Humboldtian Science, Creole Meteorology, and the Discovery of Human-Caused Climate Change in South America

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ABSTRACT

The belief that human land use is capable of causing large-scale climatic change lies at the root of modern conservation thought and policy. The origins and popularization of this belief were deeply politicized. Alexander von Humboldt's treatment of the Lake Valencia basin in Venezuela and the desert coast of Peru as natural laboratories for observing the interaction between geophysical and cultural forces was central to this discovery, as was Humboldt's belief that European colonialism was especially destructive to the land. Humboldt's overt cultivation of disciples was critical to building the prestige of this discovery and popularizing the Humboldtian scientific program, which depended fundamentally on local observers, but willfully marginalized chorographic knowledge systems. In creating new, global forms of environmental understanding, Humboldtian science also generated new forms of ignorance.

In February 1937, at the behest of Swiss-born botanist Henri Pittier, Venezuela established its first national park in order to protect a forested swath of coastal mountains between the Caribbean Sea and the fertile Lake Valencia plain (fig. 1). Over the next few years, the Venezuelan state created a forest service with twenty-five rangers at its command, established a botanical directorate to survey the biodiversity of government lands, began sponsoring Arbor Day celebrations, and signed the 1940 Hemispheric Convention on Nature Protection. Nearly all of these projects were placed under the administration of trained scientists intent on preventing the degradation of Venezuela's forests in order to protect the country's water supply.[1] In April 1940 in

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[1] Henri Pittier, *Consideraciones acerca de la destrucción de los bosques y del incendio de las sabanas* (Caracas, 1936), 1–4; Pittier, *Notas sobre la crisis de agua en la parte central de Venezuela* (Caracas, 1948), 13–5, 22–5; Manuel González Vale, *Un plan nacional forestal venezolano* (Trujillo, 1942), 3–4, 8.

the underlying structure of the landscape.[28] These interactions underscore the significance of interpersonal contacts and companionship in both hemispheres to the early development of Humboldtian science. As we shall see, social relationships of this sort also played a vital role in its popularization.

Humboldt used a combination of these ideas and methods to make sense of the dry-season landscapes of north-central Venezuela. He tentatively concluded that the high ridges of the coastal range blocked the entry of humid air into interior valleys from the Caribbean Sea to the north and the Orinoco plain to the south. From his own experiences during the rainy season in Cumaná, Humboldt had observed that rainstorms in the tropics seemed to result from local electrical processes, usually during the heat of the day, unlike in northern regions, where storms migrated from place to place.[29] These meteorological observations are critical to understanding how Humboldt arrived at his conclusions regarding Lake Valencia and human-caused climate change in the region. His belief that tropical thunderstorms form in situ enabled him to treat this lake basin and other tropical watersheds as closed systems, analogous to tropical islands, that could serve as natural laboratories for understanding the physical relationship between the air, soil, vegetation, moisture, and human agency.

On February 13, 1800, Humboldt and his associates reached the head of the Tuy Valley, then journeyed quickly west along the northern shore of Lake Valencia, before making a quick jaunt to Puerto Cabello over the coastal range, taking instrumental measurements at almost every turn. The broad inland valley occupied by Lake Valencia was the heartland of irrigated cacao, coffee, sugarcane, cotton, tobacco, and especially indigo cultivation in Venezuela. The Marques del Toro and other valley plantation owners well read in agricultural works explained to Humboldt that indigo rapidly depleted the land: "In four to five years, nothing will grow in the wasted soil. . . . One cultivates the soil like one operates a mine." Humboldt identified three possible factors that played into this wastage: American greed to make money from the land, poisonous "excrement" produced by the indigo plant, and the ill effects of clearing natural vegetation for farming, which opened the soil to the sun and eliminated the shade and moisture needed for humus to form and for oxygen, hydrogen, and carbonic acid to nutrify plants.[30]

Locals insisted that Lake Valencia had been drying up rapidly since about 1740. The Cabrera Peninsula and a long list of hills, points, and outcrops had all reputedly been islands within the past century. The previous eight years had been particularly dry, by most accounts, resulting in the appearance of three flat-topped islets in 1796 known as the Nuevas Aparecidas, which now stood a meter above the waves. Most locals considered the clear blue skies and drying of the lake basin to be a good thing, however, because they spared the valley from the deadly fever epidemics of the previous decade and created rich alluvial lands along the lakeshore.[31]

Humboldt had no reason to doubt these assertions, but took a far more negative view of the situation. In his opinion, the "misconduct" of civilized society had "forcefully disturb[ed] nature's economy" within the lake basin to such an extent that it threatened to destroy the productivity of the region forever. After rejecting local

[28] Cañizares, "How Derivative Was Humboldt?" (cit. n. 13); John Wilton Appel, *Francisco José de Caldas: A Scientist at Work in Nueva Granada* (Philadelphia, 1994).
[29] Humboldt, *Reise durch Venezuela* (cit. n. 16), 186.
[30] Ibid., 199, 208–9, 220, on 208–9.
[31] Ibid., 215–9.

speculation that subterranean filtration was responsible, he identified four interlinked causes for the shrinkage of Lake Valencia:

1. The surrounding mountains had been mostly cleared of vegetation for wood, charcoal, plantations, and grazing over the past century. Every night after the sun set, Humboldt was mesmerized by the "spectacular theatrical effect" of dry-season fires used by ranchers to eliminate pests and keep the upland range open and nutritious for cattle.
2. As a consequence, there was little tall, leafy, woody vegetation to suck up water and shade the ground in the valley. This allowed the tropical sun to beat down on the ground, inhibiting the formation of nutritive humus and accelerating soil desiccation. There was also little vegetation to slow runoff after storms. Humboldt compared this situation to that of the German province of Franconia, which suffered from a severe wood famine.
3. Practically all of the rivers and streams that flowed into the lake had been diverted for plantation irrigation during the recent indigo boom. "Hardly a drop now enters the lake," Humboldt noted—again based on what he saw during the dry season. According to local informants, these alterations dated back to the late seventeenth century, when a rancher redirected the flow of the Río Paíto away from the lake's western shore toward the distant Orinoco. "This drove the plain into desert" in the vicinity, Humboldt concluded.
4. Cleared ground absorbed much greater quantities of heat from the intense sunlight of the low latitudes, which caused the whole lake basin to heat up, thus decreasing the humidity of the air and speeding up the rate of evaporation from the lake. Humboldt did not think the lake would ever dry up completely, but he was greatly concerned that these processes would make it too salty to drink, kill off the lake's fish life, and turn the whole basin into "a dry desert." He encouraged the Marques del Toro, the town of Valencia's most prominent sugar planter, to install granite limnometers in the lake to precisely quantify its rate of recession.

Humboldt explicitly compared this situation to Lake Geneva, thus revealing his intellectual debt to Saussure. This explanation exemplified Humboldt's emerging obsession with "the confluence and interweaving" of geophysical, organic, and social forces. Humboldtian science came into definitive being for the first time along the receding shoreline of Lake Valencia.[32]

Humboldt repeated this reasoning almost verbatim in his *Personal Narrative of Travels to the Equinoctial Regions*. By the time he wrote this best-selling work in the 1820s, Humboldt had come to believe that climate change of this sort was representative of a much broader tendency of European colonialism to abuse American lands and peoples: "These natural desiccations, so important to the colonial agriculture, have been eminently considerable during the last ten years [the 1790s], in which *all America* has suffered from great droughts."[33] Humboldt's visit to the Pacific shore of the New Continent was particularly important in convincing him of this.

[32] Ibid.; Dettelbach, "Humboldtian Science" (cit. n. 10).
[33] Humboldt, *Personal Narrative* (cit. n. 5), 4:129–230, on 151 (emphasis added).

THE ULTIMATE HUMAN-DEGRADED LANDSCAPE?

On September 18, 1802, under the watchful eyes of several Andean condors, Humboldt, his companions, and his porters began their final descent from the highlands of northern Peru after eighteen months exploring the northern Andes. He was amazed by the aridity and barrenness of Peru's coastal slope, even though it lay in the heart of the tropics. Great torrents of water had obviously flowed through its deep, bone-dry canyons, perhaps "at a time when the abundance of water was much greater around the globe." At first glance, this landscape seemed to confirm the Buffonian idea that Earth had grown progressively drier over time, and he imagined that Lower Peru had once been as green and leafy as the lowland rainforests of the Orinoco or Marañon. Humboldt was particularly interested in what appeared to be newer valleys dissecting Peru's coastal range. They were too remote from the highlands to be caused by seasonal runoff. Perhaps a massive earthquake had thrown great quantities of dust into the atmosphere and caused an enormous rainstorm. This is the sort of explanation that Georg Forster and other devotees of exhalationist meteorology might have proposed.[34]

Suddenly, in the midst of the brown coastal desert, Humboldt came upon a massive stone wall of great antiquity that appeared to be defending the lowlands from highland invaders, and below that the "sad remains" of canals and aqueducts. What had become of the ancient civilization that built them? He soon found out. On September 26, 1802, Humboldt finally made it to the shore of the Pacific Ocean near Trujillo. He made sure to take a sea-level barometer reading the moment he arrived at the seashore, so he could convert his barometric measurements on Chimborazo and other Andean heights into absolute measures of altitude. He also dipped a thermometer into the cold ocean surf. Humboldt and his companions soon turned their attention to the nearby ruined city of Chan Chan, the ancient capital of the Chimor Empire. Its mud-brick labyrinth, palaces, and pyramids partly fulfilled his dream of exploring Egypt. Humboldt even arranged to meet fat, burbling Chayhuac, the latest of a long line of indigenous nobles descended from the last Chimu king. The Inca Empire conquered the Chimu at the end of the fifteenth century, followed soon after by the Spanish in the 1530s. Like generations of his lineage before him, Chayhuac used gold and silver looted from the tombs of his ancient ancestors to pay his people's tribute to the Spanish. To Humboldt, Chayhuac's situation encapsulated the abusive nature of Spanish colonial rule. "A bad government destroys everything," Humboldt recorded in his journal. "Away from their own lands, Europeans are as barbarous as Turks, or more, since they are more fanatical." On the long walk south to Lima, Humboldt passed many signs of abandoned irrigation works, and he was especially struck by a barren field near the mouth of the Santa River covered with human bones, mummified body parts, and crushed skulls. He imagined this to be the site of a cataclysmic battle at the time of the Inca conquest. He wondered how green the Peruvian coast must have been before the invading Incas and Spanish destroyed the Chimu aqueduct network and cut off the thick, silt-laden water that once fertilized the Peruvian coast

[34] Humboldt, "Diario de viaje," in *Alexander von Humboldt en el Perú: Diario de viaje y otros escritos* (1802; repr., Lima, 2002), 31–88, on 71–3; Vladimir Jankovic, *Reading the Skies: A Cultural History of English Weather, 1650–1820* (Chicago, 2001), 27–8.

"like the mud of the Nile."[35] For many years, Humboldt considered the dry deserts of coastal Peru to be the ultimate *human*-degraded landscape.[36]

Humboldt was even less impressed with the state of intellectual and cultural life in coastal Peru. In an acidic letter written to the governor of the highland province of Jaén, he harshly criticized the "cold egotism" of the *limeño* elite and their supposed lack of patriotic interest in the glories and good government of their country: "In Lima, I learned nothing of Peru."[37] This commentary says far more about Humboldt's prejudices than it does about the status of scientific life in the capital of the Viceroyalty of Peru. Humboldt was introduced to a long list of notables during the two months he spent in Lima surrounding his observation of the transit of Mercury across the sun on November 9, 1802. This included several figures with close ties to the Sociedad Académica de Amantes del País, an organization dedicated to the improvement of the viceroyalty that was best known for publishing the intellectual journal *Mercurio Peruano* (1791–5). This was one of many patriotic societies of its type, which were signature institutions of the Enlightenment within Spain's global empire.[38] In contrast to Venezuela, Lima had a long-established community with an interest in scientific pursuits. Most prominent among this group was Creole physician Hipólito Unanue (1755–1833), a native of the southern port of Arica on the edge of the Atacama Desert. Unanue is known for a host of contributions to cultural life in late colonial Peru and his leadership of the newborn Peruvian Republic during the independence wars. He was also the leading exponent of a vigorous Creole tradition of medical meteorology.[39]

This tradition had deep roots in Lima and many similarities to the "patriotic astrology" produced by Creole science elsewhere in the Americas.[40] It took on a far more visible form as the result of a natural disaster. On October 28, 1746, one of the most destructive earthquakes of modern times struck the central coast of Peru. The Spanish viceroy responded to this crisis by appointing French astronomer Louis Godin (1704–60), a recent member of La Condamine's geodesic expedition to the equator, to chair an expert commission to plan the rebuilding of Lima. Jesuit mathematician Juan Rehr (1691–1756) received a similar call to travel 1,100 kilometers from a remote indigenous mission on the other side of the Andes to oversee the reconstruction

[35] Humboldt, "Diario de viaje" (cit. n. 34), 73–81, on 73, 81; Miguel Feijóo de Sosa, *Relación descriptiva de la ciudad, y provincia de Truxillo del Perú* (1763; repr., Lima, 1984), 1:25–6, 84–6, 158–9; 2:90–1.

[36] Humboldt, *Political Essay on the Kingdom of New Spain* (1811; repr., New York, 1966), 2:45; Humboldt, *Personal Narrative* (cit. n. 5), 4:143, 296; 5:346; 6:182; Humboldt, *Aspects of Nature in Different Lands and Different Climates* (Philadelphia, 1850), 45–6.

[37] Humboldt to Ignacio Checa, 18 January 1803, in *Humboldt en el Perú* (cit. n. 34), 214–5.

[38] Paul Rizo-Patrón, "Arrogance and Squalor? Lima's Elite," in *Alexander von Humboldt: From the Americas to the Cosmos; an International Interdisciplinary Conference, October 14–16, 2004* (New York, 2004), 69–81; Robert Schafer, *The Economic Societies in the Spanish World, 1763–1821* (Syracuse, N.Y., 1958).

[39] Adam Warren, *Medicine and Politics in Colonial Peru: Population Growth and the Bourbon Reforms* (Pittsburgh, 2010); Jorge Cañizares-Esguerra, "La utopía de Hipólito Unanue: Comercio, naturaleza, y religión en el Perú," in *Saberes andinos: Ciencia y tecnología en Bolivia, Ecuador y Perú*, ed. Marcos Cueto (Lima, 1995), 91–108; John Edward Woodham, "Hipólito Unanue and the Enlightenment in Peru," (PhD diss., Duke Univ., 1964).

[40] Jorge Cañizares-Esguerra, "New World, New Stars: Patriotic Astrology and the Invention of Indian and Creole Bodies in Colonial Spanish America, 1600–1650," *Amer. Hist. Rev.* 104 (1999): 33–68.

of Jesuit properties in the capital. After spending two decades in the Amazonian wilderness, this Prague native took over from Godin as royal cosmographer and took command of rebuilding Lima's main cathedral.[41]

Rehr used his position to make some potent political statements regarding modern science. He firmly believed that "everyone can see clearly in the theater of nature" and publicly declared that Galileo had proven "our movement."[42] He continued the astronomical observations, astrological prognostications, and calendrical tasks that had long been required by this office. But Rehr was dissatisfied with the idea that the movements of the heavenly bodies provided a good instrument for predicting the meteorological shifts that affected local agriculture and medical practice.[43] His predecessor as royal cosmographer, Creole virtuoso Pedro de Peralta Barnuevo (1663–1743), had lamented that a "rustic" could foretell rain by the sky's appearance, while he as a "doctor of astrology" found it impossible to predict one of Lima's rare rain showers or other "accidents" of nature.[44] To remedy this situation, Rehr initiated a systematic program of instrumental measurements, supplemented by qualitative observations he called "rustic astrology." In the 1756 edition of the almanac *El conocimiento de los tiempos*, Rehr published the first known systematic atmospheric measurements from Peru. This friar's simple act of setting up a barometer was a sure sign that the Enlightenment had arrived in Peru.[45]

Rehr's research program was motivated by an intense desire to understand the local environment as part of "the workings of the world machine." His once-a-day observations with a mercury barometer informed him that the "weight of the Atmosphere" over Lima increased slightly during the winter months, leading him to speculate that ambient pressure on the body's blood vessels and soft tissues was responsible for the prevalence of strokes and paralysis during this season. His observations with an alcohol thermometer were intended to establish daily maximum and minimum temperatures so he and his successors could decide whether the climate of a particular day or season was relatively hot or cold, so physicians could prescribe appropriate treatment to their patients.[46] These records confirmed what everyone already knew to be true: the climate and weather of Lima barely varied from day to day and year to year. Rehr's successor as royal cosmographer, Cosme Bueno (1711–98), discontinued publishing barometric measurements in 1761, since they almost never varied more than a couple of lines during the year. Barometers provided very little enlightenment to Lima's cognoscenti.[47]

[41] *El conocimiento de los tiempos* [hereafter cited as *Conocimiento*]. *Ephemeride del año de 1745* (Lima, 1744), final page; *Conocimiento. Ephemeride del año de 1750* (Lima, 1749), 3, 21; *Diccionario histórico y biográfico del Perú: Siglos XV–XX* (Lima, 1986), s.v. "Rehr, Juan"; David Block, *Native Tradition, Jesuit Enterprise, and Secular Policy in Moxos, 1660–1880* (Lincoln, Neb., 1994), 40, 114; Charles Walker, *Shaky Colonialism: The 1746 Earthquake-Tsunami in Lima, Peru, and Its Long Aftermath* (Durham, N.C., 2008).

[42] *Conocimiento. Ephemeride del año de 1754* (Lima, 1753), 6; *Conocimiento. Ephemeride del año de 1756* (Lima, 1755), 4–5.

[43] *Ephemeride de 1750* (cit. n. 41), 5–6, 16, 18–22.

[44] *Conocimiento. Ephemeride del año de 1733* (Lima, 1732), 2–5; Manuel Moreyra Paz-Soldán, "Peralta: Astrónomo," *Revista Histórica* 29 (1966): 105–23.

[45] *Ephemeride de 1750* (cit. n. 41), 18; *Conocimiento. Ephemeride de 1755* (Lima, 1754), 12–3; Jan Golinski, *British Weather and the Climate of Enlightenment* (Chicago, 2007), chap. 5.

[46] *Conocimiento. Ephemeride del año de 1758* (Lima, 1757), 13–4; *Conocimiento. Ephemeride del año de 1780* (Lima, 1779), 22.

[47] *Conocimiento. Ephemeride del año de 1762* (Lima, 1761), 9–10.

But in other matters, Bueno greatly extended the environmental investigations of Rehr. Bueno was born in the countryside of northeastern Spain and immigrated to Lima at the age of nineteen, where he took up the professions of pharmacy, then medicine. He considered himself a follower of Leiden physician Herman Boerhaave (1668–1738) and his disciple, Viennese court physician Anton de Haen (1704–76). They were Europe's leading exponents of a return to Hippocratic medicine with its emphasis on airs, waters, and places, modified by the modern materialist belief that physical factors in the environment were the principal determinants of human health. Boerhaave and Haen made careful empirical observation of their patients and were among the earliest advocates of the use of the thermometer as a tool for diagnosis.[48] Bueno applied insights from Boerhaavean medicine, Stephen Hales's work on exhalations, and local wisdom to attempt to explain why the Peruvian coast almost never experiences rainstorms, but instead is watered by heavy winter mists (*garua*) and runoff from the Andes.[49]

Bueno also made an immense contribution to geographical knowledge in South America by soliciting reports from district officials (*corregidores*) throughout the Viceroyalty of Peru, which he published in serialized form. Humboldt relied heavily on information of this sort, particularly when drafting his political essays criticizing Spanish rule in the Americas.[50] For Bueno, acquiring exact chorographical knowledge of the people, places, and natural resources of Peru had a vital role to play in public life—far more so than the old astrological prognostications expected of the cosmographer's office: "Honesty, . . . perseverance, . . . justice, . . . pity, . . . foresight, . . . zeal, . . . disinterest, . . . are the true *astros*, . . . the true influences under the political sky of he who operates a Good Government."[51] He asked his respondents to give special attention to "accidents of nature." The Peruvian-born *corregidor* of Trujillo, Miguel Feijóo de Sosa (1718–91), produced a model report of this sort. It concluded with an entire chapter on the catastrophic coastal rains and floods of 1701, 1720, and 1728—a treatise now recognized as one of the first scientific treatments of the recurrent El Niño phenomenon in Peru.[52] Like Rehr, Bueno was preoccupied with the physical phenomena that produced these rare disasters mainly because of their influence on human illness. For example, Bueno noted that the strange weather of 1720 corresponded with a horrific plague in the Andes lasting from 1719 to 1721.[53]

Hipólito Unanue was a disciple of Bueno and this Creole tradition of medical meteorology. Humboldt spent significant time interacting with Unanue in Lima and successfully recruited Unanue to extend some of his observational investigations in Peru. Humboldt later commented favorably on Unanue's 1802 vaccination campaign against smallpox and his "excellent physiological treatise on the climate of Lima,"

[48] Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York, 1999), 246–61, 344; D. W. McPheeters, "The Distinguished Peruvian Scholar Cosme Bueno, 1711–1798," *Hispanic-Amer. Hist. Rev.* 35 (1955): 484–92; Glacken, *Traces on the Rhodian Shore* (cit. n. 24), chap. 12.

[49] Cosme Bueno, "Dissertación Physico Experimental sobre la Naturaleza del Agua," in *Conocimiento. Ephemeride del año de 1759* (Lima, 1758), 46–80.

[50] For Humboldt's use of Unanue's "guide for foreigners," see *Political Essay on New Spain* (cit. n. 36), 3:240, 245.

[51] *Conocimiento. Ephemeride del año de 1778* (Lima, 1777), 3–5.

[52] Feijóo, *Relación descriptiva* (cit. n. 35), chap. 12.

[53] *Ephemeride de 1759* (cit. n. 49), 12; *Conocimiento. Ephemeride del año de 1766* (Lima, 1765), 2–9; *Conocimiento. Ephemeride del año de 1768* (Lima, 1767), 62; *Conocimiento. Ephemeride del año de 1769* (Lima, 1768), 19.

Observaciones sobre el clima de Lima (1806, 1815), but Humboldt ignored its main findings for many years.[54]

Hints of Humboldt's influence are scattered throughout this text, which like many Creole works from this era sought to refute Buffon's derogatory speculations about climate in the New World. Unanue recognized that Lima's environs had changed over time and that humans could change the environment for the worse. But he had no use for the notion that human abuse of the land had created Peru's peculiar coastal climate. Echoing patriotic Creoles elsewhere, Unanue believed that God's design had blessed the Peruvian Andes with "all the climates of the universe" and given coastal locales an eternal spring that made it akin to paradise.[55]

Unanue also had little use for the idea that tropical weather is produced in situ. In his view, the heat of the sun acted as the basic force stimulating "evaporation" from the sea, "transpiration" from all organic beings, and atmospheric electricity. The fact that Lima lies in an enclosed basin did seem to explain why the valley was particularly susceptible to fogs produced by "aqueous vapors" emanating from the ground during winter. But Unanue insisted that evaporation from the Pacific Ocean was ultimately responsible for all the rain and snow that fell in the high Andes—an idea corresponding with ancient indigenous beliefs. The coldness of these waters originated from even farther away. In the 1815 edition of *Observaciones*, Unanue inserted a note crediting the ocean current flowing north along the Peruvian coast for bringing "the frigidity impart[ed] by the waters of Cape Horn" to the region.[56]

For Unanue, changes in the wind determined the variability of precipitation within the Viceroyalty of Peru and enabled distant regions to influence local climes. For example, Unanue thought that cool, "boreal" winds during the summer months, blowing regularly from the ocean to the northwest, were capable of causing winter to arrive early and bringing drought to strike the highlands, as was the case in 1799, a year in which Unanue kept a complete weather diary. On the other hand, if these northwesterlies blew irregularly, moisture carried by southeasterly winds greatly augmented summertime rains in the Sierra—and, on rare occasions, reached all the way to the coast, bringing thunderstorms to the desert.[57]

Unanue was mainly interested in climate phenomena because of their relevance to human health. Anomalies were therefore of special concern. The chorographical work of his forebears enabled Unanue to recognize immediately that the summer of 1791 was the hottest on record and that extreme rains and floods along the northern coast that year bore a strong resemblance to those of 1720 and 1728.[58] Unanue also noted similarities between 1791 and the summer of 1803, which culminated in one of the most spectacular weather events of his lifetime: a strong nighttime thunderstorm over Lima with bright lightning. He credited this extremely rare electrical storm with

[54] Humboldt, *Personal Narrative* (cit. n. 5), 6:202; Humboldt, *Political Essay on New Spain* (cit. n. 36), 1:8.

[55] Unanue, *Observaciones sobre el clima de Lima y sus influencias en los seres organizados en especial el hombre*, 4th ed. (1815; repr., Barcelona, 1914), 12–4, 18, 20–3, 40, 49–83, 104; Gerbi, *Dispute of the New World* (cit. n. 24), 252–68, 302–5.

[56] Unanue, *Observaciones sobre el clima* (cit. n. 55), 25–8, 32, 34–5; Victoria Cox, *Guaman Poma de Ayala: Entre los conceptos andino y europeo del tiempo* (Cuzco, 2002).

[57] Unanue, *Observaciones sobre el clima* (cit. n. 55), 31–5, 175–81.

[58] Ibid., 33; *Mercurio Peruano* 1 (1791): 275–80; 2 (1791): 258; *Conocimiento. Ephemeride del año de 1792* (Lima, 1791), 6–7; Joëlle Gergis and Anthony Fowler, "A History of ENSO Events since A.D. 1525: Implications for Future Climate Change," *Climatic Change* 92 (2009): 343–87.

causing the immediate arrival of the winter mists, which fell in such great abundance that year that the coastal desert erupted with life. This reveals a glaring epistemological blind spot of Humboldtian science. Its obsession with average conditions made it difficult to detect and make sense of climate variability and extremes. Just one year after Humboldt walked down the Peruvian coast in 1802, disgusted by its aridity, it was wetter and greener than Unanue had ever seen it.[59]

On the other hand, Unanue did not possess a clear enough picture of average conditions to determine whether the climate of Lima was changing over time. The summer of 1804 in Lima was hotter than ever and caused coastal crops to flower and fruit far ahead of schedule, only to give way to one of the worst highland droughts in memory, greatly reduced water for coastal irrigation, and a severe rabies epidemic. Unanue heard that Hamburg, Paris, and Vienna also experienced anomalously warm winters in 1804. According to Buffon, the global climate was supposed to be getting cooler and drier. Unanue wondered whether the strange conditions of 1803–4 represented a reversion to the warmer, wetter "primitive order" of the past—with ominous implications for societal progress. Sharing perceptions of climate across a distance was a major difficulty for place-based knowledge systems and made it impossible for Creole meteorologists to recognize the phenomena we now associate with El Niño and La Niña as anything other than a regional curiosity.[60] (Historical climatologists now recognize 1791 and 1803 as strong El Niño years and 1801–2 as a strong La Niña.)[61]

Humboldt's freedom to travel, in contrast, enabled him to see enough of the Americas to become convinced that human activities were changing the climate for the worse on a hemispheric scale. His travels to Mexico in 1803 strongly reinforced this perception. Since the catastrophic floods of 1607 and 1629, the colonial government had been working to drain Lake Texcoco and other lakes in the Valley of Mexico. By the late eighteenth century, Felipe de Zúñiga y Ontiveros (1717–93), the head of the royal observatory at Tacubaya and keeper of some of Mexico's earliest meteorological records, had become aware that the climate of central Mexico was becoming noticeably drier, and food scarcities and epidemics more frequent. This pattern only seemed to get worse at the beginning of the nineteenth century. Humboldt was a bit shocked to learn that Mexico City, which had been founded on the island ruins of Tenochtitlan in 1520, was now 3.5 kilometers from the lake. In his *Political Essay on New Spain*, Humboldt directly blamed the conquering Spaniards' "hatred" of trees and their massive drainage works for overturning the natural order in the Valley of Mexico and converting what had been a verdant garden into a desiccated plain. He did not think it would be long before "the new continent, jealous of its independence, shall wish to dispense with the productions of old" and throw off the shackles of colonialism that had produced this disorder. The massive peasant rebellion known as the Hidalgo Revolt (1810–1)—the opening act of Mexico's wars for independence—made Humboldt look like a prophet regarding the political significance of environmental mismanagement.[62]

[59] Unanue, *Observaciones sobre el clima de Lima* (cit. n. 55), 36–8.

[60] Ibid.; Enrique Tandeter, "Crisis in Upper Peru, 1800–1805," *Hispanic-Amer. Hist. Rev.* 71 (1991): 35–71.

[61] Gergis and Fowler, "History of ENSO Events since A.D. 1525" (cit. n. 58).

[62] Humboldt, *Political Essay on New Spain* (cit. n. 36), 2:31–3, 45–6, 167–73, 403–6, 507–8, 529–31, on 31, 530; Nicolaas Rupke, "A Geography of Enlightenment: The Critical Reception of Alexander von Humboldt's Mexico Work," in *Geography and Enlightenment*, eds. David N. Livingstone

HUMBOLDTIAN DISCIPLESHIP AND THE CONFIRMATION OF CLIMATE CHANGE

Creole disciples of Humboldt played a central role in the creation of the Republics of Peru, Bolivia, and Gran Colombia, the last of which dissolved into Colombia, Ecuador, and Venezuela in 1830. These disciples also played an indispensable role in convincing the world of science that Humboldt's findings regarding the connection between climate change, colonialism, and human abuse of the land were correct.

Simón Bolívar (1783–1830), the most important military figure in the liberation of these territories, aspired to place scientific men in Humboldt's mold in prominent political positions. In 1805, Bolívar accompanied a team of explorers led by Humboldt to investigate the eruption of Vesuvius. To Humboldt's great amusement, Bolívar often sported a version of Napoleon's "legendary hat and grey frock coat" and began aspiring to follow Napoleon's example during this trip. In 1820, after establishing a strong foothold for independence forces in northern South America, Bolívar sent his second in command, Medellin-born botanist Francisco Antonio Zea (1766–1822), on a mission to Europe to seek diplomatic recognition, foreign loans, and a cadre of European-trained technocrats to help rebuild these war-torn territories. Bolívar later appointed Hipólito Unanue as his second in command within the Republic of Peru during his campaign of liberation in the southern Andes.[63]

On Humboldt's recommendation, Zea recruited a young Peruvian-born mining engineer, Mariano de Rivero (1798–1857), to organize this technocratic mission to Gran Colombia. Rivero was one of the first foreigners to graduate from the École Polytechnique and École des Mines in Paris and was one of a long line of young South Americans whom Humboldt took into his confidence. Rivero, in turn, recruited Jean-Baptiste Boussingault (1802–87), a talented French chemist who was employed at a mine that was rapidly consuming the forests of Alsace and who was eager to travel abroad. Rivero was an exemplar of the Creole intellectuals who looked to Humboldt and Europe for legitimation as they sought to build self-sufficient postcolonial states founded on white dominance in the Americas. Boussingault exemplified the European travelers and traders who descended in droves on the liberated territories of Latin America and the West of the United States to develop their mineral wealth, in the hope of converting the Western Hemisphere into a scene of industry and efficiency.[64]

Humboldt drafted a detailed list of instructions for these young disciples and

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and Charles W. J. Withers (Chicago, 1999), 319–39; Andrew Sluyter, "Humboldt's Mexican Texts and Landscapes," *Geogr. Rev.* 96 (2006): 361–81; Louisa Schell Hoberman, "Bureaucracy and Disaster: Mexico City and the Flood of 1629," *J. Latin Amer. Stud.* 6 (1974): 211–30; Hoberman, "Technological Change in a Traditional Society: The Case of the Desagüe in Colonial Mexico," *Tech. Cult.* 21 (1980): 386–407; Arij Ouweneel, *Shadows over Anáhuac: An Ecological Interpretation of Crisis and Development in Central Mexico, 1730–1800* (Albuquerque, N.Mex., 1996), 72–100; Georgina Endfield, *Climate and Society in Colonial Mexico: A Study in Vulnerability* (Malden, Mass., 2008), chap. 6.

[63] Jean-Baptiste Boussingault, *Memorias* (1892; repr., Bogota, 1985), 3:11–2, 97–103; Gerhard Masur, *Simon Bolivar* (Albuquerque, N.Mex., 1969), 36–43, 191, 203, 254–5, 282–4, 288–9, 313; Fred Rippy and E. R. Brann, "Alexander von Humboldt and Simón Bolívar," *Amer. Hist. Rev.* 52 (1947): 697–703; Haraldur Sigurdsson, *Melting the Earth: The History of Ideas on Volcanic Eruptions* (New York, 1999), 120–4, 163–4.

[64] F. Urbani, "Mariano Eduardo de Rivero y Ustariz (1798–1857)," *Boletín Histórico de Geociencias* 46 (1992): 18–38; Monique Alaperrine-Bouyer, ed., *Mariano Eduardo de Rivero en algunas de sus cartas al Barón Alexander von Humboldt* (Arequipa, 1999), 13–8, 24; Boussingault, *Memorias* (cit. n. 63), 1:21, 32, 39–42, 56, 100–2, 149–51, 164–5; Pratt, *Imperial Eyes* (cit. n. 11), chaps. 7–8.

provided them with a set of precision instruments so they could retrace his travels through northern South America, thereby aggrandizing his earlier work. Humboldt hoped their efforts would establish the northern Andes as a center for training additional disciples who would fan out and create a network of meteorological and magnetic observatories across this liberated continent. In return, Humboldt enthusiastically promoted Boussingault and Rivero's activities within European scientific circles.[65]

Rivero and Boussingault arrived at the port of La Guaira, Venezuela, on November 22, 1822—again at the beginning of the dry season—and dutifully set up a meteorological observatory for hourly observations in the hotel patio. Rivero was shocked at the disorder of the region after more than a decade of war. After ascending the Silla de Caracas and exploring the ruined city of Caracas, which had been mostly destroyed by the great earthquake of 1812, they followed the Tuy Valley to Lake Valencia, where they spent several weeks exploring. They set up a meteorological observatory at Maracay, participated in the coffee and cacao harvests, observed indigo extraction, witnessed the burning of upland slopes for cattle grazing, looked for guano in the caves of San Juan, and, in Boussingault's case, began taking Spanish lessons from an attractive *señorita*—all the while fearful of meeting a violent end at the hands of royalist guerillas still prowling the area.[66]

Rivero and Boussingault also gave close attention to the lake level and signs of environmental change in the valley since Humboldt's visit two decades before. At least initially, Rivero was of the opinion that the lake had continued to shrink.[67] From Humboldt's disparaging description, Boussingault expected the region to be desiccated and infertile, but instead was "surprised" at its verdure. Other things were different as well. The Nuevas Aparecidas had become submerged. To the consternation of locals, the north shore road around the lake, the isthmus of the Cabrera Peninsula, and lakeside fields were now frequently flooded. The town of Valencia, a bustling metropolis of 7,000 when Humboldt visited, was mostly deserted by 1823. Years later, in an often-cited article first published in the *Annales de chimie et de physique* in 1837, Boussingault concluded that wartime chaos and the flight of freed slaves had caused regional depopulation, leading to a marked decline in irrigated plantation agriculture and cattle grazing, which allowed reforestation by "the invasive jungle of the Tropics." The *absence* of human activity appeared to have alleviated the geophysical and cultural causes for this closed lake basin's desiccation, allowing the lake level to rebound.[68]

Boussingault's interpretation of environmental change in the Lake Valencia watershed was reinforced by the observation that the water supply to the mines of Marmato in Colombia's Cauca Province declined rapidly during the mining boom of the late 1820s as the area's forests were denuded to produce charcoal for ore smelting.

[65] Humboldt to Boussingault, 5 August 1822; Boussingault to his parents, 27 August 1822; Vaudet to Boussingault, 8 June 1823, 27 July 1823, in Boussingault, *Memorias* (cit. n. 63), 1:167, 179–81; 3:19–20, 154, 156.

[66] Rivero to Humboldt, 7 December 1822, in Alaperrine-Bouyer, *Mariano Eduardo de Rivero* (cit. n. 64), 48–51; Boussingault, *Memorias* (cit. n. 63), 2:10–2, 24, 37–52.

[67] Rivero to Humboldt, 15 February 1823, in Alaperrine-Bouyer, *Mariano Eduardo de Rivero* (cit. n. 64), 53–4.

[68] Boussingault, *Memorias* (cit. n. 63), 2:35–7, 52; Boussingault, "Sobre la influencia de los desmontes en la diminución de las aguas corrientes," in *Viajes científicos a los Andes ecuatoriales*, by Boussingault and François Désiré Roulín (1849; repr., Bogota, 1991), 1–23, on 1–7, 15–18, 19, 24.

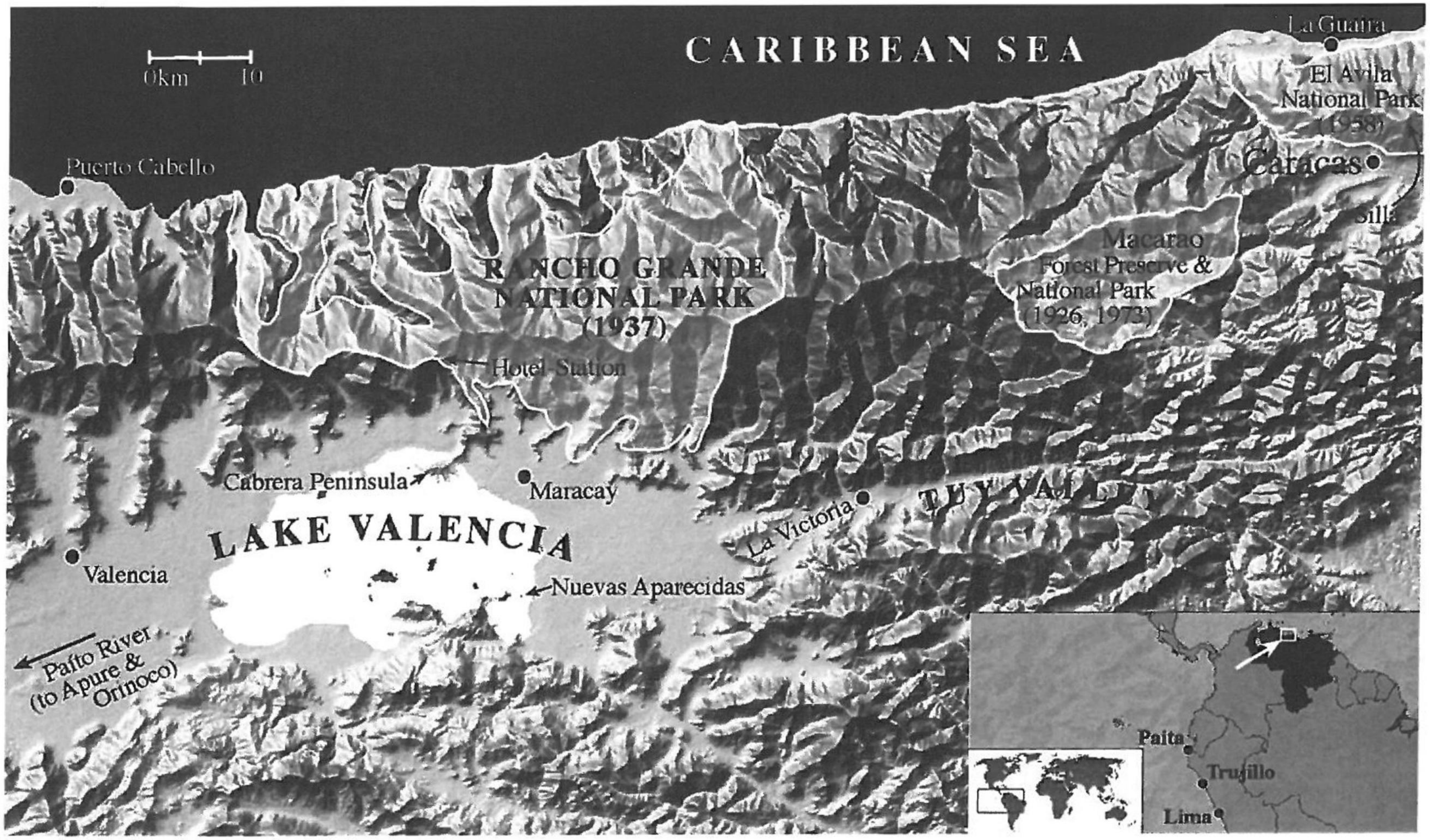

Figure 1. Map of the Lake Valencia basin and coastal range of north-central Venezuela, with major conservation areas. Map by author; used with the author's permission. Based on "Parque Nacional copiado del mapa levantado por Dr. Alfredo Jahn Sr" (1937), overleaf insert in La protección de la naturaleza en las Américas, *by Wallace Atwood (Mexico City, 1941); "Mapa del Lago de Valencia" (1955), overleaf insert in* El desecamiento del Lago de Valencia, *by Alberto Böckh (Caracas, 1956); Christopher Garrity et al.,* Digital Shaded-Relief Map of Venezuela *(Reston, Va., 2004), electronic resource accessed through the University of Kansas Library.*

Boussingault's visit to coastal Peru appeared to clinch the argument that deforestation could result in regional-scale climate change. Immediately after his famous ascent of the Ecuadorian volcano Chimborazo, where he surpassed the altitude attained by Humboldt, Boussingault made a trip to the whaling port of Paita in early 1832 to see the desert coast of Peru. Boussingault was astounded by what he saw: "The surroundings are as arid as a person could imagine; not a plant, nor a stream, sand is everywhere." According to locals, the town had not experienced a substantial rainstorm in seventeen years.[69]

Paita's treeless, rainless, goat-ridden wastes became Boussingault's ultimate scenario for illustrating his conclusions on the subject of deforestation and climate change. He made a definitive statement of these in his wildly popular study, *Rural Economy* (1843–4):

> 1st. That extensive destruction of forests lessens the quantity of running water in a country. 2nd. That it is impossible to say precisely whether this diminution is due to a less mean annual quantity of rain, or to more active evaporation, or to these two effects combined. 3rd. That the quantity of running water does not appear to have suffered any diminution or change in countries which know nothing of agricultural improvement. 4th. That independently of preserving running streams, by opposing an obstacle to evaporation, forests economize and regulate their flow. 5th. That agriculture established in a dry country, not covered with forests, dissipates an additional portion of its running water. 6th. That clearings of forest land of limited extent may cause the disappearance of particular springs. . . . 7th and lastly. That in assuming the meteorological data collected in inter-tropical countries, it may be assumed that clearing of the forests does actually diminish the mean annual quantity of rain which falls.[70]

For George Perkins Marsh and many other readers, Boussingault appeared to have decided the question for good, and Humboldt's efforts to advance Boussingault's career once he returned to France only reinforced this perception. Boussingault's views went on to exercise a special influence over conservation policy in Restoration France, where scientists became obsessed with determining how damage to forests during the French Revolution might have increased the intensity of droughts and floods.[71] Mariano de Rivero, meanwhile, was appointed by Bolívar as the Peruvian Republic's first minister of mines and public education and worked closely with two subsequent scientific travelers to Peru, Joseph Pentland and Johann Jakob von Tschudi, to further a number of projects Humboldt set out for them.[72]

THE FATE OF HUMBOLDTIAN CLIMATOLOGY

Later in life, Humboldt returned to the question of human-caused climate change. In 1829, he and two companions journeyed across the vast expanse of the Russian Empire in central Asia, from the rich mines of the Ural Mountains, across the swampy

[69] Boussingault, "Sobre la influencia de los desmontes" (cit. n. 68), 17–20; Boussingault, *Memorias* (cit. n. 63), 5:147–50, on 148.

[70] Jean-Baptiste Boussingault, *Rural Economy, in Its Relations with Chemistry, Physics, and Meteorology* (London, 1845), 673–90, on 688–9.

[71] Radkau, *Nature and Power* (cit. n. 6), 219; Caroline Ford, "Nature, Culture and Conservation in France and Her Colonies, 1840–1940," *Past Present* 183 (2004): 173–98.

[72] Urbani, "Mariano de Rivero" (cit. n. 64); William Sarjeant, ed., "An Irish Naturalist in Cuvier's Laboratory: The Letters of Joseph Pentland, 1820–1832," *Bulletin of the British Museum of Natural History, Historical Series* 6 (1979): 245–319.

Barabinskaja steppe of western Siberia, to the Altai Mountains on the Chinese imperial frontier, then back again to the north shore of the Caspian Sea. Humboldt blamed the progressive desiccation of the Barabinskaja plain and the great saltpans of this region on human culture, and he posited that the shrinking Caspian and Aral seas may once have been a massive arm of the Arctic Ocean. He handed out thermometers to notables he met along the way, whom he hoped to recruit as participants in his project to determine geophysical causes for the "inflexion of isothermal lines" around the globe. On his way home, Humboldt beseeched the Academy of St. Petersburg to take the next step and establish an imperial network of meteorological observatories modeled after those in the United States. In his 1831 account of these travels, Humboldt restated his opinion, backed up by citing Hales and Saussure, that the removal of forests and foliage had the effect of intensifying the climatic tendencies of this region. But Humboldt gave far more credit to the remoteness of the ocean in creating this "continental climate," which he blamed for the unstable, despotic tendencies of Asian society. Meanwhile, new temperature data from the eastern United States suggested to Humboldt that the connection between deforestation and desiccation had been overblown—a finding that opened the door for others to propose that rain would follow the plow as European settlement expanded into the dry continental interior of North America.[73]

Humboldt applied this interest in the climatic influence of oceans to other regions as well. He noticed the peculiar coldness of the Pacific off Peru when he first dipped his thermometer into the ocean in September 1802.[74] Stimulated by hydrographic data from Louis Isidore Duperrey's 1822–5 expedition to the region for the French navy, Humboldt began to reconsider his entire opinion regarding the geophysical causes of the aridity of the Peruvian coast. He eventually embraced Unanue's belief that a cold ocean current originating in the Antarctic powerfully influenced the coastal climate of Peru and that anomalous winds were somehow responsible for the extraordinary rains and electrical storms of 1552, 1701, 1720, 1728, 1747, 1790, and 1803.[75] Eager to promote the accomplishments of Prussian oceanography, cartographer Heinrich Berghaus (1797–1884) sought to recognize him for discovering the cold "Humboldt Current." Humboldt objected to receiving credit for discovering something long known to South American mariners. Berghaus changed the name to the "Peruvian Current" in his *Physikalischer Atlas* (1849–52), but retained the commentary celebrating Humboldt's role in its discovery. The first name stuck. Humboldt never credited Unanue for any insights on the subject, and he perpetuated the preposterous claim that these cold temperatures had "remained unnoticed until my visit to the shores of the Pacific."[76] This story is typical of the way place-based knowledge has become incorporated into globalist versions of modern science. We rightly celebrate Humboldt for liberating this knowledge from local obscurity. Yet in the rush to credit him with discovery, we elided Unanue from this history and forgot

[73] Humboldt, *Fragments de géologie et de climatologie asiatiques* (Paris, 1831), 1:45–6, 90–6; 2:309, 453–8, 493–517, 556–64; Fleming, *Historical Perspectives on Climate Change* (cit. n. 6), 48–52.

[74] Humboldt, *Political Essay on New Spain* (cit. n. 36), 4:149; Humboldt, *Personal Narrative* (cit. n. 5), 2:66–75; 7:369–70, 419–27.

[75] Humboldt, "Memoria sobre la corriente fría," in *Humboldt en el Perú* (cit. n. 34), 223–38, originally published in *Länder- und Völkerkunde* (Berlin, 1831–6).

[76] Humboldt, *Aspects of Nature* (cit. n. 36), 110.

altogether that Humboldt once mistakenly blamed human activities for creating Peru's arid coastal climate.[77]

Postcolonial American scientists quickly learned that they could attain legitimacy for their own work by associating themselves with Humboldt—including in the United States.[78] Later Humboldtians also examined the connection between deforestation, agriculture, and climate change. In 1831, Italian-born military engineer Agostino Codazzi (1793–1859) took command of a chorographical commission charged with producing a detailed geographical survey of the newly independent Republic of Venezuela. As part of this work, he resurveyed the Lake Valencia basin. Colombian-born scientist Joaquín Acosta (1800–52) interpreted his work as indicating that the lake had resumed receding. Acosta had personal reasons for caring about this issue. On Boussingault's recommendation, Humboldt had taken Acosta under his wing when the state of Gran Colombia paid for Acosta to study military engineering in Paris during the late 1820s. Codazzi and Acosta both made elaborate overtures to dedicate their national maps of Venezuela and Colombia to Humboldt and receive his approval. Acosta remained close to Boussingault for the rest of his life.[79] But this did not prevent Acosta from questioning whether changes in the vegetation of the Lake Valencia basin were capable of causing the lake's recession. The postindependence boom in coffee cultivation had not denuded the landscape nearly to the extent of the indigo boom, but the valley was drying up anyway. "The question is therefore complex and requires more careful consideration," Acosta concluded in an easily overlooked footnote to Boussingault's work.[80]

Subsequent Humboldtians muddied the waters even more. Alfredo Jahn (1867–1940) was a Caracas-born, German-trained engineer who combined professional skill in making topographical observations with broad interests in meteorology, ethnology, and geology. From 1892 to 1895, he made the first systematic attempt to track changes in the level of Lake Valencia while working for the Great Railway of Venezuela. According to Jahn's initial survey, the lake level had fallen at least four meters from Humboldt's time—then promptly rose by 1.57 meters during his first two years of observation (fig. 2). Pluviometric measurements from the lake basin also showed marked annual variability. The first thirteen years of the rainfall series seemed to confirm Humboldt's old belief that the lake basin was becoming drier over time, but the record varied much more wildly thereafter. The lake level rose abruptly by four meters after bottoming out at a record low of 399.86 meters above sea level in summer 1932. This increase was roughly equal to the amount the lake was thought to have dropped between Humboldt's visit and Jahn's first measurements, and it called into question the entire belief that human altera-

[77] Heinrich Berghaus, *Physikalischer Atlas* (Gotha, 1849–52), vol. 2, map 2; Gerhard Kortum, "Humboldt und das Meer: Eine ozeanographiegeschichtliche Bestandaufnahme," *Northeastern Naturalist* 8, special issue 1 (2001): 91–108.

[78] Sachs, *Humboldt Current* (cit. n. 8); William Goetzman, *Exploration and Empire: The Explorer and Scientist in the Winning of the American West* (New York, 1966).

[79] Alberto Böckh, *El desecamiento del Lago de Valencia* (Caracas, 1956), 103–4, 131–4; S. Acosta de Samper, *Biografía del General Joaquín Acosta* (Bogota, 1901), 13, 109–18, 135, 184–7, 207, 210–2, 425–7, 432–6, 488–92; Freites, "De la colonia a la república oligárquica" (cit. n. 18), 73–4, 78–9.

[80] Boussingault, "Sobre la influencia de los desmontes" (cit. n. 68), 7.

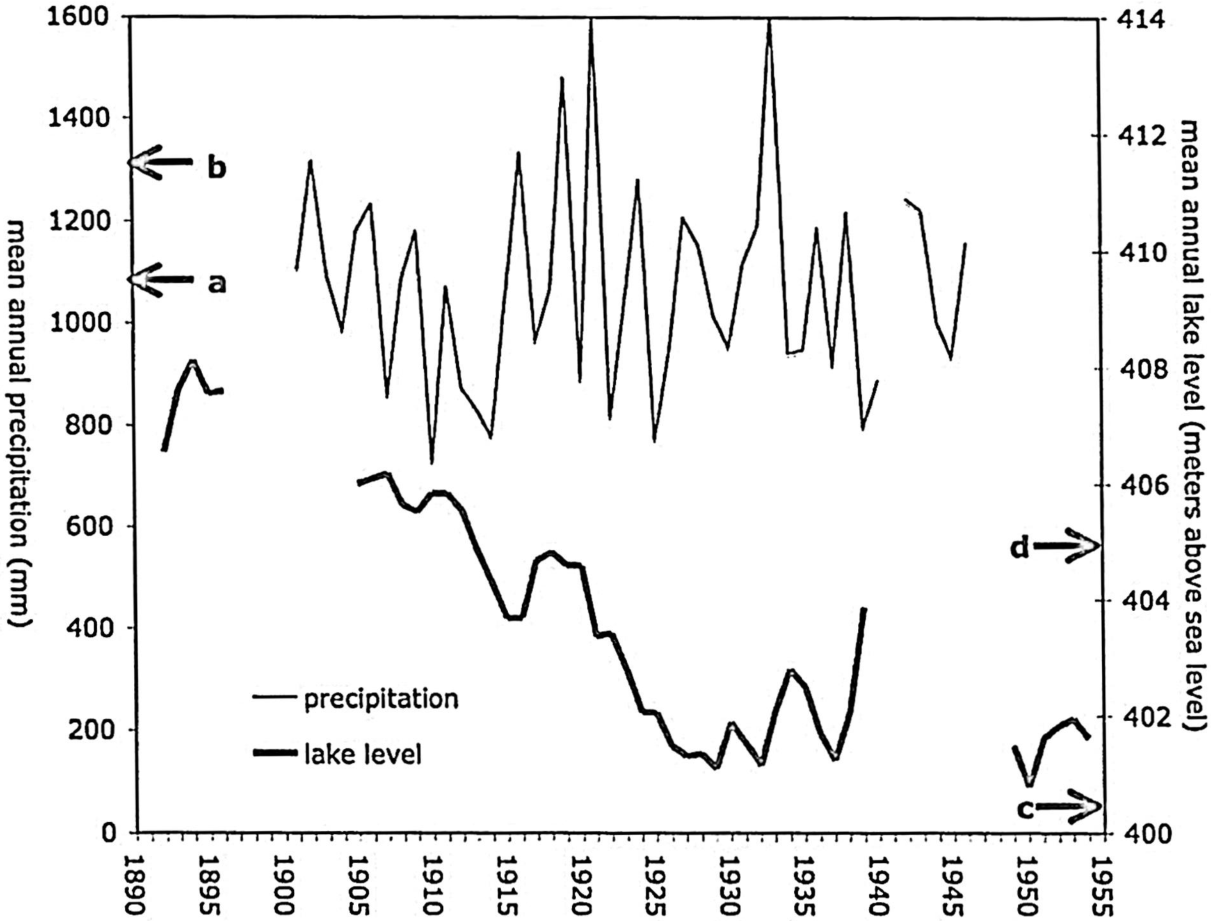

Figure 2. Annual lake level and precipitation in the Lake Valencia Basin, 1890–1955. Precipitation averaged between Valencia, Maracay, and La Victoria. Lake levels: a, *approximate level in 1800, 409.5 m (measured by Humboldt);* b, *approximate level c. 1835, 411.5–413 m (Agostino Codazzi);* c, *lowest historic mean annual level, 1976, 400.8 m (Ministerio del Ambiente);* d, *approximate level today, 405 m (International Lake Environment Committee). Figure by author; used with the author's permission. Based on Alberto Böckh,* El desecamiento del Lago de Valencia *(Caracas, 1956), tables 3, 8, 15; "Lago de Valencia," World Lakes Database, International Lake Environment Committee Web site, http://www.ilec.or.jp/database/sam/sam-05.html (accessed 14 February 2011).*

tions within the lake basin were responsible for general tendencies in the regional climate.[81]

Another self-declared "follower of Humboldt" figured out a way to accommodate this anomaly to Humboldtian orthodoxy and, in the process, sparked the modern conservation movement in Venezuela. The career of Henri Pittier (1857–1950) exemplifies the long-term impact that Humboldtian science has had on environmental management and the institutionalization of science. Pittier became obsessed with tropical forests as a young engineering student living in central Europe after reading the travels of Humboldt and similar works. In Costa Rica, he organized a classic Humboldtian institution dedicated to combined topographical, geophysical, agricultural, and ethnographical investigations. Pittier settled permanently in Venezuela in 1917 to

[81] Böckh, *Desecamiento del Lago de Valencia* (cit. n. 79), 19–22, 42, 76; Yajaira Freites, "Auge y caída de la ciencia nacional: La época del Gomecismo (1908–1935)," in Roche, *Perfil de la ciencia en Venezuela* (cit. n. 18), 153–98, on 167–70.

protect his deteriorating health and received generous support from the authoritarian government of General Juan Vicente Gómez for the establishment of an agricultural experiment station at Maracay and a national museum. Pittier briefly managed Venezuela's National Astronomical and Meteorological Observatory and its network of meteorological stations, but he was run out of government service in 1933.[82]

Gómez died a year later, and the vast personal properties he had acquired with the nation's petrodollars returned to the ownership of the Venezuelan state. This included a huge forested tract known as Rancho Grande stretching across the mist-shrouded heights of the coastal range north of Lake Valencia. Pittier surveyed this estate for the new military government in 1935 and was horrified to see that squatters were already using the macadam highway Gómez had built through this reserve for illegal logging and farming. When Pittier reported his findings to Caracas, he chose to ignore that the region had just received record amounts of rain. Instead, he repeated the Humboldtian doctrine that deforestation, the annual burning of savanna, free-range cattle, and soil erosion had caused a general "deterioration of the climate" along Venezuela's coastal range—resulting in drier summers, irregular rainfall, and waterways that oscillated violently from raging torrents to an almost worthless trickle. If these changes continued, Pittier warned, then Venezuela's most densely populated and productive region would soon be doomed to near-constant thirst, with occasional destructive floods and landslides like those of 1934 that destroyed an opulent hotel and casino Gómez was building within Rancho Grande. Lake Valencia would turn into "a mere puddle." To reverse this disastrous trend, Pittier recommended rigidly enforcing existing laws intended to protect the country's forest and water resources, aggressively fighting forest and range fires, reforesting degraded areas important to the nation's water supply, and establishing a national system of forest reserves. To Pittier's surprise, General Eleazar López Contreras promptly established Rancho Grande as Venezuela's first national park. It now protects 107,800 hectares and has been renamed Henri Pittier National Park. Humboldt's long association with these ideas went a long way toward establishing their validity with government officials. Gómez's twenty-seven-year dictatorship helped out by sweeping away most traditional forms of political organization in Venezuela, which left his successors with a great deal of latitude to generate new forms of governance—most of which had a distinct technocratic orientation.[83]

Later governments did even more to fulfill Pittier's vision of a verdant Venezuela. In 1944, the national government built a concrete hydroelectric dam and reservoir in the Macarao Valley, and in the mid-1960s, it planted three million exotic pine and eucalyptus trees around the lake to protect the supply of drinking water to Caracas—all of which now lies at the heart of Macarao National Park (established 1973). In 1955–6, the authoritarian government of General Marcos Pérez Jiménez built a far more spectacular monument to Humboldt. On the mountains above northern Cara-

[82] Luis Alberto Crespo, *Henri Pittier: Caminante y morador de nuestro trópico* (Caracas, 1997), 26, 39–40, 48, 58; Marshall Eakin, "The Origins of Modern Science in Costa Rica: The Instituto Físico-Geográfico, 1887–1904," *Latin Amer. Res. Rev.* 34 (1999): 123–50; McCook, *States of Nature* (cit. n. 14), chap. 2.

[83] See n. 1 above; Humberto Ruiz Calderón, "La investigación científica en el gobierno, la universidad y el sector privado (1936–1958), in Roche, *Perfil de la ciencia en Venezuela* (cit. n. 18), 199–254, on 201–3; John Lombardi, *Venezuela: The Search for Order, the Dream of Progress* (New York, 1982), 211–51.

cas, German engineers erected a strikingly modern, fourteen-story spire connected to the city below by aerial cable car. The Humboldt Hotel now lies within El Ávila National Park (established 1958), which protects 81,000 hectares, including the lofty peak Humboldt scaled on New Year's Day 1800. Thanks to these efforts, almost five thousand square kilometers of Venezuela's coastal range lie under official protection today, including San Esteban National Park (established 1987), which protects 44,500 hectares just west of the original Rancho Grande preserve.[84] Since the late 1970s, government efforts to supply the cities and farms that surround Lake Valencia with water piped in from other watersheds have caused the lake to stop shrinking, but at the cost of severely polluting its waters with fertilizer, pesticides, and sewage.[85]

More recently, scientists have figured out ways of reconstructing environmental change within the Lake Valencia watershed by sampling layers of sediment formed in the lake bottom. These indicate that Lake Valencia has been drying up, more or less continuously, for 2,500 years. Similar studies using ocean sediments and cave stalagmites have demonstrated that Humboldt visited Lake Valencia at the tail end of the driest period for the coastal range of Venezuela since the end of the last ice age. Therefore, locals had good reason to be concerned about the desiccation of the region, although they cannot be blamed for its occurrence.[86]

Geological investigations have established that hyperarid conditions have existed along the Peruvian coast for at least fifteen million years, and perhaps much longer.[87] It is still an open question, however, whether deforestation and other human activities may have been responsible for climate change in northern South America during recent millennia. Over the past three thousand years, precipitation patterns have completely diverged from cyclic trends in solar radiation in northern Venezuela and many other regions, suggesting that human land-use patterns may be a factor in these changes. Climate simulations indicate that regional deforestation probably contributed to anomalously cool summers and autumns in the North American Midwest during the nineteenth century. Others have suggested that the regrowth of canopy forest in the tropical Americas in the wake of indigenous depopulation after 1492 may have played a role in generating the Little Ice Age, when Lake Valencia experienced its great drought.[88]

This article's examination of the origins and popularization of the belief that human land use is capable of causing large-scale climatic change also reveals some forms of ignorance inherent to the Humboldtian episteme. Most scientific voyages in the

[84] Information compiled from the respective national parks' profiles at Parkswatch, Venezuela, http://www.parkswatch.org (accessed November 2010).

[85] Robert Apmann, *Estudio ambiental del Lago de Valencia* (Caracas, 1979).

[86] Jason Curtis et al., "Climate Change in the Lake Valencia Basin, ~12 600 yr BP to Present," *Holocene* 9 (1999): 609–19; Luis González and Roger Gomes, "High Resolution Speleothem Climatology of Northern Venezuela: A Progress Report," *Boletín de la Sociedad Venezolana de Espeleología* 36 (2002): 27–9; Larry Peterson and Gerald Haug, "Variability in the Mean Latitude of the Atlantic Intertropical Convergence Zone as Recorded by Riverine Input of Sediments to the Cariaco Basin (Venezuela)," *Palaeogeography, Palaeoclimatology, Palaeoecology* 234 (2006): 97–113.

[87] Tibor Dunai et al., "Oligocene-Miocene Age of Aridity in the Atacama Desert Revealed by Exposure Dating of Erosion-Sensitive Landforms," *Geology* 33 (2005): 321–4.

[88] Stacey Rosner, "Stalagmite Based Paleoclimate Reconstruction, Northern Venezuela: A Record of Caribbean Holocene Climate Change," (MS thesis, Univ. of Kansas, 2006); Gordon Bonan, "Frost Followed the Plow: Impacts of Deforestation on the Climate of the United States," *Ecological Applications* 9 (1999): 1305–15; Richard Nevle and Dennis Bird, "Effects of Syn-pandemic Fire Reduction and Reforestation in the Tropical Americas on Atmospheric CO_2 during European Conquest," *Palaeogeography, Palaeoclimatology, Palaeoecology* 264 (2008): 25–38.

Humboldtian mode were too short to observe how a place develops over a season—much less over years, decades, or centuries. Humboldt recognized this problem, and this goes a long way toward explaining why he was so eager to cultivate disciples who would follow up on his journeys and measurements, ideally by systematizing them; why he gave credence to early Spanish chronicles, in order to provide his travels with historical depth; and why he was so obsessed with calculating the averages of climatic phenomena he encountered, at the expense of ignoring extremes. These considerations motivated some of the most significant efforts to observe geophysical phenomena of the nineteenth century, including the so-called Magnetic Crusade of the 1830s–40s.[89] In the process, "climate" lost many of its qualitative, chorographical properties and came to possess a much narrower meaning as "the long average of weather in a single place." This is typically defined by quantitative measurements of temperature, precipitation, wind, and the like—even for locales where mean conditions rarely exist.[90]

As historian Michael Dettelbach has pointed out, Humboldt and his disciples often took this fascination with the gathering of statistics and determination of the mean one step farther to assume that the economy of nature tends toward a steady-state equilibrium—unless humanity acts to disrupt it.[91] This belief lay at the heart of the Humboldtian political critique of Spanish colonialism and the "pristine myth" to which it is so closely attached.[92] It pervaded Boussingault's outspoken belief in a "balance of nature" and may have influenced the growing predominance of the counternotion during the late nineteenth century that climate is an environmental constant, rather than something that changes over human timescales. These steady-state ideas continue to haunt the sciences of climatology, ecology, and conservation, even today.[93] Meanwhile, American Creoles such as Jefferson, Bolívar, Unanue, Rivero, and Acosta appropriated these doctrines for their own use when advocating the overthrow of European rule and celebrating their ascendance as the rightful, technocratic stewards of the land. Interestingly, their actions as builders of centralized postcolonial states sometimes proved just as debilitating to place-based traditions of environmental knowledge as Humboldt's zeal for large-scale explanations for geographical phenomena.[94]

On the other hand, Humboldtian ideas on these subjects were responsible for inspiring some of the world's most important institutions for the conservation of forests and preservation of wild nature. Does it matter that we no longer accept the scientific reasoning that created them? Do we have to get the science right to reap benefits from policies designed to prevent catastrophic climate change?

[89] Christopher Carter, "Humboldt, Herschel, and the Magnetic Crusade," in *Alexander von Humboldt* (cit. n. 38), 509–18.

[90] *Oxford English Dictionary*, 2nd ed., s.v. "climate."

[91] Dettelbach, "Humboldtian Science" (cit. n. 10).

[92] Rupke, "Geography of Enlightenment" (cit. n. 62); William Denevan, "The Pristine Myth: The Landscape of the Americas in 1492," *Ann. Assoc. Amer. Geogr.* 82 (1992): 369–85.

[93] Jean Baptiste Dumas and Jean-Baptiste Boussingault, *The Chemical and Physiological Balance of Organic Nature* (New York, 1844); Fleming, *Historical Perspectives on Climate Change* (cit. n. 6), 50–3; Donald Worster, *Nature's Economy: A History of Ecological Ideas* (New York, 1994), pt. 6.

[94] Pratt, *Imperial Eyes* (cit. n. 11), chap. 8; Jankovic, *Reading the Skies* (cit. n. 34), 165–7; Frank Safford, *The Ideal of the Practical: Colombia's Struggle to Form a Technical Elite* (Austin, Tex., 1976); Julyan Peard, *Race, Place, and Medicine: The Idea of the Tropics in Nineteenth-Century Brazil* (Durham, N.C., 2000).

Peru, a similar group of scientists, agronomists, and engineers formed the Comité Nacional de Protección a la Naturaleza. This private advocacy group focused most of its early efforts on the protection of native forests and establishment of forest plantations, particularly along Peru's arid coast. Their efforts led directly to the creation of a government Department of National Reforestation in 1944. One committee member, oceanographer Erwin Schweigger, a Jewish refugee from Nazi Germany, later proposed using recurrent El Niño rains to try to plant trees in the coastal Sechura Desert with the hope of permanently moistening the climate of this barren, sandy waste.[2] In the United States, Russian-born forester Raphael Zon convinced the New Deal government to begin installing a massive forest shelterbelt through the heart of the Great Plains as a remedy for the 1930s Dust Bowl.[3] After an intense period of drought during the late 1940s, Josef Stalin inaugurated an even more grandiose campaign to reengineer the landscape and climate of collective farms in central Russia by using trees to wall off this valuable agricultural region from the desiccated heart of Inner Eurasia. A few years earlier, Adolf Hitler had personally canceled a wartime plan to resettle thousands of Eastern European Jews to drain the wild Pripet marshes in order to prepare the way for eventual German settlement of the Ukraine, partly out of fear that this action would permanently desiccate the region and make German-ruled lands to the west vulnerable to dust storms blowing in from the eastern steppes.[4]

The widespread popularity of these plans to plant and preserve trees in order to affect the climate spanned the political spectrum. They derived from a century and a half of scientific opinion, dating back to the 1799–1802 visit by Prussian naturalist Alexander von Humboldt to northern Venezeula and coastal Peru, that *human land use* had caused the climate in these regions to become significantly drier over time. Humboldt believed that the progressive shrinking of Venezuela's Lake Valencia and the incredible aridity of Lower Peru provided "striking proofs of the justness" of what became the most influential dictum of scientific conservation of this epoch:

> By felling the trees, that cover the tops and the sides of mountains, men in every climate prepare at once two calamities for future generations; the want of fuel, and a scarcity of water.[5]

It is difficult to overstate the historical significance of the supposed discovery of human-caused climate change in northern South America and its apparent confirmation by Humboldt's disciples. Conservation advocates as well known as George Perkins Marsh directly cited this work as proof that deforestation and forest regrowth had produced measurable climate change over large regions. These findings reenergized international debate, dating back to earlier centuries, over whether large-scale

[2] *Boletín del Comité Nacional de Protección a la Naturaleza* 1 (1944): 30–2, 89–96, 99–104; 2 (1945): 68–80, 216–21; 5 (1948): 37–44; 7 (1951): 39–44, 69–71; 8 (1952): 31–8.

[3] Raphael Zon, "Shelterbelts—Futile Dream or Workable Plan," *Science* 81 (1935): 391–4; Donald Worster, *Dust Bowl: The Southern Plains in the 1930s* (New York, 1979), 220–3.

[4] Raphael Zon, "The Volga Valley Authority: The New Fifteen-Year Conservation Plan for the U.S.S.R.," *Unasylva* 3, no. 2 (1949), http://www.fao.org/docrep/x5349e/x5349e02.htm (accessed 19 November 2010); Paul Josephson, *Industrialized Nature: Brute Force Technology and the Transformation of the Natural World* (Washington, D.C., 2002); David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York, 2006), chap. 5.

[5] Humboldt, *Personal Narrative of Travels to the Equinoctial Regions of the New Continent* (1818–29; repr., New York, 1966), 4:143.

deforestation had caused climate change on a continental scale in places like eastern North America and central Asia. During the late nineteenth century, these findings profoundly influenced the science of forestry and forest conservation policy in places as diverse as India, Australia, the United States, and Pittier's Switzerland.[6] Related ideas continue to fuel anxieties about desertification and its possible connection to global warming.[7] One recent book even cites Humboldt's interest in "the general connections that link organic beings" as the fountainhead of American environmentalism and the modern science of ecology.[8]

The idea that human activities have changed the climate has been deeply politicized for at least two hundred years. Yet we have given surprisingly little attention to the origin—much less the validity—of these deep-seated beliefs. This is especially true when it comes to evaluating the life and work of Humboldt (1769–1858)—a scientific saint of such stature that the followers of Hitler and Stalin as well as greens and gays have all used his persona to bolster their political movements. Scientists and historians continue to embrace uncritically the notion that Humboldt is the father of modern environmental thought, environmental science, and environmental movements.[9]

This article will trace the history and ultimate validity of the belief that human activities caused large-scale climate change in parts of Latin America, from Humboldt's first arrival on the Venezuelan coast in 1799 to the advent of paleoclimatological techniques for reconstructing past environments in the late twentieth century. It will employ travel diaries and correspondence to produce a "thick description" of Humboldt's and his disciples' reading of desiccated landscapes in order to reveal the intellectual context and epistemological basis for this discovery and its confirmation. Most interpretations of Humboldtian science portray it as a method or program of scientific research,[10] or emphasize its political uses.[11] Few give detailed attention to its development and findings. The following account will emphasize the political motivations and social dimensions of Humboldtian science, especially Humboldt's interaction with locals during his travels, his exuberant efforts to cultivate disciples, and his disdain for Spanish colonialism. It demonstrates that the methodological preoccupation with travel and precision measurements associated with Humboldtian science served to establish patron-client relationships between Humboldt and his dis-

[6] George Perkins Marsh, *Man and Nature; or, Physical Geography as Modified by Human Action* (New York, 1864), 8–9, 145–6, 160–1, 183–4, 191–3, 200–5; James Rodger Fleming, *Historical Perspectives on Climate Change* (New York, 1998), chap. 4; Michael Williams, *Americans and Their Forests: A Historical Geography* (New York, 1989), 144–5, 307–9, 379–90, 401–3; Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism, 1600–1860* (New York, 1995), 364–79, 427–31, 436, 443; Joachim Radkau, *Nature and Power: A Global History of the Environment* (New York, 2008), 212–21.

[7] Reid Bryson and Thomas Murray, *Climates of Hunger: Mankind and the World's Changing Weather* (Madison, Wis., 1979), pt. 3; Helmut Geist, *The Causes and Progression of Desertification* (Aldershot, 2005).

[8] Aaron Sachs, *The Humboldt Current: Nineteenth-Century Exploration and the Roots of American Environmentalism* (New York, 2006), 2.

[9] Nicolaas Rupke, *Alexander von Humboldt: A Metabiography* (New York, 2005); Gregory Cushman and Kent Mathewson, "Humboldt, Guano, and the Hermeneutics of Empire," in *Humboldt and the Americas*, ed. Vera Kutzinski, manuscript (Vanderbilt University, Department of English), chap. 7.

[10] Susan Faye Cannon, "Humboldtian Science," in *Science in Culture: The Early Victorian Period* (New York, 1978), 73–110; Michael Dettelbach, "Humboldtian Science," in *Cultures of Natural History*, eds. Nicholas Jardine, James A. Secord, and Emma C. Spary (New York, 1996), 287–304.

[11] Mary Louise Pratt, *Imperial Eyes: Travel Writing and Transculturation* (New York, 1992), pt. 2; Rupke, *Humboldt* (cit. n. 9).

ciples that aggrandized the scientific reputations of both parties, even as it served a technocratic political program aimed at placing enlightened, globe-trotting scientists in positions of power.

This approach reveals that Humboldtian climatology sometimes willfully marginalized or ignored other competing explanations for phenomena.[12] Unlike much of Humboldt's other work, the discovery of human-caused climate change in Latin America owed surprisingly little to local understanding and sometimes overtly flew in the face of it.[13] This is particularly apparent with regard to a vibrant Creole tradition of meteorology in late colonial Lima focused on climate anomalies and the environmental determinants of human health. The term "Creole science" is often used to refer to systematic knowledge about the natural world produced by European settlers and their American-born progeny under colonial rule. It typically incorporated a hybrid of European, indigenous, or even African-derived ideas, along with novel elements, and often focused on the interaction between race and place. Like the term "Creole" from which it derives, this term has been used promiscuously to refer to a vast array of knowledges produced in the colonial and postcolonial world.[14] This article proposes narrowing usage of the term "Creole science" to refer to a specific geopolitical context in which systematic knowledge of the natural world provided a basis for Americans of European and mixed ethnicity to assert their own authority and dominance over regional environments and their residents while living under colonial rule. This distinguishes it historically from systematic forms of knowledge primarily intended to legitimate imperial rule or to strengthen the controllers of centralized postcolonial states—phenomena better referred to as imperial science or national science, respectively. Humboldt is rightfully famous for undermining Spanish rule in the Americas, but it is vital to recognize that he often belittled Creole achievements under colonial rule as well.

The broad influence of Humboldt's views on the human causes of climate change in South America ultimately hinged on three factors: one epistemological, one social, and one political. (1) Humboldt convincingly portrayed closed lake basins and watersheds as natural laboratories for understanding the interaction between geophysical forces and human endeavors. Paleoclimatologists operating under this very assumption eventually invalidated Humboldt's conclusion that Spanish imperialism was responsible for the desiccation of Lake Valencia and other regions of South America. (2) Humboldt achieved great success at recruiting disciples loyal to his scientific

[12] On the history of scientific ignorance in colonial contexts, see Londa Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge, Mass., 2004).

[13] Jorge Cañizares-Esguerra, "How Derivative Was Humboldt? Microcosmic Narratives in Early Modern Spanish America and the (Other) Origins of Humboldt's Ecological Sensibilities," in *Nature, Empire, and Nation: Explorations of the History of Science in the Iberian World* (Stanford, Calif., 2006), 112–28.

[14] Key recent studies include Stuart McCook, *States of Nature: Science, Agriculture, and Environment in the Spanish Caribbean, 1760–1940* (Austin, Tex., 2002), chap. 3; Schiebinger, *Plants and Empire* (cit. n. 12); Judith Carney, *Black Rice: The African Origins of Rice Cultivation in the Americas* (Cambridge, Mass., 2001); Jorge Cañizares-Esguerra, *How to Write the History of the New World: Histories, Epistemologies, and Identities in the Eighteenth-Century Atlantic World* (Stanford, Calif., 2002); James Delbourgo and Nicholas Dew, eds., *Science and Empire in the Atlantic World* (New York, 2007); Daniela Bleichmar et al., *Science in the Spanish and Portuguese Empires, 1500–1800* (Stanford, Calif., 2008); María Portuondo, *Secret Science: Spanish Cosmography and the New World* (Chicago, 2009). For an overview of earlier diffusionist perspectives on science and colonialism, see Antonio Lafuente and María Ortega, "Modelos de mundialización de la ciencia," *Arbor* 142 (1992): 93–117.

program. These self-identified disciples demonstrated great skill at accommodating potentially conflicting observations to the Humboldtian episteme. (3) Humboldtian science proved to be quite useful for undermining existing forms of domination in order to replace them with new, technocratic forms of authority. In fact, it proved so useful for these purposes that many Creole scientists learned to embrace the Humboldtian program for their own ends.

THE BIRTH OF HUMBOLDTIAN SCIENCE

Humboldt and his ever-present travel companion, French botanist Aimé Bonpland (1773–1858), first set foot in South America on July 16, 1799, in the coastal district of Cumaná in the Captaincy-General of Venezuela. They spent the second half of the year's rainy season investigating this mountainous region, following in the footsteps of Linnaean botanist Peter Löfling's expedition of 1754–6. In late November, they relocated to the province of Caracas. This was one of the up-and-coming regions of Spanish-ruled South America as an exporter of cacao, indigo, and coffee and had recently come to enjoy unimpeded access to the lucrative markets of the British and Danish Caribbean and the United States.[15] While staying in La Guiara, the province's main port, Humboldt learned that this newfound economic liberty had ominous consequences for local health. La Guiara physician José Herrera, a member of the Royal Medical Society of Edinburgh, operated a small meteorological observatory where he sought to determine the relationship between changing environmental conditions and epidemic disease. He told Humboldt that yellow fever had jumped from Philadelphia to the island of Trinidad during the Great Epidemic of 1793, then over to Venezuela with the opening of free trade in 1797. Herrera also thought there was a correspondence between this outbreak and a rare tropical cyclone, which dumped rain on the region for sixty straight hours. As we shall see, these were hallmarks of the Hippocratic revival in eighteenth-century medicine. In Puerto Cabello, the main port for the Lake Valencia valley, Humboldt spent an enjoyable time with Gaspar Juliac, a physician and polymath who kept his house well adorned with birds, books, plants, animals, and mulatto girls. Juliac reported that nine thousand people had died of yellow fever in Puerto Cabello since 1793, and that the European born only needed to breathe putrid, miasmatic air in this locale to become sick and die. According to Caracas residents, winds from the south were particularly deadly because they brought miasmas from the distant swamps of the Río Negro. It relieved Humboldt to learn that he had arrived during the dry season when more healthful airs predominated.[16]

At least at this juncture, Humboldt recognized the dangers of travel to new climates and the importance of extreme events in defining the climate of a place. Nevertheless, he emphatically rejected the advice of the Baron de Montesquieu and other thinkers that the safest and most productive course for an individual was to stay put in the climate of his birth.[17] For Humboldt, the act of travel provided a powerful method

[15] Michael McKinley, *Pre-revolutionary Caracas: Politics, Economy, and Society, 1777–1811* (New York, 1985), chaps. 2–3.

[16] Humboldt, *Reise durch Venezuela: Auswahl aus den amerikanischen Reisetagebüchern* (Berlin, 2000), 175–82; this German translation is the only complete published version of Humboldt's manuscript field journals. All quotations in this article originating from non-English texts are the author's own translation.

[17] Fleming, *Historical Perspectives on Climate Change* (cit. n. 6), 16–7.

to test the limitations that climate supposedly imposed on an organism. His own body provided a moving laboratory and a finely calibrated set of instruments for examining these climatic boundaries. Humboldt therefore relished the "frenzy of pain" he experienced while scaling the lofty Silla de Caracas. He thought the "punishments" of scientific travel made "the thinking man . . . more aware of his condition when compared to his accompanying rabble"—a group that included the capital's most notable naturalist, Capuchin friar Francisco de Andújar (1760–1817), an outspoken advocate of making science and mathematics features of study for the priesthood in Venezuela. For Humboldt, mountain climbing acted as "a wonderful balm" that "heals the wounds of the physical organism . . . which shackle one's own and others' reason." According to this emerging paradigm, travel provided a means to liberate the body and the mind from inherited strictures, while attachment to place blinded a person to the true workings of nature. In his private writings, Humboldt loved making fun of Venezuelan Creoles' hesitance to travel, and he associated their resistance to looking beyond the horizon with an atavistic lack of interest in the future. Unsurprisingly, he had little good to say about Creole science in his published writings about Venezuela, with the marked exception of scientist Carlos del Pozo y Sucre (1743–1813), who operated a meteorological observatory equipped with a cabinet of electrical instruments "nearly as complete as our first scientific men in Europe possess," despite living in the country's isolated inland savanna.[18]

This prejudice against place-based knowledge blinded Humboldt to certain features of the Venezuelan landscape and climate—particularly those that were temporary. Humboldt was immediately struck by the apparent dryness of the central Venezuelan coast as compared to Cumaná. He made special note of changes in vegetation while scaling the Silla de Caracas and explicitly blamed these changes on seasonal burning of the lower slopes by cattle ranchers, rather than natural conditions at elevation. This indicates that Humboldt was predisposed to see humans as major agents of environmental change from the moment he arrived in South America. While walking between Caracas and Lake Valencia, he was struck by wanton destruction of forests, particularly in the vicinity of a copper mine where slaves used huge quantities of charcoal for "incompetent smelting." Humans were obviously at fault for the resultant soil erosion, which was progressively covering ore-bearing strata with silt. But the "thick vegetation" of intact seasonal forests in this area also failed to impress him, because he never saw a large tree with a full branch of leaves. Humboldt speculated that their trunks were too thick to maintain good sap flow, and that their great age and size was debilitating. Locals informed him that the landscape looked like this because of the "winter calm" and lack of rain, but Humboldt kept looking for a reason to blame humans. After reaching the green fields at the head of the Tuy Valley, Humboldt still found plenty to criticize: "A great part of the [lower] valley is vacant and dry, not from drought, but because water never reaches it because it is taken up by La Victoria's coffee, sugar cane, plantains, and wheat fields that surround it."[19] Like many northern travelers before and after, Humboldt struggled mightily to make sense of the unfamiliar ways of nature in the tropics. Generations of scientific

[18] Humboldt, *Reise durch Venezuela* (cit. n. 16), 179, 185, on 179; Humboldt, *Personal Narrative* (cit. n. 5), 4:343–4, 398–9; Yajaira Freites, "De la colonia a la república oligárquica (1498–1870)," in *Perfil de la ciencia en Venezuela*, ed. Marcel Roche (Caracas, 1996), 25–92, on 33–4, 42–3, 74.

[19] Humboldt, *Reise durch Venezuela* (cit. n. 16), 177–82, 186, 188, 190–4, 196, on 186, 188, 193, 196.

travelers—and environmental historians depending on their accounts—have allowed similar prejudices to shape their interpretation of semiarid landscapes, to the continuing detriment of our understanding of desertification.[20]

Travel was an essential component of Humboldtian science, in which subjective experience produced by bodily sensations was just as important as objective measurements produced by the precision instruments Humboldt and his servants lugged with them. According to historian Ovar Löfgren, Humboldt profoundly influenced the practice of modern travel: from tourists' propensity to measure, evaluate, and describe the scenery, peoples, and situations they encounter, to the binoculars, thermometers, and other scientific knickknacks found in tourists' luggage, to the popularity of travel to southern climes. Humboldtian travel also had a social component. It enabled the traveler to attain liberation from the everyday norms of existence, to expand horizons, experience new environments, attain new levels of companionship, achieve a higher social status, even to take on a different bodily form—if only for a brief holiday.[21] Humboldt did not invent this style of travel. Journeying to the seaside, hot springs, and other healthful climes emerged as a popular pastime among Europe's leisure class during the late eighteenth century.[22] Humboldt spent the year 1790 traveling around northwestern Europe with naturalist Georg Forster (1754–94), a veteran of Captain Cook's expeditions to the Pacific. This trip directly exposed Humboldt to revolutionary movements emanating from France and to the idea that exhalations from soil, plants, and water might influence rainfall on Tahiti, St. Helena, and other tropical islands. Forster was fascinated by the relationship between climate and politics and dedicated the rest of his life to bringing revolution to the German lands. Their journey together awakened Humboldt to the possibility of traveling to South America and the Pacific Ocean.[23]

Humboldt's interest in these subjects also derived from the "great climate debate" of the eighteenth century. The former superintendent of the Royal Botanical Garden in Paris, the Comte de Buffon (1707–88), had popularized the notion that Earth had once been wetter and had grown progressively drier over time as it cooled from its original molten state. Buffon seized on a report by Harvard physician Hugh Williamson to the American Philosophical Society in 1770 that forest clearance along the eastern seaboard of North America had caused the climate to become warmer and more amenable to civilization. Buffon deduced from this that Europe would be as cold as equivalent latitudes in Quebec and Labrador if their forests had not been cut, their marshes not drained, and their rivers not controlled in centuries past. (Humboldt later invented the isoline to map this exact phenomenon.) Buffon vigorously

[20] Nancy Leys Stepan, *Picturing Tropical Nature* (Ithaca, N.Y., 2001), chap. 1; Georgina Endfield and Sarah O'Hara, "Degradation, Drought, and Dissent: An Environmental History of Colonial Michoacan, West Central Mexico," *Ann. Assoc. Amer. Geogr.* 89 (1999): 402–19; Endfield and David Nash, "Drought, Desiccation and Discourse: Missionary Correspondence and Nineteenth-Century Climate Change in Central Southern Africa," *Geogr. J.* 168 (2002): 33–47; Karl Butzer, "Environmental History in the Mediterranean World: Cross-disciplinary Investigation of Cause-and-Effect for Degradation and Soil Erosion," *Journal of Archaeological Science* 32 (2005): 1773–1800.

[21] Ovar Löfgren, *On Holiday: A History of Vacationing* (Berkeley and Los Angeles, 1999).

[22] Alain Corbin, *The Lure of the Sea: The Discovery of the Seaside, 1750–1840* (New York, 1995).

[23] Georg Forster, *Ansichten vom Neiderrhein von Brabant, Flandern, Holland, England und Frankreich im April, Mai und Junius 1790* (Berlin, 1791–4); T. C. W. Blanning, *French Revolution in Germany: Occupation and Resistance in the Rhineland, 1792–1802* (Oxford, 1983); Grove, *Green Imperialism* (cit. n. 6), 153–67, 326–32, 364–75.

promoted the idea that humans had emerged as a powerful force for environmental change during the recent "Epoch of Man," and he speculated that the primeval Americas had fallen behind the development of the Old World in a host of ways because they lacked these climatic improvements.[24] Humboldt's mentor at the Royal Saxon School of Mines in Freiberg, Abraham Gottlieb Werner (1749–1817), also contributed to this debate. Werner's belief that the world was becoming gradually cooler and drier provided the basis for his Neptunist theory of the formation of geological strata by water. He taught Humboldt to use the layering of the landscape to reconstruct its ancient history. According to this geognostic methodology, a scientific traveler could move forward and backward through geological time by climbing mountains, descending valleys, and exploring caves and mines. The published work of Horace-Bénédict de Saussure (1740–99) describing his exploration of the Alps taught Humboldt the value of precision field instruments and convinced him that mountain lakes could serve as natural laboratories for understanding environmental change within a montane basin. Changes in Lake Geneva, for example, played a special role in convincing Saussure that the Alps had become much drier over time thanks to human activities.[25]

On the eve of Humboldt's voyage to the Americas, he worked closely with French analytical chemist Louis Nicolas Vauquelin (1763–1829) in a series of experiments on pneumatic chemistry, the absorption of oxygen by soils, and the influence of electricity on plant germination and crop growth. This laboratory work fueled Humboldt's interest in the environmental significance of gaseous chemicals and their role in plant fertility and animal vigor—key obsessions of experimental chemists of the time.[26] On Humboldt's way to South America, he made contact with Paris-trained botanist Antonio José Cavanilles (1745–1804) and American botanical explorers at the Real Jardín Botánico in Madrid. The relationship between agriculture, deforestation, soil fertility, disease, and drought was a major preoccupation in late eighteenth-century Spain. Based on his own travels, Cavanilles was of the opinion that deforestation had caused detrimental changes to the Spanish province of Valencia and that wet rice cultivation, which had replaced fields of wheat and fruiting trees, had made the region vulnerable to tertian fevers. His intellectual circle (*tertulia*) bestowed its blessing on Humboldt's voyage—a critical act of political patronage.[27] Humboldt eventually obtained some useful tools for understanding the microcosmic diversity and communitarian nature of plant life in the Andes while botanizing in what is now Colombia with José de Caldas (1768–1816), a Creole scientist from the mining center of Popayán. Caldas, in turn, adopted some of Humboldt's geognostic methods for understanding

[24] Fleming, *Historical Perspectives on Climate Change* (cit. n. 6), chap. 2; Clarence Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley and Los Angeles, 1967), chap. 14; Antonello Gerbi, *The Dispute of the New World: The History of a Polemic, 1750–1900* (Pittsburgh, Pa., 1973), 171–3, 404–17.

[25] M. J. S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago, 2005), 15–22, 84–97, 420; René Sigrist, ed., *H.-B. de Saussure (1740–1799): Un regard sur la terre* (Chêne-Bourg, 2001).

[26] Wolfgang-Hagen Hein, ed., *Alexander von Humboldt: Life and Work* (Ingelheim am Rhein, 1987), 155–9, 164–5.

[27] Luis Urteaga, *La tierra esquilmada: Las ideas sobre la conservación de la naturaleza en la cultura española del siglo XVIII* (Barcelona, 1987), chaps. 8–9; Miguel Ángel Puig-Samper, "Humboldt, un prusiano en la corte del Rey Carlos IV," *Rev. Indias* 59 (1999): 329–51; Antonio González Bueno, *Antonio José Cavanilles (1745–1804): La pasión por la ciencia* (Madrid, 2004), 16–7, 161, 166, 303.