CHAPTER 7

The Struggle over Airways in the Americas, 1919–1945

Atmospheric Science, Aviation Technology, and Neocolonialism

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BEYOND COLONIAL SCIENCE

Why are Latin America and Canada so marginal to our understanding of the history of science and technology? From the beginning, Latin America's rulers have had technocratic tendencies as strong as those of any world region. In 1822, less than a year after sending his botanist vice-president to Europe to import a commission of scientific advisors, Simón Bolívar repeated Humboldt's famous ascent of Chimborazo in order to gain a bird's-eye view of the vast territory he had liberated from Spanish rule.[1] We have ignored Latin America's scientific contributions at our own peril. The inhabitants of Galveston, Texas, for example, might have appreciated knowing that Jesuit meteorologists in U.S.-occupied Cuba had warned of a hurricane heading in their direction in September 1900.[2] This chapter will examine a 25-year period when the skies of the Western Hemisphere, from the Arctic Ocean to Cape Horn, became a major concern to the industrial world's most influential aviators and atmospheric scientists.

But the main reason for this marginality stems not from the poverty of science and technology in these regions, but instead from the *poverty of* *concepts* we employ to understand the geopolitical ramifications of environmental knowledge and technological development. Thanks to a flurry of recent scholarship, it is no longer acceptable to dismiss the contribution of colonial science and technology to modern history.[3] But except for "white settler colonies" like Australia, South Africa, the U.S., and Canada, historians have given little attention to science and technology in postcolonial contexts.[4] This poverty of research makes it difficult to answer postcolonial critics who claim that Western science and technology are, in essence, tools of empire for subjugating indigenous peoples and knowledge systems to the will of the "laboratory state."[5] This chapter will introduce the concept of *neocolonialism* to this discussion.

As an analytical concept, neocolonialism seeks to explain the lasting external dependence of postcolonial states and peoples, as well as the long historical persistence of global power structures after formal decolonization. Neocolonialism (or "informal empire," as it is sometimes known), also represents a particular historical era in the relationship between the Great Powers and the rest of the world. Neocolonialism has been called "the American stage of colonialism" in recognition of the marked tendency of U.S. international relations to take neocolonial forms, particularly in the Western Hemisphere during the first half of the twentieth century.[6] Latin American historians use this analytical concept with great frequency to make sense of challenges to national sovereignty faced by the former colonies of Spain, Portugal, and France since Haiti's independence in 1804, and they often refer to the period 1870–1930 as Latin America's neocolonial epoch.[7] In contrast, Canadian historians seldom use this term, though it may be useful to consider "Americanization," a long-standing Canadian concern, as a variety of neocolonialism.[8] These considerations all point to the importance of Latin America, Canada, and their relationship to the United States for any general understanding of postcolonial science and technology.

Neocolonialism has several specific historical tendencies. Neocolonial relationships often lacked centralized supervision, much less control, by state-level powers. Foreign business and financial interests were often paramount in these relationships, though the exchange of education, expertise, and technological aid could also play an important role. Typically, local elites were critical to the establishment and maintenance of neocolonial relationships and often profited richly from them. The actors involved often did not consciously intend to encourage inequality. (Of course, much the same can be said for the haphazard, pragmatic way in which earlier colonial relationships developed.) However, few neocolonial theorists have recognized the ability of locals to play one neocolonial power against another. This opportunity makes neocolonialism distinct from formal colonial rule, and it potentially provided local actors with substantial "room for maneuver" to avoid external coercion—as the following case study will show.[9]

From the end of World War I to the end of World War II, the airways of Latin America and Canada served as a major battleground for neocolonial ambitions. U.S. aviation companies won this struggle, largely at the expense of German settler enclaves in the Americas. (In the process, "airminded" Germans refocused their colonialist ambitions away from South America and scientific internationalism toward the lands and airways of Central and Eastern Europe—and another World War.[10]) Atmospheric science attained enormous strategic value in this geopolitical context. A small group of Scandinavian scientists and their disciples took decisive advantage of this situation. The "Bergen school" of meteorology used this conflict to conquer an entire hemisphere—the Western hemisphere—for a particular approach to understanding the atmosphere based on polar front theory and air mass analysis. Their triumph led directly to the establishment of new centers of action for atmospheric research in North America, as well as the rapid expansion of scientific capabilities in Latin America and the Caribbean, even as it marginalized some promising research programs in tropical meteorology. To a lesser extent, this study will explore the following themes: (1) the geopolitical ramifications of the migration of European scientists and the formation of new settler enclaves and research schools in the Americas, (2) the influence of less spectacular (and often overlooked) aviation technologies on atmospheric science, (3) the potential for science and technology to improve the social status of individuals, and (4) the contingent relationships linking scientific to technological development.

In stark contrast to the determinism of most studies of neocolonial engagements, this history will emphasize the variety of outcomes that arose from this neocolonial struggle over atmospheric science and aviation technology in the Americas. German scientists used neocolonial expeditions to the Americas to develop the world's leading center for maritime meteorology. From the point of view of many practicing meteorologists in the United States, their country was forcibly colonized by an unwelcome, "Norwegian" science between the wars. Both Norwegian and Canadian meteorologists, on the other hand, used polar front theory to assert their scientific autonomy. As a result of World War II, Brazil acquired a vast network of modern airports and meteorological observatories; Argentina became a haven for talented refugee meteorologists from Germany; while parts of Ecuador were forcibly occupied by the United States to enforce its power over the airways of the equatorial Pacific. Adherents of the Bergen school working in colonial Puerto Rico, meanwhile, discovered that polar front theory had little to teach tropical scientists and founded a new discipline: modern tropical meteorology. Depending on context, science and technology served as potent tools for external domination as well as for postcolonial liberation.

In the eyes of most historians, the World Wars and Great Depression precipitated crisis, if not collapse, for the Age of Empire. This was not true for the atmospheric realm. The symbiosis between science, technology, and external domination flourished during the Age of Aviation. Meteorology, in many ways, became a neocolonial science between the wars. This only becomes clear when its historical development is examined from a global perspective.[11]

"TRANSPORTATION IS CIVILIZATION"

Unlike North Americans, who gave birth to the Wright Brothers, Latin Americans are often considered laggards when it comes to embracing modern science and technology. Yet Brazilian aviation enthusiasts will happily inform you that their compatriots accomplished an impressive list of "firsts" using craft of their own design, including the first launch of a paper airship before the court of João I in Lisbon in 1709.[12] But most innovations in aviation technology and atmospheric science have diffused from Europe and the United States to the rest of the Americas.[13] These transfers took place with extraordinary rapidity and by a remarkable variety of avenues. News of the Montgolfier brothers' first balloon flights in France reached Mexico within months, helped along by science-oriented newspapers signifying Spanish America's Enlightenment. The *Gaceta de Méjico* reported the flight of hot-air balloons—and an occasional aeronaut willing to risk immolation—in five Mexican cities in 1785. That same year, in Concepción, Chile, the French explorer La Pérouse launched the first known balloon in South America as a display of French scientific prowess and imperial ambition in the Pacific. During the 1830s and 1840s, self-proclaimed "professors of physics" launched balloons in major cities all over the hemisphere. Some American aeronauts used balloons to make scientific observations of the upper atmosphere from an early date. Adolfe Theodore, a French-born mulatto, tested the effects of altitude on the behavior of birds and the flavor of volatile spirits during an early hydrogen balloon flight above Havana in 1830. (He determined that

Cuban rum tastes just as good when one approaches the heavenly realm.) Latin Americans also embraced airplanes with similar rapidity and flair. In November 1911, two years after a rich playboy from a powerful Mexican political family made the inaugural airplane flight in Latin America, Mexico's President Francisco Madero became the first head-of-state in the world to fly in an airplane.[14] Scientific men like Madero, a Berkeley-trained agronomist, would have enthusiastically embraced the motto "Transportation Is Civilization." Latin America's postcolonial rulers have long lusted after the power, prestige, and progress promised by new technologies, especially railroads. The transportation revolution they helped engineer contributed mightily to the emergence of a neocolonial order spanning the region after 1870.[15]

But one crucial innovation in aviation technology, particularly where meteorology is concerned, diffused from the southern periphery. In 1883, after spending a decade extending the scientific reach of the British Empire in Oceania, Lawrence Hargrave retired from the Sydney Observatory to dedicate himself to human flight. In stark contrast to the Wright Brothers (whom he influenced), Hargrave was philosophically opposed to proprietary research and enthusiastically shared his designs internationally. In 1893, he invented the box kite and reported this to the World's Columbian Exposition in Chicago. U.S. kite designers immediately began corresponding with Hargrave and initiated meteorological observations using kites at Blue Hill Observatory near Boston in 1894. The Hargrave kite quickly emerged as the preferred instrument platform for systematic observation of the upper atmosphere because of its simplicity, durability, stability, superior lifting prowess—and lack of patent protection. Their use soon spread to exotic locations, following the tentacles of empire: to India and the tropical Atlantic in 1905, Samoa and Spitsbergen in 1906, Lapland and Siberia in 1907, East Africa and Java in 1908. Kites remained standard equipment for first-order observatories in the United States until 1933.[16]

The Second Latin American Scientific Congress in March 1901 provided direct stimulus for the initiation of upper-air meteorology in South America. Delegates from eleven Latin American republics celebrated the opening of a new meteorological observatory at Montevideo's Alameda Park. Later that year, the observatory's first director, Luis Morandi, began making observations using Hargrave's kite designs, albeit with disappointing results. Meteorologists in Rio de Janeiro and Buenos Aires followed suit in 1905 and 1910. In 1909, Morandi also became the first Latin American to experiment with rubber weather balloons—one year before the Canadian

Meteorological Service initiated kite and sounding balloon observations. Like kites, sounding balloons carry recording instruments, but they are often untethered and can reach far greater altitudes. Morandi quickly abandoned their use when it proved difficult to recover their expensive, imported instruments in the sparsely inhabited pampas. He had much better success with pilot balloons, a technique to measure the speed and direction of upper-level winds by tracking expendable balloons with a theodolite (Figure 1). By 1912, Morandi had made a total of 31 launches using German balloons when Montevideo's only hydrogen plant closed down and forced him to discontinue this line of work—a symbol of the material barriers that have long faced Latin Americans working on the cutting edge.[17]

"THE LAST FREE CONTINENT"

The end of World War I brought the world's first aviation boom to a crashing halt. Unemployed military pilots and mechanics scattered to the ends of the earth to start dozens of airlines. Great Britain, France, Italy, the Netherlands—even Switzerland—quickly located outlets for their accumulated expertise, industrial capacity, and surplus aircraft: either by providing rapid transportation and "air control" for their overseas empires, or by sending postwar air missions to Latin America explicitly aimed at diluting the influence German military missions had acquired before World War I.[18] After purchasing 85 French warplanes in 1921, the Brazilian government made a half-hearted attempt to centralize its meteorological service and produce aerological forecasts, starting with a kite observatory strategically placed close to Brazil's southern border with Argentina and Uruguay. Argentina invited military air missions and instituted systematic upper-air surveys of its own in order to keep up with its powerful neighbor.[19]

The Versailles Treaty closed off most of these options to Germans. Even before the end of the war, various economic interests in Germany and immigrant groups abroad initiated a conscious reengagement with Latin America, "the Last Free Continent" open to large-scale German investment and influence. The new international relationships they formed exhibited classic features of neocolonialism: the primacy of economic issues, the centrality of business interests and settler enclaves, the unbalanced exchange of primary materials for high-tech industrial goods, and the lack of formal, centralized control. Most significantly for the history of science and technology, *experts* played a critical role in fostering these relationships, usually by coordinating local and external interests.[20]

In December 1919, a group of Colombian and *Auslandsdeutschen* investors formed the Sociedad Colombo-Alemana de Transportes Aéreos. SCADTA made its first flight from the coast into the interior on 19 October 1920 after the importation of two Junkers F-13s—an all-metal, four-passenger monoplane explicitly designed for German export—and an inventive team of pilots and mechanics from Germany. SCADTA's efforts received an enormous boost with the arrival of Peter Paul von Bauer, an ambitious, wealthy Austrian scientist with a newly minted Ph.D. and prewar map-making experience in the Colombian Amazon. Unlike the meteorologists described in Deborah Coen's article in this volume, Bauer looked abroad for opportunities after the dissolution of the Austro-Hungarian Empire. He purchased a controlling share of SCADTA and two more F-13s altered to specifications suggested by SCADTA technicians to make them suitable for Colombian conditions. Additional cross-Atlantic financing and technical support from Junkers Flugzeugwerke AG and Deutschen Petroleum AG enabled the survival of this fledgling company. A lucrative air mail subsidy, loans for route expansion, and vociferous support from the Colombian government (over repeated French and U.S. protests) turned SCADTA into the most successful early airline in the Western Hemisphere.[21] Junkers tried to duplicate this triumph with aviation missions to the Southern Cone, Cuba, Mexico, Venezuela, Brazil, and Bolivia. SCADTA and Lloyd Aéreo Boliviano (LAB) together purchased 34 F-13s, one-tenth of the total production run of this revolutionary aircraft. This entailed the continued use of Junkers parts, loans, and technical support, which encouraged, in turn, the purchase of later models. German-supported airlines utterly dominated commercial air travel in the region during the 1920s (Table 1), converting the German city of Dessau (the headquarters of Junkers and the Bauhaus movement) into the metropole for Latin American aviation technology. These overseas endeavors not only enabled Junkers to survive ruthless postwar competition and economic upheavals in Europe, they convinced the Weimar government to provide official support to Junkers and Latin American aviation, most notably through the incorporation of Deutsche Luft Hansa (1926). For Rinke, this was a definitive case of the formation of German foreign policy "from below."[22]

Science played an important supporting role in these endeavors by strengthening the perception that Germany's technological advancement

TABLE 1 Ownership of Major Latin American Passenger Airlines, 1927–1940

	route miles 1927	*miles flown 1927*	*route miles 1934*	*miles flown 1934*	*route miles 1940*	*miles flown 1940*
Pan American Airways Corp.[a]	110	15,000	25,009	6,625,000	41,619	13,801,000
Other U.S.[b]	412	n.d.	4,608	1,652,000	6,156	2,311,000
German[c]	2,574	399,000	5,332	1,338,000	12,890	2,291,000
Latin American (German equipped)[d]	0	0	2,792	576,000	5,167	1,273,000
Other Latin American[e]	0	0	8,700	1,242,000	19,809	3,809,000
British Commonwealth[f]	0	0	1,700	600,000	5,000	2,300,000
Dutch[g]	0	0	0	0	1,982	599,000
Italian[h]	0	0	0	0	6,125	590,000
French[i]	2,200	35,000	2,900	327,000	0	0
Total	4,884	449,000	51,549	12,472,000	98,748	26,974,000

Sources: William A. M. Burden, *The Struggle for Airways in Latin America* (New York: Council on Foreign Relations, 1943), tables 6, 15, 53, maps 4, 6–7; R. E. G. Davies, *Airlines of Latin America since 1919* (Washington, DC: Smithsonian University Press, 1984), app. 3.

[a] Pan American Airways, Pan American-Grace Airways, and local subsidiaries: Mexicana, Cubana, Aerovías de Guatemala, Panama, SCADTA/Avianca (after 1931, Colombia), UMCA (Colombia), Panair do Brasil.

[b] Local airways owned by resident U.S. citizens: Aeronaves de México, Cía. Aeronáutica del Sur (Mex.), LAMSA (Mex.), Pacifico (Mex.), West Indian Aerial Express, Caribbean-Atlantic, Faucett (Peru), Condor Peruana.

[c] Includes German-owned airlines: Syndicato Condor (Brazil), SEDTA (Ecuador), Lufthansa Sucursal (Peru), Deutsche Lufthansa, and locally owned airlines with significant German financial interest, staff, and equipment: SCADTA (until 1931, Colombia), VARIG (Brazil), LAB (Bolivia).

[d] Locally owned private and government airlines flying German planes: VASP (Brazil), Aeroposta Argentina, LASO (Argentina), LAN-Chile, CAUSA (Uruguay).

[e] Locally owned private and government airlines: includes 5 Mexican, 2 Brazilian, 1 Panamanian, 1 Venezuelan, 1 Peruvian, 1 Uruguayan, and 1 Argentine airlines.

[f] British West Indian Airways and TACA (Central America), an airline owned by a New Zealand-born Canadian WWI veteran.

[g] Royal Dutch Air Lines (KLM).

[h] LATI and Corporación (Argentina).

[i] Lignes Latécoère and Air France.

stemmed from its scientific prowess. Bauer organized a Scientific Section as one of his first acts as SCADTA director. He surreptitiously imported a complete set of aerial photographic equipment from Germany and immediately set his staff to mapping local air routes. In 1923, SCADTA offered its services to the Swiss scientific mission surveying the Colombia-Venezuela border. This generated enormous goodwill among nationalist Colombian officials who later granted lucrative concessions to map the Panamanian border and vast Colombian Amazon. The Venezuelan state, in turn, bought its first civilian airplane, a Junkers W-34, to do its own cartographic work on the Colombian border.[23]

Meanwhile, meteorologists based at the Deutsche Seewarte (German Marine Observatory) in Hamburg coordinated a vast research project to aid German trade with the Americas. Two giants of German environmental science, Wladimir Köppen and Alfred Wegener, hatched a plan during the closing days of the Great War to equip German merchant vessels for observing upper-level weather conditions in the shipping lanes of the Atlantic. This served Köppen's long-standing goal to develop a three-dimensional typology of the world's climatological zones. Wegener directed the first Deutsche Seewarte meteorological expedition to the Gulf of Mexico in spring 1922—just in time for Junkers's aviation missions to Cuba and Mexico.[24]

José Carlos Millás, the energetic hurricane expert who directed the Cuban National Observatory, was impressed when Wegener made the first pilot balloon soundings ever performed in Havana. This provided a far more direct method for keeping track of upper-air currents than the nephoscopes Cuban meteorologists had been using since the early 1880s to follow cloud movements. In 1925, Millás approached the U.S. Weather Bureau, "the best Meteorological Service in the world," for help. The head of the U.S. Weather Bureau provided apparatus and several U.S. publications on aerological meteorology. On 26 January 1926, after receiving further practical advice from British meteorologists in Jamaica, the Havana observatory initiated daily pilot balloon observations, to great public acclaim, and began exchanging them with Kingston during the subsequent hurricane season (Figure 1). Following the lead set by his predecessors, Millás immediately began using this data to hone his theories regarding hurricane structure and movement.[25]

In 1925, SCADTA finally received grudging permission from U.S. officials to fly across the Panama Canal Zone, the centerpiece of the United States' neocolonial empire in the Caribbean. With financial support from the Colombian government and the Condor Syndikat, a new German company founded to promote Latin American aviation, Peter Paul von Bauer began

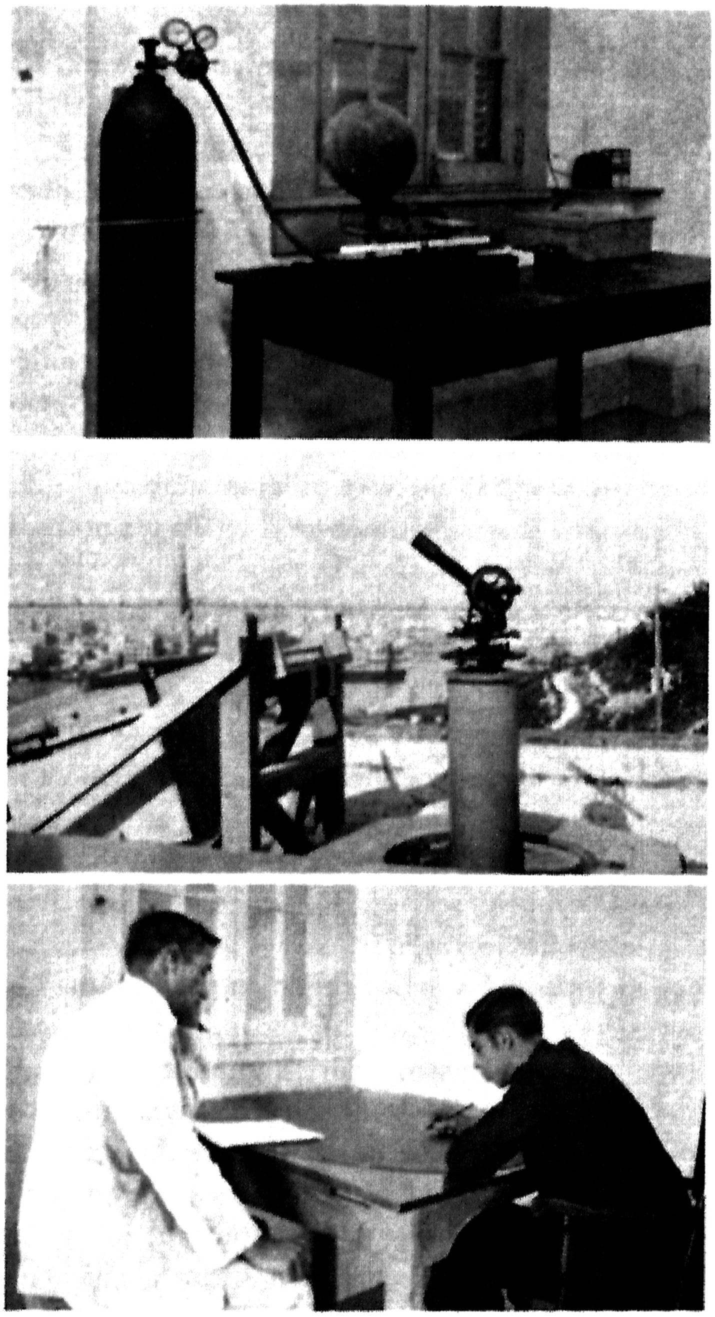

FIGURE 1 Upper-air observations at the Cuban National Observatory, Havana 1926. Top: Filling. A rubber pilot balloon filled with hydrogen must be carefully weighed to assure an accurate ascent rate. This apparatus was donated by the U.S. Weather Bureau. Middle: Tracking. Theodolite used to track an ascending pilot balloon. Note retractable, "hurricane-proof" cover. Bottom: Analysis. Cuba's first team of aerological observers, José Santiago (left) and Gustavo Castillo (right), plotting a pilot balloon trajectory for deriving upper-level wind speed and direction. In *Boletín del Observatorio Nacional* (Havana) 22, no. 1 (1926).

implementing his long-standing plan to establish the first airline connecting South America and the United States. The Deutsche Seewarte again provided timely scientific support. During its fifth expedition to Latin America, German meteorologists established contact with SCADTA and began arranging to use its planes to survey atmospheric conditions above the southern Caribbean. A sixth expedition arrived in Colombia in June 1925 and stayed for five weeks. In the course of seven survey flights, Walter Georgii and his assistant Heinrich Seilkopf made the most extensive aerological investigation of the tropical atmosphere that had ever been made in the Americas. In addition, they provided a crash meteorological course to SCADTA's pilots. After leaving Colombia, they made a double transect by ship along the Central American coast all the way to Guatemala and made a valuable discovery: a persistent line where upper-level winds abruptly shift direction during the summer in the western Caribbean: a "cyclonic shear zone." These observations paved the way for SCADTA's celebrated flight from Colombia, through Central America and Cuba, to Florida in August–September 1925.[26]

Together, these 1925 expeditions exercised a major influence on the relationship between aviation, atmospheric science, and neocolonialism in the Western Hemisphere. Despite tentative support from U.S. Department of Commerce officials, Bauer failed to obtain landing rights in the United States for a regular trans-Caribbean service. Following a well-established pattern, the U.S. War Department portrayed SCADTA's Germanic ties as a violation of the Monroe Doctrine and a major threat to the Panama Canal; they refused to tolerate any "Pan-American" airline in the Caribbean that was not under total U.S. control.[27] German aviation interests and the Deutsche Seewarte gave in to this reality and shifted their focus away from the Caribbean. From 1922 to 1930, the Deutsche Seewarte completed ten meteorological expeditions to Latin America, five to West Africa, and several more to the North Atlantic (Figure 2), and played an important role in the celebrated 1925–1927 *Meteor* expedition to the South Atlantic. (Wegener died on an expedition to the Danish colony Greenland.) Their work paved the way for new German airlines on the eastern coast of South America and for the first trans-Atlantic flights by catapult mail planes and the *Graf Zeppelin*.[28] Following their lead, Argentine aviation boosters with colonial aspirations in Antarctica planned a meteorological expedition to the South Pole for the end of 1926. But the German hydroplane slated to fly meteorological instruments above the southern continent crashed before it arrived in Argentina and quashed these ambitions.[29]

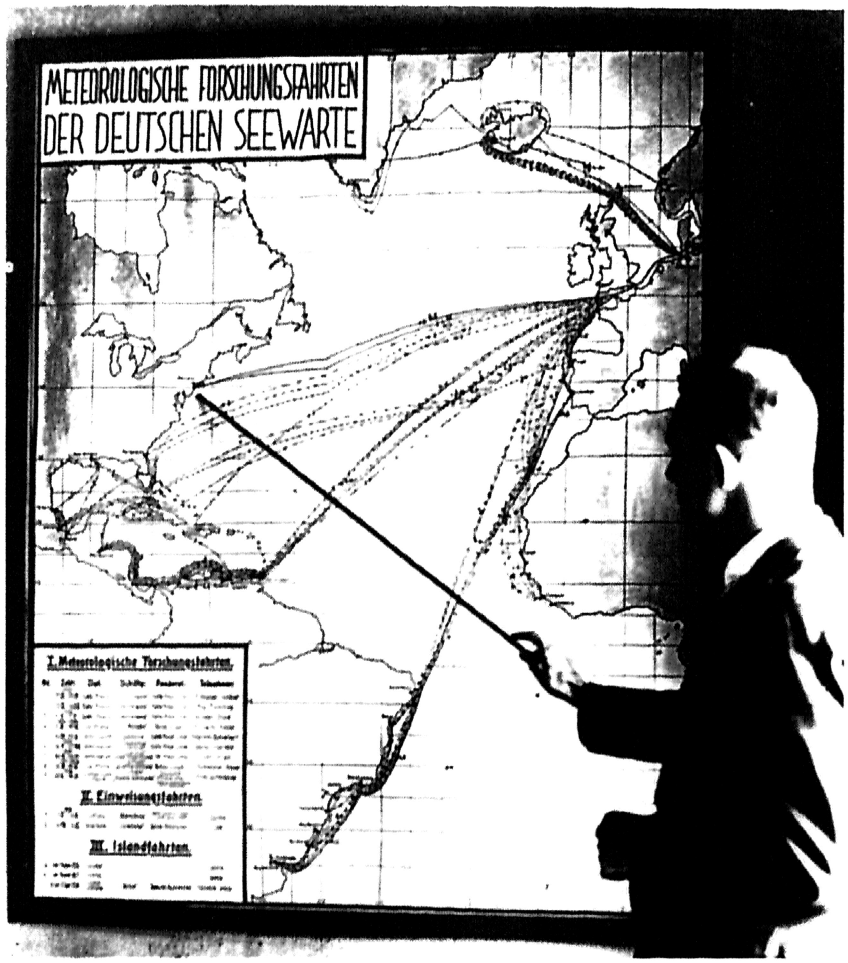

FIGURE 2 Meteorological Research Voyages by the German Oceanographic Observatory, 1922–1928. Gulf of Mexico (Azores, Cuba, Mexico, U.S., 3 trips, 1922–23), Atlantic South America (Canary Is., Brazil, Uruguay, Argentina, 3 trips, 1924–25, 1927–28), Caribbean Sea (Trinidad, Venezuela, Curaçao, Colombia, Panama, Costa Rica, Nicaragua, Honduras, Guatemala, Haiti, 3 trips, 1924–25, 1927), West Africa (Canary Is., Liberia, Sierra Leone, Portuguese Guinea, French West Africa, Gambia, 2 trips, 1928), New York (1 trip, 1928), Iceland/Greenland (3 trips, 1926–28). Not shown: *Meteor* expedition to the equatorial and southern Atlantic (1925–27). Photo: 1931, courtesy of Bundesamt für Seeschiffahrt und Hydrographie, Hamburg.

Germany's interest in the airways of the Western Hemisphere laid foundations for a major change in German meteorological practice, largely through the efforts of Heinrich Seilkopf and his disciples. After completing his habilitation thesis on the Deutsche Seewarte's first six meteorological voyages to the Americas, Seilkopf became a standard fixture on important

German flights, including two inaugural voyages by the *Graf Zeppelin* to Brazil in 1931. Meanwhile, he oversaw the marked expansion of the Deutsche Seewarte's maritime meteorological staff and network of shipborne aerological observers in the Atlantic Basin. Most significantly, a group of young meteorologists under Seilkopf's supervision developed a powerful new forecasting technique keyed on changes in the topography of barometric pressure in the upper atmosphere revealed by these maritime surveys. In 1940, these "isobaric" techniques supplanted "Norwegian" air-mass analysis as the preferred tool used by the Reichswetterdienst to direct the Luftwaffe's long-range bombing campaigns.[30] Thus, neocolonial meteorology not only increased German prestige—and deadly force—abroad, it influenced the basic content of the "exact sciences" back home.[31] By appropriating the weather in the Atlantic Basin, the Deutsche Seewarte transformed itself into the world's unrivaled center for maritime meteorology.

As with so many aspects of international affairs, the United States was late to join this struggle, but it made a decisive impact once it did. Rather than sending atmospheric scientists as its advance guard, the U.S. War Department sent military fliers. In response to SCADTA's 1925 trip, on 22 December 1926, five Loening hydroplanes crossed the Rio Grande for a grand tour that touched down in every Latin American republic. This "Pan American Good Will Flight" sought to generate publicity, to survey potential commercial routes, and, internal documents reveal, to counter "alien" aerial activity in the region. The result was a public relations disaster. U.S. marines had directly intervened in the affairs of nine Latin American states since 1919, and locals clearly detected the "military character" of the flight. Army Air Force fliers met a frosty reception in many locations. To make matters worse, their planes broke down repeatedly, and two pilots died in Argentina after two Loenings collided in flight—hardly a strong showing of technological prowess.[32]

This perception changed overnight in 1927 when Charles Lindbergh, "the Columbus of the Air," piloted *The Spirit of St. Louis* non-stop from New York to Paris. Six months after Lindbergh's historic flight, he made a complete circuit around the Caribbean timed to inaugurate the Sixth Pan American Conference in Havana and Pan American Airways' new passenger service from Key West to Havana.[33] Through a lucrative $2 per mile subsidy, the U.S. Postal Service ensured that a single U.S.-controlled airline acquired a virtual monopoly over North-South air service in the Americas. Pan American Airways used this enormous political and financial leverage to purchase the latest U.S. aircraft and to buy up a long list of regional airlines. At the nadir of the Great Depression, Peter Paul von Bauer reluctantly sold 84 percent of SCADTA's shares to Pan American Airways. This brought an end to SCADTA's special relationship with Junkers Flugzeugwerke and turned SCADTA into a consumer of second-hand U.S. aircraft. But Pan American shrewdly retained SCADTA's German staff and profited from their long experience, their contractual obligation to work at a much lower pay scale than U.S. employees, and their utility in obscuring this northern takeover from Colombian nationalists. As Table 1 shows, by 1934 Pan American Airways and its subsidiaries had became as large as the rest of the region's commercial airlines put together. Profits from Latin America, in turn, enabled Pan American to offset enormous operating losses accrued by its pioneering East-West transoceanic routes during the late 1930s.[34]

Science played a role in the meteoric rise of Pan American Airways. It immediately stood to benefit from the new pilot balloon observatory in Havana, and its partner in flight along the Pacific Coast, W. R. Grace & Co., already had experience reporting maritime observations from Grace Lines ships meant to keep track of El Niño.[35] But instead of depending on existing scientific institutions in the region, Pan American Airways preferred to organize its own, private meteorological network. By 1933, its subsidiary Mexicana had come to operate twelve pilot balloon observatories and five radio stations issuing weather reports at Mexican airports. Pan American Airways also used science to generate publicity. In 1929, Lindbergh made a five-day photographic survey of lowland Mesoamerica in search of remote Mayan ruins in a Pan American hydroplane. Most significantly, Pan American meteorologists aggressively applied "standard high-latitude methods of frontal analysis" to tropical weather, particularly in the zone of equatorial wind convergence, a phenomenon christened by Norwegian meteorologists as the "inter-tropical front."[36]

Latin American politicians, businessmen, and soldiers made their own mark on this neocolonial struggle. Local capitalists founded dozens of small, regional airlines, and even rabid nationalists had good reasons for embracing aviation. Better transportation promised increased trade and greater local incomes (even if a tiny elite got the lion's share). Like railroads for previous generations, airplanes represented the cutting edge of modern technology and potent symbols of progress. Thus, Brazil's nationalist president Getúlio Vargas saw fit to spend US$1 million to build a terminal outside Rio to receive German dirigibles in 1936, only to close it a year later in the wake of the *Hindenburg* disaster. Vargas also used a German hydroplane to fly around Brazil campaigning for political support, an eventual key to his transformation into Brazil's definitive populist politician. Economic nationalists made sure these flying enclaves were not isolated from their host societies. Mexico, Brazil, and Chile led a trend requiring foreign airlines to employ local ground crews and administrators, train citizen pilots and mechanics, and maintain a level of national ownership. Even more than railroads, airplanes held enormous strategic importance for Latin America's rulers, since they provided a rapid, effective means to integrate national territory under a single, centralized power. (In the eyes of some critics, this enabled a potent form of *internal colonialism* by postcolonial governments.) To this end, the Peruvian, Chilean, and Brazilian militaries established their own airlines to serve regions either too remote or too important to leave to private companies. Argentina and Venezuela, meanwhile, took advantage of the Great Depression by taking control of routes and equipment orphaned by the bankruptcy of another contributor to this struggle, the French firm Aéropostale.[37]

Meanwhile, the growth of Latin American aviation indirectly exacerbated the gulf in technological innovation and industrial productivity separating the United States from its neighbors. During the mid-1930s, vigorous competition between U.S. airlines for the fastest, most efficient planes propelled a revolution in aerodynamic design. This revolution was led by the famous DC-series of aircraft, a product of close collaboration between hydrodynamic physicists at Cal Tech, airframe engineers at Douglas Aircraft in Santa Monica, California, and Transcontinental and Western Airlines (TWA). By the end of 1941, 260 of 322 scheduled airliners flying in the United States were DC-3s. To support this spending spree, U.S. airlines sold their obsolete aircraft abroad. This enabled Latin American airlines to expand their fleets while freeing the U.S. aviation industry to "push the envelope" technologically. In this way, "exports saved the air industry" in the United States during the Great Depression.[38]

German manufacturers could no longer compete on these terms. Instead, as an explicit part of National Socialist trade policy, Junkers offered slow but rugged JU-52 tri-motors and other craft at lower prices and much better repayment terms than its U.S. competitors. Deutsche Lufthansa's Brazilian subsidiary, Syndicato Condor, sweetened the deal by offering convenient servicing at shops in Rio and Buenos Aires. Meanwhile, Focke-Wulf arranged to open local assembly plants in Brazil and Argentina, thus supporting the beginnings of import-substituting industrialization. In Brazil, the most competitive market in Latin America, German aircraft maintained their numerical edge until World War II. Many expert observers, dazzled by U.S.

technological superiority, irrationally dismissed this inability to vanquish German aviation as a sign of Latin America's backwardness. Preference for German aircraft actually represented a shrewd strategy of postcolonial development on the cheap.[39]

These circumstances directly influenced atmospheric science. South American meteorologists, led by Argentina and Brazil, began organizing themselves internationally to keep up with the rapid expansion of commercial aviation during the 1930s. They looked for leadership to the International Meteorological Organization (IMO) based in Europe, as they established shortwave radiotelegraph networks to broadcast weather bulletins long distance and altered local observation practices to comply with IMO standards. This often meant looking to Germany for instruments and assistance. Pilot balloon observers were asked to coordinate their work with IMO Aerological Commission headquarters in Berlin. In December 1938, the Argentine Meteorological Service sent its master barometer (Wild-Fuess no. 100751) for calibration with official instruments in Berlin. Representatives at the Montevideo meteorological conference held the following February then resolved to calibrate most weather service barometers in South America with this Argentine instrument. To reinforce these international relationships, the Deutsche Seewarte permanently stationed German meteorologists at Syndicato Condor headquarters in Rio de Janeiro in 1935 and the Argentine Meteorological Service in 1938 and distributed its synoptic maps, free of charge, to all South American meteorological services.[40] Few South American meteorologists shared José Carlos Millás's lofty opinion of atmospheric science in the United States. Nevertheless, technology provided an entry point for U.S. influence: conference organizers asked the instrument division of Bendix Aviation, a long-time supplier to the U.S. Navy and Weather Bureau, to send an engineer to Montevideo to demonstrate radiosonde, the latest technique for sounding the upper atmosphere.[41] This was a portent of things to come.

THE COLONIZATION OF NORTH AMERICAN METEOROLOGY

Scandinavian science has long had imperial ambitions, particularly in the Arctic.[42] During World War I, Norwegian geophysicist Vilhelm Bjerknes originated the concept of an ever-undulating "polar front" demarcating the violent collision between cold and warm air masses. He hoped to use this concept to found a new, imperial form of meteorology based on hydrodynamic physics. Ideally, his home institution, the Bergen Geofysisk Institut—itself an expression of Norwegian scientific independence from Sweden—would become an "international central" charged with analyzing "the general weather conditions of the whole northern hemisphere."[43] But imperial rivalries prevented Vilhelm Bjerknes from accomplishing this hemispheric vision. Nevertheless, scientific apostles originally trained by Bjerknes at Bergen did succeed at colonizing an entire hemisphere for this "Norwegian school" of meteorology—the Western Hemisphere. This breakthrough represents one of the most dramatic geographical expansions of a research school in the history of science and underscores the importance of students to the success of a research school. Unfortunately, the literature on research schools has given little attention to their geographical propagation, due to its preoccupation with founding personalities and training institutions.[44]

Vilhelm Bjerknes's ambitions shifted decisively west toward North America during the 1920s. In 1924, he and his son Jacob visited U.S. Weather Bureau headquarters in Washington. Vilhelm put his son to work analyzing working charts in order to determine if polar front theory was applicable to North American conditions. Jacob tentatively concluded that it was, but needed more aerological data to be sure. In 1926, the Swedish-American Foundation paid another disciple, Carl-Gustaf Rossby, to spend a year at the U.S. Weather Bureau continuing this task. Rossby confidently attacked the most complicated U.S. weather maps and "furnished conclusive evidence that the polar front theory . . . enables us to explain phenomena which" otherwise "would hardly be understood."[45] Cash-strapped Weather Bureau officials were less than enthusiastic about Rossby's bold recommendation to overhaul the U.S. observation network to produce high-quality aerological data for air mass analysis. The Guggenheim Fund for the Promotion of Aeronautics, on the other hand, embraced this gospel and hired Rossby to develop an experimental "airway weather service" in California and establish a meteorology program at MIT. Ever the empire builder, Rossby imported Jacob Bjerknes, Sverre Petterssen, and Jörgen Holmboe to teach courses in the United States. Rossby and an occasional U.S. convert also made pilgrimages back to Norway to keep abreast of advances in Bergen-school techniques.[46]

Aviation thus provided a beachhead for the colonization of the U.S. meteorological profession by Scandinavian science. In 1935—the same year the German Weather Service autocratically imposed "Norwegian" air mass analysis on its forecasters—three of Rossby's American students were hired to inculcate these techniques at the U.S. Weather Bureau.[47] In 1938, one of the original U.S. converts to the Bergen school, U.S. Navy aerologist F. W. Reichelderfer, was appointed head of the U.S. Weather Bureau and hired Rossby as his assistant chief. As Roger Turner shows elsewhere in this volume, they used these positions to wage a successful campaign to transform U.S. meteorological culture along Nordic lines.[48] An essential element in the long-term success of a research school lies in its ability to conquer other scientific communities.

In July 1939, Jacob Bjerknes and his wife Hedvig left Norway for another extended tour of meteorological institutions in Canada and the United States.[49] It is highly significant that Jacob Bjerknes headed first to Canada. This vast country makes for a fascinating comparison with Latin America because in many ways it was still asserting its independence. After the carnage of World War I, autonomy from British foreign policy became the "linchpin" of Canadian national politics. Meanwhile, the Canadian economy was becoming far more dependent on the United States. Like Latin America, Canada experienced an economic boom during the 1920s based on the export of primary materials, particularly paper and metals produced on its northern frontier. Except for automobile assembly plants established by U.S. companies to evade imperial tariffs, Canadian industry fell into decline. Even during the height of the 1920s boom, lack of high-paying jobs, particularly in research and development, encouraged a brain drain across the U.S. border. Winnipeg was devastated when the Panama Canal, the most obvious symbol of U.S. neocolonialism in the Americas, diverted trade from Canada's celebrated transcontinental railways. Nevertheless, Presidents Coolidge and Hoover virtually ignored Canada, in stark contrast to the attention they lavished on Latin America. This was widely resented by Canadians, who also began to express concern about the impact of American film and radio on Canadian national culture. Even though criticism was muted, U.S. neocolonialism was a genuine threat to Canada.[50]

The same can be said regarding U.S. influence over Canadian meteorology and aviation. Once the British Empire's Magnetic Crusade exhausted itself in the 1850s, the development of meteorology in Canada became closely tied to the United States. Early Canadian observers reported to the Smithsonian, then to the U.S. Army Signal Corps' weather telegraphy network. For many years, Toronto's central observatory depended on Washington to provide instruments and relay data from western Canada. Circa 1939, more Canadian meteorologists belonged to the American Meteorological Society than to its much older British counterpart. Commercial aviation, in contrast, got its start with a multitude of tiny, independent airlines, often staffed by Canadian World War I veterans, who transported mail, payroll, and fire spotters beyond the reach of railways. These services played an important role in promoting export-led growth during the 1920s, stoking the fear that U.S. companies might try to move in to take advantage. In 1930, the increasingly independent Canadian Meteorological Service organized its first pilot balloon network to serve the growing list of Canadian airlines. This came to an abrupt halt in 1932 when the Great Depression compelled the Canadian government to cancel air mail subsidies as a cost-cutting measure. This nearly grounded commercial aviation in Canada.[51]

Lack of demand for aerological forecasts enabled a handful of Canadians, led by tropical meteorologist Andrew Thomson, to travel to Bergen at their own expense and learn "the latest methods in meteorology." Upon returning home, they began attempting air mass analysis. This required a great deal of trial and error as they developed new mapping techniques and an intuitive "feel" for the behavior of Canadian air masses, thus displaying the sort of local innovation that typically accompanies successful diffusion of scientific techniques. In 1933, Thomson established a graduate program in meteorology at the University of Toronto. Jacob Bjerknes and Sverre Petterssen both journeyed to Toronto for extended periods in the mid-1930s to help out their new converts. Meanwhile, Canadian and Irish politicians made an alliance with British Imperial Airways to forestall any attempt by Pan American Airways to dominate trans-Atlantic air service. This led to the creation of Trans-Canada Air Lines (TCA)—and to the importation of a fleet of Lockheed Electras and a team of former United Airlines executives from the United States to run the service. But thanks to Thomson's efforts, Canada did not have to import meteorologists to fill the new positions this demanded. Canadian scientists triumphantly produced forecasts using Bergen school techniques for the first experimental flights across the far northern Atlantic in 1935. By 1939, 34 of the 51 practicing meteorologists in Canada and Newfoundland had been trained by Thomson's program, nearly all of whom were employed by the Air Services Branch of the Dominion of Canada.[52]

Jacob Bjerknes spent the month of August 1939 lecturing at the Canadian Meteorological Office in Toronto. This series culminated with an unprecedented joint meeting of the Royal and American Meteorological Societies. Visiting dignitaries witnessed the official inauguration of the Canadian Branch of the RMS, the first autonomous branch to be organized in a British overseas dependency. The presence of a formidable line-up of Scandinavian scientists and their acolytes let everyone know how this long-anticipated event had come to pass (Figure 3). In fact, those in attendance could not avoid expressing a sense of ownership over these men: "I cannot regard Dr. Bjerknes as a Norwegian," declared one professor from the Imperial College of Science and Technology in London, "he is to me an international institution."[53]

These dignified ceremonies were followed up by serious atmospheric science, most notably during an all-day seminar on extra-tropical cyclone development led by Bergen school scientists. This seminar not only revealed how closely knit the Bergen school continued to be, it also showed how far its techniques had advanced. Those in attendance were honored with a detailed discussion of arguably the most significant advance in theoretical meteorology of the century: Rossby's derivation of his famous equation describing the propagation of large-scale atmospheric waves.[54] This meeting could not have confirmed more clearly the Bergen school's conquest of Canadian meteorology. Only one afternoon session granted significant time to scientists who were not declared adherents of the Bergen program. Canada's embrace of the "Norwegian School" during the 1930s thus helped it achieve scientific autonomy from both Great Britain and the United States.[55]

Unfortunately, the warm internationalist sentiments expressed at this reunion quickly faded. Germany invaded Poland two days after the meeting ended.

It is inaccurate to say that Scandinavian scientists were "stranded" in the United States by the outbreak of war, as is sometimes claimed. Several returned to Europe soon after, perhaps to their later regret. The United States had numerous attractions for those who remained. Most importantly, the core of this group had become highly dependent on each other for advances in their research. Rossby was able to derive his celebrated wave equation thanks to Jacob Bjerknes's progress in understanding upper-level conditions during "front-building." Bjerknes, in turn, had come to rely heavily on radiosonde observations, a new aerological technique using radio communication to transmit atmospheric conditions from a weather balloon to the ground. In Europe, this required delicate international coordination by the IMO Aerological Commission office in Berlin in the face of deteriorating political circumstances. The U.S. Weather Bureau, meanwhile, was well on its way toward converting its vast network to radiosonde; aerological observations on the scale of Europe's vast "experiment" of December 1937 were not far from becoming a daily occurrence in the United States.[56] North America also presented abundant opportunities for scientific leadership. In 1936, the

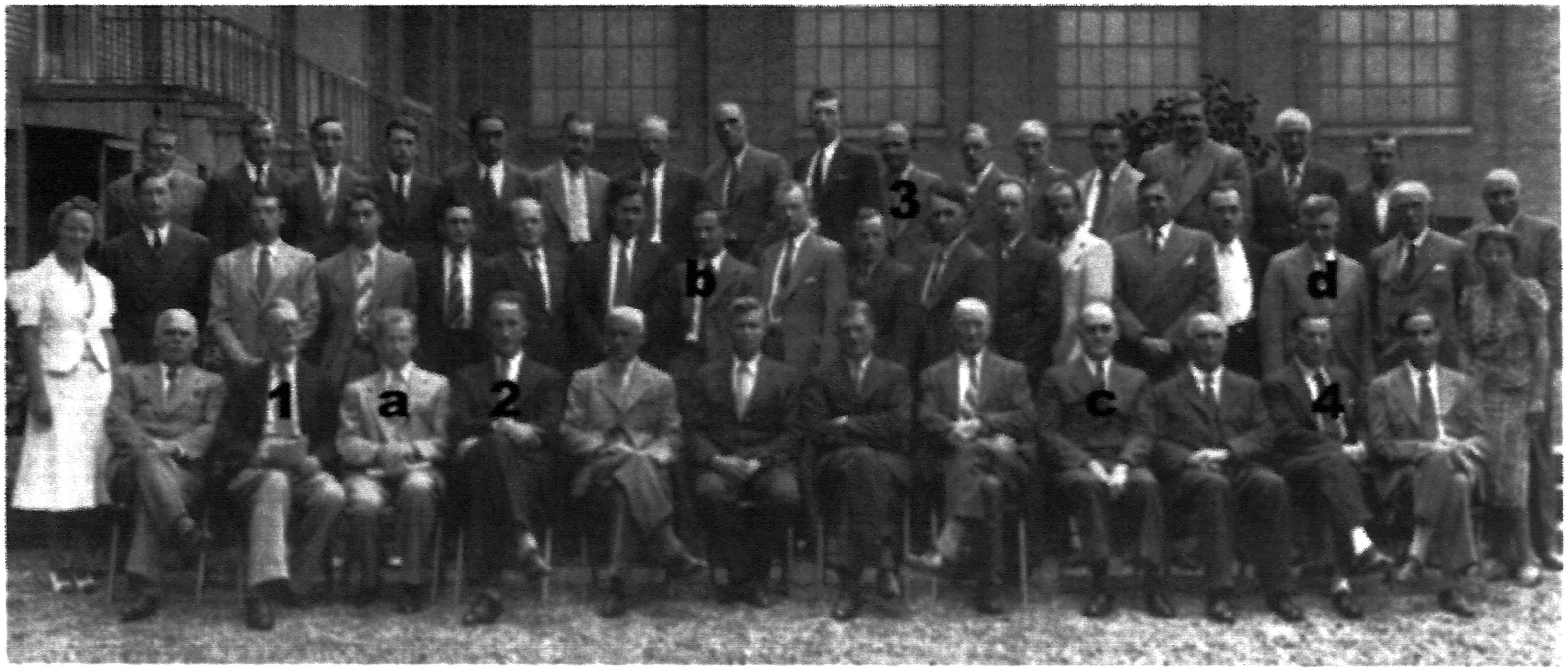

FIGURE 3 Canadian Meteorology Comes of Age: Participants at the first meeting of the Canadian Branch of the Royal Meteorological Society, 28–29 August 1939. "Norwegian School" scientists: 1. V. W. Ekman, 2. Jacob Bjerknes, 3. Halvor Solberg, 4. Sverre Petterssen. Not pictured: C-G Rossby. Prominent North American disciples: a. Horace R. Byers, b. Bernhard Haurwitz (a recent immigrant from Germany), c. Francis W. Reichelderfer, d. Andrew Thomson. Many of those pictured received training in Bergen School techniques at the University of Toronto. Source: *Quarterly Journal of the Royal Meteorological Society* 66, supplement (1940).

patriarch of Norwegian oceanography, Bjørn Helland-Hansen, had arranged for Harald Sverdrup to become director of the Scripps Institution of Oceanography (SIO). This established a firm beachhead for the Bergen school on the Pacific coast. Like Rossby before him, Sverdrup seized this opportunity to leave Norway for a position where he could "plan and have an influence on others' work" rather than live under the shadow of the founders of the Bergen school—in spite of the intense homesickness this caused him and his wife.[57]

With Europe so unsettled, a competition ensued to see where Jacob Bjerknes would land, establishing one of the world's centers for meteorological research in the process. All of this was well underway before a fleet of Junkers JU-52 hydroplanes led the German invasion of Norway on 9 April 1940 and ended its reign as the headquarters of the Bergen school.[58] Attracted by Sverdrup's presence, Bjerknes soon settled on the University of California's southern branch in the city of Los Angeles, one of the world's emerging centers for scientific and technological research and its largest producer of aircraft.[59] Bjerknes enthusiastically embraced the scientific challenges posed by Pacific Coast meteorology, helped along by timely U.S. Weather Bureau grants to study "typical frontal and air mass patterns over the Pacific, with particular reference to . . . the general circulation . . . and flood-producing rains in California."[60] But he held out signing a contract until he negotiated the hire of meteorologist Jörgen Holmboe, a long-time Bergen colleague. Holmboe, in turn, extracted a promise from Bjerknes to settle permanently in Los Angeles. Like so many settler colonists, these Scandinavians ultimately preferred to live where they already had friends from the home country. Pull factors far outweighed push factors in bringing them to the United States.[61]

But these men had little time for research, as they became consumed with planning and providing hands-on "Education and Training in Meteorology for the Armed Forces." Sverdrup, in fact, spent far more time than he intended teaching oceanography to UCLA meteorology students—to the lasting benefit of the meteorology profession—when "remote hearsay" regarding supposed German sympathies delayed his security clearance for wartime research.[62] As Roger Turner explains elsewhere in this volume, these efforts completed the colonization of North America by Scandinavian geophysical science: During the course of the war, 1,400 students at UCLA and SIO, 375 students in Canada, hundreds of practicing Weather Bureau scientists, and thousands of students attached to the British Commonwealth and U.S. armed forces received "advanced" training at programs run by disciples of the Bergen school.[63] These educational programs provided a launching point for the spread of polar front theory to the rest of the Western Hemisphere.

NORDIC SCIENCE INVADES THE TROPICS

The westward shift of the "Norwegian School" changed its geographical perspective. The leaders of the Bergen school could not forget events in Europe, of course. Through a long-time German friend, Jacob Bjerknes worked to assure good treatment for his father and to prevent the execution of a Bergen meteorologist accused of espionage in German-occupied Norway.[64] Sverdrup provided jobs for refugee scientists such as Wladyslaw Gorczynski, a prominent Polish climatologist with years of experience directing solar radiation research in the tropics, even though Sverdrup, reflecting the Bergen school's biases, had "*no intention whatsoever* to add climatology to the subjects under investigation at the Scripps Institution."[65] With European scientific channels closed off, these Scandinavian expatriates began turning their gaze south toward Latin America.

A major international scientific event helped inspire this shift. In May 1940, a vast contingent of Latin American scientists and diplomats descended on Washington, D.C., for the Eighth American Scientific Congress, the most recent in a series dating back to Buenos Aires in 1898 and Montevideo in 1901. President Franklin Roosevelt set the tone with an important statement of U.S. policy regarding hemispheric unity: "The annihilation of time and space" by "planes and bombs" meant that "every acre—every hectare—of the Americas" was in danger. "I am a pacifist," Roosevelt declared, making reference to his Good Neighbor Policy rejecting U.S. military intervention and embracing bilateral collaboration in the Americas. "You, my fellow citizens of twenty-one American Republics are pacifists. But I believe . . . you and I . . . will act together to protect and defend by every means our science, our culture, our freedom and our civilization." A parade of Latin American spokesmen echoed Roosevelt's "Messianic words" affirming the "duty of science" to make "Pan Americanism . . . a living and tangible thing."[66]

About 125 people attended the meteorological session of the Congress, though only one Latin American meteorologist read his own paper of the 36 submitted to the session. The Chief of the Mexican Meteorological Service impressed everyone with his report detailing Mexico's upper-air weather observatories and radio network, all modeled on U.S. Weather Bureau operations.[67] The American Meteorological Society made sure this meeting had a broad impact by distributing its published proceedings as a supplement to the AMS *Bulletin*. At the urging of Argentina's chief meteorologist Alfredo Galmarini, the foremost proponent of scientific internationalism among South American atmospheric scientists, the AMS Council took a further step: In 1941, it decided the "Society should fulfill its *true hemispherical nature* by publishing parts of its BULLETIN in Spanish as well as English" in order to encourage "greater interchange of ideas and closer personal relations between Spanish, Portuguese and English speaking Americans." This ran counter to well-established plans to publish "an Inter-American review of meteorology" edited by Galmarini's Uruguayan rival, Luis Morandi—and it was likely intended by Galmarini to counter-balance German influence in Argentine science.[68]

This incident hints at far deeper conflicts dividing the region, many focused on air power. Bolivia had just lost its protracted "Chaco War" with Paraguay, notwithstanding the contribution of LAB's growing fleet of Junkers aircraft. In 1938, Brazil fired off a salvo of threats after learning that the U.S. Army had made a secret arrangement to re-staff Argentina's flight-training program after Germany pulled out. And in 1941, a coordinated blitzkrieg offensive by Peru seized a vast portion of Ecuador's Amazonian frontier. Not only were South America's militaries mutual enemies, they were internally fractured into pro-French, German, and U.S. cliques. The situation became so tense that Panair do Brasil's chief executive was hauled before a military tribunal for German espionage in 1942.[69]

Aviation technology and atmospheric science both played critical roles in achieving a semblance of hemispheric political unity during World War II. As we have seen, German science and industry exercised substantial influence over aviation and meteorology in South America, mainly because of relationships established during the 1920s long before the National Socialists seized power. But U.S. observers, as a reflection of their own neocolonial aspirations, self-servingly interpreted these relationships as evidence of a "Nazi imperialist drive to dominate South American airlines."[70]

An ill-timed request by Deutsche Lufthansa's Ecuadorian subsidiary to initiate service to the Galápagos, together with Nelson Rockefeller's influential report calling for the "economic defense" of the Americas, triggered an aggressive U.S. campaign to eliminate even the weakest German ties to Latin American aviation. On 8 June 1940, under intense pressure, Pan American Airways summarily fired 80 pilots, mechanics, and administrators from SCADTA—some with over one million hours of flight experience.

Many German- and Austrian-born employees had formed local families and taken Colombian citizenship, including Peter Paul von Bauer, who reputedly did so as a reaction against Nazi overtures. Some ended up among the 4,058 Germans, 2,264 Japanese, 258 Italians—and not a few Jews and communists—who were deported from Latin America to U.S. prison camps for the duration of the war. In 1941, the Peruvian, Bolivian, and Ecuadorian governments expropriated local German airlines, to the direct benefit of Pan American-Grace Airways (Panagra) which immediately took over their routes. Los Angeles manufacturers also benefited from "de-Germanification." With help from an $8 million U.S. program, several airlines acquired fleets of new Lockheed planes to replace old Junkers aircraft. But nationalists in the Brazilian military, fearful of the growing strength of Pan American Airways, stubbornly resisted U.S. efforts to close down Syndicato Condor. After years of collaborating with Germany on development issues, Getúlio Vargas eventually gave way to U.S. pressure, though only after finalizing arrangements for building a string of air bases through northern Brazil, a vast coal-steel complex, and other lucrative concessions. In return, the U.S. military gained access to northern Brazil for the duration of the war. These agreements entailed the installation of U.S. Army Air Force forecasters—most with training in polar front theory—along the airway connecting Florida to North Africa via Brazil. This included placing a U.S. supervisor in charge of Rio de Janeiro's aviation forecast center, the Deutsche Seewartes's former stronghold. Syndicato Condor became Brazilian property and its remaining German employees were fired when Brazil declared war on Germany in August 1942. Its new management was promptly rewarded with four coveted DC-3s, the first of an eventual 278 DC-3/C-47s purchased by major Brazilian airlines. Vargas hailed these agreements as symbols of Brazil's economic emancipation.[71]

In one notorious case, the United States used naked force to move this policy forward. On 16 January 1942, under the cover of night and a secret diplomatic agreement, U.S. military detachments invaded three of the Galápagos Islands and the tip of the oil-rich Santa Elena peninsula in Ecuador in order to construct bases for the defense of the western approach to the Panama Canal. With much of Ecuador under Peruvian occupation, its government was in no position to protest. In return for a mere $35,000, it signed an agreement after the fact granting a long list of demeaning concessions.[72] The U.S. Sixth Weather Squadron used this opportunity to install the first three meteorological observatories with radiosonde capability to be established on the Pacific coast of South America. Its officers acquired aerological data of unprecedented detail for the "tropical front" thought to separate air masses of the northern and southern hemisphere in the course of thousands of survey flights between Guatemala, the Galápagos, and the South American mainland (Figure 4).[73] But the U.S. military ignored repeated entreaties to share these observations with allied Ecuadorian and Mexican meteorologists. Nor did they "put themselves into contact with the Meteorological Service of Ecuador so as to find a way to maintain the functioning of this important center . . . in the equatorial zone of the Pacific Ocean" at the end the war—to the eternal regret of scientists interested in the El Niño phenomenon.[74] This U.S. military foray in Ecuador did nothing to unite Latin American enemies in a common cause.

In stark contrast, civilian atmospheric scientists in the United States embraced Nelson Rockefeller's emphasis on peaceful, international cultural and scientific exchange with Latin America.[75] Jacob Bjerknes headed straight to Gorczynski's old stomping ground, Mexico City, between his first two semesters at UCLA in order to teach air mass analysis to the Mexican Meteorological Service. The U.S. Weather Bureau then sent its chief scientist R. Hanson Weightman—Rossby's first American disciple—on a tour of South America "to attain . . . greater collaboration in the exchange of meteorological information" and to extend invitations to a hemispheric meteorological meeting to be held in Washington. The Weather Bureau also put together a six-month training program for ten circum-Caribbean students focused on hurricane prediction and radiosonde technique.[76]

In the fall of 1941, Rossby hatched a plan to expand these activities. He suggested an extended tour of the "principal meteorological centers" of Latin America by two "recognized meteorologists" with "tact and sympathy for the Latin American temperament." Rossby also proposed an exchange program that would have sent ten young U.S. meteorologists to Latin America to equip five new radiosonde observatories, and ten young South American nationals to the United States for advanced meteorological training. He explicitly hoped to extend "modern methods" of air mass analysis to temperate regions of the Southern Cone and to find out if Bergen school techniques could provide insights into the vertical stability and moisture content of "true equatorial air." The fact that Rossby volunteered himself and Bjerknes to serve as missionaries shows the high priority he placed on this plan's success—it meant the conquest of a vast new region for the Bergen school. Others immediately began promoting Rossby's plan as a means to eliminate Germans from South America's weather services and prevent "Nazi sabotage" of hemispheric forecasts.[77]

The United States' full mobilization after Pearl Harbor prevented Rossby and Bjerknes from taking this tour. Instead, they got something far better: an elaborate Latin American training program that lasted for the duration of the war. The U.S. Weather Bureau kicked off this program with the Inter-American Institute of Meteorology held in Medellin, Colombia, in 1943. A total of 200 students representing every Latin American republic attended this six-month course. Nelson Rockefeller's Interdepartmental Committee for Cultural and Scientific Cooperation hastily translated a U.S. textbook intended for commercial pilots for the Institute. It focused explicitly on "polar front theory" and "air mass analysis" as originated by "Norwegian scientists," but unlike many textbooks of that time, its examples derived almost entirely from the United States. The Institute depended on Latin American assistant instructors to provide regional applications.[78] Students also received practical training in map analysis, tracking pilot balloons, and the English language. Forty-six graduates with the best language and mathematical skills were then sent to the United States for nine to twelve months of advanced training.[79] California's long-standing efforts to promote itself as Latin America's new Mediterranean metropole paid off handsomely in this case.[80] In view of the "long background of connections . . . this part of the country has with Latin-American affairs," 28 members of this initial advanced class were sent to UCLA, 42 more by the end of the war.[81]

Latin Americans enthusiastically embraced the opportunities presented by this training program. Eight hundred applicants competed for the original 200 positions at the Institute. Many were quickly rewarded for their efforts. Approximately half of the Institute's graduates promptly obtained professional positions in meteorology. Gustavo Wray, for example, became Panagra's chief observer at the Guayaquil airport, and he was eventually charged with supervising Ecuador's entire coastal network of government observatories. Rafael Dávila Cuevas, the enterprising son of highland immigrants to Lima, represented a new class "of strong, dark complexion" that had only recently been allowed to attend Latin America's universities. When the war forced him to abandon geophysical studies at the University of Kyoto, he headed straight for UCLA to work with Bjerknes. As a professor of geophysics at the Universidad Nacional Mayor de San Marcos, Dávila went on to train a new generation of Peruvian scientists in atmospheric science—on a couple occasions, with Bjerknes's direct assistance.[82] In addition to serving individual ambitions, these educational exchange programs enabled Latin Americans, like Canadians, to fulfill growing regional demand for meteorological expertise, and they helped several nations' efforts to form a technical elite. In the process, they established direct ties of allegiance between the Latin American and U.S. meteorological professions. Programs like these worked so well toward these ends that they soon formed the backbone of Cold War development strategies in the Third World.[83]

These high-profile international programs provided direct stimulus for the reorientation of atmospheric science in much of Latin America. Brazil, Mexico, and Ecuador dutifully initiated detailed investigations of regional air masses and established training programs of their own to produce experts in frontal analysis.[84] To better serve regional aviation, Ecuador and Bolivia abruptly shifted their meteorological services away from climatology and toward synoptic meteorology during the war. The Ecuadorian government also initiated the expensive task of retrofitting its observatories with U.S. equipment—though not fast enough to make up for the systematic breakdown of German and French precision instruments lacking recording drums and routine factory maintenance during the war.[85] Luis Mena, an instructor at Medellín, returned home intent on initiating pilot balloon soundings at the Quito Astronomical Observatory. Obtaining local government support was the least of his problems. U.S. military staff controlled the wartime supply of meteorological instruments, and they placed Ecuador near the bottom of the waiting list. (After all, the U.S. Army Air Force operated its own observatories in Ecuador.) Only direct intervention by the head of the U.S. Weather Bureau to provide a package of scarce balloon valves enabled the Quito Observatory to initiate upper-air observations in March 1946 after a two-year wait.[86] This sort of treatment became a major sore spot in hemispheric relations. After making big promises to Latin America in order to cement the wartime alliance, the United States repeatedly required its southern allies to wait in line for basic economic and technical aid after the war: first until after the rebuilding of Europe and Japan under the Marshall Plan, then until after the Korean conflict, then until after international organizations took the lead. (An all-out revolt in a U.S. client state, the 1959 Cuban Revolution, eventually forced a change in U.S. development policy and scientific engagement in the region.)[87]

Meanwhile, the reorientation of scientific resources toward synoptic meteorology and other wartime disruptions discouraged some promising lines of climatological research in the Southern Hemisphere. Before the war, the main observatory in Santiago de Chile had nurtured scientific ties that spanned the entire Pacific. It took part in a project with New Zealand and Argentina to determine the average trajectories of depressions and anticyclones in the South Pacific. Like their colleagues in India, Chilean meteorologists showed a particular interest in the correlation between abnormal precipitation and the Southern Oscillation; to this end, they carefully collected daily reports transmitted by shortwave from Manila, Hanoi, and Batavia.[88] Ecuadorian scientists were similarly engaged in projects to relate solar radiation, abnormal precipitation patterns, and variations in the strength of the "El Niño countercurrent" off the coast of Ecuador. They had even established a transoceanic data exchange that used high rainfall anomalies in coastal Ecuador and Peru to produce drought forecasts for the Dutch East Indies. World War II not only cut off Quito from Batavia, anti-espionage regulations also prevented Ecuadorian government meteorologists from freely exchanging data with private companies operating locally—a vital source of data from the El Niño-prone coast.[89] As Harald Sverdrup's promise to Wladyslaw Gorczynski illustrates, Bergen school scientists viewed research focused on statistical weather cycles and solar forcing with open disdain. Their overwhelming triumph during World War II converted these approaches into a signifier of scientific backwardness. These interests did not revive until after the International Geophysical Year of 1957–1958.[90]

THE BIRTH OF MODERN TROPICAL METEOROLOGY

In the midst of all this, some disciples of the Bergen school became convinced that polar front theory had almost nothing to contribute to tropical forecasting. In 1943, through Rossby's initiative, the University of Chicago organized an Institute of Tropical Meteorology at the University of Puerto Rico. Seven of the original 46 Latin American students who came to the United States for advanced training were invited to this Institute. Rossby realized that his growing meteorological empire would never last—and wartime forecasts in the tropics would fail—unless they were founded on rigorous empirical research based in the Torrid Zone. He selected Puerto Rico, not only because it was close by and governed directly by the United States, but also because U.S. and Puerto Rican scientists had compiled the oldest, most detailed set of pilot balloon observations for this hurricane-prone region. He looked far afield for an experienced tropical meteorologist to direct the Institute: Clarence Palmer, a New Zealander who had become a disciple of the Bergen school during Jörgen Holmboe's extended stay at the New Zealand Meteorological Office in the mid 1930s. Palmer had gained renown as a tropical forecaster during his tour of duty at Guadalcanal with the Royal New Zealand Air Force. Rossby also arranged for Herbert Riehl, a promising young German immigrant prohibited from more sensitive tasks, to attend as a student.[91]

Palmer and Riehl dedicated themselves to the systematic study of upper-air data from the Caribbean, including high-quality radiosondes that had recently become available from U.S. colonial observatories at San Juan, Guantánamo Bay, and Swan Island. They relied on a number of techniques developed by Scandinavian meteorologists, including Vilhelm Bjerknes's method for analyzing streamlines and Rossby's kinematic approach to atmospheric waves. But empirical evidence forced them to reject the principle that frontal dynamics at the boundary between air masses contributed significantly to tropical weather. Riehl, instead, concentrated on the development of perturbations *within* tropical air masses, particularly "waves in the easterlies." These westward-moving troughs of low pressure not only provided a valuable tool for predicting convective rainfall and upper-level winds in the Caribbean, they also marked where a hurricane was likely to form (Figure 4).[92]

In a review of "progress" made by the profession during the 1940s, Palmer could not have been more pessimistic about the future of the air-mass approach to tropical meteorology. "This theory failed to pass the test to which all theoretical work in meteorology must finally come; . . . it was found almost useless as a guide to short-period forecasting in low latitudes." In fact, "a large part of the more successful short-range tropical forecasting in World War II," he concluded, had relied on older, statistical approaches to climate—exactly the kind of meteorology the triumph of the Bergen school had done so much to discourage. Pilot balloons, as it turned out, proved ill-suited to producing reliable data on upper-level winds in the humid tropics except during fair weather—they usually got lost in the convective cloud cover associated with tropical precipitation. Only expensive, high-precision barometers and barographs, radiosondes, airplane surveys, and radar produced meaningful measures of day-to-day changes governing the tropical atmosphere. These realizations led to "the disillusionment of a whole generation of tropical meteorologists."[93] This was particularly true in countries like Ecuador and Peru where the resulting "lack of knowledge of the meteorological processes involved in the formation of daily weather" and lack of resources to replace low-precision instruments deprived southern forecasters of the basic theoretical and empirical tools they needed to do

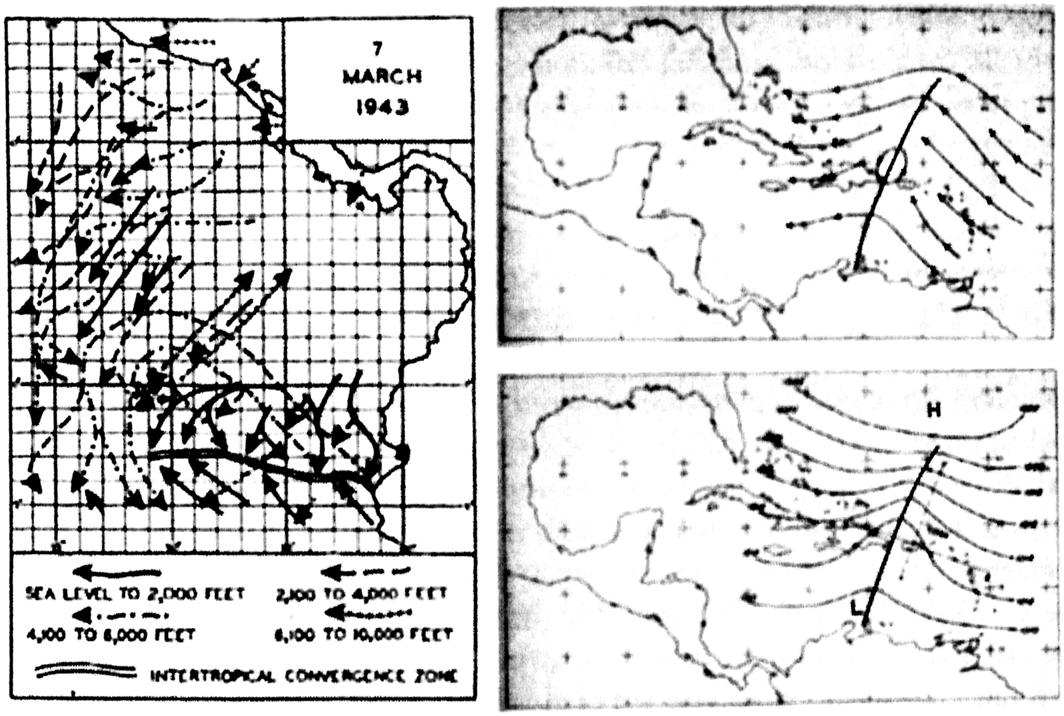

FIGURE 4 Two competing models of tropical meteorology at the end of World War II.

Left: The Equatorial Front. Following the lead of Vilhelm Bjerknes, tropical forecasters used the wind field in the tropics to map the boundary between tropical air masses, even though marked temperature differentials rarely accompanied these "fronts." This map of winds over the eastern tropical Pacific shows the "intertropical convergence zone" several degrees south of its usual position in March, a hallmark of the El Niño phenomenon, as well as the presence of "anti-trades" above 6,100 feet over the Galápagos.

Right: The Easterly Wave. In these idealized diagrams, upper-level winds (above, at 10,000 feet) and surface-level pressure (below) indicate a downward sloping atmospheric wave transecting the Antilles from north to south. By locating "waves in the easterlies," a synoptic meteorologist could predict zones of convective storms (marked by dotted line) and "shear zones" (abrupt changes in wind direction). Most importantly, a forecaster could expect these waves to propagate east to west and sometimes give birth to tropical depressions.

Sources: Leo Alpert, "Weather over the Tropical Eastern Pacific Ocean, 7 and 8 March, 1943," *Bulletin of the American Meteorological Society* 27 (1946): 389; Herbert Riehl, *Waves in the Easterlies and the Polar Front in the Tropics*, University of Chicago, Department of Meteorology, Miscellaneous Reports No. 17 (Chicago: University of Chicago Press, 1945), 7, 9.

reliable work.[94] (This discouraging situation mirrored the postwar circumstances that faced Latin American economists trained in the North. They responded by generating their own theoretical approach to economic reality: dependency theory.)[95] South of the Rio Grande, only the meteorology profession in Argentina—the only Latin American state that stayed out of the wartime alliance—seems to have benefited unambiguously from the war. The knowledge young Argentine meteorologists gained at Medellín and UCLA worked quite well in the temperate zone of South America. After the war, a number of gifted German scientists immigrated to Argentina. Like Scandinavian scientists, they, too, welcomed the opportunity to pursue upper-air research while living in settler colonies of their compatriots.[96]

Tropical meteorology in the United States had a very different fate. As a result of Palmer and Riehl's research, Rossby abruptly revised his understanding of the role of the tropics in the general circulation after the war, and he used his enormous influence to encourage the development of a new Tropical Meteorology. After four years in Puerto Rico, Herbert Riehl returned to the University of Chicago where he completed a Ph.D. under Rossby's supervision. With Rossby's support, Riehl stayed on in Chicago and established a major research school dedicated to the study of tropical cyclones. Clarence Palmer joined the new Institute of Geophysics at UCLA built around Jacob Bjerknes after the war. In this way, Chicago, Los Angeles, and later Miami emerged as major centers of action for tropical research and utterly eclipsed centers like Havana, Manila, and Batavia that had flourished under colonial rule.[97]

What, then, does this case study tell us about the historical relationship between science, technology, and neocolonialism? The protagonists of this hemispheric struggle over airways were conscious that these forces were closely intertwined and mutually reinforcing. But different actors used a wide variety of strategies in an attempt to manipulate these relationships to their benefit. Some of the strategies formed patterns that might be considered "national styles in science."[98] The contrast between German and U.S. "styles" was particularly marked: Germans often used science to lead the way for other neocolonial endeavors, while American science tended to follow on the heels of other forms of dominance, often imposed from the top-down. Scandinavians used the struggle over airways to assert their supremacy more narrowly, in a scientific realm; their endeavors, meanwhile, helped the Bergen school to maintain a lasting sense of cohesion, even when the polar front paradigm revealed its many limitations. Canadian scientists, in turn, used

Scandinavian supremacy to establish professional autonomy from the U.S. and U.K. This diversity of strategies was just as marked within Latin America. Argentines, Brazilians, and Colombians repeatedly worked conflicting neocolonial aspirations in South America to their own advantage. Some strategies did not work: Ecuadorians, despite their best efforts, found themselves in a position inferior to Puerto Rico and the Canal Zone, at least where scientific and technological development were concerned, though they did convince the U.S. to abandon its military bases after the war.

The diffusion of atmospheric science and aviation technology between 1919 and 1945, in the final analysis, played an important role in dividing the Americas into First and Third Worlds and exacerbated regional disparities of wealth, productivity, expertise, and innovative capacity. Most of these outcomes were unintended, and some were almost incomprehensible to those involved. How else can we explain the widespread, North-South consensus that emerged after the war promoting further education, scientific research, and technological innovation as answers to these "developmental problems"? Perhaps neocolonialism deserves its reputation as "the worst form of imperialism," not because of the economic constraints it created, but because of the "particular cast of mind" it encouraged, in which scientific knowledge, technological development, and economic growth came to be seen as automatically beneficial by so many postcolonial rulers, despite their long-term consequences for local environments and livelihoods."[99]

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NOTES

Abbreviations used in notes: Archivo del Observatorio Astronómico de Quito: Comunicaciones Recibidas (AOAQ-CR); U.S. Weather Bureau correspondence (AOAQ-USWB); International Meteorological Organization correspondence (AOAQ-IMO). University of California, Los Angeles, Charles E. Young Research Library: Jacob Bjerknes papers, special collection 1709 (UCLA-Bjerknes). UCLA Archives, Office of Chancellor, Administrative Files, record series 359: Scripps Institution of Oceanography, General Matters (UCLA-SIO); Department of Physics, Meteorology Program, (UCLA-PhysMet); Department of Meteorology (UCLA-Met). Scripps Institution of Oceanography Archives, University of California, San Diego: Office of the Director, Sverdrup, Records, (SIO-Sverdrup). *Quarterly Journal of the Royal Meteorological Society* (*QJRMS*); *Bulletin of the American Meteorological Society* (*BAMS*).

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4. The two best-known interpretive models for understanding the global spread of Western science were heavily based on the experience of British settler colonies: George Basalla, "The Spread of Western Science," *Science* 5 May 1967: 611–622; Roy MacLeod, "On Visiting the 'Moving Metropolis': Reflections on the Architecture of Imperial Science," *Historical Records of Australian Science* 5, no. 3 (Nov. 1982): 1–16. For critiques of these models, motivated by the histories of Canada and Latin America, see Richard A. Jarrell, "Differential Development

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8. John Herd Thompson and Allen Seager, *Canada 1922–1939: Decades of Discord* (Toronto: McClelland and Stewart, 1985), esp. 190–192.
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14. Kuhn, "The History of Aeronautics in Latin America," 36–42, 46–48, 51–54, 65–66, 74–79, 120–124, 160–161, 165; Vicente Gesualdo, "Andar en globo: Las primeras ascensiones aerostáticas en Argentina y Sudamérica," *Todo es historia* (Buenos Aires) Jan. 1983: 40–47, 54–61.
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17. *Segundo reunión del Congreso Científico Latino Americano celebrada en Montevideo del 20 a 31 de marzo de 1901* (Montevideo: Tip. y Enc. "Al Libro Inglés," 1901), xiii, 13, 19–20; L. Morandi, "Los primeros sondeos aerológicos en el Uruguay," *Revista meteorológica* (Montevideo) 1, no. 1 (Jan. 1942): 34–39; J. Patterson, "A Century of Canadian Meteorology," *QJRMS* 66, supplement (1940): 26–28.
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20. My interpretation relies heavily on Stefan H. Rinke, *"Der letzte freie Kontinent": Deutsche Lateinamerikapolitik im Zeichen transnationaler Beziehungen, 1918–1933*, 2 vols. (Stuttgart: Heinz, 1996).
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22. Rinke, "Die Firma Junkers auf dem lateinamerikanischen Markt, 1919–1926," in *Grenzenlose Märkte?: Die deutsch-lateinamerikanischen Wirtschaftsbeziehungen vom Zeitalter des Imperialismus bis zur Weltwirtschaftskrise*, ed. Boris Barth and Jochen Meissner (Munster: Lit Verlag, 1995), 157–184; Rinke, "*Der letzte freie Kontinent*", 1:35–36, 2:684–699; Amalia Villa de la Tapia, *Alas de Bolivia: Síntesis histórica de la aviación nacional* (La Paz: Editorial Aeronáutica Fuerza Aérea Boliviana, 1974), 1:141–165.
23. Gustavo Arias De Greiff, *Otro cóndor sobre los Andes: Historia de la navegación aérea en Colombia* (Bogotá: BANCAFE/FIDUCAFE, 1999), 110–113; Boy, *Una historia con alas*, 86–88; Florencio Gómez Núñez, *Mis apuntes sobre la aviación venezolana: Documento para la historia de al aviación venezolana* (Caracas: Impresos Moranduzzo, 1970), 153–158.
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26. Newton, *The Perilous Sky*, 64–70; Davies, *Airlines of Latin America*, 338; Rinke, "*Der letzte freie Kontinent*", 2:668–672; Rudloff, "Ozeanflugwetterdienst," 156; Walter Georgii and Heinrich Seilkopf, "Ergebnisse einer flugwissenschaftlichen Forschungsreise nach Columbia (S.A.)," *Aus dem Archiv der Deutschen Seewarte* (Hamburg) 43, no. 3 (1926): 5–10, 14, 52–56; Herbert Riehl, *Tropical Meteorology* (New York: McGraw-Hill, 1954), 243–244.
27. Newton, *The Perilous Sky*, 70–77; see also Nancy Mitchell, *The Danger of Dreams: German and American Imperialism in Latin America* (Chapel Hill: University of North Carolina Press, 1999).
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29. This was the second time an accident prevented Argentina from establishing a meteorological presence on the southern continent. Antonio Pauly, *Proyecto de Expedición Aérea Argentina al Polo Sur* (Buenos Aires, 1926), esp. 37–39, 49–51; Alfredo G. Galmarini, "Antecedentes sobre la organización del Servicio Meteorológico Argentino y su organización actual," *Revista meteorológica* 1, no. 2 (Apr. 1942): 24–25; Santiago Mauro Comerci, *Cronología de la presencia aérea argentina en la Antártida* (Buenos Aires: Instituto Antártico Argentino, 1995), 3–7.
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32. Nunn, *Yesterday's Soldiers*, 177–179; Newton, *The Perilous Skies*, ch. 5; quotes come from primary sources cited by Newton.
33. Newton, *The Perilous Skies*, 16–17, 21, 103 [quote], 125–133; Rosalie Schwartz, *Pleasure Island: Tourism and Temptation in Cuba* (Lincoln: University of Nebraska Press, 1999), 65–67.
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35. Cushman, "Enclave Vision: Foreign Networks in Peru and the Internationalization of El Niño Research during the 1920s," *History of Meteorology* 1, no. 1 (2004): 67–68.
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38. Donald M. Pattillo, *Pushing the Envelope: The American Aircraft Industry* (Ann Arbor: University of Michigan Press, 1998), 94–97 [quote], 100; Roger E. Bilstein, *The Enterprise of Flight: The American Aviation and Aerospace Industry*

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39. Burden, *The Struggle for Airways*, 39–44, 47–48, 95–97, map 7; Davies, *Airlines of Latin America*, 403–407, 418–419, 526.
40. Ludwig Weickmann to Galmarini, 12 July 1937; Galmarini to Juan Odermatt, 20 Aug. 1937; "Temario para la Segunda Reunión de la Comisión Regional III en Montevideo, Febrero 1939," 10 Oct. 1938; Prasident der Deutsche Seewarte to Observatorio de Astronomía y Meteorología de Quito, 3 Sept. 1938; all AOAQ-CR. Galmarini, "Nuevos horizontes de la meteorología continental americana," *BAMS* 24, no. 1 (Jan. 1943): 2–4; Otto Schneider, "Relato sobre los trabajos para la intercomparación de los barómetros patrones sudamericanos," *Proceedings of the Eighth American Scientific Congress Held in Washington, May 10–18, 1940* (Washington, DC: Department of State, 1941), 7:331–335; Rudloff, "Ozeanflugwetterdiesnt," 156, 158.
41. Lucien L. Friez to Director del Observatorio, 5 Jan. 1939, AOAQ-CR. Pro-German sentiment among South American meteorologists had been years in the making, see Hoxmark, *La aviación y la meteorología*, 12; Sampaio Ferraz, *Meteorologia brasileira*, 419.
42. See Michael Bravo and Sverker Sörlin, eds., *Narrating the Arctic: A Cultural History of Nordic Scientific Practices* (Canton, MA: Science History Publications, 2002); Trevor H. Levere, *Science and the Canadian Arctic: A Century of Exploration, 1818–1918* (Cambridge: Cambridge University Press, 1993), esp. 362–377.
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1924): 521–527; Carl-Gustaf Rossby and Richard Hanson Weightman, "Application of the Polar-Front Theory to a Series of American Weather Maps," *Monthly Weather Review* 54, no. 12 (Dec. 1926): 485–496 [quote p. 496].

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47. "The *Bulletin* Interviews: Professor H. Flohn," 189.
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52. Patterson, "A Century of Canadian Meteorology," 28–29; "Minutes of the Joint Meeting at Toronto of the Royal Meteorological Society and the American Meteorological Society on August 28 and 29, 1939," *QJRMS* 66, supplement (1940): 6–7; Thomas, "The Formation and Early Days of the Canadian Branch of the Royal Meteorological Society," *CMOS Bulletin SCMO* 22, no. 1 (Feb. 1994): 7–13; Petterssen, *Weathering the Storm*, 68; Edward A. Doty to Louis B. Myers, 17 Mar. 1977, box 1:5, UCLA-Bjerknes; Smith, *It Seems Like Only Yesterday*, 29, 35, 54, 56–57, 59, 62; David MacKenzie, *Canada and International Civil Aviation, 1932–1948* (Toronto: University of Toronto Press, 1989), 27–32, 36–38, 54–55.
53. "Minutes of the Joint Meeting at Toronto," 5–6, 8–10.
54. Rossby spent most of his time in Toronto discussing the most important publication of his storied career, "Relation between Variations in the Intensity of the Zonal Circulation of the Atmosphere and the Displacement of the Semi-Permanent Centers of Action," *Journal of Marine Research* 2, no. 1 (1939): 38–55. He submitted arguably his second most important article for publication

in the Toronto proceedings, "Planetary Flow Patterns in the Atmosphere," *QJRMS* 66, supplement (1940): 68–87; for other seminar participants' contributions, see ibid., 57–67, 88–111. Cf. Nebeker, *Calculating the Weather*, 88–90.

55. A fully independent Canadian Meteorological Society was formed on 1 Jan. 1967; "Minutes of the Joint Meeting at Toronto," 14–15; cf. Thomas, "The Formation and Early Days of the Canadian Branch."

56. "International Union of Geodesy and Geophysics: Meteorological Association, Program for the Washington Assembly," *BAMS* 20, no. 6 (June 1939): 274–275; J. Bjerknes, P. Mildner, E. Palmén, and L. Weickmann, *Synoptisch-aerologische Untersuchung der Wetterlage während der internationalen Tage vom 13. bis 18. Dexember 1937* (Leipzig: Veroffentlichungen des Geophysikalischen Instituts der Universität Leipzig, 1939), esp. 3–6; Eliassen, *Jacob Aall Bonnevie Bjerknes*, 11; "Minutes of the Joint Meeting at Toronto," 11; Nebeker, *Calculating the Weather*, 104–106. Cf. Deborah Day, "Bergen West: Or, How Four Scandinavian Geophysicists Found a Home in the New World," *Historisch-Meereskundliches Jahrbuch* 6 (1999): 69–82.

57. Mrs. Robert G. Sproul to H. U. Sverdrup, 20 Mar. 1936; Sverdrup to Robert G. Sproul, 11 Apr. 1936; Csüdriu Sverdrup to Mrs. T. Wayland Vaughan, 6 May 1936; 1:8, SIO-Sverdrup. J. C. Harper to Sproul, 8 Jan. 1938; Sproul to Harper, 19 Jan. 1938, UCLA-SIO; Friedman, "Contexts for Constructing an Ocean Science: The Career of Harald Ulrik Sverdrup (1888–1957)," in *Oceanographic History: The Pacific and Beyond*, ed. Keith R. Benson and Philip F. Rehbock (Seattle: University of Washington Press, 2002), 21–23; Eric L. Mills, "The Oceanography of the Pacific: George F. McEwen, H. U. Sverdrup and the Origin of Physical Oceanography on the West Coast of North America," *Annals of Science* 48, no. 3 (May 1991): 261–262; Tor Bergeron, "The Young Carl-Gustaf Rossby," in *The Atmosphere and the Sea in Motion*, 53–54.

58. Burton M. Varney to Vern O. Knudson, 16 Jan. 1940; Rossby to Sproul, 7 Mar. 1940; Sverdrup to Sproul, 19 Mar. 1940; Sproul to Bjerknes, 22 Apr. 1940; Bjerknes to Sproul, 2 May 1940, 5 Aug. 1940; 84:1, UCLA-PhysMet.

59. See Kevin Starr, *The Dream Endures: California Enters the 1930s* (New York: Oxford University Press, 1997), ch. 3; Judith R. Goodstein, *Millikan's School: A History of the California Institute of Technology* (New York: W. W. Norton, 1991); J. M. Lewis, "Cal Tech's Program in Meteorology: 1933–1948," *BAMS* 75, no. 1 (1994): 69–82; Roger W. Lotchin, *Fortress California, 1910–1961: From Warfare to Welfare* (New York: Oxford University Press, 1992), ch. 4.

60. Rossby to Sproul, 3 May 1940; G. M. Richards to Regents of UCLA, 20 June 1940; Joseph Kaplan to Deming G. Maclise, 18 Dec. 1941; Reichelderfer to Bjerknes, 5 Nov. 1941, 12 Dec. 1941; 84:1, 108:14, UCLA-PhysMet.

61. Bjerknes to Sproul, 2 May 1940, 11 May 1940; Holmboe to Bjerknes, 24 June 1940; Holmboe to Kaplan, 10 July 1940; Sproul to Holmboe, 30 or 31 [?] Aug.

1940; 84:1, UCLA-PhysMet. For a contrasting viewpoint, see Sverdrup to Sproul, 1 May 1940, 1:16, SIO-Sverdrup.

62. Sverdrup to Sproul, 30 Apr. 1942; George Turner to Sproul, 21 May 1942; 139:9 UCLA-SIO. See also Naomi Oreskes and Ronald Rainger, "Science and Security before the Atomic Bomb: The Loyalty Case of Harald U. Sverdrup," *Studies in History and Philosophy of Modern Physics* 31, no. 3 (2000): 309–369.
63. Andrew Thomson served as chief organizer of meteorological training for the British Commonwealth Air Training Plan. Bjerknes to Sproul, 5 Aug. 1940; Rossby to Bjerknes, 13 Aug. 1940; Reichelderfer to Bjerknes, 13 Aug. 1940; Kaplan to Sproul, 24 Feb. 1942; "Announcement of Program in Meteorology, 1942," Mar. 1942; 84:1, 136:2 UCLA-PhysMet. "Scripps Institution of Oceanography of the University of California," Report to the Regents of the University of California, [1945], 87:18, UCLA-SIO. Bjerknes to Sproul, 1 Feb. 1946, 223:19, UCLA-Met. "District Forecast Center at Los Angeles," *BAMS* 21, no. 7 (Sept. 1940): 309; Thomas, "The Formation and Early Days of the Canadian Branch," 9–10; Thomas, "Andrew Thomson," Canadian Meteorological and Oceanographic Society, http://www.cmos.ca/prizebios.html (accessed 19 Oct. 2005).
64. These acts helped rehabilitate Ludwig Weickmann's reputation after the war. Weickmann to Carl Störmer, 31 Oct. 1946; Störmer, Armed Forces affidavit, 27 Dec. 1946; 1:5, UCLA-Bjerknes. Hermann Flohn, "Ludwig Weickmann zum Gedächtnis," *Beiträge zur Physik der Atmosphäre* 35, no. 3/4 (1962): 141–144.
65. Sverdrup's emphasis; Sverdrup to Gorczynski, 19 Sept. 1941, 1:19, SIO-Sverdrup. Sverdrup to Sproul, 22 Nov. 1939; J. H. Corley to Maclise, 16 May 1941; 112:1, UCLA-SIO. Ladislas Gorczynski, *Breve reseña sobre observaciones de radiación solar y aparatos termoeléctricos registradores: Importancia de su estudio en la República Mexicana* (Tacubaya, Mexico: Imprenta de la Dirección de Estudios Geográficos y Climatológicos, 1926), 1–6, 14, 18; Carlos Theye, "Radiación solar en la Habana," *Boletín del Observatorio Nacional* (Havana) 22, no. 2 (1926): 19–32; Theye, "Estudios comparativas de radiación solar (1)," *Boletín del Observatorio Nacional* 24, no. 1 (1928): 51–74; Gorczynski to Luis G. Tufiño, 20 May 1928, AOAQ-CR.
66. Canada did not generally participate in "Pan-American" events; *Proceedings of the Eighth American Scientific Congress Held in Washington, May 10–18, 1940* (Washington, DC: Department of State, 1941), 1:9–10, 13, 15–16, 24, 31, 35.
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