The R square value was high at 0.942 which is an almost near perfect fit. This equation is a good tool to use when identifying variables needed for the FPs in this area in relation to a specific wind direction. There were no multicollinearity issues present in this equation.

The 3HP model run uses some of the same variables that were used in the entire Elk Mountain cluster at 3HP. Stronger positive U component wind shears between 600 and 500 mb, warmer temperatures at 200 mb, stronger south-north winds at 600 mb, smaller surface mixing ratios, stronger south-north winds at the surface, and weaker U component wind shears between the surface and 500 mb are needed for larger FPs from initiation that will occur in three hours according to this equation. The combination of all these variables provides a good fit to the data, nearly perfect at 0.960. This equation can be used for identifying the necessary variables for the FP within a reasonable amount of error at three hours before initiation. There are no multicollinearity issues present which proves that the variables are truly independent of each other and the equation gives an accurate representation of the data.

The 2HP model run in the Elk Mountain Wind Direction Group 2 cluster is very different from that of the entire Elk Mountain at 2HP. There are 15 variables in this new equation as compared to the original equation which only contained two variables. Larger V component winds at 300 mb, more negative V component wind shears between 600 and 500 mb, smaller values of CAPE, warmer columns of air between the surface and 200 mb, and a dry pocket of air at 600 mb are needed for larger FPs. Colder columns of air between the surface and 300 mb, more negative V component winds at 200 mb, colder temperatures at 200 mb, stronger, positive U component wind shears between the surface and 600 mb, and LCLs closer to the ground are also needed for larger FPs within this cluster's domain. More negative V component winds at 500 mb, smaller V component wind shears between the surface and 500 mb, smaller U component wind shears between 600 and 500 mb, smaller U component winds at 300 mb, and stronger west-east winds at 200 mb are also needed for larger FPs which occur within this cluster's domain. An R square value of 1.000 was achieved; therefore, this equation can be used to identify the necessary variables needed for the eventual FP at 2HP, but there are multicollinearity issues.

The 1HP model run contained four variables but was still a near perfect fit to the data. Weaker, east-west winds at 500 mb, a dry pocket of air at 500 mb, larger surface mixing ratios, and higher LCL values are needed for larger FPs according to this equation. These are the variables that need to be observed at 1HP to determine if initiation will occur. The combination of variables shows a near perfect fit at an R square value of 0.983, and there are no multicollinearity issues present in this model run.

The model run for the initiation hour for the Elk Mountain Wind Direction Group 2 cluster contains some of the same variables included in the initiation hour model run for the entire Elk Mountain cluster. Weaker U component wind shears between 600 and 500 mb, warmer temperatures at 200 mb, stronger V component wind shears between the surface and 500 mb, and larger Thickness values are needed for larger FPs to occur within the hour within this cluster's domain. The fit to the data is an acceptable fit at 0.715 and there were no multicollinearity issues present in this model run.

There were several variables that were not included in any of the MLR model runs for the Elk Mountain Wind Direction Group 2 cluster: PW, SRH, GH600, GH500, SH850, SH800, SH300, SH200, UC600, WD600, VWSS600, T600, and T500. Moist air is needed for larger FPs but the specific humidity variables are not used at several levels and the question of importance of those variables is raised. The variables used the most were VWSS500 and T200, for five out of ten model runs, showing VWSS500 is important to initiation and T200 is important to propagation of the system and creation of new cells. The rest of the variables not previously mentioned were used between one and four times. Wind direction and wind shear variables were used often overall (wind shear from JC07). No one variable is more important than the others, even though VWSS500 and T200 are used five out of ten times.

4.2.9: Principal Component Analysis – Wind Direction Group 2

PCAs were run every hour of the ten hours between 6HP through 3HA. The variables with 90 percent or more variance, the number of components with eigenvalues greater than one, and accounted for variance are included in Table 4.2.12. Three of the PCAs had all variables on the most used list. The other model runs show most of the variables having 90 percent or more of the variance accounted for in that hour.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. The variables loaded the highest into the first component were STHC (4HP, 1HP), SMXS (4HP, 1HP), PW (6HP, 5HP), Thickness (5HP, 4HP, 1HP), PW (1HP), geopotential height, specific humidity (4HP, 3HP, 1HP), WD500 (4HP, 1HP), V component wind (4HP, 1HP), and temperature variables. These variables were loaded in positively. For most of these variables, the larger the value of the variable, the greater the contribution will be to the component. In the second component, the variables loaded the highest were STHC (6HP), SMXR (6HP), SMXS (6HP), UWND (6HP, 4HP), VWND (6HP), LCL (5HP), CAPE (5HP, 1HP), CIN (1HP), SRH (5HP, 4HP), specific humidity (4HP, 3HP, initiation), U component wind (2HP), U component wind shear (4HP, 2HP), V component wind (2HP), and V component wind shear (5HP, 2HP) variables. These variables were also loaded in positively with the exception of CAPE (5HP), CIN, SRH, and specific humidity (3HP) variables. The contribution from the wind and wind shear and SRH variables depends on the value of the variable. While the amounts of loading are different from one model run to the next with every component, certain variables are more prominent than others such as the geopotential height and temperature variables. Each variable plays a specific role in the PCA.

All of the variables were included at least five out of ten times. Multiple variables were included in every most used list: VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, and T300. Since these variables were included in every model run, these variables are important to MCSMI and development. If a variable was positive and was also loaded positively into the components, then the variable would give a greater positive contribution, as was the case with the geopotential height variables. If a variable was negative and was also loaded negatively into the components, the variable would also give a greater positive contribution. The biggest similarity among all the model runs is the inclusions of all the variables listed above that were contained in every model run.

4.2.10: Cluster Discussion

The entire Elk Mountain cluster model runs were not good fits to the data. There were two prominent wind directions within the Elk Mountain cluster. The Wind Direction Group 1 MCSs formed when the wind was coming out of the southwest; the Wind Direction Group 2 MCSs formed when the wind was coming out of the southeast. Breaking up the Elk Mountain cluster into two clusters solved the poor fits. The fits to the data were much better in the MLRs and more of the variance was accounted for in the PCAs with the two clusters.

There were several similarities between the entire Elk Mountain cluster and the Elk Mountain Wind Direction Group 1 cluster which were the result of the sample size. Wind Direction Group 1 contained most of the members of the original Elk Mountain cluster. While there were similarities between the entire Elk Mountain cluster and Wind Direction Group 1, there were very few between the entire Elk Mountain cluster and Elk Mountain Wind Direction Group 2 cluster. A few variables used in the original Elk Mountain model runs were used in the Wind Direction Group 2 model runs. Frequently the Wind Direction Group 1 model runs were almost identical to those of the original Elk Mountain. Therefore, separating the original Elk Mountain cluster into two clusters was a good statistical move. When the wind direction is determined for this cluster, the right set of variables could be used to determine if the potential for MCSMI exists.

The PCA indicates conditions for possible MCSMI, while MLR could determine the eventual size of the initiating MCS. Occasionally the MLR did give a good fit to the data, especially after the second cluster analysis was performed. MLR is easier to understand and implement than the PCA which can be difficult to analyze and use, especially since every variable is included. Variables used most often in the PCAs are deemed more important overall since most of the variance is accounted for. The variables appearing throughout the Elk Mountain clusters with the highest loadings most often were the geopotential height and temperature variables. This was the biggest similarity found among all the Elk Mountain clusters. When the cluster is fixed, the fit to the data is better and the new model runs give a more accurate representation of the data overall. These equations could be used for identifying the variables needed for forecasting MCSs within the cluster domain.

The Elk Mountain, NM cluster is in a portion of the Rocky Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation yields winds from the southwest. The median wind direction at 500 mb and initiation yields winds from the west. This indicates that the winds at 600 mb are along the ridgeline while the winds at 500 mb come into the ridgeline at an angle.

The composite map for Elk Mountain, NM is Figure 4.2.5. The most important temperature variable was T500. The composite map indicates lower 500 mb temperatures to the north of the domain; therefore, the temperatures at 500 mb are considered relatively warm. The most important geopotential height variable was GH200. There is a ridge to the west and a trough to the east of the cluster domain. This indicates the GH200 variable will increase as the ridge moves through the area. The most important moisture variable was SH850. There is a high moisture value to the east of the domain which could indicate that the low level winds are bringing moisture into the area for initiation. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 6.064 ms^{-1} at 301.328°.

The Elk Mountain, NM Wind Direction Group 1 cluster is in a portion of the Rocky

Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the west-northwest. This indicates that winds at 600 mb are basically oriented along the ridgeline and the winds at 500 mb are perpendicular to the ridgeline.

The composite map for Elk Mountain, NM Wind Direction Group 1 is Figure 4.2.6. The most important temperature variable was T500. The composite map indicates lower 500 mb temperatures to the north showing that the temperatures at 500 mb are relatively warm in the cluster domain. The most important geopotential height variable was GH500. There is a trough to the east of the domain which indicates that the higher heights have already passed through the domain. The most important moisture variable was SH850. There is an inflow of moist air to the east of the domain and an inflow of dry air west of the domain which should indicate the air is relatively dry at 850 mb. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 7.021 ms^{-1} at 288.000˚.

The Elk Mountain, NM Wind Direction Group 2 cluster is in a portion of the Rocky Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the south-southeast. The median wind direction at 500 mb and initiation gives winds from the northeast which indicates that the winds at 600 mb arrive at an angle to the ridgeline and winds at 500 mb are along the ridgeline.

The composite map for Elk Mountain, NM Wind Direction Group 2 is Figure 4.2.7. The most important temperature variable was T300. There are cooler temperatures at 300 mb to the northeast of the cluster domain. If the cooler temperatures move to the east, the temperatures at 300 mb will increase within the cluster domain. The most important geopotential height variable was GH300. There is a negatively tilted trough to the east of the cluster domain at 300 mb. As this moves east, higher heights will occur within the domain. The most important moisture variable was SMXR. There is a dry pocket of air to the west and a moist pocket of air to the east, indicating relatively dry air within the cluster domain. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 7.961 ms^{-1} at 21.2535˚.

4.2.11: Cluster Figures and Tables

Table 4.2.1: Median Values for the Upper Air and Surface Variables for the Entire Elk Mountain, NM Cluster.

Variable	Median Value
STHC	40.610
SMXR	9.135
SMXS	19.810
UWND	-2.315
VWND	1.410
LCL	631.280
LI	-0.795

Table 4.2.2: Median Values for the NARR Variables for the Entire Elk Mountain, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5846.700	5825.500	5863.000	5868.300	5835.400
PW	16.250	14.200	15.800	17.050	15.300
CAPE	156.450	287.400	223.900	163.600	169.900
CIN	-25.350	-20.700	-16.000	-13.550	-15.500
SRH	22.800	35.900	25.900	23.800	30.200
GH600	4468.850	4459.400	4476.700	4469.200	4455.000
GH500	5918.400	5900.200	5918.500	5917.200	5906.700
GH300	9725.300	9683.600	9718.500	9723.300	9687.600
GH200	12464.450	12415.500	12451.500	12458.500	12412.700
SH850	1.090e-2	1.020e-2	9.700e-3	1.040e-2	9.600e-3
SH800	9.450e-3	8.900e-3	8.600e-3	9.000e-3	8.300e-3
SH600	4.350e-3	4.200e-3	5.000e-3	5.300e-3	4.800e-3
SH500	2.500e-3	2.000e-3	2.300e-3	2.700e-3	2.100e-3
SH300	3.650e-4	1.800e-4	2.700e-4	4.300e-4	2.700e-4
SH200	4.900e-5	4.000e-5	4.300e-5	5.050e-5	4.200e-5
UC600	2.250	0.856	1.800	1.850	0.458
UC500	2.500	2.000	1.400	2.850	2.300
UC300	5.150	4.700	5.400	5.700	4.000
UC200	9.250	8.400	8.000	9.150	8.400
UWSS500	4.763	3.710	4.480	5.275	3.705
UWS600500	0.360	0.500	-0.511	1.148	-0.200
UWSS600	3.830	2.860	3.801	3.44	3.900
WD600	254.404	220.855	244.983	231.426	247.932
WD500	253.954	238.678	270.836	267.792	235.726
VC600	-0.704	-0.309	-0.776	0.689	-0.042
VC500	-0.883	-1.900	-2.800	-1.650	-3.100
VC300	1.850	-0.936	-1.900	2.350	0.049
VC200	1.700	-1.900	-2.200	2.200	-0.644
VWSS500	-2.415	-2.140	-3.010	-2.263	-3.740
VWS600500	0.268	-0.600	-1.900	-2.292	-2.970
VWSS600	-2.130	-0.940	-1.846	-1.245	-0.880
T600	2.500	1.600	2.600	2.500	1.700
T500	-7.250	-8.500	-7.700	-7.100	-8.300
T300	-32.000	-34.700	-33.700	-31.800	-34.600
T200	-53.450	-53.300	-53.300	-53.350	-52.800
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5869.800	5872.450	5835.800	5852.200	5854.050
PW	16.500	16.850	15.500	15.700	16.900
CAPE	82.800	41.950	37.800	94.800	115.450
CIN	-24.900	-23.900	-25.800	-41.600	-33.250

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	30.800	28.350	33.000	39.300	46.850
GH600	4470.900	4465.050	4463.000	4475.600	4466.500
GH500	5920.900	5915.200	5907.300	5917.500	5914.550
GH300	9729.600	9733.850	9693.200	9717.800	9728.500
GH200	12444.500	12478.400	12418.900	12450.500	12470.650
SH850	9.800e-3	9.850e-3	9.200e-3	1.020e-2	1.055e-2
SH800	8.500e-3	8.600e-3	8.000e-3	8.900e-3	9.150e-3
SH600	5.000e-3	5.400e-3	4.600e-3	4.600e-3	5.100e-3
SH500	2.700e-3	3.100e-3	2.400e-3	2.500e-3	2.850e-3
SH300	3.500e-4	3.800e-4	3.100e-4	3.700e-4	4.550e-4
SH200	4.600e-5	5.350e-5	4.700e-5	4.800e-5	5.400e-5
UC600	2.600	2.300	1.700	2.400	3.200
UC500	3.200	3.350	2.700	3.700	3.400
UC300	4.300	5.750	3.600	5.900	6.050
UC200	8.300	8.700	7.200	7.700	10.350
UWSS500	5.640	5.180	4.200	4.140	4.525
UWS600500	-0.200	1.100	-0.100	-0.200	0.900
UWSS600	4.846	4.080	3.900	4.884	4.010
WD600	261.402	233.203	248.629	270.414	250.121
WD500	292.166	272.833	228.240	283.241	265.314
VC600	-0.456	0.403	-0.116	-1.700	-0.482
VC500	-3.700	-2.100	-2.800	-4.300	-3.100
VC300	-1.900	1.650	-0.586	-2.000	3.800e-3
VC200	-2.600	2.000	-1.900	-4.800	2.050
VWSS500	-4.140	-3.153	-3.770	-5.140	-3.385
VWS600500	-3.300	-3.143	-2.794	-2.664	-3.000
VWSS600	-1.110	-1.191	-1.480	-2.560	-1.778
T600	2.800	3.050	2.100	2.700	2.750
T500	-7.200	-6.550	-8.100	-7.200	-7.000
T300	-33.800	-31.450	-34.400	-33.900	-31.900
T200	-53.200	-53.250	-53.400	-53.200	-53.400

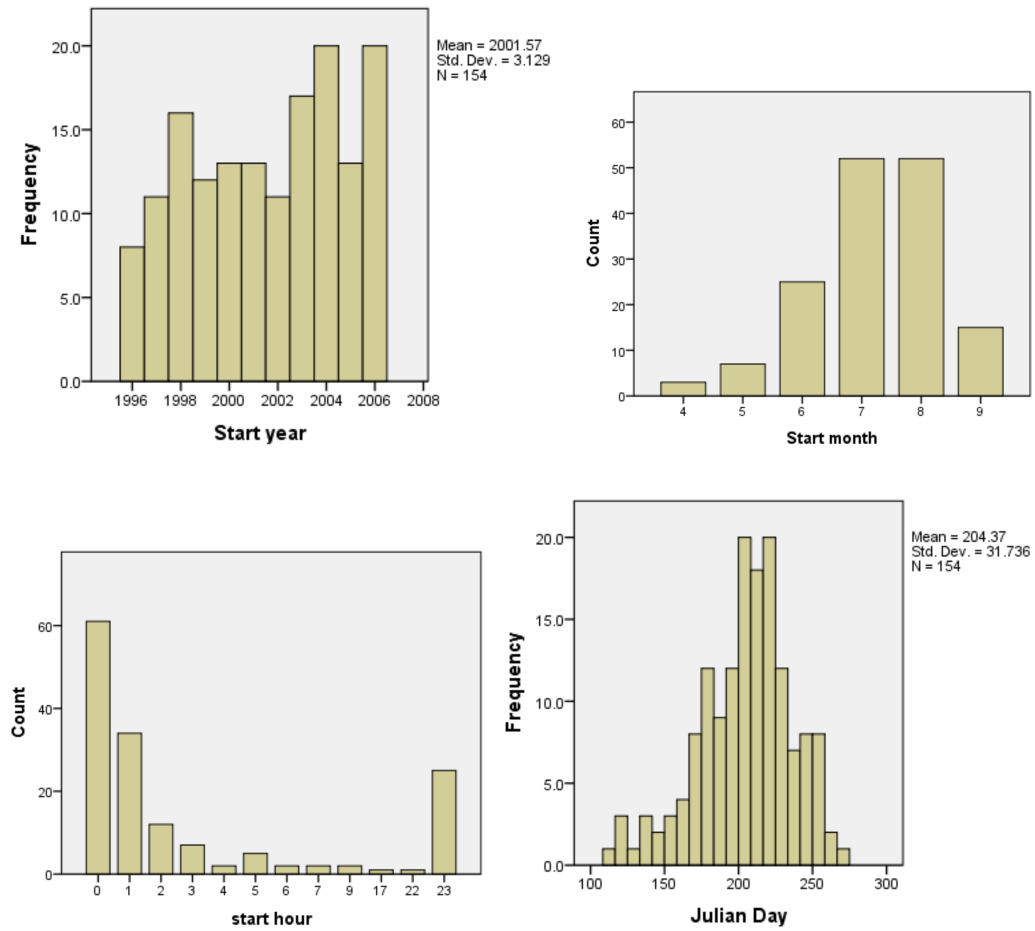


Figure 4.2.1: Time Histograms for the Entire Elk Mountain, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram had gaps. The histograms included are start year, start month, start hour, and the Julian Day. These histograms were previously seen in Callen and Tucker (2012).

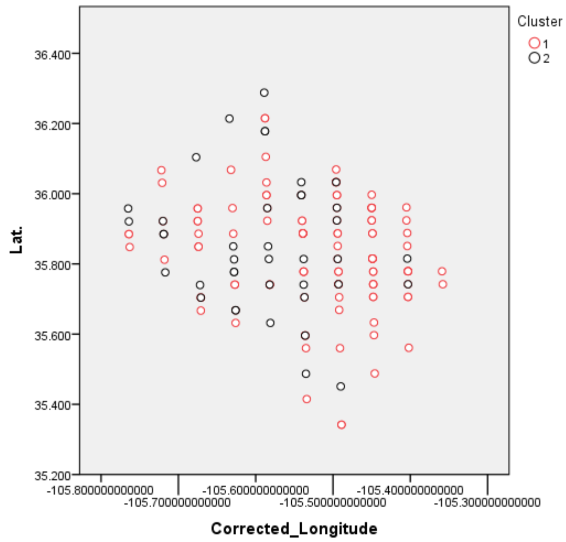


Figure 4.2.2: Results of the Cluster Analysis on the Wind Direction of the Entire Elk Mountain, NM Cluster. Group 1 is shown with the red circles, while Group 2 is shown with the black circles.

Table 4.2.3: Results of the MLRs Run on the Entire Elk Mountain, NM Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – GH200 + UWS600500 + SH200	0.456
5HP	FP ≈ constant + VC200 + LCL + CIN	0.268
4HP	FP ≈ constant + UWSS500 + CAPE – SMXS + LI + SH200 – VC500	0.759
3HP	FP ≈ constant + UWS600500 + T200 – SMXR – WD500 – UC300 + VC200	0.433
2HP	FP ≈ constant + VC200 + LCL	0.226
1HP	FP ≈ constant + UWSS500 + SH600 – GH200 + LI – VC500 + SH850	0.638
Initiation	FP ≈ constant + T200 + UWS600500 – T600	0.236

Table 4.2.4: Results of the PCAs Run on the Entire Elk Mountain, NM Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	UWND, VWND, Thickness, PW, GH500, GH300, SH850, SH800, UC600, UC500, UWSS500, UWSS600, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	11	84.731%
5HP	SMXS, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC500, UC300, UWSS500, VWSS500, VWSS600, T600, T500, T300	9	85.527%
4HP	UWND, VWND, Thickness, PW, SRH, GH500, GH300, GH200, SH800, SH500, SH300, UC500, UC300, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	10	87.155%
3HP	UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, SH500, UC600, UC500, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	11	85.934%
2HP	Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, VC500, VWSS500, VWSS600, T600, T500, T300	9	85.409%
1HP	SMXS, VWND, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, UC600, UC500, UWSS500, UWS600500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	11	89.751%
Initiation	UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T500	10	84.042%

Table 4.2.5: Median Values for the Upper Air and Surface Variables for the Elk Mountain, NM Wind Direction Group 1 Cluster.

Variable	Median Value
STHC	40.505
SMXR	9.150
SMXS	19.775
UWND	-2.315
VWND	1.420
LCL	625.730
LI	-0.845

Table 4.2.6: Median Values for the NARR Variables for the Elk Mountain, NM Wind Direction Group 1 Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5840.900	5818.400	5851.200	5857.700	5829.600
PW	16.300	14.200	15.750	17.100	14.300
CAPE	145.300	287.400	223.250	147.700	126.100
CIN	-25.000	-17.800	-17.450	-13.200	-16.500
SRH	21.400	35.900	23.150	23.500	38.900
GH600	4465.200	4453.100	4467.400	4461.600	4450.800
GH500	5914.000	5898.700	5914.100	5909.700	5896.300
GH300	9722.000	9676.000	9707.200	9721.400	9665.400
GH200	12462.200	12407.700	12419.600	12453.300	12391.900
SH850	1.120e-2	1.020e-2	9.900e-3	1.040e-2	9.500e-3
SH800	9.700e-3	8.800e-3	8.850e-3	9.100e-3	8.300e-3
SH600	4.300e-3	4.100e-3	4.750e-3	5.300e-3	4.500e-3
SH500	2.500e-3	2.000e-3	2.250e-3	2.800e-3	2.100e-3
SH300	3.500e-4	2.300e-4	3.250e-4	4.300e-4	2.600e-4
SH200	4.900e-5	3.800e-5	4.400e-5	5.000e-5	4.000e-5
UC600	2.700	3.200	2.350	2.100	2.600
UC500	3.300	3.700	2.450	3.700	4.200
UC300	6.800	7.400	6.850	7.200	8.000
UC200	10.400	13.100	10.450	9.600	12.900
UWSS500	6.800	5.570	5.354	6.840	6.590
UWS600500	0.900	1.983	0.116	1.614	1.589
UWSS600	5.080	4.246	4.955	4.600	5.244
WD600	260.140	239.381	272.183	234.462	254.932
WD500	268.355	277.665	302.430	289.385	299.899
VC600	-0.585	0.586	-0.790	1.100	0.225
VC500	-0.364	-1.800	-2.750	-1.500	-3.100
VC300	2.500	-0.206	-0.892	2.800	-0.864
VC200	3.400	-0.803	-0.661	3.400	-0.344
VWSS500	-0.450	-2.770	-2.939	-1.580	-3.600
VWS600500	0.400	-0.700	-1.674	-2.097	-2.970
VWSS600	-1.473	-0.460	-1.625	-1.01	-0.880
T600	2.300	1.300	2.300	2.400	1.300
T500	-7.300	-8.600	-7.900	-7.300	-9.300
T300	-31.900	-35.200	-34.150	-31.800	-35.400
T200	-53.200	-53.400	-53.150	-53.100	-52.900
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5851.950	5862.300	5820.000	5837.600	5838.400
PW	16.300	17.000	15.000	15.300	16.800
CAPE	53.100	39.300	37.800	78.050	121.600
CIN	-23.000	-22.300	-28.400	-42.400	-31.500

Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
SRH	30.650	28.200	50.300	37.200	45.300
GH600	4464.650	4461.300	4453.600	4468.700	4463.000
GH500	5910.200	5911.500	5904.900	5907.650	5906.100
GH300	9700.550	9728.800	9669.100	9705.350	9727.000
GH200	12428.150	12475.300	12389.200	12424.250	12468.000
SH850	1.005e-2	1.020e-2	9.200e-3	1.035e-2	1.080e-2
SH800	8.750e-3	9.000e-3	8.000e-3	9.000e-3	9.300e-3
SH600	4.800e-3	5.300e-3	4.600e-3	4.400e-3	5.100e-3
SH500	2.550e-3	3.100e-3	2.400e-3	2.550e-3	2.900e-3
SH300	3.550e-4	3.800e-4	3.100e-4	3.800e-4	4.500e-4
SH200	4.650e-5	5.300e-5	4.200e-5	4.850e-5	5.400e-5
UC600	3.200	2.600	4.900	4.100	3.700
UC500	4.300	4.600	6.200	4.750	4.400
UC300	7.250	6.600	7.700	7.700	6.900
UC200	9.900	9.900	11.500	8.850	11.200
UWSS500	6.490	6.680	7.850	6.996	6.550
UWS600500	0.950	1.600	1.000	0.950	1.211
UWSS600	6.655	5.358	6.417	6.665	5.170
WD600	266.330	240.524	274.908	283.218	254.827
WD500	305.797	288.435	293.121	303.934	289.867
VC600	-0.303	0.805	-0.790	-1.500	0.439
VC500	-3.550	-1.800	-3.700	-3.650	-2.800
VC300	-1.350	2.000	-0.425	-1.450	1.200
VC200	-0.075	3.200	-1.100	-0.308	2.900
VWSS500	-4.225	-2.160	-5.200	-4.915	-3.100
VWS600500	-2.934	-2.900	-2.600	-2.283	-2.800
VWSS600	-1.155	-0.280	-1.526	-2.480	-0.916
T600	2.150	2.700	1.800	2.150	2.500
T500	-7.700	-6.500	-8.600	-7.800	-7.000
T300	-33.950	-31.400	-35.100	-34.150	-31.900
T200	-53.150	-53.200	-53.500	-53.400	-53.300

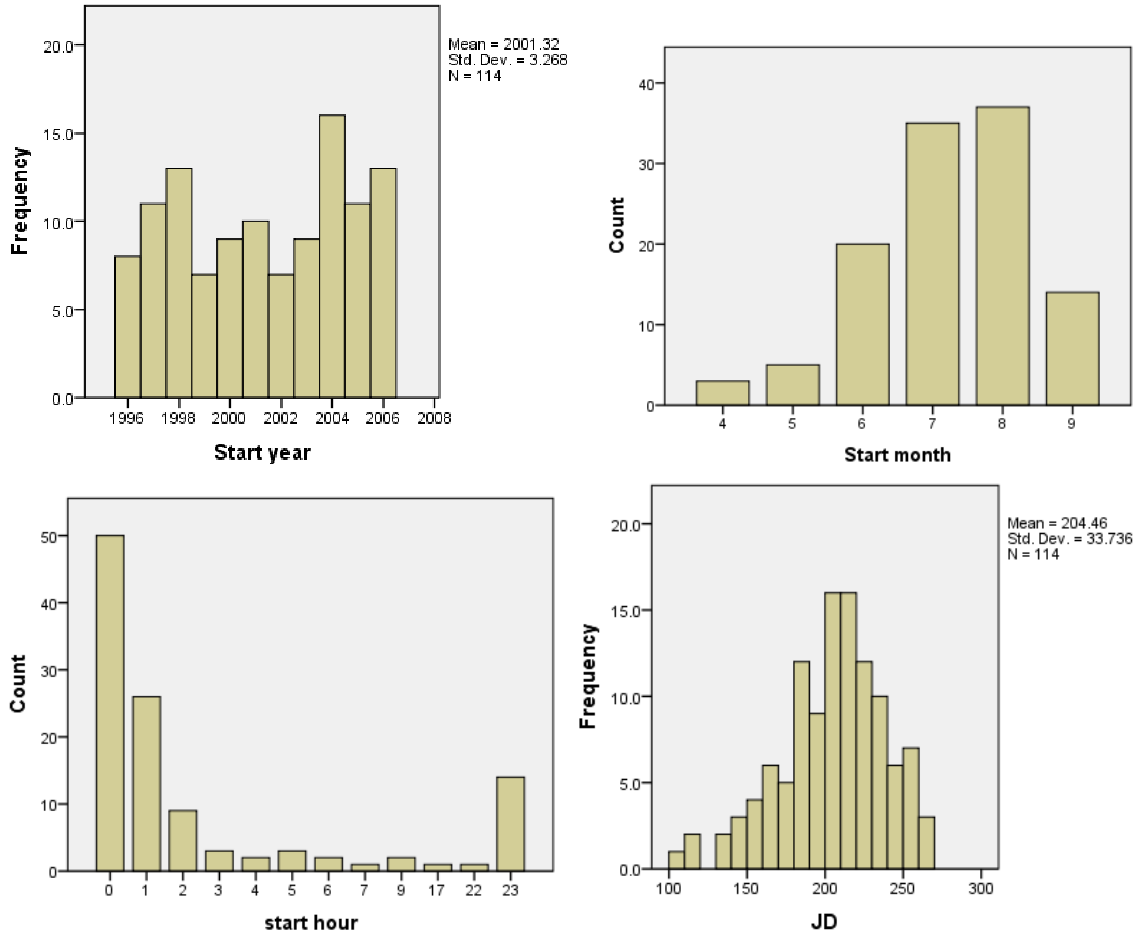


Figure 4.2.3: Time Histograms for the Elk Mountain, NM Wind Direction Group 1 Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram had gaps. The histograms included are start year, start month, start hour, and the Julian Day (JD).

Table 4.2.7: Results of the MLRs Run on the Elk Mountain, NM Wind Direction Group 1 Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – GH200 + UWS600500 + SH200	0.467
5HP	FP ≈ constant + LCL + CIN	0.291
4HP	FP ≈ constant + CAPE + LI + T300 – GH200 – UWND – SRH – STHC + GH300	0.893
3HP	FP ≈ constant + UWS600500 + T200 – SMXR – UC300 – WD500 + SH500 – T300	0.539
2HP	FP ≈ constant + VC200 + LCL – VC300	0.391
1HP	FP ≈ constant + UWSS500 + SH600 – T200 – SRH + UC200 + SH300 – CIN – VC300	0.795
Initiation	FP ≈ constant + T200 + UWS600500 – UC200 + SH200 – T300 + VWSS500 + SH500	0.443

Table 4.2.8: Results of the PCAs Run on the Elk Mountain, NM Wind Direction Group 1 Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	UWND, VWND, Thickness, PW, GH500, GH300, UC600, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	11	85.839%
5HP	STHC, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, GH600, GH500, GH300, SH850, SH800, SH200, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	9	90.434%
4HP	UWND, Thickness, PW, GH600, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC600, VC500, VC300, VWSS500, T600, T500, T300	9	86.409%
3HP	UWND, VWND, PW, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T500, T300	10	85.687%
2HP	STHC, SMXS, UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	8	88.098%
1HP	SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	11	91.377%
Initiation	UWND, PW, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T500	10	84.528%

Table 4.2.9: Median Values for the Upper Air and Surface Variables for the Elk Mountain, NM Wind Direction Group 2 Cluster.

Variable	Median Value
STHC	42.165
SMXR	8.970
SMXS	20.865
UWND	-2.205
VWND	1.285
LCL	636.05
LI	-0.705

Table 4.2.10: Median Values for the NARR Variables for the Elk Mountain, NM Wind Direction Group 2 Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5864.600	5842.800	5902.000	5887.400	5858.750
PW	15.800	14.500	16.600	17.000	15.800
CAPE	280.800	251.500	230.200	212.400	250.200
CIN	-31.400	-24.650	-15.800	-15.300	-15.250
SRH	32.600	33.450	38.100	26.800	8.550
GH600	4486.300	4466.100	4506.200	4487.900	4469.850
GH500	5935.200	5911.100	5960.600	5934.000	5913.750
GH300	9743.200	9708.550	9762.900	9751.900	9716.600
GH200	12477.900	12436.650	12487.000	12494.800	12450.050
SH850	9.700e-3	1.025e-2	9.700e-3	1.030e-2	1.010e-2
SH800	8.500e-3	8.900e-3	8.500e-3	9.000e-3	8.800e-3
SH600	4.400e-3	4.450e-3	5.300e-3	5.500e-3	5.250e-3
SH500	2.300e-3	2.000e-3	2.400e-3	2.400e-3	2.050e-3
SH300	3.800e-4	1.800e-4	2.200e-4	3.700e-4	2.750e-4
SH200	5.200e-5	4.850e-5	4.200e-5	5.100e-5	5.000e-5
UC600	-0.795	-1.200	-2.700	0.318	-0.634
UC500	-1.600	-2.050	-5.800	-2.100	-2.700
UC300	0.780	-1.414	-2.600	0.726	-0.828
UC200	3.600	4.550	-2.600	5.500	5.300
UWSS500	-3.030	0.660	-2.200	-2.130	0.115
UWS600500	-2.100	-1.195	-2.600	-1.977	-1.955
UWSS600	-1.730	-0.175	1.210	-0.350	0.500
WD600	82.300	96.404	79.143	193.778	138.690
WD500	25.616	47.199	44.071	24.702	29.951
VC600	-2.000	-0.734	-0.748	-0.900	-0.307
VC500	-2.400	-2.100	-6.200	-3.800	-3.650
VC300	-2.000	-1.418	-3.400	6.200e-3	9.775e-2
VC200	-0.460	-5.700	-5.600	-1.900	-3.300
VWSS500	-4.720	-2.015	-6.900	-6.550	-4.195
VWS600500	-1.316	-0.345	-4.200	-3.600	-2.770
VWSS600	-2.658	-1.445	-3.728	-2.798	-1.005
T600	3.900	2.100	4.100	3.500	1.750
T500	-6.700	-8.300	-7.100	-6.700	-8.000
T300	-32.400	-33.700	-32.600	-31.700	-33.350
T200	-53.800	-52.800	-53.300	-53.800	-52.400
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5911.400	5888.200	5860.850	5889.0	5873.800
PW	18.200	16.400	15.800	16.900	17.400
CAPE	308.200	161.900	37.250	236.600	59.200
CIN	-31.400	-26.200	-23.850	-37.000	-44.100

Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
SRH	45.100	35.400	18.900	50.500	72.600
GH600	4486.200	4482.800	4470.950	4496.700	4472.100
GH500	5943.600	5934.000	5919.500	5951.200	5931.700
GH300	9748.100	9747.900	9718.450	9757.300	9741.200
GH200	12479.600	12493.400	12449.200	12492.200	12493.900
SH850	9.700e-3	9.200e-3	9.050e-3	9.900e-3	9.800e-3
SH800	8.400e-3	8.000e-3	7.900e-3	8.600e-3	8.500e-3
SH600	5.900e-3	5.500e-3	4.850e-3	4.900e-3	5.200e-3
SH500	2.800e-3	2.500e-3	2.200e-3	2.400e-3	2.800e-3
SH300	2.800e-4	4.000e-4	3.150e-4	3.400e-4	4.600e-4
SH200	4.600e-5	5.400e-5	4.900e-5	4.400e-5	5.700e-5
UC600	-2.400	-0.517	-0.534	-1.800	0.550
UC500	-5.200	-1.800	-2.200	-5.000	-2.100
UC300	-1.700	3.200	1.400	0.266	2.400
UC200	-0.596	6.000	4.800	2.200	6.000
UWSS500	-2.680	-2.886	0.138	-1.550	-2.370
UWS600500	-2.810	-2.347	-1.891	-3.313	-2.452
UWSS600	-0.490	0.780	0.810	1.100	1.160
WD600	109.058	152.630	161.733	59.036	190.389
WD500	43.995	43.854	45.924	30.411	50.981
VC600	-1.600	-0.382	0.552	-3.600	-1.000
VC500	-6.600	-5.800	-2.200	-6.900	-4.500
VC300	-3.300	-1.900	-0.782	-2.900	-2.500
VC200	-5.800	-1.900	-5.000	-6.400	-1.800
VWSS500	-4.040	-7.420	-1.835	-5.140	-5.160
VWS600500	-5.000	-4.800	-3.050	-3.300	-3.172
VWSS600	-1.080	-2.250	-0.480	-2.720	-2.480
T600	4.900	4.100	2.500	4.200	3.800
T500	-6.300	-6.600	-7.550	-6.700	-6.900
T300	-32.100	-31.800	-33.050	-32.300	-32.100
T200	-53.200	-53.700	-52.650	-53.200	-53.700

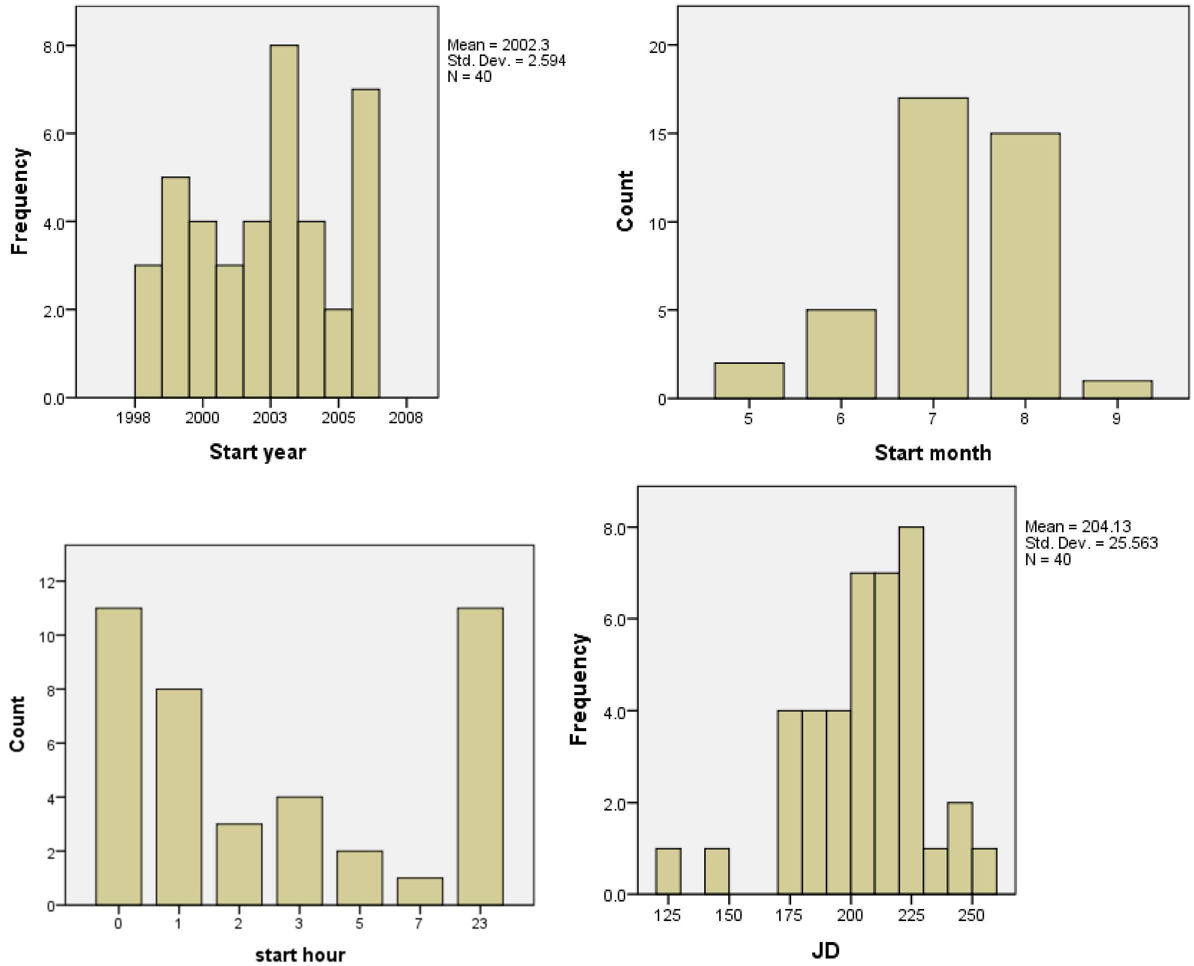


Figure 4.2.4: Time Histograms for the Elk Mountain, NM Wind Direction Group 2 Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram had gaps. The histograms included are start year, start month, start hour, and the Julian Day (JD).

Table 4.2.11: Results of the MLRs Run on the Elk Mountain, NM Wind Direction Group 2 Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + UWS600500 + T200 + VC600 – CIN + UWSS600 – UC200	0.936
5HP	FP ≈ constant + LCL – UWND – VWSS500 – SMXS + SMXR	0.825
4HP	FP ≈ constant + UC500 – VWSS500 + T200	0.942
3HP	FP ≈ constant + UWS600500 + T200 + VC600 – SMXR + VWND + UWSS500	0.960
2HP	FP ≈ constant + VC300 – VWS600500 – CAPE + GH200 – SH600 – GH300 – VC200 – T200 + UWSS600 + LCL – VC500 + VWSS500 + UWS600500 + UC300 + UC200	1.000
1HP	FP ≈ constant + UC500 – SH500 + SMXR + LCL	0.983
Initiation	FP ≈ constant + UWS600500 + T200 – VWSS500 + Thickness	0.715

Table 4.2.12: Results of the PCAs Run on the Elk Mountain, NM Wind Direction Group 2 Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH300, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	94.058%
5HP	STHC, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, UC600, UC500, UC300, UWSS500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	93.998%
4HP	All variables	7	99.835%
3HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	94.301%
2HP	STHC, SMXR, SMXS, VWND, LCL, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	94.116%
1HP	All variables	7	99.752%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	10	95.217%

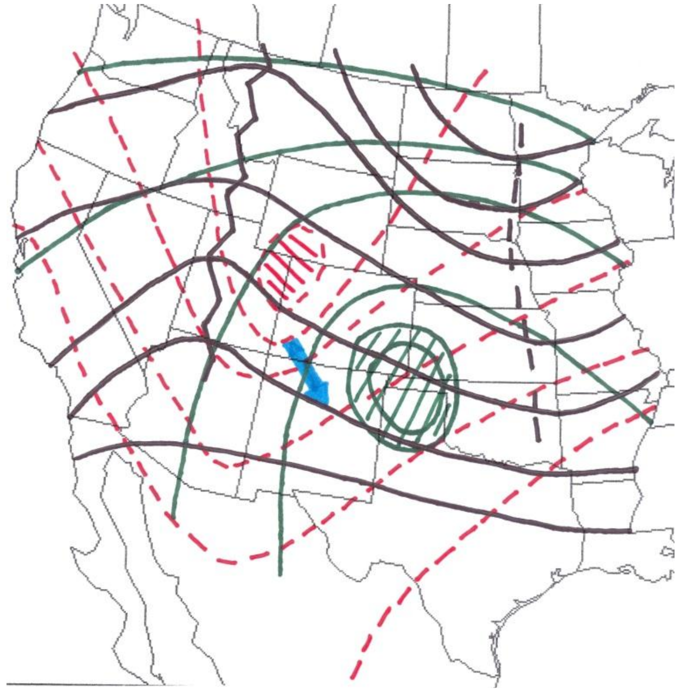


Figure 4.2.5: Composite Map for Elk Mountain, NM. The variables included on the map are T500, GH200, SH850, and wind shear between the surface and 500 mb. (Source: data compiled from Plymouth State Weather Center.)

On the composite maps, the red dashed lines indicate a temperature variable. The red shaded circles indicate low values of temperature and the red dashed line circles not shaded indicate higher temperature values. The green lines indicate a moisture variable. The shaded green line circles indicate high values of moisture and the green circles not shaded indicate relatively low values of moisture. The black lines indicate a geopotential height variable. The black dashed lines indicate a trough while a black zigzag line indicates a ridge. The blue arrow indicates a wind shear variable and the blue arrow points from the direction of wind shear. The arrow is shown in the approximate location of the cluster.

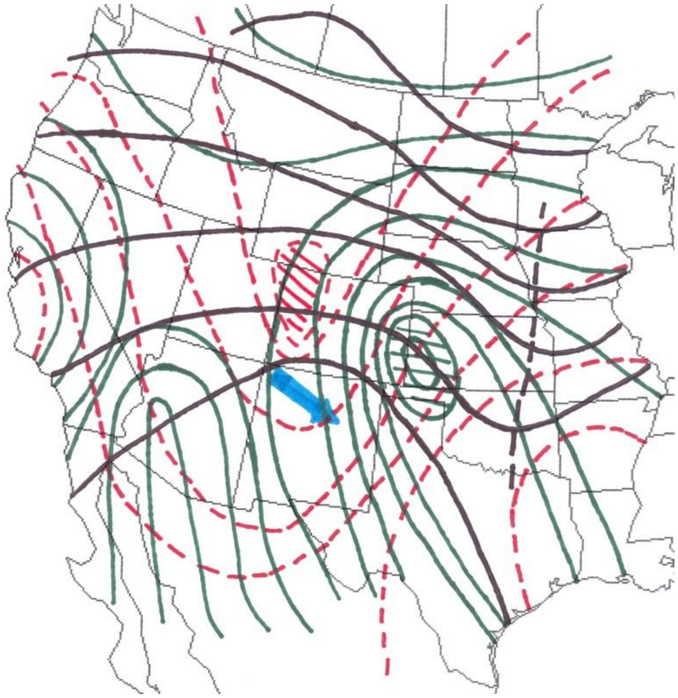


Figure 4.2.6: Composite Map for Elk Mountain, NM Wind Direction Group 1. The variables included on the map are T500, GH500, SH850, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

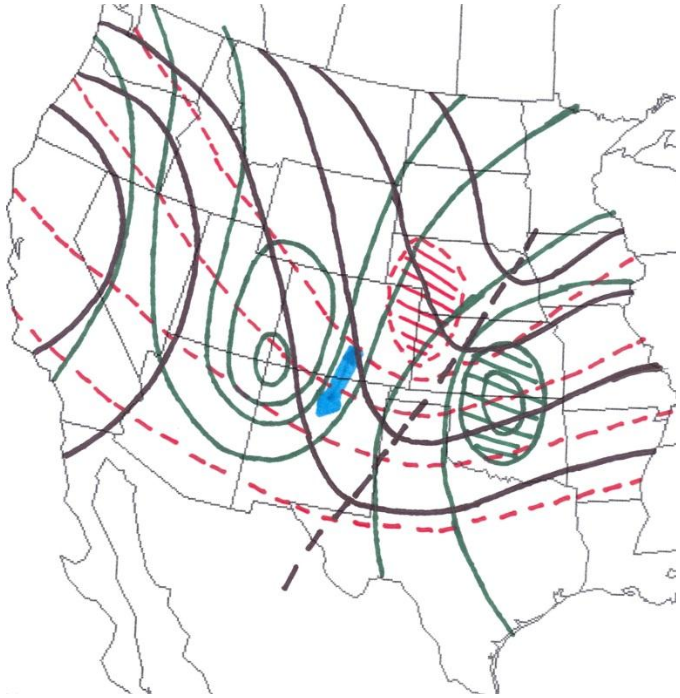


Figure 4.2.7: Composite Map for Elk Mountain, NM Wind Direction Group 2. The variables included in the map are T300, GH300, SMXR, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.3: Ute Hills/Pete Hills, CO

4.3.1: Description of Cluster

The Ute Hills/Pete Hills, CO cluster, located west of Trinidad, CO, is the second biggest cluster with 90 members. The median values given for the surface variables in Table 4.3.1 show that the air is warm at 37.970˚C (approximately 100˚F), relatively dry, and the winds are from the west. The potential temperature given at the closest reporting stations is relatively warm, so it can be assumed that the initiation location is cooler but still relatively warm. The median values of SMXR and SMXS show the air is relatively dry at approximately 53 percent relative humidity. This relatively dry air was noted in TZ99 as well. Since the VWND median value is zero, UWND shows that the wind is coming from the west. The median values given for the upper air variables in Table 4.3.1 show there is a mid-level LCL and a slightly unstable LI.

The median values obtained from the NARR data are given in Table 4.3.2 and show how each of the variables fluctuate from 6HP to 3HA. The Thickness and other geopotential height variables change little from 6HP to 3HA. There is only a slight drop in the median value for some of the geopotential height variables from the 6HP model run to the initiation hour model run. PW increases slightly from the 6HP to the model run at initiation. Once the system initiates, the PW decreases, which is expected. CAPE has a higher value at 6HP than it has at initiation. It is possible that the initiation of convection is removing the instability from the atmosphere so that CAPE has a higher value at 6HP than it does at initiation. CIN fluctuates between the 6HP model run and the model run done at initiation, but the median values at the two model runs are nearly the same. SRH is approximately the same value for all the model runs prior to initiation. Once initiation occurs, the SRH median value increases significantly. The specific humidity variables decrease in value from the 6HP to the model run at initiation. There is no significant change after initiation. There are few significant changes in the U and the V component wind variables between the 6HP and the initiation model run. There are noteworthy changes in the wind shear variables between the model runs. The V component wind shears change direction from originating from the south to originating from the north. The upper level temperatures have no significant changes between all the model runs.

Histograms for the Ute Hills/Pete Hills, CO cluster, Figure 4.3.1, were created for the start year, start month, start hour, and Julian Day. The year 2006 had the most MCSs occurring within the cluster domain, the next largest year was 1997 and the mean year value was 2000. The start-month histogram shows that the month where the most MCSs initiated was July, with approximately 30 MCSs, and the next month was August. These two months had significantly more MCSs occurring than the other months in the warm season. The start-hour histogram shows that the MCSs mainly initiate in late afternoon/early evening (consistent with FF01). The Julian-Day histogram indicates that a major portion of the MCSs initiate in July and August when the surface temperature is at its warmest.

4.3.2: Multiple Linear Regression

MLRs were run on each of the 6HP through 3HA initiation on this cluster. The resulting equations and the R square values are included in Table 4.3.3. These equations suggest the conditions needed for an MCS to form in that location. The results discussed below for the Ute Hills/Pete Hills, CO cluster come from a combination of Table 4.3.1, Table 4.3.2, and Table 4.3.3.

The 6HP model run has an R square value of less than 0.600; therefore, this model run is included in Table 4.3.3 but will not be discussed. There were no multicollinearity issues present.

The 5HP model run was still a relatively poor fit to the data but the R square value is above 0.600 at 0.662 and is similar to the 2HP model run for this cluster. LCLs lower to the ground, more negative LI values, weaker east-west winds at the surface, and negative V component surface winds will provide the greatest contribution to the FP. The fit to the data was relatively poor which can be attributed to the large range in the values of the variables, making it harder to obtain a good fit to the data for the equation. There are no multicollinearity issues present in the model run which is to be expected since the R square value is low.

The 4HP model run was not a good fit to the data. More negative LI values, a dry pocket of air at 300 mb, northwest winds, a moist pocket of air at 500 mb, larger CAPE values, a dry pocket of air at 600 mb, and higher surface saturation mixing ratios provide the greatest contribution to the FP. These are the variables that need to be observed at 4HP within this domain. The fit to the data was still relatively poor at 0.689 but there are no multicollinearity issues present.

The 3HP model run had an R square value below 0.600; therefore, this model run will not be discussed in detail but it is still included in Table 4.3.3.

The 2HP model run was a better fit to the data than the previous runs and is very similar to that at 5HP. LCL values closer to the ground, more negative LI values, U component surface winds closer to zero, and stronger V component wind shears between the surface and 600 mb are needed for larger FPs. The fit to the data was a better fit at 0.704. While this is not the best fit possible, it shows the possible variables needed for larger FPs. There were no multicollinearity issues present in this model run.

The 1HP model run had the second best fit to the data out of all of this cluster's model runs. More negative LI values, weaker V component winds at 600 mb, a dry pocket of air at 300 mb, and higher surface saturation mixing ratios are needed for larger FPs. A moist pocket of air at 500 mb, a dry pocket of air at 600 mb, stronger, west-east winds at 200 mb, LCL values closer to the ground, weaker V component wind shears between the surface and 500 mb, and stronger U component wind shears between the surface and 600 mb are also needed for larger FPs from the system that initiates in one hour within this cluster's domain. This model run was a much better fit to the data than previous model runs at 0.850. There were multicollinearity issues present in this model run which means that the variables were not truly independent of each other.

The model run done at initiation was a very poor fit to the data at 0.226, well below the cutoff of 0.600; therefore, the model run will not be described in detail but will still be included in Table 4.3.3.

There were several variables that were never used in the model runs: STHC, Thickness,

SRH, GH600, GH500, GH300, GH200, SH800, SH200, VC500, VC300, VC200, VWS600500, T600, T500, and T300. The most used variable, LI at eight out of ten model runs, if added negatively into the equation, gives the best contribution to the FP. This corresponds to the atmosphere needing to be unstable for larger FPs to form in this location according to MLR. The next most often used variables were LCL and SH300 at four out of ten model runs. Lower LCLs are key to larger FPs. If the LCL is below ridgetop height, there is a better chance of convective initiation. The geopotential height variables are not used in this cluster’s model runs because they are not a good fit to the FP. The wind and wind shear variables are not used as often as expected which is noticeably different than the previous clusters. The only upper level temperature used was T200 (once), and is a definite difference between this cluster and the entire Elk Mountain, NM cluster. The biggest similarity seen among the model runs is the inclusion of LI, since it is included so often. The biggest difference among the model runs is the inclusion of many other variables which were included in model runs either once or twice.

4.3.3: Principal Component Analysis

PCAs were run on the 6HP through 3HA initiation. Even though there were only a few multicollinearity issues seen with the MLRs, PCAs were still done for better fits to the data. The variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one and percent variance accounted for with those eigenvalues are included in Table 4.3.4. The PCA shows the variables that are important and necessary to MCSMI within this cluster location.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. The STHC (1HP, initiation), SMXR (5HP, 4HP, 1HP, initiation), SMXS (1HP, initiation), Thickness (5HP, 4HP, 3HP, 2HP, 1HP, initiation), PW (5HP, 4HP, 3HP, 2HP, 1HP, initiation), geopotential height, specific humidity, U component wind (4HP), U component wind shear (4HP), and temperature variables were loaded highest in the first component. These variables were loaded in positively with the exception of the U component wind (4HP), U component wind shear (4HP), and temperature (6HP, 3HP) variables. The specific humidity variables are expected since moisture is required for convective initiation in the dry Rocky Mountain air. These are identified as variables providing a significant contribution to the formation of the MCS. The temperature variables have a much more significant contribution to the PCA than for the MLR. The variables loaded highly into the second component were geopotential height (6HP), U component wind (5HP, 2HP), U component wind shear (5HP, 2HP), V component wind (6HP, 5HP, 4HP, 3HP, 1HP, initiation), and V component wind shear (6HP, 5HP, 4HP, 3HP, 1HP, initiation) variables. They were loaded in positively, with the exception of the V component wind (5HP), V component wind shear (5HP), and geopotential height (6HP) variables. Negative loadings with geopotential height variables indicate colder columns of air. The variables loaded highly in the first components are considered the most important identified variables for MCSMI.

Only two variables were not included on the most used list: LI and UC200. They are dissimilar to the ones not included in any of the MLRs. LI had the most times included in an MLR and it was never included in a PCA. CAPE, another stability variable, was included on only one most used list in the hours prior to initiation. CIN was only included in three most used lists in the hours prior to initiation. A stability variable was not considered important in these PCAs. The variables included the in all ten most used lists were Thickness, PW, GH500, GH300, GH200, SH800, UWSS500, VC500, VWSS500, VWSS600, T600, T500, and T300. This list is very similar to the list of the variables most highly loaded into the first component which was discussed with the model runs. SH800 and PW confirm that moisture is more important to this cluster than the previous one. The V component of the wind is important according to the PCAs. Other variables included often in the most used list are STHC, SH850, UC500, and UWSS600. The U component of the wind is important to the PCAs according to the list, but it is not as important as the V component wind values for this cluster. The other variables were used a maximum of six times in the model runs. The rest of the variables are not as important to the identification process for the variables but play a vital role in the formation and continuation at certain times prior to and after initiation. The biggest similarity between the model runs was the inclusion of the geopotential height variables. The biggest difference between the model runs was the inclusion of different specific humidity variables.

4.3.4: Cluster Discussion

Overall, the PCAs give a better description of the environment prior to initiation. Multiple MLRs failed to provide a decent fit and were not discussed. The prominent variable within the MLRs was not even used in any of the PCAs. This may be because the variance of LI was just too great for the PCA to properly account for in the model runs. The geopotential height variables were not vital to MLR but were to the PCA. This highlights the difference between the two types of analyses in that each type of analysis has a distinct way of determining the variables used and how they are used. Different analyses will provide different results. Wind variables were used often in both types of analyses, so the wind values would be important to consider if forecasting the potential for an MCS within the cluster domain.

The Ute Hills/Pete Hills, CO cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that winds at 600 mb arrive at an angle to the ridgeline and winds at 500 mb are perpendicular to the ridgeline.

The composite map for Ute Hills/Pete Hills, CO is Figure 4.3.2. The most important temperature variable was T500. The composite map indicates cooler temperatures to the north of the domain. If the cooler temperatures move west, the temperatures within the domain will also become cooler. The most important geopotential height variable was GH500. The flow is mainly zonal but there is a small ridge at the domain indicating higher heights. The most important moisture variable was SH850. Drier air is to the west and moister air is to the east of the domain. With the locations of the dry and moist air, the air is relatively moist over the domain according to this composite map. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 3.443 ms^{-1} at 291.214˚.

4.3.5: Cluster Figures and Tables

Table 4.3.1: Median Values for the Upper Air and Surface Variables for the Ute Hills/Pete Hills, CO Cluster.

Variable	Median Value
STHC	37.970
SMXR	10.195
SMXS	19.335
UWND	1.025
VWND	0.000
LCL	644.405
LI	-0.905

Table 4.3.2: Median Values for the NARR Variables for the Ute Hills/Pete Hills, CO Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5843.750	5844.950	5851.200	5866.450	5849.300
PW	15.500	14.650	16.150	16.950	15.650
CAPE	280.350	226.050	207.250	276.000	163.650
CIN	-33.500	-20.100	-20.250	-18.250	-21.750
SRH	29.000	29.850	26.800	25.800	38.500
GH600	4466.000	4455.600	4454.500	4464.500	4465.850
GH500	5913.000	5897.350	5902.200	5910.050	5916.950
GH300	9701.600	9705.150	9690.550	9705.200	9705.650
GH200	12437.500	12404.100	12412.450	12438.550	12405.200
SH850	1.075e-2	1.010e-2	9.900e-3	1.010e-2	9.750e-3
SH800	9.350e-3	8.750e-3	8.650e-3	8.800e-3	8.500e-3
SH600	4.200e-3	4.600e-3	4.900e-3	5.500e-3	4.850e-3
SH500	2.300e-3	2.250e-3	2.450e-3	2.650e-3	2.350e-3
SH300	3.350e-4	2.350e-4	3.300e-4	3.550e-4	2.400e-4
SH200	4.600e-5	4.300e-5	4.550e-5	4.850e-5	4.150e-5
UC600	3.000	2.350	2.950	2.450	2.150
UC500	4.000	5.300	5.750	4.950	5.850
UC300	6.550	8.100	8.800	6.100	9.750
UC200	9.400	11.100	12.100	9.650	11.400
UWSS500	3.050	3.620	4.795	3.380	4.115
UWS600500	1.350	2.950	3.150	3.113	3.450
UWSS600	1.805	1.815	2.745	1.125	2.385
WD600	262.551	253.834	246.993	236.041	235.986
WD500	246.804	262.552	267.637	255.128	269.601
VC600	0.664	-0.446	-0.056	0.853	1.363
VC500	0.860	-0.218	-0.589	0.356	-0.234
VC300	3.000	3.400	3.150	3.600	1.750
VC200	4.000	1.300	4.150	2.700	0.402
VWSS500	1.807	1.138	1.130	0.871	-0.240
VWS600500	1.400	0.759	-0.750	-1.103	-1.581
VWSS600	0.312	0.150	1.810	0.661	2.302
T600	3.050	2.400	2.450	3.25	2.650
T500	-7.700	-8.450	-8.000	-7.700	-8.200
T300	-32.950	-34.350	-33.950	-32.450	-34.000
T200	-53.450	-54.150	53.400	-53.250	-53.850
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5855.350	5858.950	5833.450	5837.350	5845.400
PW	15.900	16.550	14.350	16.350	16.550
CAPE	194.350	103.450	87.150	286.700	158.750
CIN	-30.100	-32.000	-47.450	-39.800	-41.650

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	37.700	32.850	64.800	48.750	45.550
GH600	4454.300	4457.100	4459.900	4444.750	4464.650
GH500	5903.400	5905.850	5907.900	5888.800	5915.150
GH300	9694.250	9707.600	9695.500	9685.500	9702.850
GH200	12420.350	12434.950	12410.950	12405.500	12431.600
SH850	9.900e-3	9.700e-3	9.800e-3	1.035e-2	9.950e-3
SH800	8.600e-3	8.450e-3	8.450e-3	9.050e-3	8.600e-3
SH600	5.100e-3	5.300e-3	4.450e-3	4.550e-3	4.900e-3
SH500	2.650e-3	2.700e-3	2.450e-3	2.550e-3	2.700e-3
SH300	3.550e-4	4.050e-4	2.850e-4	3.450e-4	4.500e-4
SH200	5.050e-5	5.600e-5	3.550e-5	4.950e-5	5.400e-5
UC600	4.400	2.350	5.000	4.950	4.200
UC500	6.150	4.950	7.100	6.000	4.800
UC300	9.100	6.900	7.900	8.350	7.400
UC200	12.300	9.450	10.700	12.950	9.850
UWSS500	6.445	3.210	4.835	5.925	3.850
UWS600500	1.900	2.950	2.394	0.500	1.350
UWSS600	3.735	0.655	3.545	4.365	3.565
WD600	249.080	241.743	251.874	261.396	251.375
WD500	287.559	275.388	280.592	270.886	282.722
VC600	0.395	1.550	1.800	0.304	0.814
VC500	-1.800	-0.828	-1.057	-2.150	-1.700
VC300	4.100	4.500	1.250	4.250	1.850
VC200	3.350	3.250	0.827	3.550	1.145
VWSS500	1.220	-1.246	-1.365	0.515	-2.200
VWS600500	-1.879	-2.207	-3.650	-1.528	-1.550
VWSS600	2.460	0.700	2.212	1.355	8.050e-2
T600	2.900	3.200	2.200	2.300	3.100
T500	-8.150	-7.250	-7.850	-8.200	-7.000
T300	-33.600	-32.350	-34.300	-33.950	-32.500
T200	-53.650	-53.400	-53.700	-53.750	-53.500

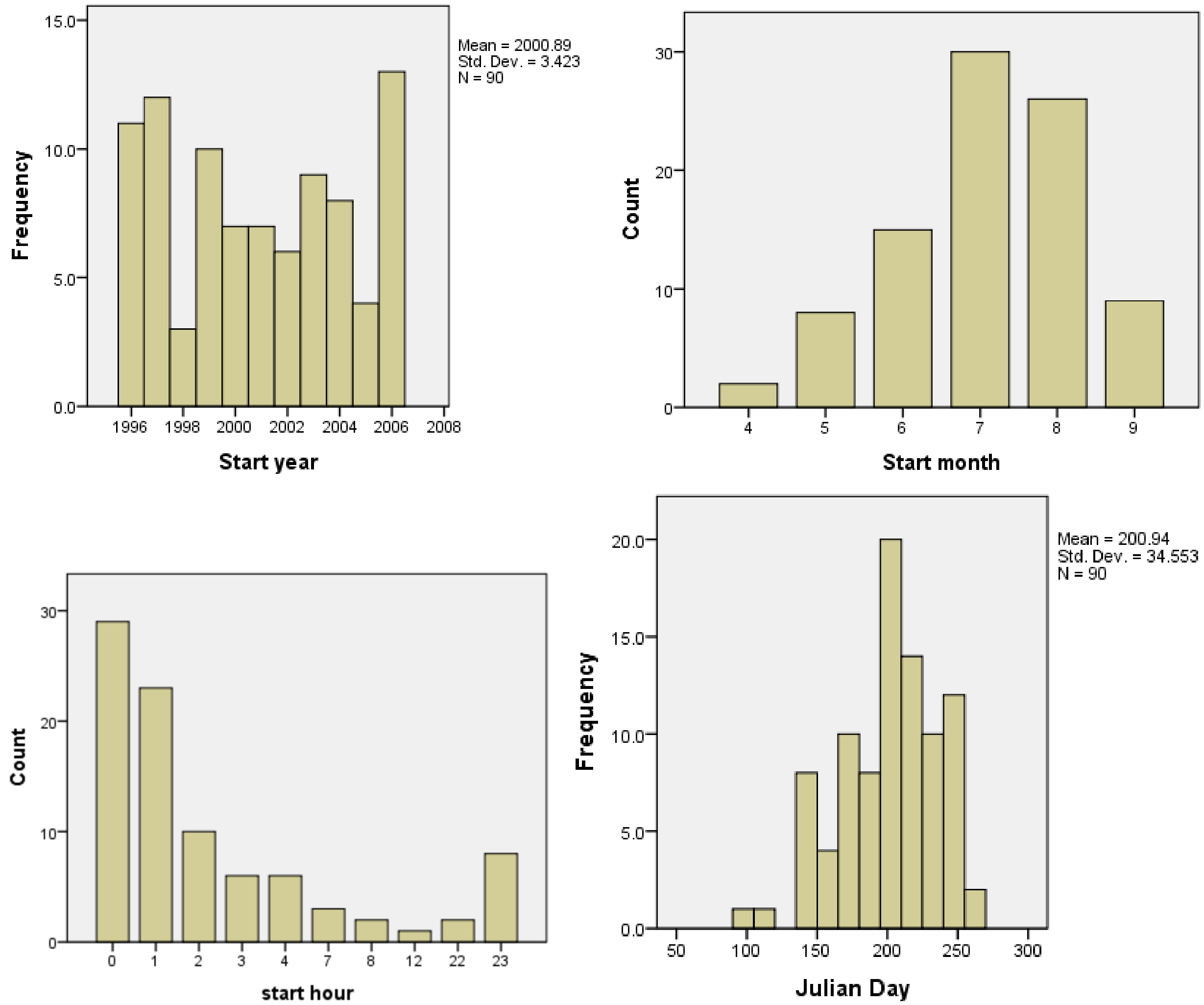


Figure 4.3.1: Time Histograms for the Ute Hills/Pete Hills, CO Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram had gaps. The histograms included are start year, start month, start hour, and the Julian Day (JD).

Table 4.3.3: Results of the MLRs Run on the Ute Hills/Pete Hills, CO Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – PW + UC600 + VWSS600 – UC300 + T200 + UC200	0.531
5HP	FP ≈ constant + LCL – LI – UWND – VWND	0.662
4HP	FP ≈ constant – LI – SH300 + WD600 + SH500 + CAPE – SH600 + SMXS	0.689
3HP	FP ≈ constant – CIN + VWSS600 + UC500 – CAPE	0.467
2HP	FP ≈ constant + LCL – LI – UWND + VWSS600	0.704
1HP	FP ≈ constant – LI – VC600 – SH300 + SMXS + SH500 – SH600 + UC200 + LCL – VWSS500 + UWSS600	0.850
Initiation	FP ≈ constant + UWSS500 + LI	0.226

Table 4.3.4: Results of the PCAs Run on the Ute Hills/Pete Hills, CO Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UC300, UWSS500, UWS600500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	8	86.596%
5HP	STHC, SMXR, SMXS, VWND, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC500, UC300, UWSS500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	8	90.832%
4HP	STHC, SMXS, UWND, VWND, Thickness, PW, CIN, SRH, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	10	89.719%
3HP	STHC, VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UWSS500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	8	87.603%
2HP	STHC, SMXR, SMXS, UWND, VWND, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWSS600, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	10	94.217%
1HP	STHC, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	9	86.300%
Initiation	STHC, SMXS, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH200, UC500, UWSS500, UWSS600, WD600, WD500, VC500, VWSS500, VWSS600, T600, T500, T300	9	90.547%

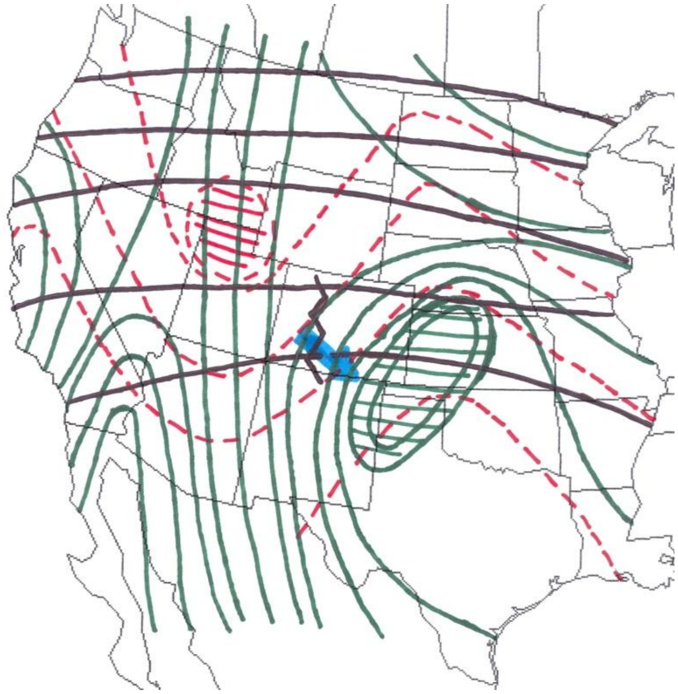


Figure 4.3.2: Composite Map for Ute Hills/Pete Hills, CO. The variables included on the map are T500, GH500, SH850, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.4: Rincon Mountains, NM

4.4.1: Description of Cluster

The Rincon Mountains, NM cluster is the third largest cluster with 76 members and are located due east of the Sangre de Cristo Mountains and southeast of Taos, NM. The median values given for the surface variables in Table 4.4.1 show that the median potential temperature is warm at 38.280˚C (approximately 101˚F), the air is relatively dry (also seen in TZ99), and the winds are from the south. Since the potential temperature is warm at the closest reporting station, it can be inferred that the potential temperature is relatively warm at the initiation location. The median values of SMXR and SMXS confirm the air is relatively dry with a median relative humidity value of approximately 54 percent. The UWND and VWND median values force a median wind direction of south since UWND's median value is zero. The median values given for the upper air variables in Table 4.4.1 show a mid-level LCL, which is close to ridgetop height, and a slightly positive LI. This LI is different from previous clusters in that the previous clusters' LI values were negative and the LI for this cluster is positive.

The median values from the NARR data are given in Table 4.4.2 show how each variable changes over time. The Thickness and geopotential height variables do not change significantly from 6HP to 3HA. There is a very small drop in the median values of each of those variables from 6HP to the initiation hour. The system initiating does not affect the height variables. While PW does not increase prior to, it does increase after initiation. CAPE decreases significantly in the hours prior to but starts to rise once again after initiation. The absolute value of CIN becomes more negative as initiation nears and continues to increase after initiation. It is expected that the absolute value of CIN would decrease but that is not the case for this cluster. The CIN and LI will have to be overcome before initiation can occur. SRH does not change significantly throughout the model runs. The specific humidity variables do not change greatly throughout the models, but the SH850 median value is relatively moist. This indicates that there is a moist pocket of air at 850 mb. There are several changes in the U component wind and wind shear variables and the V component wind and wind shear variables from the hours prior to through the initiation hour. The most significant change is seen in the V component wind variables. The upper level temperatures do not change significantly throughout the model hours.

Histograms for the Rincon Mountains, NM cluster, Figure 4.4.1, were created for the start year, the start month, the start hour, and the Julian Day. Most MCSs initiated in 2003, followed by 2002 with the fewest initiating in 2004. The mean year for initiation was 2001. The start-month histogram shows that the most MCSs occurred in the month of August, with July following closely behind. These two months contained significantly more MCSs than any of the others. The start-hour histogram illustrates that most of the MCSs initiated in late afternoon/early evening (consistent with FF01). There were a few morning initiations but these were relatively rare. The Julian-Day histogram definitely shows that July and August were the favored months for initiation, during what should be the warmest time of the year in the cluster location.

4.4.2: Multiple Linear Regression

MLRs were run on each of the 6HP through 3HA on the Rincon Mountains, NM cluster. The resulting equations and the R square values are included in Table 4.4.3. These equations identify the necessary variables needed for larger FPs. The results discussed below are derived from a combination of Table 4.4.1, Table 4.4.2, and Table 4.4.3.

The 6HP model run had a relatively good fit to the data at 0.726. Colder temperatures at 200 mb, larger values of CAPE, and stronger U component wind shears between the surface and 600 mb are needed for larger FPs within this cluster's domain. The fit to the data was not the best fit in the model runs but it is high enough that this equation can be seen as a good representation of what the atmosphere should look like at 6HP. There were no multicollinearity issues present in this model run.

The 5HP model run contained a higher number of variables than the previous but the fit to the data was slightly poorer. Weaker U component wind shears between the 500 and 600 mb, warmer columns of air between the surface and 500 mb, larger negative CIN values, lower surface saturation mixing ratios, smaller U component winds at 300 mb, and larger V component winds at 300 mb are needed for larger FPs within this cluster's domain. The larger negative CIN values mean that since the CIN value is always negative and CIN is added negatively into the equation, larger negative values will produce the best positive contribution for the FP. The fit to the data was tolerable at 0.718, slightly smaller than the previous model run and can be used to estimate the FP with error. The variables included are considered independent of each other since there were no multicollinearity issues present.

The 4HP model run had an R square value under 0.600 at 0.457; therefore, this model run will not be discussed in detail but it is still included in Table 4.4.3. There were no multicollinearity issues present in this model run.

The 3HP model run was a very good fit to the data with an R square value of 0.967. This model run contains variables that are important to larger FPs within the Rincon Mountains, NM cluster. Colder temperatures at 200 mb, smaller V component winds at 300 mb, stronger U component wind shears between the surface and 600 mb, positive U component surface winds, and northeast winds at 600 mb are needed for larger FPs according to this equation. SRH values closer to zero, relatively cooler surface temperatures, south-north winds at 500 mb, a dry pocket of air at 300 mb, a moist pocket of air at 500 mb, larger surface saturation mixing ratios, and larger CAPE values are also needed for larger FPs within this cluster's domain. The fit to the data was very good at 0.967, indicating that this equation could be used to predict the FP that will result from initiation. There were multicollinearity issues present.

At 0.995, the 2HP model run had the best fit to the data out of all the model runs. This equation also contained the most variables out of the Rincon Mountains model runs. Stronger U component wind shears between 600 and 500 mb, a moist pocket of air at 600 mb, a dry pocket of air at 850 mb, and cooler surface temperatures are needed for larger FPs within this domain. Weaker west-east winds at 300 mb, weaker V component wind shears between 600 and 500 mb, colder temperatures at 600 mb, more positive LI values, a dry pocket of air at 500 mb, and higher surface mixing ratios are also needed for larger FPs. Weaker south-north winds at 300 mb, positive U component surface winds, stronger west-east winds at 200 mb, weaker west-east winds at 500 mb, and smaller surface saturation mixing ratios are also needed for larger FPs according to this equation. The more positive LI values mean the atmosphere is more stable, but for the best positive contribution to the FP this is what is needed. This equation can be used for identifying the variables needed to accurately predict the value of the FP within an acceptable amount of error. There were multicollinearity issues present but it will be fixed within the PCA.

The 1HP model run had an R square value less than 0.600 at 0.467; therefore, the model run will not be discussed but it is still included in Table 4.4.3. There were no multicollinearity issues present in this model run.

The model run done at initiation had a fairly good fit to the data at 0.900 and was one of the best fits to the data out of all the model runs. Colder temperatures at 200 mb, a dry pocket of air at 300 mb, stronger U component wind shears between the surface and 600 mb, LCLs lower to the ground, weaker south-north winds at 300 mb, a dry pocket of air at 600 mb, larger Thickness values, colder columns of air between the surface and 500 mb (in direct contradiction to the Thickness), and stronger south-north winds at the surface will provide the greatest contribution to the FP within this cluster's domain at the hour of initiation. This equation can be used for identifying the variables needed to predict the FP with the initiation hour variables. There were multicollinearity issues present, but this is expected due to the high correlation between Thickness and GH500.

Throughout the MLRs, there were several variables that were never used: GH300, GH200, SH800, SH200, UC600, UWSS500, WD500, VC600, VC200, VWSS500, and T500. The wind shear variables are unexpected since wind shear is important to larger FPs. The most used variables were UWSS600, VC300, and T200 at four out of ten model runs. Since no variable was included in almost every model run, no particular variable was more important to larger FPs within the Rincon Mountains cluster than another variable. There is no major similarity between the model runs due to the amount all the variables used. The biggest difference between all the model runs was the different variables used in the equations. Overall, the variables are only important at specific times rather than consistently important.

4.4.3: Principal Component Analysis

PCAs were run on each of the 6HP through 3HA on the Rincon Mountains, NM cluster. The PCAs should be better fits to the data than the MLRs since PCA solves MLR's fit issues. Included in Table 4.4.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. In the first component, the variables with the highest loadings were generally the same variables that were highly loaded in the previous clusters' model runs. The STHC (1HP), Thickness, PW (5HP, 3HP), geopotential height, specific humidity (6HP, 5HP), U component wind (3HP), U component wind shear (5HP), and temperature variables were all loaded highly into the first component. Each of these variables was also loaded positively into the equation with the exception of the U component wind (3HP) and U component wind shear (5HP) variables. The Thickness and geopotential height variables' positive loadings point to warmer columns of air. The specific humidity variables' positive loadings point to moister air at all levels. The upper level temperature loadings point to warmer temperatures at the initiation location. This does not contradict the geopotential height loadings since they point to warmer columns of air. The second component's highest loadings were with the LCL (3HP), specific humidity (6HP, 4HP), V component wind (6HP, 5HP, 3HP, 2HP, initiation), and V component wind shear (6HP, 5HP, 3HP, 2HP, initiation) variables. These variables were loaded positively into the component. The wind variables indicate strong, west-east winds are best for this component. No variable was loaded highly into the second component of the 1HP model run. The loadings show these variables' importance to the formation of an MCS.

The variables included in the PCAs are different from those in the MLRs. The variables not included in these PCAs are CAPE, SH200, WD600, and T200. The only variable that was not included in both the PCAs and MLRs was SH200. The moisture in the pocket of air at 200 mb at the initiation location is not crucial to initiation and to larger FPs. Other variables are much more important and have been identified for MCSMI. The variables that were included in all the PCAs were Thickness, PW, GH500, GH300, GH200, UWSS500, UWSS600, VC500, VWSS500, T600, T500, and T300 and are considered very important to MCSMI. The geopotential height variables were included most overall. Warmer columns of air are optimal according to the PCAs. The biggest difference between the model runs is the inclusion of the specific humidity variables but, overall, the specific humidity variables are used often enough to be important as well.

4.4.4: Cluster Discussion

Overall, the PCAs are a better indication of the characteristics needed for MCSMI. A few of the MLRs have near perfect fits to the data, so the equations can provide the necessary variables needed for an accurate prediction of the FPs. The PCAs can be used for identifying the variables needed for the prediction of when an MCS will occur. The MLR variables can be used for predicting the FP. A few of the MLRs will not be good predictors of the FP since the fit to the data is so poor. This could be because the sample size is decreasing with each successive cluster so that fewer points have to be fit to a linear line.

The Rincon Mountains, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west. The median wind direction at 500 mb and initiation gives winds from the west-northwest. This indicates that the winds at 600 mb arrive perpendicular to the ridgeline and winds at 500 mb arrive at an angle to the ridgeline.

The composite map for Rincon Mountains, NM is Figure 4.4.2. The most important temperature variable was T300. The composite map indicates lower temperatures at 300 mb to the north of the domain. Overall, the composite map indicates the temperatures at 300 mb are relatively warm. The most important geopotential height variable was GH500. The heights at the initiation location will increase slightly then decrease as the ridge barely west of the cluster domain moves through. The most important moisture variable was SH850. There are high levels of moisture to the east and northeast of the cluster domain. There is a relatively dry pocket of air to the west. Since the domain is not in the moist pocket of air, the air is considered relatively dry. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 4.224 ms^{-1} at 305.248°.

4.4.5: Cluster Figures and Tables

Table 4.4.1: Median Values for the Upper Air and Surface Variables for the Rincon Mountains, NM Cluster.

Variable	Median Value
STHC	38.280
SMXR	9.610
SMXS	17.945
UWND	0.000
VWND	1.330
LCL	623.205
LI	0.130

Table 4.4.2: Median Values for the NARR Variables for the Rincon Mountains, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5842.100	5841.250	5856.550	5853.200	5848.650
PW	15.500	16.250	14.750	15.500	16.800
CAPE	309.900	200.450	242.050	295.700	136.950
CIN	-25.150	-16.100	-14.850	-15.950	-18.000
SRH	24.450	16.100	18.150	35.800	21.400
GH600	4467.200	4466.650	4443.500	4463.150	4461.500
GH500	5917.700	5916.850	5890.650	5911.700	5908.200
GH300	9696.900	9703.350	9685.850	9705.600	9708.300
GH200	12431.750	12440.550	12426.150	12442.750	12440.350
SH850	1.010e-2	1.060e-2	9.450e-3	9.800e-3	1.035e-2
SH800	8.750e-3	9.250e-3	8.250e-3	8.500e-3	8.950e-3
SH600	4.650e-3	4.450e-3	4.850e-3	5.000e-3	5.300e-3
SH500	2.150e-3	2.500e-3	1.950e-3	2.250e-3	2.800e-3
SH300	2.450e-4	2.850e-4	2.350e-4	2.650e-4	3.700e-4
SH200	4.400e-5	4.150e-5	4.250e-5	4.500e-5	5.150e-5
UC600	2.650	1.450	3.300	2.900	2.950
UC500	2.650	1.550	4.600	3.350	2.250
UC300	5.600	5.750	5.800	5.250	5.100
UC200	8.400	7.400	8.800	9.150	6.850
UWSS500	3.605	2.325	6.220	3.916	2.875
UWS600500	-0.050	-0.175	1.750	0.952	0.400
UWSS600	3.170	1.970	4.935	3.530	3.560
WD600	256.053	235.144	238.587	260.212	223.234
WD500	234.500	216.749	257.151	269.524	222.457
VC600	-0.610	0.571	0.734	2.710e-2	1.150
VC500	-1.850	0.442	-0.603	-2.900	6.270e-2
VC300	2.250	3.300	3.100	2.250	3.200
VC200	1.550	2.600	3.200	1.325	3.050
VWSS500	-3.130	1.500	-2.731	-3.742	0.876
VWS600500	0.000	0.880	-1.662	-3.158	-0.964
VWSS600	-2.216	1.700	-1.860	-1.140	1.100
T600	2.450	1.850	1.800	2.550	1.800
T500	-7.650	-7.550	-8.350	-7.800	-7.200
T300	-33.300	-32.450	-33.750	-32.950	-32.250
T200	-52.700	-53.200	-53.450	-53.100	-53.200
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5836.700	5851.250	5834.500	5809.550	5835.050
PW	14.700	15.700	16.150	15.600	16.100
CAPE	148.000	79.750	68.200	215.600	170.300
CIN	-29.250	-34.400	-29.950	-39.000	-43.400

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	28.650	37.500	28.800	38.550	59.200
GH600	4435.050	4463.500	4464.950	4453.850	4465.900
GH500	5880.150	5911.800	5912.200	5895.250	5914.300
GH300	9686.950	9706.250	9701.050	9690.400	9707.450
GH200	12422.650	12449.350	12440.800	12423.000	12439.450
SH850	9.000e-3	1.000e-2	1.020e-2	9.350e-3	1.040e-2
SH800	7.850e-3	8.700e-3	8.800e-3	8.150e-3	9.100e-3
SH600	4.450e-3	5.050e-3	5.100e-3	4.400e-3	4.800e-3
SH500	2.250e-3	2.600e-3	2.550e-3	2.350e-3	2.650e-3
SH300	2.550e-4	2.650e-4	3.850e-4	3.250e-4	3.100e-4
SH200	3.650e-5	4.650e-5	5.350e-5	4.150e-5	5.050e-5
UC600	2.600	3.350	3.600	4.400	3.850
UC500	4.150	3.650	2.850	4.250	3.700
UC300	8.150	5.850	6.100	5.250	5.650
UC200	10.850	10.350	8.500	10.800	10.800
UWSS500	6.270	4.675	3.860	7.085	4.407
UWS600500	1.830	0.300	0.392	0.478	-0.600
UWSS600	6.370	3.450	4.020	7.305	3.555
WD600	226.479	263.529	251.909	250.766	261.871
WD500	266.959	292.863	239.937	275.907	284.498
VC600	1.900	0.291	0.178	1.500	0.028
VC500	-1.321	-3.650	-0.567	-1.039	-2.750
VC300	2.250	1.550	2.500	1.950	0.547
VC200	2.250	0.144	2.600	5.250	-1.956
VWSS500	-2.616	-4.845	1.270	-0.583	-4.735
VWS600500	-3.126	-3.029	-0.722	-2.639	-2.443
VWSS600	0.127	-2.438	-0.020	-0.717	-2.323
T600	2.100	2.750	2.300	1.800	2.400
T500	-8.450	-7.050	-7.400	-8.750	-7.500
T300	-33.650	-32.700	-32.550	-33.700	-33.300
T200	-52.900	-52.550	-53.250	-53.450	-53.000

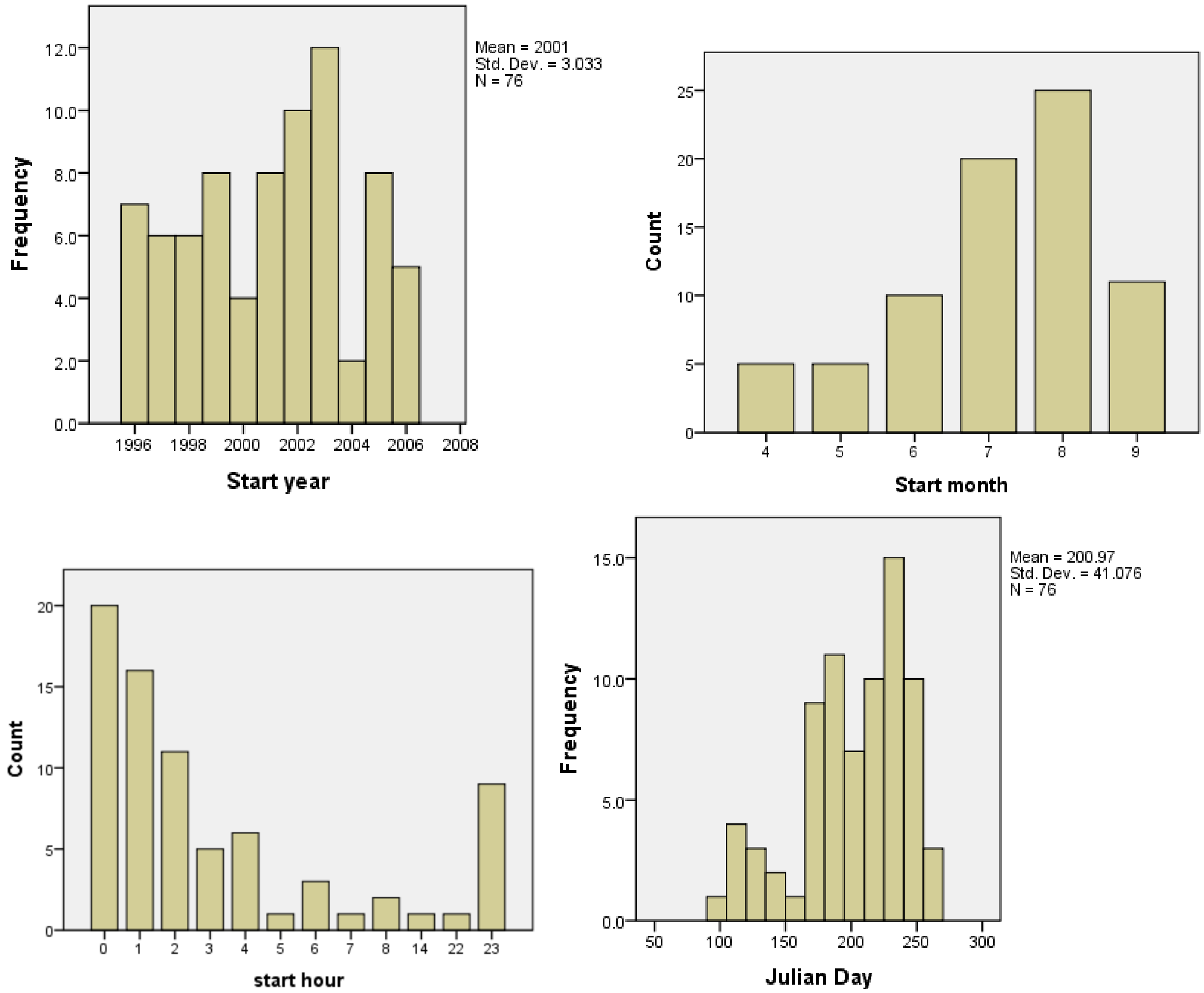


Figure 4.4.1: Time Histograms for the Rincon Mountains, NM Cluster. Frequency was used on the y-axis when the data used in the histogram contained no gaps. Count was used on the y-axis when the data used in the histogram had gaps. The histograms included are start year, start month, start hour, and the Julian Day (JD).

Table 4.4.3: Results of the MLRs Run on the Rincon Mountains, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – T200 + CAPE + UWSS600	0.726
5HP	FP ≈ constant + UWS600500 + GH500 – CIN – SMXS – UC300 + VC300	0.718
4HP	FP ≈ constant – GH600 – VWND	0.457
3HP	FP ≈ constant – T200 – VC300 + UWSS600 + UWND – WD600 – SRH – STHC – VC500 – SH300 + SH500 + SMXS + CAPE	0.967
2HP	FP ≈ constant + UWS600500 + SH600 – SH850 – STHC – UC300 + VWS600500 + T600 + LI – SH500 + SMXR – VC300 + UWND + UC200 – UC500 – SMXS	0.995
1HP	FP ≈ constant – GH600 + VWSS600	0.467
Initiation	FP ≈ constant – T200 – SH300 + UWSS600 + LCL – VC300 – SH600 + Thickness – GH500 + VWND	0.900

Table 4.4.4: Results of the PCAs Run on the Rincon Mountains, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, UC500, UC200, UWSS500, UWSS600, VC500, VWSS500, T600, T500, T300	9	88.045%
5HP	UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH500, UC300, UWSS500, UWSS600, VC500, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	87.859%
4HP	STHC, SMXS, UWND, VWND, LCL, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	9	90.620%
3HP	STHC, UWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, SH500, UC500, UC300, UWSS500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	9	88.944%
2HP	UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH500, UC500, UWSS500, UWSS600, VC600, VC500, VC200, VWSS500, VWSS600, T600, T500, T300	8	87.452%
1HP	STHC, UWND, VWND, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	8	90.381%
Initiation	STHC, SMXR, SMXS, UWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC300, UWSS500, UWSS600, VC500, VWSS500, T600, T500, T300	8	86.017%

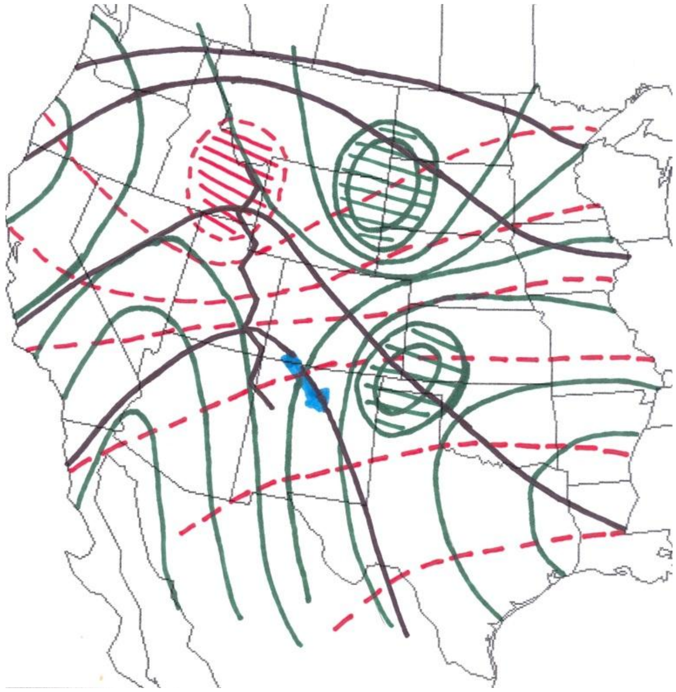


Figure 4.4.2: Composite Map for Rincon Mountains, NM. The variables included on the map are T300, GH500, SH850, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.5: Lookout Peak/Rayado Peak, NM

4.5.1: Description of Cluster

The Lookout Peak/Rayado Peak, NM cluster (located due east of Taos, NM) contained 70 members. The median values for the surface variables in Table 4.5.1 show that the potential temperature is relatively warm at 39.305˚C (approximately 103˚F), the air is relatively dry (also from TZ99), and the winds are from the south. Even though the potential temperature at the reporting station was cooler than previous model runs, the potential temperature was still warm enough to assume that the air was relatively warm at the initiation location. The median values of SMXR and SMXS show that the air is relatively dry at the reporting station with a relative humidity of approximately 48 percent. The UWND and VWND shown give a southerly median wind direction since the median UWND is zero. The upper air variables' median values show that the LCL is around or right below ridgetop height and the LI indicates the air is slightly unstable.

The median values from the NARR data are given in Table 4.5.2 and show how each variable changes throughout the model runs. The geopotential height variables do not change much throughout the model runs, but there is a change seen in the Thickness variable. There is an increase in value from 6HP through the initiation hour which could be an indication of strong surface heating or large-scale warm air advection. The Thickness median value decreases to the starting value once the system initiates. The PW variable does not contain any significant changes throughout the runs. CAPE starts out at a reasonable value 6HP and then increases to its highest value at 4HP. At the initiation hour, CAPE is a little under a fourth of what it was at 4HP. When looking at the 6HP value and comparing it to the 3HA value with the CIN variable, the median value has doubled. This implies it should be harder to initiate a system since CIN is present but cells are still continuing to form. No significant changes worth noting are seen with SRH. There are no discernible changes seen within the specific humidity variables; however, the only change is the decrease seen in SH850 from the 6HP to the model run done at initiation. Within the wind and wind shear variables there are no major changes to the value of the median value throughout all the model runs. The upper level temperature values do not change significantly within the model runs.

Histograms for the Lookout Peak/Rayado Peak, NM cluster, Figure 4.5.1, were created for the start year, start month, start hour, and the Julian Day. The most MCSs occurred in the year 1999 followed closely by 2004 and 2006, with the mean year of 2001. The start-month histogram shows that July and August have equal opportunity for MCS formation with the same number of MCSs. The start-hour histogram shows that the MCSs usually initiate in late afternoon/early evening (consistent with FF01). The Julian-Day histogram shows that the MCSs mainly form in July and August.

4.5.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA for this cluster. The information included in Table 4.5.3 is the resulting equations and the R square value. The results discussed below for the Lookout Peak/Rayado Peak, NM cluster originate from a combination of Table 4.5.1, Table 4.5.2, and Table 4.5.3.

The 6HP model run barely made the R square cutoff at a value of 0.637 and only included four variables. Stronger west-east winds at 500 mb, warmer column of air between the surface and 600 mb, northeast winds at 600 mb, and a dry pocket of air at 600 mb are needed for larger FPs within this cluster's domain. The fit to the data is not very good, so the variables provide an FP with a large associated error. There were no multicollinearity issues present which is expected since none of the four variables used in the equation are related.

The 5HP model run had the best fit to the data out of all the model runs at 0.996, a nearly perfect fit. Weaker south-north surface winds, west-east surface winds, more negatively valued LIs, stronger negative V component wind shears between 600 and 500 mb, a dry pocket of air at 600 mb, a moist pocket of air at 500 mb, stronger south-north winds at 300 mb, stronger north-south winds at 200 mb, and a dry pocket of air at 200 mb are needed for larger FPs within this cluster's domain. The fit was near perfect; therefore, the 5HP model run can be used for identifying the variables needed to accurately predict the FP of the eventual MCS. There were multicollinearity issues present in this model run which can be seen with the inclusion of the wind and specific humidity variables.

The 4HP model run had an R square value less than 0.600 at 0.392 which is a very poor fit to the data. This model run will not be discussed in detail but will still be included in Table 4.5.3.

The 3HP model run was a relatively poor fit to the data at 0.619. Stronger U component winds at 500 mb, a warmer column of air between the surface and 500 mb, more negative LI values, smaller CAPE values, and northeast winds at 500 mb will provide the greatest contribution to larger FPs. The fit to the data was poor, and there were no multicollinearity issues present within this model run.

The 2HP and the 1HP model runs have R square values below 0.600 at 0.530 and 0.347, respectively. The 1HP model run had the second lowest R square value. Both model runs contained no multicollinearity issues. These model runs will not be discussed in detail but are still included in Table 4.5.3.

The model run done at initiation was a reasonable fit at 0.760 and had seven variables included in the equation. Stronger south-north winds at 300 mb, stronger U component wind shears between the surface and 600 mb, lower values of CAPE, weaker south-north winds at 200 mb, warmer surface potential temperatures, stronger V component wind shears between 600 and 500 mb, and more negative values of CIN are needed for larger FPs for the MCSs that initiate within this cluster's domain. Since CIN is a negative valued variable and it was added negatively into the equation, CIN gives the greatest positive contribution to the FP when CIN is more negatively valued. The fit to the data was average, so the FP could be estimated accurately within a given amount of error. There were multicollinearity issues present which could be due to the inclusion of the wind and wind shear variables.

There were several variables that were never used throughout the model runs: SMXR, SMXS, LCL, Thickness, PW, GH300, GH200, SH850, SH800, SH300, UC600, UWS600500, VC600, VC500, T600, T500, T300, and T200. This list is unexpected due to the inclusion of the upper level temperature variables. Several moisture variables were also included in this list. The variable used the most was VWND at five out of ten times which is considered the most important variable and was not recorded at the initiation location but at the closest reporting station. The most used variables are the wind and wind shear variables (from JC07). Very few of the other sets of variables are included significantly into the equations. The biggest similarity among the model runs is the inclusion of VWND.

4.5.3: Principal Component Analysis

PCAs were run on each of the 6HP through 3HA on the Lookout Peak/Rayado Peak, NM cluster. Included in Table 4.5.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. The variables loaded highly into the first component were Thickness (6HP, 4HP, 3HP, 1HP, initiation), PW, geopotential height, specific humidity, a few of the U component wind (6HP, initiation), and temperature variables. All of these variables are loaded positively into the component with exception of the U component wind variables. The individual loadings of the variables can be compared to the tables containing the median values to determine the variables' contributions to the model run. The contributions from wind and wind shear variables depend on the value of the variable and the loading. A negatively loaded wind variable with positive winds will give a smaller contribution to the initiation than a negatively loaded wind variable with negative winds. Since the geopotential height and specific humidity variables are always positive and were loaded positively into the component, larger values of these variables are the best for MCSMI using the PCA. With the second component, the variables that are loaded highly in are the LCL (5HP), Thickness (2HP), V component wind, and V component wind shear (6HP, 4HP, 3HP, 1HP, initiation) variables. These variables are loaded positively into the component with the exception of V component wind (2HP) variables. Higher values of LCL mean values closer to the ground, making it easier to initiate convection. With these variables loaded highly into multiple model runs, these variables are important to MCSMI according to PCA.

The variable LCL was not included in any most used list and was also not included in any of the MLRs previously discussed since there was too much variance in the LCL for it to be included in the most used list. The variables included in every most used list were Thickness, PW, GH500, GH300, GH200, SH850, SH800, UWSS500, VWSS500, T600, and T500 which are similar to the loadings in the components. These variables are considered the most important to MCSMI for the PCAs. There were several other variables that were included in almost every model run: SH500, UC500, UWSS600, VC500, and T300. Variables at 500 mb are very important to initiation and should be observed before initiation within the cluster domain. The biggest similarities between the model runs are the variables included on the most used list and the loadings into the components.

4.5.4: Cluster Discussion

Overall, the PCAs were a much better fit to the data than the MLRs. While there were only two MLRs with multicollinearity issues, half of the MLRs' R square values fell below the 0.600 cutoff. Those equations are not accurate enough to give an indication of what the atmosphere should be before initiation and for larger FPs. The PCAs account for most of the variance in each case and give an accurate representation. The same variables were loaded highly into the same components every time (PW, geopotential height, specific humidity, and temperature variables), contributing to those variables' importance to MCSMI. The most frequently loaded variables indicate values of each will provide the greatest contribution to the PCA within this cluster's domain since those variables contain positive median values.

The Lookout Peak/Rayado Peak, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that winds at 600 mb arrive at an angle to the ridgeline and winds at 500 mb arrive perpendicular to the ridgeline.

The composite map for Lookout Peak/Rayado Peak, NM is Figure 4.5.2. The most important temperature variable was T500. There are relatively cooler temperatures to the northwest of the cluster domain. Overall, the temperatures at 500 mb would be considered relatively warm. The most important geopotential height variable was GH500. There is a ridge located at the cluster domain – highest heights are at the initiation location and the system will form within the ridge. The most important moisture variable was SH500. There is a moist pocket of air due east of the cluster domain indicating relatively moist air within the domain. The air will become moister as the pocket of air moves into the region. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 4.733 ms^{-1} at 309.238°.

4.5.5: Cluster Figures and Tables

Table 4.5.1: Median Values for the Upper Air and Surface Variables for the Lookout Peak/Rayado Peak, NM Cluster.

Variable	Median Value
STHC	39.305
SMXR	9.155
SMXS	18.920
UWND	0.000
VWND	1.045
LCL	609.530
LI	-0.285

Table 4.5.2: Median Values for the NARR Variables for the Lookout Peak/Rayado Peak, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5826.800	5826.250	5857.800	5850.450	5825.000
PW	16.400	14.600	16.200	17.650	15.550
CAPE	231.400	309.800	500.600	240.100	103.350
CIN	-23.450	-17.700	-14.950	-9.950	-20.950
SRH	31.850	38.200	41.000	27.600	49.900
GH600	4457.500	4446.450	4467.050	4460.650	4450.150
GH500	5901.950	5887.250	5910.200	5891.150	5894.800
GH300	9717.000	9648.150	9662.850	9706.500	9667.700
GH200	12448.300	12367.000	12391.950	12445.250	12389.250
SH850	1.115e-2	8.800e-3	9.600e-3	1.000e-2	8.250e-3
SH800	9.650e-3	7.700e-3	8.350e-3	8.750e-3	7.100e-3
SH600	4.200e-3	4.600e-3	4.850e-3	5.300e-3	4.800e-3
SH500	2.200e-3	1.900e-3	2.100e-3	2.350e-3	2.200e-3
SH300	3.100e-4	2.150e-4	2.350e-4	3.250e-4	2.500e-4
SH200	4.100e-5	3.500e-5	4.200e-5	4.300e-5	4.200e-5
UC600	3.100	3.850	3.050	3.000	2.750
UC500	4.200	5.550	4.850	4.900	5.450
UC300	8.650	9.950	7.000	8.550	11.050
UC200	10.900	13.750	11.650	11.450	12.800
UWSS500	4.090	5.725	4.980	4.420	5.905
UWS600500	0.850	1.650	1.900	2.550	2.300
UWSS600	2.905	3.145	3.350	1.240	3.845
WD600	286.265	269.170	272.901	262.613	250.624
WD500	275.195	275.715	307.657	283.598	277.662
VC600	-1.012	-0.345	-1.850	-0.430	1.350
VC500	-0.818	-2.200	-5.050	-1.950	-2.250
VC300	2.100	0.402	-3.900	0.574	-0.668
VC200	3.150	-0.331	-5.850	2.450	2.500
VWSS500	-2.405	-2.818	-6.500	-3.120	-4.048
VWS600500	1.283	-1.691	-2.750	-0.608	-3.200
VWSS600	-4.277	-1.945	-1.395	-2.625	-2.915
T600	1.800	1.600	2.850	2.100	1.850
T500	-6.800	-9.050	-8.750	-7.400	-8.300
T300	-32.800	-36.450	-35.200	-32.750	-34.900
T200	-52.950	-52.950	-53.750	-52.600	-53.650
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5856.200	5849.950	5804.300	5828.600	5828.900
PW	15.950	17.700	15.200	16.650	17.850
CAPE	262.800	122.700	72.250	241.650	150.850
CIN	-33.600	-25.100	-41.850	-41.550	-44.100

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	48.250	32.550	59.350	82.400	60.300
GH600	4465.050	4455.250	4441.100	4464.600	4450.600
GH500	5911.450	5907.050	5888.900	5909.250	5892.050
GH300	9673.000	9708.400	9653.050	9665.400	9705.350
GH200	12394.700	12454.350	12373.250	12392.200	12443.350
SH850	8.700e-3	9.100e-3	8.850e-3	9.550e-3	9.750e-3
SH800	7.600e-3	7.900e-3	7.650e-3	8.250e-3	8.300e-3
SH600	4.900e-3	5.400e-3	4.400e-3	4.500e-3	4.900e-3
SH500	2.450e-3	2.700e-3	2.300e-3	2.300e-3	2.400e-3
SH300	3.200e-4	3.850e-4	2.100e-4	3.100e-4	3.650e-4
SH200	4.400e-5	4.850e-5	3.400e-5	4.150e-5	5.150e-5
UC600	3.400	3.350	5.800	3.850	3.800
UC500	5.300	4.550	5.950	5.900	4.650
UC300	7.500	9.000	6.950	7.100	7.900
UC200	10.000	11.500	10.700	10.050	12.600
UWSS500	6.140	3.666	6.455	6.290	4.941
UWS600500	1.350	2.200	0.450	0.850	1.161
UWSS600	3.340	1.581	6.330	2.925	2.965
WD600	292.302	242.415	263.515	295.123	262.880
WD500	307.306	278.988	281.404	314.495	285.673
VC600	-1.800	1.075	-0.123	-2.800	-0.306
VC500	-6.250	-2.100	-2.700	-7.250	-2.250
VC300	-3.900	2.050	-1.450	-5.150	2.100
VC200	-6.600	2.400	1.006	-6.800	1.167
VWSS500	-5.890	-2.994	-2.645	-6.095	-4.738
VWS600500	-3.574	-2.249	-1.248	-3.600	-2.300
VWSS600	-2.787	-1.700	-1.925	-3.125	-2.325
T600	3.100	2.150	1.850	2.200	1.950
T500	-8.450	-7.300	-9.050	-9.150	-7.850
T300	-34.750	-32.900	-35.200	-34.900	-32.950
T200	-53.550	-53.050	-53.600	-53.400	-52.750

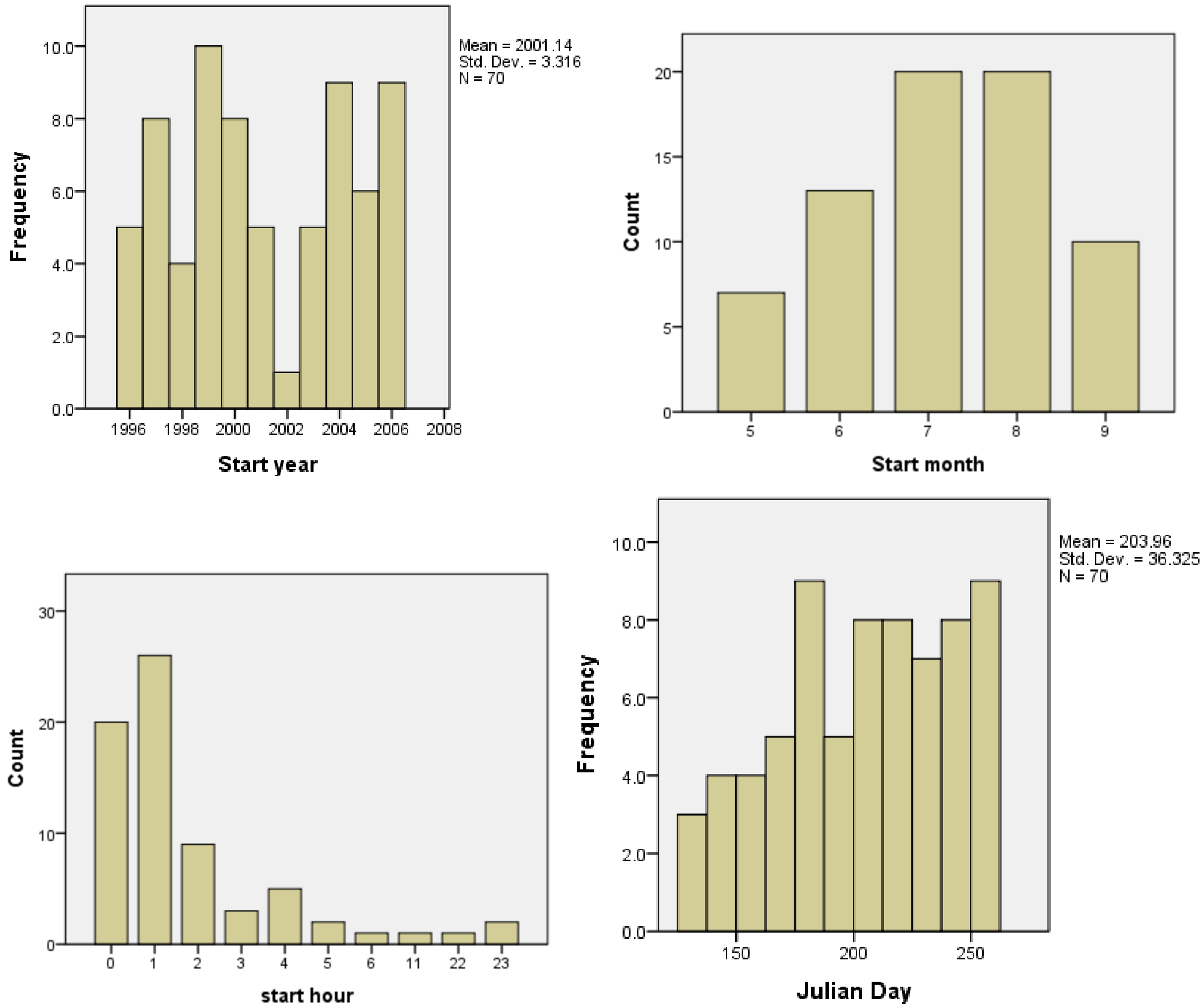


Figure 4.5.1: Time Histograms for the Lookout Peak/Rayado Peak, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day (JD).

Table 4.5.3: Results of the MLRs Run on the Lookout Peak/Rayado Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + UC500 + GH600 – WD600 – SH600	0.637
5HP	FP ≈ constant – VWND + UWND – LI – VWS600500 – SH600 + SH500 + VC300 – VC200 – SH200	0.996
4HP	FP ≈ constant + VWSS600 + SRH	0.392
3HP	FP ≈ constant + UC500 + GH500 – LI – CAPE – WD500	0.619
2HP	FP ≈ constant – VWND + CAPE	0.530
1HP	FP ≈ constant – VWND + UWSS500 – VWS600500	0.347
Initiation	FP ≈ constant + VC300 + UWSS600 – CAPE – VC200 + STHC – VWS600500 – CIN	0.760

Table 4.5.4: Results of the PCAs Run on the Lookout Peak/Rayado Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, VWND, Thickness, PW, GH500, GH300, SH850, SH800, SH500, SH200, UC500, UC300, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	9	90.599%
5HP	SMXR, UWND, VWND, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWSS600, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	93.249%
4HP	STHC, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, UC600, UC500, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VWSS500, T600, T500, T300	10	89.755%
3HP	STHC, SMXR, SMXS, VWND, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC500, UWSS500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	91.807%
2HP	STHC, SMXR, UWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, SH200, UC600, UC500, UWSS500, WD600, WD500, VC500, VWSS500, T600, T500, T300, T200	8	92.545%
1HP	UWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, SH500, UC500, UWSS500, UWS600500, UWSS600, VWSS500, T600, T500, T300	9	86.564%
Initiation	STHC, SMXR, SMXS, UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	9	91.114%

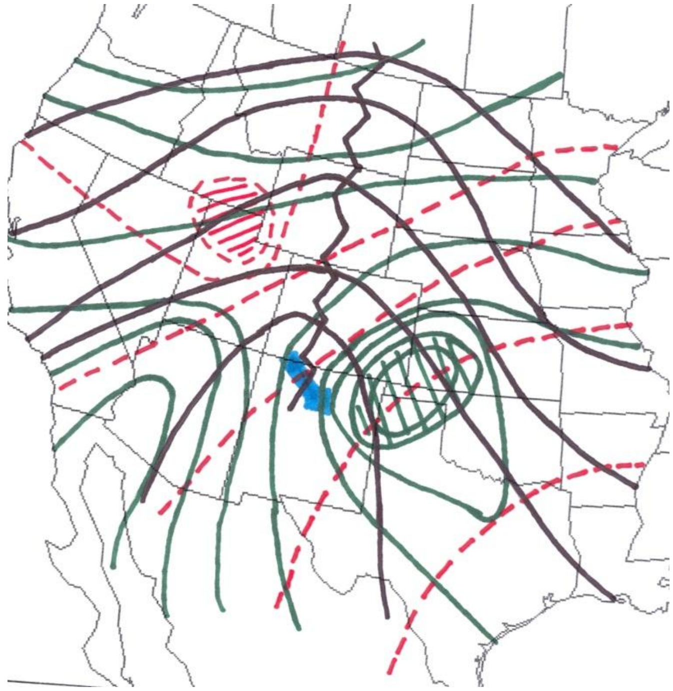


Figure 4.5.2: Composite Map for Lookout Peak/Rayado Peak, NM. The variables included on the map are T500, GH500, SH500, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.6: Pajarito Mountain/Cerro Grande, NM

4.6.1: Description of Cluster

The Pajarito Mountain/Cerro Grande, NM cluster contains 61 members and is located on the western edge of the Santa Fe National Forest and due west of Los Alamos, NM. The median values given for the surface variables in Table 4.6.1 show that the potential temperature is warm at 37.750˚C (approximately 100˚F), the air is relatively moist, and the winds are from the east. Since the potential temperature is warm at the closest reporting station, it can be inferred that the potential temperature at the initiation location is still relatively warm. The median values of SMXR and SMXS demonstrate that the air is relatively moist with a relative humidity of approximately 61 percent, which is higher than seen in previous clusters. The UWND and VWND provide an easterly median wind direction, which is different from the upper level wind directions indicating the potential for large wind shears. The median values given for the upper air variables in Table 4.6.1 show a slightly lower LCL than previously seen, still below ridgetop height, and an LI that indicates the air is slightly unstable.

The median values from the NARR data are given in Table 4.6.2 and demonstrate how each of the variables changes from hour to hour. The Thickness and geopotential height variables do not change significantly throughout the model runs. PW does not change significantly throughout but contains a significantly higher median value for each model run than was seen with previous clusters. While CAPE does vary among the hours, the value is still relatively small. CAPE peaks first at 5HP and again at the hour of initiation. SRH varies significantly between the model runs. The biggest change is seen when comparing the 6HP median value to the median value of one hour after (1HA). The specific humidity variables do not change significantly over the model runs but appear to be of higher values than previous clusters. The wind and wind shear variables vary substantially between the model runs. Higher wind and wind shear values are seen at initiation as opposed to 6HP. The temperature values do not change significantly between the model runs.

Histograms for the Pajarito Mountain/Cerro Grande, NM cluster, Figure 4.6.1, were created for the start year, start month, start hour, and Julian Day. The most MCSs occurred in 1996, followed by 2003 and 2006 and the mean year value was 2000. The month with the most MCSMIs was July, followed by August. Very few initiations occurred in April, May, June, and September. MCSs initiated throughout the day in this cluster, with a large portion initiating in late afternoon/early evening (consistent with FF01). Several MCSs initiated in the overnight hours, which is different from the previous clusters. The Julian-Day histogram shows that most of the MCSs originated in July and August which corresponds to the start-month histogram.

4.6.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Pajarito Mountain/Cerro Grande, NM cluster. The resulting equations and the R square values are included in Table 4.6.3. All of the equations for this cluster are perfect or near perfect fits to the data. The results discussed below for the Pajarito Mountain/Cerro Grande, NM cluster come from a combination of Table 4.6.1, Table 4.6.2, and Table 4.6.3.

The 6HP model run was a near perfect fit at 0.995 and contained 12 variables in the equation. High positive SRH values (from JC07), stronger U component wind shears between the surface and 500 mb, lower surface mixing ratios, more negative V component wind shears between 600 and 500 mb, more negative V component winds, and smaller Thickness values are needed for larger FPs within this cluster's domain. A dry pocket of air at 200 mb, larger PW values, stronger U component wind shears between 600 and 500 mb, more negative LI values, a moist pocket of air at 300 mb, and lower values of CAPE are also needed for larger FPs. The combination of these variables gives an R square value of 0.995, which is a very good fit to the data and can be used to accurately estimate the FP with a very small error. There were multicollinearity issues present with this equation.

The 5HP model run was a poorer fit than the previous model run at 0.988, but still near perfect. Stronger V component wind shears between the surface and 500 mb, stronger west-east winds at 200 mb, weaker west-east winds at 300 mb, a dry pocket of air at 800 mb, stronger positive SRH values (from JC07), and northwest winds at 600 mb are needed for larger FPs according to the equation for this hour. A moist pocket of air at 500 mb, larger values of CAPE, a dry pocket of air at 600 mb, warmer columns of air between the surface and 600 mb, stronger south-north winds at 300 mb, stronger U component wind shears between 600 and 500 mb, and a dry pocket of air at 300 mb are needed for initiation to occur in five hours and larger FPs within this cluster's domain. This combination gives a near perfect fit to the data which can be used for the identification of variables needed for the FP at 5HP. There were multicollinearity issues present but this is expected with the inclusion of multiple wind shears and specific humidities.

The 4HP model run was a perfect fit to the data with 14 variables included in the equation. Stronger south-north winds at 300 mb, warmer temperatures at 200 mb, stronger west-east winds at 200 mb, warmer columns of air between the surface and 600 mb, cooler surface potential temperatures, more negative CIN values, and stronger positive SRH values (from JC07) are needed for larger FPs according to this equation. A moist pocket of air at 600 mb, larger surface saturation mixing ratios, a dry pocket of air at 300 mb, a warmer column of air between the surface and 300 mb, stronger east-west winds at 600 mb, larger Thickness values, and stronger negative V component wind shears between the surface and 600 mb are needed for larger FPs within this cluster's domain. All of these variables produce a perfect fit to the data which can give an accurate representation of the FP at 4HP. There were multicollinearity issues present but this was expected due to the inclusion of multiple geopotential height variables.

The 3HP model run was a near perfect fit to the data at 0.997 which will give an accurate representation of the FP. Stronger positive SRH values (from JC07), larger more negative CIN values, weaker south-north winds at 600 mb, weaker V component wind shears between the surface and 500 mb, a colder column of air between the surface and 300 mb, stronger east-west surface winds, and lower surface mixing ratios are needed for larger FPs within this cluster's domain at 3HP. Smaller Thickness values, weaker U component winds at 200 mb, a dry pocket of air at 600 mb, lower values of CAPE, northwest winds at 500 mb, and weaker U component wind shears between 600 and 500 mb are also needed for larger FPs within this cluster's domain.

The greatest positive contribution from CIN is achieved when the value of CIN is more negative and is added negatively into the equation, as seen here. This is a near perfect fit which is used for the identification of variables needed to predict the eventual FP of the system that will form within the cluster domain in the next three hours. There were multicollinearity issues present.

The 2HP model run was a good fit at 0.995 and contained 15 variables. Stronger U component winds at 200 mb, stronger V component winds at 300 mb, a dry pocket of air at 800 mb, warmer temperatures at 600 mb, weaker west-east winds at 300 mb, and more negative LI values are needed for larger FPs initiating within this cluster's domain. Smaller Thickness values, a moist pocket of air at 200 mb, lower surface mixing ratios, stronger SRH values (from JC07), stronger east-west winds at the surface, stronger U component wind shears between 600 and 500 mb, warmer columns of air between the surface and 300 mb, northwest winds at 500 mb, and warmer surface potential temperatures are also needed for larger FPs within this domain. The combination of these variables gives an accurate representation of the eventual FP which is crucial in forming an MCS. There were multicollinearity issues present which is to be expected due to the combination of variables given in the equation.

The 1HP model run contained significantly fewer variables in the equation than the previous model runs. The R square value is also considerably lower at 0.899, but it is considered a good fit to the data. Larger CAPE values, lower surface saturation mixing ratios, warmer columns of air between the surface and 600 mb, stronger south-north winds at 200 mb, and a dry pocket of air at 200 mb are needed for larger FPs according to this equation. While this combination of variables gives a poorer fit than was seen in previous model runs, the equation is still considered a decent fit with some error. There were no multicollinearity issues present in this model run.

The model run done at initiation contained more variables than the previous model run but had a poorer R square value at 0.869 – the lowest of all the model runs for this cluster. A dry pocket of air at 300 mb, warmer temperatures at 600 mb, northwest winds at 600 mb, warmer temperatures at 200 mb, colder columns of air between the surface and 600 mb, and stronger U component wind shears between the surface and 500 mb are needed for larger FPs from the initiation that will occur within in the hour in this cluster's domain. This combination of variables still gives an acceptable fit to the data and can be used for the identification of variables needed to accurately estimate the eventual FP with a given amount of error. There were no multicollinearity issues present in the model run done at initiation.

Throughout the MLRs, there were several variables that were never used: GH500, GH200, SH850, UC500, VC500, and T500. Therefore, variables at 500 mb are not as essential to larger FPs within this cluster's domain as in previous clusters. The variable which was included in the most model runs was SRH at six out of ten model runs. It varies significantly depending on the model hour and is important to larger FPs which differs from previous clusters. The next variables included most were CAPE, GH600, SH300, and UC200 at five out of ten model runs which are frequent enough to be considered important to initiation. The biggest similarity between the model runs is the inclusion of these most used variables. The biggest difference between the model runs is the value of the SRH, the most used variable.

4.6.3: Principal Component Analysis

PCAs were run on the 6HP through the 3HA on the Pajarito Mountain/Cerro Grande, NM cluster. Included in Table 4.6.4 are the variables with 90 percent accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those eigenvalues. These PCAs will solve some of the fit issues seen with the MLRs.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. The variables loaded most highly into the first component were SMXR (2HP), Thickness (5HP, 4HP, 2HP, 1HP), PW (6HP, 5HP, 4HP, 3HP, 2HP, 1HP), SRH (4HP, 1HP), geopotential height (6HP, 5HP, 4HP, 2HP, 1HP, initiation), specific humidity (6HP, 4HP, 3HP, 2HP, 1HP, initiation), U component wind (5HP, 4HP), U component wind shear (5HP), V component wind (5HP, 4HP, 2HP), and mid-level temperature variables. All of the variables were loaded in positively with the exception of the SRH, U component wind, U component wind shear, and V component wind shear variables. Because of this, higher values of most of the variables will give the best contribution to the component and to the model run. This list is similar to those seen in previous clusters. In the second component, the STHC (5HP, 3HP), SMXS (5HP, 3HP), LCL (6HP, initiation), Thickness (3HP), geopotential height (3HP), specific humidity (2HP), V component wind (4HP, 1HP), and V component wind shear (1HP) variables were loaded in the highest. All of these variables were loaded in negatively with the exception of STHC (3HP), SMXS (3HP), Thickness, geopotential height, specific humidity, V component wind, and V component wind shear variables. Lower values of LCL (higher off the ground) provide the best contribution. Since these variables were loaded highly into the first and second component, they are considered important to MCSMI according to the PCA. Since all of these variables are repeatedly used in the first and second components, it is assumed that these variables are the most important to MCSMI.

All of the variables were included at least once in the most used list, which differs from the MLRs for this cluster. The variable with the lowest times included in the most used list was CIN at one out of ten times. The variables included in every most used list were Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, VC500, VWSS500, VWSS600, T500, and T300 which is similar to the variables that were routinely loaded the most highly into the first two components. These variables are the most important variables to MCSMI according to the PCAs run on this cluster. It is also noted that the 500 mb level is crucial since many of the variables were included from that level. STHC, UWND, UC300, UC200, UWSS600, VC600, VC300, and T600 were included either eight or nine times out of ten and are significant to initiation as well. Wind variables are included often in the PCA's most used list. The biggest similarity between the model runs is the inclusion of the variables on the most used list as compared to the ones that were loaded the most highly.

4.6.4: Cluster Discussion

For this cluster, MLRs and PCAs are both acceptable models. Both models include most if not all of the variables overall. The fits to the data in the MLRs and the accounted for variance in the PCAs are high. One of the MLR model runs was a perfect fit to the data, but there were still multicollinearity issues present. For a quick estimate of the FP, these MLRs give an accurate reading. The PCAs can be easily used for identification of variables needed to predict if an MCS will form. Both model runs work well with the data and could be used for the identification of variables needed for the forecasting for an MCS within the Pajarito Mountain/Cerro Grande, NM domain. For this cluster, the shear variables are used often, indicating shear is important in MCSMI and larger FPs within this domain. The moisture variables are also important to MCSMI and larger FPs, but not as important as the shear variables.

The Pajarito Mountain/Cerro Grande, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from west-southwest. This indicates that winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for Pajarito Mountain/Cerro Grande, NM is Figure 4.6.2. The most important temperature variable was T300. The pocket of lowest temperatures at 300 mb is far from the initiation location located northeast of the domain. The temperatures are relatively warm and will continue with the present pattern. The most important geopotential height variable was GH300. There is a ridge located west-northwest of the cluster domain which will affect the domain area as it moves through but it will not affect it as much as locations farther north. The most important moisture variable was SH850. There is a moist pocket of air southeast of the cluster domain but the initiation location was in drier air coming from the desert southwest. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 6.000 ms^{-1} at 270.191˚.

4.6.5: Cluster Figures and Tables

Table 4.6.1: Median Values for the Upper Air and Surface Variables for the Pajarito Mountain/Cerro Grande, NM Cluster.

Variable	Median Value
STHC	37.750
SMXR	11.240
SMXS	18.480
UWND	-1.340
VWND	0.000
LCL	661.260
LI	-0.750

Table 4.6.2: Median Values for the NARR Variables for the Pajarito Mountain/Cerro Grande, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5856.100	5835.800	5856.600	5872.300	5842.000
PW	20.150	21.450	17.600	20.850	21.150
CAPE	125.950	221.550	137.800	173.150	183.000
CIN	-20.600	-14.050	-12.500	-14.450	-18.900
SRH	15.850	43.450	28.600	20.400	49.800
GH600	4471.150	4472.400	4447.300	4464.750	4474.350
GH500	5923.000	5921.750	5892.600	5914.150	5922.750
GH300	9726.100	9738.550	9696.800	9725.600	9730.300
GH200	12480.100	12470.700	12422.400	12472.150	12470.900
SH850	1.050e-2	1.005e-2	8.800e-3	9.900e-3	1.025e-2
SH800	9.200e-3	8.850e-3	7.600e-3	8.650e-3	8.900e-3
SH600	4.700e-3	5.250e-3	4.900e-3	5.700e-3	5.500e-3
SH500	2.900e-3	2.900e-3	2.600e-3	3.100e-3	3.150e-3
SH300	3.850e-4	4.800e-4	2.700e-4	4.600e-4	4.650e-4
SH200	4.950e-5	5.700e-5	3.500e-5	5.450e-5	5.750e-5
UC600	2.600	2.500	2.500	2.400	3.000
UC500	2.900	4.450	4.400	3.100	3.750
UC300	5.950	6.100	9.000	6.800	6.400
UC200	6.350	8.650	14.000	7.050	7.800
UWSS500	4.400	5.120	6.320	5.210	5.265
UWS600500	7.500e-2	1.920	2.395	0.900	1.234
UWSS600	4.776	2.545	3.320	4.745	3.920
WD600	249.782	240.174	244.323	263.471	236.693
WD500	273.782	255.640	247.087	271.294	278.161
VC600	-0.174	1.300	0.992	0.162	1.450
VC500	-0.425	-0.221	1.600	-1.027	-0.751
VC300	1.550	8.550e-2	3.000	1.300	0.574
VC200	0.491	0.546	3.500	1.650	-1.500
VWSS500	-0.480	1.188	1.230	-0.626	1.680
VWS600500	0.000	-1.550	1.300	-0.300	-1.849
VWSS600	0.195	2.620	-0.669	0.550	3.300
T600	3.000	1.900	1.800	2.95	1.700
T500	-6.300	-7.050	-7.800	-6.500	-7.100
T300	-31.500	-32.150	-32.300	-31.450	-32.000
T200	-52.900	-53.100	-53.100	-52.800	-53.000
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5848.900	5868.600	5827.300	5833.100	5852.000
PW	18.300	21.550	19.650	19.300	20.200
CAPE	118.700	222.200	170.400	99.000	171.600
CIN	-25.300	-21.750	-23.750	-31.200	-22.700

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	28.300	26.950	61.550	26.800	38.700
GH600	4448.400	4470.500	4472.550	4456.800	4471.750
GH500	5889.700	5924.000	5919.500	5890.800	5921.950
GH300	9703.900	9738.100	9725.800	9685.900	9731.700
GH200	12428.000	12484.450	12471.350	12434.400	12480.200
SH850	9.100e-3	1.005e-2	1.040e-2	9.400e-3	1.010e-2
SH800	7.900e-3	8.700e-3	9.100e-3	8.200e-3	8.850e-3
SH600	5.000e-3	5.600e-3	5.200e-3	5.100e-3	5.200e-3
SH500	2.900e-3	3.250e-3	3.000e-3	2.900e-3	3.050e-3
SH300	2.700e-4	4.450e-4	4.450e-4	3.900e-4	5.050e-4
SH200	3.400e-5	5.350e-5	5.450e-5	4.100e-5	5.700e-5
UC600	2.100	3.100	3.250	3.900	4.150
UC500	6.200	3.900	4.950	5.500	4.400
UC300	9.900	7.600	4.150	10.000	7.350
UC200	14.100	6.500	8.250	14.500	9.900
UWSS500	8.000	6.000	5.820	6.500	5.760
UWS600500	2.200	0.800	0.400	2.000	5.000e-2
UWSS600	4.382	5.400	4.135	4.979	6.005
WD600	225.735	257.389	252.562	262.221	252.502
WD500	265.020	253.261	286.392	270.795	259.882
VC600	0.381	0.975	0.172	-0.152	0.873
VC500	0.915	0.730	-1.950	-9.020e-2	-0.223
VC300	0.231	1.500	-0.234	1.100	0.963
VC200	2.700	3.400	-0.983	4.000	2.750
VWSS500	-0.320	-0.020	9.500e-2	-1.224	-0.495
VWS600500	-0.200	-0.700	-1.423	-0.997	-0.200
VWSS600	0.982	-7.850e-2	1.680	0.490	5.000e-3
T600	2.200	2.750	2.100	2.100	2.400
T500	-7.900	-6.350	-7.100	-7.600	-6.500
T300	-32.700	-31.200	-32.500	-32.500	-31.550
T200	-53.100	-53.050	-53.000	-53.100	-52.700

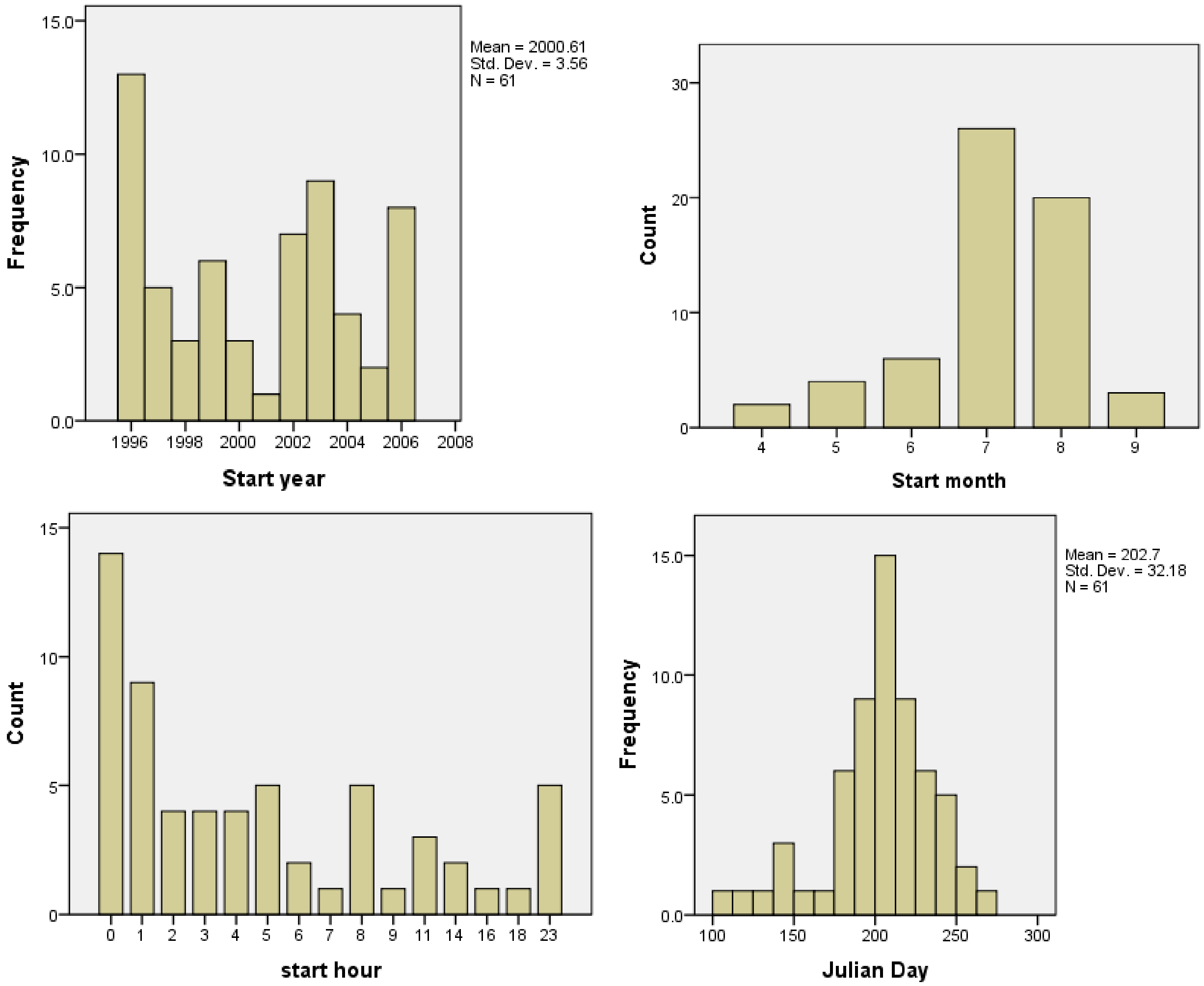


Figure 4.6.1: Time Histograms for the Pajarito Mountain/Cerro Grande, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram does have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.6.3: Results of the MLRs Run on the Pajarito Mountain/Cerro Grande, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + SRH + UWSS500 – SMXR – VWS600500 – VWND – Thickness – SH200 + PW + UWS600500 – LI + SH300 – CAPE	0.995
5HP	FP ≈ constant + VWSS500 + UC200 – UC300 – SH800 + SRH + WD600 + SH500 + CAPE – SH600 + GH600 + VC300 + UWS600500 – SH300	0.988
4HP	FP ≈ constant + VC300 + T200 + UC200 + GH600 – STHC – CIN + SRH + SH600 + SMXS – SH300 + GH300 + UC600 + Thickness – VWSS600	1.000
3HP	FP ≈ constant + SRH – CIN – VC600 + VWSS500 – GH300 – UWND – SMXR – Thickness – UC200 – SH600 – CAPE + WD500 – UWS600500	0.997
2HP	FP ≈ constant + UC200 + VC300 – SH800 + T600 – UC300 – LI – Thickness + SH200 – SMXR + SRH – UWND + UWS600500 + GH300 + WD500 + STHC	0.995
1HP	FP ≈ constant + CAPE – SMXS + GH600 + VC200 – SH200	0.899
Initiation	FP ≈ constant – SH300 – T600 + WD600 + T200 – GH600 + UWSS500	0.869

Table 4.6.4: Results of the PCAs Run on the Pajarito Mountain/Cerro Grande, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXS, UWND, LCL, LI, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH200, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	10	92.049%
5HP	Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH500, UC500, UWSS500, UWS600500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	8	87.970%
4HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	94.912%
3HP	STHC, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH200, UC500, UC300, UC200, UWSS500, UWSS600, VC600, VC500, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	10	91.891%
2HP	VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH200, UC600, UC500, UWSS500, WD500, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	8	88.828%
1HP	STHC, SMXR, UWND, VWND, LCL, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH200, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	93.714%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T500, T300, T200	11	94.261%

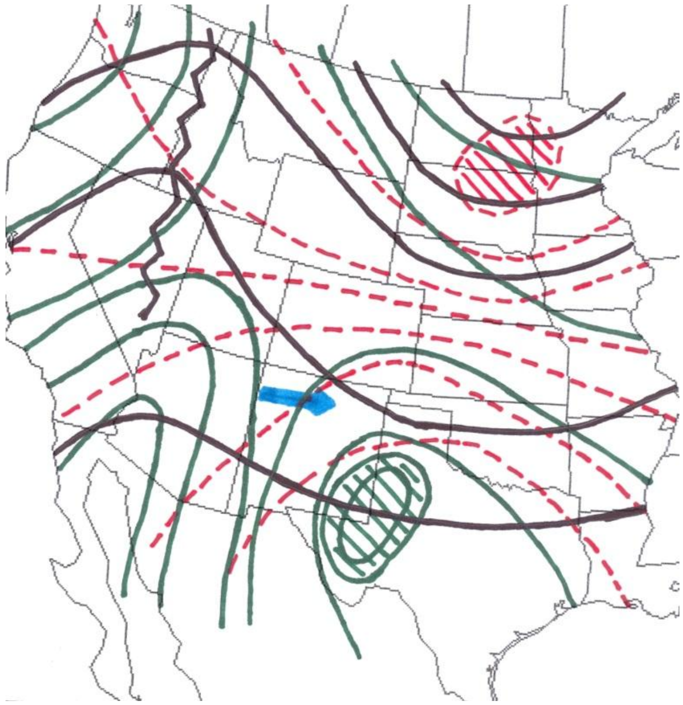


Figure 4.6.2: Composite Map for Pajarito Mountain/Cerro Grande, NM. The variables included on the map are T300, GH300, SH850, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.7: Culebra Range/Sangre de Cristo Mountains, CO

4.7.1: Description of Cluster

The Culebra Range/Sangre de Cristo Mountains cluster, located west of the Ute Hills/Pete Hills, CO and southeast of Alamosa, CO, contains 56 members. The median values given for the surface variables in Table 4.7.1 show that the air is hot at 42.800˚C (approximately 109˚F) and relatively dry (also from TZ99), and the winds are from the south (also from BS87). With the potential temperature hot at the closest reporting station, it can be inferred that the air is still relatively hot at the initiation location. The median values of SMXR and SMXS show that the air is relatively dry with an approximate 48 percent relative humidity. The UWND and VWND give a southerly median wind direction since UWND’s median value is zero. The median values for the upper air variables in Table 4.7.1 show a mid-level LCL which is around ridgetop height and an LI that indicates the air is slightly unstable.

The median values from the NARR data are given in Table 4.7.2 and show how the variables change throughout the model runs. The Thickness and geopotential height variables do not vary significantly between the 6HP and the model run done at initiation. Thickness decreases from the model run done at initiation to the 3HA and the geopotential height variables stay approximately the same. This is unexpected since the value of Thickness and GH500 should be approximately the same which indicates the surface pressure (approximately 1000 mb) is increasing. The PW does not vary significantly throughout the model runs. The PW median values are not as high as those seen in the previous cluster. The CAPE value varies significantly in that it reaches a high point at 4HP and is at its lowest at 1HA. The highest point is almost 11 times the value of the lowest point. CIN does not vary by much but reaches its highest point after initiation, which is contradictory. SRH does not vary significantly throughout the model runs and the value could be important to the analysis. The specific humidity variables do not vary significantly throughout the model runs but show that the air at the initiation location is relatively moist, especially at the surface. The wind and wind shear variables always vary between the model runs but that is expected since these are considered hour dependent. The temperature variables do not vary greatly but are relatively cold for the level.

The histograms for the Culebra Range/Sangre de Cristo Mountains, CO cluster, Figure 4.7.1, were created for the start year, start month, start hour, and Julian Day. Most MCSs occurred within the cluster domain in the year 2003, with 2006 as the next and 2002 as the mean year. The early years in the cluster have fewer MCSs initiating than in the later years. The months of July and August initiate the most MCSs. Throughout all the analysis years, only one

MCS was initiated in April. Most of the MCSs initiated in late afternoon/early evening (consistent with FF01). For the Julian-Day histogram, a spike in MCSMIs is very clear and the lone MCS in April is also very clear. The combination of these histograms details that the best time of year for MCSs to initiate within this cluster's domain is July and August.

4.7.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Culebra Range/Sangre de Cristo Mountains, CO cluster. The resulting equations and the R square values are included in Table 4.7.3. Each of the variables included in the model runs are vital to producing larger FPs. The results discussed below for this cluster come from a combination of Table 4.7.1, Table 4.7.2, and Table 4.7.3.

The 6HP model run was a near perfect fit at 0.970. Twelve variables are included in the equation to determine the FP estimate. Stronger west-east winds at 500 mb, more negative LI values, stronger south-north winds at 200 mb, larger values of CAPE, a moist pocket of air at 300 mb, and smaller Thickness values are needed for larger FPs within this cluster's domain. Northeast winds at 500 mb, weaker south-north winds at 300 mb, a dry pocket of air at 600 mb, weaker V component wind shears between the surface and 500 mb, lower SRH values, and a moist pocket of air at 850 mb are also needed for larger FPs within this cluster's domain. This equation can, within an acceptable amount of error, be used for the identification of the variables needed for prediction of the eventual FP of the system at 6HP. There are multicollinearity issues present in this model run but that is expected because of the inclusion of multiple wind, wind shear, and specific humidity variables.

The 5HP model run was a near-perfect fit to the data at 0.990. Larger positive SRH values (from JC07), stronger U component wind shears between 600 and 500 mb, weaker west-east winds at 200 mb, larger surface saturation mixing ratios, cooler surface potential temperatures, weaker south-north winds at 600 mb, and more negative U component surface winds are needed for larger FPs within this cluster's domain and the initiation occurring in five hours. The combination of these variables will give an accurate representation of the eventual FP of the forming system with little error. There were multicollinearity issues present in this model run which could be caused by the inclusion of multiple wind and wind shear variables.

The 4HP model run produced a much worse fit to the data than the previous model runs but the R square value was still above 0.600 at 0.632. LCL values closer to the ground, warmer columns of air between the surface and 600 mb, a dry pocket of air at 500 mb, and weaker south-north winds at 600 mb are needed for larger FPs from the initiation that will occur in four hours within this cluster's domain. This combination of variables produces a poor fit to the data at 4HP. There were no multicollinearity issues present in this model run.

The 3HP model run was a slightly better fit to the data than the previous model run at 0.662, still relatively close to the R square value cutoff. Stronger U component wind shears between 600 and 500 mb, stronger south-north winds at 200 mb, more negative LI values, stronger west-east winds at 600 mb, and colder temperatures at 200 mb are needed for larger FPs. This combination of variables gives a relatively poor fit to the data and there is a potential for this equation to be a better fit because of the low R square value. There were no multicollinearity issues present in this equation.

The 2HP model run is the best fit out of all the model runs at 0.996. Larger SRH values (from JC07), weaker V component wind shears between the surface and 500 mb, lower values of CAPE, stronger U component wind shears between 600 and 500 mb, weaker west-east winds at 200 and 600 mb, and stronger U component wind shears between the surface and 500 mb are needed for larger FPs within this cluster's domain. The lower values of CAPE are because it was added negatively into the equation meaning the greatest contribution to the FP would be associated with lower values of CAPE. This combination of variables gives a very good fit to the data. This means that the FP can be accurately estimated at 2HP within the cluster domain. There were no multicollinearity issues present in this equation.

The 1HP model run contains a poor fit the data at 0.682 and only uses four variables in the equation. LCLs closer to the ground, stronger U component wind shears between 600 and 500 mb, warmer columns of air between the surface and 600 mb, and more negative values of CIN are needed for larger FPs that will initiate in the upcoming hour. This combination of variables does not give a good fit to the data. There are no multicollinearity issues.

The model run done at initiation has an R square value less than 0.600 at 0.298 – a very poor fit to the data. Only one variable was used in the equation and it will not be discussed in detail. The equation is included in Table 4.7.3.

There were several variables that were not used throughout the MLRs and are not considered important to larger FPs: SMXR, VWND, PW, GH500, GH300, GH200, SH800, SH200, UC300, UWSS600, WD600, VC500, VWSS600, T600, T500, and T300. The variable included the most in the model runs was UWS600500, in five out of ten model runs. While this is only half of the model runs, this variable is still considered important to larger FPs within the cluster domain. Even though one variable was included in five model runs, no variable was more important than any other variable. The biggest similarity between the model runs is the inclusion of wind and wind shear variables (from JC07) since there was at least one included in every model run. The biggest difference between the model runs was the inclusion or exclusion of different specific humidity variables. Moisture is important to larger FPs but it is not as evident in this cluster as in previous clusters.

4.7.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA on the Culebra Range/Sangre de Cristo Mountains, CO cluster. Since there were fit issues present in the MLRs, the PCAs were done to solve those issues. Included in Table 4.7.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run have similar variables loaded into the first components. In the first component, the variables loaded the most highly were STHC (5HP, 4HP, 1HP), SMXS (4HP), LI (5HP, 2HP), Thickness (5HP, 4HP, 2HP, 1HP), PW (6HP, 3HP, 2HP, 1HP, initiation), geopotential height, a few of the specific humidity, U component wind (1HP, initiation), and temperature variables. These variables were loaded positively into the components with the exception of LI and U component wind (1HP) variables. This means that larger values of each will give a greater positive contribution to the component and to the PCA. Wind and wind shear variable contributions will depend on the value of the variable. The variables loaded highly into the second component include the STHC (3HP, initiation), VWND (2HP), LCL (4HP, 1HP), CAPE (5HP), V component wind (6HP, 4HP, 3HP, 2HP, 1HP), V component wind shear (5HP, 4HP), and temperature (3HP, initiation) variables. All of these variables were loaded in positively with the exception of the STHC (3HP), V component wind shear (5HP), and temperature (initiation) variables. Larger values of CAPE will provide a greater, positive contribution to the potential MCSMI. Since several of these variables reappear in the most highly loaded lists, then these are the most important to MCSMI within the cluster domain.

Only one variable, LCL, was never included on the most used lists which differs from the MLRs but is possible even though the PCAs use every variable in every model run. There were several variables that were included in every model run: Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, UWSS600, VC500, VWSS500, T500, and T300. This list is similar to the variables that were loaded the highest into the first and second components. This combination demonstrates that these variables are the most important to MCSMI. Several other variables were included most of the time: UWND, GH600, VC600, VC300, VWSS600, and T600. Many of these variables were also loaded the most highly into the first two components. The variables contained the most often in the most used lists and loaded the highest into the first two components are the variables to observe before initiation.

4.7.4: Cluster Discussion

The PCAs were a much better fit to the data than the MLRs due to the very poor fits observed in several MLRs. There were a few near perfect R square values but the number of poor fits exceeded the number of good fits especially when each PCA was a relatively good fit to the data. The PCA was the better fit because it took more of the data into account than the MLR. MLR provides some clues as to the eventual FP with a few of the equations but not enough to offset the PCA results. The PCAs corrected the fit issues that were present in three MLRs. Therefore, PCAs are the best option for initiation the Culebra Range/Sangre de Cristo Mountains, CO cluster domain. One item of note is that the wind shear variables were very important in the MLRs but not as important in the PCAs. This is due to the fact that the variables in the MLRs are predicting the FP of the MCS and in the PCAs are predicting initiation.

The Culebra Range/Sangre de Cristo Mountains, CO cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that the winds at 600 and 500 mb arrive perpendicular to the ridgeline.

The composite map for Culebra Range/Sangre de Cristo Mountains, CO is Figure 4.7.2. The most important temperature variable was T500. There is a pocket of relatively low temperatures at 500 mb along the west coast. Since those low temperatures are far from the cluster domain, there are relatively warm temperatures within the cluster domain. The most important geopotential height variable was GH500. There is a ridge east of the cluster domain indicating the high heights have already passed through the domain and the heights will continue to decrease. The most important moisture variable was SH850. There is a moist pocket of air to the east and a dry pocket of air to the west of the cluster domain. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 4.654 ms^{-1} at 296.446°.

4.7.5: Cluster Figures and Tables

Table 4.7.1: Median Values for the Upper Air and Surface Variables for the Culebra Range/Sangre de Cristo Mountains, CO Cluster.

Variable	Median Value
STHC	42.800
SMXR	8.600
SMXS	17.905
UWND	0.000
VWND	1.320
LCL	626.180
LI	-0.905

Table 4.7.2: Median Values for the NARR Variables for the Culebra Range/Sangre de Cristo Mountains, CO Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5860.350	5847.550	5875.150	5872.250	5865.600
PW	14.550	16.150	15.850	15.850	16.750
CAPE	168.250	150.650	296.600	170.900	65.650
CIN	-25.250	-15.200	-20.150	-14.100	-19.650
SRH	22.400	25.250	24.700	24.050	23.350
GH600	4477.550	4470.500	4481.650	4468.650	4460.750
GH500	5925.800	5917.150	5935.900	5918.950	5909.300
GH300	9729.000	9738.750	9735.600	9728.250	9732.750
GH200	12455.550	12481.400	12463.200	12459.250	12469.750
SH850	1.065e-2	1.085e-2	1.135e-2	1.025e-2	1.070e-2
SH800	9.250e-3	9.450e-3	9.900e-3	8.850e-3	9.250e-3
SH600	4.400e-3	4.750e-3	5.500e-3	5.400e-3	5.500e-3
SH500	2.550e-3	2.700e-3	2.500e-3	2.750e-3	2.900e-3
SH300	3.650e-4	3.050e-4	3.550e-4	4.000e-4	3.800e-4
SH200	5.000e-5	5.050e-5	4.700e-5	5.000e-5	5.000e-5
UC600	1.800	2.700	2.700e-2	1.350	2.000
UC500	1.900	3.550	2.000	2.900	3.150
UC300	5.350	4.800	6.050	6.150	3.850
UC200	10.700	8.000	5.300	9.600	6.700
UWSS500	0.252	1.164	3.075	2.525	2.010
UWS600500	0.000	0.519	1.320	1.771	0.650
UWSS600	2.120	3.340	0.957	2.370	2.480
WD600	246.962	241.508	188.502	228.832	227.101
WD500	234.335	244.706	267.060	260.429	232.618
VC600	-0.228	0.569	0.321	0.414	2.600
VC500	1.300	-1.177	-0.933	-0.224	-0.529
VC300	2.700	5.350	2.300	3.650	5.700
VC200	1.050	5.700	1.950	3.150	6.100
VWSS500	-1.210	-3.950	-3.277	-1.744	-3.674
VWS600500	1.201	5.000e-2	-1.616	-0.300	-2.345
VWSS600	-2.010	-2.269	-1.600	-0.980	-0.188
T600	3.250	2.500	2.900	3.150	2.650
T500	-7.200	-7.100	-6.900	-7.500	-6.650
T300	-33.100	-32.350	-32.600	-32.600	-31.850
T200	-53.200	-53.150	-53.600	-52.650	-53.350
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5875.300	5863.050	5861.150	5859.700	5849.600
PW	16.450	15.850	15.300	16.000	16.300
CAPE	112.200	103.900	27.700	137.200	114.450
CIN	-26.400	-28.450	-23.250	-37.550	-36.350

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	38.450	22.750	29.650	43.800	29.900
GH600	4479.650	4479.800	4460.300	4475.050	4477.350
GH500	5931.300	5931.300	5906.400	5930.800	5928.250
GH300	9739.750	9734.450	9733.800	9733.250	9732.050
GH200	12470.500	12468.500	12472.600	12465.850	12464.100
SH850	1.075e-2	1.000e-2	1.025e-2	1.150e-2	1.070e-2
SH800	9.400e-3	8.650e-3	8.800e-3	1.000e-2	9.250e-3
SH600	5.450e-3	5.000e-3	4.900e-3	5.250e-3	4.750e-3
SH500	3.050e-3	2.900e-3	2.800e-3	2.750e-3	2.800e-3
SH300	3.750e-4	3.900e-4	3.750e-4	4.300e-4	4.550e-4
SH200	4.950e-5	5.350e-5	4.800e-5	5.350e-5	5.250e-5
UC600	0.304	2.850	4.100	2.500	4.000
UC500	3.550	2.950	2.050	3.900	3.200
UC300	5.300	6.250	5.350	4.150	7.400
UC200	7.800	8.850	10.150	7.550	10.700
UWSS500	4.275	4.130	1.787	3.825	5.400
UWS600500	2.100	1.555	-1.950	0.675	1.100
UWSS600	1.173	4.395	3.838	1.540	4.345
WD600	199.760	259.355	245.923	243.453	279.336
WD500	271.353	268.156	254.361	276.760	287.733
VC600	0.776	0.447	1.151	1.550	-0.833
VC500	-1.750	1.475e-2	-0.285	-1.650	-2.250
VC300	2.000	3.500	3.700	1.181	3.050
VC200	2.020e-2	2.800	6.450	-1.882	3.350
VWSS500	-2.960	-2.145	-2.497	-2.104	-3.560
VWS600500	-3.349	-0.962	-1.623	-3.984	-1.091
VWSS600	-0.854	-1.505	-1.130	0.255	-2.509
T600	3.050	3.150	2.900	3.000	2.850
T500	-6.700	-7.000	-6.850	-6.600	-7.100
T300	-32.100	-32.500	-31.850	-32.400	-32.650
T200	-53.350	-53.450	-53.350	-53.350	-53.050

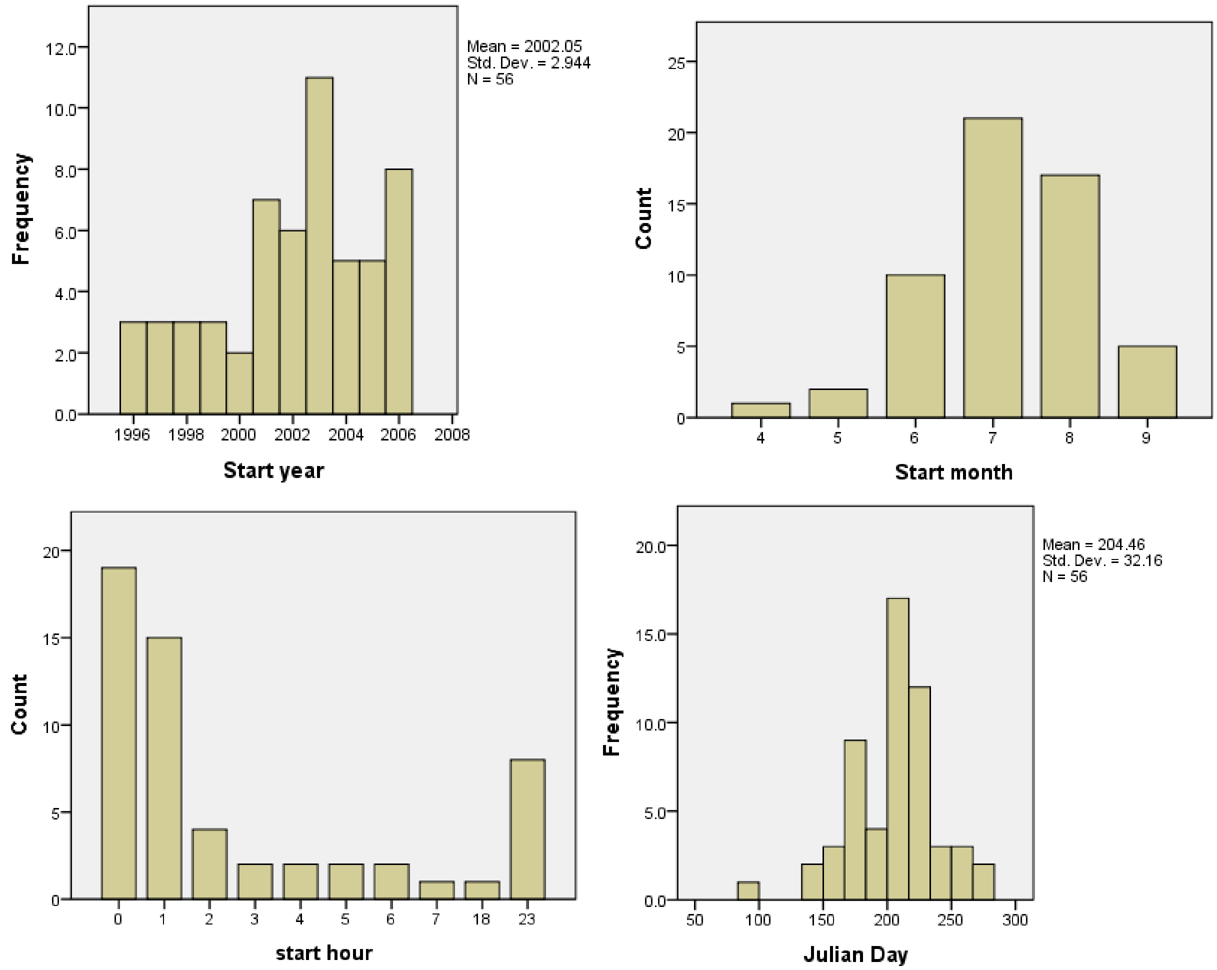


Figure 4.7.1: Time Histograms for the Culebra Range/Sangre de Cristo Mountains, CO Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.7.3: Results of the MLRs Run on the Culebra Range/Sangre de Cristo Mountains, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + UC500 – LI + VC200 + CAPE + SH300 – Thickness – WD500 – VC300 – SH600 + VWSS500 – SRH + SH850	0.970
5HP	FP ≈ constant + SRH + UWS600500 – UC200 + SMXS – STHC – VC600 – UWND	0.990
4HP	FP ≈ constant + LCL + GH600 – SH500 – VC600	0.632
3HP	FP ≈ constant + UWS600500 + VC200 – LI + UC600 – T200	0.662
2HP	FP ≈ constant + SRH + VWSS500 – CAPE + UWS600500 – UC200 – UC600 + UWSS500	0.996
1HP	FP ≈ constant + LCL + UWS600500 + GH600 – CIN	0.682
Initiation	FP ≈ constant + UWSS500	0.298

Table 4.7.4: Results of the PCAs Run on the Culebra Range/Sangre de Cristo Mountains, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	SMXR, UWND, VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, UC600, UC500, UC300, UWSS500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	10	90.383%
5HP	STHC, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	93.926%
4HP	STHC, SMXS, UWND, VWND, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	9	92.806%
3HP	SMXR, UWND, VWND, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	10	90.983%
2HP	STHC, SMXS, UWND, LI, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VWSS500, VWS600500, T600, T500, T300, T200	8	93.740%
1HP	STHC, UWND, VWND, Thickness, PW, SRH, GH500, GH300, GH200, SH850, SH800, SH300, SH200, UC600, UC500, UC300, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	92.246%
Initiation	SMXR, UWND, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T500, T300	9	88.737%

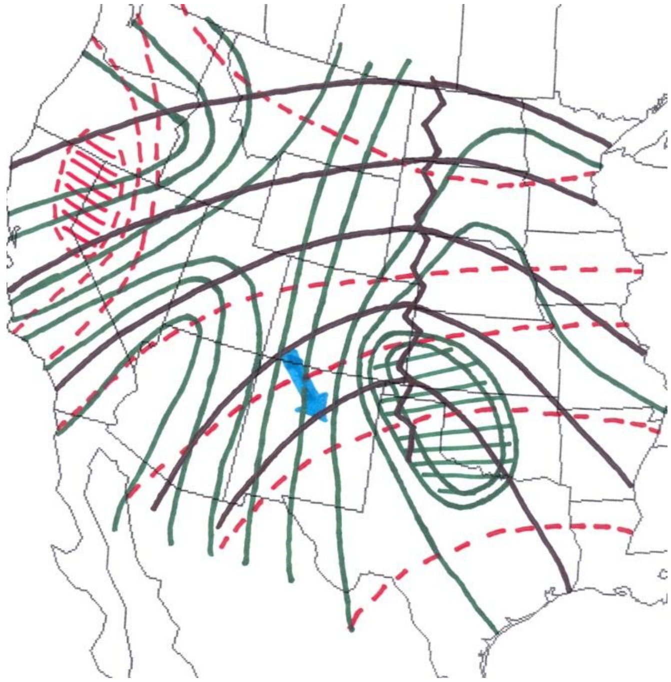


Figure 4.7.2: Composite Map for Culebra Range/Sangre de Cristo Mountains, CO. The variables included on the map are T500, GH500, SH850, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.8: Shaggy Peak, NM

4.8.1: Description of Cluster

The Shaggy Peak, NM cluster contains 51 members and is southeast of Santa Fe, NM. The median values for the surface variables in Table 4.8.1 show that the potential temperature is relatively hot at 38.580˚C (approximately 101˚F), the air is relatively moist, and the winds are from the southeast (also from BS87). Even though these values are taken some distance away, it will still be relatively hot at the initiation location. The median values of SMXR and SMXS show that the air is relatively moist at approximately 55 percent relative humidity. The UWND and VWND give a median wind direction of southeast. The median values given for the upper air variables in Table 4.8.1 show an LCL that is below ridgetop height and an LI that indicates the air is slightly unstable.

The median values from the NARR data are given in Table 4.8.2, showing how the median values change throughout the model runs. Thickness increases from 6HP to the initiation hour but decreases to around 6HP level at 3HA. The geopotential height variables do not change significantly throughout the model runs. There is little change in the PW over the course of the model runs, but PW peaks in value at 4HP. CAPE varies throughout the model runs and peaks at 4HP. There is a significant drop in CAPE from 6HP to 5HP. CIN also varies throughout the model runs and reaches a maximum (most negative) value at 2HA. The SRH varies significantly but is considered hour dependent. The specific humidity variables change little from 6HP to 3HA and confirm that the air is relatively dry at each level. The wind and wind shear variables vary throughout the model runs which aids the initiation of the mountain MCS. The temperature variables do not change significantly throughout the model runs.

Histograms for the Shaggy Peak, NM cluster, Figure 4.8.1, were created for the start year, start month, start hour, and Julian Day. Most MCSs occurred in the year 2003 and were almost equally divided among the remaining years. The mean year value was 2001 with the lowest number of MCSs occurring in the year 1996. Most of the MCSs occurred in July and August. While MCSs initiated throughout the day, a majority of the MCSs initiated in the late afternoon/early evening hours (consistent with FF01). The Julian-Day histogram shows that most of the MCSs occurred in July and August which corresponds to the start-month histogram. MCSs initiate during the time of year and day when the temperature is highest.

4.8.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Shaggy Peak, NM cluster. The resulting equations and the R square values are included in Table 4.8.3. The goals of these equations are to determine the characteristics needed for a larger FP. The results discussed below for the Shaggy Peak, NM cluster come from a combination of Table 4.8.1, Table 4.8.2, and Table 4.8.3.

The 6HP model run was a fairly good fit to the data at 0.967 and contained nine variables. More negative values of CIN, stronger positive U component wind shears between the surface and 500 mb, LCLs closer to the ground, warmer surface potential temperatures, stronger west-east winds at 200 mb, and warmer columns of air between the surface and 500 mb are needed for larger FPs within this cluster's domain. Lower surface saturation mixing ratios, weaker SRH values, and more negative V component wind shears between the surface and 500 mb are also needed for larger FPs for the initiation occurring in six hours within this cluster's domain. This combination of variables gives an accurate estimation of the eventual FP since it is a near perfect fit. There were multicollinearity issues present in this equation.

The 5HP model run was significantly worse than the previous model run at 0.770, but still well above the R square cutoff value. A dry pocket of air at 600 mb, weaker south-north winds at the surface, and more negative CIN values are needed for larger FPs within this cluster's domain. The R square value was a reasonable fit but it is not as good as the previous hour's. There were no multicollinearity issues present in this model run.

The 4HP model run was a better fit to the data than the two previous model runs at 0.997. Cooler surface potential temperatures, larger Thickness values, weaker south-north winds at 600 mb, stronger south-north winds at 300 mb, and weaker SRH values contribute to larger FPs within the cluster domain. Weaker south-north winds at the surface, stronger west-east winds at 500 mb, warmer columns of air between the surface and 200 mb, and smaller PW values are also needed for larger FPs within this cluster's domain. This combination of variables provides a near perfect fit and can be used to accurately estimate the eventual FP at 4HP. There were multicollinearity issues present but this is expected due to the inclusion of the geopotential height and wind variables.

The 3HP model run was a slightly worse fit to the data than the previous model run at 0.977. Larger values of CAPE, warmer surface potential temperatures, larger surface mixing ratios, lower PW values, a moist pocket of air at 200 mb, stronger west-east winds at 200 mb, and lower SRH values are needed for larger FPs within this cluster. Warmer columns of air between the surface and 600 mb, lower surface saturation mixing ratios, higher surface mixing ratios, LCLs closer to the ground, more negative V component wind shears between the 600 and 500 mb, and stronger U component wind shears between the surface and 500 mb are also needed for larger FPs within this cluster's domain. The combination of these variables creates a near perfect fit and can be used to identify the variables needed for predicting eventual FP of the system that will form in three hours' time. There were multicollinearity issues present.

The 2HP model run was a very poor fit and barely made the R square cutoff at 0.610. Colder columns of air between the surface and 200 mb and more negative LI values are needed for larger FPs according to this equation. The fit to the data was poor and there were no multicollinearity issues present since only two variables were included in the equation.

The 1HP model run was the best fit to the data out of all of this cluster's model runs at 0.999 and contained eight variables. Cooler surface potential temperatures, larger Thickness values, weaker south-north winds at 600 mb, weaker V component wind shears between the surface and 500 mb, less negative LI values, more positive U component wind shears between the surface and 600 mb, stronger west-east winds at 200 mb, and a dry pocket of air at 500 mb are needed for larger FPs within the cluster domain. The near perfect fit to the data can be used for the identification of variables needed to accurately predict the size of the system that will form in the next hour. There were multicollinearity issues present in this equation.

The model run done at initiation was a fairly good fit to the data at 0.961. More positive U component wind shears between 600 and 500 mb, warmer temperatures at 200 mb, more positive SRH values (from JC07), warmer columns of air between the surface and 600 mb, and stronger west-east winds at 200 mb are needed for larger FPs. LCLs closer to the ground, more negative V component wind shears between 600 and 500 mb, more positive U component wind shears between the surface and 600 mb, weaker west-east winds at 300 mb, warmer temperatures at 600 mb, and a dry pocket of air at 500 mb are also needed to contribute to larger FPs. While this combination of variables does not give the best fit out of all the model runs, it is still a near perfect fit and can be used to accurately estimate the FP. There were multicollinearity issues present in this model run.

Throughout the MLRs, there were several variables that were never included in the model runs: GH300, SH850, SH800, UC600, WD600, VC200, and T500. The variables used the most were STHC and SRH at five out of ten model runs. According to MLR, these two variables are the most important to larger FPs within the cluster domain. Only one variable was included in four out of ten model runs – UC200. The combination of variables is more important to initiation than an individual variable. There is a wind or wind shear (from JC07) variable in almost every model run, but the variable used is not consistent.

4.8.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA on the Shaggy Peak, NM cluster. Included in Table 4.8.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater or equal to one, and percent variance accounted for with those eigenvalues. PCAs were done to solve the multiple fit issues seen in the Shaggy Peak, NM cluster MLRs.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. In the first component, the variables with the highest loadings were STHC (5HP, 2HP), SMXR (4HP), SMXS (2HP), Thickness (5HP, 4HP, 2HP, 1HP), PW (5HP, 4HP, 2HP, 1HP, initiation), geopotential height, specific humidity (5HP, 4HP, 2HP, 1HP, initiation), U component wind (6HP, 3HP), U component wind shear (6HP, 3HP), and temperature (5HP, 4HP, 3HP, 2HP, 1HP, initiation) variables. The variables loaded in negatively were the geopotential height (6HP), U component wind (3HP), and U component wind shear (3HP) variables. Therefore, colder columns of air are needed for the greatest contribution to this component at that time. The contribution from the U component wind and wind shear variables depends on the value of the variables. In the second component, the variables with the highest loadings were LI (initiation), PW (6HP, 3HP, initiation), specific humidity (6HP, 3HP) U component wind (5HP, 4HP, 1HP), WD500 (5HP), and V component wind (2HP, 1HP, initiation) variables. All of these variables, with the exception of LI, were loaded positively into the second component; therefore, larger values of the PW and specific humidity variables are needed for the variables to have the greatest contribution. These model runs are different from previous clusters due to the individual variables' loadings. The variables that were loaded highly multiple times are considered the most important to MCSMI within the Shaggy Peak, NM cluster.

All variables were included on a minimum of three most used lists. SH200 was included only three times which shows that this variable was not as important as others for this cluster. The variables included in every most used list were Thickness, GH500, GH300, GH200, SH850,

SH800, UC500, UWSS500, VWSS500, VWSS600, T600, T500, and T300. The variables that were included in almost every most used list were STHC, SMXS, UWND, VWND, PW, SH300, UC300, UWS600500, UWSS600, VC600, VC500, and VC300. These variables combined with the loadings from the model runs above show the variables that are most important to MCSMI according to the PCAs. The above most used variables need to be observed within the cluster domain to determine when an MCS will form.

4.8.4: Cluster Discussion

There were still some poor fits to the data in the MLRs which means that since the PCAs were all good fits with most of the variance accounted for in each model run, the PCA contains the best model runs for the possibility of identifying the variables needed for MCSMI within the Shaggy Peak, NM cluster domain. There were multicollinearity issues present in six out of ten model runs of the MLRs that were corrected when the PCAs were run on the same data, providing further evidence that the PCAs are the best for this cluster. Also, the variables loaded the most highly into each model run and those used the most often on the most used list are very similar showing that those variables are the most important. There was no variable in the MLRs that stood out as the most important as it did in the PCAs. The most important PCA variables included Thickness, the geopotential height (except GH600), SH850, SH800, several wind and wind shear, and temperature (except T200) variables. Therefore, the PCAs will give the most accurate description of the variables needed for eventual MCS formation within this cluster.

The Shaggy Peak, NM cluster is in a portion of the Rocky Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the south-southwest. The median wind direction at 500 mb and initiation gives winds from the southwest. This indicates that the winds at 600 mb arrive at a slight angle to the ridgeline and the winds at 500 mb arrive along the ridgeline.

The composite map for Shaggy Peak, NM is Figure 4.8.2. The most important temperature variable was T300. The lowest temperatures are located east-northeast of the cluster domain. The cluster domain is within warmer temperatures at 300 mb and the temperature values will not change significantly within the next few hours. The most important geopotential height variable was GH200. There is a ridge and a trough to the east of the cluster domain. The trough is farther east than the ridge. Higher heights have passed through the cluster domain and are decreasing in value. The most important moisture variable was SH850. There is a moist pocket of air to the east of the cluster domain; however, the cluster domain is in relatively dry air overall. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 5.183 ms^{-1} at 298.840˚.

4.8.5: Cluster Figures and Tables

Table 4.8.1: Median Values for the Upper Air and Surface Variables for the Shaggy Peak, NM Cluster.

Variable	Median Value
STHC	38.580
SMXR	9.870
SMXS	17.920
UWND	-1.800
VWND	0.980
LCL	652.410
LI	-0.550

Table 4.8.2: Median Values for the NARR Variables for the Shaggy Peak, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5836.500	5861.625	5872.100	5849.200	5852.900
PW	17.100	17.350	20.500	16.800	18.100
CAPE	233.200	82.950	249.350	148.400	166.500
CIN	-24.500	-15.450	-14.400	-16.200	-25.700
SRH	26.400	19.550	33.950	31.700	24.650
GH600	4469.600	4462.250	4469.050	4469.600	4467.750
GH500	5918.300	5908.450	5918.100	5916.300	5918.100
GH300	9714.500	9703.850	9733.750	9717.200	9701.000
GH200	12450.200	12418.500	12480.550	12449.200	12417.350
SH850	9.300e-3	8.600e-3	9.700e-3	8.900e-3	8.950e-3
SH800	8.000e-3	7.500e-3	8.700e-3	7.700e-3	7.800e-3
SH600	4.400e-3	4.600e-3	5.900e-3	4.700e-3	5.150e-3
SH500	2.600e-3	2.650e-3	2.750e-3	2.800e-3	2.850e-3
SH300	2.000e-4	3.650e-4	4.200e-4	3.100e-4	3.800e-4
SH200	4.100e-5	3.900e-5	5.550e-5	4.300e-5	4.400e-5
UC600	9.320e-2	0.788	-0.591	0.760	0.819
UC500	0.163	2.400	1.400	1.400	2.100
UC300	0.393	6.150	5.750	-0.449	5.300
UC200	0.627	6.250	8.500	2.200	6.450
UWSS500	3.380	3.185	1.788	2.440	3.335
UWS600500	-0.300	1.350	1.700	0.600	0.500
UWSS600	4.690	1.805	1.502	3.990	1.620
WD600	207.842	227.372	169.661	233.130	204.490
WD500	205.880	275.661	251.253	190.587	281.740
VC600	-0.307	-2.400	1.350	-0.253	-0.703
VC500	-1.400	-4.250	-1.032	-2.300	-2.800
VC300	-0.509	-3.700	1.869	-0.561	-4.600
VC200	0926	-2.200	5.000e-2	1.000	-1.128
VWSS500	-2.470	-4.905	-0.833	-3.200	-2.755
VWS600500	-0.600	-1.800	-1.219	-1.600	-2.550
VWSS600	-2.130	-1.930	1.500e-2	-1.380	-0.710
T600	2.400	2.400	2.300	2.300	2.050
T500	-7.000	-8.450	-6.650	-7.000	-8.400
T300	-33.000	-33.800	-32.350	-32.900	-34.500
T200	-53.000	-53.300	-53.550	-52.800	-53.500
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5858.250	5854.100	5829.600	5840.550	5842.400
PW	19.850	18.200	17.050	19.800	18.100
CAPE	137.200	140.400	112.200	151.150	130.100
CIN	-31.500	-29.200	-33.900	-40.750	-38.400

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	46.950	39.900	39.900	64.150	65.600
GH600	4470.350	4474.600	4465.050	4470.000	4467.000
GH500	5919.850	5923.100	5917.800	5917.700	5916.000
GH300	9732.550	9731.400	9695.350	9730.100	9711.500
GH200	12477.450	12464.000	12422.250	12468.400	12457.200
SH850	9.550e-3	9.100e-3	9.100e-3	1.040e-2	9.300e-3
SH800	8.800e-3	7.900e-3	7.950e-3	9.200e-3	8.100e-3
SH600	5.450e-3	5.100e-3	4.650e-3	4.850e-3	4.700e-3
SH500	2.850e-3	2.500e-3	2.400e-3	3.000e-3	2.600e-3
SH300	4.200e-4	3.200e-4	3.850e-4	4.450e-4	3.600e-4
SH200	5.750e-5	4.300e-5	5.100e-5	5.800e-5	4.600e-5
UC600	0.732	0.399	1.500	1.490	0.490
UC500	0.888	0.604	1.750	1.950	1.800
UC300	4.850	0.875	6.750	4.600	3.700
UC200	7.050	5.400	7.850	8.500	6.100
UWSS500	0.876	4.540	4.009	2.675	5.140
UWS600500	1.382	0.588	-0.250	1.142	-0.100
UWSS600	1.292	3.640	2.414	1.475	4.347
WD600	193.226	193.570	231.953	208.236	198.090
WD500	244.073	222.138	232.308	212.968	243.435
VC600	0.202	0.671	-1.600	-0.812	-0.408
VC500	-1.361	-1.300	-4.150	-2.380	-2.700
VC300	-0.876	0.398	-4.250	-1.550	7.140e-2
VC200	-0.500	0.141	0.377	-2.528	-0.279
VWSS500	-0.770	-2.500	-3.705	-1.445	-1.464
VWS600500	-2.120	-1.700	-2.369	-2.700	-1.227
VWSS600	-0.720	-0.530	-2.135	-0.920	-1.208
T600	2.350	2.200	1.900	2.450	2.100
T500	-6.850	-7.300	-8.550	-6.850	-7.300
T300	-32.100	-33.000	-34.400	-32.050	-32.900
T200	-53.350	-53.100	-53.100	-53.500	-53.100

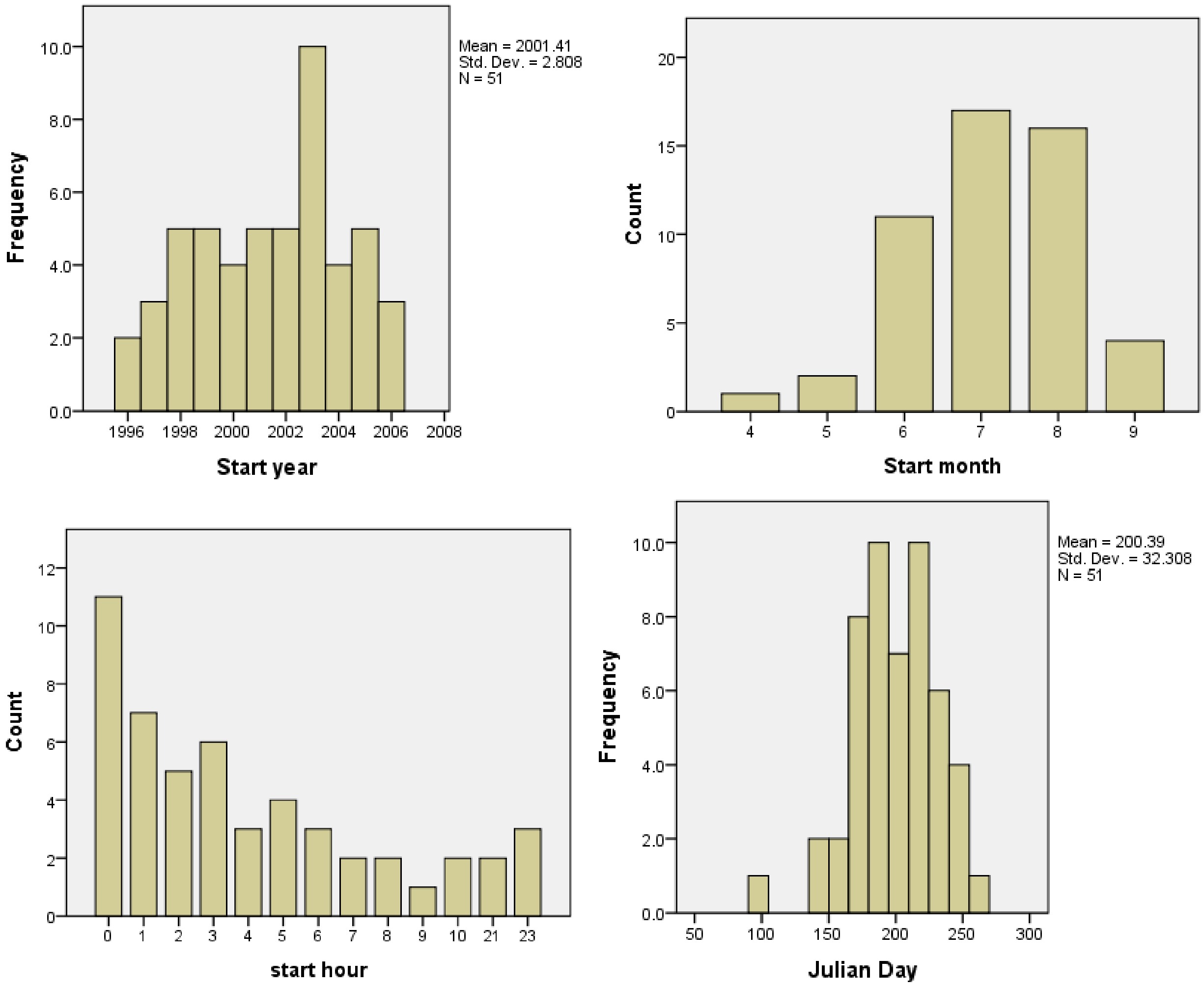


Figure 4.8.1: Time Histograms for the Shaggy Peak, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.8.3: Results of the MLRs Run on the Shaggy Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – CIN + UWSS500 + LCL + STHC + UC200 + GH500 – SMXS – SRH – VWSS500	0.967
5HP	FP ≈ constant – SH600 – VWND – CIN	0.770
4HP	FP ≈ constant – STHC + Thickness – VC600 + VC300 – SRH – VWND + UC500 + GH200 – PW	0.997
3HP	FP ≈ constant + CAPE + STHC + SMXR – PW + SH200 + UC200 – SRH + GH600 – SMXS + LCL – VWS600500 + UWSS500	0.977
2HP	FP ≈ constant – GH200 – LI	0.610
1HP	FP ≈ constant – STHC + Thickness – VC600 + VWSS500 + LI + UWSS600 + UC200 – SH500	0.999
Initiation	FP ≈ constant + UWS600500 + T200 + SRH + GH600 + UC200 + LCL – VWS600500 + UWSS600 – UC300 + T600 – SH500	0.961

Table 4.8.4: Results of the PCAs Run on the Shaggy Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH600, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	10	92.775%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	8	94.597%
4HP	STHC, SMXS, UWND, Thickness, PW, CAPE, SRH, GH500, GH300, GH200, SH850, SH800, SH500, SH300, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	92.738%
3HP	SMXS, UWND, VWND, Thickness, PW, CAPE, GH500, GH300, GH200, SH850, SH800, UC500, UC300, UWSS500, WD600, VC300, VWSS500, VWSS600, T600, T500, T300	9	88.736%
2HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	95.357%
1HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	95.102%
Initiation	STHC, SMXS, UWND, VWND, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	10	92.644%

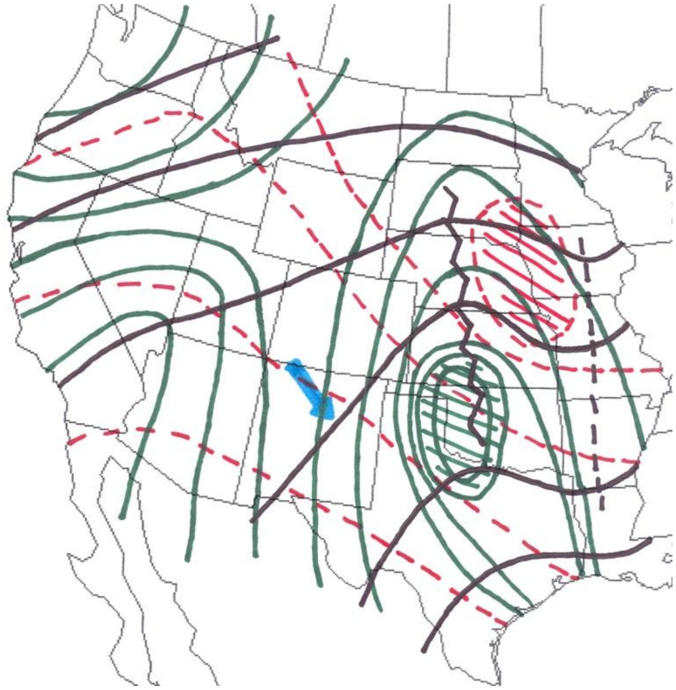


Figure 4.8.2: Composite Map for Shaggy Peak, NM. The variables included on the map are T300, GH200, SH850, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.9: Los Pinos Mountains, NM

4.9.1: Description of Cluster

The Los Pinos Mountains, NM cluster is located northeast of Socorro, NM and contains 43 members. The median values given for the surface variables in Table 4.9.1 show that the potential temperature is relatively hot at 35.190˚C (approximately 95˚F), the air is relatively moist, and the winds are from the southeast (also from BS87). Since the air is relatively hot at the closest reporting station, it is assumed that it will still be warm at the initiation location. The air is relatively moist, especially compared to some of the previous clusters, at approximately 56 percent relative humidity. The UWND and VWND variables give a median wind direction of southeast. The median values given for the upper air variables in Table 4.9.1 show an LCL relatively close to the ground, which is better for convective initiation, and an LI that indicates the air is slightly unstable.

The median values from the NARR data are given in Table 4.9.2 and show how the variables change from 6HP to 3HA. While the geopotential height variables do not change much from 6HP to 3HA, Thickness does change. There is very little change seen in Thickness between 6HP and the initiation hour but the change is seen when progressing to 3HA. There is a significant drop in value indicating a colder column of air over the initiation location. While the PW median value does not change significantly throughout the model runs, it is of relatively high values, especially compared to previous clusters. CAPE's maximum is at 4HP and it also spikes at 2HA. CIN does not vary greatly throughout the model runs but hits its lowest point at 5HP. SRH fluctuates around a value of 50. The specific humidity variables do not vary significantly and indicate relatively dry air. The wind and wind shear variables change but this is expected due to the changing flow patterns and topographic influences. The upper level temperatures do not vary greatly throughout the runs.

Histograms for the Los Pinos Mountains, NM cluster, Figure 4.9.1, were created for the start year, start month, start hour, and Julian Day. The start-year histogram shows that the most MCSs initiated in 1996, followed by 2006. The least number of MCSs initiated during the mean year of 2000. The most MCSs initiated in August, followed by September, then July. This is different from previous clusters in that most of the MCSs initiated in July and August. A large portion of the MCSs initiated at the late afternoon/early evening (consistent with FF01), but also throughout the day in this cluster with a spike at 1200 UTC. The Julian-Day histogram shows that almost all of the MCSs initiated in July, August, and September. Not all of the MCSs initiated at what is considered the hottest part of the year or day.

4.9.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Los Pinos Mountains, NM cluster. The resulting equations and the R square values are included in Table 4.9.3. The variables included in the equations are important to larger FPs within the cluster domain according to the MLRs. The results discussed below for this cluster are derived from a combination of Table 4.9.1, Table 4.9.2, and Table 4.9.3.

The 6HP model run was a poor fit to the data at 0.687. Stronger south-north winds at 600 mb, stronger SRH values (from JC07), weaker west-east winds at 300 mb, and weaker east-west winds at the surface contribute the most to larger FPs within the cluster's domain. This relatively poor fit can be used for the identification of variables needed to predict the eventual FP, but with a significant amount of error. There were no multicollinearity issues present which is expected due to the poor fit of the data and the few variables that were used.

The 5HP model run was a much better fit to the data than the previous model run at 0.926. More positive V component wind shears between the surface and 500 mb, weaker west-east winds at 300 mb, weaker V component wind shears between 600 and 500 mb, and northeast winds at 600 mb are needed for larger FPs within the cluster's domain. The combination of these variables provides a near perfect fit to the data and shows that this equation can be used for the identification of variables needed to accurately predict the eventual FP from the initiation that will occur in five hours. There were no multicollinearity issues present. This was unexpected due to the inclusion of the two wind shear variables covering the same part of the atmosphere.

The 4HP model run contained eight variables within the equation to create a perfect fit. Northwest winds at 600 mb, warmer temperatures at 600 mb, colder temperatures at 300 mb, a moist pocket of air at 500 mb, more positive U component wind shears between the surface and 500 mb, stronger north-south winds at the surface, more negative V component wind shears between the surface and 600 mb, and LCLs higher off the ground are needed for larger FPs within this cluster's domain. Since this equation was a perfect fit to the data, it will be used for the identification of variables needed to predict the eventual FP of the system which will initiate in four hours within this cluster domain. There were multicollinearity issues present in this equation but that is expected since wind and wind shear variables are included in this equation.

The 3HP model run was a near perfect fit to the data at 0.993. More positive SRH values (from JC07), lower values of CAPE, more negative U component wind shears between 600 and 500 mb, less negative CIN values, weaker west-east winds at 300 mb, stronger south-north winds at 300 mb, warmer surface potential temperatures, colder temperatures at 200 mb, stronger west-east winds at 200 mb, and a moist pocket of air at 300 mb are needed for larger FPs within the cluster domain. The lower values of CAPE are needed since the variable was added negatively in the equation and to achieve the best contribution. This combination of variables provides a near perfect fit to the data and can be used to accurately predict the eventual FP, with some associated error. There were multicollinearity issues present in this equation which is predictable with the inclusion of several wind and wind shear variables.

The 2HP model run was a perfect fit to the data. More positive V component wind shears between the surface and 500 mb, weaker south-north winds at 300 mb, cooler surface potential temperatures, higher surface saturation mixing ratios, stronger west-east winds at 600 mb, and larger Thickness values contribute the most to larger FPs within the cluster domain. More positive V component wind shears between the surface and 600 mb, stronger south-north winds at 200 mb, more negative LI values, weaker south-north winds at 600 mb, weaker west-east winds at the surface, LCLs lower to the ground, and less negative CIN values are also needed for larger FPs within the cluster domain. The combination of these variables provides a perfect fit to the data; therefore, the equation will be used to accurately estimate the eventual MCS size with virtually no error. Since multiple wind and wind shear variables were included, it is expected that there were multicollinearity issues present.

The 1HP model run was also a perfect fit to the data, utilizing eight variables. Northwest winds at 600 mb, a dry pocket of air at 850 and 200 mb, weaker U component wind shears between the surface and 600 mb, weaker south-north winds at 200 mb, stronger east-west winds at the surface, northwest winds at 500 mb, and colder temperatures at 300 mb are needed for larger FPs within the cluster domain. This combination of variables provides a perfect fit to the data; therefore, the eventual FP from the initiation will be accurately estimated with virtually no error. There were multicollinearity issues present.

The model run done at initiation had the second worst fit to the data out of all of this cluster's model runs, at 0.827. Stronger south-north winds at 300 mb, smaller values of CAPE, more negative V component wind shears between 600 and 500 mb, LCLs closer to the ground, warmer columns of air between the surface and 600 mb, and smaller Thickness values contribute the most to larger FPs within the cluster domain and should be observed. This combination provides a good fit to the data and there were no multicollinearity issues present.

There were several variables that were never used in the model runs and are considered least important to larger FPs. Those variables were: SMXR, PW, GH300, GH200, SH600, VC500, and T500. The variable used in the most model runs was VC300 at six out of ten model runs. This is considered most important to larger FPs within the cluster domain according to the MLRs and will be the best variable to observe overall. Other than VC300, the other wind and wind shear variables are not included that often in the model runs. The biggest similarity between the model runs is the inclusion of VC300.

4.9.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA on the Los Pinos Mountains, NM cluster. Included in Table 4.9.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those components. The PCAs will solve the fit issues present in the MLRs.

The 6HP model run through the initiation model run have similar variables loaded highly into the first components. In the first component, the variance loaded the most highly were STHC (6HP, 4HP, 1HP), SMXR (5HP, 2HP), SMXS (4HP, 1HP), Thickness, PW (5HP, 2HP), geopotential height, specific humidity (5HP, 2HP), U component wind (6HP, 5HP, 4HP, 3HP, 2HP, initiation), U component wind shear (5HP, 4HP), V component wind (5HP, 4HP), V component wind shear (5HP), and lower level temperature (6HP, 4HP, 2HP, 1HP) variables. The loadings for this component were different from previous clusters. The variables loaded negatively into the component were STHC, SMXS (1HP), Thickness, geopotential height, U component wind (5HP, 4HP, 3HP, 2HP), U component wind shear (5HP, 4HP), V component wind (5HP, 4HP), V component wind shear (5HP), and lower level temperature variables. The U component wind (6HP) variables were loaded positively into the component and the contribution from wind and wind shear variables will depend on the value of the variable. The loadings of STHC, Thickness, and geopotential height variables point to needing lower values of the variables to provide the greatest contribution to the component. The variables loaded the highest into the second component were SMXR (6HP, 4HP, 3HP, initiation), LI (5HP), LCL (4HP), PW (6HP, 4HP, 3HP, 1HP, initiation), SRH (5HP, 4HP), lower level specific humidity (6HP, 3HP, initiation), U component wind shear (1HP), V component wind (5HP, 2HP), and V component wind shear (5HP, 2HP) variables. All of these variables were loaded positively into the component with the exception of LI, SRH, and U component wind shear variables, which means that larger values of each of the variables will provide the best contribution to the component. The contribution from LI will be greater when the value is more negative and the contribution from SRH will depend on the value of SRH. These variables are considered the most important to initiation according to this model run. This cluster is unique because the most highly loaded variables change from model run to model run.

All of the variables were included in the most used lists at least four times. This shows that most of the variables are important to MCSMI according to the PCAs. The variables that were included on every most used list were STHC, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, T500, and T300. These are the variables that should be observed for initiation within this cluster's domain and the important MLR variables should be observed for larger FPs. This list is similar to the lists of the most highly loaded variables into the components. These variables show that the 500 mb level is the most important for this cluster's MCS formation.

4.9.4: Cluster Discussion

It was difficult to determine which type of analysis was best for this cluster. The PCA determines if an MCS will initiate while the MLR will determine the FP of the MCS initiating. However, one analysis tends to be a better fit to the data than the other analysis. Four out of ten model runs were perfect fits to the data in the MLRs and only the 6HP model run was a poor fit. Six out of ten MLR model runs contained multicollinearity issues and the PCAs were run to solve the fit issues. The PCAs had over 90 percent variance accounted for with each model run. Even though no PCA had 100 percent variance accounted for, they were still very good fits to the data. Therefore, the PCAs are the better method and will identify the variables needed for the prediction of MCS formation with greater accuracy but the MLRs are easier to understand and use.

The Los Pinos Mountains, NM cluster is in an area of the Rocky Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the west-southwest. This indicates that the winds at 600 and 500 mb arrive at a slight angle to the ridgeline.

The composite map for Los Pinos Mountains, NM is Figure 4.9.2. The most important temperature variable was T300. The lowest temperatures are to the north of the cluster domain with increasing temperatures towards the south; therefore, the temperatures at 300 mb are relatively warm. The most important geopotential height variable was GH500. There is a ridge present west of the cluster domain that will move through the area. The heights will increase as time progresses and the ridge moves eastward. The most important moisture variable was SH850. The moisture values are relatively constant throughout the composite map with high moisture to the northeast of the cluster domain. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 6.861 ms^{-1} at 258.780˚ within this cluster's domain.

4.9.5: Cluster Figures and Tables

Table 4.9.1: Median Values for the Upper Air and Surface Variables for the Los Pinos Mountains, NM Cluster.

Variable	Median Value
STHC	35.190
SMXR	10.090
SMXS	17.960
UWND	-2.030
VWND	1.300
LCL	682.630
LI	-0.290

Table 4.9.2: Median Values for the NARR Variables for the Los Pinos Mountains, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5839.100	5818.750	5834.600	5830.150	5800.900
PW	21.150	23.850	21.300	21.750	22.950
CAPE	132.550	118.850	370.800	202.700	261.500
CIN	-20.400	-5.850	-11.600	-27.900	-18.700
SRH	35.750	59.300	23.900	40.750	77.950
GH600	4474.300	4457.600	4453.900	4468.500	4451.550
GH500	5919.150	5900.100	5898.600	5911.150	5895.000
GH300	9706.700	9710.000	9692.300	9698.750	9702.400
GH200	12447.200	12447.800	12417.300	12427.850	12450.950
SH850	8.850e-3	1.040e-2	8.800e-3	9.150e-3	1.105e-2
SH800	7.650e-3	9.150e-3	7.700e-3	8.000e-3	9.600e-3
SH600	5.000e-3	4.700e-3	4.600e-3	4.850e-3	4.700e-3
SH500	2.450e-3	2.800e-3	2.500e-3	2.550e-3	3.000e-3
SH300	2.800e-4	3.800e-4	3.900e-4	3.300e-4	5.000e-4
SH200	5.100e-5	5.400e-5	4.700e-5	5.350e-5	5.700e-5
UC600	2.500	3.250	0.570	3.950	3.800
UC500	2.600	4.400	2.500	2.850	3.200
UC300	7.150	8.300	1.600	6.900	7.300
UC200	12.250	13.300	2.500	13.550	12.800
UWSS500	6.355	7.285	8.420	5.265	6.065
UWS600500	0.534	-0.455	0.900	-2.100e-2	0.911
UWSS600	4.700	6.245	7.450	4.530	6.800
WD600	241.058	234.634	203.009	238.245	227.069
WD500	251.430	226.812	215.538	240.998	225.558
VC600	1.400	2.200	2.000	1.118	2.400
VC500	-9.550e-2	3.500	0.430	1.682	3.950
VC300	6.500	6.000	2.800	5.600	7.700
VC200	3.500	6.900	8.300	2.500	6.600
VWSS500	0.221	2.070	-1.929	1.152	4.045
VWS600500	-1.100	1.300	-1.700	-2.300	1.250
VWSS600	1.535	1.855	-2.340	1.521	2.595
T600	1.800	1.450	1.600	1.750	1.300
T500	-8.050	-7.300	-8.700	-8.750	-6.650
T300	-32.850	-31.800	-33.200	-33.200	-31.750
T200	-52.800	-52.600	-53.000	-52.850	-52.450
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5842.800	5818.400	5783.950	5824.600	5813.900
PW	22.100	21.050	24.200	23.300	20.750
CAPE	192.300	174.300	105.350	354.200	244.400
CIN	-17.800	-24.750	-21.850	-21.200	-35.300

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	57.300	47.650	71.750	40.300	81.000
GH600	4445.300	4460.800	4455.150	4452.500	4460.100
GH500	5899.100	5905.150	5908.600	5905.200	5906.550
GH300	9690.800	9703.700	9715.350	9669.400	9703.900
GH200	12407.100	12436.400	12462.950	12404.400	12441.900
SH850	9.300e-3	9.300e-3	1.110e-2	9.600e-3	9.300e-3
SH800	8.200e-3	8.100e-3	9.800e-3	8.600e-3	8.250e-3
SH600	5.700e-3	4.600e-3	4.750e-3	4.700e-3	4.350e-3
SH500	3.300e-3	2.800e-3	3.250e-3	2.800e-3	2.450e-3
SH300	3.700e-4	3.550e-4	4.200e-4	4.100e-4	3.850e-4
SH200	5.300e-5	5.500e-5	6.100e-5	5.400e-5	5.100e-5
UC600	0.888	4.150	3.900	2.100	3.600
UC500	0.563	3.350	4.850	3.100	4.300
UC300	1.400	6.950	6.000	2.300	7.300
UC200	1.900	12.250	13.100	2.900	14.050
UWSS500	10.278	6.730	7.145	10.680	6.530
UWS600500	2.428	-0.250	0.550	2.311	1.200
UWSS600	9.520	4.880	6.400	8.390	5.965
WD600	218.118	243.463	246.328	265.711	250.356
WD500	202.751	243.038	210.060	244.799	242.379
VC600	2.200	1.900	1.300	0.345	0.881
VC500	0.361	0.997	2.400	-0.569	0.372
VC300	3.200	2.400	5.600	2.800	3.291
VC200	6.300	1.100	5.400	6.500	-0.104
VWSS500	-3.660	1.335	3.875	-4.580	0.596
VWS600500	-1.200	-1.250	1.485	4.500e-2	-0.550
VWSS600	0.500	0.475	1.270	-2.816	0.385
T600	1.300	1.450	1.250	0.667	1.400
T500	-7.300	-8.450	-6.600	-8.700	-8.600
T300	-33.200	-33.30	-31.900	-33.300	-32.950
T200	-54.100	-52.900	-51.950	-53.700	-53.200

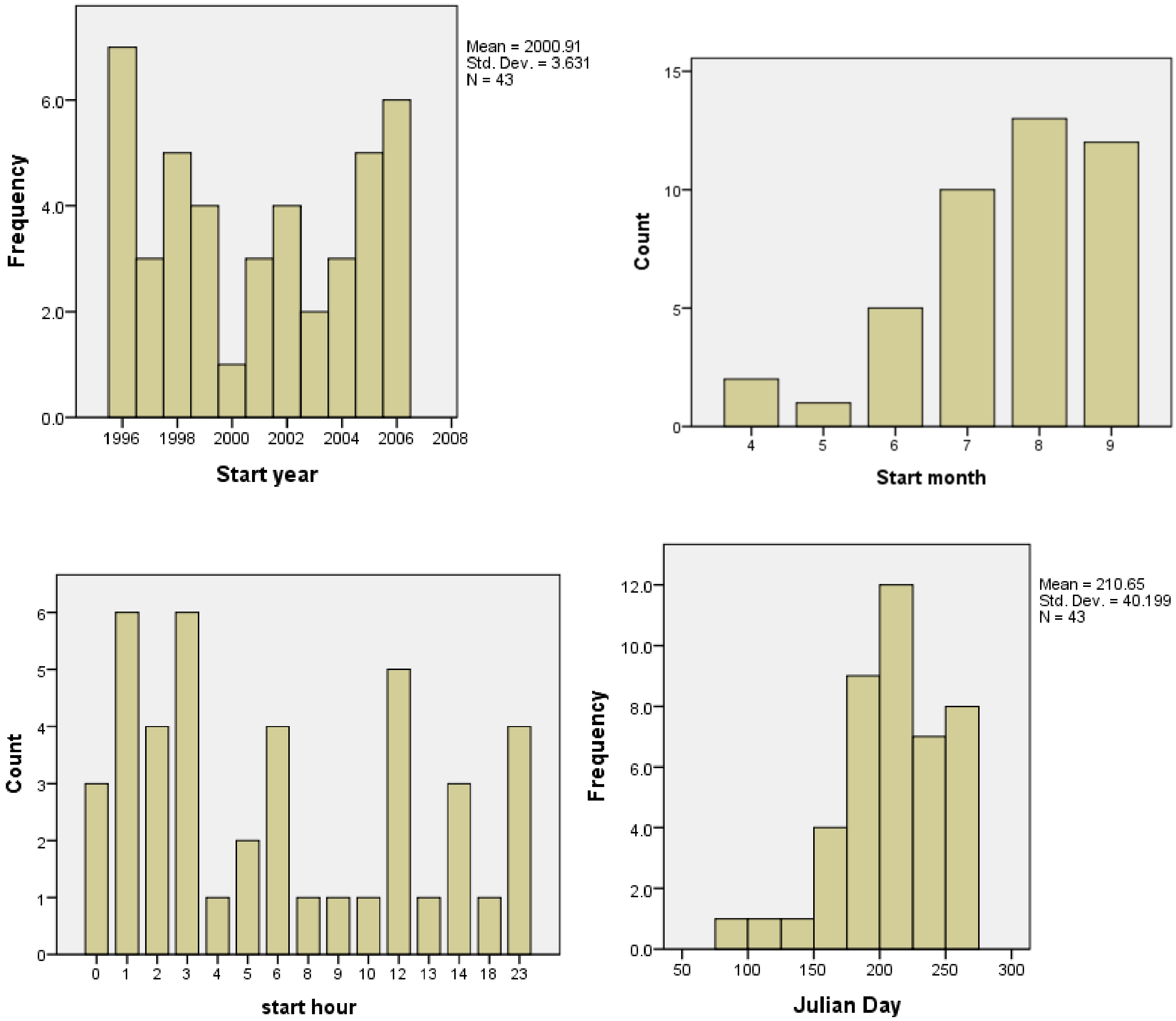


Figure 4.9.1: Time Histograms for the Los Pinos Mountains, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.9.3: Results of the MLRs Run on the Los Pinos Mountains, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + VC600 + SRH – UC300 + UWND	0.687
5HP	FP ≈ constant + VWSS500 – UC300 – VWS600500 – WD600	0.926
4HP	FP ≈ constant + WD600 + T600 – T300 + SH500 + UWSS500 – VWND – VWSS600 – LCL	1.000
3HP	FP ≈ constant + SRH – CAPE – UWS600500 + CIN – UC300 + VC300 + STHC – T200 + UC200 + SH300	0.993
2HP	FP ≈ constant + VWSS500 – VC300 – STHC + SMXS + UC600 + Thickness + VWSS600 + VC200 – LI – VC600 + UWND + LCL + CIN	1.000
1HP	FP ≈ constant + WD600 – SH850 – SH200 – UWSS600 – VC200 – UWND + WD500 – T300	1.000
Initiation	FP ≈ constant + VC300 – CAPE – VWS600500 + LCL + GH600 – Thickness	0.827

Table 4.9.4: Results of the PCAs Run on the Los Pinos Mountains, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, LCL, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH500, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	91.312%
5HP	STHC, SMXR, SMXS, VWND, LCL, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	94.521%
4HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.830%
3HP	STHC, LCL, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC500, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T500, T300	8	89.600%
2HP	STHC, SMXR, SMXS, UWND, VWND, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	94.243%
1HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	7	97.876%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, SRH, GH500, GH300, GH200, SH850, SH800, SH500, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	93.473%

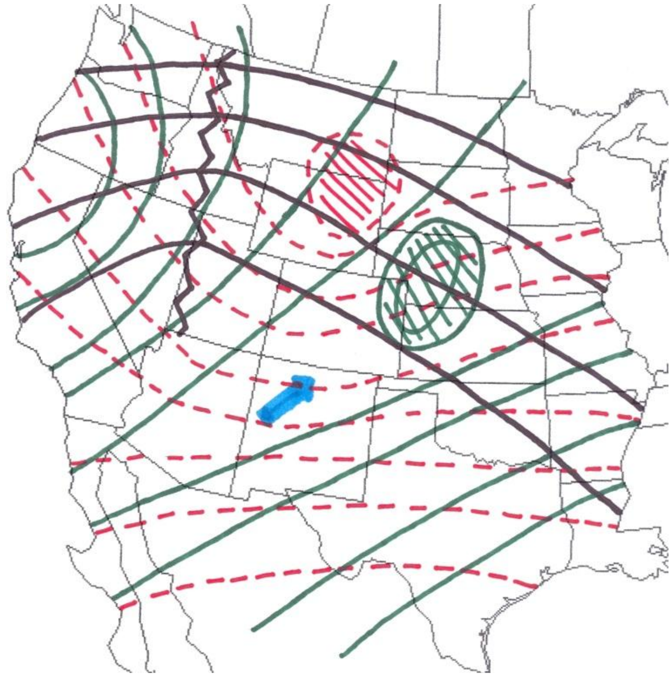


Figure 4.9.2: Composite Map for Los Pinos Mountains, NM. The variables included on the map are T300, GH500, SH850, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.10: Mount Washington, NM

4.10.1: Description of Cluster

The Mount Washington, NM cluster contained 38 members and is located east-southeast of Kirtland Air Force Base in NM. The median values given for the surface variables in Table 4.10.1 show that the air is relatively hot at 37.825˚C (approximately 100˚F) and relatively moist, and the winds are from the southeast (from BS87). The potential temperature will be relatively warm at the initiation location, since the air is relatively hot at the reporting station. The combination of SMXR and SMXS shows that the air is relatively moist with an approximate 53 percent relative humidity median value. The median values of UWND and VWND provide a median surface wind direction of southeast which is different from the upper level wind directions which were coming from the south-southwest at 600 and 500 mb. The median values given for the upper air variables in Table 4.10.1 show a high valued, low to the ground LCL which will make convection easier to achieve. The LCL median value is below ridgetop height and the LI shows a slightly negative value meaning the air is slightly unstable.

The median values from the NARR data are given in Table 4.10.2 and show how the variables change from the 6HP through the 3HA. The Thickness and geopotential height variables do not vary significantly throughout the model runs. There are some variations in each variable but are so slight that it does not warrant discussion. PW varies and is a relatively high value, especially compared to previous clusters' median values. The CAPE value varies significantly, reaching its high point at 3HP and its low point at 3HA. CIN does not vary greatly but reaches its most negative value after initiation. The SRH variable varies throughout the model runs. The specific humidity variables show the air is relatively moist at each level throughout the runs. The wind and wind shear variables vary throughout the model runs and are considered hour dependent. The upper level temperatures do not change significantly throughout the ten model runs but are relatively cold.

Histograms for the Mount Washington, NM cluster, Figure 4.10.1, were created for the start year, start month, start hour, and Julian Day. Between two and five MCSs occurred each year within the cluster domain. The years 1996 and 1999 each had five MCSs initiate and the mean year for initiation was 2000. According to the start-month histogram, most of the MCSs initiated in July, and April initiated more MCSs than May. The remaining months initiated approximately the same number. The start-hour histogram shows that MCSs initiated throughout the day in this cluster but a large portion initiated in late afternoon/early evening (consistent with FF01). The Julian-Day histogram shows that these MCSs initiated mainly in July and August. Most of the time conditions point to the hottest time of the year and day for the initiation of the thunderstorms that will eventually become an MCS.

4.10.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA. The resulting equations and the resulting R square values are contained in Table 4.10.3. This cluster differs from previous clusters in that three of the model runs would not form and two had a different entry and removal values. The results discussed below for the Mount Washington, NM cluster come from a combination of Table 4.10.1, Table 4.10.2, and Table 4.10.3.

The 6HP model run had an R square value of less than 0.600 at 0.246. This model run will not be discussed in detail but the resulting equation with one variable is included in Table 4.10.3. There were no multicollinearity issues present.

The 5HP model run was a better fit to the data than the previous model run at 0.754. Smaller Thickness values, weaker U component wind shears between 600 and 500 mb, and stronger V component wind shears between the surface and 600 mb are needed for larger FPs within the cluster domain. This combination of variables gives a reasonable fit and can be used for the identification of the variables needed to anticipate the FP but there is error associated with that value. There were no multicollinearity issues present with this equation.

The 4HP model run is considered missing and therefore not discussed in detail. There was no model run when the entry value was 0.15 so it was increased to 0.20, but a model run did not result from increasing the entry value. A higher entry value was not used because it would introduce too much error.

The 3HP model run is similar to the previous run. No model run resulted when an entry value of 0.15 was used but did result when a 0.20 entry value was used. This equation is considered a perfect fit to the data but there is still error associated with it because of the high entry value. A dry pocket of air at 200 mb, warmer temperatures at 200 mb, stronger east-west winds at the surface, a moist pocket of air at 800 mb, a dry pocket of air at 850 mb, higher surface and surface saturation mixing ratios, stronger south-north winds at 200 mb, less negative LI values, and stronger south-north winds at the surface are needed for larger FPs within this cluster's domain and should be observed. This combination of variables provides a perfect fit to the data but there is some error associated with it because of the increased entry value. There were multicollinearity issues present in this equation.

The 2HP model run was a perfect fit to the data and the entry value was 0.15. LCLs closer to the ground, weaker U component wind shears between 600 and 500 mb, colder columns of air between the surface and 300 mb, stronger north-south winds at the surface, warmer temperatures at 300 mb, and smaller surface mixing ratios contribute highly to larger FPs within the cluster domain. Warmer temperatures at 600 mb, northwest winds at 500 mb, a moist pocket of air at 200 mb, less negative LI values, larger CAPE values, colder columns of air between the surface and 200 mb, weaker south-north winds at 200 mb, and weaker west-east winds at 200 mb are also needed for larger FPs within the domain. The combination of these variables provides a perfect fit to the data and can be used for the identification of the variables needed to accurately predict the FP of the MCS with less associated error than the last model run.

The 1HP model run is considered missing and therefore not discussed in detail. There was no model run when the entry value was 0.15 so it was increased to 0.20 but a model run still did not result. A higher entry value higher was not used because there would be too much error.

The model run done at initiation did not have an equation result with an entry value of 0.15 but an equation did result with an entry value of 0.20. Stronger U component wind shears between the surface and 600 mb, larger values of CAPE, weaker west-east winds at 200 mb, a dry pocket of air at 600 mb, smaller SRH values, and northeast winds at 600 mb are needed for larger FPs within this cluster's domain. Stronger south-north winds at 200 mb, weaker south-north winds at 500 mb, stronger V component wind shears between the surface and 600 mb, and colder columns of air between the surface and 500 mb are also needed for larger FPs within the domain. The combination of these variables provides a perfect fit to the data with some associated error since a higher entry value was used and could be used to accurately predict the FP of the system initiating in this hour. There were multicollinearity issues present in this equation.

There were several variables that were never included in any of the seven model runs: STHC, GH600, SH500, UC600, UC500, UWSS500, VC600, and VC300. They are considered least important to larger FPs within the cluster domain according to the MLRs. The variable included the most often was UC200 at four out of seven model runs and therefore, considered important to larger FPs and should be monitored to suggest initiation. The combination of the variables provides the best tools for the identification of variables needed to forecast FP from initiation within the Mount Washington, NM cluster domain.

4.10.3: Principal Component Analysis

The PCAs were run on each of the 6HP through the 3HA on the Mount Washington, NM cluster. The variables with 90 percent variance accounted for, the number of components within eigenvalues of one or greater, and percent variance accounted for with those eigenvalues are included in Table 4.10.4. The variables included on the most used lists and loaded the highest into the individual components are considered the most important variables to MCSMI.

The 6HP model run through the initiation model run had similar variables loaded in the first components. In the first component, the variables that were loaded the highest were STHC

(5HP, 2HP), SMXS (5HP, 2HP), LI (6HP), Thickness (6HP, 4HP, 3HP, 2HP, 1HP, initiation), PW (6HP, initiation), geopotential height, specific humidity (6HP, 3HP, initiation), U component wind (5HP, 2HP), V component wind (6HP, 3HP), and temperature (6HP, 4HP, 3HP, 1HP, initiation) variables. STHC, SMXS, LI, Thickness (2HP), geopotential height (5HP, 2HP) and the V component wind variables were loaded negatively into the component and the rest were loaded positively. The contribution of LI, Thickness, PW, geopotential height, and specific humidity variables give positive contributions. The contribution was better within the cluster's domain using larger values of these variables. The temperature variables needed to be warmer values to give the better contribution and the contribution from the V component wind variables will depend on the value of the variable. In the second component, the variables loaded the highest were the SMXR (5HP, 2HP), LI (5HP), PW (5HP, 2HP), specific humidity (5HP, 2HP), U component wind (6HP, 4HP, 3HP, 1HP, initiation), and U component wind shear (4HP, 3HP, 1HP, initiation) variables. LI, U component wind (1HP), and U component wind shear (1HP) variables loaded negatively into the component and the remaining variables were loaded positively into the component. The wind and wind shear variables will provide varying contributions depending on the value of the variable. The variables that are loaded the highest change from hour to hour but there are still similarities to be seen.

All of the variables were included in at least four most used lists. SH600 and SH200 were included in four out of ten most used lists and are considered the least important to the identification of variables needed for MCSMI for this cluster. A large portion of the variables were included on every most used list: STHC, SMXR, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, and T300. They are considered the most important variables to MCSMI within the Mount Washington, NM cluster and are the ones to observe before initiation to determine if and when it will occur. The rest of the variables were included often in the most used list and are considered vaguely important to initiation.

4.10.4: Cluster Discussion

The Mount Washington, NM cluster was different from previous clusters in that there were complications with the MLRs. Even though four of the remaining seven model runs were perfect fits to the data, there were still too many issues for the MLRs to be considered the best method of analysis on this cluster. The PCAs were much better fits with all of the model runs having at least 93 percent of the variance accounted for and will be much more accurate in determining when and if an MCS will form within the Mount Washington, NM domain. The PCA output could be used for the identification of the variables needed in forecasting for MCSMI within this cluster's domain.

The Mount Washington, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the south-southwest. The median wind direction at 500 mb and initiation gives winds from the south-southwest. This indicates that the winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for Mount Washington, NM is Figure 4.10.2. The most important temperature variable was T300. Lower temperatures are to the north and relatively warm temperatures are present within the cluster domain. The most important geopotential height variable was GH300. A ridge is present to the east of the cluster domain and a negatively tilted trough is present to the west of the cluster domain. The heights will decrease at 300 mb as the trough passes through. The most important moisture variable was SMXR. Moist pockets of air are located east of the cluster domain and a dry pocket of air is located northwest of the cluster domain. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 4.654 ms^{-1} at 215.900˚.

4.10.5: Cluster Figures and Tables

Table 4.10.1: Median Values for the Upper Air and Surface Variables for the Mount Washington, NM Cluster.

Variable	Median Value
STHC	37.825
SMXR	9.835
SMXS	18.545
UWND	-1.330
VWND	1.530
LCL	692.655
LI	-0.870

Table 4.10.2: Median Values for the NARR Variables for the Mount Washington, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5845.100	5823.200	5833.300	5851.800	5830.000
PW	22.900	21.900	20.000	23.800	23.500
CAPE	113.200	210.400	245.900	344.200	278.800
CIN	-13.000	-13.500	-11.800	-8.700	-16.400
SRH	40.400	14.700	52.800	71.500	28.400
GH600	4439.900	4450.100	4466.150	4444.300	4453.700
GH500	5878.800	5892.100	5910.800	5888.500	5900.100
GH300	9682.000	9696.000	9685.200	9669.500	9706.900
GH200	12419.500	12435.200	12392.600	12411.800	12427.300
SH850	9.200e-3	1.000e-2	8.300e-3	9.700e-3	1.010e-2
SH800	7.900e-3	8.700e-3	7.250e-3	8.400e-3	8.800e-3
SH600	4.900e-3	4.700e-3	4.400e-3	5.600e-3	4.900e-3
SH500	2.800e-3	2.700e-3	2.500e-3	2.600e-3	2.800e-3
SH300	3.000e-4	4.300e-4	2.900e-4	4.100e-4	4.000e-4
SH200	5.000e-5	4.800e-5	3.300e-5	5.400e-5	4.900e-5
UC600	2.700	1.300	0.909	2.700	3.600
UC500	3.700	2.800	3.700	4.400	3.300
UC300	1.600	7.400	5.850	6.500	5.600
UC200	2.800	10.000	10.400	10.100	7.800
UWSS500	5.870	5.750	2.830	6.990	6.960
UWS600500	1.000	1.800	1.900	1.700	1.093
UWSS600	2.860	5.340	1.928	4.010	5.27
WD600	215.641	219.946	241.650	205.570	240.018
WD500	210.985	225.000	271.783	215.647	225.830
VC600	6.800	1.600	0.750	5.400	1.700
VC500	7.200	1.900	-1.600	6.900	0.691
VC300	9.700	6.700	4.100	10.200	7.300
VC200	11.000	6.800	1.950	10.800	6.100
VWSS500	5.580	3.790	-1.552	4.080	0.390
VWS600500	1.100	1.300	-0.920	0.600	1.900
VWSS600	4.200	1.770	-1.485	2.894	1.600
T600	1.900	1.900	1.550	2.200	1.300
T500	-7.500	-7.700	-8.450	-7.300	-7.500
T300	-32.200	-32.500	-34.750	-32.800	-32.000
T200	-54.500	-53.100	-53.000	-53.600	-52.600
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5825.600	5846.000	5825.400	5807.150	5833.000
PW	20.400	22.100	23.500	20.750	21.800
CAPE	169.700	174.300	245.500	137.850	106.500
CIN	-26.450	-29.800	-22.500	-37.700	-26.700

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	70.950	43.600	32.100	75.700	32.300
GH600	4459.150	4440.100	4456.200	4459.750	4452.700
GH500	5910.350	5884.100	5902.600	5898.950	5895.200
GH300	9684.350	9680.900	9701.100	9662.000	9671.100
GH200	12386.650	12415.400	12440.700	12389.600	12398.200
SH850	8.500e-3	9.000e-3	9.600e-3	8.600e-3	8.800e-3
SH800	7.400e-3	7.900e-3	8.300e-3	7.400e-3	7.800e-3
SH600	5.100e-3	5.100e-3	5.100e-3	4.600e-3	4.800e-3
SH500	3.050e-3	2.800e-3	2.900e-3	2.700e-3	2.700e-3
SH300	3.100e-4	3.300e-4	4.300e-4	3.250e-4	4.800e-4
SH200	3.700e-5	5.300e-5	5.300e-5	3.900e-5	5.400e-5
UC600	1.400	2.300	3.600	1.850	3.100
UC500	3.850	3.400	3.000	3.450	4.500
UC300	6.350	3.800	8.500	8.450	6.600
UC200	7.950	7.600	11.600	9.250	3.900
UWSS500	5.130	6.090	6.664	4.330	5.190
UWS600500	1.550	1.900	-0.500	1.150	0.700
UWSS600	2.265	2.729	7.080	3.220	3.910
WD600	244.235	197.266	244.486	274.005	210.801
WD500	297.009	212.905	253.361	310.554	219.579
VC600	0.220	5.900	0.731	-0.473	5.200
VC500	-2.100	5.500	0.393	-3.450	3.700
VC300	2.750	9.100	6.300	0.737	8.600
VC200	1.600	11.800	7.600	1.493	13.700
VWSS500	-2.865	3.284	-1.147	-4.405	3.700
VWS600500	-2.753	-0.400	1.294	-1.955	-1.100
VWSS600	0.138	3.770	1.300	-2.845	4.070
T600	1.688	2.600	1.600	1.269	2.400
T500	-7.900	-7.100	-7.700	-8.800	-7.100
T300	-34.600	-32.600	-32.000	-34.700	-33.000
T200	-53.500	-53.600	-53.100	-53.450	-53.900

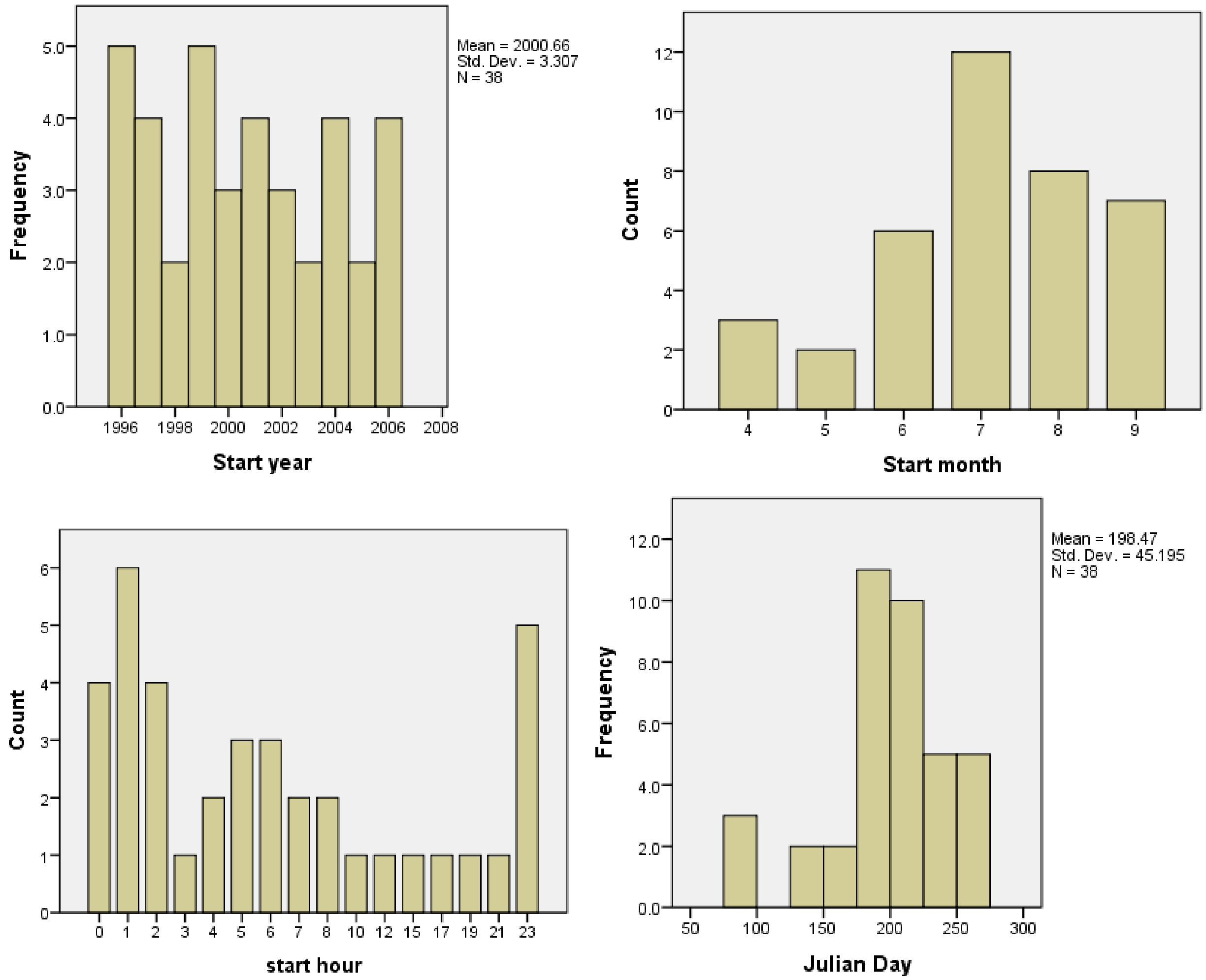


Figure 4.10.1: Time Histograms for the Mount Washington, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.10.3: Results of the MLRs Run on the Mount Washington, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + VWS600500	0.246
5HP	FP ≈ constant – Thickness – UWS600500 + VWSS600	0.754
4HP	MISSING	N/A
3HP	FP ≈ constant – SH200 + T200 – UWND + SH800 – SH850 + SMXR + SMXS + VC200 + LI + VWND	1.000
2HP	FP ≈ constant + LCL – UWS600500 – GH300 – VWND + T300 – SMXR + T600 + WD500 + SH200 + LI + CAPE – GH200 – VC200 – UC200	1.000
1HP	MISSING	N/A
Initiation	FP ≈ constant + UWSS600 + CAPE – UC200 – SH600 – SRH – WD600 + VC200 – VC500 + VWSS600 – GH500	1.000

Table 4.10.4: Results of the PCAs Run on the Mount Washington, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with λ > 1	Accounted for Variance
6HP	STHC, SMXR, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	6	95.060%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH200, UC600, UC500, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T300, T200	9	94.547%
4HP	STHC, SMXR, SMXS, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	94.694%
3HP	STHC, SMXR, UWND, VWND, LCL, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	94.909%
2HP	STHC, SMXR, SMXS, UWND, LCL, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	94.179%
1HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.170%
Initiation	STHC, SMXR, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.947%

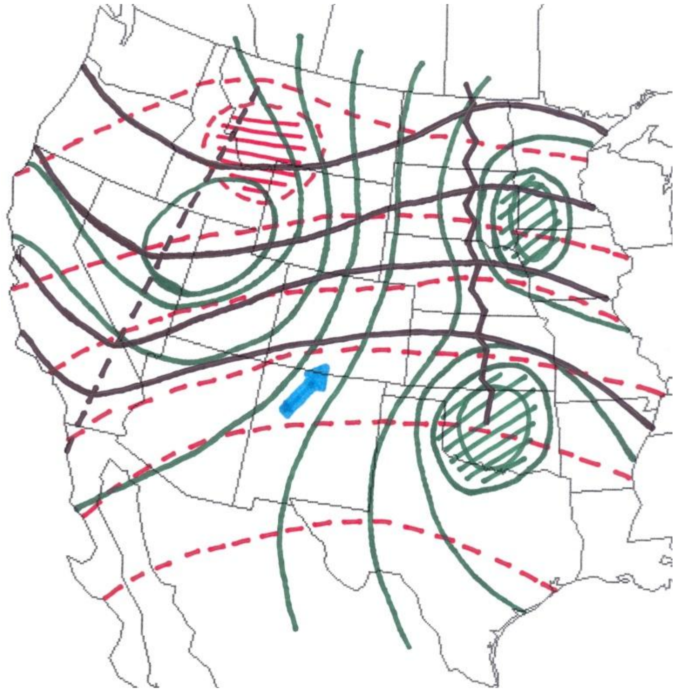


Figure 4.10.2: Composite Map for Mount Washington, NM. The variables included on the map are T300, GH300, SMXR, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.11: Wrye Peak, NM

4.11.1: Description of Cluster

The Wrye Peak, NM cluster contained 36 members and is located due north of the White Sands Missile Range in NM. The median values for the surface variables in Table 4.11.1 show that the air is relatively warm at 34.015˚C (approximately 93˚F) and moist, and the winds are from the north. It can be assumed that the potential temperature at the initiation location is relatively warm. The median values of SMXR and SMXS show that the air is moist with a relative humidity of approximately 66 percent. The UWND and VWND median values provide a median wind direction of north which differs from previous model runs. The median values listed for the upper air variables in Table 4.11.1 show a below ridgetop height LCL and a negative LI indicating unstable conditions.

The median values from the NARR data are given in Table 4.11.2 and show how the variables change throughout the model runs. Thickness dropped significantly from 6HP to 3HA. The geopotential height variables did not vary significantly throughout the model runs. The PW median values were higher than previous clusters. The median values for the PW are closer to values seen in previous studies (McAnelly and Cotton 1986) – the high water content is very important. CAPE varies significantly throughout the model runs and reaches its highest value at the hour of initiation. CAPE achieved its lowest median value at 2HA. CIN also varies significantly throughout the model runs with least negative value at 6HP. SRH varies but is not considered significant. The specific humidity variables show that the air is relatively moist throughout for all the levels. The wind and wind shear variables vary but the contribution from these variables are considered hour dependent. The temperature variables do not fluctuate significantly throughout the model runs.

Histograms for the Wrye Peak, NM cluster, Figure 4.11.1, were created for the start year, start month, start hour, and Julian Day. Most MCSs initiated in 2006, followed by 2001. No MCSs initiated in the year 2003 within the cluster domain and mean year for this cluster was 2002. The start-month histogram shows the majority of the MCSs initiated in August, followed by July. The start-hour histogram proves that an MCS could be initiated throughout the day but most of the systems initiated in the early evening. The Julian-Day histogram shows that the majority of the MCSs initiated in late July/early August.

4.11.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Wrye Peak, NM cluster. Included in Table 4.11.3 are the resulting equations and the R square values. The results discussed below for the Wrye Peak, NM cluster come from a combination of Table 4.11.1, Table

4.11.2, and Table 4.11.3.

The 6HP model run provided a perfect fit to the data with only four variables used in the equation. Warmer columns of air between the surface and 500 mb, weaker south-north winds at 300 mb, larger values of CAPE, and smaller surface mixing ratios are needed for larger FPs within this cluster's domain. This equation will be used for the identification of variables needed to accurately predict the FP at 6HP within the Wrye Peak, NM domain. There were multicollinearity issues present in this equation.

The 5HP model run was also a perfect fit to the data. A moist pocket of air at 300 mb, stronger south-north winds at 600 mb, weaker south-north winds at 200 mb, stronger U component wind shears between 600 and 500 mb, positive U component winds at the surface, and stronger west-east winds at 300 mb are needed for larger FPs within the cluster domain. Warmer columns of air between the surface and 500 mb, weaker V component wind shears between the surface and 600 mb, stronger south-north winds at 300 mb, a moist pocket of air at 600 mb, warmer surface potential temperatures, smaller values of CAPE, LCLs higher off the ground, colder columns of air between the surface and 600 mb, and colder temperatures at 500 mb are also needed for larger FPs within the cluster domain. Since this equation provides a perfect fit to the data, it will be used for identifying the variables needed for the prediction of the eventual FP 5HP to the first appearance of precipitation. There were multicollinearity issues present in this equation but is expected due to the inclusion of wind and wind shear variables.

The 4HP model run was a very poor fit to the data at 0.178 and will not be discussed in detail, but is still included in Table 4.11.3 for reference. There were no multicollinearity issues present.

The 3HP model run was another perfect fit to the data. Warmer columns of air between the surface and 300 mb, weaker south-north winds at 300 mb, stronger U component wind shears between the surface and 600 mb, and a dry pocket of air at 800 mb are needed for larger FPs according to this equation. This equation can be used for identifying the variables needed for accurate prediction of the eventual FP within the cluster domain since a perfect fit was provided. There were multicollinearity issues present in this equation.

The 2HP model run was a near perfect fit to the data at 0.992, but this was a lower R square value than the previous model runs. Larger values of CAPE, stronger U component wind shears between 600 and 500 mb, weaker west-east winds at 500 mb, weaker V component wind shears between the surface and 600 mb, stronger V component wind shears between the surface and 500 mb, and weaker south-north winds at 200 mb are needed for larger FPs within this domain. A dry pocket of air at 600 mb, less negative values of CIN, and smaller surface saturation mixing ratios are also needed for initiation in two hours within this cluster's domain. This combination of variables can be used to estimate the FP with some error due to the near perfect fit. There were multicollinearity issues present in this equation but that is expected with the inclusion of multiple wind and wind shear variables.

The 1HP model run was a relatively poor fit to the data and only included four variables in the equation. Weaker west-east winds at 300 mb, stronger west-east winds at 200 mb, stronger U component wind shears between 600 and 500 mb, and weaker U component wind shears between the surface and 500 mb are needed for larger FPs. The combination of these variables provides a relatively poor fit to the data at 0.697, so this equation cannot accurately predict the FP without error. There were no multicollinearity issues present in this equation.

The model run done at initiation was a perfect fit to the data. Weaker south-north winds at 600 mb, smaller values of CAPE, warmer columns of air between the surface and 300 mb, and weaker north-south winds at 500 mb are needed for larger FPs within the cluster domain. Since this equation gives a perfect fit, it can be used for the identification of the variables needed for the accurate prediction of the eventual FP of the system initiating in this hour. There were multicollinearity issues present in this equation.

Throughout the model runs there were several variables that were never used: VWND, Thickness, PW, SRH, GH200, SH850, SH500, SH200, UC600, WD600, WD500, VWS600500, T600, T300, and T200. These variables are considered the least important to FP according to this cluster's MLRs. The variable used most often in the model runs was CAPE at five out of ten model runs. The combination of variables is more important to larger FPs than any individual variable within this cluster.

4.11.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.11.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run all contain similar variables loaded highly into the first components. In the first component, the variables that were loaded the highest were STHC (6HP, 3HP, initiation), SMXS (6HP, 3HP, initiation), Thickness (6HP, 3HP, initiation), PW, geopotential height (6HP, 3HP, initiation), specific humidity (6HP, 5HP, 4HP, 3HP, 1HP, initiation), U component wind (3HP, 2HP, initiation), and temperature (6HP, 5HP, 3HP, 2HP, 1HP, initiation) variables. Since most of these variables were loaded in positively and are always positive, higher values will provide the greatest contribution. U component wind (3HP, 2HP) variables were loaded in negatively. The contribution from the temperature variables will depend on the value of the variable. The variables loaded highly into the second component were VWND (3HP), LI (6HP, initiation), SRH (2HP), Thickness (4HP, 1HP), V component wind (5HP, 2HP), V component wind shear (5HP), and T600 (4HP, 1HP) variables. LI was loaded positively into the equation, so less negative values will provide the best contribution to MCSMI. SRH was loaded negatively into the component. The contribution from the wind and wind shear variables will depend on the value of the variable. The variables loaded the highest and most frequently are the variables to observe when watching for initiation within the cluster domain.

Since four of the model runs had all of the variables included on the most used list, each variable was included as least that many times. The variable that was included the least was LI at four out of ten times. There were several variables that were included in every model run: SMXS, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC500, UC200, UWSS500, UWSS600, VC600, VC500, VWSS500, VWSS600, and T300. They are considered the most important variables for MCSMI within the Wrye Peak, NM domain and correspond to the ones that were highly loaded into several of the model runs. With the combination of those two lists, the most important variables become apparent and need to be identified for the potential to forecast for MCSMI.

4.11.4: Cluster Discussion

While there were several perfect fits to the data in the MLR, there were also several poor fits. There were multicollinearity issues in seven out of ten model runs. These conditions make the MLR less than ideal to determine the eventual FP for this cluster. With the PCAs, there were four model runs that had all of the variance accounted for, therefore, those model runs were very good fits to the data and the remaining ones had over 90 percent accounted for variance. The PCAs are much better at indicating the possibility for MCS formation than the MLRs and would be valuable to use in identifying the variables needed for MCSMI within the Wrye Peak, NM cluster domain.

The Wrye Peak, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the south-southwest. The median wind direction at 500 mb and initiation gives winds from the southwest. This indicates that the winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for Wrye Peak, NM is Figure 4.11.2. The most important temperature variable was T300. There is a pocket of low temperatures located northwest of the cluster domain and relatively warm temperatures located at the cluster domain. The most important geopotential height variable was GH300. There is a ridge located east of the cluster domain. As the ridge moves out of the region, the heights will continue to decrease. The most important moisture variable was SMXR. There is a moist pocket of air located east of the cluster domain and a dry pocket of air located in almost the same location as the low 300 mb temperatures. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 4.486 ms^{-1} at 163.019°.

4.11.5: Cluster Figures and Tables

Table 4.11.1: Median Values for the Upper Air and Surface Variables for the Wrye Peak, NM Cluster.

Variable	Median Value
STHC	34.015
SMXR	13.270
SMXS	20.165
UWND	0.000
VWND	-1.205
LCL	688.730
LI	-1.010

Table 4.11.2: Median Values for the NARR Variables for the Wrye Peak, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5846.500	5839.900	5843.700	5842.100	5836.550
PW	26.800	27.650	27.500	26.000	29.050
CAPE	230.300	229.200	173.400	340.600	363.900
CIN	-7.500	-25.550	-21.100	-16.800	-20.350
SRH	35.500	35.100	22.200	20.800	40.950
GH600	4474.900	4457.700	4464.700	4472.800	4455.300
GH500	5928.000	5906.700	5915.000	5883.400	5902.550
GH300	9753.900	9728.650	9730.800	9746.300	9728.000
GH200	12492.800	12477.200	12488.000	12491.500	12486.650
SH850	9.700e-3	9.800e-3	9.600e-3	9.400e-3	1.075e-2
SH800	8.800e-3	9.050e-3	8.900e-3	8.600e-3	9.950e-3
SH600	5.000e-3	5.200e-3	5.000e-3	5.000e-3	5.600e-3
SH500	2.900e-3	3.250e-3	3.300e-3	3.000e-3	3.100e-3
SH300	5.000e-4	4.700e-4	5.300e-4	4.900e-4	4.650e-4
SH200	5.600e-5	6.100e-5	6.200e-5	5.100e-5	5.950e-5
UC600	1.100	2.350	1.500	0.264	2.850
UC500	0.675	3.300	2.400	0.323	2.500
UC300	-0.974	7.550	2.100	-1.100	6.550
UC200	0.962	9.400	7.800	1.900	7.850
UWSS500	2.148	3.041	2.880	0.520	3.185
UWS600500	0.726	0.800	0.989	1.100	0.309
UWSS600	2.009	2.445	1.320	1.492	1.935
WD600	197.464	242.768	214.452	187.520	219.263
WD500	193.103	218.636	231.340	182.055	225.980
VC600	2.100	2.300	2.000	2.000	1.700
VC500	2.400	2.500	2.000	1.700	2.000
VC300	3.100	6.300	5.000	2.600	7.250
VC200	7.100	8.100	7.000	7.100	7.450
VWSS500	3.190	4.705	3.450	2.690	3.050
VWS600500	0.300	0.500	0.000	-1.200	-0.500
VWSS600	4.550	3.675	4.280	3.850	2.391
T600	1.700	2.300	2.000	2.000	2.000
T500	-6.700	-5.900	-6.300	-7.100	-6.300
T300	-31.300	-30.850	-30.600	-31.200	-30.700
T200	-53.700	-52.500	-52.700	-53.300	-52.450
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5834.300	5826.160	5826.800	5815.700	5808.000
PW	28.400	25.900	28.650	29.600	27.400
CAPE	67.300	468.000	294.650	36.100	452.800
CIN	-26.300	-20.700	-23.200	-27.500	-26.500

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	29.300	29.800	38.600	38.400	8.600
GH600	4459.700	4463.500	4451.300	4451.400	4476.600
GH500	5913.300	5914.400	5903.200	5904.600	5925.500
GH300	9734.200	9736.800	9728.150	9734.000	9741.700
GH200	12485.100	12481.100	12484.800	12483.000	12480.500
SH850	9.800e-3	9.700e-3	1.095e-2	1.020e-2	9.700e-3
SH800	9.000e-3	8.800e-3	9.800e-3	9.600e-3	8.800e-3
SH600	5.300e-3	4.700e-3	5.200e-3	5.600e-3	4.800e-3
SH500	3.400e-3	2.800e-3	3.000e-3	3.100e-3	3.400e-3
SH300	5.100e-4	4.200e-4	4.650e-4	5.100e-4	4.400e-4
SH200	6.400e-5	5.300e-5	5.950e-5	5.900e-5	6.000e-5
UC600	1.300	0.446	2.750	2.000	-0.363
UC500	1.400	-0.908	2.300	2.400	-0.690
UC300	2.400	-0.334	4.550	5.300	-0.179
UC200	4.900	2.500	6.800	6.500	1.200
UWSS500	0.870	-1.310	2.156	3.287	0.560
UWS600500	0.331	-1.800	-0.250	0.208	-1.565
UWSS600	0.287	1.769	1.755	2.900	1.612
WD600	209.932	201.448	231.133	212.768	174.242
WD500	198.034	236.004	233.519	222.109	170.729
VC600	2.500	0.747	1.722	1.600	2.800
VC500	2.500	-0.482	0.247	2.700	3.000
VC300	6.000	2.300	5.650	5.900	3.200
VC200	5.500	5.900	7.100	5.700	5.200
VWSS500	3.110	4.290	2.229	4.100	4.950
VWS600500	-0.400	-1.229	-6.500e-2	-0.200	-0.200
VWSS600	3.810	2.710	3.025	2.300	4.192
T600	2.200	1.800	2.250	2.200	1.600
T500	-6.400	-7.300	-6.550	-5.900	-6.500
T300	-30.800	-31.300	-30.650	-30.700	-31.800
T200	-52.900	-53.300	-52.350	-53.000	-53.900

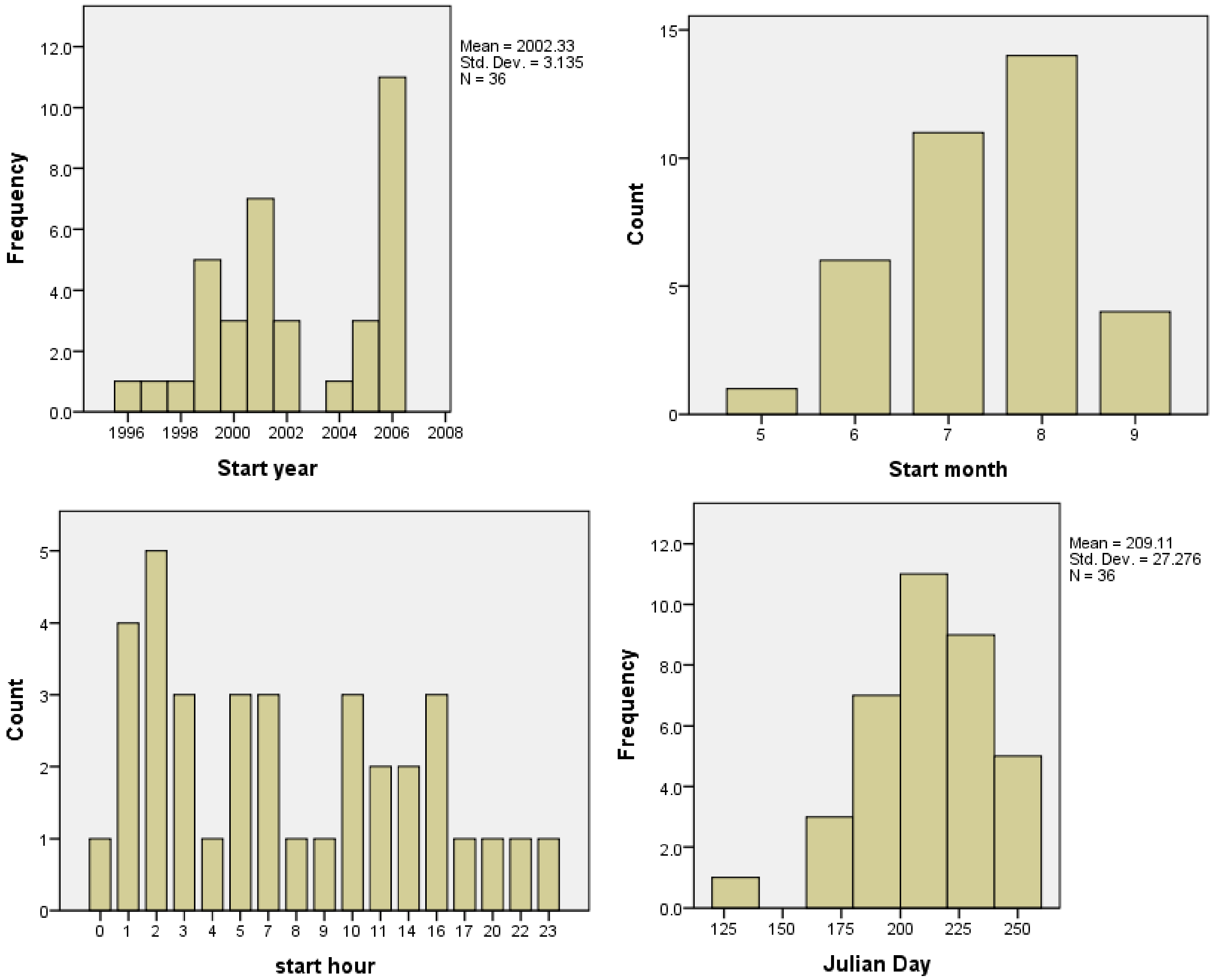


Figure 4.11.1: Time Histograms for the Wrye Peak, NM Cluster. Frequency was used on the y-axis when the data used in the histograms had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.11.3: Results of the MLRs Run on the Wrye Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + GH500 – VC300 + CAPE – SMXR	1.000
5HP	FP ≈ constant + SH300 + VC600 – VC200 + UWS600500 + UWND + UC300 + GH500 – VWSS600 + VC300 + SH600 + STHC – CAPE – LCL – GH600 – T500	1.000
4HP	FP ≈ constant – CIN	0.178
3HP	FP ≈ constant + GH300 – VC300 + UWSS600 – SH800	1.000
2HP	FP ≈ constant + CAPE + UWS600500 – UC500 – VWSS600 + VWSS500 – VC200 – SH600 + CIN – SMXS	0.992
1HP	FP ≈ constant – UC300 + UC200 + UWS600500 – UWSS500	0.697
Initiation	FP ≈ constant – VC600 – CAPE + GH300 + VC500	1.000

Table 4.11.4: Results of the PCAs Run on the Wrye Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	4	100.000%
5HP	STHC, SMXS, VWND, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, VC600, VC500, VC200, VWSS500, VWSS600, T600, T300	8	92.265%
4HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	95.908%
3HP	All variables	4	100.000%
2HP	STHC, SMXR, SMXS, UWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	94.469%
1HP	SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC200, VWSS500, VWSS600, T600, T500, T300	9	94.118%
Initiation	All variables	4	100.000%

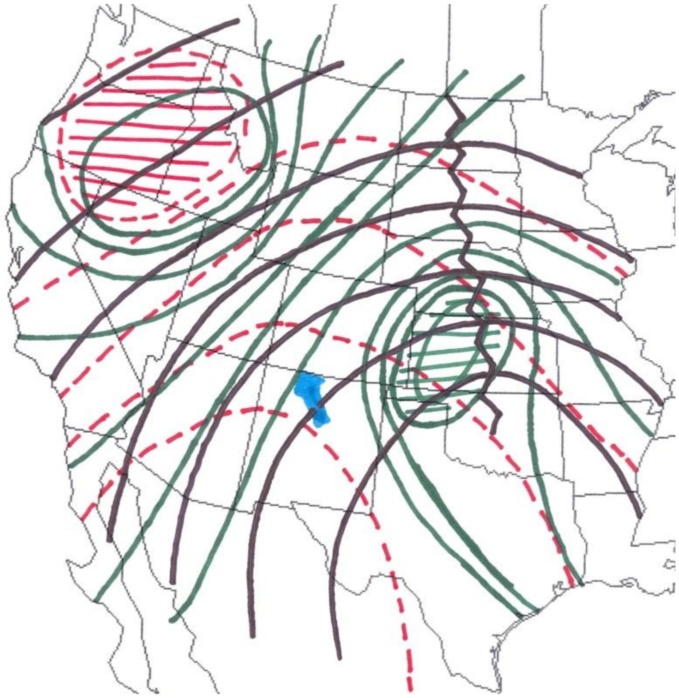


Figure 4.11.2: Composite Map for Wrye Peak, NM. The variables included on the map are T300, GH300, SMXR, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.12: Mesa de los Jumanos, NM

4.12.1: Description of Cluster

The Mesa de los Jumanos, NM cluster contained 34 members and is located west of Trinchera Mesa and northwest of Corona, NM in central NM. The median values given for the surface variables in Table 4.12.2 show that the air is hot at 40.150˚C (approximately 104˚F) and relatively moist, and the median wind direction is from the southeast (from BS87). The hot potential temperature at the closest reporting station means that the air is still relatively hot at the initiation location. The median values of SMXR and SMXS provide a relative humidity of approximately 51 percent, which is considered relatively moist. The UWND and VWND median values give a wind direction of southeast which is different from the calculated upper air values. The median values for the upper air variables show the LCL as slightly higher in the atmosphere than several of the previous clusters and the LI indicates that the air is slightly unstable.

The median values from the NARR data are given in Table 4.12.2 and show how the values of the variables change throughout the model runs. While the Thickness and geopotential height variables vary throughout the model runs, a comparison between the 6HP and 3HA model run shows that the variables do not change significantly. PW does not change significantly throughout the model runs but the median values are higher than a majority of the other clusters. CAPE varies significantly throughout the model runs with a maximum at 5HP and a minimum at 3HA. CIN varies but it is considered insignificant. SRH varies but it is considered hour dependent. The specific humidity variables show that the values are relatively moist for each level throughout the runs. The wind and wind shear variables vary throughout and the values are considered hour dependent. The temperature values do not vary and are relatively cold for each level.

Histograms for the Mesa de los Jumanos, NM cluster, Figure 4.12.1, were created for the start year, start month, start hour, and Julian Day. The start-year histogram shows the years 1997, 2000, and 2004 as when the most MCSs occurred. The mean year for MCSs forming within this cluster's domain was 1999 which shows a majority initiated early in the time frame. The start-month histogram shows that no MCSs initiated in May and June. July and August initiated an almost equal number of MCSs. The start-hour histogram shows that MCSs initiated throughout the day within the cluster domain but most of the MCSs originated in the late afternoon/early evening (consistent with FF01). The Julian-Day histogram shows most of the MCSs occurred June, July, and August.

4.12.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Mesa de los Jumanos, NM cluster. The resulting equations and the R square values are included in Table 4.12.3. The results discussed below for the Mesa de los Jumanos, NM cluster are from a combination of Table 4.12.1, Table 4.12.2, and Table 4.12.3.

The 6HP model run was an average fit to the data at 0.713 and was achieved using only three variables. Less negative U component wind shears between 600 and 500 mb, cooler surface potential temperatures, and weaker west-east winds at 600 mb are needed for larger FPs within the cluster domain according to this equation. The combination of these variables provided an acceptable fit to the data. This equation can be used for identifying the variables needed to anticipate the eventual FP but there is some error. There were no multicollinearity issues present.

The 5HP model run was a perfect fit to the data, one of several in this cluster. Larger surface saturation mixing ratios, a dry pocket of air at 800 mb, weaker west-east winds at 500 mb, more negative V component wind shears between 600 and 500 mb, stronger south-north winds at the surface, weaker west-east winds at 200 mb, more negative LI values, a dry pocket of air at 200 mb, and northeast winds at 600 mb are needed for larger FPs according to this equation. The perfect fit to the data means that the FP of the system that will initiate in five hours can be accurately determined. There were multicollinearity issues present.

The 4HP model run was also a perfect fit to the data. More negative values of CIN, stronger V component wind shears between 600 and 500 mb, stronger U component wind shears between the surface and 600 mb, larger values of CAPE, larger surface mixing ratios, less negative LI values, a dry pocket of air at 300 mb, northwest winds at 500 mb, and stronger east-west winds at the surface are needed for larger FPs within the cluster domain. Since the equation is a perfect fit to the data, it will be used for the identification of variables needed to accurately predict the FP of the system. There were multicollinearity issues present.

The 3HP model run was another perfect fit to the data. Stronger U component wind shears between 600 and 500 mb, weaker north-south winds at 500 mb, warmer columns of air between the surface and 600 mb, colder columns of air between the surface and 500 mb, LCLs closer to the ground, and more negative V component wind shears between the surface and 500 mb are needed for larger FPs within this cluster's domain. Stronger west-east winds at 500 mb, larger surface saturation mixing ratios, colder temperatures at 200 mb, stronger north-south winds at 300 mb, larger PW values, and colder columns of air between the surface and 300 mb are also needed for larger FPs within the cluster domain. The equation is able to be used for identifying the variables needed for the eventual FP of the system that will form in three hours within the cluster domain. There were multicollinearity issues present in this equation.

The 2HP model run was another perfect fit to the data. Larger surface saturation mixing ratios, a dry pocket of air at 850 mb, LCLs higher off the ground, weaker west-east winds at 500 mb, warmer temperatures at 500 mb, and stronger south-north winds at 600 mb are needed for larger FPs. More negative values of CIN, stronger U component wind shears between the surface and 600 mb, weaker south-north winds at 300 mb, and stronger west-east winds at 300 mb are also needed for larger FPs from the initiation in two hours according to this equation. This perfect fit to the data can be used for the identification of variables needed for the FP. There were multicollinearity issues present in this equation.

The 1HP model run was another perfect fit to the data. Weaker south-north winds at 500 mb, stronger west-east winds at 500 mb, warmer surface potential temperatures, a dry pocket of air at 500 mb, and warmer temperatures at 200 mb are needed for larger FPs according to this equation. Weaker west-east winds at 200 mb, colder temperatures at 300 mb, and warmer temperatures at 500 and 600 mb are also needed for larger FPs within the cluster domain. This equation can be used for identifying the variables needed for FP prediction since it is a perfect fit. There were multicollinearity issues present in this equation.

The model run done at initiation was the last perfect fit to the data in this cluster. Less negative U component wind shears between 600 and 500 mb, more negative values of CIN, less negative V component wind shears between the surface and 500 mb, more negative LI values, northeast winds at 500 mb, and smaller surface saturation mixing ratios contribute the most to larger FPs within the cluster domain. Warmer temperatures at 600 mb, warmer columns of air between the surface and 600 mb, stronger U component wind shears between the surface and 600 mb, less negative V component wind shears between the surface and 600 mb, weaker south-north winds at the surface, and warmer columns of air between the surface and 500 mb will also contribute the most to larger FPs within the cluster domain. This equation is able to be used identifying the variables needed to accurately predict the FP of the system which is forming within the cluster domain due to the perfect fit. There were multicollinearity issues present.

Throughout the model runs there were a few variables that were never included in the model runs: Thickness, SRH, GH200, SH600, and VC200. This list contains significantly fewer variables than in previous clusters and these are considered the least important to larger FPs within the Mesa de los Jumanos, NM domain. The variable included the most often in the MLRs was SMXS at five out of ten model runs which is still considered important to larger FPs but the combination of variables is more important than that one variable alone. The variables required for initiation are considered hour dependent. The upper level temperature variables were prominent in this cluster as well.

4.12.3: Principal Component Analysis

PCAs were run on each of the 6HP to 3HA for the Mesa de los Jumanos, NM cluster. The variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one and percent variance accounted for with those eigenvalues are all included in Table 4.12.4. The PCAs should be a better fit since they include more variables than the MLRs.

The 6HP model run through the initiation model run are similar in that the same variables are consistently loaded highly into the first components. In the first component, the variables that were loaded in the highest were Thickness (5HP, 4HP, 2HP, 1HP), PW (6HP, 5HP, 4HP, 3HP, 2HP, 1HP), SRH (4HP, 1HP), geopotential height, specific humidity, U component wind (4HP, 1HP), and temperature variables which were all loaded in positively with the exception of SRH and U component wind variables. This means that the larger the value of each positively valued variable, the greater the contribution to the component and to the overall PCA, with the exception of the temperature variables. Wind and wind shear variable contributions will depend on the value of the variable and the loading. The variables loaded the highest into the second component were SMXR (2HP), Thickness (initiation), U component wind (3HP), U component wind shear (5HP, 3HP), V component wind (4HP), V component wind shear (2HP, 1HP), WD600 (3HP), and WD500 (6HP, 3HP) which were loaded in positively with the exception of Thickness and V component wind shear (2HP) variables. The value of the variable will determine the amount of contribution to the PCA. Similarities between the model runs are already apparent and will become more visible as initiation nears. The variables that are highly loaded are considered some of the most important variables to MCSMI within the cluster domain.

All variables were included in a majority of the most used lists. The variable that was included the least was LCL at six out of ten. A majority of the variables were included in every model runs' most used list: STHC, Thickness, PW, CIN, GH500, GH300, GH200, SH850,

SH800, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, VC500, VC300, VWSS500, VWSS600, T600, T300, and T200. These, in combination with the variables that were loaded the highest into the components, are considered the most important variables to the MCSMI. Since the variable that was least included was included six times out of ten, all of the variables used are considered sufficient for MCSMI within the Mesa de los Jumanos, NM cluster domain.

4.12.4: Cluster Discussion

Even though six out of ten MLRs had perfect fits to the data, those model runs also had multicollinearity issues. Two of the MLRs were relatively poor fits to the data and would not be used for the identification of needed variables. The PCAs corrected the fit issues and all had over 93 percent accounted for variance. The PCAs were much better fits to the data and would be used for the identification of needed variables for accurate formation than the MLRs; therefore, to potentially forecast for MCSMI within this cluster's domain, the PCAs need to be utilized.

The Mesa de los Jumanos, NM cluster is in a portion of the Rocky Mountains that contains no ridgeline since this cluster is on a mesa. The median wind direction at 600 and 500 mb and initiation give winds from the west which indicates that westerly winds are needed for initiation along this mesa.

The composite map for Mesa de los Jumanos, NM is Figure 4.12.2. The most important temperature variable was T200. There is a pocket of lower temperatures at 200 mb due north of the cluster domain. The pattern would bring in relatively cooler air at 200 mb as it moves eastward and the temperatures at initiation are already relatively cool overall. The most important geopotential height variable was GH500. The flow is zonal and the same heights will continue within the cluster domain for a while. The most important moisture variable was

SH300. There is a pocket of relatively moist air over the cluster domain. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 5.278 ms^{-1} at 279.928˚.

4.12.5: Cluster Figures and Tables

Table 4.12.1: Median Values for the Upper Air and Surface Variables for the Mesa de los Jumanos, NM Cluster.

Variable	Median Value
STHC	40.150
SMXR	10.080
SMXS	19.600
UWND	-1.415
VWND	1.980
LCL	628.805
LI	-0.515

Table 4.12.2: Median Values for the NARR Variables for the Mesa de los Jumanos, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5842.500	5844.700	5838.850	5865.200	5847.700
PW	21.100	19.400	23.000	21.500	20.700
CAPE	343.900	452.100	238.400	243.600	306.100
CIN	-29.800	-16.300	-16.100	-22.500	-19.600
SRH	29.700	32.500	24.550	53.500	35.800
GH600	4462.900	4455.200	4462.550	4474.000	4461.000
GH500	5909.200	5896.300	5915.200	5919.100	5898.700
GH300	9724.400	9676.200	9727.550	9733.000	9652.400
GH200	12462.300	12410.100	12464.200	12466.000	12379.800
SH850	1.110e-2	8.900e-3	9.700e-3	9.100e-3	9.200e-3
SH800	9.400e-3	7.700e-3	8.350e-3	7.900e-3	7.900e-3
SH600	4.400e-3	4.300e-3	4.550e-3	5.200e-3	4.800e-3
SH500	2.400e-3	2.500e-3	2.600e-3	2.600e-3	2.700e-3
SH300	2.200e-4	3.100e-4	4.450e-4	3.500e-4	3.500e-4
SH200	5.100e-5	4.000e-5	5.650e-5	5.100e-5	3.900e-5
UC600	1.800	1.900	1.277	2.800	0.485
UC500	2.100	2.100	1.950	3.100	2.500
UC300	3.200	3.200	6.500	3.800	3.900
UC200	3.000	8.100	8.300	3.500	9.100
UWSS500	3.700	1.560	2.644	4.490	1.660
UWS600500	-0.200	0.599	0.873	0.300	0.910
UWSS600	4.000	0.160	3.520	4.860	1.192
WD600	264.277	205.514	231.802	262.306	188.162
WD500	246.194	236.310	237.097	285.945	243.435
VC600	-7.640e-2	0.871	0.350	-8.300e-2	0.697
VC500	-1.200	-2.300	1.032	-2.900	-3.400
VC300	-0.813	4.400	3.300	-0.517	1.600
VC200	9.340e-2	2.600	1.750	0.795	-1.600
VWSS500	-1.716	-6.690	3.106	-3.370	-6.270
VWS600500	-1.300	-1.600	0.682	-3.300	-2.000
VWSS600	-2.840	2.000e-2	3.087	-1.180	-0.770
T600	2.200	2.100	1.600	2.600	1.600
T500	-7.200	-9.000	-7.050	-7.300	-8.200
T300	-31.500	-32.800	-32.100	-31.700	-33.700
T200	-53.400	-53.300	-52.700	-53.100	-53.400
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5839.000	5852.500	5831.200	5831.800	5838.500
PW	22.500	23.300	19.800	21.550	22.100
CAPE	130.450	361.100	174.400	190.550	114.000
CIN	-15.500	-31.200	-25.600	-19.000	-32.100

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	44.950	41.100	69.200	45.050	74.200
GH600	4462.200	4473.900	4462.500	4461.150	4469.000
GH500	5909.250	5921.900	5906.700	5914.650	5920.900
GH300	9729.050	9724.900	9692.600	9720.950	9734.100
GH200	12469.700	12467.300	12413.800	12458.250	12467.600
SH850	9.300e-3	9.400e-3	9.300e-3	9.400e-3	1.000e-2
SH800	8.100e-3	8.100e-3	8.000e-3	8.250e-3	8.700e-3
SH600	4.450e-3	5.300e-3	5.000e-3	4.550e-3	5.000e-3
SH500	2.950e-3	2.800e-3	2.800e-3	2.850e-3	3.100e-3
SH300	4.250e-4	4.000e-4	3.800e-4	4.900e-4	5.200e-4
SH200	4.750e-5	5.200e-5	4.000e-5	5.500e-5	5.200e-5
UC600	1.200	3.300	2.500	2.150	3.900
UC500	2.800	3.900	3.300	3.600	2.300
UC300	6.350	5.300	3.200	8.300	4.000
UC200	10.400	4.500	6.200	13.050	5.900
UWSS500	3.645	5.190	2.096	5.817	3.950
UWS600500	1.450	-1.700	-0.295	1.867	-2.200
UWSS600	3.615	5.199	4.080	5.115	4.700
WD600	238.097	262.424	243.604	274.199	280.713
WD500	246.954	267.904	275.621	272.654	227.847
VC600	1.071	0.700	0.269	-1.485	-0.691
VC500	-1.142	-2.100	-4.300	-0.913	-2.300
VC300	5.350	0.113	3.900	4.900	-2.100
VC200	3.350	0.564	1.200	3.350	-0.199
VWSS500	0.290	-2.123	-5.256	0.2900	-2.744
VWS600500	-0.647	-1.213	-1.800	0.636	-0.500
VWSS600	2.108	-0.910	-2.690	-0.965	-1.267
T600	1.300	2.500	2.000	1.750	2.300
T500	-7.350	-6.800	-8.500	-7.150	-7.100
T300	-32.000	-31.600	-33.000	-32.200	-32.000
T200	-52.900	-53.200	-53.000	-52.300	-53.700

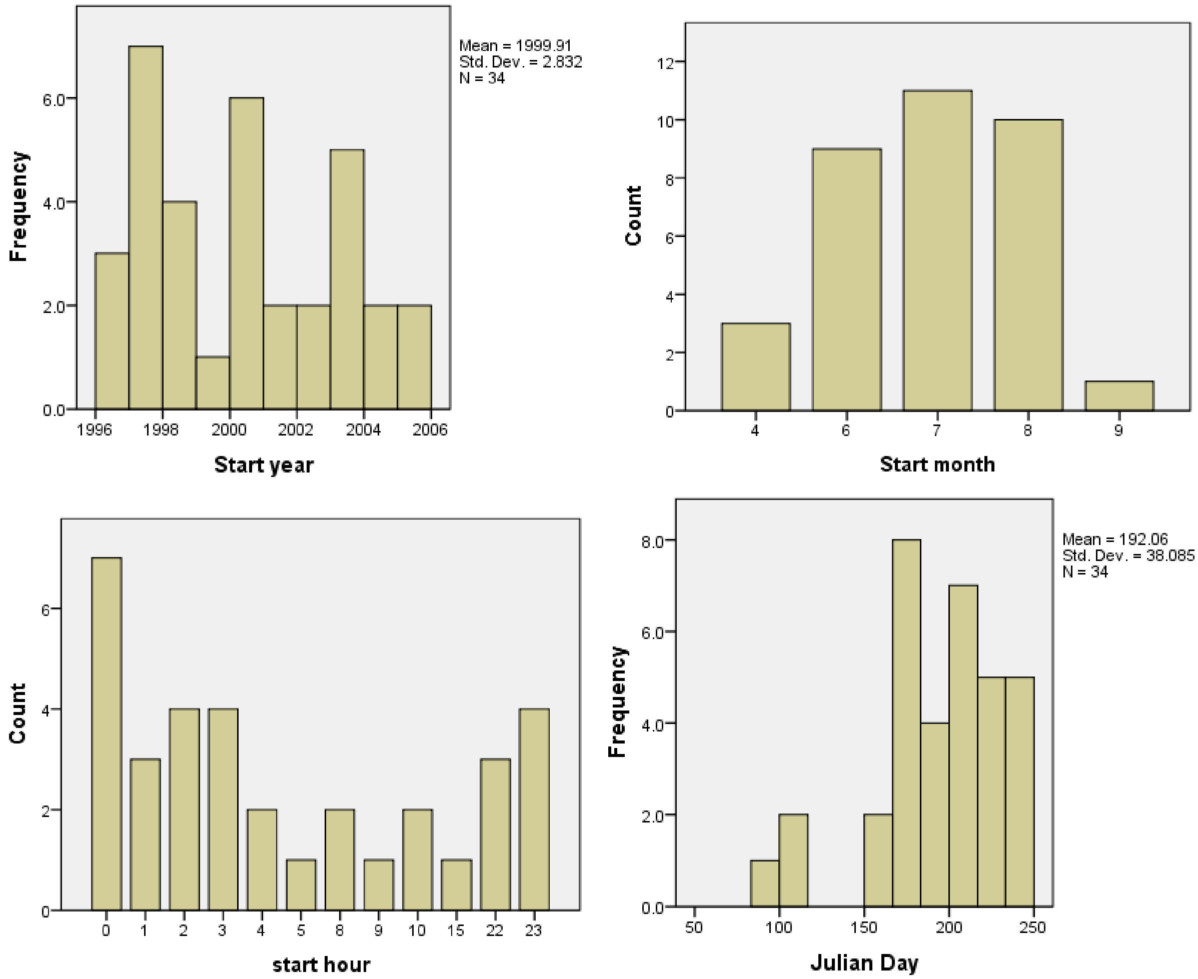


Figure 4.12.1: Time Histograms for the Mesa de los Jumanos, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.12.3: Results of the MLRs Run on the Mesa de los Jumanos, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + UWS600500 – STHC – UC600	0.713
5HP	FP ≈ constant + SMXS – SH800 – UC500 – VWS600500 + VWND – UC200 – LI – SH200 – WD600 + SH300	1.000
4HP	FP ≈ constant – CIN + VWS600500 + UWSS600 + CAPE + SMXR + LI – SH300 + WD500 – UWND	1.000
3HP	FP ≈ constant + UWS600500 + VC500 + GH600 – GH500 + LCL – VWSS500 + UC500 + SMXS – T200 – VC300 + PW – GH300	1.000
2HP	FP ≈ constant + SMXS – SH850 – LCL – UC500 + T500 + VC600 – CIN + UWSS600 – VC300 + UC300	1.000
1HP	FP ≈ constant + VC500 + UC500 + STHC – SH500 + T200 – UC200 – T300 + T500 + T600	1.000
Initiation	FP ≈ constant + UWS600500 – CIN + VWSS500 – LI – WD500 – SMXS – T600 + GH600 + UWSS600 + VWSS600 – VWND + GH500	1.000

Table 4.12.4: Results of the PCAs Run on the Mesa de los Jumanos, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T300, T200	10	97.338%
5HP	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	97.004%
4HP	STHC, SMXR, SMXS, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	96.006%
3HP	STHC, SMXR, UWND, VWND, LCL, Thickness, PW, CIN, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T300, T200	8	93.769%
2HP	STHC, SMXR, SMXS, UWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.478%
1HP	STHC, SMXR, SMXS, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300, T200	6	94.997%
Initiation	All variables	10	97.647%

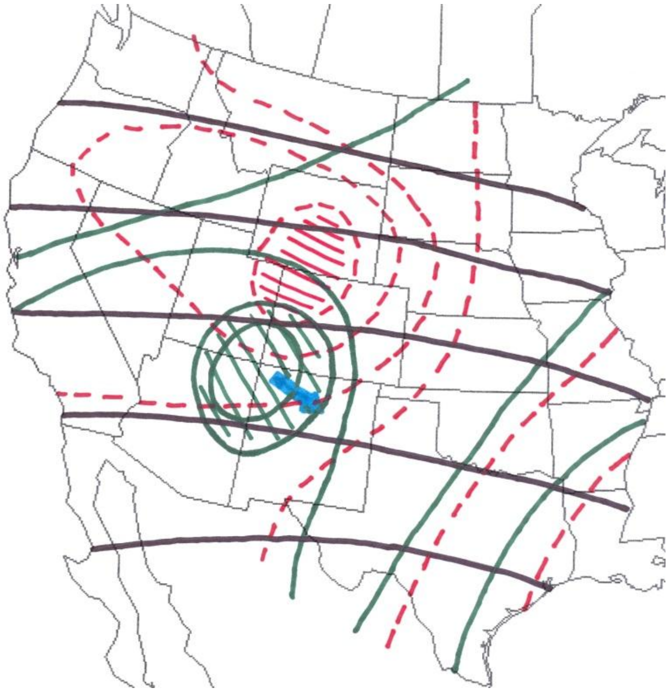


Figure 4.12.2: Composite Map for Mesa de los Jumanos, NM. The variables on the map are T200, GH500, SH300, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.13: Jacinto Mesa, NM

4.13.1: Description of Cluster

The Jacinto Mesa, NM cluster contained 32 members and is located north-northwest of Vaughn, NM and north-northeast of multiple salt lakes. The median values given for the surface variables in Table 4.13.1 show that the potential temperature is relatively hot at 38.265˚C (approximately 101˚F) and relatively dry (also from TZ99), and the median wind direction is from the south. The potential temperature is still considered relatively hot at the initiation location. The median values of SMXR and SMXS show that the air is relatively dry at approximately 47 percent relative humidity, drier than some of the previously discussed clusters. The median value of UWND and VWND show that the median wind direction is from the south. The median values given for the upper air variables in Table 4.13.1 show that the median LCL is around ridgetop height and LI has a slightly negative value indicating the air is slightly unstable.

The median values from the NARR data are given in Table 4.13.2 and show how the variables change throughout the model runs. Thickness varies significantly throughout the model runs in that it decreases in value from 6HP to 3HA. However, the geopotential height variables do not show much change in value from one model run to the next. PW does not vary significantly throughout the model runs. CAPE varies significantly throughout the models in which it reaches a maximum at 6HP and a minimum at 2HP. While CIN varies, it is not considered significant because it is not a large variation. The SRH varies but it is considered hour dependent. The specific humidity variables show that the air is drier than was seen in some of the previous clusters but could be considered relatively moist. The wind and wind shear variables vary throughout the model runs, but the variables are considered hour dependent. The temperature variables do not vary significantly throughout the model runs, but are considered relatively cold overall.

Histograms for the Jacinto Mesa, NM cluster, Figure 4.13.1, were created for the start year, start month, start hour, and the Julian Day. Most MCSs initiated in the year 1997, followed by 2002 and 2005 and the mean year was 2001. A large portion of the MCSs originated in August, and July and September supplied the same number of MCSs. The MCSs initiated in the early evening hours (consistent with JC07). A few MCSs originated later in the day, but most initiated between 0000 UTC and 0300 UTC. The Julian-Day histogram shows that most of the systems initiated in July, August, and September.

4.13.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Jacinto Mesa, NM cluster. The resulting equations and the R square values are included in Table 4.13.3. The more often a variable is included in the equations, the more important that variable is considered for larger FPs. The results discussed below for the Jacinto Mesa, NM cluster come from a combination of Table 4.13.1, Table 4.13.2, and Table 4.13.3.

The 6HP model run is one of five model runs in this cluster to have a perfect fit to the data. More negative values of CIN, more negative V component wind shears between 600 and 500 mb, weaker SRH values, smaller CAPE values, warmer temperatures at 200 mb, northeast winds at 600 mb, larger surface saturation mixing ratios, weaker south-north winds at the surface, a moist pocket of air at 850 mb, and more negative LI values are needed for larger FPs within this cluster's domain. This equation can be used in the identification of the variables needed to predict the FP at 6HP. There were multicollinearity issues present in this equation.

The 5HP model run was a perfect fit to the data. Less negative values of CIN, a dry pocket of air at 600 mb, northeast winds at 500 mb, smaller CAPE values, stronger south-north winds at 600 mb, and a moist pocket of air at 500 mb are needed for larger FPs within the domain according to this equation. With this equation, the FP of the system forming in five hours can be used for the identification of the variables needed for the potential for accurate prediction. There were multicollinearity issues present in this equation.

The 4HP model run was a near perfect fit to the data, at 0.957. Stronger U component wind shears between the surface and 600 mb, a moist pocket of air at 500 mb, weaker south-north winds at the surface, larger Thickness values, and colder columns of air between the surface and 500 mb (in direct contradiction to the Thickness) are needed for larger FPs within this cluster's domain. The equation can be used to estimate the FP of the eventual MCS with a small amount of associated error and there were no multicollinearity issues.

The 3HP model run was an acceptable fit to the data at 0.821. Weaker south-north winds at 500 mb, LCLs closer to the ground, larger Thickness values, and colder columns of air between the surface and 300 mb are needed, according to this equation, for larger FPs. This equation can be used for the identification of the variables needed for the FP but there is definitely some error associated with the calculated value. There were no multicollinearity issues present in this equation.

The 2HP model run was another perfect fit to the data. Less negative V component wind shears between the surface and 600 mb, warmer columns of air between the surface and 500 mb, stronger U component wind shears between 600 and 500 mb, positive U component winds at the surface, larger Thickness values, and more negative LI values are needed for larger FPs. The equation can be used for the identification of the variables needed to accurately predict the MCS FP that will form in two hours. There were multicollinearity issues present but that is expected with the inclusion of GH500 and Thickness.

The 1HP model run is another perfect fit to the data. Stronger west-east winds at 600 mb, a moist pocket of air at 600 mb, colder temperatures at 200 mb, smaller Thickness values, weaker V component wind shears between the surface and 500 mb, weaker SRH values, and a dry pocket of air at 300 mb are needed for larger FPs from the initiation in one hour according to this equation. This equation can be used for the identification of the variables needed to accurately predict the eventual FP of the MCS initiating in the next hour since it was a perfect fit. There were multicollinearity issues present in this equation.

The model run done at initiation will not be discussed in detail here since the R square value is below the 0.600 R square cutoff at 0.526. There were no multicollinearity issues present in this equation.

Throughout the model runs there were several variables that were never included in the model runs: STHC, PW, SH800, UC500, UC300, UC200, VC300, VC200, T600, T500, and T300. They are considered the least important to larger FPs within the Jacinto Mesa, NM cluster domain according to the MLRs. In these variables, the 300 mb level is the least important; three of the variables included in the above list are from this level. The variable used the most often in the MLRs was Thickness at four out of ten times. Since this is the case, there is not a particular variable that is the most important to larger FPs within this cluster's domain. The combination of variables is more important than a single variable. The set of variables used the most often were the surface and upper air variables, which is a change from some of the previous clusters.

4.13.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA for the Jacinto Mesa, NM cluster. The fit issues seen in the MLRs will be resolved in the PCAs. Included in Table 4.13.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run have similar variables included in the first components. In the first component, the variables that were loaded highest were the STHC (5HP, 2HP), Thickness (5HP, 4HP, 2HP, 1HP, initiation), PW (5HP, 2HP), geopotential height (6HP, 4HP, 3HP, 1HP, initiation), specific humidity (6HP, 2HP), U component wind (6HP, 3HP, 1HP, initiation), U component wind shear (1HP), V component wind (2HP), VWSS500 (5HP, 2HP), and lower level temperature (5HP, 4HP, 1HP, initiation) variables. STHC, Thickness (5HP), U component wind (6HP, 1HP, initiation), U component wind shear (1HP), and T600 (5HP, 2HP) variables were loaded in negatively. The remaining variables were loaded in positively. The higher the values for the geopotential height and specific humidity variables, the greater the contribution is to the PCA and MCSMI. The contribution from U component wind variables will depend on the value of the variable. Smaller values of STHC, Thickness, and T600 and larger values of PW will provide the greatest contribution. In the second component, the variables that were loaded the highest were UWND (2HP), VWND (5HP), SMXR (1HP), LCL (4HP, 1HP), SRH (5HP), PW (6HP, 3HP), specific humidity (6HP, 4HP, 3HP, initiation), WD600 (5HP), and U component wind shear (2HP) variables. VWND, SMXR, LCL, WD600, PW, specific humidity, and U component wind shear variables were loaded in positively. UWND and SRH were loaded in negatively. The variables' contribution will depend on the value of the variable. The variables that are loaded highly the most often are considered the most important to MCSMI within the Jacinto Mesa, NM cluster.

The variables that were included on the fewest most used lists were SRH, SH500, UC200, and WD500 at six out of ten times. There were several variables that were included in every most used list, including STHC, SMXR, UWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC300, VWSS500, VWSS600, T600, T500, and T300. The variables that were loaded highly into the components and were included in all the most used lists are considered the most important to MCSMI according to the PCAs. The most important variables are the ones that need to be observed in the hours prior to MCSMI within the Jacinto Mesa, NM cluster.

4.13.4: Cluster Discussion

With the MLRs, there were five model runs that were perfect fits to the data, but several had multicollinearity issues. Two of the MLRs were very poor fits to the data. With the PCAs, there were three model runs that had all of the variance accounted for and the remaining ones were still good fits and gave a very good indication of the variables needed for MCSMI within the cluster domain. Therefore, the better analysis for the Jacinto Mesa, NM cluster is the PCA. It will give a more accurate estimate of MCSMI and should be used for the identification of variables needed for potential to forecast within the cluster domain.

The Jacinto Mesa, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 and 500 mb and initiation give winds from the west-southwest which indicates that the winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for Jacinto Mesa, NM is Figure 4.13.2. The most important temperature variable was T200. There is a pocket of lower temperatures to the northwest of the cluster domain. The cluster domain sits in relatively warmer temperatures when compared to the pocket of cooler air. The most important geopotential height variable was GH500. The flow is mainly zonal at 500 mb with the exception of a small trough to the northeast of the cluster domain. The most important moisture variable was SMXR. There is a pocket of moist air to the southeast and a pocket of dry air to the northwest of the cluster domain. The cluster domain sits directly in the middle of those two competing pockets of air. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 2.176 ms^{-1} at 310.901˚.

4.13.5: Cluster Figures and Tables

Table 4.13.1: Median Values for the Upper Air and Surface Variables for the Jacinto Mesa, NM Cluster.

Variable	Median Value
STHC	38.265
SMXR	9.165
SMXS	19.565
UWND	0.000
VWND	0.755
LCL	616.455
LI	-0.470

Table 4.13.2: Median Values for the NARR Variables for the Jacinto Mesa, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5853.300	5901.800	5869.400	5853.900	5877.000
PW	21.050	18.500	21.700	21.400	18.200
CAPE	551.450	242.700	330.400	273.300	58.400
CIN	-17.000	-17.000	-14.900	-18.300	-22.600
SRH	20.600	24.600	41.500	19.700	43.300
GH600	4475.250	4491.600	4462.900	4467.300	4487.000
GH500	5925.100	5934.400	5906.200	5918.850	5935.900
GH300	9721.250	9716.600	9687.400	9724.750	9708.300
GH200	12442.200	12448.700	12415.900	12441.150	12437.000
SH850	9.000e-3	8.000e-3	9.200e-3	8.800e-3	8.900e-3
SH800	7.800e-3	6.800e-3	8.400e-3	7.700e-3	7.600e-3
SH600	4.950e-3	5.100e-3	4.700e-3	5.250e-3	4.600e-3
SH500	2.700e-3	2.100e-3	2.300e-3	2.800e-3	2.200e-3
SH300	4.200e-4	3.400e-4	3.800e-4	3.950e-4	4.700e-4
SH200	4.800e-5	5.100e-5	4.800e-5	5.250e-5	6.100e-5
UC600	1.228	2.700	1.700	1.018	1.700
UC500	1.349	4.000	1.300	2.750	4.700
UC300	5.800	7.300	6.700	5.500	6.300
UC200	4.250	11.800	13.400	4.800	10.600
UWSS500	1.744	4.310	0.320	1.295	6.110
UWS600500	0.350	1.200	0.400	1.659	1.700
UWSS600	2.028	3.710	3.260	2.418	4.910
WD600	240.482	262.781	220.301	235.160	295.017
WD500	228.972	235.008	234.324	253.637	255.895
VC600	1.700	0.342	1.700	1.550	-0.970
VC500	0.150	1.800	1.200	0.103	0.378
VC300	3.550	2.800	5.300	5.100	3.400
VC200	2.600	2.200	5.800	3.600	-1.200
VWSS500	0.575	0.230	2.030	-0.533	-1.590
VWS600500	-0.350	-0.600	-0.300	5.000e-2	-0.100
VWSS600	-3.500e-2	-7.850e-2	3.140	-0.294	-1.373
T600	2.600	3.900	2.500	2.950	4.300
T500	-6.700	-8.000	-8.800	-6.700	-7.600
T300	-32.450	-33.100	-32.900	-32.450	-32.700
T200	-53.550	-53.100	-53.700	-53.800	-53.100
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5855.300	5847.550	5862.000	5836.700	5831.950
PW	19.300	21.950	21.800	19.700	22.500
CAPE	255.300	209.950	91.400	437.100	201.750
CIN	-29.700	-33.700	-41.100	-44.100	-36.050

Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
SRH	46.900	29.900	58.100	54.300	59.800
GH600	4444.600	4464.000	4491.000	4457.400	4470.950
GH500	5900.700	5919.950	5932.300	5913.200	5921.350
GH300	9688.400	9724.550	9709.100	9689.400	9715.850
GH200	12393.700	12453.800	12450.800	12414.900	12452.100
SH850	9.400e-3	9.100e-3	9.300e-3	9.600e-3	9.550e-3
SH800	8.200e-3	7.900e-3	8.200e-3	8.600e-3	8.200e-3
SH600	4.800e-3	5.050e-3	4.700e-3	4.600e-3	5.000e-3
SH500	2.500e-3	2.950e-3	2.500e-3	2.500e-3	2.750e-3
SH300	3.900e-4	3.800e-4	4.300e-4	3.600e-4	3.600e-4
SH200	5.000e-5	5.200e-5	5.500e-5	4.700e-5	5.000e-5
UC600	1.700	1.394	3.500	2.800	3.150
UC500	0.986	2.200	3.900	2.900	2.100
UC300	6.100	5.250	6.100	5.000	4.700
UC200	17.000	6.550	12.700	14.300	5.450
UWSS500	1.478	1.645	4.037	1.750	1.280
UWS600500	0.720	0.683	0.400	0.900	0.200
UWSS600	2.892	1.024	4.000	2.085	2.530
WD600	223.479	255.057	268.267	230.793	265.710
WD500	229.844	249.822	223.264	236.083	251.750
VC600	1.800	0.938	0.121	1.200	-0.539
VC500	2.100	-1.400	-0.634	0.407	-1.649
VC300	2.900	3.400	2.700	3.600	3.450
VC200	3.000	3.350	-0.599	2.600	2.548
VWSS500	1.450	-1.425	-0.870	-6.000e-2	-1.980
VWS600500	-1.400	-0.650	-3.400	-0.500	-0.400
VWSS600	2.650	-0.569	-2.100	2.940	-1.269
T600	2.300	2.650	4.200	1.700	1.950
T500	-7.500	-6.650	-7.900	-8.100	-7.100
T300	-32.900	-32.450	-32.700	-33.200	-32.500
T200	-53.400	-53.350	-53.000	-53.400	-53.650

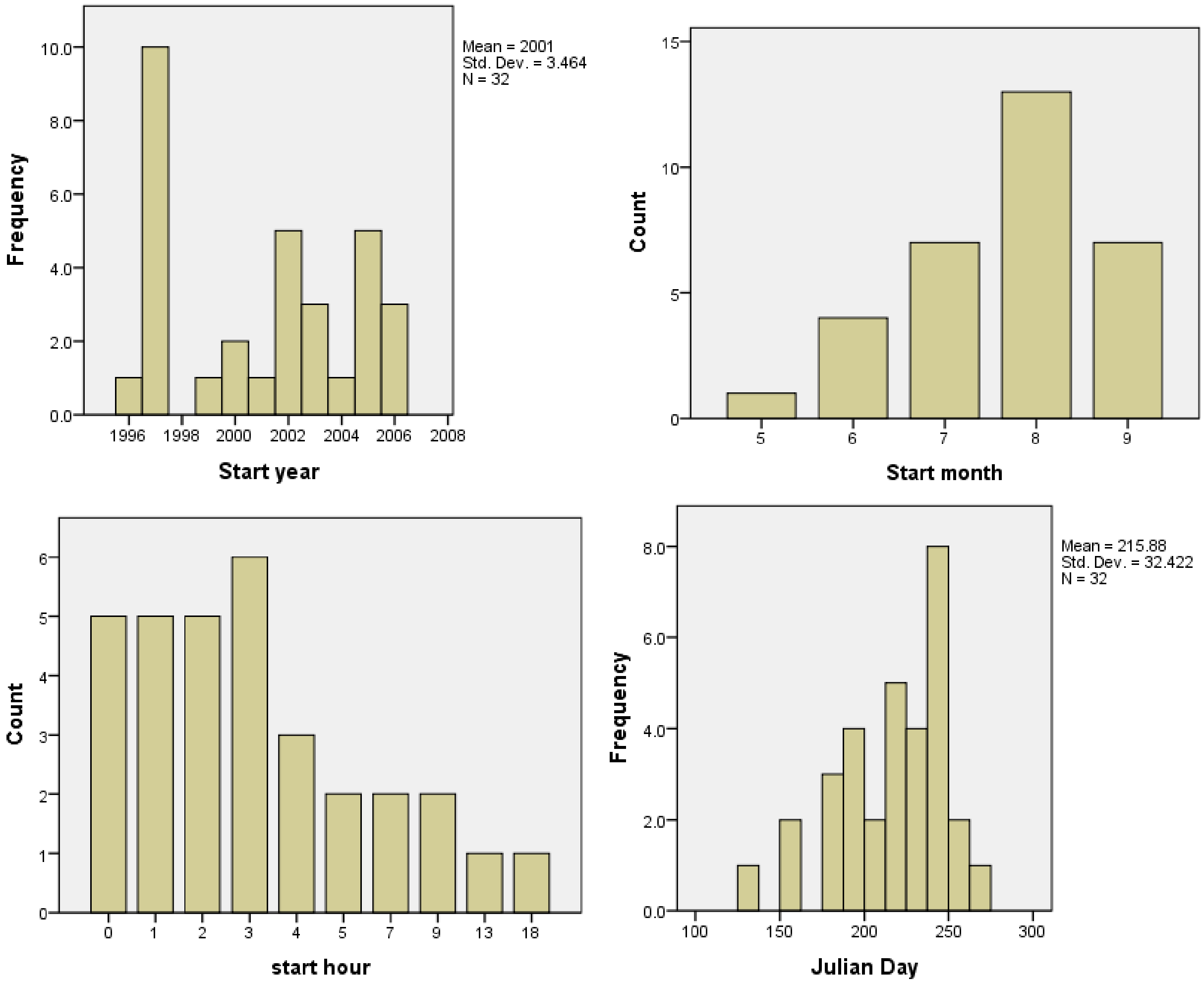


Figure 4.13.1: Time Histograms for the Jacinto Mesa, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.13.3: Results of the MLRs Run on the Jacinto Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – CIN – VWS600500 – SRH – CAPE + T200 – WD600 + SMXS – VWND + SH850 – LI	1.000
5HP	FP ≈ constant + CIN – SH600 – WD500 – CAPE + VC600 + SH500	1.000
4HP	FP ≈ constant + UWSS600 + SH500 – VWND + Thickness – GH500	0.957
3HP	FP ≈ constant – VC500 + LCL + Thickness – GH300	0.821
2HP	FP ≈ constant + VWSS600 + GH500 + UWS600500 + UWND + Thickness – LI	1.000
1HP	FP ≈ constant + UC600 + SH600 – T200 – Thickness – VWSS500 – SRH – SH300	1.000
Initiation	FP ≈ constant – T200 + UWND	0.526

Table 4.13.4: Results of the PCAs Run on the Jacinto Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, VC600, VC300, VWSS500, VWSS600, T600, T500, T300, T200	8	93.055%
5HP	All variables	6	100.000%
4HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	95.901%
3HP	STHC, SMXR, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	9	94.182%
2HP	All variables	6	100.000%
1HP	STHC, SMXR, SMXS, UWND, LCL, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	6	93.889%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	95.021%

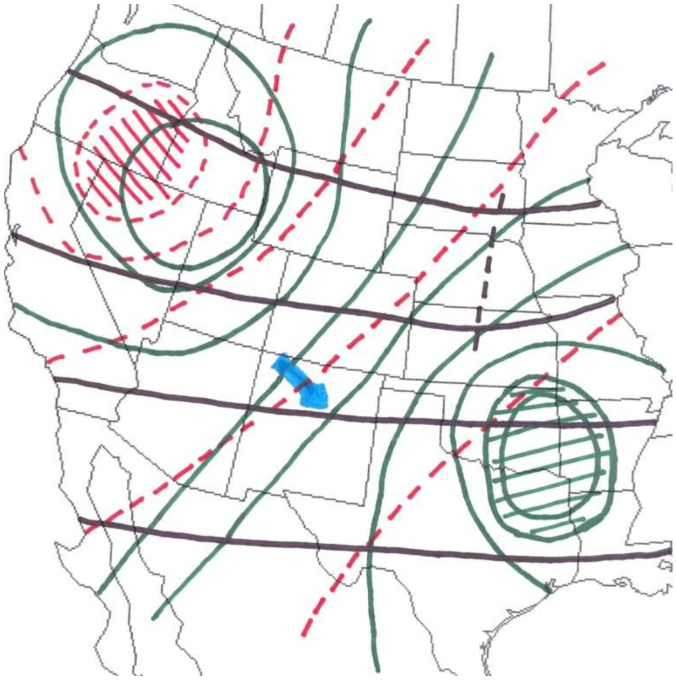


Figure 4.13.2: Composite Map for Jacinto Mesa, NM. The variables included on the map are T200, GH500, SMXR, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.14: Bartlett Mesa/Horse Mesa, NM

4.14.1: Description of Cluster

The Bartlett Mesa/Horse Mesa, NM cluster contains 31 members and is located directly north of Raton, NM. The median values given for the surface variables in Table 4.14.1 show that the surface potential temperature is relatively hot at 35.440˚C (approximately 96˚F), the air is relatively moist, and the winds are calm. The surface potential temperature will be relatively hot at the initiation location as compared to the closest reporting station. The median values of SMXR and SMXS show that the air is relatively moist with a relative humidity value of approximately 58 percent. The median values of UWND and VWND show that there is no median wind speed and direction which is different from the upper levels. The upper air median values included in Table 4.14.1 show an LCL that is relatively close to the ground and an LI that is slightly negative indicating the air is unstable.

The NARR median values for the 6HP through the 3HA model runs are given in Table 4.14.2. Thickness falls significantly in value from the 6HP to the 3HA, however, the geopotential height variables did not vary significantly throughout the model runs. PW did not vary significantly but the overall value was lower than what has been seen in some of the previous clusters. Overall, the CAPE values are higher than what has been previously seen. The CAPE is at maximum at 3HP and is at minimum at 1HA. CIN did not vary much and relatively low values were seen throughout. The SRH variable varies significantly, but the contribution from the variable depends on the hour being observed. While the specific humidity variables do not vary significantly throughout the model runs, the overall values show that the air is relatively moist. The wind and wind shear variables vary significantly but the values are considered hour dependent. The temperature variables do not vary much but the values are considered relatively cold.

Histograms for the Bartlett Mesa/Horse Mesa, NM cluster, Figure 4.14.1, were created for the start year, start month, start hour, and Julian Day. The start-year histogram shows that each year between 1996 and 2006 has between one and four MCSs occurring. The mean year for initiation in this cluster was 2001. According to the start-month histogram, the month of August is when most MCSs occurred followed by June and July. The start-hour histogram shows that MCSs initiated throughout the day but most of the MCSs were initiated in the late afternoon/early evening (consistent with FF01). The Julian-Day histogram shows a spike of MCSs in June and the main spike of MCSs in August.

4.14.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA. The resulting equations and the R square values are included in Table 4.14.3. The results discussed below for the Bartlett Mesa/Horse Mesa, NM cluster come from a combination of Table 4.14.1, Table 4.14.2, and Table 4.14.3.

The 6HP model run was a perfect fit to the data. More negative LI values, cooler surface potential temperatures, weaker west-east winds at 600 mb, LCLs higher off the ground, northwest winds at 500 mb, stronger west-east winds at 500 mb, warmer columns of air between the surface and 600 mb, and larger surface saturation mixing ratios are needed for larger FPs within this cluster's domain. The equation can be used in the identification of variables needed for the prediction the FP of the MCS. There were multicollinearity issues present.

The 5HP model run was another perfect fit, achieved with only six variables. Colder temperatures at 200 mb, a moist pocket of air at 200 mb, more negative CIN values, a dry pocket of air at 600 mb, stronger U component wind shears between 600 and 500 mb, and more negative LI values are needed for larger FPs according to this equation. This equation can be used for identifying the variables needed to accurately estimate the MCS FP that will initiate in five hours due to the perfect fit to the data. There were multicollinearity issues present.

The 4HP model run is a perfect fit to the data and contains significantly more variables in its equation than the previous model run. A dry pocket of air at 850 mb, LCLs closer to the ground, weaker east-west winds at 200 mb, larger SRH values (from JC07), larger Thickness values, weaker south-north winds at 300 mb, and stronger south-north winds at 500 mb are needed for larger FPs at this time. A moist pocket of air at 600 mb, warmer temperatures at 300 mb, a dry pocket of air at 800 mb, colder temperatures at 200 mb, smaller PW values, and stronger west-east winds at 500 and 600 mb are also needed for larger FPs within this cluster's domain. This equation can be used to accurately anticipate the FP of the MCS that will form within the cluster domain in four hours' time due to the perfect fit. There were multicollinearity issues present.

The 3HP model run was considered a near perfect fit, at 0.997, with only four variables. Northeast winds at 500 mb, positive U component winds at the surface, warmer temperatures at 600 mb, and stronger V component winds at the surface are needed for larger FPs within this domain. This equation can be used for identifying the variables needed for the potential to predict the FP of the MCS that will initiate in three hours' time with a certain amount of error. There were no multicollinearity issues present.

The 2HP model run was a perfect fit to the data and was achieved using only six variables. Stronger south-north winds at 600 mb, weaker U component wind shears between the surface and 600 mb, stronger west-east winds at 300 mb, negative LI values, weaker south-north winds at 300 mb, and weaker U component wind shears between the surface and 500 mb are needed at 2HP for larger FPs within this cluster's domain. This combination of variables will be used to accurately predict the FP of the eventual MCS due to the perfect fit. There were multicollinearity issues present.

The 1HP model run was another perfect fit to the data. LCLs closer to the ground, weaker west-east winds at 200 mb, warmer temperatures at 600 mb, a dry pocket of air at 600 mb, smaller surface saturation mixing ratios, stronger U component wind shears between 600 and 500 mb, and positive V component winds at the surface are needed for larger FPs. Weaker V component wind shears between the surface and 600 mb, more negative CIN values, a moist pocket of air at 500 mb, a dry pocket of air at 850 mb, northeast winds at 600 mb, weaker west-east winds at 600 mb, and a dry pocket of air at 800 mb are also needed for larger FPs within this cluster's domain. This equation can be used for identifying the necessary FP variables due to another perfect fit, but there were multicollinearity issues present.

The model run done at initiation was a near perfect fit to the data, at 0.923, and only three variables were used. More negative LI values, northwest winds at 600 mb, and weaker U component wind shears between 600 and 500 mb are needed at the hour of initiation according to this equation. This equation can be used for identifying the variables needed for predicting the FP at this hour with a small amount of error. There were no multicollinearity issues present.

Throughout the Bartlett Mesa/Horse Mesa, NM cluster model runs there were several variables that were never used in the equations: SMXR, GH500, GH300, SH300, VC200, and VWSS500. They are considered the least important to the eventual FP. The variable used the most times was LI at five out of ten model runs; therefore, no one variable is more important than the others. The variables used in the model runs are hour dependent since no variable is considered more important than another. The biggest similarity between the model runs is the inclusion of wind and wind shear variables (from JC07).

4.14.3: Principal Component Analysis

PCAs were run on each of the 6HP through 3HA on the Bartlett Mesa/Horse Mesa, NM cluster. The fit issues seen with the MLRs are solved using the PCAs. Included in Table 4.14.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues greater than one, and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run had similar variables loaded highly into the first components. In the first component, the variables that were loaded the highest were SMXR (4HP, 1HP), Thickness (6HP, 5HP, 4HP, 3HP), PW, SRH (6HP, 3HP), geopotential height, specific humidity (5HP, 4HP, 2HP, 1HP, initiation), U component wind (6HP, 3HP, initiation), V component wind (5HP, 2HP), WD600 (2HP), WD500 (2HP), and temperature variables. Thickness, PW, geopotential height, specific humidity, V component, WD600, WD500, and temperature variables were loaded positively into the component. These variables, with the exception of the temperature variables, provide a greater positive contribution to the component and to the PCA. SRH, V component wind (2HP), and U component wind variables were loaded negatively into the component and their contributions depend on the value of the variable. In the second component, the highest loaded variables were SMXR (3HP, initiation), LCL (3HP, 2HP), specific humidity (5HP), U component wind shear (5HP), and V component wind (4HP, 1HP) variables which were loaded in positively and STHC (initiation) and VWND (initiation) were loaded in negatively. The greater the value of SMXR and LCL, the greater the contribution will be to the PCA. Cooler surface potential temperatures will provide the greater contribution to the PCA. Wind and wind shear contributions depend on the value of the variable and the loading into the component. The variables that are loaded highest in the most components are the variables that can be considered the most important to MCSMI.

Every variable was included at least seven times and most of the variables were included in every most used list. This list, in combination with the variables that were loaded highly into the components, shows the variables that are the most important to MCSMI within the Bartlett Mesa/Horse Mesa, NM cluster's domain.

4.14.4: Cluster Discussion

Even though six of the ten model runs for the MLRs were perfect fits to the data, there were still multiple runs which had multicollinearity issues present. In the PCAs, most of the variance was accounted for in every model run and all of the variables were included often in the most used lists. Therefore, the PCAs are considered the better fit to the data and give a better representation of the conditions needed for MCSMI within the Bartlett Mesa/Horse Mesa, NM cluster.

The Bartlett Mesa/Horse Mesa, NM cluster is in a portion of the Rocky Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-northwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that the winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for Bartlett Mesa/Horse Mesa, NM is Figure 4.14.2. The most important temperature variable was T500. Cooler temperatures are to the northwest with a ridge of warmer temperatures above the cluster domain. The most important geopotential height variable was GH200. There is a ridge present to the east of the cluster domain. Decreasing heights will continue as the ridge moves farther east. The most important moisture variable was SH850. A pocket of moist air is to the east-northeast of the cluster domain and affects the moisture within the domain. The air within the domain is considered relatively moist at SH850 according to the composite map. The most important wind shear was between 600 and 500 mb. The wind shear at initiation has a median value of 1.166 ms^{-1} at 239.036°.

4.14.5: Cluster Figures and Tables

Table 4.14.1: Median Values for the Upper Air and Surface Variables for the Bartlett Mesa/Horse Mesa, NM Cluster.

Variable	Median Value
STHC	35.440
SMXR	9.780
SMXS	16.740
UWND	0.000
VWND	0.000
LCL	694.780
LI	-0.581

Table 4.14.2: Median Values for the NARR Variables for the Bartlett Mesa/Horse Mesa, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5850.000	5886.900	5807.500	5842.600	5869.200
PW	18.300	19.400	17.400	18.200	18.700
CAPE	556.900	126.600	252.800	668.000	220.300
CIN	-25.400	-21.900	-20.700	-20.900	-34.500
SRH	54.200	44.100	47.900	35.700	54.000
GH600	4469.000	4455.100	4455.400	4458.300	4455.300
GH500	5921.400	5908.000	5891.800	5911.200	5905.900
GH300	9685.700	9719.800	9692.100	9702.500	9717.000
GH200	12418.900	12436.300	12436.400	12409.400	12417.800
SH850	1.050e-2	8.700e-3	9.400e-3	1.000e-2	8.100e-3
SH800	9.100e-3	7.600e-3	8.100e-3	8.700e-3	7.100e-3
SH600	4.600e-3	4.800e-3	4.400e-3	4.900e-3	5.000e-3
SH500	2.300e-3	2.800e-3	2.000e-3	2.400e-3	2.400e-3
SH300	2.100e-4	3.700e-4	2.500e-4	2.400e-4	3.800e-4
SH200	4.600e-5	4.400e-5	5.400e-5	4.400e-5	5.800e-5
UC600	3.100	4.700	3.600	3.000	5.500
UC500	6.100	9.500	5.200	5.700	9.000
UC300	12.400	6.800	8.000	10.400	11.500
UC200	6.100	7.600	12.600	8.600	14.000
UWSS500	6.100	8.770	4.280	5.200	9.100
UWS600500	2.600	5.200	2.600	2.200	3.300
UWSS600	3.100	6.410	4.060	3.800	7.070
WD600	265.785	230.711	276.930	278.931	261.363
WD500	247.671	267.542	246.881	257.412	278.746
VC600	-0.120	2.500	-0.517	-0.598	1.100
VC500	1.200	0.425	0.406	-0.516	-1.000
VC300	2.300	5.500	1.500	0.322	4.700
VC200	0.766	8.700	2.800	0.890	6.100
VWSS500	0.950	1.420	0.640	-2.056	-0.263
VWS600500	-0.600	-2.400	0.527	-2.300	-2.281
VWSS600	-0.380	3.820	-1.557	1.470	3.090
T600	2.400	3.300	1.600	3.100	3.500
T500	-9.200	-7.100	-8.800	-8.800	-7.400
T300	-34.400	-33.900	-32.700	-34.400	-34.100
T200	-53.100	-54.000	-53.900	-53.900	-53.700
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5806.600	5814.800	5856.800	5787.400	5795.600
PW	18.000	18.900	18.700	17.000	17.700
CAPE	110.000	595.400	109.000	121.500	431.400
CIN	-40.100	-39.700	-68.400	-57.900	-69.200

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	44.500	32.000	70.500	72.100	41.100
GH600	4450.300	4469.100	4442.800	4452.200	4463.600
GH500	5889.100	5919.700	5896.800	5896.200	5914.200
GH300	9688.600	9729.900	9706.800	9698.800	9691.200
GH200	12435.400	12436.500	12440.500	12437.500	12386.600
SH850	9.900e-3	9.600e-3	8.800e-3	9.600e-3	9.900e-3
SH800	8.500e-3	8.500e-3	7.900e-3	8.500e-3	8.700e-3
SH600	4.600e-3	4.800e-3	4.900e-3	4.000e-3	4.600e-3
SH500	2.300e-3	2.300e-3	2.300e-3	2.100e-3	2.100e-3
SH300	2.600e-4	3.200e-4	3.900e-4	2.000e-4	3.100e-4
SH200	4.700e-5	4.900e-5	4.900e-5	5.000e-5	3.900e-5
UC600	3.800	3.400	5.400	3.300	3.400
UC500	3.800	4.100	6.200	3.500	7.800
UC300	11.000	9.200	13.500	10.000	10.100
UC200	14.200	12.800	18.300	14.800	10.900
UWSS500	4.990	4.100	7.960	4.290	9.030
UWS600500	1.874	1.000	0.700	0.600	2.200
UWSS600	2.146	3.400	7.010	2.610	5.200
WD600	263.265	285.524	262.231	263.660	269.458
WD500	265.040	269.421	268.786	263.774	262.740
VC600	-0.581	-1.600	0.573	-0.829	-2.900e-3
VC500	0.518	-0.677	-1.600	8.020e-2	0.400
VC300	-0.579	-7.950e-2	0.800	-2.100	-1.100
VC200	1.100	1.000	5.300	0.150	0.309
VWSS500	0.870	-0.580	0.125	0.145	1.090
VWS600500	-0.694	0.600	-3.773	0.300	-0.300
VWSS600	-0.430	-1.000e-2	2.563	-1.220	-1.480
T600	0.797	2.700	3.700	0.856	2.200
T500	-9.000	-8.300	-6.500	-9.300	-8.000
T300	-32.400	-34.800	-33.500	-32.600	-35.500
T200	-53.100	-54.100	-53.800	-53.000	-53.400

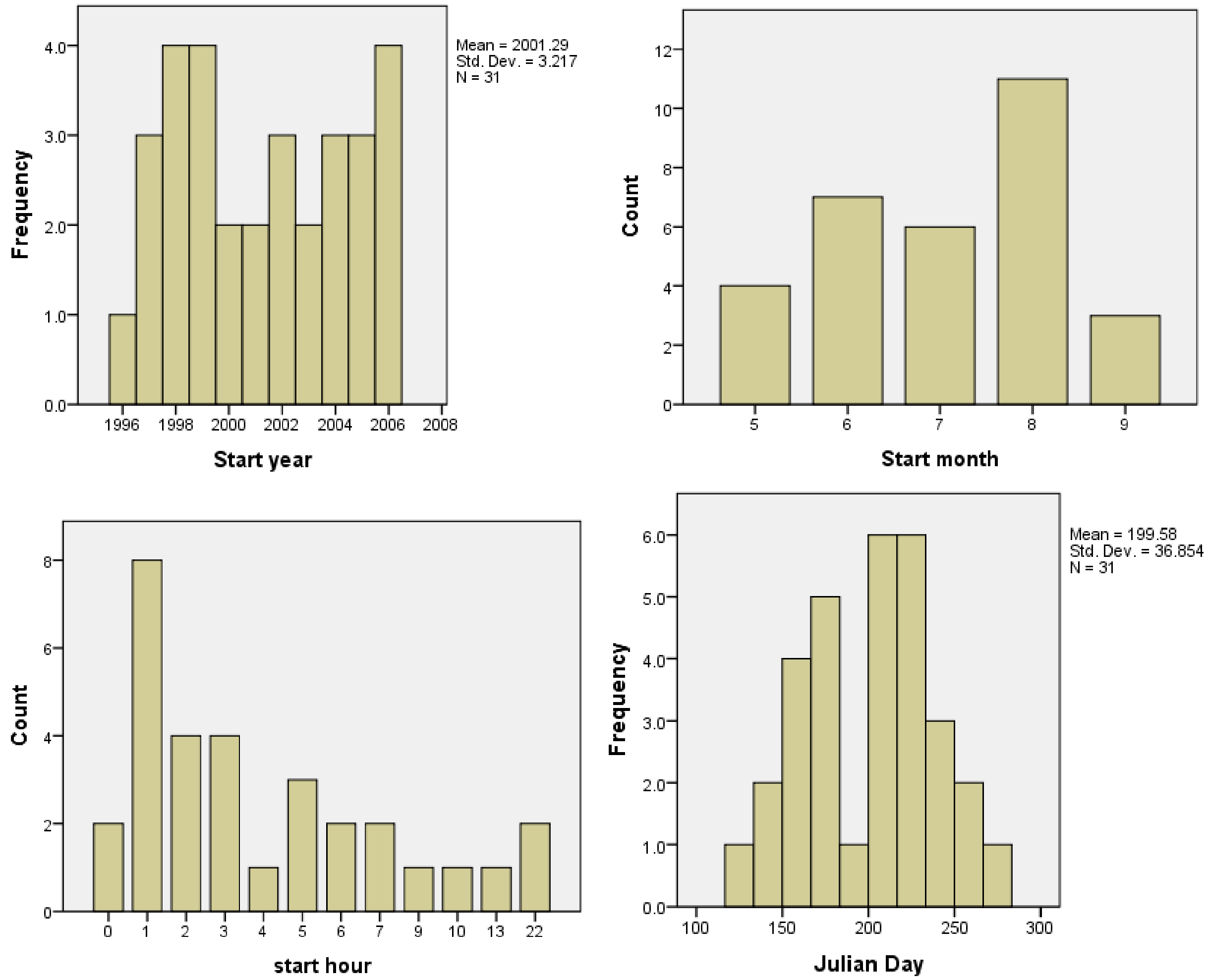


Figure 4.14.1: Time Histograms for the Bartlett Mesa/Horse Mesa, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.14.3: Results of the MLRs Run on the Bartlett Mesa/Horse Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – LI – STHC – UC600 – LCL + WD500 + UC500 + GH600 + SMXS	1.000
5HP	FP ≈ constant – T200 + SH200 – CIN – SH600 + UWS600500 – LI	1.000
4HP	FP ≈ constant – SH850 + LCL – UC200 + SRH + Thickness – VC300 + VC500 + SH600 + T300 – SH800 – T200 – PW + UC500 + UC600	1.000
3HP	FP ≈ constant – WD500 + UWND + T600 + VWND	0.997
2HP	FP ≈ constant + VC600 – UWSS600 + UC300 + LI – VC300 – UWSS500	1.000
1HP	FP ≈ constant + LCL – UC200 + T600 – SH600 – SMXS + UWS600500 + VWND + VWSS600 – CIN + SH500 – SH850 – WD600 – UC600 – SH800	1.000
Initiation	FP ≈ constant – LI + WD600 – UWS600500	0.923

Table 4.14.4: Results of the PCAs Run on the Bartlett Mesa/Horse Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	96.875%
5HP	All variables	6	100.000%
4HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	95.117%
3HP	All variables	7	98.921%
2HP	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	5	97.881%
1HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	96.286%
Initiation	All variables	7	99.268%

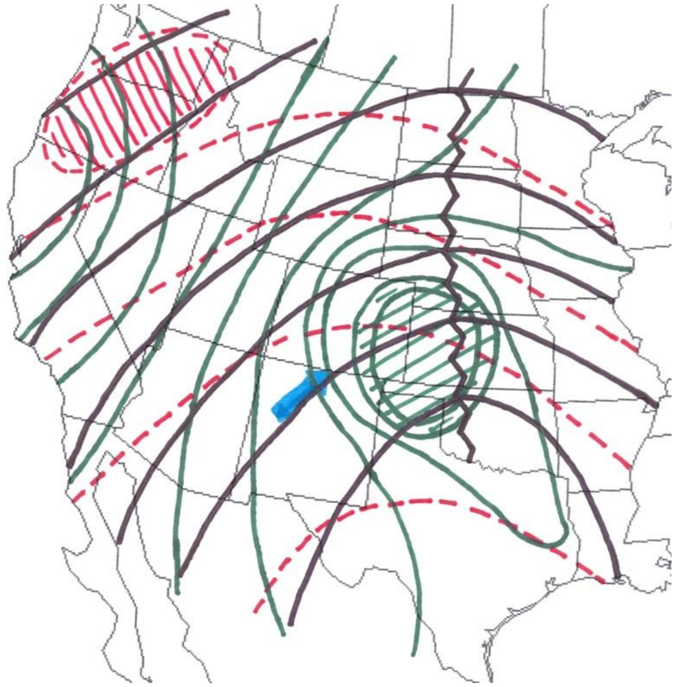


Figure 4.14.2: Composite Map for Bartlett Mesa/Horse Mesa, NM. The variables included on the map are T500, GH200, SH850, and wind shear between 600 and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.15: Trinchera Mesa/Valencia Hills/Howard Mountain, NM

4.15.1: Description of Cluster

The Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster is located due east of the Mesa de los Jumanos, NM and contains 31 members. The median values given for the surface variables in Table 4.15.1 show that the air is relatively hot at 38.820˚C (approximately 102˚F), and relatively moist, and the winds are from the south (as seen in BS87). The surface potential temperature at the initiation location is still considered warm. The median values of SMXR and SMXS show that the air is relatively moist at approximately 63 percent relative humidity. The UWND and VWND variables give a southerly median wind direction since the UWND median value is zero. The median values given for the upper air variables in Table 4.15.1 shows that the LCL is below-ridgetop level height and the LI is a negative value showing that the air is unstable.

The median values from the NARR data are given in Table 4.15.2 and show how the variables change throughout the model runs. Thickness varies significantly throughout the model runs but the geopotential height variables do not. Thickness increases in value from 6HP to 3HA. While the PW has a relatively high median value overall, it changes little throughout the model runs. CAPE varies significantly, reaching its maximum at 3HA and its minimum at 2HA. While CIN varies throughout the model runs, it does not significantly differ from one hour to another. SRH varies, but is considered to be hour dependent. The specific humidity variables do not vary much throughout the model runs but the air can be considered relatively moist throughout all the model runs at every level. The wind and wind shear variables vary throughout the model runs but are considered hour dependent. The temperature variables do not vary significantly throughout the model runs and remain at a consistent value.

Histograms for the Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster were created for the start year, start month, start hour, and Julian Day. The start-year histogram shows that the most MCSs occurred in 1997 and no MCSs occurred in 2005. The mean year for MCSMI was 2000. The start-month histogram shows that July and August are the months with the most MCSMIs. The other months had few MCSs initiating. While the start-hour histogram shows that MCSs could initiate throughout the day within the cluster domain, most occurred in late afternoon/early evening (consistent with FF01). The Julian-Day histogram shows that most of the MCSs initiated in July and August which is consistent with the start-month histogram.

4.15.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster. The resulting equations and the R square values are included in Table 4.15.3. The results discussed below for this cluster come from a combination of Table 4.15.1, Table 4.15.2, and Table 4.15.3.

The 6HP model run was a near perfect fit to the data, at 0.929, and can be used for identifying the variables needed for the prediction of the FP. LCLs closer to the ground, a moist pocket of air at 300 mb, a dry pocket of air at 200 mb, and stronger U component winds at the surface are needed for larger FPs. This equation can be used to determine the FP of the eventual MCS with a small amount of error. There were no multicollinearity issues present.

The 5HP model run was another near perfect fit to the data, at 0.949. Stronger south-north winds at the surface, warmer temperatures at 600 mb, and weaker V component wind shears between 600 and 500 mb are needed for larger FPs according to this equation. With a relatively small amount of error, the FP of the MCS that will form in five hours can be accurately estimated. There were no multicollinearity issues present in this equation.

The 4HP model run was a perfect fit to the data using nine variables. Northeast winds at 500 mb, larger CAPE values, less negative LI values, LCLs higher off the ground, weaker south-north winds at 600 mb, and a dry pocket of air at 200 mb are needed for larger FPs within this cluster's domain. Warmer columns of air between the surface and 200 mb, a moist pocket of air at 600 mb, and cooler surface potential temperatures are also needed for initiation according to this equation. This equation can be used to determine the FP of the system that will form in four hours. There were multicollinearity issues present in this equation.

The 3HP model run is considered a relatively good fit at 0.824. LCLs closer to the ground, weaker west-east winds at 600 mb, and stronger north-south winds at 200 mb are needed for larger FPs within this cluster's domain. This equation can be used for the identification of the variables needed for potential to predict the FP with some associated error. There were no multicollinearity issues present in this equation.

The 2HP model run was a perfect fit to the data for this cluster. Warmer temperatures at 600 mb, stronger south-north winds at the surface, larger Thickness values, northeast winds at 500 mb, colder columns of air between the surface and 500 mb (contradiction to Thickness), weaker south-north winds at 300 mb, and weaker U component wind shears between 600 and 500 mb are needed for larger FPs within this cluster's domain. This equation can be used for identifying the variables needed to accurately predict the FP of the MCS that will initiate in two hours. There were multicollinearity issues present in this equation which is expected from the inclusion of Thickness and GH500.

The 1HP model run was a poor fit to the data at 0.416. Only one variable was used in the equation and there were no multicollinearity issues present. This model run will not be discussed in detail but will be included in Table 4.15.3 for reference.

The model run done at initiation was a near perfect fit, at 0.994. LCLs closer to the ground, stronger north-south winds at 500 mb, a moist pocket of air at 500 mb, stronger south-north winds at 300 mb, and warmer columns of air between the surface and 600 mb are needed for larger FPs within the cluster domain. This equation can be used for identifying the variables needed for the potential to predict the value of the FP with a small amount of associated error. There were multicollinearity issues present in this equation.

There were several variables that were never used in the model runs: SMXR, CIN, GH300, SH850, SH800, UC500, UC300, WD600, T500, and T300 and are considered the least important to larger FPs according to the MLRs. The variable included the most often was LCL at five out of ten model runs; therefore, none of the variables are considered significant to larger FPs. The combination of variables given for each equation is more important to larger FPs within this cluster rather than one or several individual variables.

4.15.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA and solved the multiple fit issues seen in the MLRs for this cluster. Included in Table 4.15.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater and percent variance accounted for with those eigenvalues.

The 6HP model run through the initiation model run include several of the same highly loaded variables in the first components. In the first component, the variables that were loaded the highest were Thickness (6HP, 5HP, 3HP, 2HP, initiation), PW, geopotential height (6HP, 5HP, 3HP, 2HP, 1HP, initiation), specific humidity (6HP, 4HP, 3HP, 1HP, initiation), U component wind (6HP, 3HP, initiation), V component wind (6HP), and temperature variables with the exception of T200. The U component wind and the V component wind variables were loaded in negatively at 6HP and initiation and positively at 3HP, and the other highly loaded variables were loaded in positively. However, the temperature variables were loaded in negatively at 3HP. The contribution from most of the variables will be a positive contribution. The contribution from the wind variables will depend on the value of the variable at that time. Warmer temperatures will provide a greater contribution to the MCSMI within the cluster domain than colder temperatures. In the second component, the variables loaded the highest were WD600 (6HP), VC600 (6HP), CAPE (5HP, 1HP), U component wind (5HP), LCL (4HP), V component wind shear (4HP), VWND (3HP), SRH (3HP), SMXS (2HP), VWND (2HP, initiation), and VWSS600 (1HP). WD600 was loaded in negatively, while VC600, CAPE, LCL, V component wind shears, VWND, SRH, SMXS, VWND and U component winds were loaded in positively. The contribution from CAPE and SMXS will be greater the larger the value. The contributions from the remaining variables will depend on the value of the variables at that time. Though this happened more often with the first component than the second component, the variables that were loaded highly often are the ones that are considered the most important to MCSMI within this cluster's domain.

All of the variables were included at least six times out of ten. LCL was included in only six lists and SH200 was included in seven lists. Many of the variables were included in every model run's most used list: STHC, SMXR, SMXS, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, UC500, UC300, UC200, UWSS500, VC500, VWSS500, VWSS600, T600, T500, and T300. This list, in combination with the variables loaded the highest into the components, are the ones that are considered the most important to MCSMI within the Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster.

4.15.4: Cluster Discussion

For this cluster, there were four MLRs that were perfect fits to the data and five of the model runs contained multicollinearity issues. The PCAs were very good fits to the data and a few of the model runs had every variable contained in the most used list. Over 93 percent of the variance was accounted for in every model run. Therefore, the best type of analysis for this cluster is the PCA which will be used for the identification of the variables needed for the accurate prediction of MCSMI within the Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster.

The Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster is in a portion of the Rocky Mountains that contains a barely noticeable southwest-northeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the southwest. The median wind direction at 500 mb and initiation gives winds from the west-southwest. This indicates that the winds at 600 mb arrive along the ridgeline and winds at 500 mb arrive at an angle to the ridgeline.

The composite map for Trinchera Mesa/Valencia Hills/Howard Mountain, NM is Figure 4.15.2. The most important temperature variable was STHC. A pocket of relatively cooler air is to the south and one of relatively warmer air is to the west of the cluster domain. The surface potential temperatures are relatively cool according to the composite map. The most important geopotential height variable was GH500. There is a ridge located to the east and a trough located to the west of the cluster domain. The heights will continue to decrease until the trough passes through the area. The most important moisture variable was SH500. There is a pocket of relatively moist air located west of the cluster domain and the air within the domain can be considered relatively moist. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 3.682 ms^{-1} at 320.234˚.

4.15.5: Cluster Figures and Tables

Table 4.15.1: Median Values for the Upper Air and Surface Variables for the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster.

Variable	Median Value
STHC	38.820
SMXR	11.250
SMXS	17.660
UWND	0.000
VWND	1.670
LCL	662.910
LI	-1.140

Table 4.15.2: Median Values for the NARR Variables for the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5824.300	5844.900	5838.550	5844.550	5865.200
PW	22.050	23.300	24.800	21.600	23.100
CAPE	420.500	433.000	403.850	415.150	234.900
CIN	-24.500	-14.300	-7.350	-13.100	13.300
SRH	21.400	32.300	41.550	27.100	41.700
GH600	4465.250	4466.000	4459.500	4465.900	4454.400
GH500	5909.400	5917.000	5907.800	5910.100	5899.200
GH300	9723.150	9720.600	9734.200	9718.700	9723.500
GH200	12462.600	12469.100	12486.750	12460.250	12466.400
SH850	9.900e-3	9.900e-3	1.125e-2	8.950e-3	9.300e-3
SH800	8.600e-3	8.600e-3	9.800e-3	7.850e-3	8.300e-3
SH600	4.350e-3	4.800e-3	4.750e-3	4.400e-3	5.400e-3
SH500	2.600e-3	2.600e-3	2.550e-3	2.450e-3	2.800e-3
SH300	3.400e-4	3.900e-4	3.400e-4	3.950e-4	4.400e-4
SH200	5.100e-5	5.000e-5	5.400e-5	4.700e-5	5.300e-5
UC600	2.750	0.509	2.750	3.400	2.000
UC500	2.250	1.500	3.950	2.850	0.106
UC300	5.450	0.122	5.050	5.300	1.800
UC200	5.450	3.600	11.550	5.850	5.100
UWSS500	2.176	1.320	4.825	2.529	1.320
UWS600500	-0.207	-0.300	1.004	0.339	-0.300
UWSS600	2.645	0.250	3.220	3.541	0.270
WD600	226.659	182.829	240.351	243.892	200.674
WD500	239.114	231.340	235.547	251.641	230.711
VC600	3.200	2.600	0.800	1.440	2.400
VC500	2.450	2.300	1.376	0.735	1.500
VC300	3.300	4.900	4.900	2.550	3.400
VC200	-1.300	3.100	3.940	-0.650	0.333
VWSS500	0.260	1.800	0.278	-1.385	1.700
VWS600500	-0.632	0.700	.0372	-0.150	-1.600
VWSS600	-0.520	2.280	-0.659	-1.931	2.300
T600	1.700	2.300	1.200	1.600	2.300
T500	-7.950	-7.100	-6.800	-8.150	-7.300
T300	-33.000	-32.100	-30.500	-32.800	-32.500
T200	-53.350	-53.400	-52.250	-52.950	-53.100
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5838.700	5861.900	5865.200	5833.950	5850.300
PW	24.950	24.000	22.400	22.500	22.600
CAPE	188.800	383.000	236.800	155.150	446.700
CIN	-17.100	-25.000	-17.500	-27.500	-20.350

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	44.500	41.800	43.600	54.850	56.400
GH600	4459.450	4455.600	4448.000	4466.000	4475.250
GH500	5910.800	5903.600	5904.700	5913.600	5917.450
GH300	9739.850	9723.500	9715.200	9740.700	9718.250
GH200	12490.950	12466.950	12450.800	12492.800	12455.000
SH850	9.950e-3	1.005e-2	8.800e-3	9.700e-3	9.450e-3
SH800	8.650e-3	8.800e-3	7.800e-3	8.600e-3	8.350e-3
SH600	5.500e-3	5.100e-3	5.200e-3	4.800e-3	4.750e-3
SH500	3.000e-3	3.100e-3	3.000e-3	2.800e-3	2.550e-3
SH300	3.250e-4	3.600e-4	4.500e-4	4.000e-4	4.300e-4
SH200	5.850e-5	5.400e-5	5.200e-5	5.900e-5	4.750e-5
UC600	4.150	2.950	3.100	5.050	3.400
UC500	5.700	2.800	4.100	6.600	1.818
UC300	6.450	4.150	6.600	8.000	5.200
UC200	12.550	6.100	7.200	12.900	5.350
UWSS500	6.070	2.355	1.020	7.205	1.885
UWS600500	1.250	0.650	-0.900	-5.000e-2	-1.633
UWSS600	4.333	3.040	1.920	5.520	3.185
WD600	239.371	221.264	205.769	247.181	235.864
WD500	235.373	252.826	198.808	249.483	239.891
VC600	1.800	2.250	2.300	2.550	1.950
VC500	1.892	-0.941	-0.140	0.459	-0.351
VC300	5.800	2.436	2.400	3.850	0.760
VC200	3.350	1.842	0.833	4.250	0.900
VWSS500	1.180	-2.830	-0.671	-0.154	-1.620
VWS600500	0.485	5.000e-2	-2.161	-1.956	-1.495
VWSS600	0.662	-0.105	2.988	1.415	-0.405
T600	1.650	2.200	2.500	1.650	1.700
T500	-6.400	-7.200	-7.200	-7.200	-7.500
T300	-30.550	-32.900	-32.500	-30.850	-32.750
T200	-52.650	-53.050	-53.200	-52.350	-53.300

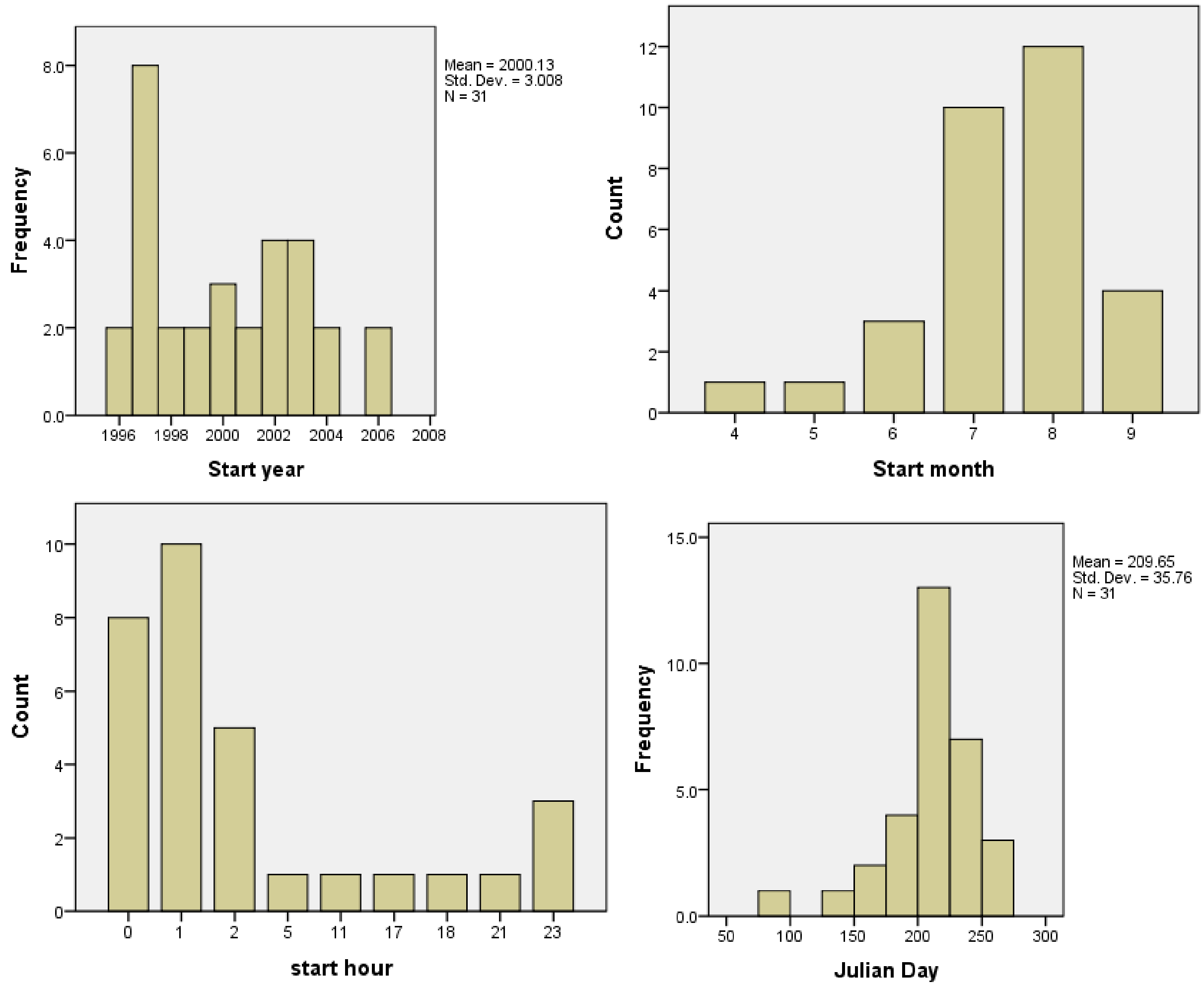


Figure 4.15.1: Time Histograms for the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster. Frequency was used on the y-axis when the data used in the histogram contained no gaps. Count was used on the y-axis when the data used in the does have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.15.3: Results of the MLRs Run on the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + LCL + SH300 – SH200 + UWND	0.929
5HP	FP ≈ constant + VWND – T600 – VWS600500	0.949
4HP	FP ≈ constant – WD500 + CAPE + LI – LCL – VC600 – SH200 + GH200 + SH600 – STHC	1.000
3HP	FP ≈ constant + LCL – UC600 – VC200	0.824
2HP	FP ≈ constant – T600 + VWND + Thickness – WD500 – GH500 – VC300 + UWS600500	1.000
1HP	FP ≈ constant – WD500	0.416
Initiation	FP ≈ constant + LCL – VC500 + SH500 + VC300 + GH600	0.994

Table 4.15.4: Results of the PCAs Run on the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	7	98.134%
5HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	7	95.401%
4HP	STHC, SMXR, SMXS, UWND, VWND, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.582%
3HP	All variables	7	98.033%
2HP	STHC, SMXR, SMXS, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, UC600, UC500, UC300, UC200, UWSS500, UWS600500, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	6	93.562%
1HP	STHC, SMXR, SMXS, UWND, LCL, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	96.871%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.106%

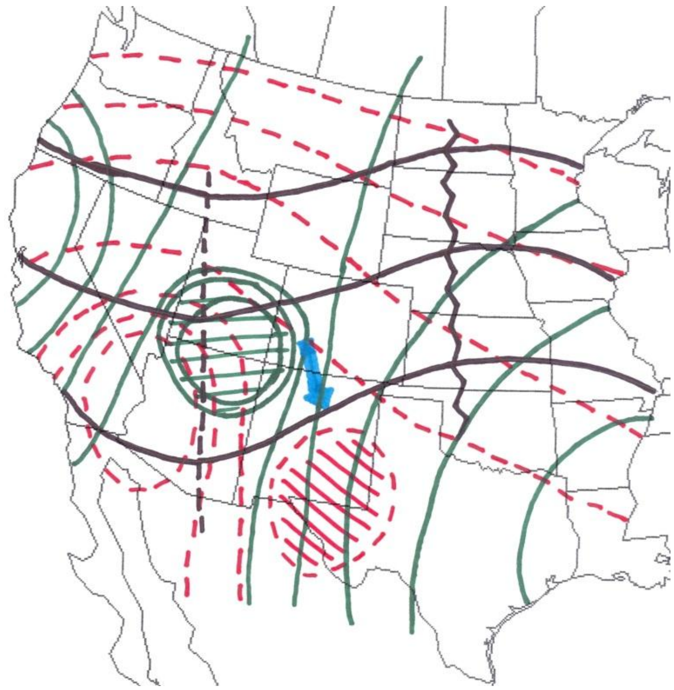


Figure 4.15.2: Composite Map for Trinchera Mesa/Valencia Hills/Howard Mountain, NM. The variables included on the map are STHC, GH500, SH500, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.16: West Mesa, NM

4.16.1: Description of Cluster

The West Mesa, NM cluster contains 29 members, and, therefore, is the first of the partial analyses. This cluster is located northeast of Socorro, NM. The median values for the surface and upper air variables are given in Table 4.16.1 and the median values from the NARR data are given in Table 4.16.2. Histograms for the West Mesa, NM cluster, Figure 4.16.1, were created for the start year, start month, start hour, and Julian Day.

4.16.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA on the West Mesa, NM cluster. The resulting equations and the R square values are included in Table 4.16.3. There were several variables that were never included in the model runs: SMXS, PW, GH500, GH300, GH200,

SH500, UC500, UC200, UWSS500, VC500, VC200, VWSS600, and T500 which are considered the least important to larger FPs within this cluster's domain. The variable used in the most model runs was T200 in six out of ten model runs. UC300, the next most used variable, was used in five out of ten model runs. These two variables are considered independently important to larger FPs within this cluster's domain; however, they are not used often enough to be considered significantly more important to larger FPs than any other variable. Seven of the ten model runs had multicollinearity issues present.

4.16.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.16.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues valued one or greater and percent variance accounted for with those eigenvalues. Most of the variables were used in every model run's most used list. The variables that were not included in every model run were LCL, CAPE, CIN, SRH, SH500, SH300, WD600, and WD500. The variable included in the fewest most used lists was LCL at seven out of ten model runs. This means that most of the variables are very important to MCSMI within the West Mesa, NM cluster domain. Each PCA can be used for the identification of what variables are needed to predict whether an MCS will form within the cluster domain in the given time frame.

4.16.4: Cluster Discussion

With the information from the two previous sections and the tables in section 4.16.5, the PCA is considered the better analysis for the West Mesa, NM cluster. There were too many model runs with multicollinearity issues even though eight of the model runs were perfect fits. Four of the PCAs had all of the variance accounted for with the components that had eigenvalues of one or greater. Therefore, the PCA will give a more accurate representation of the initiation.

The West Mesa, NM cluster is in a portion of the Rocky Mountains that contains no ridgeline since this cluster is on a mesa. The median wind direction at 600 and 500 mb and initiation give winds from the west-southwest; therefore, this indicates that winds from the west-southwest are needed for initiation along the mesa.

The composite map for West Mesa, NM is Figure 4.16.2. The most important temperature variable was T200. There is a relatively cooler pocket of air located over the cluster domain at 200 mb. The most important geopotential height variable was GH500. There is a ridge located barely west of the cluster domain. The heights will continue to increase until the ridge passes through, then the heights will begin to decrease. The most important moisture variable was SH200. There is a moist pocket of air located directly over the cluster domain at 200 mb. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 3.576 ms^{-1} at 310.805°.

4.16.5: Cluster Figures and Tables

Table 4.16.1: Median Values for the Upper Air and Surface Variables for the West Mesa, NM Cluster.

Variable	Median Value
STHC	36.610
SMXR	10.660
SMXS	15.960
UWND	1.800
VWND	1.940
LCL	636.030
LI	-0.560

Table 4.16.2: Median Values for the NARR Variables for the West Mesa, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5840.100	5847.000	5847.100	5854.600	5849.300
PW	24.300	22.200	22.200	26.200	22.500
CAPE	86.800	392.000	321.700	141.700	224.400
CIN	-5.900	-18.300	-14.900	-24.400	-23.700
SRH	28.800	43.800	12.500	54.600	60.100
GH600	4447.300	4458.200	4461.500	4435.400	4445.400
GH500	5901.700	5906.900	5910.200	5889.300	5900.400
GH300	9729.600	9710.100	9732.900	9725.000	9706.900
GH200	12472.800	12442.500	12474.100	12468.300	12436.200
SH850	1.160e-2	8.800e-3	9.600e-3	1.100e-2	9.600e-3
SH800	9.900e-3	7.800e-3	8.200e-3	9.700e-3	8.100e-3
SH600	5.000e-3	4.500e-3	4.900e-3	6.000e-3	5.600e-3
SH500	2.800e-3	2.300e-3	2.700e-3	3.500e-3	2.600e-3
SH300	4.400e-4	3.300e-4	4.500e-4	4.500e-4	4.100e-4
SH200	5.500e-5	5.100e-5	5.300e-5	5.200e-5	5.000e-5
UC600	4.100	0.876	1.900	3.200	1.700
UC500	3.400	3.700	1.500	3.900	3.100
UC300	2.300	3.800	3.400	2.300	4.000
UC200	3.800	6.000	5.000	1.500	6.600
UWSS500	1.660	1.910	-0.300	2.360	0.430
UWS600500	1.100	0.741	-1.278	0.800	1.100
UWSS600	1.530	3.092	0.730	1.830	0.940
WD600	208.811	243.130	247.166	217.093	232.595
WD500	269.116	277.415	244.235	278.881	279.549
VC600	1.200	0.479	0.486	1.900	1.300
VC500	-0.128	-1.900	-0.663	-1.500	-2.700
VC300	3.400	1.900	5.500	1.700	1.300
VC200	-0.548	0.559	3.900	0.490	-2.300
VWSS500	-2.225	-4.375	-3.460	-2.600	-4.730
VWS600500	1.300	-1.800	-1.137	-1.792	-4.100
VWSS600	-1.470	-3.000e-2	-1.520	-1.220	-0.140
T600	2.300	2.200	1.800	2.500	2.100
T500	-6.400	-6.900	-7.700	-6.000	-6.700
T300	-30.300	-31.900	-32.700	-30.600	-32.000
T200	-51.200	-53.600	-53.000	-51.200	-52.800
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5856.900	5851.900	5831.400	5848.400	5839.700
PW	22.800	23.300	20.900	22.200	25.100
CAPE	105.500	183.600	204.800	341.500	209.300
CIN	-24.600	-20.700	-37.400	-27.400	-21.700

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	23.100	50.000	64.900	20.400	74.000
GH600	4468.700	4438.000	4471.700	4463.100	4450.100
GH500	5918.100	5886.200	5908.500	5913.900	5903.000
GH300	9738.500	9708.400	9707.400	9724.800	9723.500
GH200	12476.900	12469.100	12444.900	12453.800	12471.100
SH850	9.400e-3	1.000e-2	9.100e-3	9.100e-3	1.140e-2
SH800	8.200e-3	8.700e-3	7.800e-3	8.100e-3	9.800e-3
SH600	5.300e-3	5.100e-3	4.600e-3	5.100e-3	5.100e-3
SH500	2.900e-3	3.200e-3	2.400e-3	2.700e-3	3.200e-3
SH300	3.700e-4	4.500e-4	4.500e-4	4.100e-4	4.700e-4
SH200	4.700e-5	5.000e-5	4.800e-5	5.600e-5	4.900e-5
UC600	2.300	1.700	5.100	3.000	2.000
UC500	1.100	2.500	3.900	1.500	-0.325
UC300	0.659	3.000	4.300	3.600	0.644
UC200	2.100	3.700	7.300	5.300	0.946
UWSS500	-0.700	0.600	1.430	-1.417	-2.032
UWS600500	0.458	0.000	0.400	-1.000	-1.600
UWSS600	0.460	2.707	4.430	0.930	0.460
WD600	236.889	241.763	240.164	252.897	241.113
WD500	272.992	253.124	272.132	293.459	58.373
VC600	0.133	0.783	0.692	-0.569	-1.500
VC500	-0.523	-0.985	-1.400	-2.100	-0.303
VC300	3.600	2.500	3.600	3.800	3.100
VC200	1.800	-0.149	-0.610	-0.534	0.860
VWSS500	-2.771	-3.655	-2.030	-2.300	-2.973
VWS600500	-0.455	-0.200	-2.300	-1.531	-0.600
VWSS600	-2.437	-2.337	1.910	-1.843	-2.860
T600	2.400	2.700	2.600	2.000	2.700
T500	-6.400	-6.500	-6.500	-6.800	-6.000
T300	-32.500	-31.200	-31.800	-32.800	-31.500
T200	-52.800	-51.400	-52.600	-52.800	-51.500

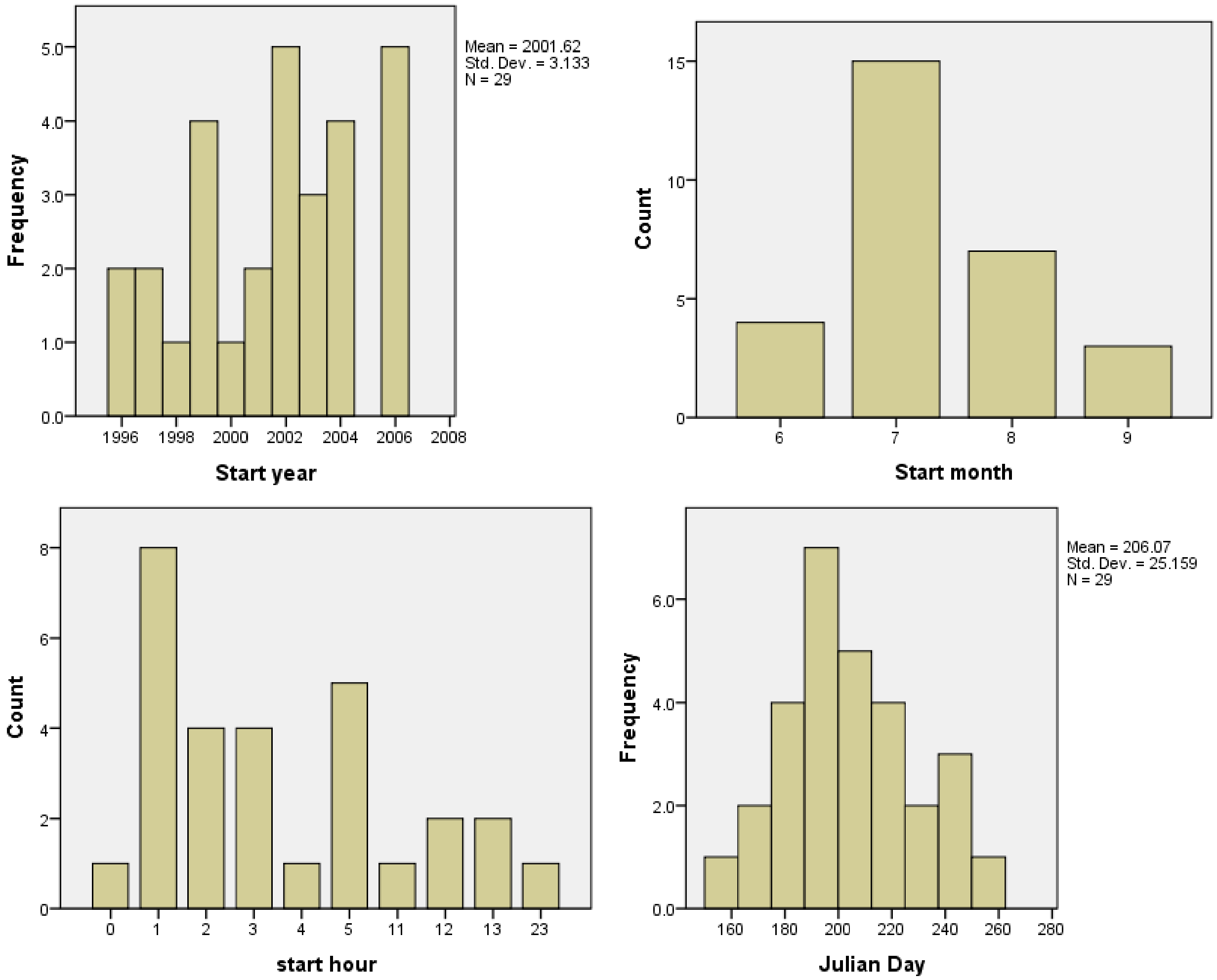


Figure 4.16.1: Time Histograms for the West Mesa, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.16.3: Results of the MLRs Run on the West Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – GH600 – UC600 + WD500 – VWND + T300 – Thickness	1.000
5HP	FP ≈ constant + VC600 – SH600 + WD600 – UC600 – CAPE – SMXR + T200 – LCL	1.000
4HP	FP ≈ constant + T200 + LI + UC300 – UWS600500 + SRH + VWS600500 – VC300 – VWND – GH600 – LCL	1.000
3HP	FP ≈ constant + CIN – CAPE + UC300 + STHC – UWSS600 – SRH	1.000
2HP	FP ≈ constant + VC600 – SH600 + T200 – GH600 – UC300 – SH800 + SH850 + Thickness + SH200 – T300	1.000
1HP	FP ≈ constant + T200 + LI + CAPE + UC300 + SH300 – VC600 – SH600 + LCL – VC300 – T600	1.000
Initiation	FP ≈ constant – CIN + T200 – SH850 + SH300 – WD500 + SH600	1.000

Table 4.16.4: Results of the PCAs Run on the West Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	6	100.000%
5HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.546%
4HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.531%
3HP	All variables	6	100.000%
2HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.908%
1HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	98.705%
Initiation	All variables	6	100.000%

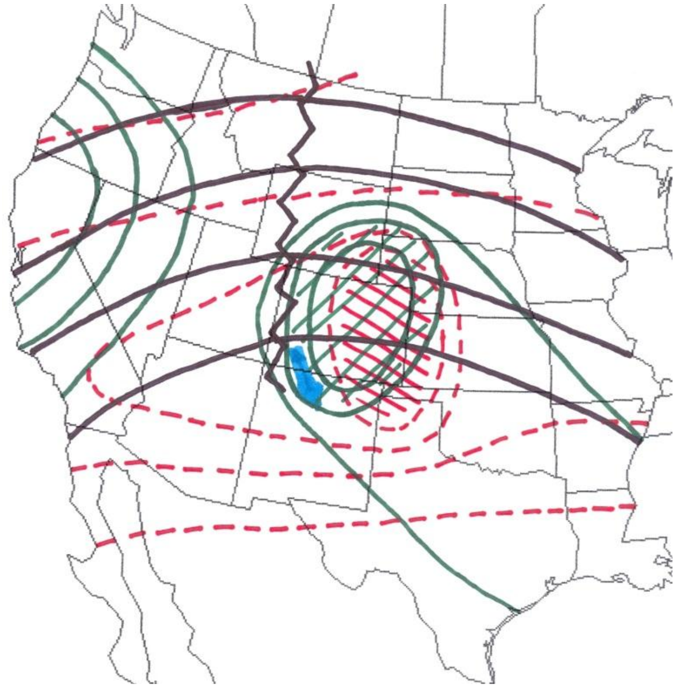


Figure 4.16.2: Composite Map for West Mesa, NM. The variables included on the map are T200, GH500, SH200, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.17: South Mountain, NM

4.17.1: Description of Cluster

The South Mountain, NM cluster, located east of Albuquerque, NM and just south of the San Pedro Mountains, contained 28 members. The median values for the surface and upper air variables are given in Table 4.17.1 and the median values from the NARR data are given in Table 4.17.2. Histograms for the South Mountain, NM cluster, Figure 4.17.1, were created for the start year, start month, start hour, and Julian Day.

4.17.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the South Mountain, NM cluster. The resulting equations and the R square values are included in Table 4.17.3. There were a few variables that were never included in the model runs: CAPE, CIN, GH500, UWSS500, VC600, and VWSS500. CAPE and CIN show that the stability variables are not important in the MLRs. These are considered to be the least important to larger FPs within the South Mountain, NM cluster. The variable included the most often was SRH at five out of ten model runs; therefore, the individual variables are not more important than any other variable. For the equations, the combination of the variables is the most important to larger FPs within this cluster's domain. Eight of the ten model runs had multicollinearity issues present in the equation and seven of the model runs were perfect fits. The 4HP model run was the poorest fit with an R square value of 0.627.

4.17.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.17.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. All of the variables were included in at least eight of the model runs; therefore, it can be assumed that all of the variables included in this analysis are important to MCSMI within this cluster's domain. Five of the model runs had every variable included in the most used list and four of the model runs had 100 percent of the accounted for variance.

4.17.4: Cluster Discussion

With the information gathered from the two sections above, the PCAs are considered the better fit to the data and should be used for the identification of variables needed for forecasting of an MCS within the South Mountain, NM domain. There were too many fit issues present with the MLRs and were corrected with the PCAs. All of the PCAs had accounted for variance of 93 percent or higher indicating a very good fit to the data. The PCAs would be used to accurately predict if an MCS will initiate within the next six hours within this cluster's domain.

The South Mountain, NM cluster is in a portion of the Rocky Mountains that contains no ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the east-southeast. This indicates that multiple wind directions are possible for initiation over this cluster.

The composite map for South Mountain, NM is Figure 4.17.2. The most important temperature variable was T500. There are pockets of cooler air to the northwest and north of the cluster domain indicating the cluster is in relatively warmer air. The most important geopotential height variable was GH300. The flow is fairly zonal with a small ridge located northwest of the cluster domain. The most important moisture variable was SH200. There are moist pockets of air to the west and east of the cluster domain indicating the domain is in relatively drier air at 200 mb. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 2.944 ms^{-1} at 323.286°.

4.17.5: Cluster Figures and Tables

Table 4.17.1: Median Values for the Upper Air and Surface Variables for the South Mountain, NM Cluster.

Variable	Median Value
STHC	37.460
SMXR	10.650
SMXS	18.205
UWND	0.000
VWND	0.000
LCL	687.100
LI	-0.760

Table 4.17.2: Median Values for the NARR Variables for the South Mountain, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5822.200	5847.550	5827.400	5814.500	5860.750
PW	22.000	24.250	20.200	21.200	23.350
CAPE	231.900	347.800	273.400	338.100	282.350
CIN	-13.100	-14.450	-29.500	-23.700	-15.050
SRH	23.700	42.450	44.300	39.400	44.950
GH600	4463.300	4474.050	4452.000	4469.900	4479.700
GH500	5906.000	5920.600	5892.600	5914.400	5929.950
GH300	9691.200	9733.500	9661.500	9699.100	9748.050
GH200	12423.200	12466.750	12406.900	12429.700	12486.000
SH850	9.500e-3	1.060e-2	9.200e-3	1.000e-2	1.040e-2
SH800	8.200e-3	9.250e-3	8.000e-3	8.800e-3	9.250e-3
SH600	4.500e-3	5.350e-3	4.300e-3	4.900e-3	4.950e-3
SH500	2.600e-3	3.000e-3	2.600e-3	2.500e-3	3.000e-3
SH300	3.900e-4	4.100e-4	4.100e-4	4.100e-4	4.500e-4
SH200	4.800e-5	5.650e-5	5.600e-5	4.900e-5	5.250e-5
UC600	-0.292	1.650	1.500	1.300	1.492
UC500	1.400	0.173	0.897	0.641	0.659
UC300	5.700	0.470	1.700	6.600	2.600
UC200	6.700	0.867	7.100	10.800	2.541
UWSS500	1.251	1.548	1.500	2.383	2.946
UWS600500	1.013	-0.858	0.300	-0.311	-0.852
UWSS600	0.620	3.600	2.800	1.900	2.498
WD600	178.032	221.585	228.715	232.431	211.067
WD500	233.720	182.542	219.196	231.953	206.676
VC600	-0.287	2.568	1.600	0.804	1.766
VC500	-1.600	4.500	2.900	-1.300	3.450
VC300	5.300	4.250	8.900	5.000	3.000
VC200	3.800	5.200	9.200	4.300	5.100
VWSS500	-1.730	5.266	4.150	-2.930	4.455
VWS600500	-0.100	-0.338	-1.025	-1.200	-0.573
VWSS600	-1.840	5.944	1.059	-1.571	5.326
T600	0.764	2.150	2.100	0.858	2.200
T500	-7.700	-6.750	-8.400	-7.400	-6.600
T300	-33.600	-31.500	-33.300	-33.000	-31.250
T200	-53.400	-52.550	-52.400	-52.900	-52.200
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5819.000	5809.100	5858.800	5805.900	5789.000
PW	23.300	22.400	24.250	21.300	23.200
CAPE	260.400	181.300	272.850	291.700	401.500
CIN	-15.200	-21.900	-23.100	-17.100	-35.600

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	28.500	42.400	44.500	54.800	45.600
GH600	4450.100	4467.800	4475.050	4443.400	4473.300
GH500	5893.000	5912.000	5926.250	5886.100	5912.700
GH300	9666.500	9688.400	9745.400	9662.100	9699.700
GH200	12398.400	12427.000	12487.400	12404.200	12416.700
SH850	9.500e-3	9.600e-3	1.050e-2	9.500e-3	1.070e-2
SH800	8.900e-3	8.700e-3	9.650e-3	8.300e-3	9.400e-3
SH600	5.300e-3	5.200e-3	5.300e-3	5.100e-3	4.600e-3
SH500	3.200e-3	2.800e-3	3.200e-3	2.900e-3	2.600e-3
SH300	2.900e-4	4.200e-4	5.400e-4	3.900e-4	4.300e-4
SH200	5.600e-5	5.400e-5	6.400e-5	4.600e-5	5.100e-5
UC600	4.400	0.755	1.950	5.400	0.536
UC500	4.100	-0.762	0.849	1.900	-0.285
UC300	1.200	5.300	0.356	3.400	4.800
UC200	5.200	10.700	-3.450	7.400	11.300
UWSS500	5.800	0.297	2.335	5.020	-0.440
UWS600500	-0.300	-0.400	-0.332	0.300	-1.900
UWSS600	6.173	1.760	3.405	7.110	2.148
WD600	229.939	251.565	215.037	252.933	199.447
WD500	236.310	105.715	195.743	261.730	127.875
VC600	3.700	1.200	1.950	3.200	-0.105
VC500	3.400	-0.914	2.818	0.588	-0.638
VC300	6.600	4.300	3.100	5.000	5.000
VC200	8.400	3.800	5.850	6.700	2.800
VWSS500	2.000	-3.040	3.671	0.150	-2.673
VWS600500	-0.300	-0.800	-0.684	-0.200	0.200
VWSS600	2.300	-2.360	4.490	-0.150	-2.160
T600	1.900	1.200	2.350	1.500	0.688
T500	-8.300	-8.000	-6.650	-8.800	-8.100
T300	-33.700	-33.100	-31.250	-33.200	-32.700
T200	-52.600	-53.500	-52.650	-52.600	-53.100

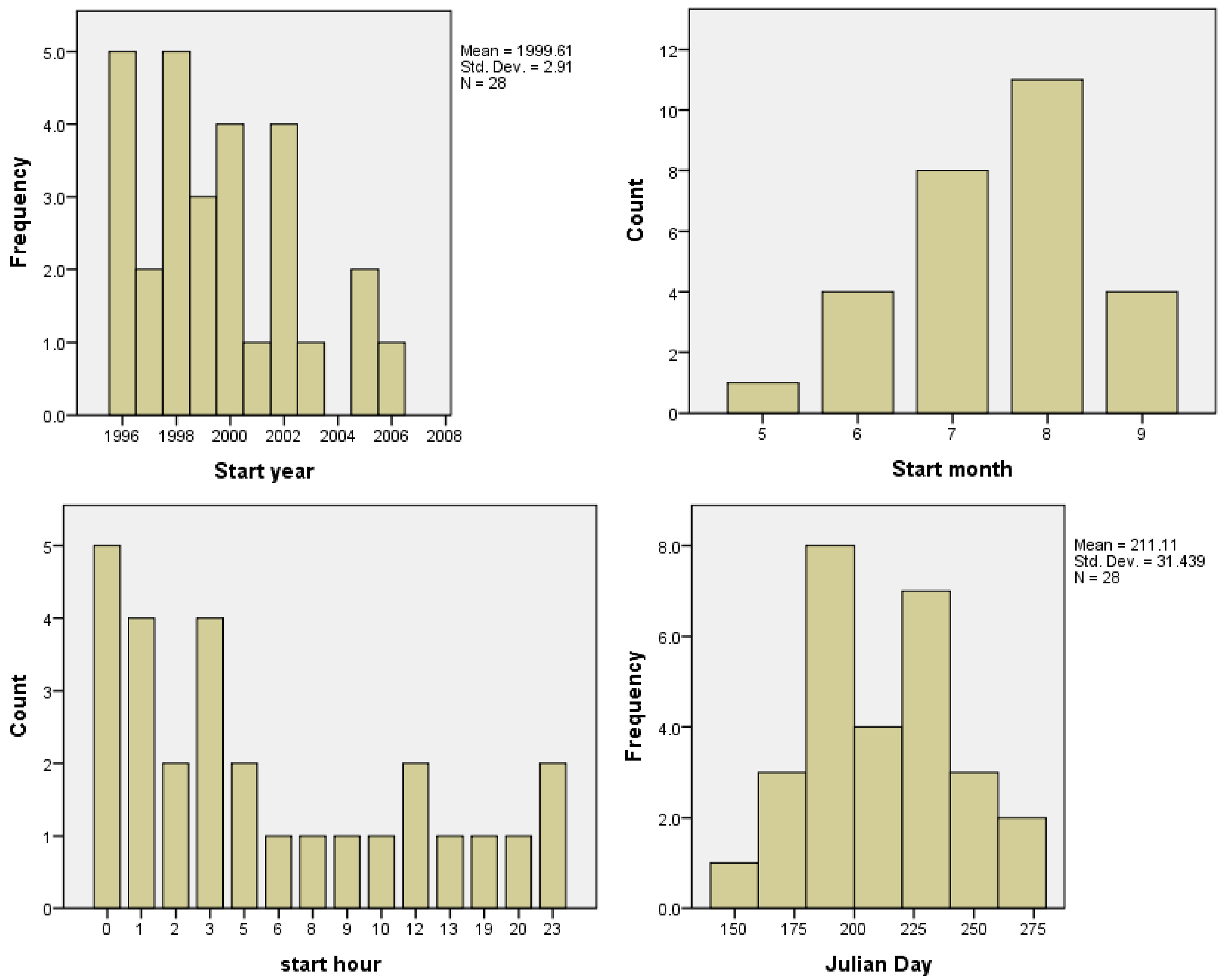


Figure 4.17.1: Time Histograms for the South Mountain, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.17.3: Results of the MLRs Run on the South Mountain, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – Thickness + SH500 + SMXS – SH300 + T600 + LI + T500 + UC600 – SH200	1.000
5HP	FP ≈ constant + SRH + VWSS600 – SH800 + UWND – VC300 – SH200 – SH850	1.000
4HP	FP ≈ constant – Thickness	0.627
3HP	FP ≈ constant + LCL – SH850 – SRH – UC200 + UWS600500 – VWND – T500 + GH200 + PW + UC500 – WD500 + GH300	1.000
2HP	FP ≈ constant + SH600 – Thickness	0.880
1HP	FP ≈ constant + UC300 + LI + LCL – T300 – UC200 – VC500	1.000
Initiation	FP ≈ constant + LCL – T600 – T200 – SRH – UC200 + SH600 + WD500 – UWSS600	0.999

Table 4.17.4: Results of the PCAs Run on the South Mountain, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T500, T300, T200	7	94.757%
5HP	All variables	7	100.000%
4HP	All variables	6	100.000%
3HP	All variables	9	97.681%
2HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	98.053%
1HP	All variables	6	100.000%
Initiation	STHC, SMXR, SMXS, UWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH800, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	93.859%

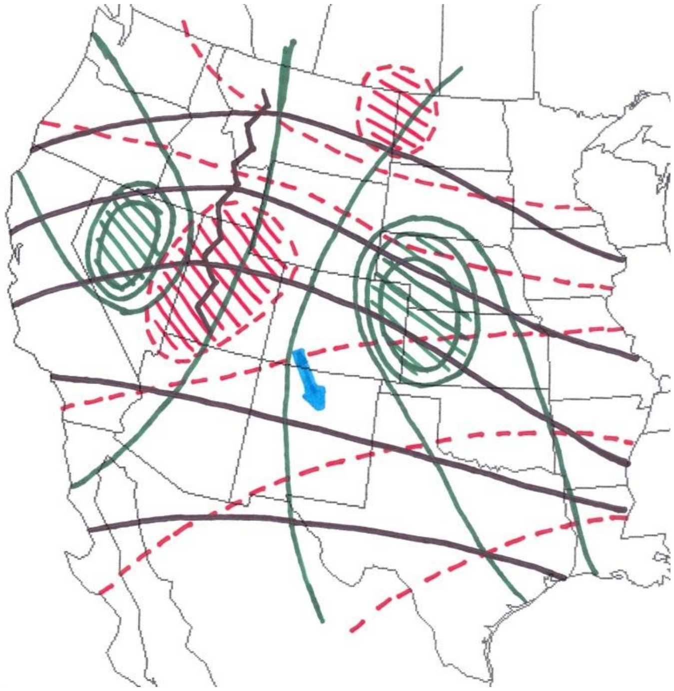


Figure 4.17.2: Composite Map for South Mountain, NM. The variables included on the map are T500, GH300, SH200, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.18: Badito Cone, CO

4.18.1: Description of Cluster

The Badito Cone, CO cluster, located due east of the Great Sand Dunes National Monument, contained 27 members. The median values for the surface and upper air variables are given in Table 4.18.1 and the median values from the NARR data are given in Table 4.18.2. Histograms for the Badito Cone, CO cluster, Figure 4.18.1, were created for the start year, start month, start hour, and Julian Day.

4.18.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Badito Cone, CO cluster. The resulting equations and the R square values are included in Table 4.18.3. There were several variables that were never included in the model runs: STHC, SMXS, UWND, VWND, PW, GH500, SH500, UC200, UWSS500, UWSS600, and T600. These variables are considered the least important to the creation of larger FPs within the Badito Cone, CO cluster domain according to the MLRs. The most included variables were LCL, CAPE, and VWS600500 at four out of ten model runs; therefore, no variable is considered more important than another variable. The combinations of the variables give the best fit to the data and are the most important to larger FPs. Six of the ten model runs were perfect fits and seven of the ten model runs had multicollinearity issues present.

4.18.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.18.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues valued one or greater, and percent variance accounted for with those eigenvalues. Almost every variable was included in every model run's most used list. The variables that were included between seven and nine times were: VWND, LCL, CIN, SRH, SH300, SH200, UC600, UC500, UWS600500, UWSS600, WD600, WD500, VC200, VWS600500, and T200. This indicates that every variable is important to MCSMI within the Badito Cone, CO cluster according to the PCAs. Within the PCAs, there were five model runs in which every variable was included in the most used list and four of those model runs accounted for 100 percent of the variance.

4.18.4: Cluster Discussion

With the information from the previous two sections and the tables included in section 4.18.5, it is determined that the PCA is the better type of analysis to use for this cluster. The fit issues seen in many of the MLRs are corrected with the PCAs. Even though the MLRs are good fits and can be quickly used to determine the variables needed for the potential FP, they do not determine if the potential for initiation is present. The PCAs will be used for identifying the variables needed for MCSMI that will occur within the Badito Cone, CO cluster.

The Badito Cone, CO cluster is in a portion of the Rocky Mountains that contains a northwest-southeast oriented ridgeline. The median wind direction at 600 and 500 mb and initiation give winds from the west-northwest which indicates that winds at 600 and 500 mb arrive at a slight angle to the ridgeline.

The composite map for Badito Cone, CO is Figure 4.18.2. The most important temperature variable was T500. A pocket of cooler temperatures is located to the north and one of warmer temperatures is located to the south of the cluster domain. The temperatures at 500 mb within the cluster domain can still be considered relatively warm. The most important geopotential height variable was GH300. There is a ridge located east of the cluster domain indicating the heights are falling at 300 mb. The most important moisture variable was SMXR. There are pockets of moist air to the east and west and a pocket of dry air to the northwest of the cluster domain. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 6.728 ms^{-1} at 277.164°.

4.18.5: Cluster Figures and Tables

Table 4.18.1: Median Values for the Upper Air and Surface Variables for the Badito Cone, CO Cluster.

Variable	Median Value
STHC	33.350
SMXR	10.510
SMXS	18.080
UWND	-1.780
VWND	0.000
LCL	662.980
LI	-0.520

Table 4.18.2: Median Values for the NARR Variables for the Badito Cone, CO Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5837.400	5837.500	5780.350	5835.100	5835.200
PW	17.050	18.900	16.550	18.050	18.300
CAPE	272.100	461.500	72.350	562.400	283.100
CIN	-59.750	-19.900	-15.200	-32.750	-35.400
SRH	18.000	43.200	50.700	24.700	31.600
GH600	4469.000	4456.200	4432.250	4468.450	4450.500
GH500	5923.300	5900.100	5877.500	5923.400	5894.500
GH300	9731.150	9647.400	9664.000	9726.900	9631.900
GH200	12457.150	12370.800	12396.050	12450.650	12341.200
SH850	1.020e-2	1.000e-2	8.600e-3	1.030e-2	1.010e-2
SH800	8.850e-3	8.500e-3	7.400e-3	8.950e-3	8.800e-3
SH600	4.350e-3	4.900e-3	3.800e-3	5.150e-3	4.600e-3
SH500	2.200e-3	2.300e-3	2.350e-3	2.250e-3	2.700e-3
SH300	4.050e-4	2.900e-4	2.700e-4	4.800e-4	3.700e-4
SH200	5.900e-5	5.100e-5	4.550e-5	5.800e-5	5.000e-5
UC600	4.850	1.800	1.650	2.750	1.300
UC500	4.300	4.400	5.550	4.200	3.900
UC300	8.350	7.100	6.500	9.050	7.300
UC200	16.600	12.500	9.750	16.300	11.000
UWSS500	6.975	5.060	3.580	6.875	5.560
UWS600500	0.200	2.966	3.299	1.000	3.200
UWSS600	7.825	3.800	0.170	4.705	2.846
WD600	279.675	256.171	248.658	255.820	236.821
WD500	264.047	266.566	257.737	278.312	253.740
VC600	-0.915	-0.655	0.173	-2.150	-0.222
VC500	-1.550	-1.700	-0.445	-1.848	0.646
VC300	1.823	6.100	5.900	0.863	5.600
VC200	-2.393	3.700	8.550	-1.600	5.100
VWSS500	-1.565	-5.400e-2	1.000e-2	-1.676	1.600e-2
VWS600500	-0.185	0.000	-0.327	0.337	1.300
VWSS600	-1.840	6.000e-2	0.801	-1.995	-0.762
T600	2.750	2.100	1.047	2.250	2.800
T500	-6.950	-8.500	-7.700	-7.450	-9.000
T300	-32.750	-33.400	-33.600	-32.950	-34.000
T200	-53.400	-53.500	-52.200	-53.250	-53.700
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5749.300	5841.150	5820.600	5742.700	5846.000
PW	17.400	17.900	18.800	16.600	20.300
CAPE	53.700	626.200	426.700	45.450	388.550
CIN	-15.900	-56.000	-40.000	-11.350	-56.050

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	54.500	15.550	-33.400	47.500	42.100
GH600	4421.200	4460.150	4460.200	4425.200	4461.800
GH500	5856.050	5912.850	5898.800	5860.950	5916.200
GH300	9637.900	9726.900	9631.100	9640.350	9731.100
GH200	12371.900	12451.000	12346.200	12370.500	12468.000
SH850	9.350e-3	1.055e-2	1.070e-2	9.850e-3	1.095e-2
SH800	8.100e-3	9.200e-3	9.200e-3	8.600e-3	9.500e-3
SH600	4.400e-3	4.800e-3	4.500e-3	4.000e-3	5.000e-3
SH500	2.450e-3	2.500e-3	2.600e-3	2.600e-3	2.900e-3
SH300	3.000e-4	4.250e-4	4.400e-4	2.650e-4	5.300e-4
SH200	5.100e-5	5.900e-5	5.700e-5	5.150e-5	5.850e-5
UC600	2.150	2.900	4.000	1.900	1.650
UC500	4.750	5.500	4.200	4.250	3.950
UC300	7.050	10.850	8.500	7.800	10.050
UC200	10.850	17.150	11.400	10.700	18.000
UWSS500	5.975	6.675	5.790	4.725	4.289
UWS600500	2.700	2.150	1.500	2.350	1.100
UWSS600	1.370	4.407	4.290	1.375	3.655
WD600	271.816	289.802	275.654	276.442	300.252
WD500	285.983	285.138	272.367	308.552	294.278
VC600	-0.341	-1.660	-0.396	-3.150	-2.050
VC500	-1.900	-1.950	-7.440e-2	-3.850	-3.350
VC300	2.250	1.190e-2	5.000	2.000	-1.000
VC200	2.800	-0.800	3.900	2.950	-1.857
VWSS500	-1.875	-0.839	-1.750	-3.340	-2.940
VWS600500	-0.701	-0.290	-0.600	-0.700	-1.100
VWSS600	-0.436	-0.614	-0.640	-2.440	-2.337
T600	2.430e-2	2.950	2.200	-0.539	2.750
T500	-8.850	-7.150	-8.700	-9.200	-6.750
T300	-34.400	-32.200	-33.300	-34.050	-31.700
T200	-52.750	-52.850	-53.900	-52.550	-52.850

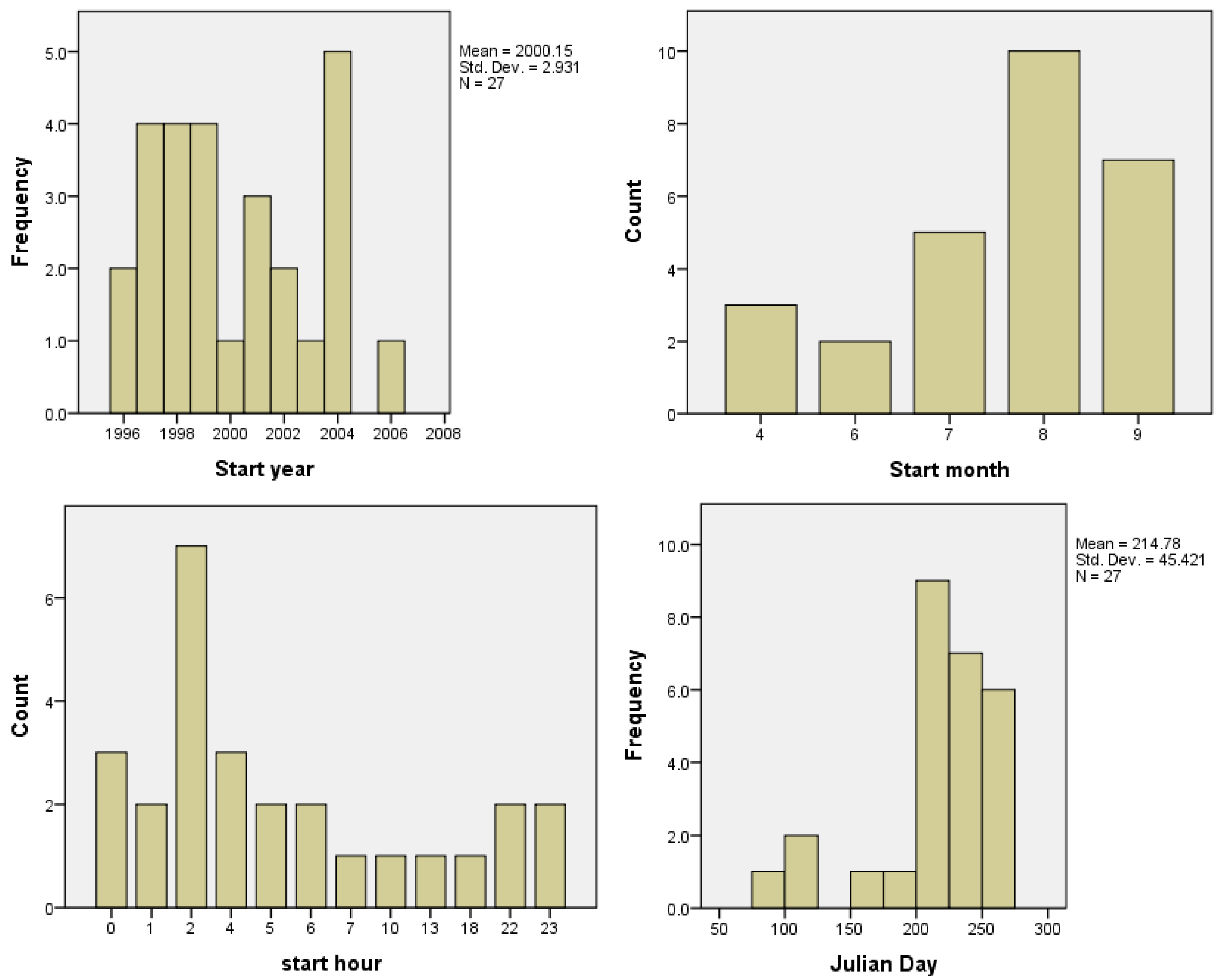


Figure 4.18.1: Time Histograms for the Badito Cone, CO Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.18.3: Results of the MLRs Run on the Badito Cone, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + LCL – CIN	0.881
5HP	FP ≈ constant – VWS600500 – SH800 – WD500 + WD600 + VC600 – VC200 + SH850	0.995
4HP	FP ≈ constant + VWSS500 – GH600 – LI – T200 + SH300 – GH300 + SH600 + VC300 – UC300	1.000
3HP	FP ≈ constant + LCL – CAPE + UC500 – UC300 + VC500	1.000
2HP	FP ≈ constant + UC600 – VWSS600 + CIN + SMXR + SH300 – GH300 – VC300 – CAPE + GH200 – SH800	1.000
1HP	FP ≈ constant + VWS600500 – SH200 – T300 + CAPE + SH300 + WD500 + VC200	1.000
Initiation	FP ≈ constant + LCL	0.718

Table 4.18.4: Results of the PCAs Run on the Badito Cone, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	5	100.000%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	97.146%
4HP	All variables	7	98.082%
3HP	All variables	5	100.000%
2HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	7	95.698%
1HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC300, UC200, UWSS500, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	94.620%
Initiation	All variables	5	100.000%

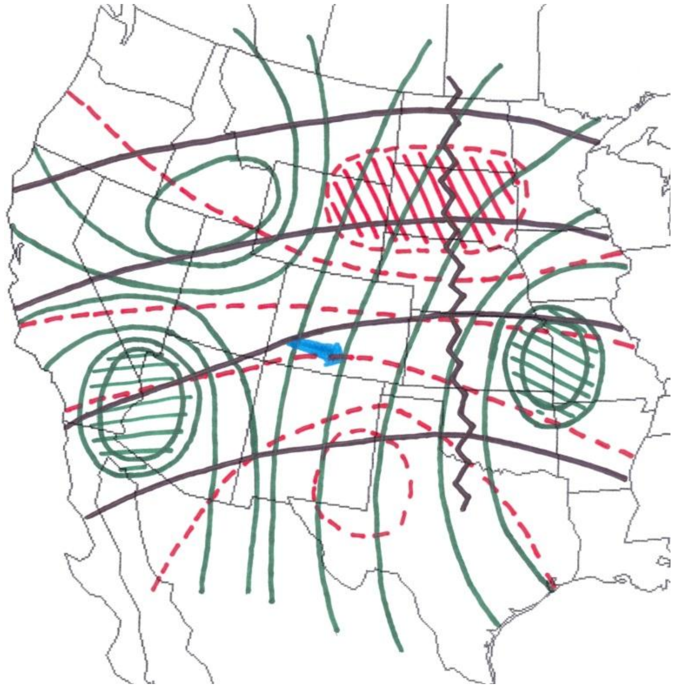


Figure 4.18.2: Composite Map for Badito Cone, CO. The variables included on the map are T500, GH300, SMXR, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: compiled from Plymouth State Weather Center.)

4.19: Bunker Hill, CO

4.19.1: Description of Cluster

The Bunker Hill, CO cluster, located north of Trinidad, CO, contained 27 members. The median values for the surface and upper air variables are given in Table 4.19.1 and the median values from the NARR data are given in Table 4.19.2. Histograms for the Bunker Hill, CO cluster, Figure 4.19.1, were created for the start year, start month, start hour, and Julian Day.

4.19.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Bunker Hill, CO cluster. The resulting equations and the R square values are included in Table 4.19.3. There were several variables that were never included in any model run: STHC, LCL, GH500, GH300, GH200, UC600, UWSS500, VC500, and VC300. Since they were never included in a model run, they are considered the least important variables to larger FPs within the domain. The variable that was included the most often was LI at six out of ten model runs. The next most included variable was T200 at five out of ten model runs. These two variables are considered the most important variables to larger FPs within this cluster's domain. Since they are not included in every model run, it can be assumed that the combination of variables is more important to initiation than individual variables. Six of the model runs were perfect fits and seven contained multicollinearity issues.

4.19.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.19.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues valued one or greater, and percent variance accounted for with those eigenvalues. Most of the variables were included in every model run's most used list except SMXS, UWND, VWND, LCL, LI, CAPE, SH600, SH200, UC300, WD600, WD500, VC300, VC200, and T200. LI was included the least often at five model runs which is different from the MLRs since it was the variable used the most often. The bulk of the variables included in the analysis are considered important to MCSMI within the Bunker Hill, CO domain. Only three of the model runs had every variable included in the most used list and those model runs were also the only ones to achieve 100 percent accounted for variance. All of the PCAs had accounted for variance of over 95 percent, indicating a very good fit to the data.

4.19.4: Cluster Discussion

With the information included in the last two sections and the tables included in section 4.19.5, the PCA analysis will be a better predictor of MCSMI within the cluster domain than the MLRs. The MLR at initiation was a very poor fit to the data and there were several model runs with multicollinearity issues. This means the PCAs need to be used to fix the fit issues. The PCAs were better fits to the data, included every variable in every component, and could be used for the identification of variables needed for the potential to predict if an MCS will form within the Bunker Hill, CO cluster domain.

The Bunker Hill, CO cluster is in a portion of the Rocky Mountains that contains a northwest-southeast oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the southwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that the winds at 600 and 500 mb will arrive at an angle to the ridgeline.

The composite map for Bunker Hill, CO is Figure 4.19.2. The most important temperature variable was T500. A pocket of relatively cooler temperatures is located northeast of the cluster domain. The cluster domain sits in relatively warmer temperatures at 500 mb. The most important geopotential height variable was GH500. There is a ridge located to the east and a trough to the west of the cluster domain. This indicates that as the pattern moves eastward, the heights will continue to fall until the trough passes through. The most important moisture variable was SH500. A moist pocket of air is located west of the cluster domain indicating the air within the cluster domain is relatively moist. There is also a dry pocket of air located southeast of the cluster domain. The most important wind shear was between 600 and 500 mb, two upper levels. The wind shear at initiation has a median value of 3.520 ms^{-1} at 270.146˚.

4.19.5: Cluster Figures and Tables

Table 4.19.1: Median Values for the Upper Air and Surface Variables for the Bunker Hill, CO Cluster.

Variable	Median Value
STHC	34.570
SMXR	10.020
SMXS	14.510
UWND	0.000
VWND	0.880
LCL	616.880
LI	-0.720

Table 4.19.2: Median Values for the NARR Variables for the Bunker Hill, CO Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5816.800	5839.800	5823.100	5828.100	5845.300
PW	16.400	17.500	18.600	16.400	17.550
CAPE	410.500	349.400	791.600	318.700	264.300
CIN	-23.000	-20.800	-40.600	-23.100	-23.100
SRH	39.200	70.350	84.050	47.900	81.550
GH600	4430.500	4461.450	4452.300	4456.400	4442.500
GH500	5876.200	5910.150	5888.850	5901.000	5895.200
GH300	9640.300	9645.950	9617.000	9660.900	9653.750
GH200	12338.100	12322.500	12313.700	12362.500	12341.050
SH850	9.100e-3	9.500e-3	9.600e-3	8.200e-3	9.200e-3
SH800	7.900e-3	8.250e-3	8.400e-3	7.100e-3	8.050e-3
SH600	4.000e-3	3.950e-3	4.350e-3	4.300e-3	4.150e-3
SH500	2.300e-3	1.950e-3	2.450e-3	2.600e-3	2.200e-3
SH300	2.200e-4	1.900e-4	2.400e-4	2.700e-4	2.550e-4
SH200	4.200e-5	4.250e-5	4.500e-5	4.600e-5	3.850e-5
UC600	5.800	3.200	7.450	6.500	6.100
UC500	9.400	7.800	10.550	8.300	9.100
UC300	11.500	14.450	17.300	10.900	11.300
UC200	21.100	18.400	28.550	20.900	17.750
UWSS500	8.800	8.935	10.660	9.020	9.535
UWS600500	3.200	3.800	3.100	2.800	3.850
UWSS600	4.740	4.895	5.710	3.820	7.480
WD600	256.759	243.401	269.089	237.863	244.908
WD500	267.937	262.589	289.153	285.422	272.288
VC600	1.800e-2	2.265	1.175	-0.223	1.760
VC500	0.317	1.800	-4.300	-3.200	0.200
VC300	6.700	3.900	-5.618	6.400	3.200
VC200	8.100	8.050	-5.300	8.600	6.150
VWSS500	0.317	-1.115	-0.595	-0.640	-2.585
VWS600500	0.300	-0.500	-1.900	-0.300	-1.960
VWSS600	-0.134	2.910	2.775	6.050e-2	1.573
T600	1.400	2.350	2.450	1.900	2.400
T500	-8.900	-9.900	-10.050	-9.200	-8.750
T300	-36.300	-36.300	-36.800	-36.300	-36.000
T200	-52.400	-54.000	-53.750	-52.700	-53.550
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5813.000	5828.500	5829.250	5796.700	5817.600
PW	17.150	15.600	19.050	17.100	15.700
CAPE	409.850	63.100	319.500	266.050	147.500
CIN	-59.650	-41.700	-47.300	-81.250	-71.900

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	92.500	61.300	92.300	94.600	69.800
GH600	4433.800	4434.400	4446.400	4449.200	4431.500
GH500	5868.300	5884.100	5862.350	5885.600	5875.400
GH300	9605.850	9652.400	9648.950	9624.300	9634.500
GH200	12307.100	12352.500	12332.750	12323.050	12331.100
SH850	9.950e-3	8.100e-3	1.020e-2	9.900e-3	9.100e-3
SH800	8.700e-3	7.000e-3	8.950e-3	8.800e-3	7.900e-3
SH600	3.850e-3	4.400e-3	4.200e-3	3.900e-3	3.900e-3
SH500	2.150e-3	2.500e-3	2.400e-3	2.050e-3	2.200e-3
SH300	2.050e-4	2.000e-4	2.650e-4	1.500e-4	1.800e-4
SH200	4.300e-5	3.600e-5	4.700e-5	4.500e-5	4.200e-5
UC600	7.200	3.500	8.150	7.450	4.100
UC500	11.450	8.500	9.650	11.550	7.700
UC300	16.750	11.500	12.900	16.300	12.200
UC200	30.200	21.500	16.950	27.200	22.000
UWSS500	11.460	6.390	10.295	10.990	7.700
UWS600500	2.350	2.900	1.850	4.250	1.400
UWSS600	7.010	3.520	8.160	5.810	4.230
WD600	294.660	234.676	265.053	298.332	273.073
WD500	278.731	264.193	280.634	273.109	263.660
VC600	-2.500	6.940e-2	0.582	-2.800	-0.818
VC500	-2.788	-0.321	-1.900	-3.447	0.413
VC300	-3.965	5.700	3.350	-4.505	4.700
VC200	-1.950	8.400	6.750	-2.200	7.000
VWSS500	0.703	-0.321	0.285	-1.192	-0.910
VWS600500	-2.800	-0.900	-1.800	-0.715	-0.100
VWSS600	-0.720	-9.000e-2	0.865	-1.078	9.000e-2
T600	2.250	2.300	2.300	2.400	2.100
T500	-9.700	-9.400	-9.000	-9.500	-9.400
T300	-36.250	-36.300	-35.800	-36.600	-36.400
T200	-53.350	-53.000	-53.750	-53.800	-53.300

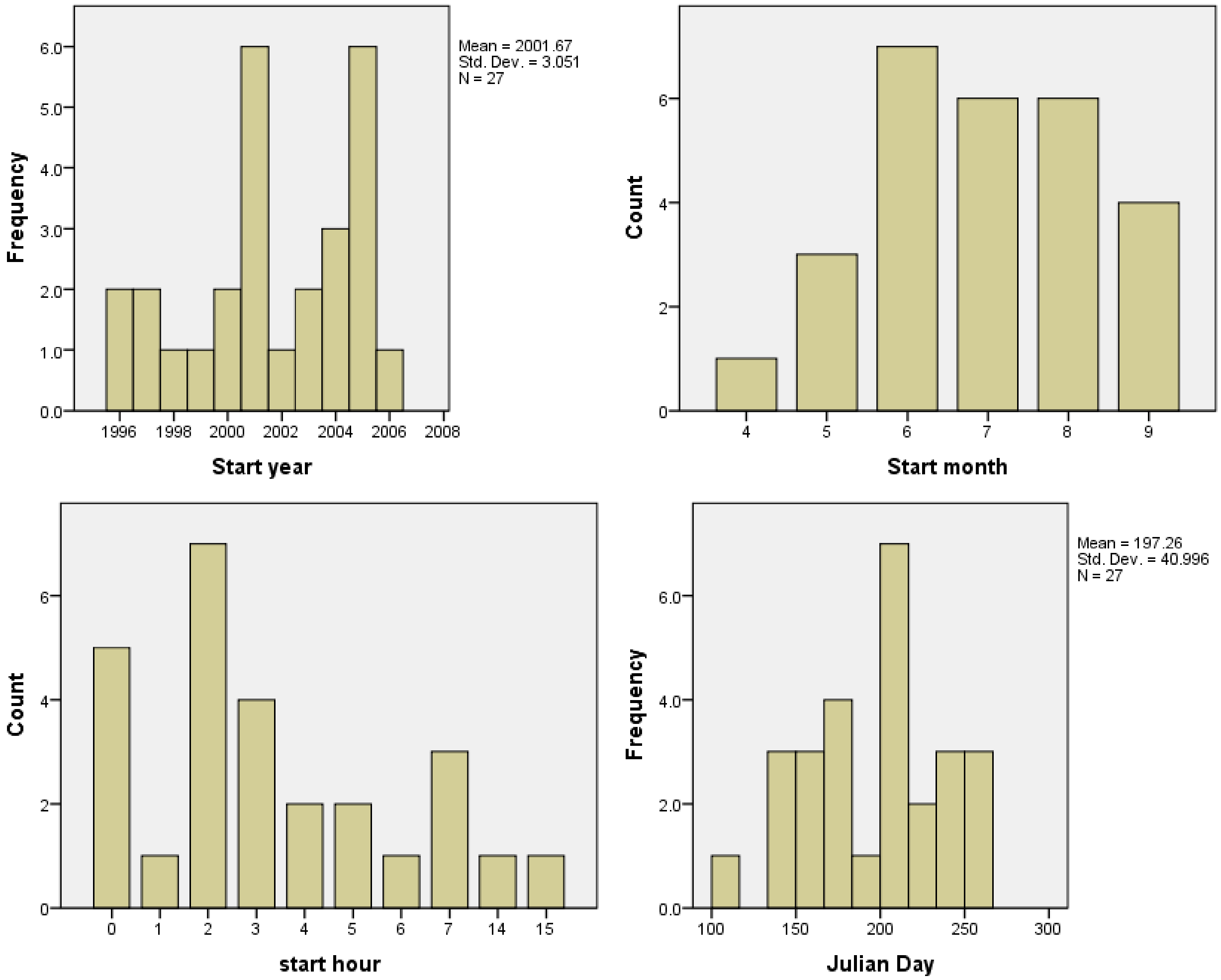


Figure 4.19.1: Time Histograms for the Bunker Hill, CO Cluster. Frequency was used in the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.19.3: Results of the MLRs Run on the Bunker Hill, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – UC200 – UWND + LI + VC600	0.812
5HP	FP ≈ constant + LI + UWS600500 + CIN + SH850 + VWSS600 – T200 + VWSS500 + WD500 – UC300	1.000
4HP	FP ≈ constant + SRH + VC200 – T200 + LI + CAPE	1.000
3HP	FP ≈ constant – UC200 + UWSS600 – VWND – SMXR + PW + GH600 – UC500 – WD500	0.999
2HP	FP ≈ constant + UC500 + LI + T600 + UWS600500	0.991
1HP	FP ≈ constant + SRH – LI + Thickness + WD500 + SH500	1.000
Initiation	FP ≈ constant + SH300	0.372

Table 4.19.4: Results of the PCAs Run on the Bunker Hill, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	95.468%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	96.672%
4HP	All variables	5	100.000%
3HP	STHC, SMXR, SMXS, UWND, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	95.736%
2HP	STHC, SMXR, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	96.383%
1HP	All variables	5	100.000%
Initiation	STHC, SMXR, SMXS, UWND, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	95.642%

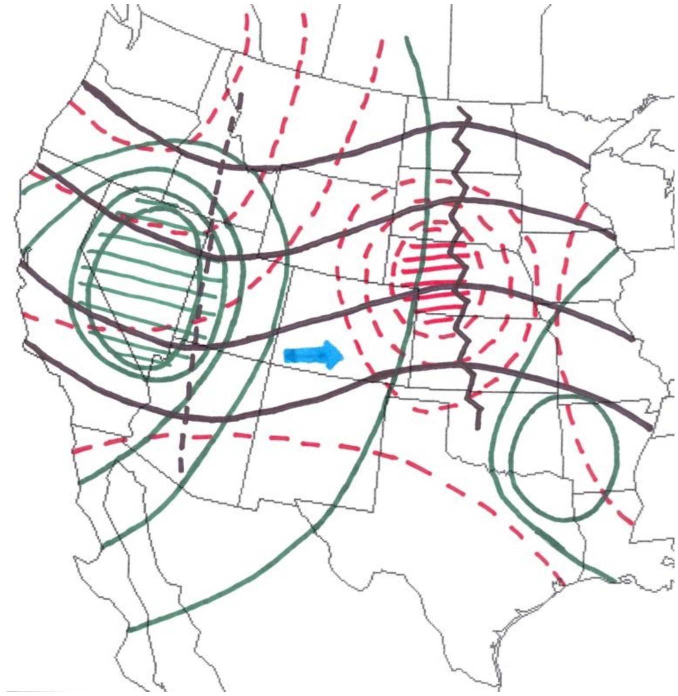


Figure 4.19.2: Composite Map for Bunker Hill, CO. The variables included on the map are T500, GH500, SH500, and wind shear between 600 and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.20: Caliente Canyon/Long Canyon, NM

4.20.1: Description of Cluster

The Caliente Canyon/Long Canyon, NM cluster, located due west of Bartlett Mesa, NM, contained 27 members. The only significant features located near the center of this cluster were several canyons. The median values for the surface and upper air variables are given in Table 4.20.1 and the median values from the NARR data are given in Table 4.20.2. Histograms for the Caliente Canyon/Long Canyon, NM cluster, Figure 4.20.1, were created for the start year, start month, start hour, and Julian Day.

4.20.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA on the Caliente Canyon/Long Canyon, NM cluster. The resulting equations and the R square values are included in Table 4.20.3. There were two model runs that had no resulting equations. The entry value was increased to 0.20 to gain model run results, but this was unsuccessful. If the entry value was increased to 0.25, there was too much error associated with the final answer. Those two model runs were at 4HP and 2HA. There were several variables that were never included in the equations: SMXR, UWND, PW, SRH, GH200, SH600, SH500, VWSS500, T500, and T300. These variables are considered the least important to larger FPs within this cluster's domain. The variables that were included the most often were LI and GH600 at three out of ten model runs. Five of six wind shear variables were used at least once in every MLR. Since the number of times the variables are used is so low, it is the combination and how they are used that is more important to larger FPs within the domain than any specific variable. Of the model runs that had results, four were perfect fits and also had multicollinearity issues. With the two model runs were missing, the PCAs needed to be run to correct these issues.

4.20.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.20.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater and percent variance accounted for with those eigenvalues. Most of the variables were included on every most used list. Those not included were STHC, SMXR, LI, CAPE, GH600, SH800, SH200, UC600, UC300, UC200, VC200, VWS600500, and T200. The variables that were included the least often were SMXR and VC200 which were included in seven most used lists. Since all of the variables were included so often in the model runs, then all are important to MCSMI within this cluster's domain. Five of six wind shear variables were included on every most used list, so this set of variables is considered very important to MCSMI within this cluster's domain. Four of the model runs had all of the variables included on the most used list and those had all of the accounted for variance. The remaining model runs accounted for 94 percent or more of the variance showing that all were good fits to the data. These PCAs will be able to be used for the identification of variables needed for the accurate prediction of MCSMI within the Caliente Canyon/Long Canyon, NM cluster domain.

4.20.4: Cluster Discussion

With the information listed above, the PCA analysis will be the better analysis type for the potential of predicting MCSMI within this cluster's domain. Between two missing model runs and the multiple multicollinearity issues, there were just too many problems with the MLRs for it to be considered the better analysis type for this cluster. The MLR equations could still be used for the potential of predicting the FP but there will be times where the equation is less useful than others. However, the PCAs were consistently good fits to the data and used every variable in the analysis. Therefore, for the identification of that variables needed for accurate prediction of an MCSMI within this cluster, the PCA results need to be used.

The Caliente Canyon/Long Canyon, NM cluster is in a portion of the Rocky Mountains that contains no ridgeline. The median wind direction at 600 mb and initiation gives winds from the west. The median wind direction at 500 mb and initiation gives winds from the west-northwest. This indicates that winds are mainly from the west for this cluster.

The composite map for Caliente Canyon/Long Canyon, NM is Figure 4.20.2. The most important temperature variable was T500. There is a pocket of cooler temperatures to the northwest and one of warmer temperatures to the east of the cluster domain. If the pattern moves eastward, the temperatures will drop at 500 mb. As it is, the temperatures are considered relatively warm within the domain. The most important geopotential height variable was GH500. There is a ridge located east of the cluster domain indicating heights are dropping within the domain. The most important moisture variable was SH300. The cluster domain sits in relatively dry air since the drier pocket of air is closer to the domain than the moist pocket of air. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 9.567 ms^{-1} at 273.286°. This wind shear value is the largest out of all the clusters.

4.20.5: Cluster Figures and Tables

Table 4.20.1: Median Values for the Upper Air and Surface Variables for the Caliente Canyon/Long Canyon, NM Cluster.

Variable	Median Value
STHC	35.280
SMXR	10.450
SMXS	16.010
UWND	-1.160
VWND	-3.090
LCL	643.940
LI	-1.100

Table 4.20.2: Median Values for the NARR Variables for the Caliente Canyon/Long Canyon, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5781.750	5849.100	5867.950	5802.850	5845.000
PW	12.600	19.500	18.650	13.300	19.200
CAPE	240.250	280.400	162.900	208.250	76.100
CIN	-20.900	-11.300	-13.750	-15.450	-34.800
SRH	48.050	19.000	36.050	52.000	14.000
GH600	4394.900	4460.300	4478.550	4391.700	4453.700
GH500	5825.800	5906.200	5924.150	5824.950	5897.300
GH300	9557.400	9695.900	9733.000	9556.300	9708.400
GH200	12242.500	12434.400	12482.250	12239.900	12445.100
SH850	8.500e-3	1.030e-2	9.600e-3	8.500e-3	9.900e-3
SH800	7.400e-3	8.900e-3	8.350e-3	7.350e-3	8.600e-3
SH600	3.450e-3	4.900e-3	5.650e-3	4.150e-3	4.900e-3
SH500	1.700e-3	2.800e-3	2.800e-3	2.000e-3	2.900e-3
SH300	2.350e-4	4.200e-4	3.600e-4	2.150e-4	3.800e-4
SH200	3.400e-5	4.700e-5	4.850e-5	3.550e-5	4.200e-5
UC600	5.500	4.500	2.850	4.800	5.500
UC500	8.650	4.200	5.750	10.050	5.700
UC300	18.400	12.400	6.100	18.350	9.900
UC200	20.600	11.100	11.950	18.650	12.000
UWSS500	10.930	5.690	7.225	12.330	7.290
UWS600500	3.150	2.482	3.250	4.400	0.500
UWSS600	7.780	3.090	4.258	6.670	5.500
WD600	284.669	256.724	248.710	280.436	258.973
WD500	274.086	271.622	266.225	285.757	272.534
VC600	-1.483	-1.570e-2	1.200	-1.194	-0.354
VC500	-1.050	-0.489	-1.200e-2	-2.336	-0.485
VC300	-5.920e-2	7.100	4.550	-2.094	3.700
VC200	0.766	6.400	4.550	-0.385	4.000
VWSS500	1.835	2.700	3.515	0.647	1.600
VWS600500	1.333	-0.419	-1.512	-0.877	-1.485
VWSS600	0.953	3.300	3.165	2.230	1.800
T600	-5.000e-2	2.900	2.500	0.500	3.000
T500	-10.550	-7.500	-6.950	-10.650	-6.900
T300	-38.000	-31.700	-31.300	-37.650	-31.900
T200	-54.550	-52.500	-52.300	-54.450	-52.400
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5866.650	5792.450	5821.400	5851.500	5766.150
PW	18.100	13.550	17.900	17.850	13.000
CAPE	134.450	122.650	191.000	299.100	189.750
CIN	-21.100	-25.600	-44.800	-44.150	-30.100

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	21.800	41.500	20.900	26.600	19.100
GH600	4476.800	4398.250	4455.700	4470.250	4390.250
GH500	5924.850	5830.050	5900.300	5920.850	5821.200
GH300	9739.650	9557.000	9702.300	9738.850	9545.950
GH200	12484.550	12238.500	12433.100	12489.300	12225.900
SH850	8.900e-3	8.000e-3	1.060e-2	9.800e-3	8.850e-3
SH800	7.750e-3	6.900e-3	9.100e-3	8.550e-3	7.650e-3
SH600	5.500e-3	3.950e-3	4.900e-3	5.150e-3	3.550e-3
SH500	2.900e-3	2.050e-3	2.300e-3	2.850e-3	1.850e-3
SH300	3.050e-4	2.050e-4	3.100e-4	4.050e-4	2.000e-4
SH200	5.350e-5	3.750e-5	5.100e-5	5.500e-5	4.500e-5
UC600	2.094	4.300	5.100	3.200	3.300
UC500	4.000	7.100	7.800	4.850	5.600
UC300	9.500	14.450	11.400	9.450	10.350
UC200	12.250	18.500	17.200	12.100	17.400
UWSS500	6.790	9.550	6.390	6.130	8.250
UWS600500	3.357	3.800	1.000	1.655	2.300
UWSS600	2.753	4.990	5.390	5.395	5.950
WD600	226.413	276.957	267.900	228.668	308.675
WD500	283.621	296.820	266.502	248.256	306.872
VC600	0.802	-1.172	0.187	1.800	-2.200
VC500	-0.871	-3.800	-0.493	-0.734	-2.900
VC300	5.500	5.000e-2	0.257	2.800	0.174
VC200	4.750	1.744	4.500	1.850	4.150
VWSS500	0.665	-0.565	1.320	1.346	-0.615
VWS600500	-2.030	-1.828	-0.358	-0.684	-2.700
VWSS600	-2.162	0.280	2.700	3.525	0.185
T600	3.000	0.500	2.600	3.000	5.000e-2
T500	-6.850	-10.600	-8.000	-7.050	-10.800
T300	-31.400	-37.900	32.500	-31.700	-37.150
T200	-52.800	-54.250	-52.400	-52.450	-54.350

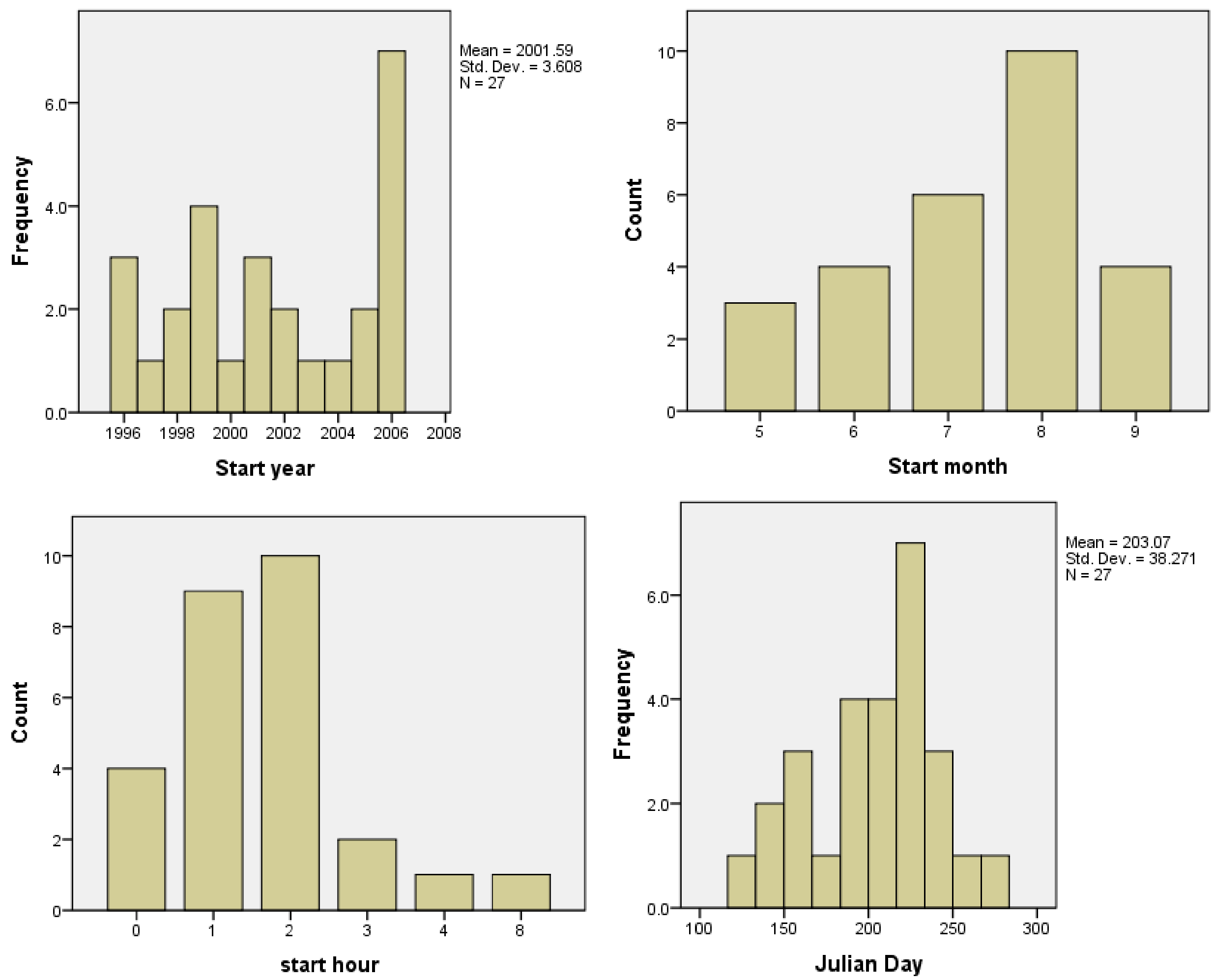


Figure 4.20.1: Time Histograms for the Caliente Canyon/Long Canyon, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.20.3: Results of the MLRs Run on the Caliente Canyon/Long Canyon, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – LI + GH600 – CIN – WD500 – UWSS500	1.000
5HP	FP ≈ constant + VC200 + CAPE + VWND – UWS600500 – SMXS – LCL + WD500 + SH200 – GH500 – SH850	1.000
4HP	MISSING	N/A
3HP	FP ≈ constant – LI	0.523
2HP	FP ≈ constant + UWSS600 – UC500 + T600 – VWND + VWS600500 – Thickness + STHC + T200 + VC600 – WD600	1.000
1HP	FP ≈ constant + WD600 – UC600 – GH600	0.836
Initiation	FP ≈ constant – LI	0.523

Table 4.20.4: Results of the PCAs Run on the Caliente Canyon/Long Canyon, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	5	100.000%
5HP	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	97.341%
4HP	SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH600, SH500, SH300, SH200, UC500, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	6	94.490%
3HP	All variables	5	100.000%
2HP	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.946%
1HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.061%
Initiation	All variables	5	100.000%

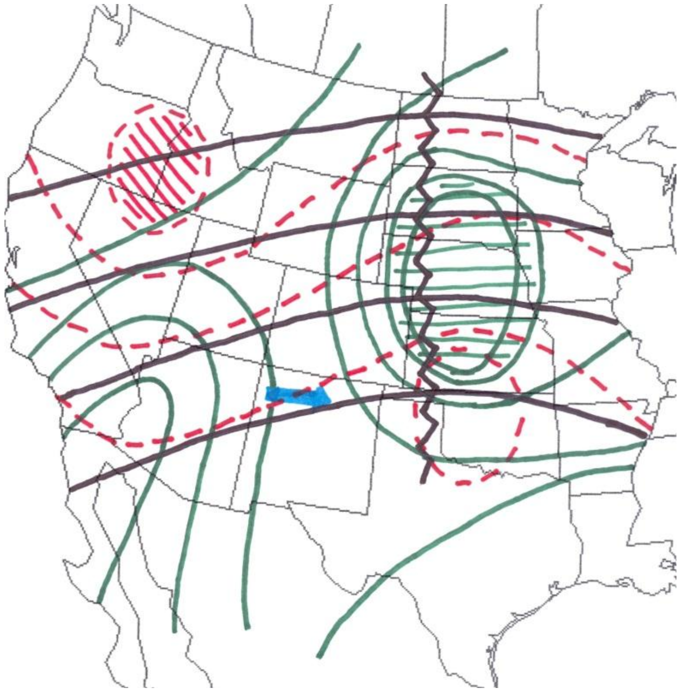


Figure 4.20.2: Composite Map for Caliente Canyon/Long Canyon, NM. The variables included on the map are T500, GH500, SH300, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.21: Cowboy Mesa, NM

4.21.1: Description of Cluster

The Cowboy Mesa, NM cluster contains 27 members and is located south-southeast of the Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster. The median values for the surface and upper air variables are given in Table 4.21.1 and the median values from the NARR data are given in Table 4.21.2. Histograms for the Cowboy Mesa, NM cluster, Figure 4.21.1, were created for the start year, start month, start hour, and Julian Day.

4.21.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA on the Cowboy Mesa, NM cluster. The resulting equations and the R square values are included in Table 4.21.3. There were several variables that were never included in the model runs: GH600, SH850, UWSS500, UWS600500, UWSS600, WD600, VC200, and VWSS600. They are considered the least important variables to larger FPs within this cluster's domain. While many of the remaining variables were included more than once in the MLRs, no variable was included more than four times (VWND, LI, SRH, and VC300). This indicates the combination of the variables is more important to larger FPs than individual variables according to the MLRs. This is also consistent with several previous clusters. Overall, the MLRs were good fits to the data with eight model runs being perfect fits. The remaining two R square values were 0.872 and 0.848, still considered relatively good fits. Multicollinearity issues were present in eight model runs – the same model runs that were perfect fits. Since there were so many multicollinearity issues present, a different type of analysis needs to be performed to correct the issue.

4.21.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.21.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. Most of the variables were included in every model run. The variable that was included in the fewest most used lists was WD600 at six out of ten and could be considered the least important variable to MCSMI within the cluster. According to the PCAs, every variable is important to the potential for MCSMI. Two model runs contained all of the variables within the most used list and had 100 percent accounted for variance. The remaining model runs had accounted for variances of 94 percent or more.

4.21.4: Cluster Discussion

Even though eight of the MLRs were perfect fits, there were multicollinearity issues associated with each model run. Therefore, the PCA was the better type of analysis for this cluster. Most of the variance was accounted for in every model run and the variables were often included in the most used lists. These PCAs will be able to be used for the identification of the variables needed to accurately predict MCSMI within the Cowboy Mesa, NM cluster.

The Cowboy Mesa, NM cluster is in a portion of the Rocky Mountains that contains no ridgeline since it is on a mesa. The median wind direction at 600 mb and initiation gives winds from the west. The median wind direction at 500 mb and initiation gives winds from the northwest. This indicates winds along this mesa have a westerly component at both 600 and 500 mb.

The composite map for Cowboy Mesa, NM is Figure 4.21.2. The most important temperature variable was T500. There is a relatively cool pocket of air to the north of the cluster domain indicating relatively warmer temperatures are present within the domain. The most important geopotential height variable was GH500. There is a ridge located east of the cluster domain indicating that as the ridge moves east the heights will drop within the domain. The most important moisture variable was SH300. Moist pockets of air are present east and west of the cluster domain indicating the cluster domain is in a relatively dry pocket of air. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 7.442 ms^{-1} at 330.007˚.

4.21.5: Cluster Figures and Tables

Table 4.21.1: Median Values for the Upper Air and Surface Variables for the Cowboy Mesa, NM Cluster.

Variable	Median Value
STHC	37.950
SMXR	11.340
SMXS	16.670
UWND	0.000
VWND	0.890
LCL	644.210
LI	0.000

Table 4.21.2: Median Values for the NARR Variables for the Cowboy Mesa, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5853.100	5823.200	5839.450	5878.850	5838.000
PW	23.800	23.200	20.000	24.200	23.700
CAPE	393.350	452.600	103.750	309.650	671.700
CIN	-23.050	-16.700	-20.300	-11.300	-26.000
SRH	38.500	23.400	36.300	39.850	37.900
GH600	4471.650	4443.900	4467.500	4471.150	4449.900
GH500	5914.050	5900.600	5916.950	5914.850	5897.500
GH300	9702.000	9677.200	9703.450	9708.950	9680.300
GH200	12423.900	12417.800	12421.300	12433.750	12422.800
SH850	1.010e-2	9.700e-3	7.300e-3	8.850e-3	1.000e-2
SH800	9.250e-3	8.600e-3	6.800e-3	8.100e-3	8.900e-3
SH600	4.400e-3	4.800e-3	4.450e-3	4.950e-3	4.700e-3
SH500	2.400e-3	2.300e-3	2.100e-3	2.600e-3	2.500e-3
SH300	2.800e-4	2.300e-4	2.600e-4	3.400e-4	4.500e-4
SH200	5.050e-5	3.000e-5	4.300e-5	5.000e-5	5.300e-5
UC600	2.150	1.400	5.450	2.200	2.700
UC500	1.950	2.400	9.450	0.910	3.500
UC300	3.850	6.900	7.550	6.100	7.000
UC200	10.500	9.700	14.850	11.400	8.800
UWSS500	2.590	3.650	7.340	2.040	2.450
UWS600500	0.309	2.100e-2	1.600	0.100	1.100
UWSS600	1.770	3.680	5.785	2.450	4.650
WD600	238.754	267.637	242.257	269.978	263.864
WD500	209.257	276.062	244.344	280.979	291.516
VC600	-1.550	0.293	0.813	-1.950	0.675
VC500	-1.098	-1.200	2.750	-3.700	-2.500
VC300	0.947	-0.901	2.750	-0.600	1.400
VC200	-2.300	-2.700	3.350	-1.750	-2.000
VWSS500	-2.995	-1.110	0.690	-5.275	-1.340
VWS600500	0.500	-1.554	-0.472	-0.400	-2.475
VWSS600	-2.340	-0.391	0.685	-2.952	-2.280e-2
T600	2.850	2.000	2.500	3.100	2.000
T500	-7.950	-7.800	-8.200	-8.150	-8.400
T300	-33.700	-32.900	-34.400	-33.650	-33.400
T200	-52.400	-52.700	-52.900	-52.800	-53.900
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5836.800	5868.850	5825.300	5822.800	5847.200
PW	22.000	23.400	24.600	22.200	23.000
CAPE	184.900	373.400	408.600	92.350	422.300
CIN	-18.900	-20.850	-40.900	-34.000	-36.400

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	47.450	48.300	37.300	67.300	78.050
GH600	4463.400	4469.300	4454.900	4454.550	4477.950
GH500	5915.850	5915.100	5901.800	5905.550	5922.300
GH300	9701.750	9700.700	9665.700	9700.950	9708.500
GH200	12412.750	12447.650	12398.500	12414.450	12441.450
SH850	7.800e-3	8.450e-3	8.000e-3	8.500e-3	9.000e-3
SH800	7.100e-3	7.800e-3	7.400e-3	7.750e-3	8.250e-3
SH600	5.000e-3	4.800e-3	5.100e-3	4.450e-3	4.650e-3
SH500	2.400e-3	2.500e-3	3.100e-3	2.750e-3	2.350e-3
SH300	3.200e-4	3.300e-4	3.800e-4	3.250e-4	3.500e-4
SH200	4.550e-5	4.400e-5	5.300e-5	4.650e-5	5.100e-5
UC600	6.450	3.050	3.500	6.450	3.300
UC500	7.450	2.200	3.500	8.200	2.050
UC300	8.550	6.900	2.900	8.350	7.550
UC200	15.300	9.800	9.700	13.500	10.350
UWSS500	7.990	3.720	5.300	7.890	3.370
UWS600500	2.294	0.200	-1.400	0.989	-0.900
UWSS600	5.735	3.653	5.780	5.840	2.670
WD600	250.510	273.928	262.669	250.631	273.792
WD500	256.617	324.208	225.000	270.740	251.439
VC600	1.038	-0.462	-3.690e-2	0.940	-2.400
VC500	0.528	-5.300	-3.300	-0.319	-6.600
VC300	4.000	-0.891	-1.500	4.850	-3.200
VC200	5.100	-2.150	-3.300	5.950	-1.112
VWSS500	-2.250	-6.445	-2.110	-3.642	-7.390
VWS600500	-2.600	-1.400	-0.955	-1.450	-2.000
VWSS600	-0.235	-3.066	0.862	-2.920	-3.200
T600	2.200	3.200	1.900	2.100	2.700
T500	-8.050	-7.450	-8.100	-7.700	-7.950
T300	-34.500	-33.450	-32.900	-34.400	-33.050
T200	-53.700	-52.700	-53.200	-53.450	-52.950

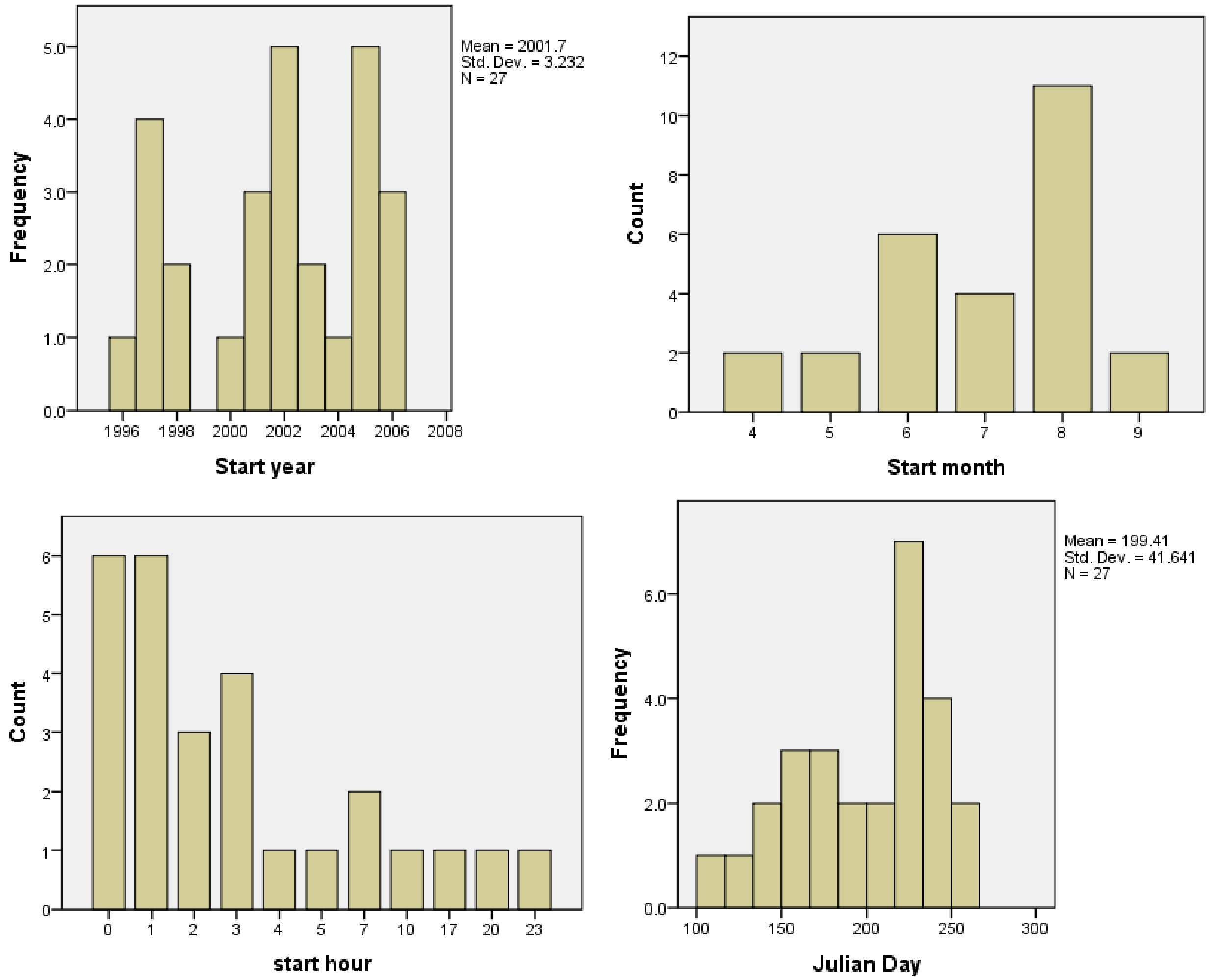


Figure 4.21.1: Time Histograms for the Cowboy Mesa, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.21.3: Results of the MLRs Run on the Cowboy Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + SH300 – PW – WD500	0.872
5HP	FP ≈ constant – Thickness + VC500 – SH200 – VC600 + GH500 + T600	1.000
4HP	FP ≈ constant + UWND + VWND	0.848
3HP	FP ≈ constant + VC300 – SH200 – WD500 + T300 + UC500 + VWSS500 + UC200 – LI + GH500	1.000
2HP	FP ≈ constant – T600 + T200 – UC600 + UC200 + VC300 + GH300	1.000
1HP	FP ≈ constant + UWND + VWND – CAPE + T200 – SMXS + UC300 + SH600 – PW + UC200	1.000
Initiation	FP ≈ constant + VC300 + SH500 – T500 – VWND + UC300 – SRH – LI – UC600 – SMXR	1.000

Table 4.21.4: Results of the PCAs Run on the Cowboy Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.176%
5HP	All variables	6	100.000%
4HP	STHC, SMXR, SMXS, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	6	94.945%
3HP	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.919%
2HP	All variables	6	100.000%
1HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.484%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	98.433%

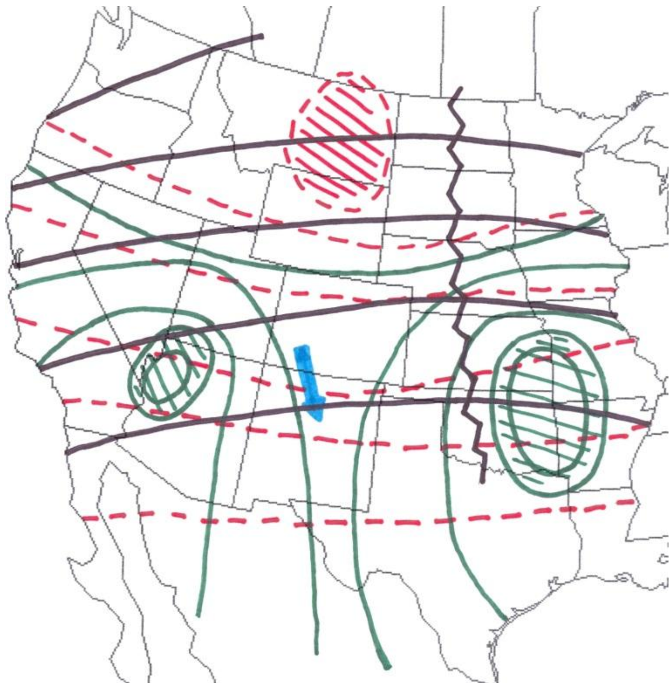


Figure 4.21.2: Composite Map for Cowboy Mesa, NM. The variables included on the map are T500, GH500, SH300, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.22: Las Mesa Del Conjelon, NM

4.22.1: Description of Cluster

The Las Mesa Del Conjelon, NM cluster contains 27 members and is located south of Springer, NM. The median values from the surface and upper air variables are given in Table 4.22.1 and the median values from the NARR data are given in Table 4.22.2. Histograms for this cluster, Figure 4.22.1, were created for the start year, start month, start hour, and Julian Day.

4.22.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA on the Las Mesa Del Conjelon, NM cluster. The resulting equations and R square values are included in Table 4.22.3. There were several variables that were never included in the model runs: GH300, GH200, SH600, UWSS500, UWS600500, WD500, VWSS500, and T200. Since the Thickness and geopotential height variables are included in this list, these variables are unimportant to larger FPs according to the MLRs which differs from previous clusters. The variable included the most often was CAPE in five out of ten model runs. Since no variable was included in a majority of the model runs, no individual variable is considered more important to larger FPs than another variable, it is the combination of variables. This cluster had six model runs that were perfect fits to the data and had multicollinearity issues present. One of the model runs was a very poor fit at 0.496.

4.22.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.22.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues valued one or greater, and percent variance accounted for with those eigenvalues. Almost every variable was included in every most used list. Those not included in every list were SMXR, CIN, and SH200. Every variable can be considered important to MCSMI within the cluster domain according to the PCAs. Six model runs had all of the variables included on the most used list. The other model runs contained almost every variable. Three of the model runs had 100 percent of the variance accounted for and all of the model runs had over 97 percent of the overall accounted for variance.

4.22.4: Cluster Discussion

Using the above information and the information included in section 4.22.5, the PCA is the better type of analysis for this cluster. The multiple multicollinearity issues and the one poor fit to the data prove the MLRs are not the best to use. They can still be used for the identification of the variables needed for larger FPs but it cannot be used for the prediction if an MCS will form as the PCAs do. The PCAs were very good fits to the data, and although harder to understand, will more easily and more accurately be used for the identification of the variables needed for the potential to predict MCSMI within the Las Mesa Del Conjelon, NM cluster.

The Las Mesa Del Conjelon, NM cluster is in a portion of the Rocky Mountains that contains no ridgeline since it is on a mesa. The median wind direction at 600 mb and initiation gives winds from the west-northwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates winds along this mesa require a westerly component at 600 and 500 mb.

The composite map for Las Mesa Del Conjelon, NM is Figure 4.22.2. The most important temperature variable was T300. A cooler pocket of air is located northwest and a warmer pocket of air is located east of the cluster domain. This indicates the cluster domain is in relatively warmer air. The most important geopotential height variable was GH300. There is a ridge that is just east of the cluster domain indicating the heights are relatively high but will decrease as the ridge moves eastward. The most important moisture variable was SH500. The cluster domain is within an area of relatively moist air at 500 mb. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 7.108 ms^{-1} at 255.788°.

4.22.5: Cluster Figures and Tables

Table 4.22.1: Median Values for the Upper Air and Surface Variables for the Las Mesa Del Conjelon, NM Cluster.

Variable	Median Value
STHC	37.620
SMXR	8.770
SMXS	17.160
UWND	0.000
VWND	0.000
LCL	606.150
LI	0.160

Table 4.22.2: Median Values for the NARR Variables for the Las Mesa Del Conjelon, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5845.700	5857.800	5860.900	5856.150	5866.300
PW	20.550	20.500	20.250	20.900	17.300
CAPE	209.000	300.800	174.050	99.350	120.100
CIN	-17.900	-16.700	-32.900	-25.550	-29.900
SRH	27.400	54.800	52.100	38.000	56.900
GH600	4453.800	4431.300	4444.9500	4455.450	4438.000
GH500	5901.750	5874.200	5886.300	5908.650	5884.600
GH300	9710.650	9671.700	9663.850	9720.000	9684.500
GH200	12447.250	12447.200	12425.450	12452.650	12458.700
SH850	9.200e-3	8.900e-3	8.800e-3	9.100e-3	7.200e-3
SH800	8.000e-3	7.700e-3	7.700e-3	8.050e-3	6.200e-3
SH600	4.900e-3	4.600e-3	4.900e-3	4.850e-3	4.900e-3
SH500	2.500e-3	2.400e-3	2.250e-3	2.900e-3	2.200e-3
SH300	3.200e-4	2.700e-4	2.250e-4	4.250e-4	1.800e-4
SH200	3.800e-5	4.100e-5	4.050e-5	4.300e-5	4.100e-5
UC600	3.050	6.000	3.450	3.550	6.800
UC500	5.600	6.800	6.250	4.550	7.000
UC300	7.850	9.200	9.950	7.100	8.700
UC200	6.500	8.100	11.850	9.150	8.100
UWSS500	7.230	8.960	6.980	4.962	10.330
UWS600500	0.518	2.100	1.591	-0.540	1.939
UWSS600	5.940	8.230	3.968	6.190	8.500
WD600	314.020	242.103	271.519	273.104	256.729
WD500	292.771	256.045	300.165	266.783	266.752
VC600	-1.350	-0.854	-0.776	-1.259	-1.100
VC500	-2.450	-1.400	-2.600	-3.500	-2.100
VC300	1.584	-0.389	-1.299	1.900	-2.400
VC200	1.656	-2.900	-1.395	0.950	-1.700
VWSS500	2.620	-4.950	-2.915	9.000e-2	-3.750
VWS600500	-0.200	-0.400	-2.547	-2.342	-1.524
VWSS600	1.743	-2.504	1.271	1.237	0.350
T600	2.000	2.600	2.400	2.500	2.900
T500	-8.050	-8.400	-8.400	-6.950	-8.600
T300	-32.250	-32.100	-31.750	-32.500	-32.000
T200	-51.850	-53.100	-52.400	-52.250	-53.100
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5839.300	5843.500	5854.400	5824.650	5828.050
PW	20.750	19.050	18.100	20.150	16.650
CAPE	232.450	135.250	162.900	217.100	99.300
CIN	-46.150	-41.950	-52.900	-74.050	-60.150

Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
SRH	61.500	37.050	88.500	80.050	10.850
GH600	4458.850	4462.900	4439.600	4461.750	4464.700
GH500	5895.300	5914.250	5885.500	5907.700	5915.900
GH300	9670.000	9712.800	9651.100	9675.550	9702.250
GH200	12437.950	12446.700	12432.500	12442.150	12433.000
SH850	9.300e-3	9.850e-3	8.400e-3	9.200e-3	9.350e-3
SH800	8.250e-3	8.850e-3	7.300e-3	8.150e-3	8.600e-3
SH600	4.800e-3	4.700e-3	4.100e-3	4.450e-3	4.050e-3
SH500	2.800e-3	2.300e-3	2.200e-3	2.500e-3	2.050e-3
SH300	2.200e-4	3.050e-4	2.000e-4	2.100e-4	2.700e-4
SH200	4.000e-5	4.850e-5	4.600e-5	4.150e-5	5.100e-5
UC600	3.550	4.000	7.200	2.350	3.200
UC500	4.200	2.166	5.900	2.850	1.575
UC300	9.800	7.700	6.200	8.650	6.550
UC200	11.550	8.350	10.100	13.000	6.900
UWSS500	5.097	3.922	11.020	2.515	4.396
UWS600500	0.450	0.400	1.700	-0.721	1.075
UWSS600	4.144	6.890	8.900	3.366	6.090
WD600	271.128	294.076	269.460	276.712	211.174
WD500	285.164	264.147	283.134	242.098	199.828
VC600	-1.133	-2.250	-1.500	-0.586	-1.289
VC500	-2.450	-3.150	-3.700	-2.426	-2.350
VC300	-1.359	0.852	-4.200	-1.079	3.050
VC200	0.101	-0.858	0.798	0.679	0.150
VWSS500	-2.215	0.975	-4.850	-1.635	2.850
VWS600500	-0.667	-1.200	-1.100	-0.560	-1.112
VWSS600	-1.045	1.745	-1.367	0.389	0.945
T600	2.400	2.450	2.100	2.350	2.650
T500	-8.500	-7.850	-8.500	-8.550	-7.400
T300	-32.000	-32.500	-32.600	-31.800	-32.650
T200	-52.150	-51.950	-52.800	-52.900	-52.000

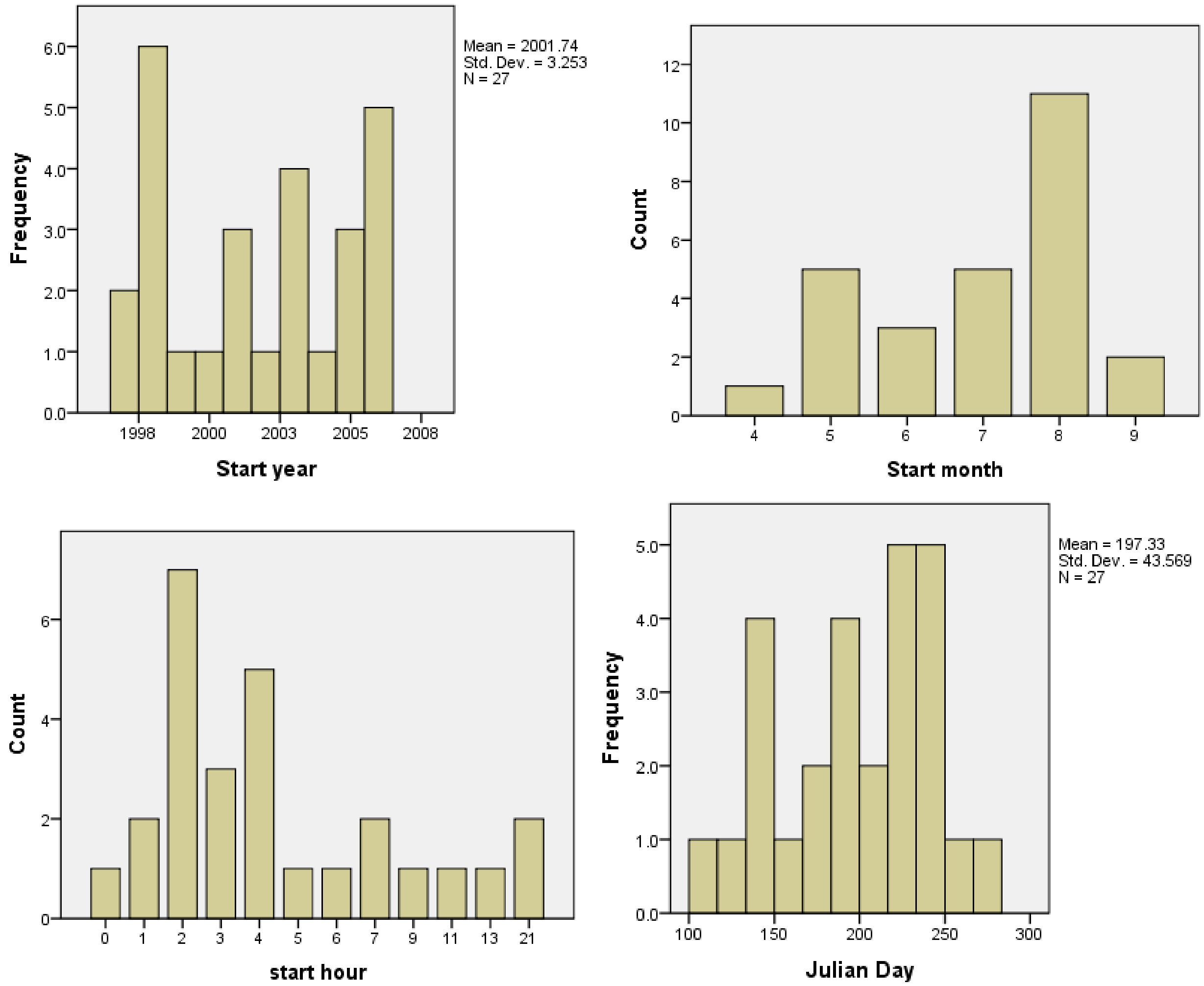


Figure 4.22.1: Time Histograms for the Las Mesa Del Conjelon, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.22.3: Results of the MLRs Run on the Las Mesa Del Conjelon, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + LCL + T600	0.763
5HP	FP ≈ constant + CAPE + VC600 + SH500 + CIN – SMXR + UWND + LI – SRH	1.000
4HP	FP ≈ constant + CAPE + VWSS600 + T300 + WD600 – SH300 + T500 + LI + UWSS600 – UC300	1.000
3HP	FP ≈ constant – WD600 – VC600 – LCL – SMXR + T300 – CIN + PW	1.000
2HP	FP ≈ constant + CAPE – UC200 – STHC	0.976
1HP	FP ≈ constant + CAPE – UWND	0.953
Initiation	FP ≈ constant – WD600 – VC600 – LCL + LI + UWND + UC500 + SH850	1.000

Table 4.22.4: Results of the PCAs Run on the Las Mesa Del Conjelon, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	97.732%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	98.081%
4HP	All variables	8	99.207%
3HP	All variables	7	100.000%
2HP	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.941%
1HP	All variables	8	98.922%
Initiation	All variables	7	100.000%

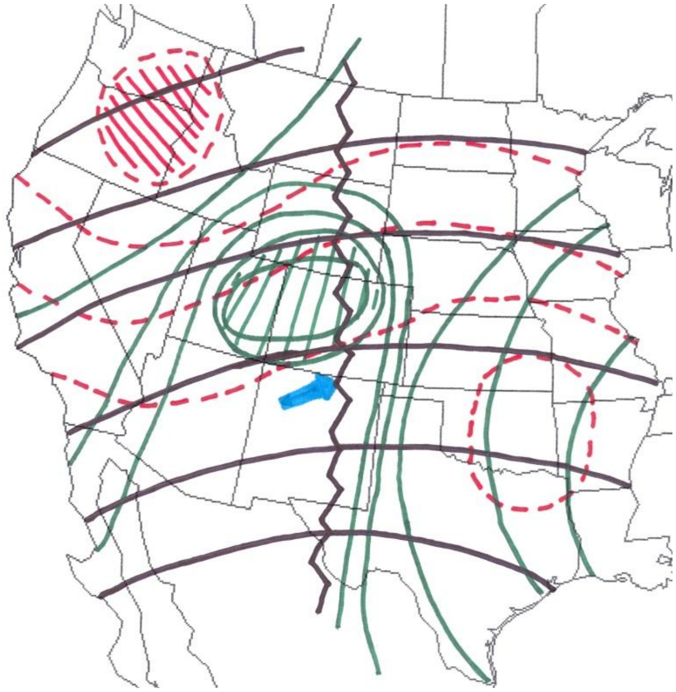


Figure 4.22.2: Composite Map for Las Mesa Del Conjelon, NM. The variables included on the map are T300, GH300, SH500, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.23: Laughlin Peak, NM

4.23.1: Description of Cluster

The Laughlin Peak, NM cluster contained 24 members and is located south-southeast of Raton, NM. The median values for the surface and upper air variables are given in Table 4.23.1 and the median values from the NARR data are given in Table 4.23.2. Histograms for this cluster, Figure 4.23.1, were created for the start year, start month, start hour, and Julian Day.

4.23.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Laughlin Peak, NM cluster. The resulting equations and the R square values are included in Table 4.23.3. There were several variables that were never used in the model runs: LI, Thickness, GH600, GH300, SH800, UC500, UWSS500, UWSS600, WD600, VC500, VC300, VWS600500, VWSS600, T500, and

T300. They are considered the least important to larger FPs within the Laughlin Peak, NM cluster domain. The variable included the most often was SH200 in seven out of ten model runs. This variable is considered the most important to larger FPs within this cluster and should be observed to determine if and when initiation will occur. The next most included variable was SMXS at five out of ten model runs. These two variables are considered the most important and the combination of them and the remaining variables will provide the best estimate for the FP and initiation within the cluster domain. All ten model runs had fit issues present which will be corrected in the PCA. Seven of the model runs were perfect fits indicating that the FP will be easily calculated within the cluster domain but there are the multicollinearity issues.

4.23.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.23.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. Most of the variables were included in every model run. Those not included were SMXS, UWND, LCL, LI, CAPE, CIN, GH600, UC300, WD500, VWS600500, and T200. This list is significantly larger than the previous cluster and indicates the stability variables are not important to this cluster. The variable included the least was LCL at seven out of ten model runs. This shows that every variable is important to MCSMI within the Laughlin Peak, NM cluster domain according to the PCAs. For this cluster, seven of the model runs had every variable included on the most used list and those same seven model runs had all of the accounted for variance. This can be due to the fact that the sample size of the clusters is decreasing making it easier to achieve a perfect fit.

4.23.4: Cluster Discussion

Since all of the MLRs had fit issues, the PCAs needed to be run to correct those dependency issues. Most of the MLRs were perfect fits but the multicollinearity issues are a significant problem, too great for the MLR analysis to be appropriate. The PCAs were very good fits and will be able to be used for identifying the necessary variables for MCSMI within the Laughlin Peak, NM cluster domain.

The Laughlin Peak, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the southwest. The median wind direction at 500 mb and initiation gives winds from the west-southwest. This indicates winds at 600 and 500 mb will arrive at an angle to the ridgeline.

The composite map for Laughlin Peak, NM is Figure 4.23.2. The most important temperature variable was STHC. Cooler potential temperatures are located northeast and warmer potential temperatures are located west and southeast of the cluster domain. This indicates that the cluster is within an area of relatively warm surface potential temperatures. The most important geopotential height variable was GH500. There is a ridge located west of the cluster domain indicating the heights within the domain will rise until the ridge passes through. The most important moisture variable was SH200. The cluster domain is located in an area of relatively moist air at 200 mb. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 5.065 ms^{-1} at 205.558˚.

4.23.5: Cluster Figures and Tables

Table 4.23.1: Median Values for the Upper Air and Surface Variables for the Laughlin Peak, NM Cluster.

Variable	Median Value
STHC	34.795
SMXR	9.420
SMXS	15.490
UWND	1.365
VWND	-0.975
LCL	639.750
LI	-0.625

Table 4.23.2: Median Values for the NARR Variables for the Laughlin Peak, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5824.350	5871.900	5827.500	5835.300	5865.200
PW	17.600	21.600	16.700	18.850	21.300
CAPE	528.400	740.200	133.000	238.750	139.100
CIN	-12.750	-21.900	-19.300	-12.650	-23.700
SRH	46.450	27.400	46.700	25.350	48.800
GH600	4464.850	4475.600	4441.600	4453.550	4481.100
GH500	5903.850	5924.600	5871.000	5894.500	5926.900
GH300	9673.900	9724.400	9629.900	9669.250	9733.900
GH200	12389.800	12445.100	12327.400	12389.100	12453.600
SH850	8.400e-3	9.100e-3	7.800e-3	8.200e-3	8.600e-3
SH800	7.150e-3	7.800e-3	6.700e-3	7.000e-3	7.400e-3
SH600	4.100e-3	4.800e-3	4.100e-3	5.200e-3	5.300e-3
SH500	2.000e-3	2.400e-3	2.100e-3	2.600e-3	2.400e-3
SH300	2.850e-4	3.200e-4	2.700e-4	2.700e-4	2.900e-4
SH200	4.000e-5	4.600e-5	4.000e-5	3.600e-5	4.900e-5
UC600	2.900	0.226	4.300	3.450	2.000
UC500	3.750	3.400	8.100	5.700	2.900
UC300	4.354	5.000	11.000	4.313	3.600
UC200	5.700	7.400	13.200	7.900	5.800
UWSS500	1.885	2.140	6.970	3.135	3.440
UWS600500	0.350	-0.441	0.766	0.550	0.900
UWSS600	1.535	2.256	4.570	0.385	1.928
WD600	217.813	252.387	242.488	239.034	244.803
WD500	252.420	243.435	267.930	273.717	255.719
VC600	4.200	-0.745	1.900	2.150	0.882
VC500	1.752	-1.700	-0.314	1.000	-2.000
VC300	2.262	-4.100	4.500	4.105	-2.600
VC200	7.100	-5.300	2.700	8.550	-6.800
VWSS500	4.132	-2.060	2.210	3.730	-2.360
VWS600500	0.289	-0.955	-2.300	-1.950	-1.924
VWSS600	6.580	-1.105	3.360	5.370	-0.437
T600	1.181	3.000	0.784	1.696	2.700
T500	-9.750	-7.500	-8.800	-9.500	-7.200
T300	-34.200	-33.800	-35.100	-33.750	-33.200
T200	-53.500	-52.700	-54.000	-52.900	-53.800
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5830.4	5822.950	5850.800	5813.100	5815.600
PW	17.300	19.450	22.300	17.300	18.200
CAPE	22.200	274.150	266.200	13.500	103.100
CIN	-25.500	-34.850	-43.500	-39.200	-47.700

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	66.700	81.600	54.200	68.600	82.700
GH600	4430.100	4450.450	4492.000	4445.900	4453.550
GH500	5874.500	5892.000	5940.700	5870.900	5897.500
GH300	9642.700	9667.200	9737.300	9632.400	9677.650
GH200	12332.900	12383.150	12457.800	12323.300	12394.300
SH850	8.400e-3	8.350e-3	8.200e-3	9.000e-3	7.800e-3
SH800	7.300e-3	7.200e-3	6.900e-3	7.800e-3	6.850e-3
SH600	4.000e-3	5.200e-3	5.100e-3	4.300e-3	4.950e-3
SH500	2.300e-3	2.650e-3	2.700e-3	2.200e-3	2.650e-3
SH300	2.800e-4	2.800e-4	3.700e-4	3.700e-4	2.900e-4
SH200	4.100e-5	4.150e-5	5.100e-5	4.000e-5	4.850e-5
UC600	5.700	2.500	4.400	4.600	3.550
UC500	7.200	4.750	3.300	6.700	1.646
UC300	11.700	4.900	2.800	10.200	3.721
UC200	14.900	8.650	5.500	15.300	7.300
UWSS500	4.480	2.185	1.260	5.970	-0.715
UWS600500	0.800	1.900	-0.230	1.000	-0.905
UWSS600	4.486	1.135	2.713	5.780	2.185
WD600	256.430	216.210	278.684	241.440	238.819
WD500	265.472	251.250	295.866	275.396	241.678
VC600	1.200	3.950	-0.672	2.200	3.300
VC500	0.198	2.189	-3.200	-0.529	1.236
VC300	1.300	3.168	-5.700	1.800	4.250
VC200	2.600	5.734	-4.300	1.700	4.097
VWSS500	1.710	4.569	-3.660	1.411	3.616
VWS600500	-3.011	-3.361	-2.400	-2.100	-3.665
VWSS600	1.470	6.920	-1.100	2.630	6.810
T600	1.400	1.411	2.100	1.400	1.773
T500	-8.700	-9.500	-7.700	-9.300	-9.300
T300	-35.200	-33.800	-32.900	-34.600	-33.750
T200	-54.400	-53.400	-53.800	-54.400	-53.350

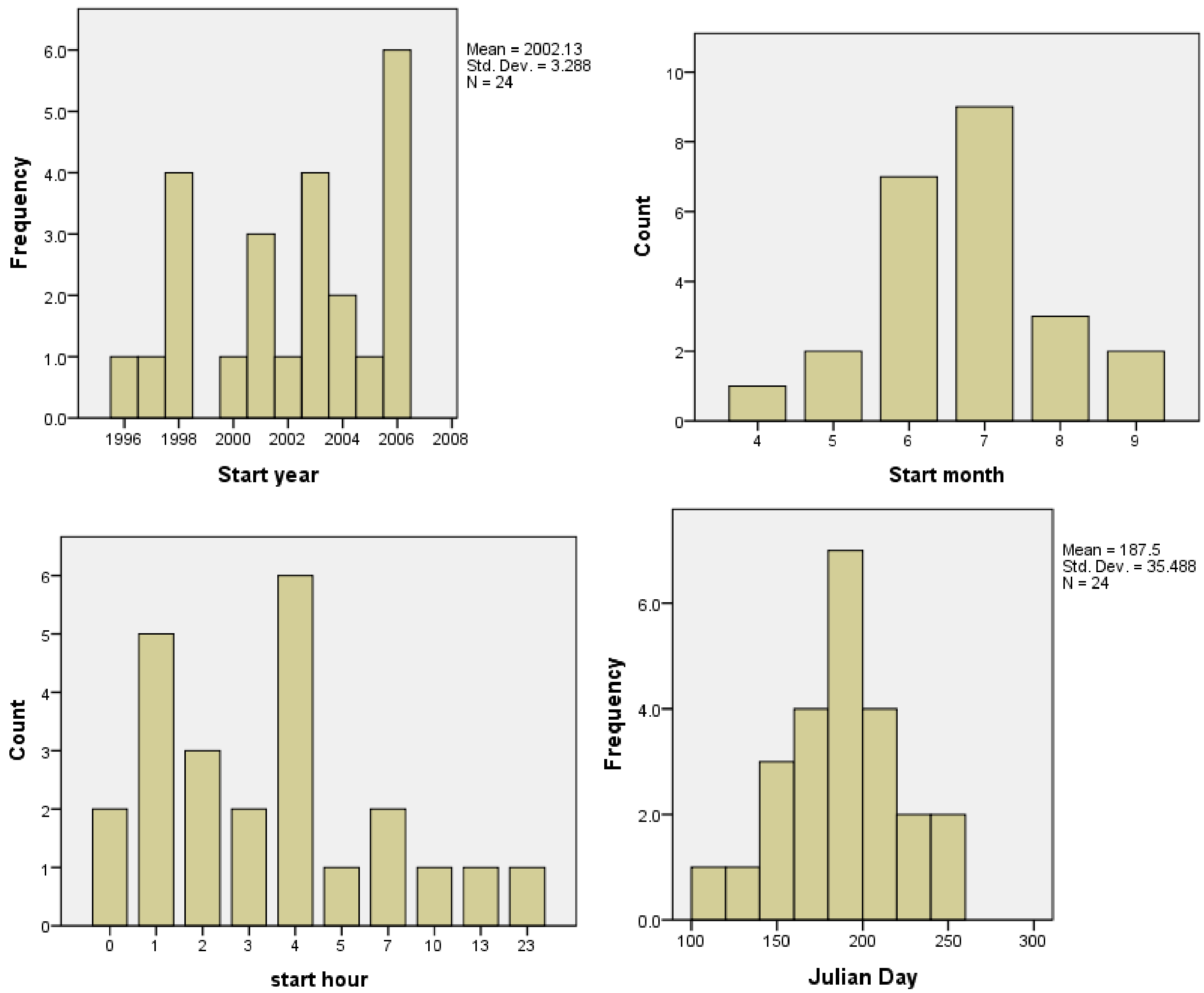


Figure 4.23.1: Time Histograms for the Laughlin Peak, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.23.3: Results of the MLRs Run on the Laughlin Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + SH200 – VWSS500 – SH850	1.000
5HP	FP ≈ constant + LCL + SRH – SMXS + UC600	1.000
4HP	FP ≈ constant + SMXS – T600 – VWND + VC200 + UWND – PW + VC600 + UC300 – CAPE	0.995
3HP	FP ≈ constant + SH200 – LCL – WD500	1.000
2HP	FP ≈ constant + LCL – SH200 + SRH + SMXS	1.000
1HP	FP ≈ constant + SMXS – SH300 + SMXR + SH600 – STHC – SH200 – SRH	0.977
Initiation	FP ≈ constant + SH200 – T200 – SH500	1.000

Table 4.23.4: Results of the PCAs Run on the Laughlin Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	3	100.000%
5HP	All variables	4	100.000%
4HP	STHC, SMXR, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	8	93.679%
3HP	All variables	3	100.000%
2HP	All variables	4	100.000%
1HP	STHC, SMXR, UWND, VWND, LI, Thickness, PW, CAPE, SRH, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	95.236%
Initiation	All variables	3	100.000%

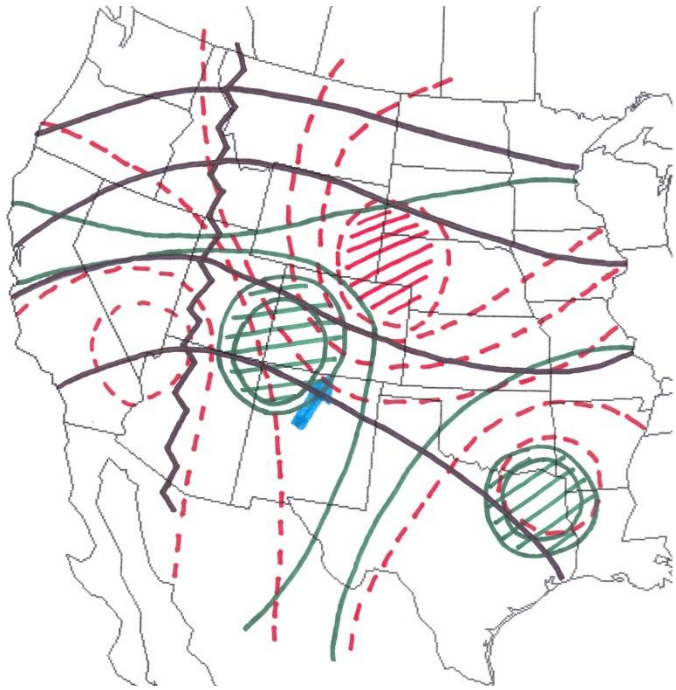


Figure 4.23.2: Composite Map for Laughlin Peak, NM. The variables included on the map are STHC, GH500, SH200, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.24: Hogback Mountain/Mt. Signal, CO

4.24.1: Description of Cluster

The Hogback Mountain/Mt. Signal, CO cluster contains 23 members and is located southwest of Pueblo, CO. The median values for the surface and upper air variables are given in Table 4.24.1 and the median values from the NARR data are given in Table 4.24.2. Histograms for the Hogback Mountain/Mt. Signal, CO cluster, Figure 4.24.1, were created for the start year, start month, start hour, and Julian Day.

4.24.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA on the Hogback Mountain/Mt. Signal, CO cluster. The resulting equations and the R square values are included in Table 4.24.3. There were several variables that were never included in the model runs: LI, GH600, GH500, GH300,

SH200, UWSS500, WD500, VC600, VC500, VWSS500, T600, and T300 and are considered least important to larger FPs within the cluster. SRH was the variable that was included most often, at five out of ten model runs. Since this variable is not included in a majority of the model runs, it is assumed that the combination of variables is more important to larger FPs rather than an individual variable. Only five of the model runs had multicollinearity issues present, which is significantly different from the previous cluster. Seven of the model runs were perfect fits to the data; therefore, there were more perfect fits to the data than there were multicollinearity issues.

4.24.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.24.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. With these PCAs, there was a concern since the 2HA model run had no results. It is believed that this was caused by the decreasing sample size. Since the sample size per cluster is decreasing, it also means that the sample size per hour is decreasing as well which could create issues. Most of the variables were included in every remaining model run. The variable included in the fewest most used lists was T200 at five times. All of the variables are important to MCSMI within the cluster domain and should be observed. Three of the model runs included every variable on the most used list and two of those model runs had 100 percent of the accounted for variance using only one component. Since those model runs only had one component, the sample size is small.

4.24.4: Cluster Discussion

With the information from the previous two sections and section 4.24.5, the PCA is considered the better analysis type for this cluster even with the problem described above. The MLRs could easily be used for identifying the variables needed to predict the FP of the system.

Fewer variables are included in the MLRs; therefore, a quicker assessment could be made. Since the PCAs used every variable in every component, a more accurate representation of the Hogback Mountain/Mt. Signal, CO cluster data can be made.

The Hogback Mountain/Mt. Signal, CO cluster is in a portion of the Rocky Mountains that contains a southwest-northeast oriented ridgeline. The median wind direction at 600 and 500 mb and initiation give winds from the west which indicates winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for Hogback Mountain/Mt. Signal, CO is Figure 4.24.2. The most important temperature variable was STHC. Cooler potential temperatures are located northeast and warmer potential temperatures are located southwest of the cluster domain. This indicates the cluster is within an area of relatively warmer potential temperatures overall. The most important geopotential height variable was GH200. A ridge is located west and a trough is located east of the cluster domain. The heights within the cluster domain will continue to increase until the ridge moves through the area. The most important moisture variable was SMXR. Relatively moist air is located east of the cluster domain but the cluster domain is located within an area of relatively drier air at the surface. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 3.898 ms^{-1} at 257.105˚.

4.24.5: Cluster Figures and Tables

Table 4.24.1: Median Values for the Upper Air and Surface Variables for the Hogback Mountain/Mt. Signal, CO Cluster.

Variable	Median Value
STHC	35.130
SMXR	9.450
SMXS	16.890
UWND	0.000
VWND	-0.710
LCL	655.310
LI	-0.650

Table 4.24.2: Median Values for the NARR Variables for the Hogback Mountain/Mt. Signal, CO Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5859.100	5784.450	5875.400	5852.000	5768.150
PW	21.100	16.700	24.700	20.500	15.200
CAPE	403.700	240.400	58.550	422.900	192.950
CIN	-16.900	-15.700	-62.100	-23.200	-33.200
SRH	50.000	22.700	42.300	54.400	31.350
GH600	4439.700	4390.100	4471.600	44.7.500	4401.300
GH500	5898.800	5816.900	5926.150	5889.900	5828.600
GH300	9695.000	9537.650	9743.350	9674.800	9549.350
GH200	12399.600	12239.700	12477.500	12377.400	12253.150
SH850	9.600e-3	7.750e-3	8.300e-3	9.000e-3	7.650e-3
SH800	8.400e-3	7.000e-3	7.600e-3	7.900e-3	6.550e-3
SH600	4.300e-3	3.200e-3	5.700e-3	5.200e-3	3.550e-3
SH500	2.700e-3	1.800e-3	3.500e-3	2.400e-3	1.850e-3
SH300	3.600e-4	1.700e-4	4.450e-4	3.900e-4	1.750e-4
SH200	4.200e-5	3.500e-5	5.750e-5	4.400e-5	4.750e-5
UC600	5.500	2.800	2.279	5.600	2.150
UC500	6.800	6.000	4.800	8.800	3.800
UC300	12.100	11.000	11.550	11.600	10.800
UC200	12.000	21.100	12.650	11.200	17.200
UWSS500	7.640	7.415	3.060	7.500	4.415
UWS600500	-0.600	3.000	2.521	4.600	2.100
UWSS600	4.720	3.955	0.539	3.820	3.015
WD600	253.811	287.161	144.774	253.610	286.956
WD500	251.940	279.641	298.454	250.313	280.337
VC600	1.800	-1.800	-3.600	2.000	-2.500
VC500	1.400	-2.150	-2.650	1.900	-3.600
VC300	4.200	3.700	0.400	4.100	1.383
VC200	3.900	3.700	-5.000e-2	2.200	5.400
VWSS500	3.000	-2.295	0.540	3.900	-3.415
VWS600500	1.000	0.785	0.950	0.300	0.150
VWSS600	2.510	-1.915	-0.410	1.860	-2.702
T600	3.000	-0.500	3.850	3.000	-0.800
T500	-6.700	-12.000	-6.200	-7.100	-11.900
T300	-34.000	-37.100	-31.650	-34.100	-36.800
T200	-53.900	-53.100	-54.000	-54.100	-52.500
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5854.450	5832.200	5721.400	5829.950	5821.800
PW	24.050	21.000	15.500	22.900	19.200
CAPE	148.000	261.600	185.750	120.600	268.400
CIN	-21.150	-46.500	-34.150	-17.450	-39.000

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	73.000	49.100	34.700	56.450	43.000
GH600	4479.000	4430.700	4404.250	4464.000	4435.200
GH500	5930.900	5883.300	5827.250	5912.950	5882.600
GH300	9743.450	9681.800	9554.250	9738.450	9670.300
GH200	12475.950	12394.600	12262.350	12476.400	12377.300
SH850	8.500e-3	8.300e-3	7.900e-3	8.700e-3	9.100e-3
SH800	7.800e-3	7.400e-3	6.900e-3	7.950e-3	8.200e-3
SH600	5.100e-3	4.700e-3	3.550e-3	4.500e-3	4.000e-3
SH500	3.000e-3	2.900e-3	1.800e-3	2.750e-3	2.300e-3
SH300	3.900e-4	4.000e-4	1.400e-4	3.200e-4	3.100e-4
SH200	5.600e-5	4.300e-5	3.500e-5	5.800e-5	4.900e-5
UC600	4.172	4.500	3.200	2.650	5.600
UC500	6.700	7.800	3.650	4.288	7.900
UC300	12.700	15.700	9.100	11.350	16.100
UC200	14.650	13.200	17.100	15.350	13.800
UWSS500	4.960	7.800	4.485	2.548	6.320
UWS600500	2.529	4.000	-3.100e-2	1.638	3.000
UWSS600	2.432	3.800	4.455	0.910	3.700
WD600	300.053	270.128	307.187	127.104	257.335
WD500	293.499	267.601	244.686	116.305	260.929
VC600	-0.900	-2.160e-2	-3.000	0.950	-0.621
VC500	-1.150	0.419	-2.087	0.000	1.900
VC300	-0.550	3.500	1.474	-0.600	3.600
VC200	-1.950	5.600	2.226	-3.624	4.600
VWSS500	2.040	1.722	-2.937	3.190	1.900
VWS600500	-0.250	0.852	1.164	-0.950	0.300
VWSS600	2.290	0.870	-3.535	4.140	0.770
T600	3.350	2.300	-1.983	2.400	2.500
T500	-6.650	-7.100	-12.200	-6.250	-7.500
T300	-31.650	-33.300	-36.050	-31.000	-33.800
T200	-53.850	-53.700	-52.050	-53.500	-54.200

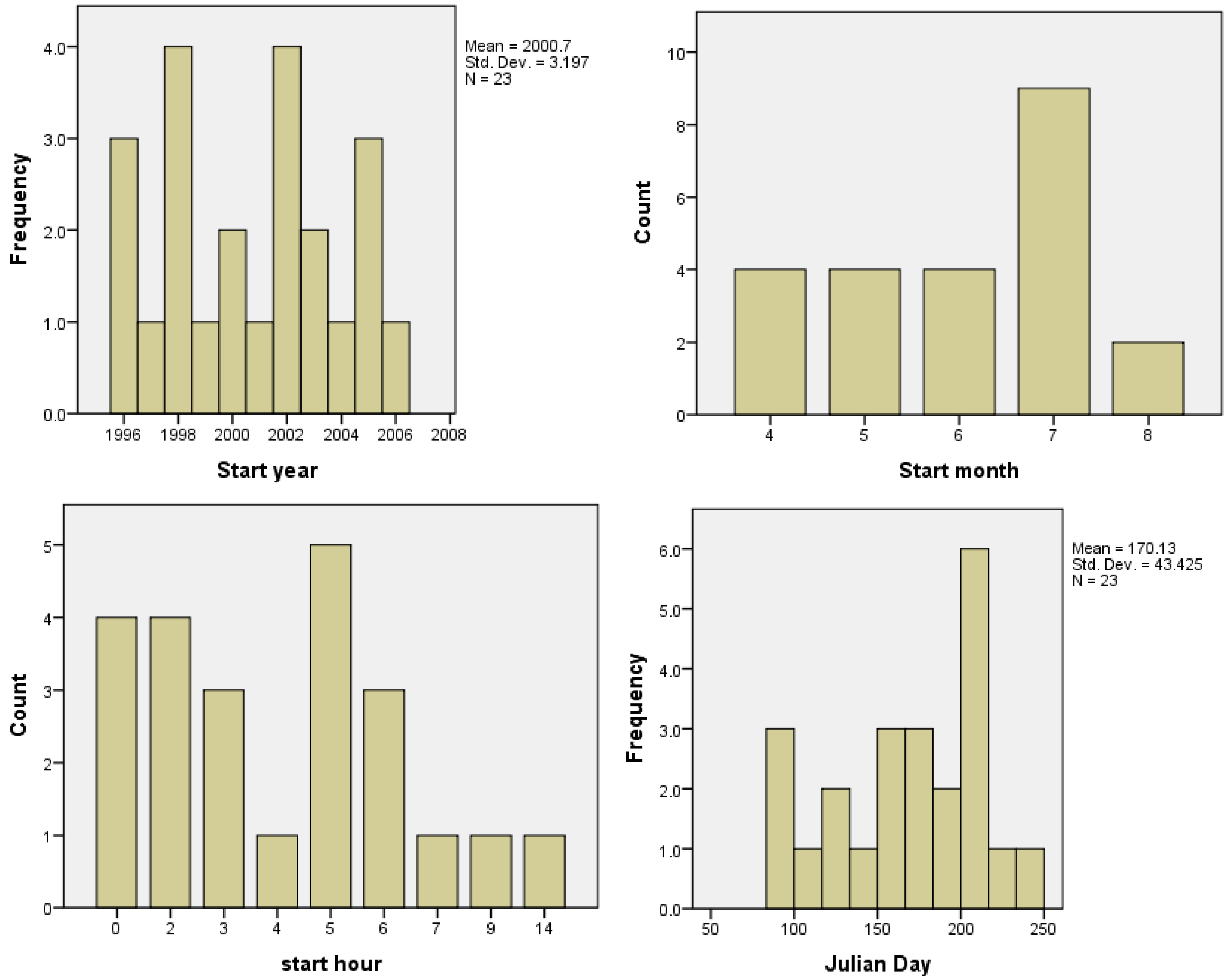


Figure 4.24.1: Time Histograms for the Hogback Mountain/Mt. Signal, CO Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.24.3: Results of the MLRs Run on the Hogback Mountain/Mt. Signal, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – SH600 + T500 – STHC + CAPE – SH500 – GH200 + UC200 – SRH + PW – SH800	1.000
5HP	FP ≈ constant + SRH – CIN – VC200 + VWS600500 – SH300 + SH850 + UC600 + UC300 – CAPE	1.000
4HP	FP ≈ constant – SMXR	1.000
3HP	FP ≈ constant – SH500 + VWSS600 + T500 – STHC – Thickness – SH800	1.000
2HP	FP ≈ constant + SRH – VWSS600 + UC600 – VWND – LCL + VWS600500 + CIN + T200 + WD600	1.000
1HP	FP ≈ constant – SMXR	1.000
Initiation	FP ≈ constant – CIN + VC300 – SMXS	0.954

Table 4.24.4: Results of the PCAs Run on the Hogback Mountain/Mt. Signal, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	6	95.103%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	7	96.615%
4HP	All variables	1	100.000%
3HP	STHC, SMXR, SMXS, UWND, LCL, Thickness, PW, CAPE, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	96.166%
2HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	7	96.969%
1HP	All variables	1	100.000%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.977%

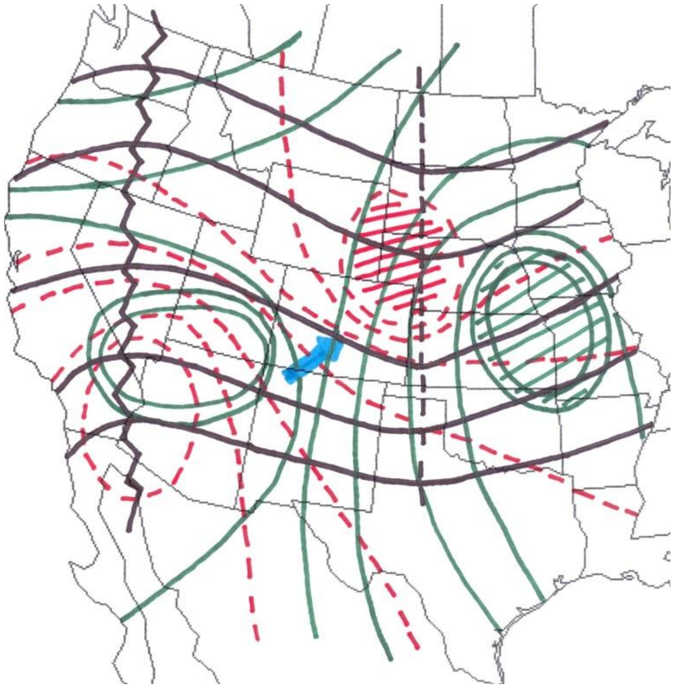


Figure 4.24.2: Composite Map for Hogback Mountain/Mt. Signal, CO. The variables included on the map are STHC, GH200, SMXR, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.25: Gacho Hill, NM

4.25.1: Description of Cluster

The Gacho Hill, NM cluster contains 22 members and is located east of the Mesa de los Jumanos, NM cluster and Trinchera Mesa/Valencia Hills/Howard Mountain, NM cluster. The median values for the surface and upper air variables are given in Table 4.25.1 and the median values from the NARR data are given in Table 4.25.2. Histograms for the Gacho Hill, NM cluster, Figure 4.25.1, were created for the start year, start month, start hour, and Julian Day.

4.25.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Gacho Hill, NM cluster. The resulting equations and the R square values are included in Table 4.25.3. There were multiple variables that were never included on the most used list: SMXS, Thickness, SRH, SH300,

UC300, UWSS500, UWSS600, VC300, VC200, VWSS500, VWS600500, and T300 which are considered to be the least important variables to larger FPs within the Gacho Hill, NM cluster. This list indicates that wind shear variables were not very important to larger FPs within this cluster's domain. The variable that was included the most often was UC200 at five out of ten model runs. Since no other variable is included in the majority of the model runs, the combination of the variables should be observed rather than an individual variable. Nine out of ten model runs were perfect fits, showing that the MLRs can be used for identifying the variables needed to accurately predict the eventual FP of the system. The same nine model runs that had perfect fits to the data also had multicollinearity issues present.

4.25.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.25.4 are the variables with 90 percent accounted for variance, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. Almost all of the variables were included in all of the most used lists. Those not included were CAPE, WD600, WD500, and T200 which were included in nine of the ten most used lists. Therefore, all of the variables are important to MCSMI within the Gacho Hill, NM cluster and should all be observed to potentially predict for MCS formation. Seven of the model runs had all of the variables contained on the most used list and had 100 percent of the accounted for variance. This means that the PCA was a very good fit to the data for this cluster.

4.25.4: Cluster Discussion

Since all but one MLR had multicollinearity issues present, the PCA would be a better fit. The MLRs could easily be used for identifying the variables needed to estimate the FP but there are multiple dependency issues. The PCAs could be used for identifying the variables needed to accurately predict when and if an MCS will occur within the Gacho Hill, NM cluster domain. Observing the variables gives an indication of when this potential for initiation will occur within the Gacho Hill, NM cluster domain.

The Gacho Hill, NM cluster is in a portion of the Rocky Mountains that contains a north-south ridgeline. The median wind direction at 600 and 500 mb and initiation gives winds from the west-northwest which indicates that the winds at 600 and 500 mb will arrive at an angle to the ridgeline.

The composite map for Gacho Hill, NM is Figure 4.25.2. The most important temperature variable was T500. Relatively cooler temperatures are located northwest and warmer temperatures are located southeast of the cluster domain. This indicates that the cluster domain is within an area of relatively warmer temperatures at 500 mb. The most important geopotential height variable was GH300. This composite map shows a ridge located to the east and a trough located to the west of the cluster domain. As the ridge and trough move eastward, the heights will continue to decrease at the cluster domain until the trough passes through the area. The most important moisture variable was SH200. A moist pocket of air at 200 mb is located directly over the cluster domain. The most important wind shear was between 600 and 500 mb, two upper levels. The wind shear at initiation has a median value of 1.265 ms^{-1} at 198.435˚.

4.25.5: Cluster Figures and Tables

Table 4.25.1: Median Values for the Upper Air and Surface Variables for the Gacho Hill, NM Cluster.

Variable	Median Value
STHC	40.255
SMXR	8.875
SMXS	19.460
UWND	3.130
VWND	0.935
LCL	649.740
LI	-0.625

Table 4.25.2: Median Values for the NARR Variables for the Gacho Hill, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5815.500	5848.550	5839.200	5834.900	5853.500
PW	20.300	24.000	22.000	19.700	25.450
CAPE	454.200	259.050	279.800	420.800	206.750
CIN	-13.800	-12.550	-7.400	-6.600	-22.600
SRH	28.700	32.850	22.500	43.400	36.800
GH600	4449.600	4467.000	4467.600	4446.900	4463.600
GH500	5892.600	5920.400	5921.600	5892.600	5912.450
GH300	9625.500	9730.000	9679.100	9636.900	9722.050
GH200	12322.420	12464.500	12392.900	12337.100	12461.700
SH850	8.200e-3	9.400e-3	8.400e-3	8.400e-3	8.850e-3
SH800	7.200e-3	8.500e-3	7.500e-3	7.500e-3	7.950e-3
SH600	3.800e-3	4.750e-3	4.400e-3	4.100e-3	5.350e-3
SH500	1.200e-3	2.450e-3	2.200e-3	2.100e-3	3.250e-3
SH300	1.600e-4	2.250e-4	2.600e-4	2.600e-4	3.750e-4
SH200	3.500e-5	4.750e-5	4.000e-5	3.600e-5	5.100e-5
UC600	5.300	4.950	3.500	5.100	4.850
UC500	5.300	5.800	4.200	4.900	6.200
UC300	10.700	6.600	6.100	10.800	7.850
UC200	16.400	9.100	9.000	18.200	9.600
UWSS500	4.600	3.211	3.080	2.600	3.135
UWS600500	1.300	0.236	0.300	-1.005	0.850
UWSS600	2.130	4.475	2.013	1.930	3.185
WD600	246.541	260.971	277.407	297.759	257.030
WD500	251.409	243.580	238.794	296.147	258.046
VC600	1.400	1.499	-0.455	-1.000	0.906
VC500	0.740	1.350	0.414	-0.759	-2.500e-2
VC300	1.700	2.100	0.891	2.200	2.000
VC200	-0.840	0.400	-1.000	-8.410e-2	3.250
VWSS500	1.630	-0.305	0.120	0.131	-1.885
VWS600500	-0.660	-7.250e-2	1.514	0.241	-2.181
VWSS600	2.290	1.000	-0.497	-0.110	6.040e-2
T600	0.834	1.850	0.830	1.100	2.100
T500	-9.600	-6.850	-8.500	-9.300	-6.700
T300	-36.800	-31.500	-34.400	-37.000	-31.250
T200	-52.500	-53.500	-52.400	-52.500	-53.050
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5840.200	5838.000	5838.950	5825.600	5822.500
PW	22.600	19.800	22.600	20.900	19.900
CAPE	111.800	408.800	162.850	190.200	315.800
CIN	-27.500	-41.700	-31.050	-28.000	-56.400

Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
SRH	27.200	43.300	62.000	59.900	85.200
GH600	4460.000	4449.500	4470.750	4454.800	4445.300
GH500	5908.800	5885.400	5920.700	5902.400	5889.800
GH300	9687.200	9625.900	9733.750	9667.700	9619.700
GH200	12414.300	12313.800	12466.800	12393.200	12331.700
SH850	8.300e-3	8.900e-3	8.850e-3	9.000e-3	9.200e-3
SH800	7.700e-3	8.000e-3	8.050e-3	8.200e-3	8.100e-3
SH600	5.100e-3	3.700e-3	5.000e-3	4.400e-3	4.000e-3
SH500	2.300e-3	2.000e-3	2.750e-3	2.000e-3	2.000e-3
SH300	2.900e-4	2.700e-4	3.650e-4	3.100e-4	2.900e-4
SH200	4.200e-5	3.800e-5	4.950e-5	4.000e-5	3.600e-5
UC600	3.300	4.900	5.250	4.700	7.000
UC500	6.400	6.100	5.950	6.400	7.900
UC300	7.000	13.200	7.550	5.700	14.500
UC200	9.100	19.900	11.250	8.000	21.300
UWSS500	6.280	3.480	2.125	4.250	3.580
UWS600500	0.700	0.400	-0.650	-0.200	0.300
UWSS600	5.080	2.800	2.905	4.620	3.970
WD600	253.881	294.944	262.152	256.083	269.173
WD500	274.983	296.188	276.187	256.891	262.488
VC600	1.000	-3.300	0.758	0.815	-2.200
VC500	-0.852	-2.100	-0.664	-1.700	-1.900
VC300	0.446	3.600	2.100	2.500	5.800
VC200	-0.806	0.319	0.457	-2.500	-0.300
VWSS500	-0.858	-1.210	-1.918	-2.770	-1.310
VWS600500	-1.852	1.200	-1.614	-1.416	1.700
VWSS600	-1.200	-2.410	-0.220	-0.615	-1.510
T600	1.500	0.882	2.000	1.700	0.972
T500	-8.000	-9.900	-6.500	-8.400	-10.200
T300	-33.200	-36.900	31.350	-33.700	-36.700
T200	-52.300	-53.500	-53.200	-52.800	-53.500

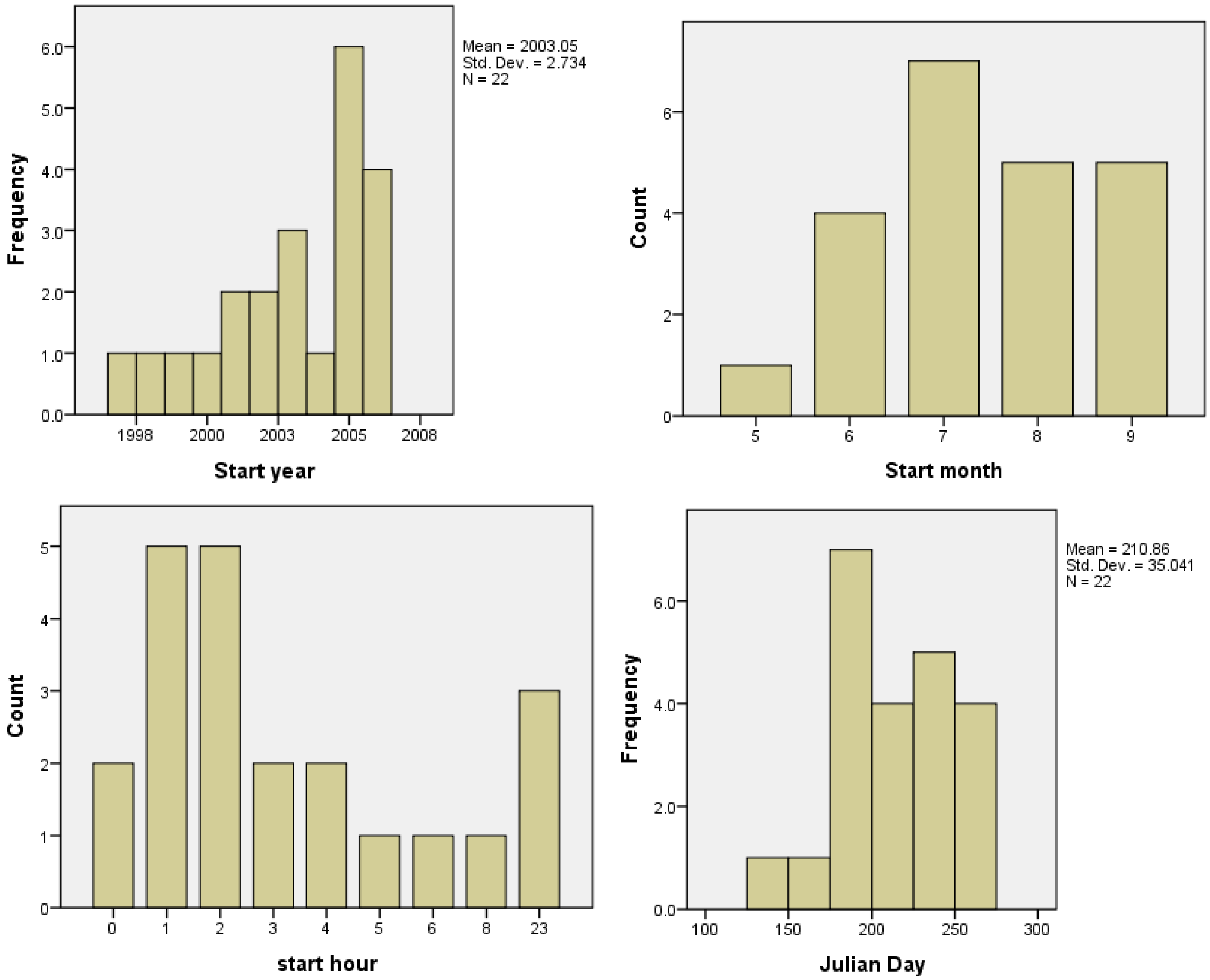


Figure 4.25.1: Time Histograms for the Gacho Hill, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.25.3: Results of the MLRs Run on the Gacho Hill, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + UWS600500 + SH200 + T600 + GH200	1.000
5HP	FP ≈ constant – GH300 – CAPE – SH800 + SH850 + T500 – GH200 + WD500 – VC500 – VWSS600	1.000
4HP	FP ≈ constant + CAPE + UC500 + CIN – WD600 + VWND + UC200	1.000
3HP	FP ≈ constant – SH800 + LCL – SH500 – UWND	1.000
2HP	FP ≈ constant – GH300 + VC600 – STHC – LCL – UC600 – PW + UC200 + GH500 – T600	1.000
1HP	FP ≈ constant + UC200 + SH200 + CIN	0.989
Initiation	FP ≈ constant – GH300 – SH800 + SH850 + VC600	1.000

Table 4.25.4: Results of the PCAs Run on the Gacho Hill, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	4	100.000%
5HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	97.007%
4HP	All variables	6	100.000%
3HP	All variables	4	100.000%
2HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	98.207%
1HP	All variables	6	100.000%
Initiation	All variables	4	100.000%

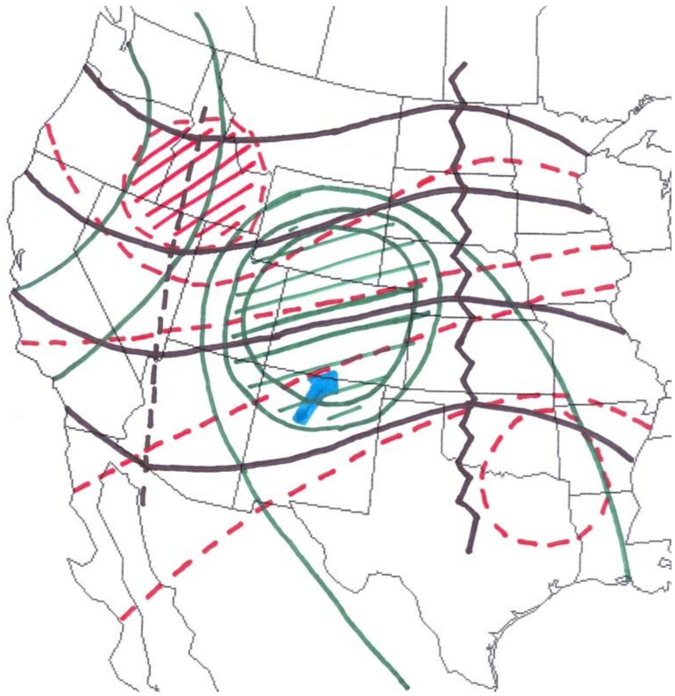


Figure 4.25.2: Composite Map for Gacho Hill, NM. The variables included on the map are T500, GH300, SH200, and wind shear between 600 and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.26: Argonne Mesa, NM

4.26.1: Description of Cluster

The Argonne Mesa, NM cluster contains 21 members and is located northeast of Vaughn, NM. The median values for the surface and upper air variables are given in Table 4.26.1 and the median values from the NARR data are given in Table 4.26.2. Histograms for this cluster, Figure 4.26.1, were created for the start year, start month, start hour, and Julian Day.

4.26.2: Multiple Linear Regression

MLRs were run on the 6HP through the 3HA on the Argonne Mesa, NM cluster. The resulting equations and the R square values are included in Table 4.26.3. There were several variables that were never included in the MLRs: Thickness, CIN, GH600, GH300, SH500, UC600, UC500, VC500, VC200, VWS600500, T600, T500, T300, and T200. They are considered the least important variables to larger FPs within the Argonne Mesa, NM cluster. All of the upper level temperature variables are included in the above list, which is different from previous clusters. The variables used the most often were STHC, SMXS, VWND, SRH, UWS600500, and WD600 all of which were used in three out of ten model runs. Therefore, not one single variable is more important to larger FPs than another. The combination of variables is more important and should be observed. Nine of the model runs were perfect fits and could all be used for identifying the variables needed to accurately predict the FP which will initiate within the cluster domain. Eight of the model runs contained multicollinearity issues.

4.26.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.26.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. Almost every variable was included in every most used list. The variable that was included in the fewest most used lists was LI at eight out of ten model runs. STHC, UWND, UWS600500, and T200 were included in nine model runs. All of the variables are considered important to MCSMI within the Argonne Mesa, NM cluster domain. There are quite a few variables to observe but the values of the variables will show if and when an MCS will form within the cluster domain. Eight of the model runs included every variable on its most used list. Seven of the model runs accounted for 100 percent of the variance. Every model run accounted for at least 96 percent of the variance indicating that the PCAs were very good fits and will be able to be used for identifying the variables needed to accurately predict MCS formation within this cluster.

4.26.4: Cluster Discussion

While many of the MLRs were perfect fits, there were several multicollinearity issues present. The MLRs will be used for the identification of the variables needed to accurately predict the FP but the variables are not independent of each other so some questions are created about the actual fit. However, the PCAs were very good, consistent fits to the data and will be able to be used for the identification of variables needed to accurately predict if an MCS is going to form. Therefore, the PCA is the better type of analysis for determining initiation characteristics in the Argonne Mesa, NM cluster domain.

The Argonne Mesa, NM cluster is in a portion of the Rocky Mountains that contains a west-east oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the west. The winds at 600 mb will arrive at an angle to the ridgeline and the winds at 500 mb will arrive along the ridgeline.

The composite map for Argonne Mesa, NM is Figure 4.26.2. The most important temperature variable was STHC. The cluster domain sits within an area of relatively warmer potential temperatures since cooler potential temperatures are located to the north-northwest and even warmer potential temperatures are located to the west and northeast. The most important geopotential height variable was GH500. A ridge is located west of the cluster domain. This indicates, that as the ridge moves eastward, the heights will continue to increase until the ridge passes through. The most important moisture variable was SH850. The cluster domain sits within an area of relatively moist air at 850 mb. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 4.889 ms^{-1} at 272.227˚.

4.26.5: Cluster Figures and Tables

Table 4.26.1: Median Values for the Upper Air and Surface Variables for the Argonne Mesa, NM Cluster.

Variable	Median Value
STHC	36.215
SMXR	9.285
SMXS	14.860
UWND	-0.890
VWND	2.365
LCL	662.035
LI	-0.255

Table 4.26.2: Median Values for the NARR Variables for the Argonne Mesa, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5811.600	5846.300	5775.500	5833.450	5839.000
PW	16.650	22.950	18.450	18.250	22.600
CAPE	368.500	466.350	247.350	225.450	369.850
CIN	-40.950	-13.200	-7.850	-17.250	-23.150
SRH	19.000	42.850	58.900	24.700	59.700
GH600	4464.850	4463.300	4406.950	4449.600	4450.200
GH500	5902.400	5918.800	5852.050	5887.900	5906.700
GH300	9630.300	9723.600	9595.950	9614.950	9718.250
GH200	12328.100	12463.100	12306.250	12314.400	12452.800
SH850	7.750e-3	9.750e-3	7.700e-3	7.150e-3	1.010e-2
SH800	6.950e-3	8.700e-3	6.700e-3	6.400e-3	9.100e-3
SH600	4.100e-3	5.250e-3	4.300e-3	4.150e-3	5.150e-3
SH500	2.300e-3	2.550e-3	2.450e-3	2.500e-3	2.600e-3
SH300	2.700e-4	3.800e-4	2.950e-4	2.750e-4	4.450e-4
SH200	4.200e-5	5.200e-5	3.050e-5	3.700e-5	5.200e-5
UC600	1.650	2.200	8.150	3.850	1.900
UC500	3.450	1.750	11.500	3.950	3.600
UC300	8.800	6.000	17.900	8.400	7.200
UC200	14.300	7.100	25.750	14.150	8.700
UWSS500	3.975	1.917	12.170	3.275	3.535
UWS600500	1.950	0.504	3.600	1.500	0.500
UWSS600	1.561	2.339	8.740	1.632	2.527
WD600	256.493	232.024	231.074	254.006	223.464
WD500	278.666	224.412	241.412	257.270	289.023
VC600	0.899	-0.770	4.450	1.168	-2.000
VC500	-0.311	-3.900	5.150	0.984	-2.900
VC300	5.053	-5.200	6.700	4.488	-5.800
VC200	3.700	-0.850	5.700	3.050	-3.850
VWSS500	-1.005	-1.590	-1.445	4.400e-2	-1.364
VWS600500	-0.318	-2.143	0.250	-0.100	-2.837
VWSS600	-4.150e-2	-0.425	-0.945	0.228	-0.575
T600	1.271	1.950	-0.666	1.312	2.300
T500	-10.250	-7.250	-9.350	-10.400	-8.200
T300	-36.950	-31.950	-36.250	-37.250	-31.300
T200	-53.850	-52.750	-52.350	-53.750	-52.700
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5790.650	5839.350	5828.250	5767.300	5820.650
PW	19.850	16.600	23.200	17.550	17.050
CAPE	117.200	226.500	361.300	337.050	384.750
CIN	-30.050	-31.550	-37.750	-25.950	-32.550

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	65.700	57.650	86.750	95.600	67.550
GH600	4421.300	4451.950	4465.050	4411.800	4447.000
GH500	5860.850	5892.700	5922.750	5853.000	5885.400
GH300	9594.550	9634.150	9735.050	9582.250	9618.950
GH200	12313.000	12326.550	12462.750	12294.850	12314.000
SH850	8.100e-3	7.700e-3	1.030e-2	7.650e-3	8.300e-3
SH800	7.050e-3	6.850e-3	9.250e-3	6.800e-3	7.500e-3
SH600	5.150e-3	3.900e-3	4.900e-3	4.000e-3	3.650e-3
SH500	2.300e-3	2.100e-3	2.650e-3	2.300e-3	2.050e-3
SH300	1.900e-4	2.700e-4	3.200e-4	1.800e-4	2.300e-4
SH200	2.950e-5	3.800e-5	5.400e-5	3.950e-5	3.250e-5
UC600	8.700	7.950	2.600	8.750	6.550
UC500	13.400	8.300	3.500	11.800	6.400
UC300	20.000	11.500	7.800	21.600	9.700
UC200	26.700	14.400	9.950	25.750	12.400
UWSS500	14.520	5.135	4.100	12.430	6.235
UWS600500	4.150	1.125	-0.750	1.700	-1.350
UWSS600	9.905	4.885	4.160	9.515	3.197
WD600	228.249	239.827	280.330	243.924	286.566
WD500	264.955	266.611	304.968	275.607	263.647
VC600	3.550	0.750	-2.800	3.600	-1.697
VC500	0.857	0.258	-5.300	-1.292	-0.867
VC300	7.200	5.300	-1.900	9.650	5.900
VC200	6.250	5.800	-3.150	8.550	4.102
VWSS500	-5.221	-0.683	-5.440	-7.330	-1.807
VWS600500	-2.490	-0.493	-2.950	-4.450	-1.054
VWSS600	-3.300	-0.190	-2.210	-2.330	-2.035
T600	-0.523	1.539	2.650	-0.790	1.137
T500	-9.950	-10.450	-6.950	-10.100	-10.150
T300	-35.850	-37.200	-32.200	-36.100	-37.250
T200	-52.350	-54.350	-53.100	-52.400	-53.850

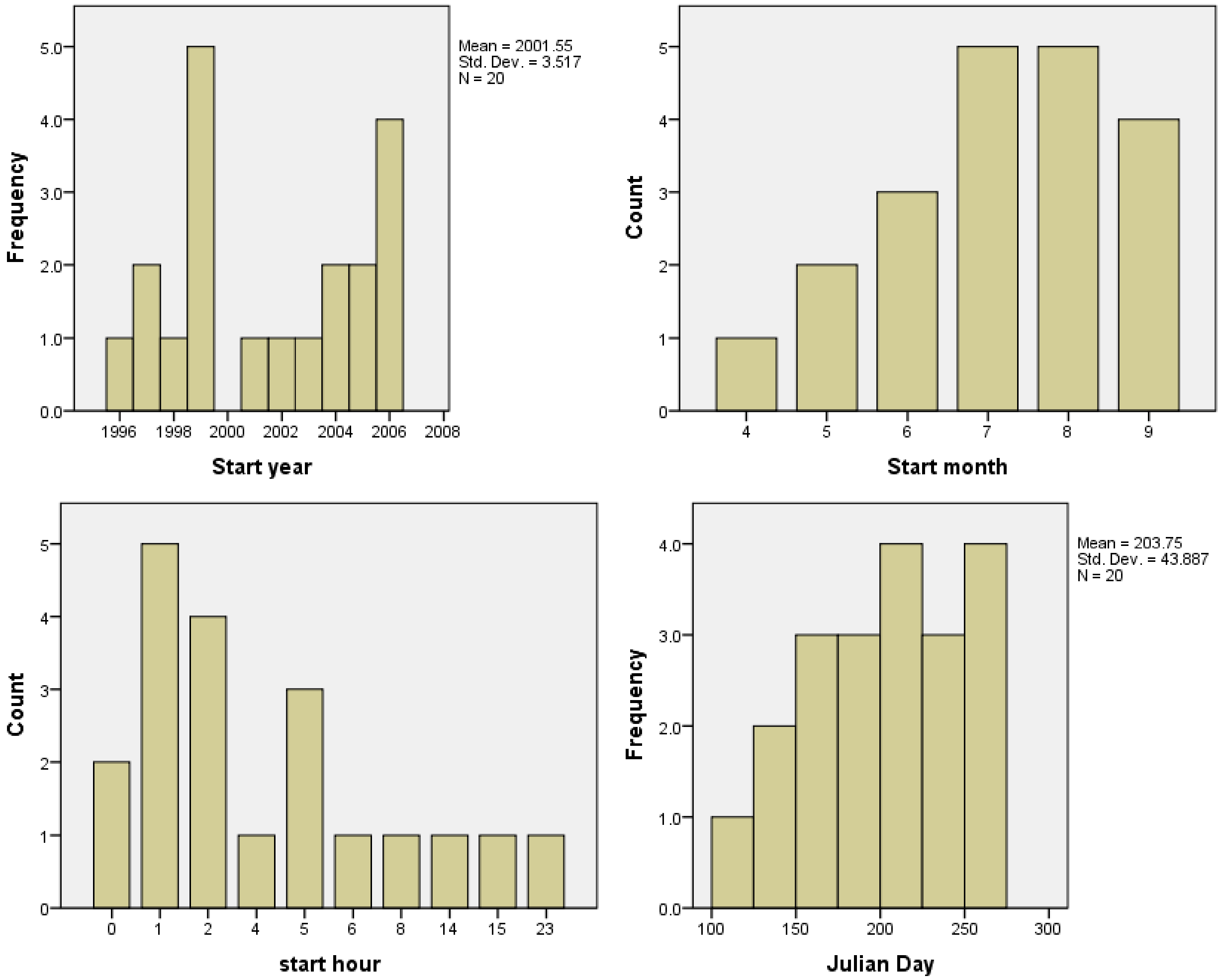


Figure 4.26.1: Time Histograms for the Argonne Mesa, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.26.3: Results of the MLRs Run on the Argonne Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + VC600 + STHC – UWSS600	1.000
5HP	FP ≈ constant – UWS600500 – STHC – LI – SMXR + SH200 + VC300 – SMXS – VWND – GH500	1.000
4HP	FP ≈ constant – SH600 + WD600 – UWS600500 – UC200 + WD500	1.000
3HP	FP ≈ constant – SH600 + VWND + LCL	1.000
2HP	FP ≈ constant – UWS600500 + CAPE – SMXS + UWSS500 + GH500 – WD500 + UWND – VWND – LCL	1.000
1HP	FP ≈ constant + WD600	0.917
Initiation	FP ≈ constant – SH850 – SRH + VC600	1.000

Table 4.26.4: Results of the PCAs Run on the Argonne Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	3	100.000%
5HP	SMXR, SMXS, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	96.293%
4HP	All variables	5	100.000%
3HP	All variables	3	100.000%
2HP	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	97.671%
1HP	All variables	5	100.000%
Initiation	All variables	3	100.000%

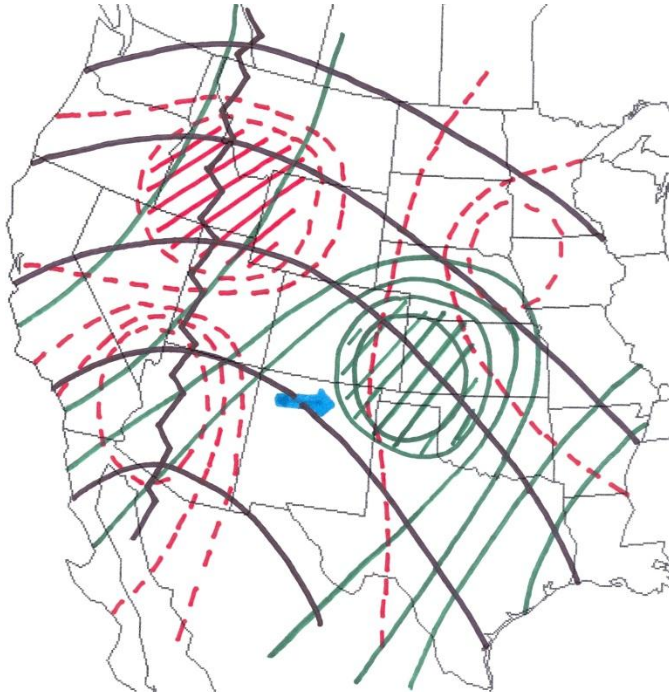


Figure 4.26.2: Composite Map for Argonne Mesa, NM. The variables included on the map are STHC, GH500, SH850, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.27: Jicarilla Mountains, NM

4.27.1: Description of Cluster

The Jicarilla Mountains, NM cluster contains 21 members and is located north-northeast of Carrizozo, NM. The median values for the surface and upper air variables are given in Table 4.27.1 and the median values from the NARR data are given in Table 4.27.2. Histograms for the Jicarilla Mountains, NM cluster, Figure 4.27.1, were created for the start year, start month, start hour, and Julian Day.

4.27.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Jicarilla Mountains, NM cluster. The resulting equations and the R square values are included in Table 4.27.3. There were several variables that were never included in the model runs and are considered the least important variables to larger FPs: STHC, SMXR, SMXS, CAPE, GH500, GH200, SH800, UC600, UWSS500, WD500, VC500, VC300, VWSS500, T600, and T500. The variables that were included in the most often were UWND, UC300, UC200, UWS600500, and VWS600500 which were included three out of ten times. This indicates that the best wind shear to observe is between 600 and 500 mb since both wind shear components between these levels are included the most often. However, the combination of variables is more important to larger FPs than any individual variable. Seven of the model runs were perfect fits and two of the model runs were fairly poor fits to the data. Each of the perfect fit model runs also contained multicollinearity issues.

4.27.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.27.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. Almost all of the variables were included on all of the most used lists. The variables that were not included every time were SMXR, CAPE, and VC200 which were included in nine most used lists and UWS600500 which was included in eight most used lists. This shows that all of the variables are important to MCSMI within the cluster domain according to the PCAs. Six of the model runs had every variable contained on the most used list and had 100 percent of the accounted for variance. Each model run accounted for over 98 percent of the variance; therefore, these model runs were very good fits to the data and can be used for the identification of the variables needed to accurately predict if and when an MCS will form within this cluster domain.

4.27.4: Cluster Discussion

With the combination of the two above sections and the following section, it is demonstrated that the PCAs will give a more accurate representation of MCSMI within the Jicarilla Mountains, NM cluster domain. There were too many problems associated with the MLRs but the MLRs could be used for identifying the variables needed to estimate the MCS FP.

The Jicarilla Mountains, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 and 500 mb and initiation give winds from the southwest which indicates that winds at 600 and 500 mb will arrive at an angle to the ridgeline.

The composite map for Jicarilla Mountains, NM is Figure 4.27.2. The most important temperature variable was T300. Cooler temperatures are located northwest and southeast of the cluster domain indicating the cluster is within an area of relatively warmer temperatures. The most important geopotential height variable was GH300. A ridge is located east of the cluster domain indicating falling heights within the cluster domain. The most important moisture variable was SH200. The cluster domain is within an area of relatively moist air at 200 mb. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 2.964 ms^{-1} at 264.482˚.

4.27.5: Cluster Figures and Tables

Table 4.27.1: Median Values for the Upper Air and Surface Variables for the Jicarilla Mountains, NM Cluster.

Variable	Median Value
STHC	37.990
SMXR	12.770
SMXS	17.710
UWND	0.000
VWND	0.000
LCL	684.600
LI	-0.120

Table 4.27.2: Median Values for the NARR Variables for the Jicarilla Mountains, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5836.550	5829.500	5841.450	5852.750	5834.800
PW	23.550	25.400	24.250	23.050	25.400
CAPE	167.550	202.000	187.800	165.850	210.400
CIN	-6.300	-22.600	-8.850	-7.900	-24.200
SRH	24.800	27.100	17.250	15.850	31.800
GH600	4471.850	4467.600	4463.000	4455.450	4474.100
GH500	5916.150	5921.400	5908.450	5902.250	5926.000
GH300	9730.850	9740.100	9703.950	9710.200	9726.400
GH200	12469.000	12463.700	12437.800	12453.000	12454.900
SH850	1.045e-2	1.000e-2	9.750e-3	9.500e-3	1.040e-2
SH800	9.150e-3	8.800e-3	8.400e-3	8.250e-3	8.900e-3
SH600	4.400e-3	5.000e-3	4.500e-3	4.700e-3	4.800e-3
SH500	2.700e-3	3.400e-3	2.950e-3	2.750e-3	3.100e-3
SH300	3.450e-4	4.300e-4	4.500e-4	4.100e-4	4.500e-4
SH200	5.600e-5	5.300e-5	4.650e-5	5.900e-5	5.800e-5
UC600	5.450e-2	2.000	1.300	1.350	-0.629
UC500	0.446	1.800	0.454	1.600	0.332
UC300	0.263	3.800	-0.450	1.847	2.300
UC200	4.750	7.600	0.150	3.600	9.200
UWSS500	0.540	0.100	0.833	1.204	0.332
UWS600500	-3.200e-2	0.000	-0.817	-0.250	0.147
UWSS600	0.770	-0.300	1.650	2.511	-0.580
WD600	182.284	194.207	244.651	196.453	170.089
WD500	184.334	209.358	202.786	199.301	185.419
VC600	3.800	3.000	-0.686	2.300	3.600
VC500	3.324	2.800	0.713	2.600	2.900
VC300	4.900	3.900	4.850	2.650	4.700
VC200	1.250	5.100	1.5300	0.723	4.900
VWSS500	2.599	0.305	0.278	1.544	2.900
VWS600500	-0.230	-0.600	0.300	-0.261	-1.000
VWSS600	3.010	1.100	0.150	1.836	3.400
T600	1.851	2.100	1.391	1.431	2.100
T500	-7.000	-6.600	-6.950	-7.350	-6.200
T300	-31.500	-32.200	-32.050	-31.450	-31.900
T200	-52.950	-53.800	-53.000	-52.750	-53.800
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5843.250	5852.950	5836.000	5837.200	5833.800
PW	23.650	23.750	23.400	22.250	23.400
CAPE	50.200	64.500	168.300	94.150	77.200
CIN	-15.450	-16.300	-44.100	-28.250	-19.250

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	45.000	22.300	35.600	51.200	34.850
GH600	4449.900	4457.800	4472.500	4470.300	4456.300
GH500	5899.200	5905.200	5924.500	5917.400	5907.450
GH300	9693.150	9722.950	9735.800	9705.500	9715.650
GH200	12428.450	12464.550	12467.100	12443.350	12462.250
SH850	9.050e-3	9.750e-3	1.010e-2	8.750e-3	9.800e-3
SH800	7.900e-3	8.550e-3	9.000e-3	7.750e-3	8.650e-3
SH600	4.900e-3	5.350e-3	4.600e-3	4.700e-3	4.650e-3
SH500	2.800e-3	3.050e-3	2.800e-3	2.950e-3	3.100e-3
SH300	3.450e-4	3.800e-4	4.500e-4	3.900e-4	4.550e-4
SH200	5.100e-5	6.250e-5	5.400e-5	6.050e-5	5.850e-5
UC600	0.651	2.700	2.100	0.668	2.550
UC500	0.250	3.100	0.822	0.327	2.250
UC300	2.150	3.600	1.800	4.200	3.550
UC200	2.950	2.600	9.200	5.400	2.850
UWSS500	1.280	2.950	0.822	0.917	1.150
UWS600500	-0.402	0.600	-1.278	0.454	1.250
UWSS600	1.503	2.950	1.119	1.115	2.850
WD600	237.079	236.196	206.565	197.195	229.930
WD500	162.666	229.889	188.816	109.568	225.165
VC600	-0.257	1.550	2.900	-0.433	1.255
VC500	0.549	2.850	1.300	0.148	2.150
VC300	3.100	2.250	3.500	2.350	-0.714
VC200	-0.900	0.651	8.500	-0.996	-0.891
VWSS500	1.044	1.985	1.300	-0.292	1.060
VWS600500	-1.051	1.000	0.335	-2.019	0.500
VWSS600	-1.629	0.285	1.340	6.250e-2	0.560
T600	1.950	2.300	1.700	1.700	2.450
T500	-7.150	-6.850	-6.600	-7.750	-6.650
T300	-32.000	-31.150	-31.800	-31.950	-31.200
T200	-52.800	-53.000	-53.300	-53.800	-52.900

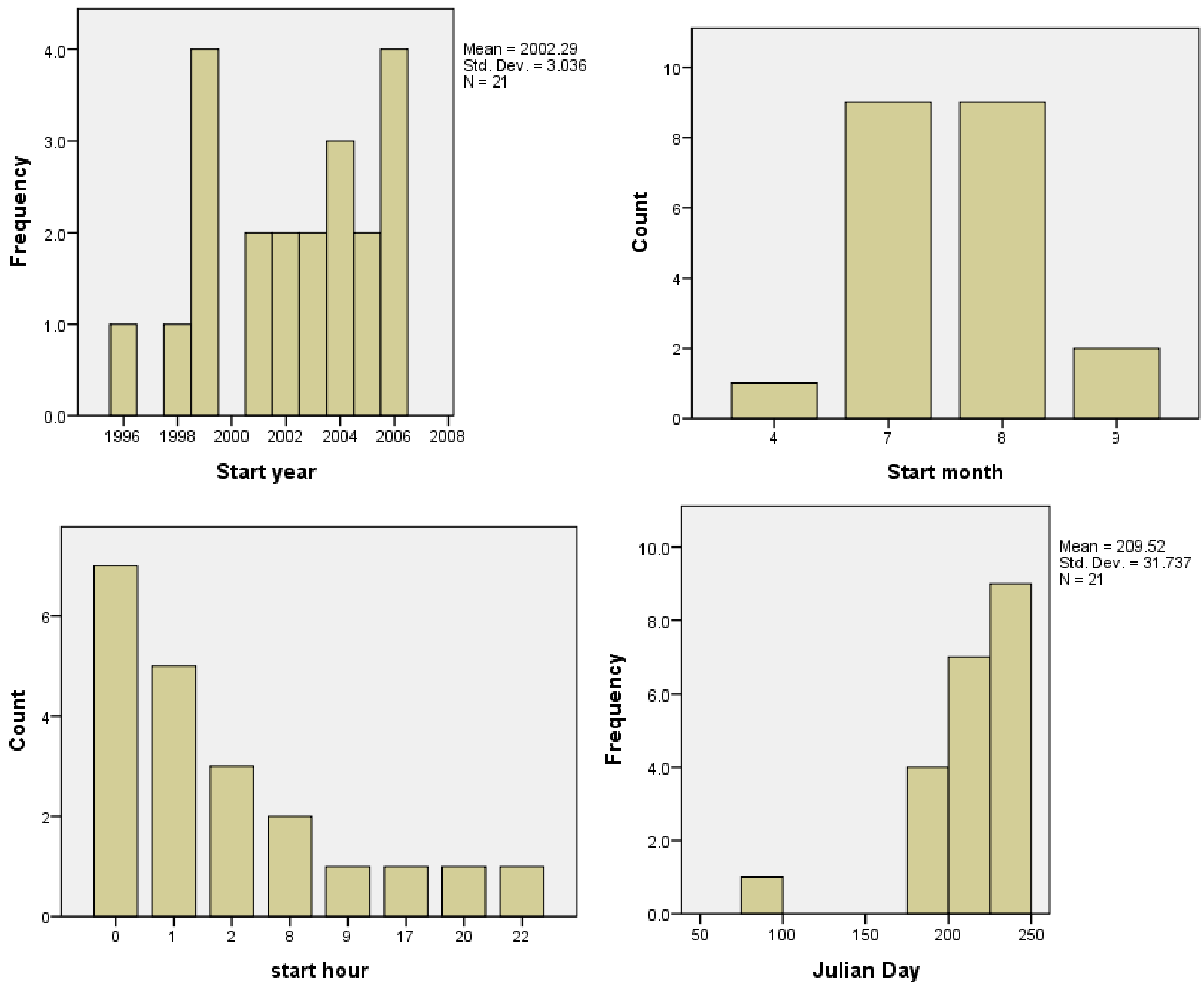


Figure 4.27.1: Time Histograms for the Jicarilla Mountains, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.27.3: Results of the MLRs Run on the Jicarilla Mountains, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – UWSS600 + UC300 + VC200 + CIN	0.992
5HP	FP ≈ constant – T200	0.620
4HP	FP ≈ constant + SH200 + UWS600500 – VWS600500 + GH300 – PW	1.000
3HP	FP ≈ constant – UWSS600 + VWSS600 + UC300 + SH600 + VC200 – UC200 – VC600	1.000
2HP	FP ≈ constant + UWS600500 – UC200 + LI – Thickness – UWND + T300	1.000
1HP	FP ≈ constant + GH600 – SH200 + WD600 + UC500 – VWSS600	1.000
Initiation	FP ≈ constant – VWS600500 + UWND + SH300 – SH850 + UC200 – CIN + LCL	1.000

Table 4.27.4: Results of the PCAs Run on the Jicarilla Mountains, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	97.862%
5HP	All variables	6	100.000%
4HP	All variables	5	100.000%
3HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	98.584%
2HP	All variables	6	100.000%
1HP	All variables	5	100.000%
Initiation	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	98.696%

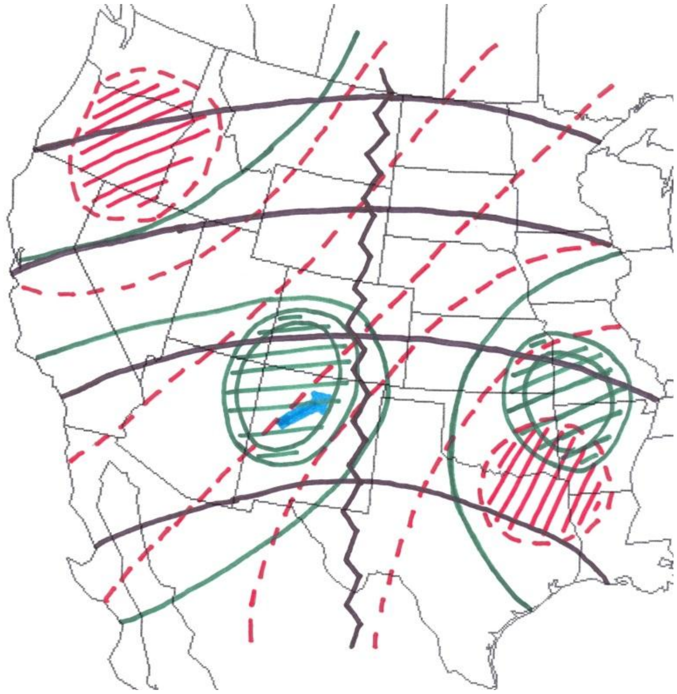


Figure 4.27.2: Composite Map for Jicarilla Mountains, NM. The variables included on the map are T300, GH300, SH200, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.28: Neff Mountain/Jarosa Peak, CO

4.28.1: Description of Cluster

The Neff Mountain/Jarosa Peak, CO cluster contains 21 members and is located west of Antonito, CO. The median values for the surface and upper air variables are given in Table 4.28.1 and the median values from the NARR data are given in Table 4.28.2. Histograms for this cluster, Figure 4.28.1, were created for the start year, start month, start hour, and Julian Day.

4.28.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Neff Mountain/Jarosa Peak, CO cluster. The resulting equations and the R square values are included in Table 4.28.3. There were several variables that were never included in the model runs and are considered the least important to larger FPs within the cluster domain: SMXS, UWND, GH500, SH800, UC600,

UC300, UWSS500, UWS600500, WD500, VC200, T500, and T300. The variable that was included in the equations the most often was UWSS600 at five out of ten model runs. Since no variable is included in the majority of the model runs, no individual variable is more important than another. The combinations of the variables that create the equations are important within this cluster, according to the MLRs. Nine of the model runs are perfect fits and one that is not a perfect fit is still a very good fit. Only one model run does not have multicollinearity issues present, the same one which was not a perfect fit. These equations can be used for identifying the variables needed to accurately predict the MCS FP that will form within the Neff Mountain/Jarosa Peak, CO cluster domain.

4.28.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA on the Neff Mountain/Jarosa Peak, CO cluster. Included in Table 4.28.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. All of the variables were included in every most used list except one – UC200 which was included in nine most used lists. Therefore, all of the variables are important to MCSMI within the cluster domain and should be observed. This also means that nine PCAs included every variable on its most used list and 100 percent variance was accounted for with all nine. The last PCA accounted for over 98 percent of its variance. The model runs were perfect or very good fits to the data indicating that these PCAs can be used for identifying the variables needed to accurately predict MCSMI within the Neff Mountain/Jarosa Peak, CO cluster.

4.28.4: Cluster Discussion

With the information from the previous two sections and the following section, the conclusion is that the PCA is the slightly better analysis for this cluster. The problem with the

MLRs is the multicollinearity issues seen with so many of the model runs. The perfect fits and the number of variables included in the equations allow MLRs to be a good analysis; however, the PCAs were better fits and included every variable. Therefore, PCA is the better choice for observing MCSMI within the Neff Mountain/Jarosa Peak, CO cluster domain.

The Neff Mountain/Jarosa Peak, CO cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-northwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that winds at 600 mb will arrive at an angle to the ridgeline and winds at 500 mb will arrive perpendicular to the ridgeline.

The composite map for Neff Mountain/Jarosa Peak, CO is Figure 4.28.2. The most important temperature variable was STHC. Cooler potential temperatures are due east and warmer potential temperatures are west of the cluster domain. This configuration indicates cooler potential temperatures are currently at the surface. The most important geopotential height variable was GH300. A trough is located east and a ridge to the west of the cluster domain. The heights will continue to increase until the ridge passes through the area. The most important moisture variable was SH300. There is a pocket of relatively moist air located directly over the cluster domain at 300 mb. The most important wind shear was between the surface and 600 mb. The wind shear at initiation has a median value of 2.125 ms^{-1} at 19.748˚.

4.28.5: Cluster Figures and Tables

Table 4.28.1: Median Values for the Upper Air and Surface Variables for the Neff Mountain/Jarosa Peak, CO Cluster.

Variable	Median Value
STHC	41.940
SMXR	7.695
SMXS	19.200
UWND	1.145
VWND	0.135
LCL	627.400
LI	-0.420

Table 4.28.2: Median Values for the NARR Variables for the Neff Mountain/Jarosa Peak, CO Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5825.050	5868.800	5893.600	5824.350	5861.400
PW	11.250	15.500	17.100	12.500	19.800
CAPE	228.200	168.100	239.100	329.700	348.300
CIN	-36.500	-21.300	-18.200	-19.100	-20.600
SRH	21.800	39.000	13.700	15.400	33.200
GH600	4483.750	4485.500	4483.100	4470.100	4483.000
GH500	5916.750	5929.700	5931.400	5909.800	5930.000
GH300	9672.350	9719.800	9736.200	9675.600	9723.400
GH200	12376.500	12454.000	12481.800	12385.300	12449.000
SH850	9.700e-3	1.120e-2	1.040e-2	9.000e-3	1.280e-2
SH800	8.400e-3	9.700e-3	9.000e-3	7.800e-3	1.120e-2
SH600	3.850e-3	6.300e-3	5.900e-3	4.900e-3	5.900e-3
SH500	1.950e-3	2.500e-3	2.800e-3	2.000e-3	3.500e-3
SH300	2.300e-4	3.700e-4	5.500e-4	2.250e-4	5.200e-4
SH200	3.950e-5	5.900e-5	5.600e-5	3.600e-5	5.400e-5
UC600	2.600	0.951	2.000	1.900	-0.550
UC500	2.500	-0.128	2.500	2.400	-1.700
UC300	6.300	0.654	3.200	7.700	1.100
UC200	11.850	-0.238	12.400	12.300	3.200
UWSS500	1.413	-1.648	1.330	-7.000e-2	-3.220
UWS600500	-5.500e-3	-1.079	0.000	-0.200	-1.150
UWSS600	1.450	-0.569	5.000e-2	1.075	-2.070
WD600	325.926	222.436	221.820	304.493	149.551
WD500	335.015	47.121	232.374	326.359	56.822
VC600	-2.850	1.800	1.900	-1.600	1.100
VC500	-3.050	-1.300	0.644	-4.750	-1.700
VC300	-1.602	-7.400	3.700	-1.319	-2.900
VC200	1.048	-6.200	3.000	-0.250	-7.600
VWSS500	-3.780	-1.300	-1.070	-6.380	-1.700
VWS600500	-0.400	-3.100	-1.575	-3.542	-3.100
VWSS600	-4.250	1.800	-1.370	-2.333	1.400
T600	1.940	2.400	4.100	2.400	2.200
T500	-9.500	-6.400	-6.800	-9.500	-7.000
T300	-35.600	-33.100	-31.900	-35.450	-32.800
T200	-54.050	-52.600	-53.500	-53.500	-53.500
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5873.600	5839.050	5872.100	5849.500	5816.950
PW	15.500	12.950	15.200	16.000	11.650
CAPE	37.500	66.200	136.500	62.500	149.000
CIN	-21.700	-16.800	-22.400	-28.300	-38.150

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	17.900	10.900	44.800	20.200	24.650
GH600	4469.200	4474.500	4477.400	4474.400	4469.500
GH500	5923.300	5920.750	5926.600	5922.800	5912.100
GH300	9740.600	9684.850	9726.000	9741.200	9683.550
GH200	12485.500	12397.400	12456.800	12486.600	12399.150
SH850	9.400e-3	8.300e-3	1.230e-2	1.040e-2	8.700e-3
SH800	8.200e-3	7.250e-3	1.070e-2	9.000e-3	7.600e-3
SH600	5.000e-3	4.400e-3	5.000e-3	5.200e-3	3.900e-3
SH500	3.000e-3	2.400e-3	2.700e-3	2.800e-3	1.950e-3
SH300	4.200e-4	2.600e-4	3.900e-4	5.100e-4	2.700e-4
SH200	5.400e-5	3.500e-5	6.100e-5	5.700e-5	3.400e-5
UC600	1.200	2.450	-0.271	3.000	2.850
UC500	2.500	1.950	-1.100	2.600	0.833
UC300	3.600	6.050	2.600	6.300	7.750
UC200	9.500	12.600	3.600	9.400	12.900
UWSS500	1.730	-1.530	-2.62	0.950	-0.778
UWS600500	0.733	-1.262	0.500	0.926	-0.298
UWSS600	0.950	-0.718	-3.120	0.940	0.475
WD600	292.751	300.405	175.443	249.864	285.328
WD500	289.385	276.814	70.346	284.365	328.711
VC600	-0.931	-2.100	0.435	-1.200	-1.137
VC500	-1.900	-4.600	-0.500	-2.100	-2.300
VC300	3.600	-3.300	-8.200	2.400	-2.750
VC200	4.900	-0.659	-9.600	3.700	-1.499
VWSS500	-1.450	-5.315	-0.500	-0.370	-2.349
VWS600500	-0.269	-2.300	-3.900	-0.114	-0.834
VWSS600	-1.950	-2.000	3.400	-3.000e-2	-1.494
T600	4.800	2.900	2.900	3.700	2.600
T500	-6.300	-9.100	-6.900	-6.400	-9.000
T300	-31.700	-35.150	-32.700	-31.100	-35.100
T200	-53.800	-54.050	-53.200	-53.300	-53.850

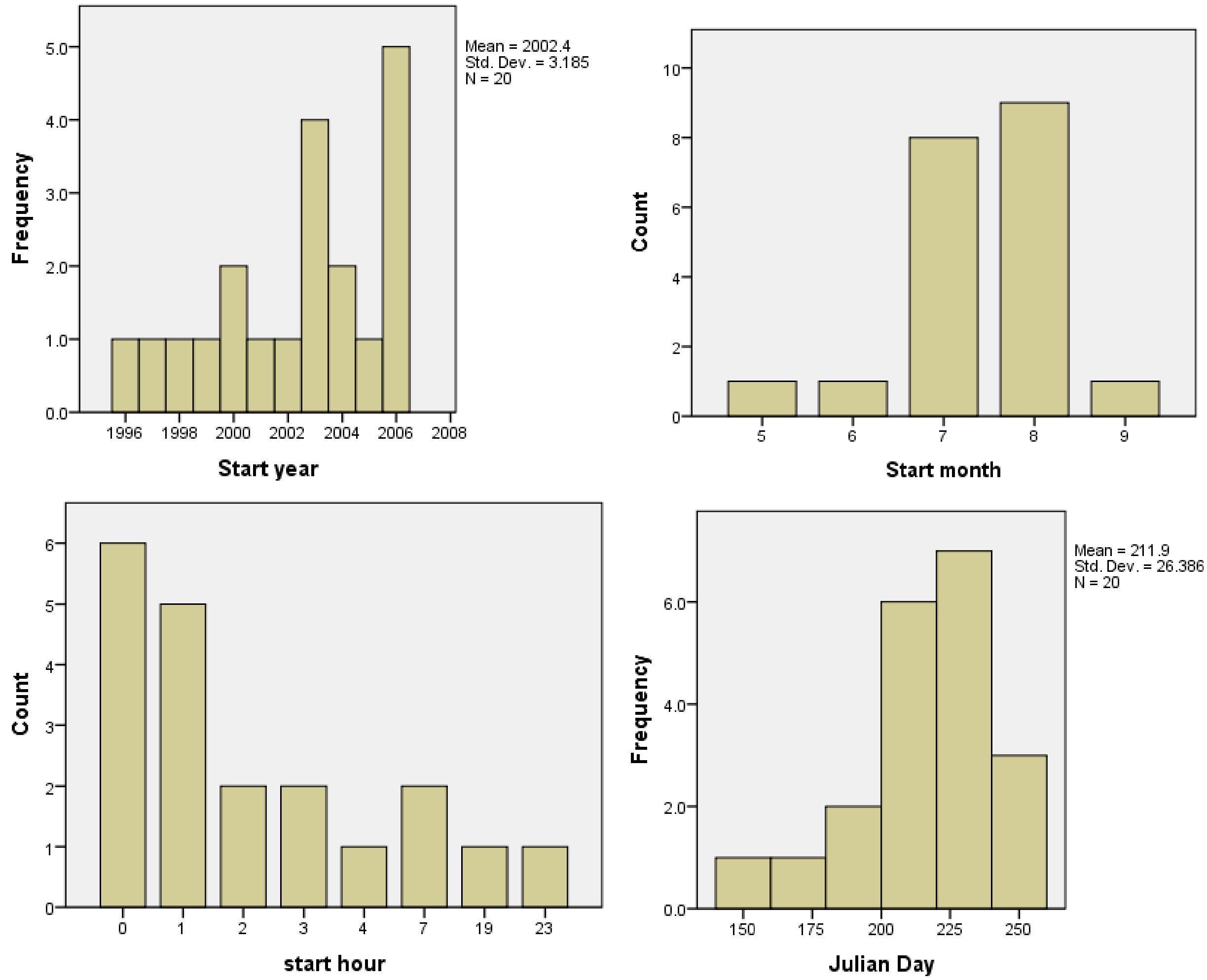


Figure 4.28.1: Time Histograms for the Neff Mountain/Jarosa Peak, CO Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.28.3: Results of the MLRs Run on the Neff Mountain/Jarosa Peak, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + UWSS600 – T600 – CAPE + VWS600500 + UC500 – GH200 + WD600	1.000
5HP	FP ≈ constant + T600 + WD600	1.000
4HP	FP ≈ constant + VC500 – Thickness + UWSS600 – VC300 – UC200 – SRH + VC600 – CIN	1.000
3HP	FP ≈ constant + UWSS600 – WD600	0.915
2HP	FP ≈ constant – VC600 – PW	1.000
1HP	FP ≈ constant + SRH + SH300 + LCL – VWSS600 + STHC – SH200 + VWND – VWS600500	1.000
Initiation	FP ≈ constant + UWSS600 – T200 – SMXR + SH850 – STHC – SH600 + GH300	1.000

Table 4.28.4: Results of the PCAs Run on the Neff Mountain/Jarosa Peak, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	7	100.000%
5HP	All variables	2	100.000%
4HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	98.322%
3HP	All variables	7	100.000%
2HP	All variables	2	100.000%
1HP	All variables	8	100.000%
Initiation	All variables	7	100.000%

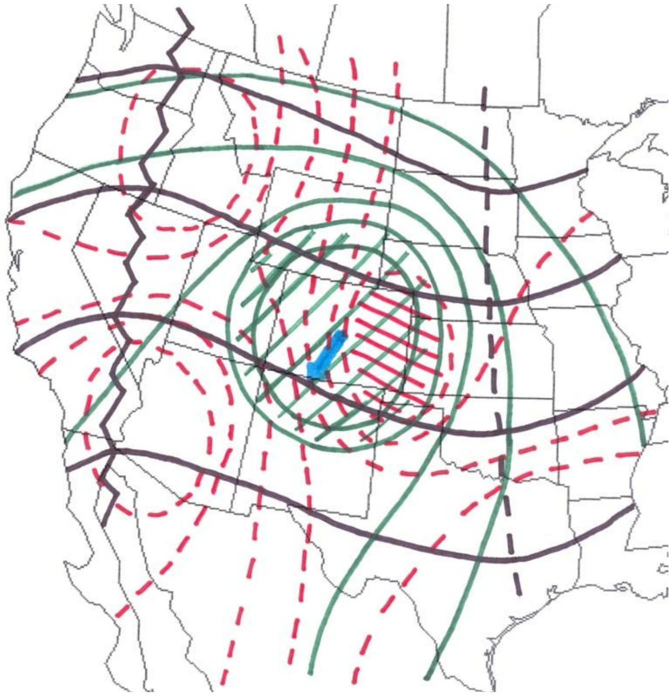


Figure 4.28.2: Composite Map for Neff Mountain/Jarosa Peak, CO. The variables included on the map are STHC, GH300, SH300, and wind shear between the surface and 600 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.29: Rincon del Cuervo, NM

4.29.1: Description of Cluster

The Rincon del Cuervo, NM cluster contains 20 members and is located due north of the San Juan Indian Reservation, NM and Santa Clara Indian Reservation, NM. The median values for the surface and upper air variables are given in Table 4.29.1 and the median values from the NARR data are given in Table 4.29.2. Histograms from the Rincon del Cuervo, NM cluster, Figure 4.29.1, were created for the start year, start month, start hour, and Julian Day.

4.29.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the Rincon del Cuervo, NM cluster. The resulting equations and the R square values are included in Table 4.29.3. Several variables were never used in the MLRs: LI, PW, GH500, SH800, SH600, UWSS500, UWSS600,

WD600, WD500, VC500, VC500, VWS600500, T300 and T200 which are considered the least important to larger FPs within this cluster's domain. The variable that was used the most was UC300 which was included in four out of ten model runs. Since there is no one variable or set of variables that is more important than any other, the conclusion can be made that it is the combination of variables that is more important to larger FPs within the Rincon del Cuervo, NM cluster domain. Eight of the model runs were perfect fits, each of which had multicollinearity issues.

4.29.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.29.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues of one or greater, and percent variance accounted for with those eigenvalues. Each variable was included on every most used list and all of the variance was accounted for with every model run. The number of components required to account for that variance depended on the model run. Between three and seven components were needed to reach 100 percent accounted for variance.

4.29.4: Cluster Discussion

Since the PCAs accounted for all of the variance with every model run and all of the variables were included on every most used list, the PCA is the better analysis type for this cluster. There were multiple multicollinearity issues present in the MLRs but the equations can still be used for identifying the variables needed to predict the FP of the systems that the PCAs will identify the necessary variables for formation within the Rincon del Cuervo, NM cluster.

The Rincon del Cuervo, NM cluster is in a portion of the Rocky Mountains that contains both north-south and east-west oriented ridgelines. The median wind direction at 600 and 500 mb and initiation give winds from the west which indicates that winds at 600 and 500 mb arrive along the east-west ridgeline and perpendicular to the north-south ridgeline.

The composite map for Rincon del Cuervo, NM is Figure 4.29.2. The most important temperature variable was STHC. Cooler potential temperatures are located east and warmer potential temperatures are located west of the cluster domain. This indicates the cluster domain is located in an area of relatively warm potential temperatures. The most important geopotential height variable was GH300. There is a ridge located west of the cluster domain. The heights will increase until the ridge moves through the area, and then the heights will decrease. The most important moisture variable was SH200. The cluster domain is located within an area of moist air at 200 mb. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 7.582 ms^{-1} at 260.128˚.

4.29.5: Cluster Figures and Tables

Table 4.29.1: Median Values for the Upper Air and Surface Variables for the Rincon del Cuervo, NM Cluster.

Variable	Median Value
STHC	39.600
SMXR	9.660
SMXS	20.260
UWND	-0.760
VWND	0.000
LCL	685.040
LI	-0.705

Table 4.29.2: Median Values for the NARR Variables for the Rincon del Cuervo, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5846.000	5793.500	5883.300	5865.000	5799.000
PW	16.300	15.700	20.200	16.100	16.900
CAPE	208.000	245.300	348.750	211.600	184.000
CIN	-16.400	-9.100	-11.650	-7.600	-12.300
SRH	5.500	27.100	14.100	0.795	29.600
GH600	4467.700	4419.800	4473.400	4472.200	4392.400
GH500	5918.200	5846.400	5918.900	5917.400	5822.500
GH300	9652.400	9591.800	9720.300	9651.400	9576.700
GH200	12353.300	12324.100	12455.650	12349.000	12306.800
SH850	7.800e-3	9.800e-3	9.450e-3	7.000e-3	8.600e-3
SH800	6.800e-3	8.500e-3	8.250e-3	6.100e-3	7.500e-3
SH600	3.600e-3	4.400e-3	5.500e-3	4.800e-3	4.700e-3
SH500	2.400e-3	2.400e-3	2.900e-3	2.300e-3	2.300e-3
SH300	2.900e-4	3.000e-4	3.350e-4	2.900e-4	3.000e-4
SH200	5.700e-5	3.900e-5	4.650e-5	5.700e-5	3.900e-5
UC600	5.100	7.200	3.550	5.000	8.300
UC500	5.600	9.000	4.650	6.000	10.200
UC300	0.881	12.900	5.950	3.000	12.200
UC200	3.000	24.500	8.000	6.200	24.100
UWSS500	4.060	10.530	7.425	4.760	13.030
UWS600500	0.400	1.400	0.950	0.700	1.100
UWSS600	8.460	9.930	6.160	4.460	9.800
WD600	256.278	251.565	236.923	253.161	252.834
WD500	233.973	237.848	240.126	258.878	254.152
VC600	1.700	2.500	1.550	0.908	2.200
VC500	2.300	2.700	2.650	0.865	3.100
VC300	4.400	9.500	3.850	3.600	9.000
VC200	1.800	9.400	0.900	3.300	9.800
VWSS500	3.770	3.563	1.623	3.187	2.370
VWS600500	1.800	0.100	0.450	0.800	0.400
VWSS600	1.570	4.110	1.960	1.670	3.780
T600	2.200	-0.702	3.300	1.600	-0.115
T500	-9.500	-8.400	-7.350	-9.600	-10.700
T300	-37.000	-35.700	-32.150	-36.300	-35.200
T200	-52.800	-52.400	-52.300	-52.600	-52.500
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5880.900	5876.700	5780.600	5859.850	5859.800
PW	19.900	19.200	16.400	19.300	17.100
CAPE	234.400	139.300	156.500	313.400	80.500
CIN	-19.000	-23.100	-12.900	-33.700	-14.300

Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
SRH	13.750	14.200	17.500	24.700	35.700
GH600	4470.400	4462.700	4386.500	4483.400	4458.000
GH500	5926.100	5912.800	5814.000	5936.500	5900.400
GH300	9714.300	9683.500	9548.500	9737.200	9658.200
GH200	12463.000	12402.400	12297.300	12464.600	12375.100
SH850	9.150e-3	8.800e-3	8.000e-3	9.350e-3	8.600e-3
SH800	7.950e-3	7.600e-3	6.900e-3	8.150e-3	7.400e-3
SH600	5.700e-3	5.200e-3	4.600e-3	5.200e-3	3.900e-3
SH500	3.100e-3	2.900e-3	2.600e-3	2.750e-3	2.500e-3
SH300	3.450e-4	3.700e-4	2.900e-4	3.900e-4	3.500e-4
SH200	4.900e-5	6.500e-5	5.100e-5	4.850e-5	5.900e-5
UC600	4.750	6.200	6.600	4.550	6.100
UC500	5.350	6.400	6.900	5.000	8.100
UC300	8.450	3.700	12.900	9.600	5.500
UC200	9.400	5.900	27.500	9.600	8.800
UWSS500	9.525	7.470	11.530	9.100	7.660
UWS600500	0.400	1.100	1.100	1.000	0.800
UWSS600	6.474	5.260	8.690	6.250	6.270
WD600	258.423	263.373	260.750	260.625	262.756
WD500	273.698	258.518	263.815	289.191	273.182
VC600	0.917	0.790	-1.100	0.355	0.966
VC500	-0.600	1.300	0.517	-2.050	-0.467
VC300	5.350	2.500	10.100	2.100	3.000
VC200	2.600	3.100	11.500	1.700	3.100
VWSS500	0.610	1.300	0.790	-1.839	-0.467
VWS600500	-0.458	-1.100	1.800	-1.649	-1.433
VWSS600	1.527	3.460	-2.216	0.179	0.966
T600	3.300	2.600	-0.372	2.950	2.400
T500	-6.900	-8.700	-10.900	-7.100	-9.600
T300	-31.750	-35.400	-35.300	-32.450	-35.600
T200	-52.900	-52.600	-51.800	-53.150	-52.300

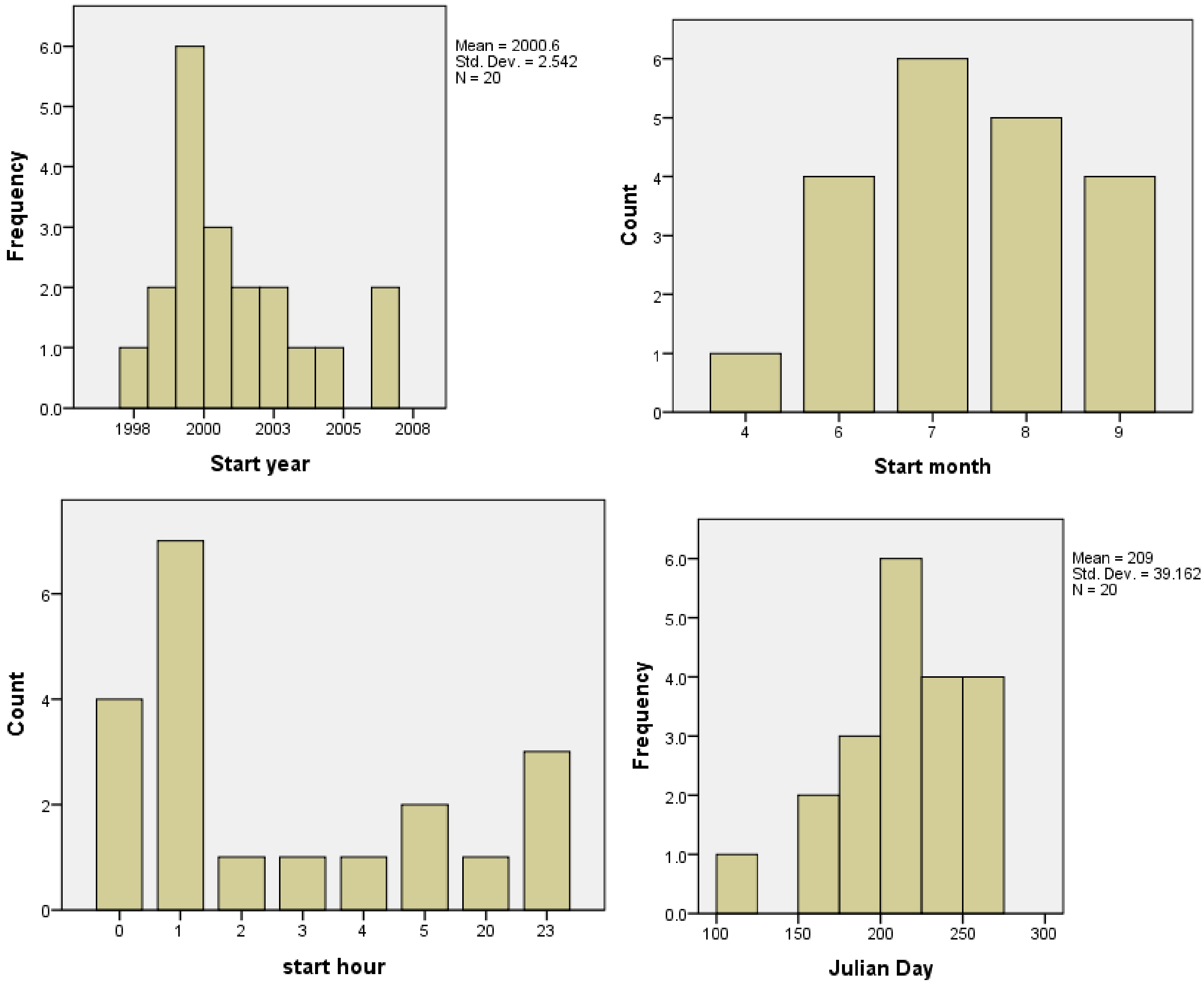


Figure 4.29.1: Time Histograms for the Rincon del Cuervo, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.29.3: Results of the MLRs Run on the Rincon del Cuervo, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – SMXS + SRH – UC500 – SH200	1.000
5HP	FP ≈ constant + UC300 + SH300 + T600 – T500 + SMXR – UC200	1.000
4HP	FP ≈ constant – STHC – SMXR + UWND – VWND – VC300 + CAPE + LCL	1.000
3HP	FP ≈ constant – SMXS	0.877
2HP	FP ≈ constant + UC300 + SH500 – VC300 – VWSS500 – GH300 – GH200	1.000
1HP	FP ≈ constant – UC600 – VC600 + CIN + SH200 – Thickness – LCL + GH600	1.000
Initiation	FP ≈ constant – STHC – VWSS500 + UWS600500	1.000

Table 4.29.4: Results of the PCAs Run on the Rincon del Cuervo, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	4	100.000%
5HP	All variables	6	100.000%
4HP	All variables	7	100.000%
3HP	All variables	4	100.000%
2HP	All variables	6	100.000%
1HP	All variables	7	100.000%
Initiation	All variables	3	100.000%

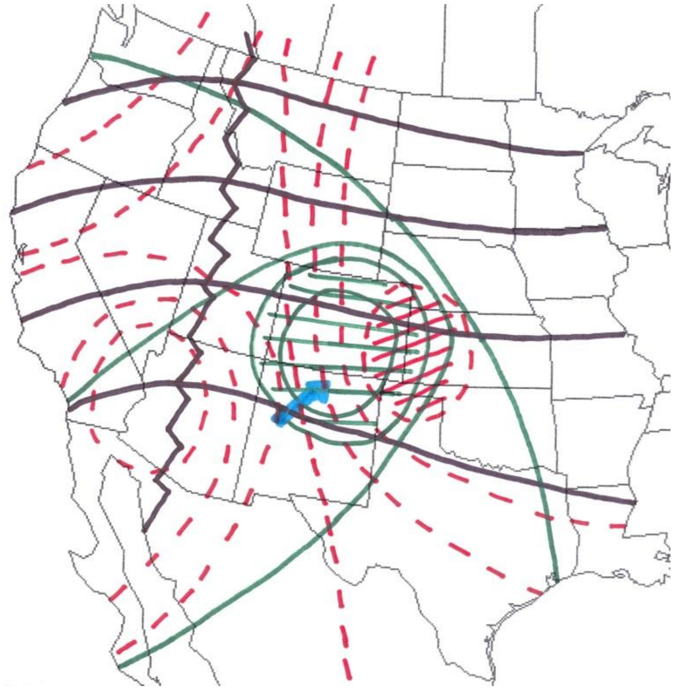


Figure 4.29.2: Composite Map for Rincon del Cuervo, NM. The variables included on the map are STHC, GH300, SH200, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.30: South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM

4.30.1: Description of Cluster

The South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM cluster contains 20 members and is located north of Taos, NM in the Wheeler Park Wilderness. The median values for the surface and upper air variables are given in Table 4.30.1 and the median values from the NARR data are given in Table 4.30.2. Histograms for this cluster, Figure 4.30.1, were created for the start year, start month, start hour, and Julian Day.

4.30.2: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM cluster. The resulting equations and the R square values are included in Table 4.30.3. There were several variables that were never included in the MLR equations and are considered the least important to larger FPs within this cluster's domain: Thickness, GH600, GH500, GH300, SH800, SH600, UC600, UC500, UWSS500, UWSS600, T600, and T300. The variable included the most in the equations was T200 at five model runs. Therefore, no individual variable but rather the combination of variables is considered important to initiation. All of the model runs were perfect fits but each had multicollinearity issues.

4.30.3: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA. Included in Table 4.30.4 are the variables with 90 percent variance accounted for, the number of components with eigenvalues valued one or greater, and percent variance accounted for with those eigenvalues. Most of the variables were included in every most used list. The variables that were not included on every list were SH500, UWS600500, and VWS600500 which were in nine of the ten lists. Therefore, all of the variables are considered important to MCS initiation within the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM cluster domain. Eight model runs had all of the variables included on the most used list and seven model runs accounted for 100 percent of the variance.

4.30.4: Cluster Discussion

With the information gathered in the two previous sections and the following section, the PCA is considered the better analysis type for this cluster. Even though the PCA is not a perfect fit every time, it corrects the fit issues seen often in the MLRs. The MLRs can be used for the identification of the variables needed to predict the FP of the eventual MCS within the cluster domain; however, the PCAs use every variable in every model run and are considered the better analysis type for the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM cluster.

The South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM cluster is in a portion of the Rocky Mountains that contains a north-south oriented ridgeline. The median wind direction at 600 mb and initiation gives winds from the southwest. The median wind direction at 500 mb and initiation gives winds from the west-northwest. This indicates that the winds at 600 and 500 mb arrive at an angle to the ridgeline.

The composite map for South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM is Figure 4.30.2. The most important temperature variable was T200. Cooler temperatures are located east of the cluster domain indicating the domain is within an area of relatively warmer temperatures. The most important geopotential height variable was GH200. A ridge is located to the east of the cluster domain. This indicates the heights are falling as the ridge moves eastward. The most important moisture variable was SH200. The cluster domain is within an area of relatively moist air since moist pockets of air are present to the east and west of the domain. The most important wind shear was between 600 and 500 mb, two upper levels. The wind shear at initiation has a median value of 3.353 ms^{-1} at 342.646˚.

4.30.5: Cluster Figures and Tables

Table 4.30.1: Median Values for the Upper Air and Surface Variables for the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster.

Variable	Median Value
STHC	39.030
SMXR	8.575
SMXS	17.335
UWND	-1.105
VWND	0.825
LCL	610.975
LI	-0.645

Table 4.30.2: Median Values for the NARR Variables for the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5870.600	5887.450	5878.100	5884.900	5876.000
PW	13.000	13.000	15.400	13.100	13.450
CAPE	168.500	144.750	221.800	162.900	51.750
CIN	-16.000	-17.500	-15.300	-29.900	-32.100
SRH	28.800	7.850	19.200	21.700	18.150
GH600	4445.500	4463.500	4489.800	4455.300	4459.450
GH500	5899.600	5905.350	5934.900	5914.600	5904.000
GH300	9699.500	9676.150	9713.900	9693.500	9686.100
GH200	12426.100	12402.800	12465.000	12427.200	12415.350
SH850	1.010e-2	9.500e-3	1.090e-2	1.050e-2	8.850e-3
SH800	8.800e-3	8.300e-3	9.500e-3	9.100e-3	7.700e-3
SH600	5.600e-3	4.900e-3	6.000e-3	5.000e-3	4.650e-3
SH500	2.100e-3	2.200e-3	2.700e-3	2.500e-3	2.450e-3
SH300	3.400e-4	3.250e-4	3.100e-4	3.700e-4	3.250e-4
SH200	5.200e-5	3.250e-5	4.900e-5	4.800e-5	5.300e-5
UC600	1.400	1.850	2.600	0.658	0.996
UC500	0.878	2.450	6.000	1.100	2.050
UC300	-1.500	0.944	8.400	0.997	1.784
UC200	0.155	-0.227	10.400	4.500	-0.207
UWSS500	7.000e-2	2.420	6.000	1.560	1.620
UWS600500	0.700	0.850	0.100	0.500	0.950
UWSS600	3.030	1.520	6.400	3.530	0.680
WD600	223.025	251.429	243.435	187.648	205.789
WD500	198.014	272.718	287.571	198.970	270.738
VC600	1.500	-0.833	-0.828	1.800	0.560
VC500	2.700	-3.350	-4.100	1.500	-3.250
VC300	2.500	-0.307	2.100	2.600	-0.520
VC200	1.900	0.800	-0.760	2.900	0.377
VWSS500	0.980	-6.150	-3.760	-0.620	-6.750
VWS600500	0.500	-1.550	-3.900	-2.600	-3.359
VWSS600	0.656	-3.961	-0.435	1.988	-2.524
T600	4.000	3.850	3.100	3.900	4.450
T500	-7.600	-7.950	-6.600	-8.200	-7.950
T300	-33.600	-34.550	-32.700	-33.400	-33.650
T200	-52.500	-53.150	-54.500	-53.200	-53.900
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5858.600	5859.500	5851.850	5837.600	5827.700
PW	14.400	16.000	13.100	13.800	14.400
CAPE	101.300	98.100	24.650	310.600	39.900
CIN	-29.700	-34.500	-56.100	-26.500	-37.400

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	11.400	35.400	33.150	16.100	42.600
GH600	4499.700	4461.400	4465.150	4502.100	4464.800
GH500	5941.600	5914.400	5906.500	5945.000	5919.800
GH300	9727.800	9695.100	9663.600	9711.000	9701.300
GH200	12492.800	12422.900	12388.200	12465.800	12433.200
SH850	1.030e-2	1.020e-2	9.400e-3	1.020e-2	9.100e-3
SH800	9.000e-3	8.800e-3	8.200e-3	8.900e-3	7.900e-3
SH600	5.700e-3	5.300e-3	4.300e-3	4.100e-3	4.700e-3
SH500	2.400e-3	2.500e-3	2.450e-3	2.200e-3	2.500e-3
SH300	3.200e-4	4.000e-4	3.500e-4	4.200e-4	4.100e-4
SH200	5.200e-5	4.900e-5	3.950e-5	5.400e-5	5.000e-5
UC600	5.100	3.400	2.150	3.600	2.200
UC500	3.500	2.500	2.200	7.000	1.700
UC300	11.300	5.600	0.999	9.400	1.700
UC200	13.600	5.400	-9.750e-2	10.100	2.900
UWSS500	3.500	4.470	0.655	7.100	2.590
UWS600500	-0.900	1.000	-1.650	-2.700	0.254
UWSS600	5.100	3.860	2.150	4.900	3.760
WD600	257.005	224.170	242.034	286.091	228.621
WD500	263.270	297.216	227.606	294.727	253.775
VC600	-1.200	1.600	1.180	-2.600	2.500
VC500	-4.300	-1.200	-1.551	-4.400	-1.500
VC300	0.274	2.600	1.256	-0.937	-9.300e-2
VC200	-5.600	1.500	-0.419	-4.200	4.900
VWSS500	-5.140	-1.320	-4.931	-3.860	1.480
VWS600500	-3.100	-3.200	-3.051	-2.140	-2.500
VWSS600	-2.060	0.628	-1.501	-3.000	1.270
T600	2.700	3.200	3.550	3.100	3.300
T500	-6.100	-7.800	-7.600	-6.500	-7.100
T300	-32.000	-32.700	-34.550	-32.400	-33.400
T200	-53.300	-52.800	-53.550	-53.800	-52.600

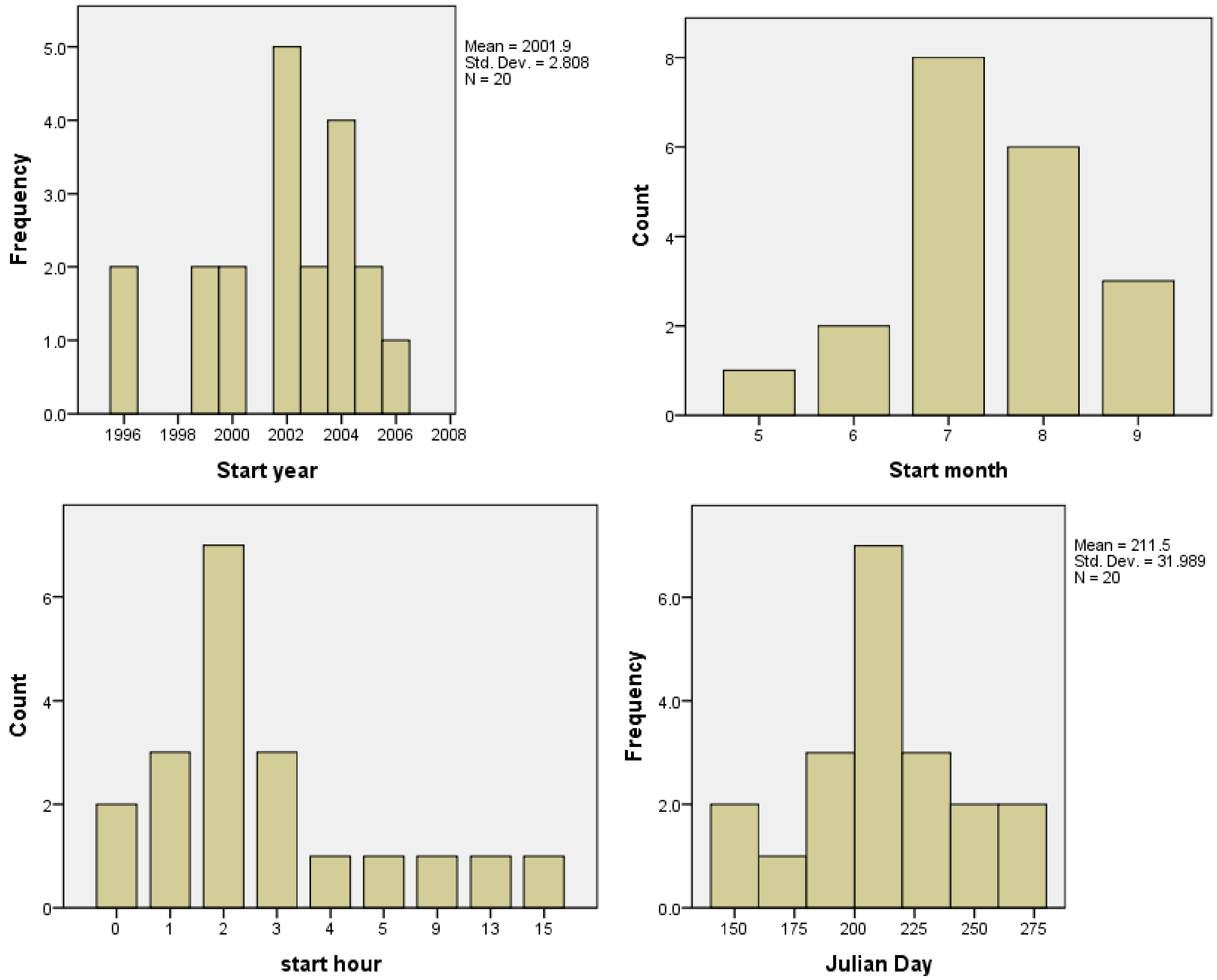


Figure 4.30.1: Time Histograms for the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 4.30.3: Results of the MLRs Run on the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant – T200 – UWND – UWS600500 + STHC + LCL + SMXS	1.000
5HP	FP ≈ constant – VC300 + UC200 + VC600 + STHC + SH200 + WD500 + SMXS	1.000
4HP	FP ≈ constant + UWS600500 + VC500 + SH850 + GH200	1.000
3HP	FP ≈ constant + LI + LCL + VWSS600 + SH200 + STHC – UC200	1.000
2HP	FP ≈ constant – VC200 + UC200 + VC600 – WD600 – T200 + SMXR – VC500	1.000
1HP	FP ≈ constant – GH200 + CIN – SH850 – VWND	1.000
Initiation	FP ≈ constant + UWS600500 + SH500 – WD500 – T200 + SH300 + SRH	1.000

Table 4.30.4: Results of the PCAs Run on the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	All variables	6	100.000%
5HP	All variables	6	98.719%
4HP	All variables	4	100.000%
3HP	All variables	6	100.000%
2HP	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	98.431%
1HP	All variables	4	100.000%
Initiation	All variables	6	100.000%

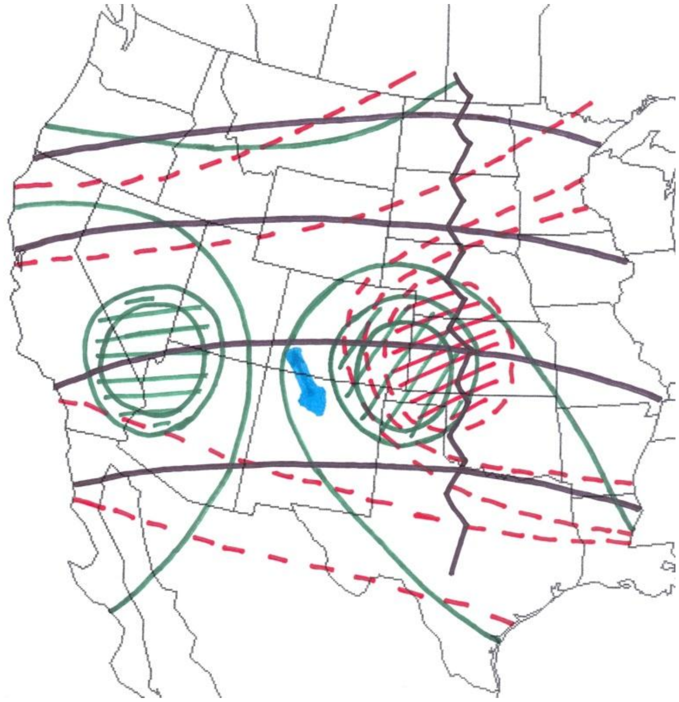


Figure 4.30.2: Composite Map for South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM. The variables included on the map are T200, GH200, SH200, and wind shear between 600 and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

4.31: Overall Individual Cluster Discussion

No two clusters produce the same results; however, there are some similarities that need to be addressed. The most important variables for each cluster are in Table 4.31.1 and were determined by the number of times a variable appeared in an MLR and the number of times a variable had 90 percent or more variance accounted for in a model run.

One similarity among the clusters is the inclusion of a wind shear variable within the most important variables. Twenty-two of 31 clusters have a wind shear variable listed in the most important variables; therefore, this indicates that the wind shears are important for identifying the variables needed for MCSMI within the overall domain. The same wind shear is not important in every cluster but, overall, the wind shear between the surface and an upper level is more important than the wind shear between two upper levels.

There was a wind variable included in 22 every most important list. These 22 clusters are not the same as those which included wind shear variables. There are some clusters that did not contain both wind shear and wind variables on the most important list. The wind variables included on the most important list are not consistent throughout but the indication is that the winds are important since a variable from the wind variable group is included on the most important list.

Nine of 31 clusters also included LCL in its most important list. There were multiple instances of the LCL varying greatly throughout a cluster. The nine clusters that included LCL the most typically did not have a greatly varying LCL value. Smaller variations in the LCL can be more easily accounted for rather than larger variations.

Several clusters also contain geopotential height variables and Thickness within the most important list. Sixteen clusters contain them and 15 clusters do not. This is definitely different from the number of times a wind shear variable was included on the most important variables list since the a wind shear variable was included often and the geopotential height variables were not included as often. These variables can indicate the placement of high and low pressures and troughs and ridges. However, the data was only recorded at the initiation location so it is difficult to determine the placement of high and low pressures and troughs and ridges from a singular point. Point values surrounding the initiation location would give a better indication of placement.

Fewer clusters included CAPE, LI, and CIN on the most important variable list. Only six clusters included CAPE on the most important variable list; therefore, CAPE is important only a fraction of the time within the overall global domain. Only four clusters included LI on the most important variable list. When the variables were originally recorded, it should be noted that LI tended to vary widely. This could account for the number of times it was included on the most important variable list. The wide variation would make it harder for the model runs to account for the variations. Only three clusters included CIN on the most important variable list which indicates that CIN is less important than CAPE. The few times CIN is included could be correlated to the value of CIN. For most of the cases, CIN was a small, negative value and would not contribute significantly overall to the FP or MCSMI. CIN may not be important since it tended to be uniformly low.

Thirteen clusters contained both a stability variable (CAPE, LCL, or CIN) and a wind shear variable on the most important variable list. Nine clusters contained a wind shear variable but no stability variable on the most important variable list. Four clusters contained a stability variable but no wind shear variable on the most important variable list. The remaining clusters (five) contained neither a wind shear variable nor a stability variable. This shows that wind shear and stability, together, are important but can also be separately important as well within the individual cluster domains.

In 13 cluster most important variable lists, upper air variables are used. This shows that that less than a majority of the time an upper air variable is considered important to the identification of the variables needed for predicting MCSMI and larger FPs. The number of times could be attributed to the fact that there are only two upper air variables, taken from GEMPAK, contained within this dataset. Large variations in LCL and LI could contribute to the low number of times they were included the most often. In 17 cluster most important variable lists, surface variables were used. This shows that in a majority of the clusters a surface variable was considered one of the most important variables.

Eight clusters contained wind shear, stability, and geopotential height variables on the most important list. These variables can give an overall indication of which conditions are needed for identifying the variables needed for MCSMI and larger FPs. Combinations of these sets of variables can also give an overall indication, just not as complete as if all the variable sets were included on the most important variable list. Six clusters contained wind shear and geopotential height variables on the most important variable list. Five clusters contained wind shear and stability on the most important variable list. Four clusters contained geopotential height variables on the most important variable list and three clusters contained wind shear variables. Two clusters contained wind shear and two clusters did not contain any wind shear, stability, or geopotential height variables on the most important variable list. Only one cluster had stability and geopotential height variables both contained on the most important variable list.

Overall conclusions for the individual cluster results include wind shear variables are very important for the identification of the variables used in estimating MCSMI and larger FPs and geopotential height variables are important but not as important as wind shear variables. The wind variables are also very important for anticipating MCSMI and larger FPs according to this analysis. While these variables may be loaded differently from one cluster to another (positively versus negatively), the overall effect of the variables is still present. The most used and important variables are the ones to use for the potential to predict MCSMI and larger FPs within each individual cluster domain and within the global domain. How a variable is loaded and used and how much that variable is loaded or used is different from cluster to cluster but the use of the variable does indicate some of its importance to MCSMI and larger FPs within the overall domain.

Several variables are related to each other but did not always tend to appear together on the most important variables list. One example would be the Thickness and GH500. These two variables cover the same approximate depth of the atmosphere and should be highly correlated to each other. However, either Thickness or GH500 appears in the most important variable list for each cluster; it does not tend to be both variables. Another example of variables being related would be several of the wind shear variables. The wind shear variables covering the surface to 500 mb and the surface to 600 mb should be of similar value and could be highly correlated with each other. This poses the question: are all the variables used in this analysis really needed? The answer is not necessarily. These variables were chosen because of the discussion included in the literature that spanned several articles. With the similar variables, the most important variable of that group could be chosen over observing multiple variables at multiple levels. This would make it easier to implement the forecast models that could eventually be derived from this analysis.

The individual cluster model runs results were good fits to the data and could be used as a first step in predicting the variables needed for the potential for MCSMI (using the PCAs) and predicting the FP resulting from the MCSMI (using the MLRs) since the results are showing what conditions are related to MCS development. The variables included the most often on the most important variable list are the ones to observe to determine if the potential for MCSMI exists within each cluster domain. Currently, this method is not a practical tool for forecasting but with verification and possible improvements, it could become a tool to be used in predicting for MCSMI.

Table 4.31.1: Most Used Variables for Each Cluster Without Count. The first column contains the cluster name. The second column contains the most important variables within each cluster (continued onto the next page).

Cluster Name	Most Important Variables
Elk Mountain, NM	GH200, GH300, Thickness, UC500, UWSS500, VC500, VWSS500
Elk Mountain, NM Wind Direction Group 1	GH300, T300, UWSS500, VWSS500
Elk Mountain, NM Wind Direction Group 2	LCL, UC500, UWS600500, UWSS600, VWSS500
Ute Hills/Pete Hills, CO	UWSS500, VWSS600
Rincon Mountains, NM	GH500, UWSS600
Lookout Peak/Rayado Peak, NM	GH500, UC500, UWSS500, VWND, VWSS500
Pajarito Mountain/Cerro Grande, NM	GH600, Thickness
Culebra Range/Sangre de Cristo Mountains, CO	Thickness, UC500, UWND, UWSS500, VWSS500, VC600
Shaggy Peak, NM	STHC, Thickness, UWSS500, VWSS500
Los Pinos Mountains, NM	VC300, VWSS500
Mount Washington, NM	GH200, GH300, GH500, LCL, SH800, SH850, SMXR, T300, T600, UC200, UWS600500, UWSS600, VC200, VC500, VWSS500, VWSS600
Wrye Peak, NM	CAPE, GH300, GH500, GH600, UC300, UWS600500, VC200, VC600, VWSS500, VWSS600
Mesa de los Jumanos, NM	CIN, SH300, SMXS, UC200, UC500, UWSS600, VC500
Jacinto Mesa, NM	Thickness, UWND
Bartlett Mesa/Horse Mesa, NM	LI, SH600, UC600, UWS600500, VC300, VWND
Trinchera Mesa/Valencia Hills/Howard Mountain, NM	GH200, GH500, GH600, LCL, PW, SMXS, STHC, T600, Thickness, UC200, UWSS500, UWSS600, VC200, VC300, VC500, VWSS500, VWSS600, WD500
West Mesa, NM	T200, UC300
South Mountain, NM	LCL, SRH, T600, Thickness, UC200, UWSS600
Badito Cone, CO	CAPE, LCL, SH800, SMXR, VC300
Bunker Hill, CO	CAPE, GH600, SH300, SH500, SRH, UC200, UC500, UWS600500, WD500
Caliente Canyon/Long Canyon, NM	CIN, GH300, GH500, GH600, LCL, LI, SH300, SH850, SMXS, T600, Thickness, UC500, UWS600500, UWSS500, UWSS600, VC300, VC500, VC600, VWND, VWSS600, WD500, WD600
Cowboy Mesa, NM	LI, SH300, SRH, T600, VC300, VWND
Las Mesa Del Conjelon, NM	CAPE, WD600
Laughlin Peak, NM	SH200, SRH
Hogback Mountain/Mt. Signal, CO	CAPE, SH300, SH500, SH800,SMXR, SRH, STHC, T500, UC600, VC200, VWSS600
Gacho Hill, NM	GH300, UC200
Argonne Mesa, NM	CAPE, GH500, LCL, SH600, SH850, SMXS, SRH, STHC, UWS600500, UWSS600, VC300, VC600, VWND, WD500, WD600
Jicarilla Mountains, NM	CIN, GH600, LI, SH200, SH600, SH850, UC200, UC300, UC500, UWND, UWSS600, VWS600500, VWSS600, WD600
Neff Mountain/Jarosa Peak, CO	STHC, UWSS600
Rincon del Cuervo, NM	LCL, SH200, SMXS, STHC, UC300, VWSS500
South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM	GH200, LCL, STHC, T200, UC200, VC600

5: Global Results

The global results are detailed in this chapter. MLRs and PCAs were run on all of the data and the following discussion is from their results. All MLRs and PCAs will be discussed in this chapter, rather than discussed if only above a threshold value. This analysis was done to show the potential that the individual cluster results give a better fit to the data than a global fit. It is also possible that the global results give a good fit to the data since some variables are important in most of the clusters. The global results were done for the possibility that an equation was possible for the entire region rather than multiple equations covering the global domain. A composite map for the global results is included in section 5.4.3.

5.1: Description of all Mesoscale Convective Systems

The global results contain all of the members from the clusters discussed above – 1,165 members in total. The global results are contained within the Arkansas-Red River Basin west of 104˚W (CO and NM). The median values for the surface variables in Table 5.4.1 show that the air is relatively hot (potential temperature) at 38.160˚C (approximately 101˚F) and relatively dry (when compared to the individual clusters, from TZ99), and the winds are from the south. Since the potential temperature is relatively hot at the closest reporting station, it can be considered relatively hot at the initiation location. The median values of SMXR and SMXS show that the air is relatively dry with a relative humidity of approximately 54 percent. The UWND and VWND give a median wind direction of south which differs from the upper level wind directions. The median values given from the upper air variables in Table 5.4.1 show a below-ridgetop level LCL and a slightly negative LI indicating that the air is unstable.

The median values from the NARR data are given in Table 5.4.2 and show how the variables change throughout all the model runs. Thickness and geopotential height variables do not change significantly overall. There are some variations when comparing the hours but it is not considered overly significant. The PW does not vary much; it stays within the 17-18 mm range throughout. CAPE values are reasonably low and top out at 6HP. CIN varies between the model runs and hinders convection but the values are low compared to the CAPE values. The SRH variable changes throughout the model runs as well, but this variable is considered hour dependent. The specific humidity variables are moist throughout the model runs which will aid in initiation. The wind and wind shear variables vary significantly throughout the model runs but are also considered to be hour dependent since the values can change drastically from one hour to the next. The temperature variables do not vary by much throughout the model runs and are relatively cold for that level. This was seen throughout most of the clusters.

Histograms from the global results, Figure 5.4.1, were created for the start year, start month, start hour, and Julian Day. The start-year histogram shows that every year had many MCSs that initiated. The year 2006 had the most MCSs, and the mean year was 2001. The start-month histogram shows that July and August were the months when the most MCSs occurred. The fewest MCSs occurred in April. The start-hour histogram shows MCSs initiating throughout the day but most of the MCSs originated in late afternoon/early evening (consistent with FF01). There is a noticeable spike in the Julian-Day histogram in the July/August range which is consistent with the start-month histogram. These histograms show that a wide range of times are needed for MCSMI within the global domain.

In section 5.2, the most used variables for each type of analysis will be discussed, followed by the least used variables for each analysis type in section 5.3. Section 5.4 will detail the results from the model runs – the equations from the MLRs and the components from the PCAs. Section 5.5 contains a discussion of the global results.

5.2: Most Used Variables

The variables discussed in this section are the ones which were included in the most model runs for both analysis types. Since these variables are included so frequently, they are considered the most important variables for initiation within the global domain.

5.2.1: Multiple Linear Regression

The variables used the most in the MLRs were LCL and SRH (from JC07), included in eight out of ten model runs. Since these variables were included in so many of the model runs, they are considered important to larger FPs within the global domain. They are the variables that would be most beneficial to observe before initiation to determine if initiation will occur. Lower to the ground values of LCL are better for convection. The values from SRH are hour dependent and will provide different contributions depending on the hour. The next most included variables were included in four of ten model runs: Thickness, CIN, GH600, UC300, UWS600500, and T300. For the global case, these variables are still considered important to larger FPs within the domain even though they were only included in four model runs. All of these variables would be observed for larger FPs within the global domain.

5.2.2: Principal Component Analysis

According to the PCAs, several variables are important to MCSMI and should be observed for changes to determine if a possible MCS could form within the global domain. The variables that were included on every most used list were UWND, Thickness, GH300, UC500, UWSS500, UWSS600, VWSS500, VWSS600, and T500. Other variables that were included often in the most used lists were VWND (eight), GH500 (nine), GH200 (nine), VC500 (nine), T600 (seven), and T300 (eight). These two lists show the variables that are most important to MCSMI within the global domain and are the ones that should be observed. When these lists are combined with the variables that were loaded highly into the components, the most important variables to initiation will become more apparent.

5.3: Least Used Variables

The variables discussed in this section were included in the fewest model runs for both analysis types. Since these variables are included in the fewest model runs, they are considered to be the least important variables to MCSMI and larger FPs according to the respective analysis types.

5.3.1: Multiple Linear Regression

In the MLRs, there were several variables that were never included in the equations: UWND, LI, CAPE, SH850, SH800, SH600, UC600, WD500, VC500, and T500. These variables are considered least important for larger FPs within the global domain according to the MLRs and were not included in the equations for a variety of reasons including too much associated error. The variables that were rarely included in the model runs are considered semi-important to initiation and become more important when combined with other variables to create a better fit.

5.3.2: Principal Component Analysis

The variables that were not included in the most used lists were STHC, SMXR, SMXS, LCL, LI, PW, CAPE, CIN, SRH, GH600, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC300, UC200, UWS600500, WD600, WD500, VC600, VC300, VC200, VWS600500, and T200. A few of these variables are the same as the ones used least in the MLRs. The variables in the list above are considered the least important to MCSMI within the global domain according to the PCAs. Most of these variables were important for individual clusters but not considered important for the global results.

5.4: Global Model Runs

The global model runs are significantly worse fits to the data than the individual clusters. The global results were run and discussed to show that the individual clusters are a much better fit to the data and will be able to used for the identification of variables needed to accurately predict MCSMI and larger FPs. The global results for both analysis types are poor fits to the data but are mentioned to show that a fit can be accomplished when there is much associated error.

5.4.1: Multiple Linear Regression

MLRs were run on each of the 6HP through the 3HA on the global domain. The resulting equations and the R square values are included in Table 5.4.3. These equations show how the global results are not a good fit to the data. The results discussed below from the global domain come from a combination of Table 5.4.1, Table 5.4.2, and Table 5.4.3. Even though these MLRs are poor fits to the data it is worth discussing due to the information that can be obtained from the discussion. This also highlights the need for individual cluster equations as opposed to global equations.

The 6HP model run was a poor fit to the data at 0.156 and there were multicollinearity issues present. Weaker north-south winds at 600 mb, larger SRH values (from JC07), stronger U component wind shears between the surface and 500 mb, a moist pocket of air at 300 mb, and warmer temperatures at 300 and 600 mb are needed for larger FPs over the entire global domain. Smaller Thickness values, colder columns of air between the surface and 300 mb, and warmer columns of air between the surface and 600 mb are also needed for initiation within the global domain. This model run is a very poor fit to the data which proves that the individual cluster model runs will be of better use than the global model run at this time.

The 5HP model run is a better fit than the previous model run but still a poor fit at 0.236 and also has multicollinearity issues present. Stronger V component wind shears between the surface and 500 mb, larger SRH values (from JC07), colder temperatures at 300 mb, stronger west-east winds at 300 mb, LCLs closer to the ground, and weaker U component wind shears between the surface and 600 mb are needed for larger FPs. Smaller CIN values, weaker south-north winds at 600 mb, colder columns of air between the surface and 600 mb, and warmer columns of air between the surface and 500 mb are also needed for larger FPs within the global domain. The combination of these variables is a very poor fit and shows that individual clusters provided better fits to the data than the global model run.

The 4HP model run was another poor fit to the data at 0.165 but contained no multicollinearity issues. Larger SRH values (from JC07), stronger V component wind shears between the surface and 600 mb, colder columns of air between the surface and 300 mb, warmer surface potential temperatures, LCLs closer to the ground, and northwest winds at 600 mb are needed for the identification of variables needed for larger FPs within the global domain. The combination of these variables still provides a very poor fit to the data, showing that the individual cluster MLRs are better than the global results.

The 3HP model run was one of the worst fits at 0.109 but there were no multicollinearity issues present. Stronger U component wind shears between 600 and 500 mb, stronger south-north winds at 600 mb, LCLs closer to the ground, warmer temperatures at 200 mb, weaker west-east winds at 300 mb, and stronger U component wind shears between the surface and 500 mb are needed for larger FPs within the global domain. This combination of variables is a very poor fit and shows that the individual clusters provide the better fit.

The 2HP model run was the best fit to the data out of all the global model runs at 0.272, contained the most variables - 12 - and there were multicollinearity issues present. Stronger west-east winds at 300 mb, colder columns of air between the surface and 200 mb, larger SRH values (from JC07), larger Thickness values, LCLs closer to the ground, and weaker U component wind shears between the surface and 600 mb are needed for larger FPs within the cluster domain. Weaker west-east winds at 200 mb, weaker V component wind shears between 600 and 500 mb, smaller surface saturation mixing ratios, smaller CIN values, stronger south-north winds at 200 mb, and weaker south-north winds at the surface are also needed for larger FPs within the global domain. While this combination of variables provides the best fit from the global model runs, the individual cluster runs are much better.

The 1HP model run is a very poor fit at 0.183, and there were no multicollinearity issues present. Stronger west-east winds at 500 mb, stronger V component wind shears between the surface and 600 mb, larger SRH values (from JC07), smaller PW values, LCLs closer to the ground, weaker west-east winds at 300 mb, and smaller CIN values are needed for larger FPs within the global domain. The combination of variables does not provide a better fit than the individual clusters.

The model run done at initiation was the worst fit to the data out of all the global model runs at 0.093. There were no multicollinearity issues present. Stronger U component wind shears between 600 and 500 mb, stronger south-north winds at 300 mb, a moist pocket of air at 200 mb, and larger SRH values (from JC07) are needed for larger FPs within the global domain. Since this model run is the worst fit to the data, it is assumed that the individual clusters will provide the better fit than this global model run.

5.4.2: Principal Component Analysis

PCAs were run on each of the 6HP through the 3HA on the global domain. These PCAs were done to solve the fit issues seen in the global MLRs. Included in Table 5.4.4 are the variables with 90 percent accounted for variance, the number of components with eigenvalues valued at one or greater, and percent variance accounted for with those eigenvalues. These global PCAs show that the individual cluster PCAs are better fits and will be able to be used for identifying the variables needed to more accurately predict possible MCSMI.

The 6HP model run through the initiation model run had the same variables loaded highly into the first two components. In the first component, the variables that were loaded the highest were Thickness, geopotential height, and lower level temperature variables which were loaded in positively. The larger the values from the Thickness and geopotential height variables the greater are the contributions to the first component and to the PCA. These larger Thickness and geopotential height values could possibly point to large-scale warm air advection. For the temperature variables, a positive value will provide a greater contribution. In the second component, the variables that were loaded the highest were LCL (6HP), V component wind, and V component wind shear (4HP, 2HP, 1HP, and initiation) variables which were also loaded in positively. The lower to the ground the LCL, the greater the contribution is to possible MCSMI. The contribution from the wind and wind shear variables will depend on the value of the individual variable. The variables loaded highly into the first two components and included in multiple most used lists are considered the most important variables to MCSMI within the global domain.

5.4.3: Global Model Run Figures and Tables

Table 5.4.1: Median Values for the Upper Air and Surface Variables for the Global Model Domain.

Variable	Median Value
STHC	38.160
SMXR	9.890
SMXS	18.260
UWND	0.000
VWND	0.540
LCL	641.120
LI	-0.570

Table 5.4.2: Median Values for the NARR Variables for the Global Model Domain (continued onto the next page).

Variable	**-6 hours**	**-5 hours**	**-4 hours**	**-3 hours**	**-2 hours**
Thickness	5843.350	5840.800	5850.700	5855.150	5843.600
PW	17.350	18.400	17.650	18.100	18.800
CAPE	254.550	239.000	244.550	243.700	188.200
CIN	-23.650	-16.700	-15.550	-15.500	-21.300
SRH	28.750	32.800	31.500	27.900	38.800
GH600	4466.600	4460.200	4462.350	4465.100	4455.800
GH500	5915.500	5907.500	5910.100	5912.900	5904.700
GH300	9713.850	9705.600	9706.750	9712.700	9708.100
GH200	12444.650	12433.600	12436.450	12445.250	12437.900
SH850	1.015e-2	9.700e-3	9.400e-3	9.600e-3	9.600e-3
SH800	8.800e-3	8.600e-3	8.300e-3	8.400e-3	8.300e-3
SH600	4.400e-3	4.700e-3	4.900e-3	5.050e-3	5.000e-3
SH500	2.500e-3	2.500e-3	2.500e-3	2.600e-3	2.600e-3
SH300	3.200e-4	3.100e-4	3.300e-4	3.700e-4	3.500e-4
SH200	4.700e-5	4.700e-5	4.650e-5	4.900e-5	5.000e-5
UC600	2.700	2.300	2.400	2.400	2.600
UC500	3.200	3.400	4.000	3.500	3.400
UC300	5.800	6.000	6.200	5.850	6.200
UC200	9.150	9.200	9.650	9.200	9.300
UWSS500	3.820	4.050	4.609	3.895	4.500
UWS600500	0.600	1.023	1.300	1.100	1.100
UWSS600	3.065	2.990	3.305	3.000	3.399
WD600	247.903	239.967	243.014	242.089	239.785
WD500	247.195	246.541	254.803	257.213	254.152
VC600	-0.190	0.435	0.332	0.367	0.926
VC500	-0.227	-0.267	-0.532	-0.831	-0.638
VC300	2.550	2.800	2.450	2.450	2.400
VC200	1.650	2.700	1.750	2.200	2.800
VWSS500	-0.606	0.275	-0.862	-1.220	-0.530
VWS600500	0.218	-0.400	-0.962	-1.071	-1.700
VWSS600	-0.840	0.526	0.180	-0.422	0.570
T600	2.400	2.000	2.200	2.400	2.000
T500	-7.400	-7.800	-7.700	-7.400	-7.600
T300	-32.800	-33.100	-33.000	-32.600	-32.800
T200	-53.200	-53.100	-53.200	-53.100	-53.100
Variable	**-1 hour**	**Initiation**	**+1 hour**	**+2 hours**	**+3 hours**
Thickness	5846.850	5852.250	5833.400	5832.650	5836.800
PW	18.200	18.250	18.500	17.900	18.050
CAPE	149.850	129.100	140.400	176.200	167.700
CIN	-26.950	-27.150	-31.100	-37.200	-36.700

Variable	-1 hour	Initiation	+1 hour	+2 hours	+3 hours
SRH	38.600	35.400	46.300	52.050	48.200
GH600	4459.700	4463.150	4460.700	4459.900	4464.400
GH500	5908.700	5912.950	5907.800	5907.650	5912.350
GH300	9704.150	9716.300	9707.200	9703.800	9710.200
GH200	12437.000	12451.850	12440.500	12435.700	12444.150
SH850	9.400e-3	9.500e-3	9.700e-3	9.700e-3	9.800e-3
SH800	8.300e-3	8.300e-3	8.500e-3	8.500e-3	8.550e-3
SH600	5.100e-3	5.100e-3	4.800e-3	4.700e-3	4.800e-3
SH500	2.700e-3	2.750e-3	2.600e-3	2.600e-3	2.600e-3
SH300	3.400e-4	3.700e-4	3.700e-4	3.700e-4	4.000e-4
SH200	4.800e-5	5.150e-5	5.000e-5	5.000e-5	5.100e-5
UC600	2.600	2.900	3.700	3.500	3.350
UC500	4.200	3.500	3.900	4.200	3.450
UC300	7.000	6.100	6.000	6.850	6.400
UC200	9.900	9.000	9.600	10.050	10.050
UWSS500	5.355	4.150	4.790	5.305	4.320
UWS600500	1.300	0.900	0.300	0.860	0.450
UWSS600	3.580	3.519	4.402	4.285	3.905
WD600	248.864	246.445	256.621	255.329	252.882
WD500	267.490	261.952	253.916	269.452	261.055
VC600	0.412	0.636	0.329	-0.173	-8.655e-2
VC500	-1.350	-1.200	-0.986	-1.750	-1.800
VC300	1.800	2.100	1.800	1.300	1.200
VC200	1.400	2.350	2.300	0.699	1.350
VWSS500	-1.585	-1.518	-1.170	-2.120	-1.735
VWS600500	-1.800	-1.542	-1.400	-1.600	-1.100
VWSS600	6.000e-2	-0.365	0.340	-0.350	-1.050
T600	2.300	2.600	2.100	2.100	2.400
T500	-7.550	-7.100	-7.600	-7.800	-7.400
T300	-32.800	-32.500	-32.900	-33.100	-32.700
T200	-53.200	-53.300	-53.200	-53.200	-53.300

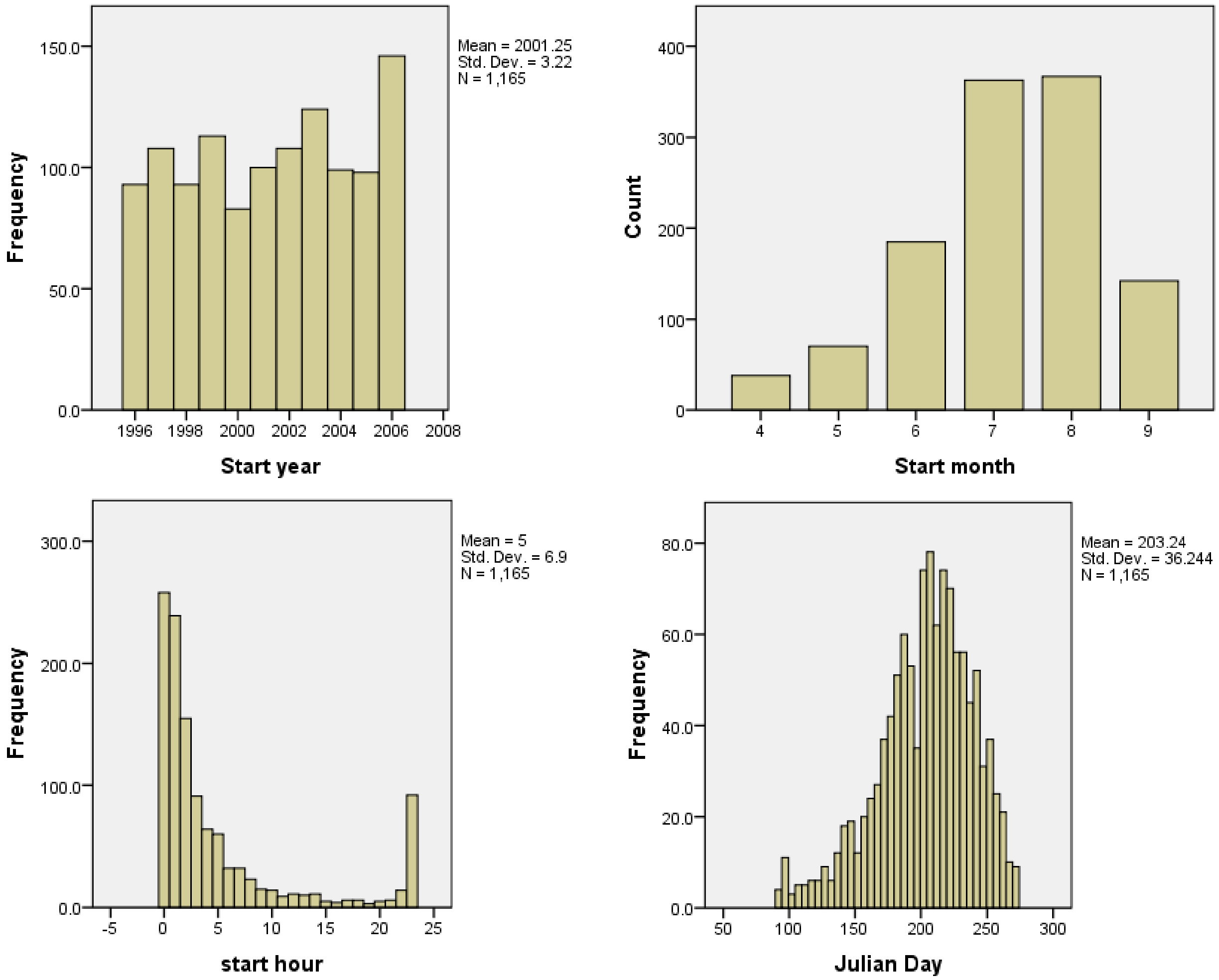


Figure 5.4.1: Time Histograms for the Global Model Domain. Frequency was used on the y-axis when the data used in the histogram had no gaps. Count was used on the y-axis when the data used in the histogram did have gaps. The histograms included are start year, start month, start hour, and the Julian Day.

Table 5.4.3: Results of the MLRs for the Global Model Domain. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
6HP	FP ≈ constant + VC600 + SRH + UWSS500 + SH300 + T300 + T600 – Thickness – GH300 + GH600	0.156
5HP	FP ≈ constant + VWSS500 + SRH – T300 + UC300 + LCL – UWSS600 + CIN – VC600 – GH600 + GH500	0.236
4HP	FP ≈ constant + SRH + VWSS600 – GH300 + STHC + LCL + WD600	0.165
3HP	FP ≈ constant + UWS600500 + VC600 + LCL + T200 – UC300 + UWSS500	0.109
2HP	FP ≈ constant + UC300 – GH200 + SRH + Thickness + LCL – UWSS600 – UC200 + VWS600500 – SMXS + CIN + VC200 – VWND	0.272
1HP	FP ≈ constant + UC500 + VWSS600 + SRH – PW + LCL – UC300 + CIN	0.183
Initiation	FP ≈ constant + UWS600500 + VC300 + SH200 + SRH	0.093

Table 5.4.4: Results of the PCAs for the Global Model Domain. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
6HP	UWND, VWND, Thickness, GH500, GH300, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T500, T300	11	80.568%
5HP	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	10	81.249%
4HP	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	10	80.023%
3HP	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T500, T300	10	82.863%
2HP	UWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500	10	80.101%
1HP	UWND, VWND, Thickness, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	10	81.307%
Initiation	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T500, T300	11	82.979%

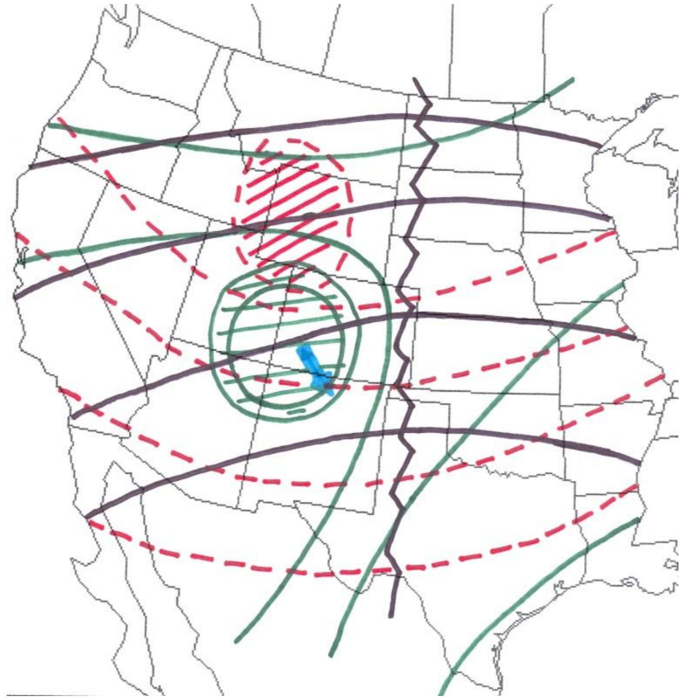


Figure 5.4.2: Composite Map for the Global Model Domain. The variables included on the map are T300, GH300, SH300, and wind shear between the surface and 500 mb. Refer to Figure 4.2.5 for figure legend. (Source: data compiled from Plymouth State Weather Center.)

5.5: Global Discussion

The MLRs and PCAs were very poor fits to the data, especially when compared to the individual cluster results. Using the individual cluster results would be more difficult, but the individual cluster results would be more accurate than that seen with the global results. Fewer variables would have to be observed within the global domain than would have to be observed in the individual cluster domains. These global results are discussed to focus on the difference between the global results and the individual cluster results and how poorly the global results fit the data. The global results are such poor fits to the data that an accurate depiction of the variables needed for the FP and MCSMI will not occur. Therefore, the individual cluster results are better overall than the global results.

The global domain is located in a portion of the Rocky Mountains that contains a southwest-northeast ridgeline. The median wind direction at 600 mb and initiation gives winds from the west-southwest. The median wind direction at 500 mb and initiation gives winds from the west. This indicates that winds at 600 mb will arrive at the ridgeline at a slight angle and winds at 500 mb arrive at an angle to the ridgeline.

The composite map for the global domain is Figure 5.4.2. The discussion for choosing the variables is located at the start of chapter 4. The most important temperature variable was T300. Cooler temperatures are located north of the domain indicating warmer temperatures are present within the entire domain at 300 mb. The most important geopotential height variable was GH300. A ridge is located to the east of the global domain indicating heights are falling as the ridge moves eastward. The most important moisture variable was SH300. The global domain is within an area of relatively moist air at 300 mb. The most important wind shear was between the surface and 500 mb. The wind shear at initiation has a median value of 4.419 ms^{-1} at 290.092˚.

6: Conclusion

Several conclusions can be drawn from the preceding analysis. Overall, the individual cluster results were more accurate than the global results. Although the global results may be used as a quick estimate, there is too much error associated with the model runs to give an accurate estimate of the FP and initiation time. This shows that overall global conditions do not have much potential in the possibility of predicting MCSMI within this section of the Rocky Mountain chain (agrees with Moninger et al 1991 results). However, the individual clusters would be better suited for use as a possible prediction method. Section 6.1 will cover individual cluster conclusions whereas section 6.2 will cover the global conclusions. Section 6.3 will cover possible improvements to the overall analysis including issues and possible future works.

6.1: Individual Cluster Conclusions

As seen in Chapter 4, every cluster had different variables which were important to MCSMI and larger FPs. No two clusters contained exactly the same variables or used the same number of times, so each cluster should be treated as unique. It makes it more difficult for the potential to forecast for an MCSMI and larger FPs when so many different equations can be used to determine the important variables over the entire domain. However, if the important variables are more prominent in one cluster over another, then the cluster can be observed for possible MCSMI.

The variables are considered hour dependent and cluster dependent. The median values of the variables changed depending on the cluster and on the hour, proving that each cluster is unique. The variables that were used in the fewest model runs were those that were considered the least important. The variables used the most often within a cluster are considered to be the most important to MCSMI and larger FPs within that cluster domain. The most important variables for each cluster should be observed to determine if initiation is going to occur within the domain.

Overall, the variables were included between 41 percent and 56 percent of the time indicating all the variables contribute to MCSMI and larger FPs. The variable included the most often in the MLRs and PCAs was VWSS500 (361 out of 640 model runs total). The second most included variable was Thickness (356 out of 640 model runs total). The third most included variable was UWSS600 (354 out of 640 model runs total). It should be noted that out of the top six most included variables, four are wind shear variables indicating that wind shear is very important to MCSMI and larger FPs according to the analyses (from JC07) and these wind shears are between the surface and an upper level and not between two upper levels. There are also several other notable variables that are worth discussing the number of times they appeared in the MLRs and PCAs. PW was included 51.8 percent (332 out of 640 total model runs) of the time indicating a majority of the time the value of PW was important to the analysis. SRH (from JC07), the next notable variable, was included 48.1 percent of the time (308 out of 640 total model runs) indicating, even though it is not a majority, SRH is still relatively important when compared to the variables included less often. CAPE, LCL, and LI are also considered notable variables and were included 45.3 percent, 45.0 percent, and 44.1 percent respectively (290, 288, and 282 out of 640 model runs respectively). These variables are not the most important but are included in more model runs than several others. The three variables included in the fewest model runs were WD500 (41.9 percent, 268 out of 640 model runs), T200 (41.7 percent, 267 out of 640 model runs), and WD600 (41.1 percent, 263 out of 640 model runs). These are the variables considered the least important to MCSMI and larger FPs within the individual cluster and global domains.

There were some similarities among the clusters (also listed in Section 4.31). One major similarity was the wind direction values at 600 and 500 mb. The most prominent wind direction at 600 mb was west-southwest which occurred 31.6 percent of the time. This wind direction is probably the most common wind direction within this portion of the Rocky Mountain chain within the warm season. The next most prominent wind direction at 600 mb was west at 21.9 percent of the time followed by southwest at 18.8 percent of the time. The most prominent wind direction at 500 mb was west at 40.6 percent of the time. This was followed by west-southwest and west-northwest at 18.8 percent of the time.

Another similarity was the year of maximum MCS occurrence for each cluster. Nine of 31 clusters (excluding the global results) had a maximum year of 2006: Elk Mountain, NM, Ute Hills/Pete Hills, CO, Wrye Peak, NM, Bartlett Mesa/Horse Mesa, NM, West Mesa, NM, Caliente Canyon/Long Canyon, NM, Laughlin Peak, NM, Jicarilla Mountains, NM, and Neff Mountain/Jarosa Peak, CO. Six of 31 clusters (excluding the global results) had a maximum year of 1999: Lookout Peak/Rayado Peak, NM, Mount Washington, NM, Bartlett Mesa/Horse Mesa, NM, Argonne Mesa, NM, Jicarilla Mountains, NM, and Rincon del Cuervo, NM. A complete listing of the years the most MCSs formed can be found in Table 6.1.1. When comparing these clusters with Table 4.31.1 a few trends are noticed. With the clusters that had a maximum year of 2006: six of the nine clusters had wind shear variables contained on the most important variable list. Five and four clusters had stability and geopotential height variables respectively. With the clusters that had a maximum year of 1999: All six clusters had wind shear variables contained on the most important variable list. Five and four clusters had stability and geopotential height variables respectively. This shows that wind shear is very important to MCSMI within the individual cluster domains.

A major difference seen in the clusters is the different variables included in the MLRs and PCAs. This difference can be attributed to the difference in the item each analysis is attempting to determine. Where PCA is attempting to identify the variables needed for MCSMI within a given cluster domain, MLR is attempting to identifying the variables needed for the FP of the MCS that is assumed will form. The conditions needed to attain each could be considered dissimilar since differences between the two analysis types occurred often. Certain variables could be deemed more important in creating larger FPs (variables used in the MLRs) and other variables, not necessarily the same ones used in the MLRs, could be deemed more important in MCSMI (variables used in the PCAs).

For the individual clusters, the PCAs were much better fits to the data than the MLRs. The PCAs were consistently better fits, used all of the variables within the components, and did not have the dependency issues seen so often with the MLRs. Several MLRs were such poor fits to the data that the results were not discussed. This did not occur with the PCAs. The MLRs provide a quicker estimate of initiation and eventual FP than the PCAs but the PCAs will be more accurate as to possibility of initiation.

The maps included at the end of each individual cluster section show the large-scale pattern needed for the four main variables within each cluster. If no other variables are observed for a cluster, the four main variables need to be observed for the pattern given in the composite maps.

These individual cluster equations can show which variables are important for MCSMI and larger FPs. Once the exact variables are determined for initiation, better possible prediction of MCSMI and FPs can occur. The potential for flooding is increased when an MCS occurs since it could bring copious amounts of rainfall into an area. While these equations cannot be used for the potential to predict the amount of precipitation that will occur, they increase the chance of knowing if heavy precipitation and potential flooding associated with an MCS, when an MCS does produce heavy precipitation, will occur within a given area since these results show which variables are needed for MCSMI and larger FPs. The heavy precipitation has the potential to be beneficial whether it is associated with an MCS or not (Doswell et al 1996).

Table 6.1.1: The Year(s) the Maximum Number of MCSs Occurred for Each Cluster.

Cluster Name	Year(s) of maximum number of MCSs
Elk Mountain, NM	2004, 2006
Elk Mountain, NM Wind Direction Group 1	2004
Elk Mountain, NM Wind Direction Group 2	2004
Ute Hills/Pete Hills, CO	2006
Rincon Mountains, NM	2003
Lookout Peak/Rayado Peak, NM	1999
Pajarito Mountain/Cerro Grande, NM	1996
Culebra Range/Sangre de Cristo Mountains, CO	2003
Shaggy Peak, NM	2003
Los Pinos Mountains, NM	1996
Mount Washington, NM	1996, 1999
Wrye Peak, NM	2006
Mesa de los Jumanos, NM	1997
Jacinto Mesa, NM	1997
Bartlett Mesa/Horse Mesa, NM	1998, 1999, 2006
Trinchera Mesa/Valencia Hills/Howard Mountain, NM	1997
West Mesa, NM	2002, 2006
South Mountain, NM	1996, 1998
Badito Cone, CO	2004
Bunker Hill, CO	2001, 2005
Caliente Canyon/Long Canyon, NM	2006
Cowboy Mesa, NM	2002, 2005
Las Mesa Del Conjelon, NM	1998
Laughlin Peak, NM	2006
Hogback Mountain/Mt. Signal, CO	1998, 2002
Gacho Hill, NM	2005
Argonne Mesa, NM	1999
Jicarilla Mountains, NM	1999, 2006
Neff Mountain/Jarosa Peak, CO	2006
Rincon del Cuervo, NM	1999
South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM	2002

6.2: Global Conclusions

The global model runs were much poorer fits to the data than the individual clusters; therefore, the individual cluster results should be used over the global results. The global model runs were done to show how much more precise the individual cluster results were than the global results. The global results can be used as a quick estimate for the entire global domain but the equations are not accurate and have a lot of associated error. This provides the conclusion that the individual cluster results are much better at determining important MCSMI and FP variables than the global results. A composite map for the global results is included in chapter 5. The large-scale pattern seen in that map can be used as a first estimate.

6.3: Improvements

6.3.1: Issues

An issue present in this analysis is the error associated with the surface and upper air reporting stations. The best way to correct this issue would be the implementation of more surface stations and upper air stations. This may not be feasible because the network would have to be several times denser than it currently is to get better readings over the domain. Another issue is the problem seen with the NARR algorithm for CIN. This was corrected as it occurred but should be addressed as a possible improvement to the algorithms.

Multicollinearity presented itself multiple times within the MLRs. These issues were present due to the variables that were highly correlated. This could be corrected by being more selective of the variables used in the analysis. An example of this would be choosing between GH500 and Thickness.

6.3.2: Possible Future Works

To increase the accuracy of the individual clusters and the global domain, more years could be added – going further back than 1996 and farther ahead than 2006. More MCSs would be added to the case list and more information could be gathered from those extra cases. Another future work possibility would be to include more variables in the analysis. Vorticity variables could be included since it was recognized that vorticity can be important to MCS initiation. Other possible variables include other wind, wind shear, and wind direction variables. Topographic variables could be included as well to determine if initiation is influenced by elevation, slope, and aspect. Other moisture variables may also be beneficial to obtaining better fits to the data. The data could also be used to investigate trends in the data to see if variables are more important at one time as compared to another.

The MLRs and PCAs could be redone with fewer variables. Instead of using one variable at multiple levels or variables that are similar to one another (ex: Thickness and GH500), deciding which variables would be best from the above analysis and rerun the analyses to determine if the fewer variables are best for the potential to predict initiation and the FP.

Also, for another possible future work, the cases used in this analysis could be compared to satellite images. Instead of the initiation location being where the first precipitation occurred, it would be where the first appearance of clouds occurred. The first appearance of clouds would be seen on the satellite images. The characteristics could be different between the two locations.

For another possible future work, the total precipitation value from the Tucker and Li (2009) database could be used as the dependent variable for the MLRs. However, the total precipitation is not based on the size of the system. If a system is relatively short lived but produces a lot of precipitation, it could be considered the same type of system as one that is longer lived and produces the same amount of precipitation over a longer period of time. It would be more difficult to determine system type if total precipitation is used as a dependent variable.

Other possible future works include other mountains in the Arkansas-Red River Basin domain – the Ozark Mountains and the Ouachitas. It is possible to isolate those mountains and see if any MCSs form on the peaks. If MCSs form, a comparison of variables needed for MCSMI could be made between all three mountain ranges to find similarities, and if they are present, generalizations be made and can possibly be applied to other mountain ranges and river basins.

This analysis can be used as a first step towards a forecast model. Verification of the MLR and PCA outcomes needs to be performed using a separate data set covering the same domain. Also, null cases (where initiation did not occur) need to be observed to determine if the characteristics seen for the clusters are exclusive to MCSMI or if similarities are present. False alarm rates (times where initiation is thought to occur but does not) could be determined from the cases used in this analysis and the null cases. The variables used in this analysis can also be observed for single cell systems and multiple cell systems to determine if the characteristics are exclusive to MCSMI or similarities exist. Also, the variables can be observed for points surrounding the initiation location rather than just observing the variables at the initiation location. This could also improve the accuracy of the eventual forecast model for this region.

7: References

Anagnostou, E.N., W.F. Krajewski, and J. Smith, 1999: Uncertainty Quantification of Mean Areal Radar-Rainfall Estimates. *J. Atmos. Oceanic Technol.*, **16**, 206-215.

Argonne Mesa, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

ARM: Climate Research Facility, cited 2011: ARM XDC Datastreams. [Available online at http://www.arm.gov/ xdc/xds/abrfc.]

Badito Cone, CO Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Banta, R.M., 1990: The Role of Mountain Flows in Making Clouds. *Atmospheric Processes Over Complex Terrain, Meteor. Monogr.,* No. 45, Amer. Meteor. Soc., 229-282.

Banta, R.M., and C.B. Schaaf, 1987: Thunderstorm Genesis Zones in the Colorado Rocky Mountains as Determined by Traceback of Geosynchronous Satellite Images. *Mon. Wea. Rev.*, **115**, 463-476.

Bartlett Mesa/Horse Mesa, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Bluestein, H.B., and M.H. Jain, 1985: Formation of Mesoscale Lines of Precipitation: Severe

Squall Lines in Oklahoma during Spring. *J. Atmos. Sci*., **42**, 1711-1732.

Bunker Hill, *CO Cluster Location Map.* Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Byers, H.R., and R.R. Braham, 1949: *The Thunderstorm*. Report of the Thunderstorm Project, U.S. Weather Bureau, Dept. of Commerce.

Caliente Canyon/Long Canyon, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Callen, E.F., and D.F. Tucker, 2012: Statistical Analysis of Mesoscale Convective System Mountain Initiation Locations. *21st Conference on Probability and Statistics in the Atmospheric Sciences*, New Orleans, LA, American Meteorological Society.

Chappell, C.F., 1986: Quasi-Stationary Convective Events. *Mesoscale Meteorology and Forecasting*, P.S. Ray, Ed., American Meteorological Society, 289-310.

Cotton, W.R., R.L. George, P.J. Wetzel, and R.L. McAnelly, 1983: A Long-Lived Mesoscale Convective Complex. Part 1: The Mountain-Generated Component. *Mon. Wea. Rev*., **111,** 1893-1918.

Cowboy Mesa, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Culebra Range/Sangre de Cristo Mountains, CO Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

DesJardins, M., and R. Petersen, 1986: GEMPAK: Applications in Research and Education. Preprints, *Second International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Miami, FL, American Meteorological Society.

Doswell, C.A., III, 1985: *The Operational Meteorology of Convective Weather. Vol. 2: Storm Scale Analysis.* NOAA Tech. Memo. ERL ESG-15.

Doswell, C.A., III, H.E. Brooks, and R.A. Maddox, 1996: Flash Flood Forecasting: An Ingredients-Based Methodology. *Wea. For.*, **11**, 560-581.

Elk Mountain, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Elk Mountain, NM Wind Direction Group 1 Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Elk Mountain, NM Wind Direction Group 2 Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Fritsch, J.M., and G.S. Forbes, 2001: Mesoscale Convective Systems. *Severe Convective Storms, Meteor. Monogr.*, No. 50, Amer. Meteor. Soc., 323-358.

Fritsch, J.M., R.J. Kane, and C.R. Chelius, 1986: The Contribution of Mesoscale Convective Weather Systems to Warm-Season Precipitation in the United States. *J. Appl. Meteor.*, **25**, 1333-1345.

Fulton, R.A., J.P. Breidenbach, D. Seo, D.A. Miller, and T. O'Bannon, 1998: The WSR-88D Rainfall Algorithm. *Wea. For.*, **13**, 377-395.

Gacho Hill, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Hogback Mountain/Mt. Signal, CO Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Iowa State, cited 2011: Mtarchive Data Server. [Available online at http://mtarchive.geol.iastate.edu/.]

Jacinto Mesa, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Jicarilla Mountains, NM Cluster Location Map. Scale 1:250,000. United States Geological

Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Jirak, I.L., and W.R. Cotton, 2007: Observational Analysis of the Predictability of Mesoscale Convective Systems. *Wea. For.*, **22**, 818-838.

Jirak, I.L., W.R. Cotton, and R.L. McAnelly, 2003: Satellite and Radar Survey of Mesoscale Convective System Development. *Mon. Wea. Rev.*, **131**, 2428-2449.

Johnson, R.H., and B.E. Mapes, 2001: Mesoscale Processes and Severe Convective Weather. *Severe Convective Storms*, *Meteor. Monogr.*, No. 50, Amer. Meteor. Soc., 71-122.

Las Mesa Del Conjelon, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online.* Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Laughlin Peak, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online.* Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Lookout Peak/Rayado Peak, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Los Pinos Mountains, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth

Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Maddox, R.A., 1980: Mesoscale Convective Complexes. *Bull. Amer. Meteor. Soc.*, **61**, 1374-1387.

McAnelly, R.L., and W.R. Cotton, 1986: Meso-β-scale Characteristics of an Episode of Meso-α-scale Convective Complexes. *Mon. Wea. Rev.*, **114**, 1740-1770.

Mesa de los Jumanos, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Mesinger, F., G. DiMego, E. Kalnay, K. Mitchell, P.C. Shafran, W. Ebisuzaki, D. Jovic, J. Woollen, E. Rogers, E.H. Berbery, M.B. Ek, Y. Fan, R. Grumbine, W. Higgins, H. Li, Y. Lin, G. Manikin, D. Parrish, and W. Shi, 2006: North American Regional Reanalysis. *Bull. Amer. Meteor. Soc.*, **87**, 343-360.

Moninger, W.R., J. Bullas, B. de Lorenzis, E. Ellison, J. Flueck, J.C. McLeod, C. Lusk, P.D. Lampru, R.S. Phillips, W.F. Roberts, R. Shaw, T.R. Stewart, J. Weaver, K.C. Young, and S.M. Zubrick, 1991: Shootout-89, A Comparative Evaluation of Knowledge-Based Systems That Forecast Severe Weather. *Bull. Amer. Meteor. Soc.*, **72**, 1339-1354.

Moller, A., 2001: Severe Local Storms Forecasting. *Severe Convective Storms. Meteor. Monogr.*, No. 50, Amer. Meteor. Soc., 433-480.

Mount Washington, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA:

Environmental Systems Research Institute, Inc., 1995-2012.

Murray, D., 2003: The Integrated Data Viewer – a web-enabled application for scientific analysis and visualization. *19th International Conference on Interactive Information Processing Systems,* Long Beach, CA, American Meteorological Society.

National Climatic Data Center, cited 2011: NOAA National Operational Model Analysis & Distribution System. [Available online at http://nomads.ncdc.noaa.gov/data.php?name=access#narr_datasets.]

Neff Mountain/Jarosa Peak, CO Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Pajarito Mountain/Cerro Grande, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Pielke, R.A., and M. Segal, 1986: Mesoscale Circulations Forced by Differential Terrain Heating. *Mesoscale Meteorology and Forecasting*, P.S. Ray, Ed., American Meteorological Society, 516-548.

Plymouth State Weather Center, cited 2012: Make Your Own … Product Generator for Archived Data. [Available online at http://vortex.plymouth.edu/u-make.html.]

Reed, S.M., and D.R. Maidment, 1999: Coordinate Transformations for Using NEXRAD Data in GIS-Based Hydrologic Modeling. *J. Hydrol. Eng.*, **4**, 174-182.

Rincon del Cuervo, NM Cluster Location Map. Scale 1:250,000. United States Geological

Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Rincon Mountains, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Rotunno, R., J.B. Klemp, and M.L. Weisman, 1987: A Theory for Squall Lines. Preprints, *3rd Conference on Mesoscale Processes*, Vancouver, B.C., Canada, American Meteorological Society.

Rotunno, R., J.B. Klemp, and M.L. Weisman, 1988: A Theory for Strong, Long-Lived Squall Lines. *J. Atmos. Sci.*, **45**, 463-485.

Shaggy Peak, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Smith, J.A., and W.F. Krajewski, 1991: Estimation of Mean Field Bias of Radar Rainfall Estimates. *J. Appl. Meteor.*, **30**, 397-412.

Smith, J.A., D.J. Seo, M.L. Baeck, and M.D. Hudlow, 1996: An Inter-Comparison Study of NEXRAD Precipitation Estimates. *Water Resour. Res.*, **32**, 2035-2045.

South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using:

ArcGIS Online. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

South Mountain, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Stensrud, D.J., 1996: Effects of Persistent, Midlatitude Mesoscale Regions of Convection on the Large-Scale Environment During the Warm Season. *J. Atmos. Sci*., **53**, 3503-3527.

Trier, S.B., and D.B. Parsons, 1993: Evolution of Environmental Conditions Preceding the Development of a Nocturnal Mesoscale Convective Complex. *Mon. Wea. Rev*., **121**, 1078-1098.

Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Tripoli, G.J., and W.R. Cotton, 1989: Numerical Study of an Observed Orogenic Mesoscale Convective System. Part I: Simulated Genesis and Comparison with Observations. *Mon. Wea. Rev.*, **117**, 273-304.

Tucker, D.F., and K.S. Zentmire, 1999: On the Forecasting of Orogenic Mesoscale Convective Complexes. *Wea. For.*, **14**, 1017 – 1022.

Tucker, D.F., and N.A. Crook, 1998: The Generation of a Mesoscale Convective System from Mountain Convection. *Mon. Wea. Rev.*, **127**, 1259-1273.

Tucker, D.F., and N.A. Crook, 2001: Favored Regions of Convective Initiation in the Rocky Mountains. *9th Conference on Mesoscale Processes*, Ft. Lauderdale, FL, American

Meteorological Society.

Tucker, D.F., and N.A. Crook, 2005: Flow Over Heated Terrain. Part II: Generation of Convective Precipitation. *Mon. Wea. Rev.*, **133**, 2565-2582.

Tucker, D.F., and X. Li, 2009: Characteristics of Warm Season Precipitating Storms in the Arkansas-Red River Basin. *J. Geophys. Res.*, **114**, D13108, doi: 10.1029/2008JD011093.

Uccellini, L.W., and D.R. Johnson, 1979: The Coupling of Upper and Lower Tropospheric Jet Streaks and Implications for the Development of Severe Convective Storms. *Mon. Wea. Rev.*, **107**, 682-703.

Ute Hills/Pete Hills, CO Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Weisman, M.L., 1993: The Genesis of Severe, Long-Lived Bow Echoes. *J. Atmos. Sci.*, **50**, 645-670.

Weisman, M.L., and C.A. Davis, 1998: Mechanisms for the Generation of Mesoscale Vortices within Quasi-Linear Convective Systems. *J. Atmos. Sci.*, **55**, 2603-2622.

Weisman, M.L., and J.B. Klemp, 1982: The Dependence of Numerically Simulated Convective Storms on Vertical Wind Shear and Buoyancy. *Mon. Wea. Rev.*, **110**, 504-520.

Weisman, M.L., and J.B. Klemp, 1984: The Structure and Classification of Numerically Simulated Convective Storms in Directionally Varying Wind Shears. *Mon. Wea. Rev.*, **112**, 2479-2498.

Weisman, M.L., and R. Rotunno, 2004: “A Theory for Strong, Long-Lived Squall Lines” Revisited. *J. Atmos. Sci.*, **61**, 362-382.

West Mesa, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

Wrye Peak, NM Cluster Location Map. Scale 1:250,000. United States Geological Survey Topographic Maps and Tucker and Li (2009) database. Lawrence, KS: Elisabeth Callen, University of Kansas, August 2012. Using: *ArcGIS Online*. Redlands, CA: Environmental Systems Research Institute, Inc., 1995-2012.

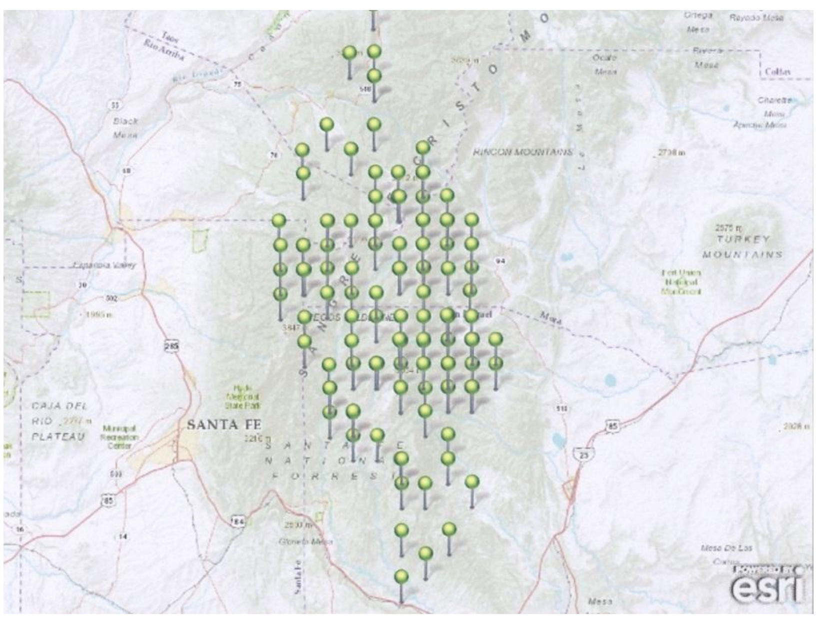
Young, C.B., A.A. Bradley, W.F. Krajewski, and A. Kruger, 2000: Evaluating NEXRAD Multisensory Precipitation Estimates for Operational Hydrologic Forecasting. *J. Hydrometeor.*, **1**, 241-254.

Zipser, E.J., 1982: Use of a Conceptual Model of the Life Cycle of Mesoscale Convective Systems to Improve Very-Short-Range Forecasts. *Nowcasting*. K. Browning, Ed., Academic Press, 191-204.

Appendix A: Cluster Location Maps

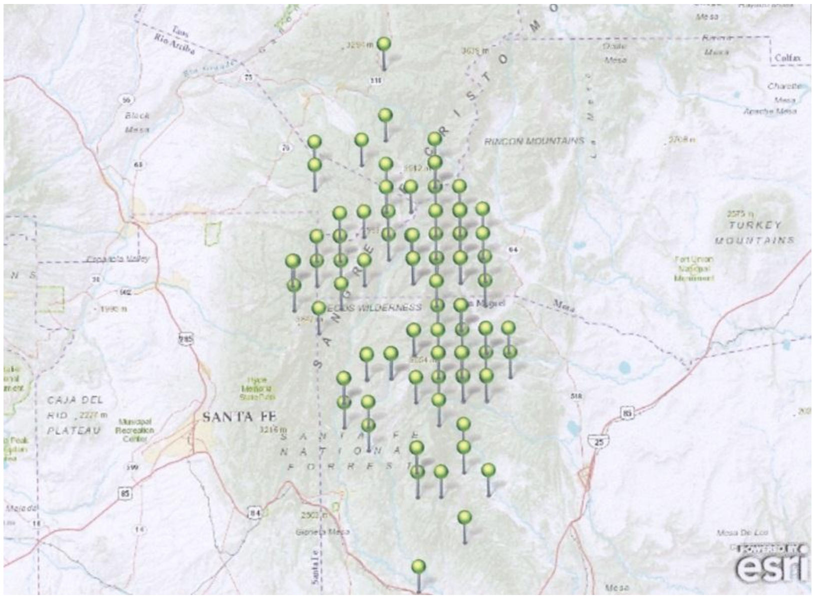
The maps included in this appendix are of the initiation location for each MCS by cluster. Each map was created using ArcGIS Online developed by Environmental Systems Research Institute (Esri). The background map for each map was from the United States Geological Survey (USGS). Each stickpin shows the location of initiation of an MCS within the cluster domain. The major topographic features and major cities are included on the maps for reference.

A.1: Elk Mountain, NM



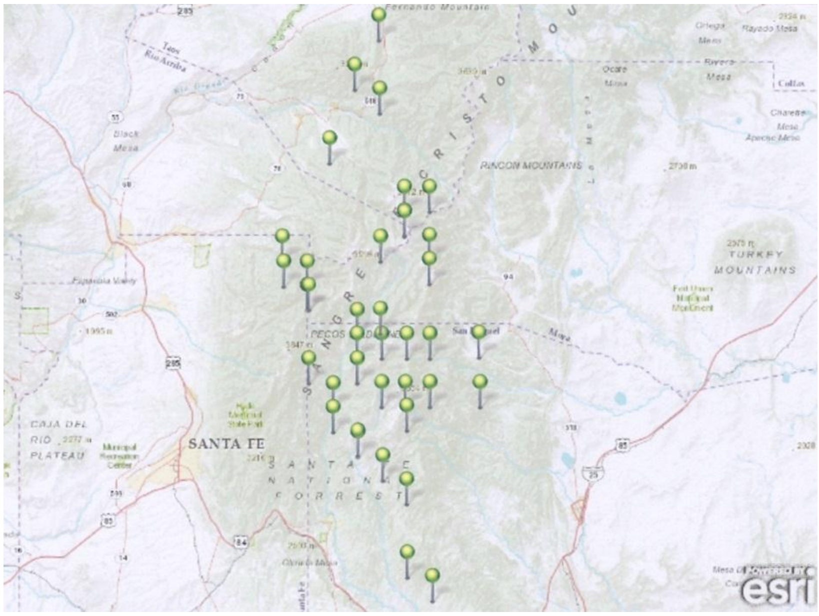
(*Elk Mountain, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.2: Elk Mountain, NM Wind Direction Group 1



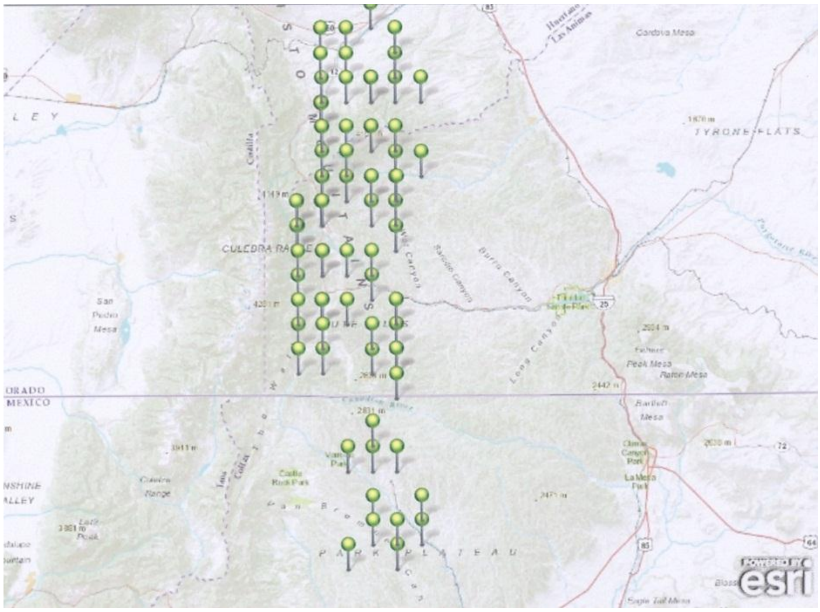
(*Elk Mountain, NM Wind Direction Group 1 Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.3: Elk Mountain, NM Wind Direction Group 2



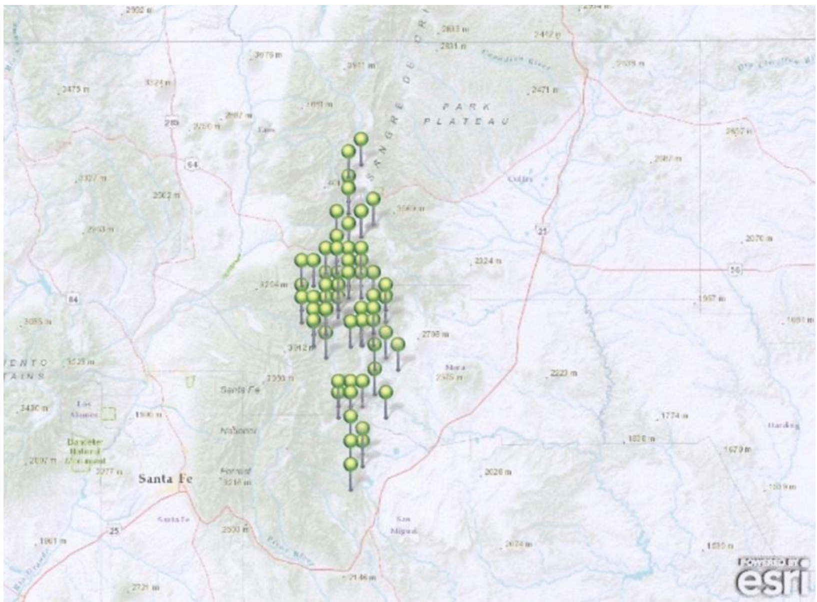
(*Elk Mountain, NM Wind Direction Group 2 Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.4: Ute Hills/Pete Hills, CO



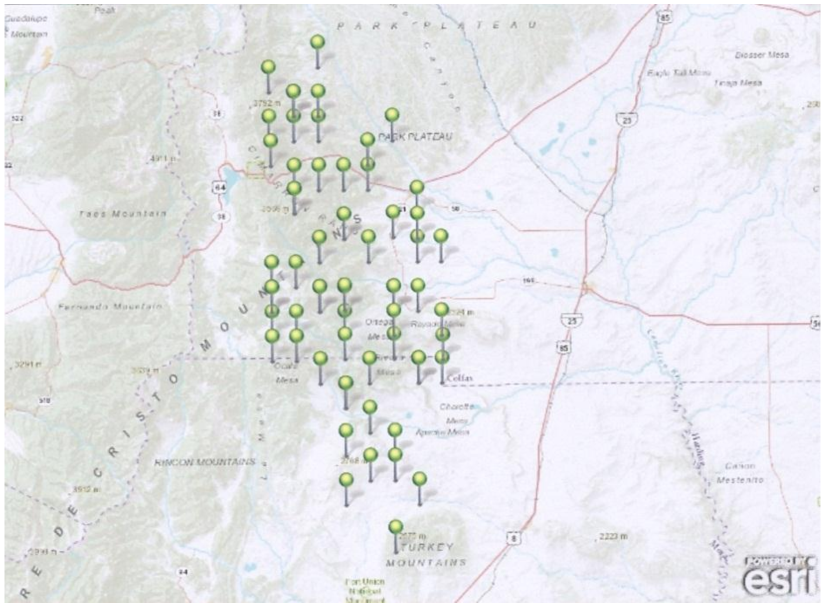
(*Ute Hills/Pete Hills, CO Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.5: Rincon Mountains, NM



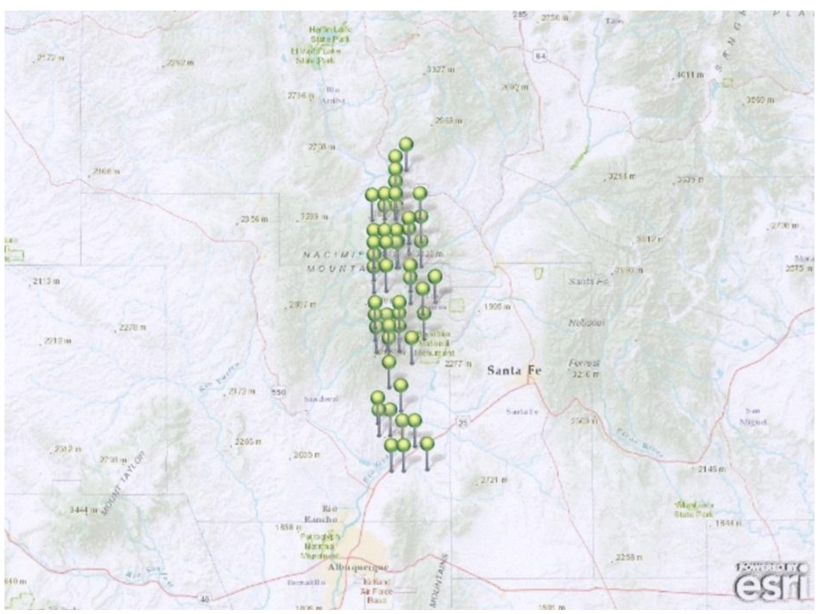
(*Rincon Mountains, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.6: Lookout Peak/Rayado Peak, NM



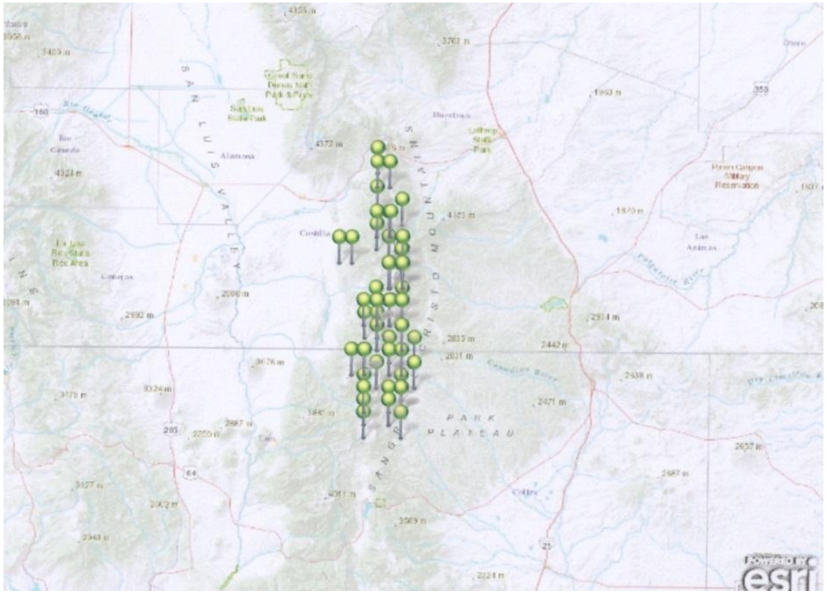
(*Lookout Peak/Rayado Peak, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.7: Pajarito Mountain/Cerro Grande, NM



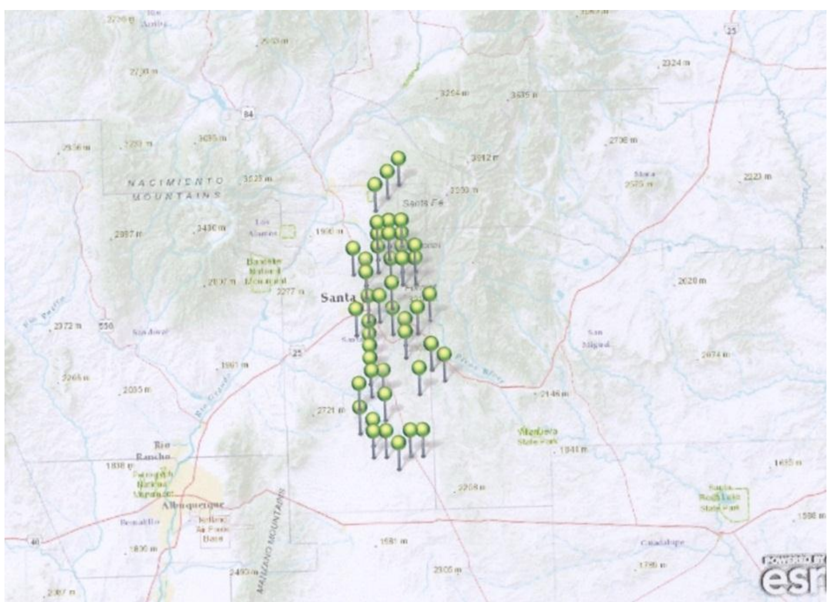
(*Pajarito Mountain/Cerro Grande, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.8: Culebra Range/Sangre de Cristo Mountains, CO



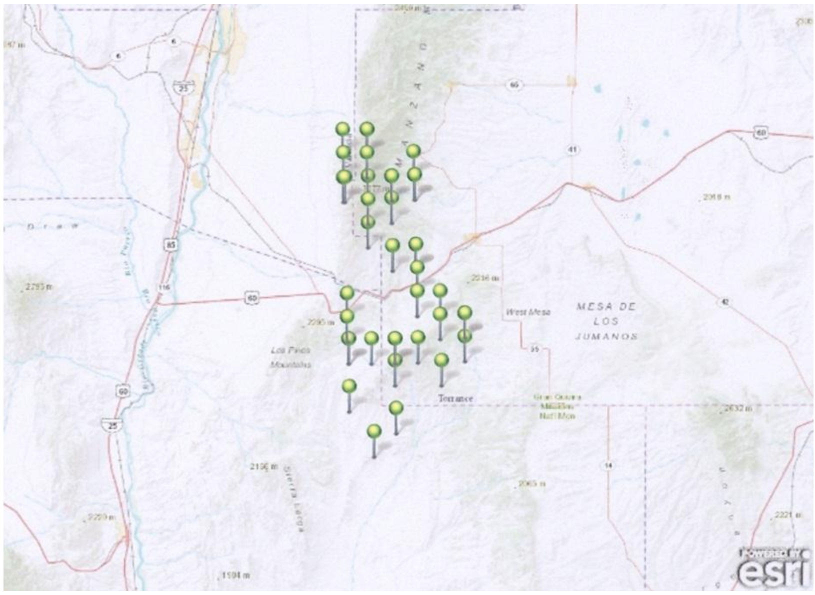
(*Culebra Range/Sangre de Cristo Mountains, CO Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.9: Shaggy Peak, NM



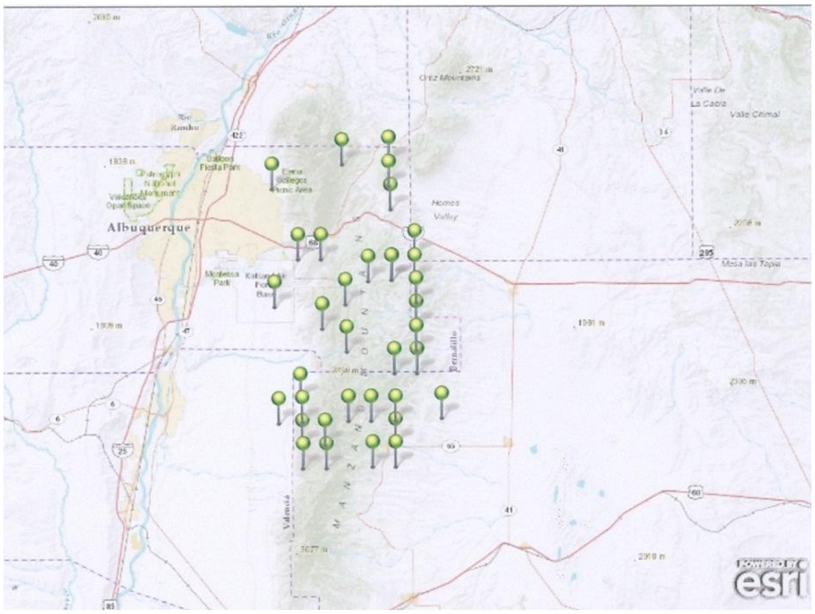
(*Shaggy Peak, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.10: Los Pinos Mountains, NM



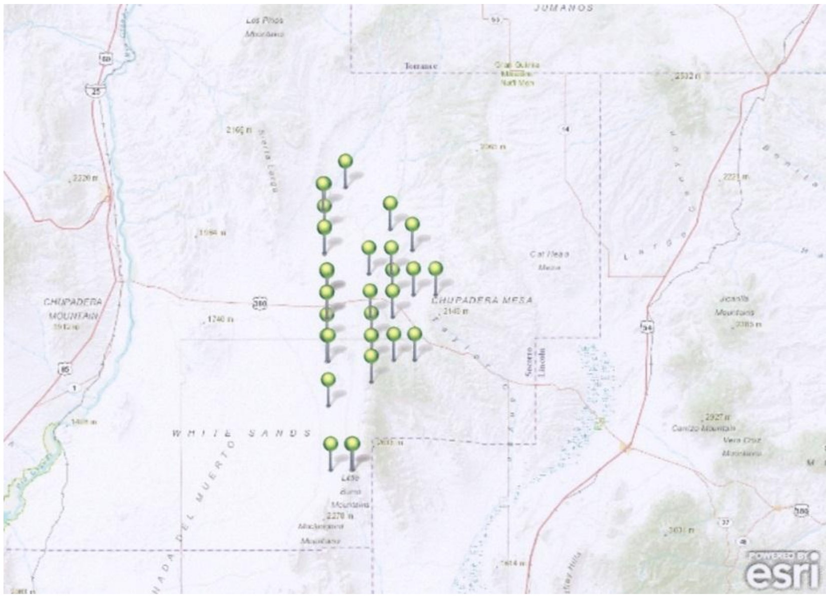
(*Los Pinos Mountains, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.11: Mount Washington, NM



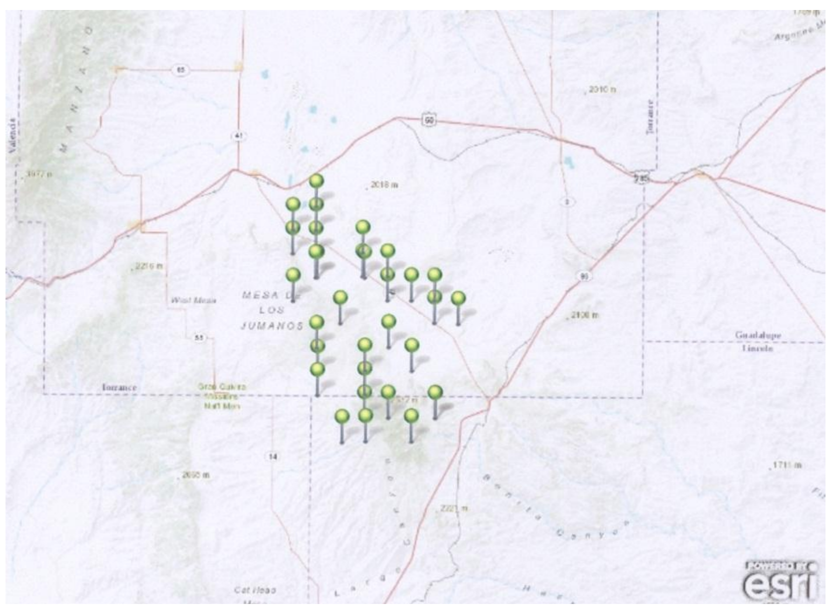
(*Mount Washington, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.12: Wrye Peak, NM



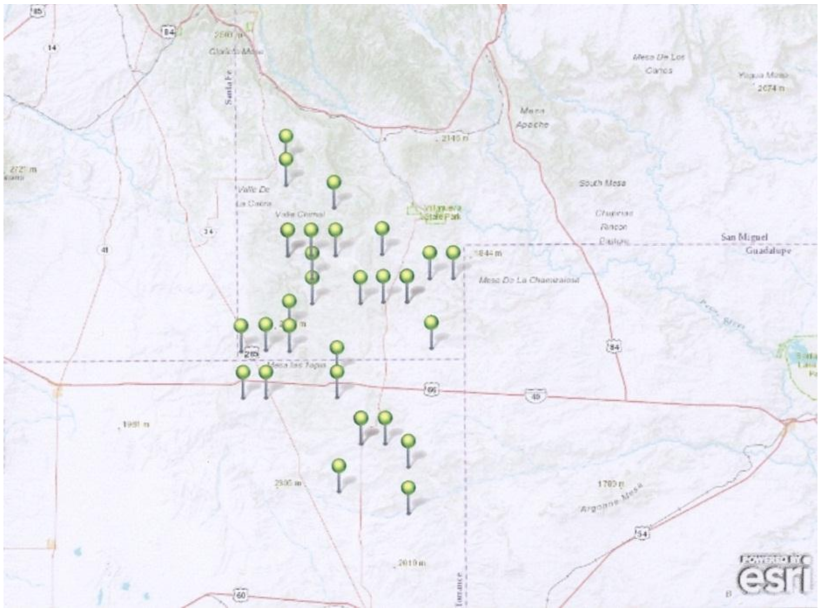
(*Wrye Peak, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.13: Mesa de los Jumanos, NM



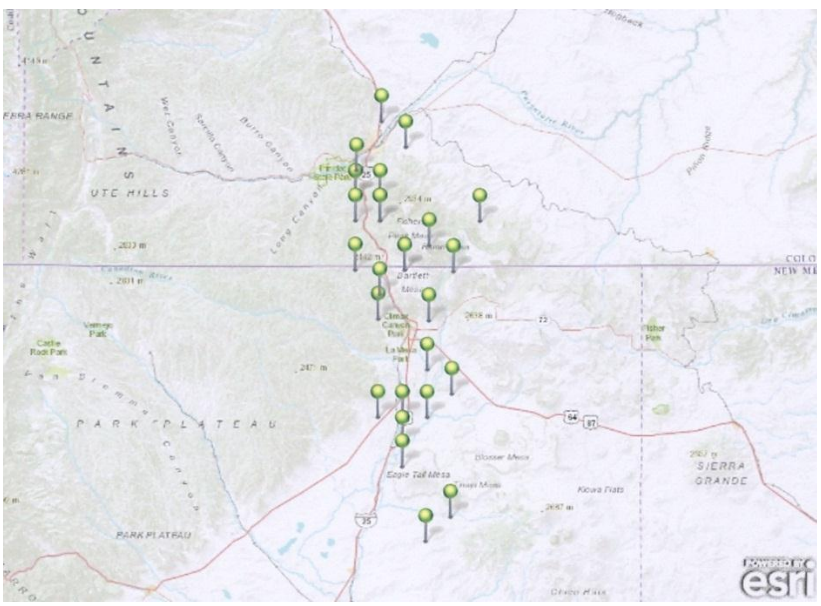
(*Mesa de los Jumanos, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.14: Jacinto Mesa, NM



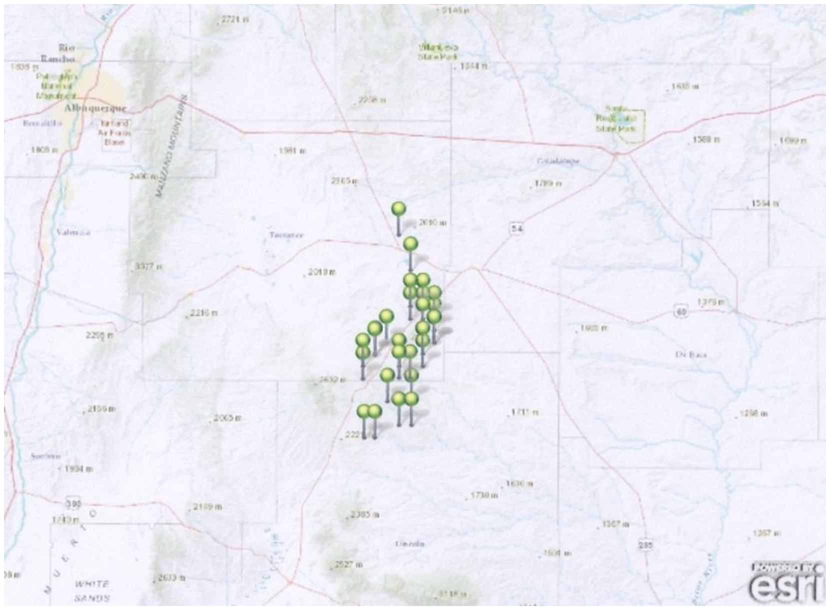
(*Jacinto Mesa, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.15: Bartlett Mesa/Horse Mesa, NM



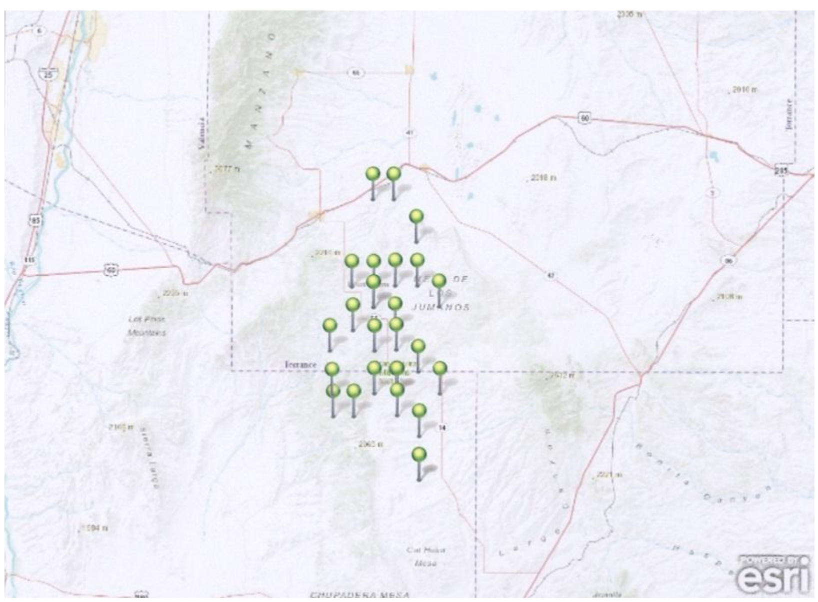
(*Bartlett Mesa/Horse Mesa, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.16: Trinchera Mesa/Valencia Hills/Howard Mountain, NM



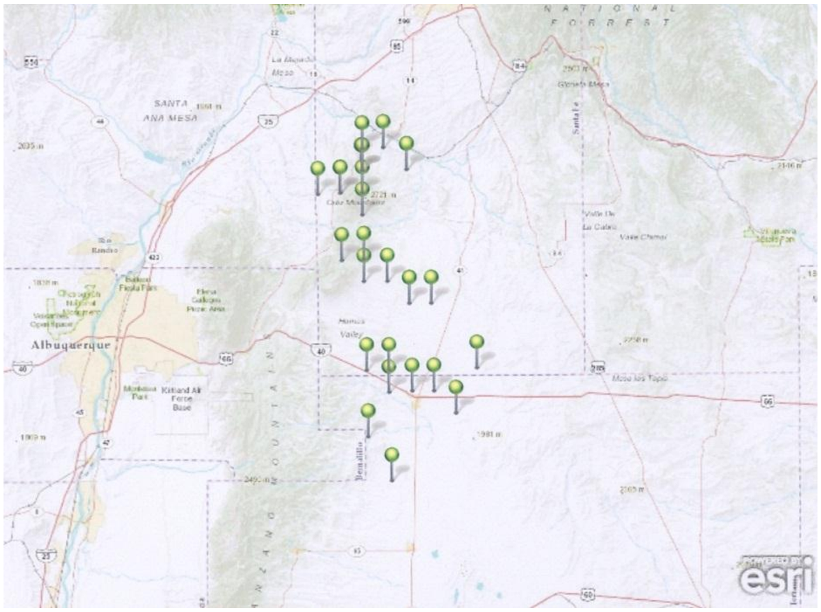
(*Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.17: West Mesa, NM



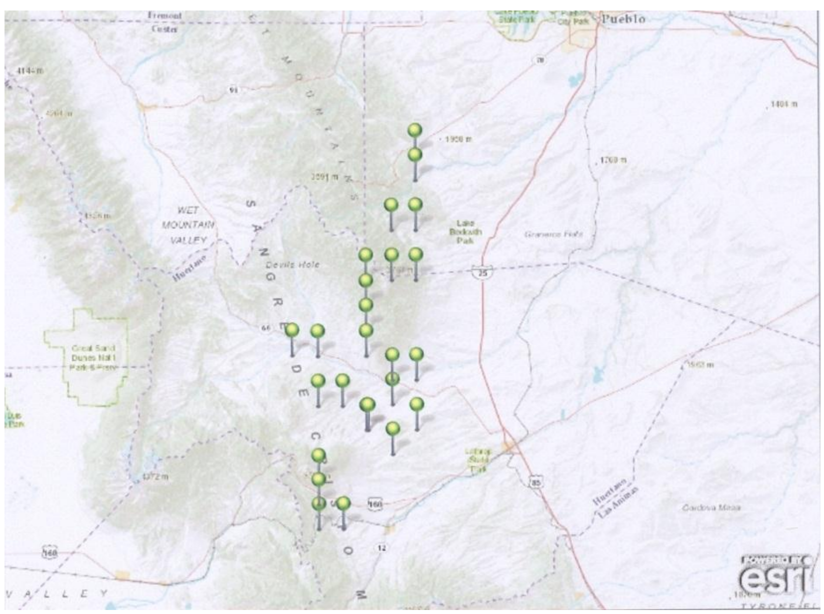
(*West Mesa, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.18: South Mountain, NM



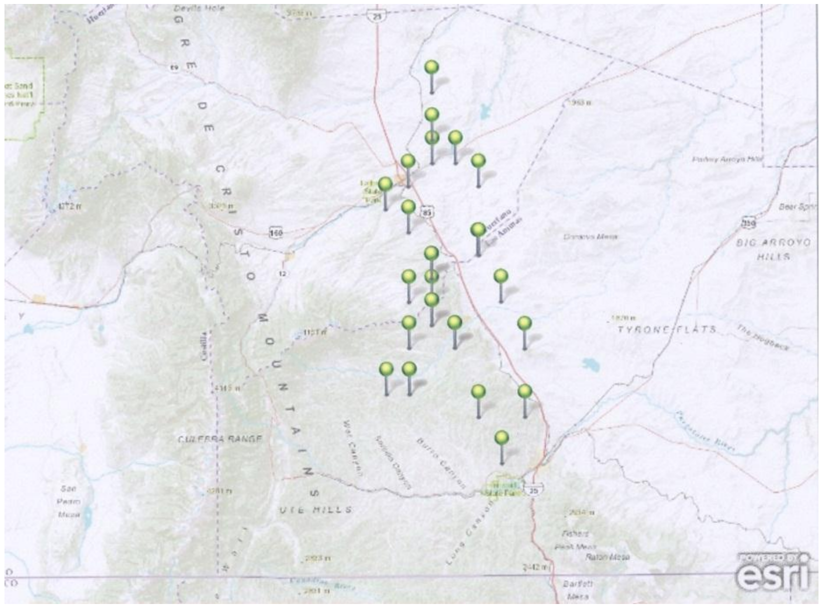
(*South Mountain, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.19: Badito Cone, CO



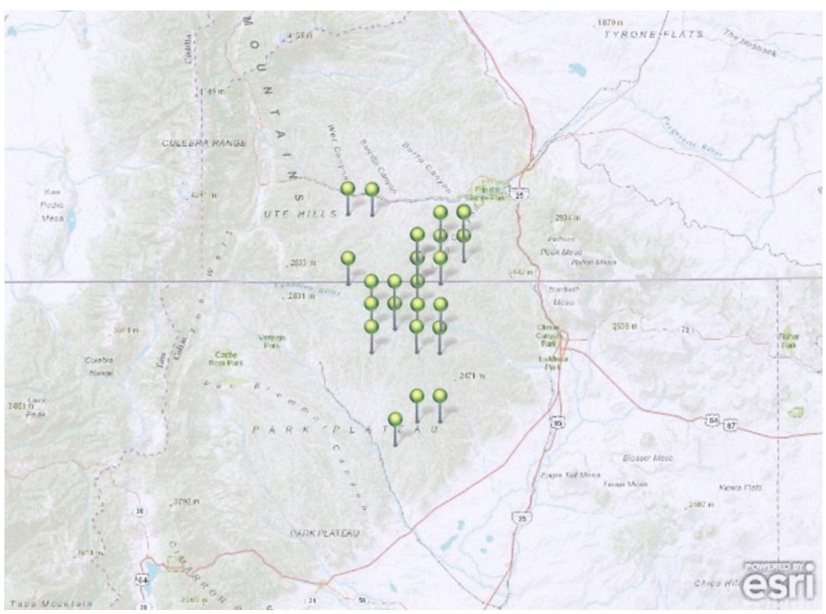
(*Badito Cone, CO Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.20: Bunker Hill, CO



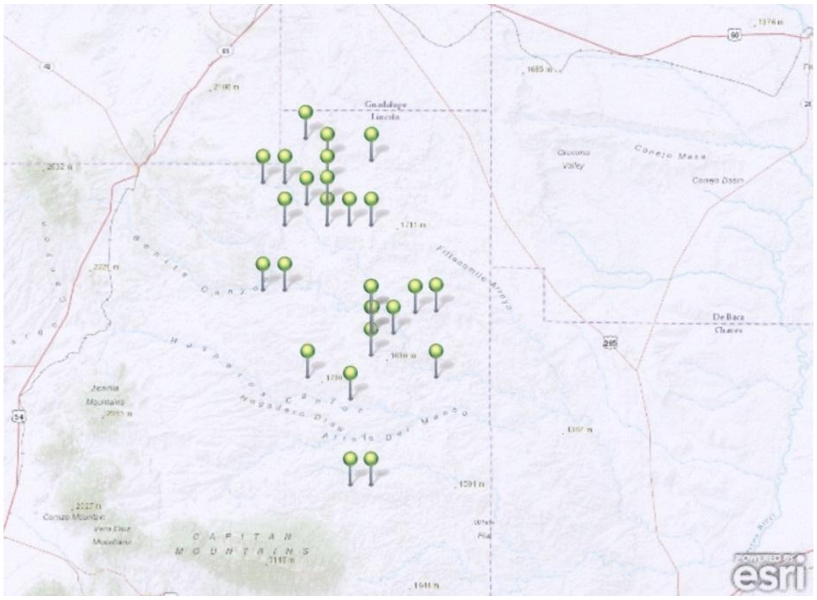
(*Bunker Hill, CO Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.21: Caliente Canyon/Long Canyon, NM



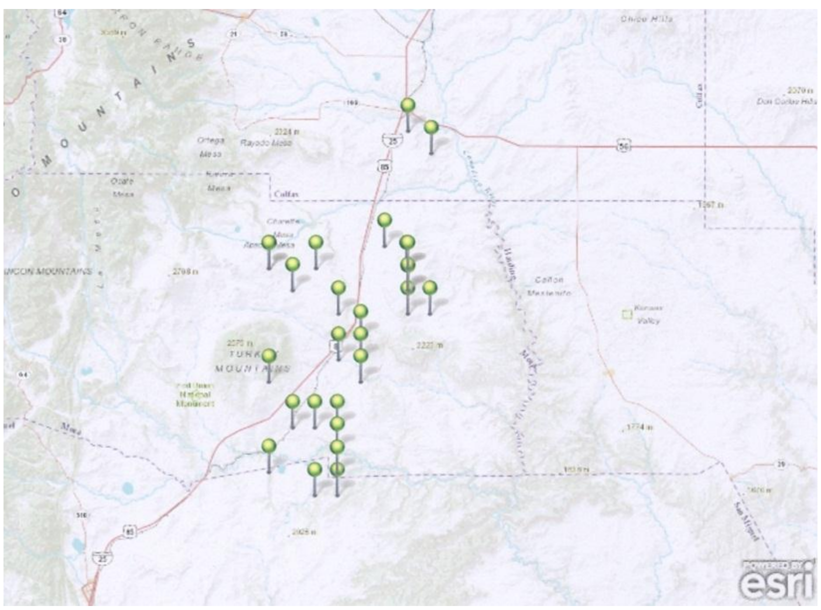
(*Caliente Canyon/Long Canyon, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.22: Cowboy Mesa, NM



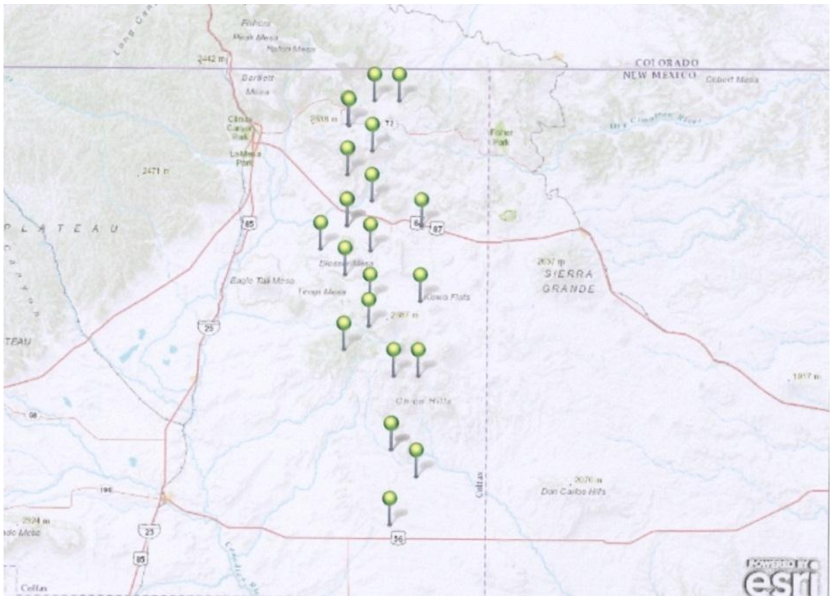
(*Cowboy Mesa, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.23: Las Mesa Del Conjelon, NM



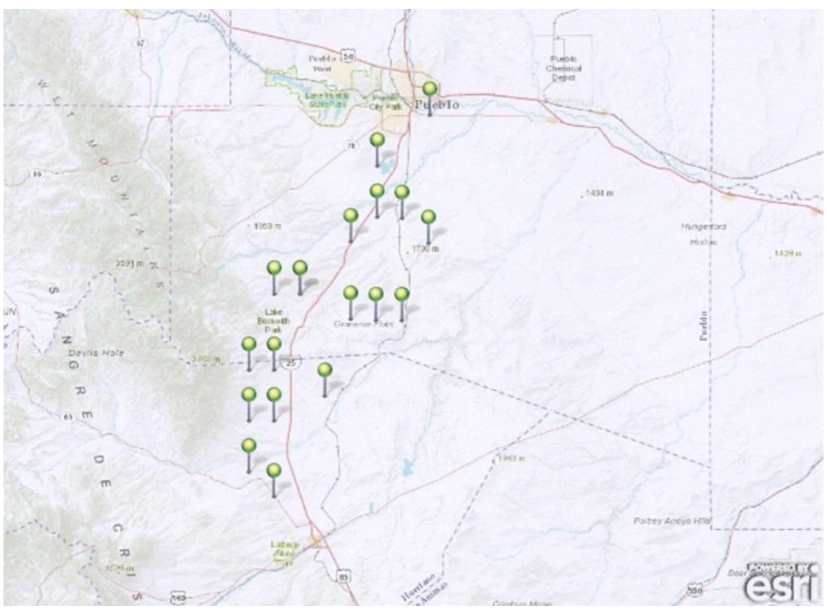
(*Las Mesa Del Conjelon, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.24: Laughlin Peak, NM



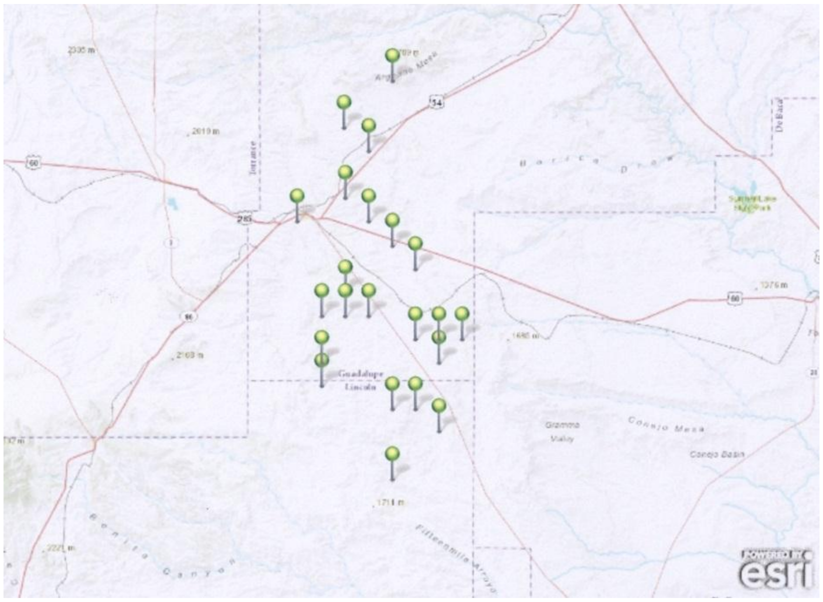
(*Laughlin Peak, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.25: Hogback Mountain/Mt. Signal, CO



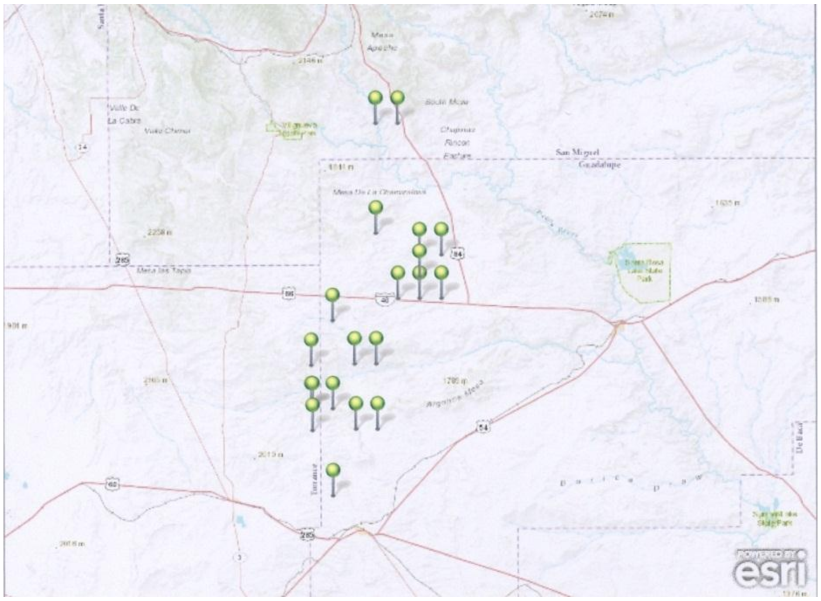
(*Hogback Mountain/Mt. Signal, CO Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.26: Gacho Hill, NM



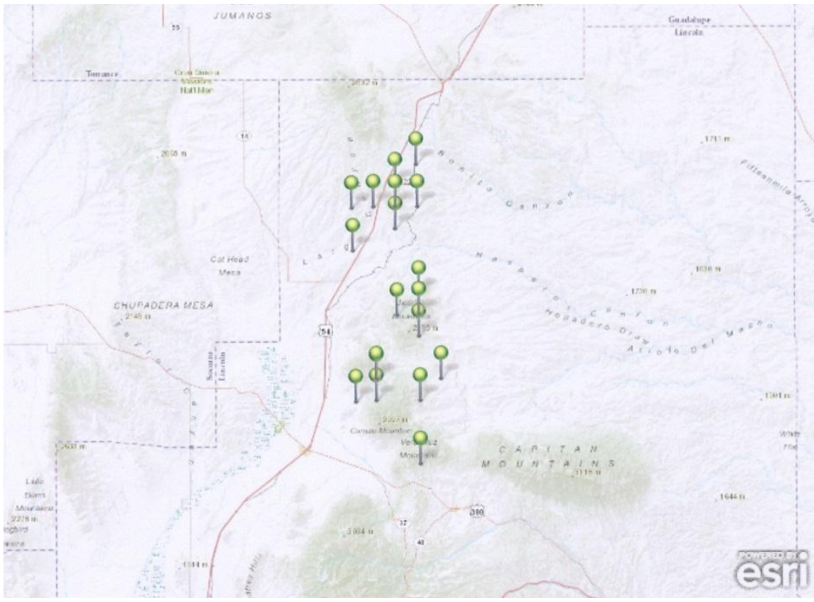
(*Gacho Hill, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.27: Argonne Mesa, NM



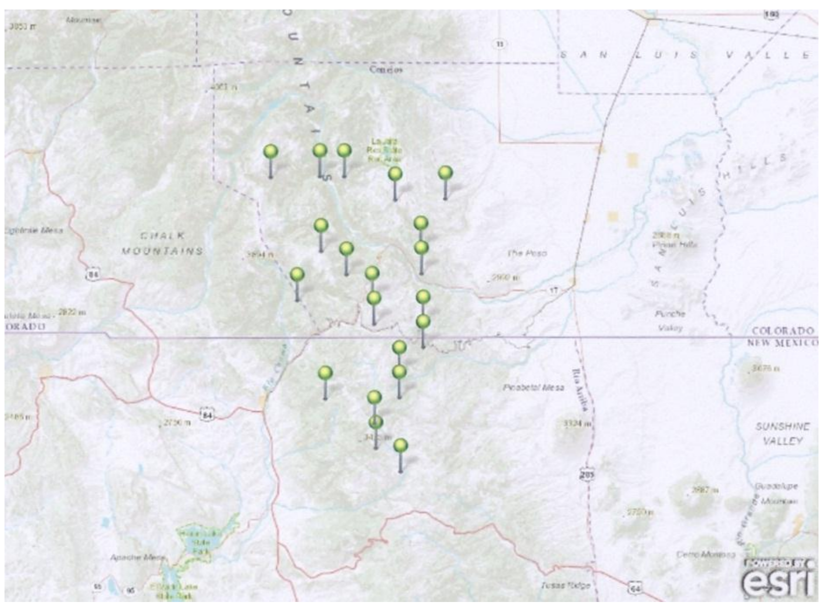
(*Argonne Mesa, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.28: Jicarilla Mountains, NM



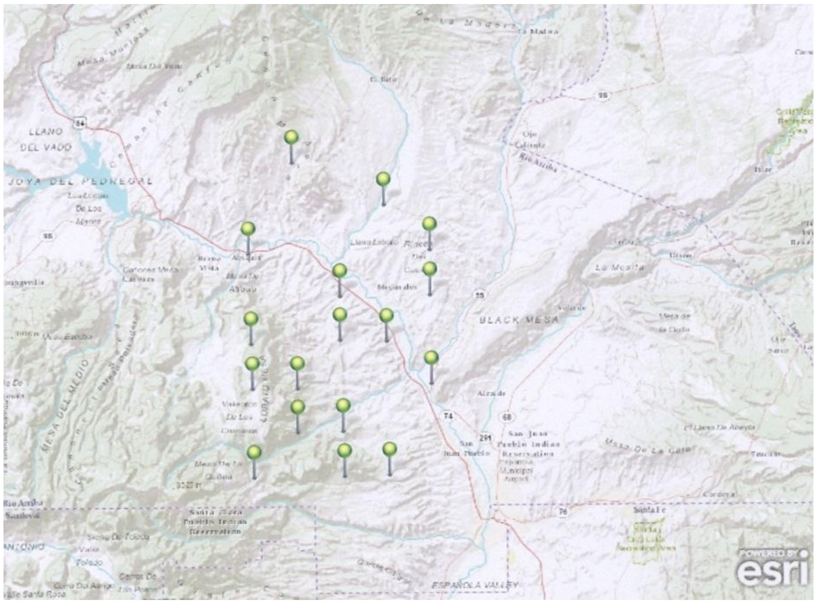
(*Jicarilla Mountains, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.29: Neff Mountain/Jarosa Peak, CO



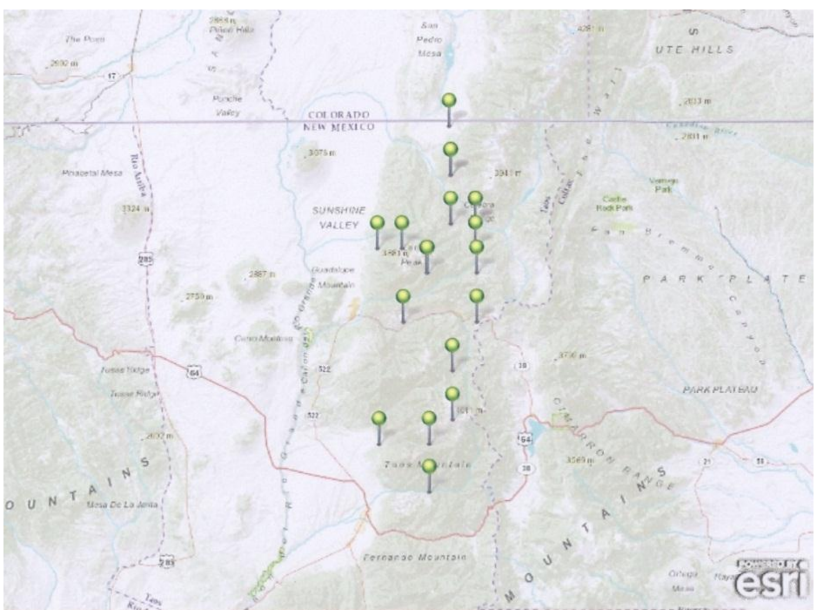
(*Neff Mountain/Jarosa Peak, CO Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.30: Rincon del Cuervo, NM



(*Rincon del Cuervo, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.31: South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM



(*South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster Location Map.* Source: data compiled from USGS and Tucker and Li (2009).)

A.32: Overall

No overall map will be included in this appendix. The individual cluster maps can be combined to show the locations for all the MCSs used in this analysis.

Appendix B: After Initiation Result Tables

B.1: Elk Mountain, NM

Table B.1.1: Results of the After Initiation MLRs Run on the Entire Elk Mountain, NM Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + VC200 – UC200 + LCL + UC500 – VWSS500 – GH600	0.444
2HA	FP ≈ constant + SH800 – VWS600500 + LI + SH200 + CAPE + UC300 + UWSS600 – VC500 + UWND – WD600	0.794
3HA	FP ≈ constant + T200 + UWS600500 – T600 + Thickness – STHC – GH300 + LCL – T300 – UWND + GH200 + SRH – UWSS600 – LI – VWND	0.769

Table B.1.2: Results of the After Initiation PCAs Run on the Entire Elk Mountain, NM Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	SMXS, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	9	86.610%
2HA	VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC500, UC300, UWSS500, UWS600500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	10	87.333%
3HA	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC600, VC500, VC300, VWSS500, VWSS600, T500	10	82.145%

B.2: Elk Mountain, NM Wind Direction Group 1

Table B.2.1: Results of the After Initiation MLRs Run on the Elk Mountain, NM Wind Direction Group 1 Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – UC200 – GH600 + SH500	0.428
2HA	FP ≈ constant + UWSS500 + SH200 + CAPE + LI + UC300 – VWS600500 – UWS600500 + T300	0.830
3HA	FP ≈ constant + T200 + UWS600500 – T600 + Thickness – STHC	0.638

Table B.2.2: Results of the After Initiation PCAs Run on the Elk Mountain, NM Wind Direction Group 1 Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UWSS500, UWS600500, UWSS600, VC600, VC500, VWSS500, VWSS600, T600, T500, T300	8	88.173%
2HA	UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH850, SH800, UC600, UC500, UC300, UWSS500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	10	88.281%
3HA	GH500, GH300, GH200, UWSS500, VC600, VWSS500, VWSS600, T500	9	80.198%

B.3: Elk Mountain, NM Wind Direction Group 2

Table B.3.1: Results of the After Initiation MLRs Run on the Elk Mountain, NM Wind Direction Group 2 Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + LCL – WD500 – UC200 + UWSS600 – VWSS500 + SH500 + STHC – SMXS	0.936
2HA	FP ≈ constant + UC300 – LI	0.872
3HA	FP ≈ constant + VC600 – T300 + SMXR + Thickness + SH500 – UC500 + LI + UC300	0.953

Table B.3.2: Results of the After Initiation PCAs Run on the Elk Mountain, NM Wind Direction Group 2 Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	SMXS, UWND, VWND, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300, T200	8	92.294%
2HA	All variables	7	99.737%
3HA	STHC, SMXR, SMXS, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	94.020%

B.4: Ute Hills/Pete Hills, CO

Table B.4.1: Results of the After Initiation MLRs Run on the Ute Hills/Pete Hills, CO Cluster. The hour the model was run is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + LCL – WD600 + WD500 – LI – UWND	0.906
2HA	FP ≈ constant – LI + UWS600500 – SH850 + CAPE + SH500 – SH300 – VC600 + SMXR	0.769
3HA	FP ≈ constant + UWSS500 + SH300 + LI – CIN	0.433

Table B.4.2: Results of the After Initiation PCAs Run on the Ute Hills/Pete Hills, CO Cluster. The hour the model was run is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	VWND, LCL, Thickness, PW, GH600, GH500, GH300, GH200, SH800, SH600, UC600, UC500, UC300, UWSS500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	9	91.262%
2HA	STHC, SMXS, Thickness, PW, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC600, UC500, UC300, UWSS500, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	9	87.016%
3HA	STHC, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	9	88.779%

B.5: Rincon Mountains, NM

Table B.5.1: Results of the After Initiation MLRs Run on the Rincon Mountains, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + SH600 – SH850 + UWSS600 + T300 + SRH + UWS600500 + VWSS600 – GH600 + LI + CAPE	0.945
2HA	FP ≈ constant + UC500 + LCL – SMXR + PW – VWS600500 – CIN	0.729
3HA	FP ≈ constant – T200 – SH300	0.730

Table B.5.2: Results of the After Initiation PCAs Run on the Rincon Mountains, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, UWND, VWND, Thickness, PW, GH500, GH300, GH200, SH300, UC600, UC500, UWSS500, UWS600500, UWSS600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	8	88.094%
2HA	STHC, UWND, VWND, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UWSS500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	9	92.545%
3HA	STHC, SMXR, SMXS, UWND, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC500, UC300, UWSS500, UWSS600, VC600, VC500, VWSS500, VWS600500, VWSS600, T600, T500, T300	10	91.357%

B.6: Lookout Peak/Rayado Peak, NM

Table B.6.1: Results of the After Initiation MLRs Run on the Lookout Peak/Rayado Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + UC500 – VWND – LI – VWSS500	0.786
2HA	FP ≈ constant – VWND + UC200	0.267
3HA	FP ≈ constant + UC300 + VC200 – UC200	0.348

Table B.6.2: Results of the After Initiation PCAs Run on the Lookout Peak/Rayado Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, UC600, UC500, UC300, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWSS600500, VWSS600, T600, T500, T300, T200	8	93.685%
2HA	STHC, SMXS, UWND, VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC300, UWSS500, UWSS600, VC600, VC500, VWSS500, VWS600500, VWSS600, T600, T500	9	89.027%
3HA	SMXR, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UWSS500, UWSS600, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	9	90.079%

B.7: Pajarito Mountain/Cerro Grande, NM

Table B.7.1: Results of the After Initiation MLRs Run on the Pajarito Mountain/Cerro Grande, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + VWSS500 + UC200 + SRH + LCL + SH500 + T600 – T300 + LI	0.938
2HA	FP ≈ constant + CAPE + VC200 + LI – UWND + WD500 – WD600	0.943
3HA	FP ≈ constant – SH300 + UWSS600 – GH600 – VC600 + UC300 + CIN + UWND	0.912

Table B.7.2: Results of the After Initiation PCAs Run on the Pajarito Mountain/Cerro Grande, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXS, UWND, VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VWSS500, VWSS600500, VWSS600, T600, T500, T300	9	91.478%
2HA	STHC, SMXR, SMXS, UWND, LCL, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, SH200, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	8	93.930%
3HA	STHC, SMXS, UWND, VWND, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, UC500, UC300, UC200, UWSS500, UWSS600, WD500, VC600, VC500, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	10	92.342%

B.8: Culebra Range/Sangre de Cristo Mountains, CO

Table B.8.1: Results of the After Initiation MLRs Run on the Culebra Range/Sangre de Cristo Mountains, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + UWS600500 – UC200	0.508
2HA	FP ≈ constant + VC600 + SRH – UWND + CIN – WD500 + VWSS500 + UC500	0.886
3HA	FP ≈ constant + UWSS500 – LI + UWND + Thickness + VC200 – VC300 + GH600 + VWS600500	0.852

Table B.8.2: Results of the After Initiation PCAs Run on the Culebra Range/Sangre de Cristo Mountains, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	SMXS, UWND, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC500, VWSS500, VWS600500, T600, T500, T300, T200	7	93.101%
2HA	STHC, SMXR, SMXS, VWND, Thickness, PW, SRH, GH500, GH300, GH200, SH850, SH800, SH600, SH300, SH200, UC500, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T500, T300	9	92.517%
3HA	SMXR, UWND, VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC500, UC200, UWSS500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	9	89.135%

B.9: Shaggy Peak, NM

Table B.9.1: Results of the After Initiation MLRs Run on the Shaggy Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – T300 + PW – UWND	0.875
2HA	FP ≈ constant – STHC + Thickness – VC600 + VC500 + UWSS500 + SH300 + VWSS600	0.993
3HA	FP ≈ constant + UWS600500 + SRH + SH500 – WD500 – CAPE + VWSS500	0.756

Table B.9.2: Results of the After Initiation PCAs Run on the Shaggy Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, UWND, VWND, Thickness, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	92.386%
2HA	STHC, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	93.791%
3HA	STHC, SMXS, VWND, Thickness, PW, CIN, GH500, GH300, GH200, SH850, SH800, SH600, SH300, UC500, UWSS500, UWS600500, UWSS600, VC600, VC500, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	90.258%

B.10: Los Pinos Mountains, NM

Table B.10.1: Results of the After Initiation MLRs Run on the Los Pinos Mountains, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + VWSS500 – VC300 – SRH	0.876
2HA	FP ≈ constant – SH800 + CAPE + VWS600500 + SH850 + GH500 – WD500 + VC200 + VC300	1.000
3HA	FP ≈ constant + VC300 + SRH – UC300 – CAPE + UC500 + LCL – VWSS500 + UWND + SH300	0.940

Table B.10.2: Results of the After Initiation PCAs Run on the Los Pinos Mountains, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300	8	95.306%
2HA	All variables	7	98.639%
3HA	STHC, SMXR, SMXS, VWND, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	91.465%

B.11: Mount Washington, NM

Table B.11.1: Results of the After Initiation MLRs Run on the Mount Washington, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + LCL – PW – UWS600500 + T500 + VWSS500 – UWND – SH600 – UC200 + CIN + SH200 + SH800 + SH300 – WD600 – UC300	1.000
2HA	MISSING	N/A
3HA	FP ≈ constant + UWSS600 – UC200	0.648

Table B.11.2: Results of the After Initiation PCAs Run on the Mount Washington, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, LCL, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	93.801%
2HA	STHC, SMXR, SMXS, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	7	93.903%
3HA	STHC, SMXR, UWND, VWND, LI, Thickness, PW, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	6	94.280%

B.12: Wrye Peak, NM

Table B.12.1: Results of the After Initiation MLRs Run on the Wrye Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + VWSS500 – VC200	0.434
2HA	FP ≈ constant + CAPE + CIN + GH600 + UC300 – LI	0.891
3HA	FP ≈ constant + GH600 – SMXR + VC600 – UWS600500	1.000

Table B.12.2: Results of the After Initiation PCAs Run on the Wrye Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH200, UC500, UC300, UC200, UWSS500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T500, T300, T200	9	92.680%
2HA	STHC, SMXR, SMXS, UWND, VWND, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	95.334%
3HA	All variables	4	100.000%

B.13: Mesa de los Jumanos, NM

Table B.13.1: Results of the After Initiation MLRs Run on the Mesa de los Jumanos, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + SMXS – SH300 – SMXR	0.947
2HA	FP ≈ constant + VC500 + UWS600500 + UWSS500	0.954
3HA	FP ≈ constant + UC200 + VC600 + UWSS600	0.613

Table B.13.2: Results of the After Initiation PCAs Run on the Mesa de los Jumanos, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXS, UWND, VWND, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.939%
2HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.159%
3HA	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	95.695%

B.14: Jacinto Mesa, NM

Table B.14.1: Results of the After Initiation MLRs Run on the Jacinto Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + SH200 – SH500 + UWND + LCL – GH200 + GH600	1.000
2HA	FP ≈ constant – VWND + WD600 + SMXR + UWSS500 – LI	0.950
3HA	FP ≈ constant – VWS600500 – SRH	0.441

Table B.14.2: Results of the After Initiation PCAs Run on the Jacinto Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	6	100.000%
2HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	96.495%
3HA	STHC, SMXR, UWND, VWND, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	9	94.953%

B.15: Bartlett Mesa/Horse Mesa, NM

Table B.15.1: Results of the After Initiation MLRs Run on the Bartlett Mesa/Horse Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – T500 – T200 + GH200	0.986
2HA	FP ≈ constant – CIN + LCL – UC200 + VC300 + SH500 – SH600 – VWS600500 + WD500 + SRH + T500 – UWSS500 + UC600 – PW – VWND	1.000
3HA	FP ≈ constant – LI – CAPE	0.864

Table B.15.2: Results of the After Initiation PCAs Run on the Bartlett Mesa/Horse Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	5	97.702%
2HA	STHC, SMXR, SMXS, VWND, LI, Thickness, PW, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH200, UC600, UC500, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	92.515%
3HA	All variables	7	98.942%

B.16: Trinchera Mesa/Valencia Hills/Howard Mountain, NM

Table B.16.1: Results of the After Initiation MLRs Run on the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – GH600 – UWSS600 + PW	0.967
2HA	FP ≈ constant + Thickness – T200 – LCL – VC300 + VWSS500 + VC500 – UWSS500 – GH500 + GH200	1.000
3HA	FP ≈ constant + SH500 + T200 – SH200 – SRH – SMXS – UWSS600 – VC200 + VWSS600 – UC200	1.000

Table B.16.2: Results of the After Initiation PCAs Run on the Trinchera Mesa/Valencia Hills/Howard Mountain, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH300, UC600, UC500, UC300, UC200, UWSS500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	96.200%
2HA	All variables	8	98.563%
3HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC200, VWSS500, VWSS600, T600, T500, T300, T200	7	96.880%

B.17: West Mesa, NM

Table B.17.1: Results of the After Initiation MLRs Run on the West Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – T600 + VC600	0.756
2HA	FP ≈ constant + T200 + LI + CIN – CAPE	0.975
3HA	FP ≈ constant – WD600 – VWSS500 + UC300 + UWND – SH850 – UWSS600	1.000

Table B.17.2: Results of the After Initiation PCAs Run on the West Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.287%
2HA	All variables	9	99.074%
3HA	All variables	6	100.000%

B.18: South Mountain, NM

Table B.18.1: Results of the After Initiation MLRs Run on the South Mountain, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + SRH + VWND – UWSS600 – LCL + SMXR – T200 + SH200	1.000
2HA	FP ≈ constant + UC200 + LI – T600 – UWSS600 + SH800 + WD600	1.000
3HA	FP ≈ constant – T600 – T200 – WD500 + Thickness + UC500 – UC300 + VC200 – VWS600500 + SRH – WD600 – STHC – GH600	1.000

Table B.18.2: Results of the After Initiation PCAs Run on the South Mountain, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	97.783%
2HA	All variables	6	100.000%
3HA	STHC, SMXR, SMXS, UWND, VWND, LCL, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	96.393%

B.19: Badito Cone, CO

Table B.19.1: Results of the After Initiation MLRs Run on the Badito Cone, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – VC300 + LI + SMXR – UC600 + SRH + VWS600500 + SH600 – SH800 – VC200 + Thickness	1.000
2HA	FP ≈ constant + SRH – VC500 – UC500 + CAPE	0.990
3HA	FP ≈ constant + LCL + UWS600500 + VWS600500 – T500 + SMXR	1.000

Table B.19.2: Results of the After Initiation PCAs Run on the Badito Cone, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.975%
2HA	STHC, SMXR, SMXS, UWND, LCL, LI, Thickness, PW, CAPE, CIN, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, UC600, UC300, UC200, UWSS500, UWSS600, WD500, VC600, VC500, VC300, VWSS500, VWSS600, T600, T500, T300	6	94.604%
3HA	All variables	5	100.000%

B.20: Bunker Hill, CO

Table B.20.1: Results of the After Initiation MLRs Run on the Bunker Hill, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + LI + UC500 + SMXS + UWS600500 + SH800 – VC200 – T500 + CAPE – T200	1.000
2HA	FP ≈ constant + SRH – GH600 + SH600 – T200 + WD600	1.000
3HA	FP ≈ constant + SH300 – WD500 + CAPE – VWND – VWS600500 + T200 + UWND + SH500 – SH200 + T300	1.000

Table B.20.2: Results of the After Initiation PCAs Run on the Bunker Hill, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	96.654%
2HA	All variables	5	100.000%
3HA	STHC, SMXR, SMXS, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	95.266%

B.21: Caliente Canyon/Long Canyon, NM

Table B.21.1: Results of the After Initiation MLRs Run on the Caliente Canyon/Long Canyon, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + SH800 – CIN – VWSS600 + VC300 + GH600 + UC300	0.993
2HA	MISSING	N/A
3HA	FP ≈ constant – VC500 + SH300 – GH300 + UC200 + UWSS500	1.000

Table B.21.2: Results of the After Initiation PCAs Run on the Caliente Canyon/Long Canyon, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	8	96.038%
2HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	96.682%
3HA	All variables	5	100.000%

B.22: Cowboy Mesa, NM

Table B.22.1: Results of the After Initiation MLRs Run on the Cowboy Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – T600 – LI + SH300 + CIN – SH500 + SRH	1.000
2HA	FP ≈ constant + UWND + VWND – SRH – CAPE + LCL + UC300 + VWS600500 + STHC – UC500	1.000
3HA	FP ≈ constant + VC300 – CAPE – LI – VWS600500 + GH200 + SRH + SH300 + WD500 – SH800	1.000

Table B.22.2: Results of the After Initiation PCAs Run on the Cowboy Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	5	98.384%
2HA	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	97.151%
3HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	98.292%

B.23: Las Mesa Del Conjelon, NM

Table B.23.1: Results of the After Initiation MLRs Run on the Las Mesa Del Conjelon, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + VC500 – CIN + SH500 + SRH – VWSS600 + VC300 + SH800 + UC600	1.000
2HA	FP ≈ constant + CAPE + SH300 – VWND + WD600 + VWS600500 – SMXS – VC200 – SH200 + CIN	1.000
3HA	FP ≈ constant + SH500	0.496

Table B.23.2: Results of the After Initiation PCAs Run on the Las Mesa Del Conjelon, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	7	98.172%
2HA	All variables	8	98.595%
3HA	All variables	7	100.000%

B.24: Laughlin Peak, NM

Table B.24.1: Results of the After Initiation MLRs Run on the Laughlin Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + LCL + SRH + UC300 + SH200	1.000
2HA	FP ≈ constant + SMXS – GH500 + UWS600500 + GH200 – UC200 + VC200 + UC300 – STHC + CIN + VWSS500	0.999
3HA	FP ≈ constant + SH200 – CIN + SH300	1.000

Table B.24.2: Results of the After Initiation PCAs Run on the Laughlin Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	4	100.000%
2HA	STHC, SMXR, SMXS, VWND, Thickness, PW, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	8	94.858%
3HA	All variables	3	100.000%

B.25: Hogback Mountain/Mt. Signal, CO

Table B.25.1: Results of the After Initiation MLRs Run on the Hogback Mountain/Mt. Signal, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + SRH + UWND + UC200 – SH300 + UWS600500	0.998
2HA	FP ≈ constant – SMXR	1.000
3HA	FP ≈ constant + UWSS600 – STHC + UC500 + CAPE + SRH – VC200	0.979

Table B.25.2: Results of the After Initiation PCAs Run on the Hogback Mountain/Mt. Signal, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300	7	97.005%
2HA	MISSING	N/A	N/A
3HA	All variables	8	97.363%

B.26: Gacho Hill, NM

Table B.26.1: Results of the After Initiation MLRs Run on the Gacho Hill, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – GH300 – UWS600500 – T200 – SH500 + GH200 – VC500 – WD500 + GH600 + WD600	1.000
2HA	FP ≈ constant + UC200 + PW + SH200 + VWND + UWND + LI	1.000
3HA	FP ≈ constant – SH600 – UC200 – SMXR – UWND	1.000

Table B.26.2: Results of the After Initiation PCAs Run on the Gacho Hill, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	8	98.617%
2HA	All variables	6	100.000%
3HA	All variables	4	100.000%

B.27: Argonne Mesa, NM

Table B.27.1: Results of the After Initiation MLRs Run on the Argonne Mesa, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – WD600 + CAPE – UC300 + VC300 + UWSS600 + PW – VWSS600 + VWSS500 + SRH	1.000
2HA	FP ≈ constant – STHC + SMXS + GH200 + SH300 + SRH	1.000
3HA	FP ≈ constant – SH850 + LI – SH800	1.000

Table B.27.2: Results of the After Initiation PCAs Run on the Argonne Mesa, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	8	98.393%
2HA	All variables	5	100.000%
3HA	All variables	3	100.000%

B.28: Jicarilla Mountains, NM

Table B.28.1: Results of the After Initiation MLRs Run on the Jicarilla Mountains, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + UWS600500	0.635
2HA	FP ≈ constant – UC300 – UWND – VWS600500 – UC500 – GH600	1.000
3HA	FP ≈ constant + SH600 – VWND – SRH + WD600 + SH850 + LI – SH500	1.000

Table B.28.2: Results of the After Initiation PCAs Run on the Jicarilla Mountains, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	6	100.000%
2HA	All variables	5	100.000%
3HA	STHC, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VWSS500, VWS600500, VWSS600, T600, T500, T300, T200	6	98.348%

B.29: Neff Mountain/Jarosa Peak, CO

Table B.29.1: Results of the After Initiation MLRs Run on the Neff Mountain/Jarosa Peak, CO Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + CAPE – SMXR	1.000
2HA	FP ≈ constant + VWS600500 – LI + GH300 – SH500 – STHC – GH600 + UC200 + PW	1.000
3HA	FP ≈ constant – VWSS600 + VWSS500 – UC500 – CAPE – STHC + UWSS600 – SH300	1.000

Table B.29.2: Results of the After Initiation PCAs Run on the Neff Mountain/Jarosa Peak, CO Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	2	100.000%
2HA	All variables	8	100.000%
3HA	All variables	7	100.000%

B.30: Rincon del Cuervo, NM

Table B.30.1: Results of the After Initiation MLRs Run on the Rincon del Cuervo, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + UC300 – UWS600500 – VWSS600 + VC200 + SH200 – SH850	1.000
2HA	FP ≈ constant – STHC – SRH – LCL – SH500 – UC300 – VWSS500 – CIN	1.000
3HA	FP ≈ constant – SMXS	0.877

Table B.30.2: Results of the After Initiation PCAs Run on the Rincon del Cuervo, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	All variables	6	100.000%
2HA	All variables	7	100.000%
3HA	All variables	4	100.000%

B.31: South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM

Table B.31.1: Results of the After Initiation MLRs Run on the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant – VC200 + UC300 + VC600 – CAPE – VWS600500 – SH300 + T200	1.000
2HA	FP ≈ constant + T500 + VC300 – WD600 – GH200	1.000
3HA	FP ≈ constant + LCL + LI – T200 – PW + VWSS500 – UWND	1.000

Table B.31.2: Results of the After Initiation PCAs Run on the South Fork Peak/Vallecito Mountain/Lake Fork Peak, NM Cluster. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	STHC, SMXR, SMXS, UWND, VWND, LCL, LI, Thickness, PW, CAPE, CIN, SRH, GH600, GH500, GH300, GH200, SH850, SH800, SH600, SH500, SH300, SH200, UC600, UC500, UC300, UC200, UWSS500, UWS600500, UWSS600, WD600, WD500, VC600, VC500, VC300, VC200, VWSS500, VWSS600, T600, T500, T300, T200	6	98.436%
2HA	All variables	4	100.000%
3HA	All variables	6	100.000%

B.32: Overall

Table B.32.1: Results of the After Initiation MLRs for the Global Model Domain. The hour the model was run for is in the first column, the approximate equation is in the second column, and the R square value is given in the third column.

Model Run	Approximate Equation	R Square
1HA	FP ≈ constant + UWS600500 – GH600 + LCL + SRH + VC300 – UWSS500 + Thickness – T300 + SH500 + SH200 – SMXS – SMXR	0.263
2HA	FP ≈ constant – T300 – VWND + LCL + Thickness – GH600 + SRH + T200 + CIN	0.190
3HA	FP ≈ constant + T200 + UWS600500 + SH300 + VC200 – VWS600500 + LCL	0.149

Table B.32.2: Results of the After Initiation PCAs for the Global Model Domain. The hour the model was run for is in the first column, the variables with 90 percent or more variance accounted for are in the second column listed in order of how the variables were observed, the number of components with an eigenvalues greater than one is in the third column, and the variance accounted for with the eigenvalues greater than one is in the fourth column.

Model Run	Variables with 90 percent or more variance	# with $\lambda > 1$	Accounted for Variance
1HA	UWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	10	81.526%
2HA	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VC500, VWSS500, VWSS600, T600, T500, T300	10	81.089%
3HA	UWND, VWND, Thickness, GH500, GH300, GH200, UC500, UWSS500, UWSS600, VWSS500, VWSS600, T600, T500	10	76.747%