7. Enclave Vision: Foreign networks in Peru and the internationalization of El Niño research during the 1920s

Gregory T. Cushman

University of Texas at Austin
Austin, Texas, USA

Environmental scientists in Peru first attached the moniker 'El Niño' in 1891 to a warm current running counter to the highly variable, but generally north-flowing Peru Current. Torrential rains along the normally arid northern Peruvian coast and catastrophic floods in many parts of the country captured the attention of a group of professionals incorporated by the newly founded Sociedad Geográfica de Lima (est. 1888). One member of this group, the naval hydrographer Camilo N. Carrillo (1830-1900), noticed that the weak countercurrent known by artisanal fishermen to appear during the austral summer along the northern coast was particularly strong that year. This was just one of several phenomena that they associated with this exceptional climate event. To keep track of such changes, the Sociedad organized a network of meteorological observers, including a station in Lima that has since been in more-or-less continuous existence. As part of such duties, the politician Víctor Eguiguren compiled and published the regional oral tradition of similar climate anomalies in northern Peru since 1791. In 1895, Federico Pezet presented a digest of this work at the Sixth International Geographical Congress in London that underscored the links between this *contracorriente El Niño* and torrential rains in the northern department of Piura.[1] In short, the 'El Niño phenomenon' as a scientific category was born in the early 1890s. But it was seen as little more than a regional geographical curiosity by foreign scientists for many years.

El Niño burst onto the international scientific scene soon after the next major event in 1925-1926, thanks in large part to the work of a single scientific traveler, the U.S. ornithologist and conservationist Robert Cushman Murphy (1887-1973). He happened to be in Peru studying marine birds when this event struck. Like any good environmental scientist, Murphy was not satisfied with his own limited perceptions, and he rapidly organized an observation network to investigate this noteworthy climate anomaly. For this purpose, he relied mainly on reports from resident U.S. engineers, businessmen, diplomats, and military men. His understanding of El Niño was fundamentally shaped by foreign enclaves in Peru.

Science studies (especially sociology of scientific knowledge) has focused an immense amount of attention over the last couple decades on the *local* social environment in which scientists operate. Like the laboratory, museum, botanical garden, or scientific society, foreign enclaves provided a real geographical place "in the field" that influenced the construction of scientific knowledge. In this important historical case, I am not talking about the kind of sealed-off islands of "exact science" or colonial hygienic institutions we are used to hearing about. Rather, I am focusing on foreign economic and political enclaves involved in science, places where controlled interaction between "natives" and "foreigners" was supposed to occur, though I do not want to suggest that this interaction typically occurred on anything like an equal basis.[2]

Much less has been said about what happens to this knowledge once it leaves these contexts. What is it about scientific knowledge that enables it to move with such efficiency across great geographical and temporal distances, even broad social and cultural gulfs? Knowledge of the 1925-1926 El Niño phenomenon passed rapidly from Peru to the United States and Germany and then across the Pacific because of preexisting economic and political ties between these places. Intense competition for global economic hegemony--in many cases via overt imperialism--provided one major stimulus for encouraging the flow of information through these channels. The scientists involved in this exchange were intensely aware of this, yet paradoxically, they organized elaborate institutions such as the Pan-Pacific Science Congress to provide a space for the free exchange of environmental knowledge produced by these networks. In essence, the discovery--or more properly, the invention--of what we now call the El Niño-Southern Oscillation phenomenon came about because such networks existed. The "enclave vision" that produced this discovery was inherently far-sighted, indeed globalist in its view of the world, though often imperialist in its intentions and effects.

I

Robert Cushman Murphy's position as a curator of birds at the Brooklyn Museum and then American Museum of Natural History in New York provided him with the opportunity to travel from Baja California to the sub-Antarctic ocean to study oceanic birds of the Western Hemisphere. From December 1924 to early March 1925, he happened to be in the field on his second expedition to Peru when he observed dramatic changes in the coastal ecology as the "El Niño countercurrent" began its onset. As a trained naturalist, he readily noticed the appearance of caimans, "man-eating sharks," dolphin-fish, frigate birds, and several other tropical species far south of their normal range. He also noted the massive deaths of plankton, fish, and marine birds endemic to the Peru Current and the complete absence of sub-Antarctic petrels. He took regular air and sea-surface temperatures as he toured the Gulf of Guayaquil in a motor launch provided by the International Petroleum Company (IPC), a Canadian-incorporated subsidiary of Standard Oil of New Jersey working the oil deposits of far northwestern Peru and southwestern Ecuador.[3]

As Murphy slowly expanded his network of informants, he looked first to IPC managers and engineers. These foreign-born officials not only managed the activities of an industrial establishment, but also directly governed this isolated, albeit immensely valuable territory for the Peruvian state. One IPC functionary, L. M. Stone--who also happened to be mayor (*alcalde*) of the district of Máncora--provided Murphy with his weather diary and the translated diary kept by the Municipalidad de Piura in the departmental capital. Even better, two staffers of the IPC geology department, Frank Kroeger and E. Willard Berry, provided air and sea-surface temperatures from two sites. Unfortunately, they installed rain gauges too late to measure directly the intense rains of March 1925, though they passed on rough quantitative estimates made by a well driller and locomotive engineer using buckets and barrels on hand. These men were fascinated by the catastrophic floods that devastated the local transport infrastructure and the social life of the few local peasants "who are not under the control of the petroleum companies". Meanwhile, these rains provided them with a brief opportunity to indulge in a North American pastime: hunters among them were delighted by the hordes of wild ducks that descended on the uncountable small lakes left by this inundation.[4]

Murphy was apparently unaware at first of similar work being done by the German-Peruvian agri-business Gildemeister & Co. On 1 December 1924, the general manager of Gildemeister's new port facility at Puerto Chicama, Pieter Reimers, started taking twice-daily measurements from a basic set of meteorological instruments including a sea-surface thermometer at the end of the company's 500 meter pier--just in time to observe the onset of this El Niño event. Murphy only came into possession of this data set because of the intervention of the U.S. ambassador to Peru Miles Poindexter who had his secretary Harriett Meek transcribe (and probably translate) data sheets that had been deposited with the Sociedad Geográfica de Lima. Puerto Chicama happens to be in a good location on the north coast of Peru to detect the environmental variations of significant El Niño events, but more importantly, this station has operated continuously since this time, and so its single sea-surface temperature thermometer has often been used by later scientists as *the* quantitative definition of an El Niño event.[5]

Meanwhile, Murphy's reports sparked the interest of his friend Isaiah Bowman (1878-1950), the famed South American explorer who presided over the American Geographical Society (AGS) in New York. Bowman immediately offered to publish Murphy's eyewitness report. It appeared in *The Geographical Review* in January 1926 and quickly became the classic account of the "remarkable change in the customary weather of the arid west coast of South America" during the austral summer of 1925 for scientists as far away as Hamburg and Java. Its translation and publication in two Peruvian scientific journals by José Antonio de Lavalle y García (1888-1957), one of Murphy's foremost Peruvian-born collaborators, made it the classic study for readers in El Niño's homeland, as well. Taken at face value, Murphy's publications seem to have relied almost entirely on data provided by a network of foreign observers in Peru and Ecuador. Therefore, it is important to point out that Murphy depended heavily for help in his research on the Compañía Administradora del Guano, a parastatal company that managed Peru's guano-producing coastal bird colonies. In a footnote to his translation, Lavalle took the opportunity to redress this slight by taking credit for accompanying Murphy and influencing his understanding of the El Niño phenomenon.[6]

Bowman took the initiative to recruit other observers for Murphy's expanding network: he convinced Otto Holstein, a retired U.S. Army major and "experienced observer" for the U.S. Weather Bureau, to set up a meteorological observatory at the coastal city Trujillo in 1926 using instruments supplied by the AGS. They provided Holstein with maximum and minimum thermometers, a sling psychrometer, rain guage, mercury barometer, barograph, hydrograph, and thermograph, thereby making the Trujillo observatory one of the most advanced in Peru for a brief time.[7] In his reports to New York, Holstein reported more than his daily observations; in fact, he organized his own elaborate network of local informants. They included beachgoers, the local port authority, ships of opportunity run by Grace Lines (a New York-based shipping company), the local U.S. consul, railway workers, even observers in several towns in the nearby sierra. But Bowman had much bigger dreams. He envisioned an expansive network of "competent observers" in the "Desert section" of South America who would provide data that could be used to predict the repetition of such climate anomalies. Following Murphy's lead, he explicitly identified foreign-owned commercial enterprises as the backbone of this network, and he thought it should be administered from a central point in the United States.[8] But where?

II

The ambitious new administrator of the Scripps Institution of Oceanography (SIO) eagerly offered up La Jolla, California, as the new metropolitan center for this network. Like Bowman, Thomas Wayland Vaughan (1879-1952) had worked much of his career to build a vast scientific empire for the United States. As the autocratic director of the U.S. Geological Survey's Coastal Plain Investigations, he took the lead in extending the Survey's purview to the entire Caribbean Basin. Even before he arrived at Scripps, he had identified the Pacific Basin as the next frontier for U.S. science. Thanks to extensive contacts with foreign scientists in Europe and Asia, he was intensely aware of imperialist competition for influence over this region, though the rules for building scientific prestige during this period mandated that research should be pursued by "nations acting in concert" and done for the benefit of "all mankind".[9]

Following the lead of colonial meteorological services on the other side of the Pacific, the SIO's resident physical oceanographer George F. McEwen (1882-1972) had initiated a program in the late 1910s to provide seasonal forecasts based on physical calculation of air-sea interactions for Southern California utility companies. Vaughan enthusiastically promoted McEwen's program after Vilhelm Bjerknes, the Norwegian "father" of modern meteorology, gave his personal seal of approval. When Murphy's investigations of the 1925 El Niño came to light, both Vaughan and McEwen immediately recognized the potential value of far-fledged observations in the Pacific for these forecasts. They could not have helped but notice the correlation between climate events in Peru and California: exceptionally warm winter sea-surface temperatures off the Scripps pier, major changes in the distribution of sardine and albacore tuna, and immense damage to Scripps's own physical plant caused by torrential rains and wave action.[10]

Vaughan did not wait for the AGS to give its go-ahead before he approached the U.S. Office of Naval Intelligence for help in making contacts in South America. The Secretary of the Navy put Vaughan in touch with the U.S. Naval Mission to Peru and U.S. Naval Attaché in Chile. U.S. naval officers in Peru responded enthusiastically to Vaughan's request. They and their Peruvian assistants initiated daily temperature measurements at five sites along the Peruvian coast using calibrated thermometers provided by Scripps that had been delivered via diplomatic pouches to avoid paying import duties. The head of the U.S. Naval Mission also arranged to pass on coastal observations taken by the Anglo-Ecuadorian Oil Fields, Ltd., in Peru and Ecuador.[11] The U.S. Naval Attaché in Chile, an old friend of Vaughan's with oceanographic experience from their naval service together in Hawaii, utterly failed to recruit the Chilean Hydrographic Office to Vaughan and McEwen's cause. So he turned to the captains of U.S.-owned steamship lines. They returned several sea-surface temperature transects from the New York-Canal Zone-Valparaiso route. This officer also recruited the manager of the Braden Copper Company to send averaged monthly temperature and precipitation records back to La Jolla, though the company refused to pay to transcribe the company's daily records.[12] Meanwhile, a good friend of Vaughan's at the U.S. Hydrographic Office put him in contact with Pedro C. Sánchez, an official at the Mexican Dirección de Estudios Geográficos y Climatológicos at Tacubaya. Sánchez agreed to send articles and data tables published by his bureau to La Jolla. Finally, an engineer in charge of dam development for the Brazilian Traction, Light & Power Co. (incorporated in Toronto) became enamored with the prospects for long-range weather prediction after chatting with Vaughan and McEwen during a trip to southern California. He tried to set up a corresponding southern-*Atlantic* network of land and sea observers that would report to La Jolla where one of McEwen's disciples would develop seasonal forecasts for southeastern Brazil.[13]

These observation networks faced a number of problems exacerbated by the immense geographical distance separating La Jolla and South America: lack of continuity and consistency in reports, lost data sheets, broken or miscalibrated thermometers, confusion over the temperature scale (Scripps unwisely supplied Fahrenheit thermometers).[14] To remedy the "scattered and incomplete" nature of this data (which makes Gildemeister's & Co.'s Puerto Chicama continuous series from December 1924 to the present all the more remarkable, by comparison) Bowman proposed "a joint expedition" to the region involving the AGS and Scripps Institution of Oceanography. This would not be "a mere dash for newspaper purposes," but "a real scientific survey" that would put "research both in South America and the Pacific . . . upon a high plane".[15] This got Vaughan to thinking, and he began to make plans for a grand oceanographic voyage to the southeastern Pacific modeled after the German *Meteor* expedition to the South Atlantic that would use the Carnegie Institute of Terrestrial Magnetism's state-of-the-art sailing ship. Sadly, fire destroyed the all-wooden *Carnegie* before Vaughan could implement his plan. But he did not give up, and he and Scripps staff participated in a series of small yacht expeditions to the eastern tropical Pacific during the 1930s.[16]

But the most galling problem facing Vaughan's network had little to do with logistics. The head of the U.S. Weather Bureau, C. F. Marvin, expressed a complete lack of interest in the data Vaughan's associates had compiled. Marvin was "very skeptical of the real value and necessity of any such elaborate program" to provide marine meteorological data, since this network's data was error prone and often discontinuous. "A few . . . observations set down in a particular way at a particular time do not represent oceanographic facts," Marvin declared. Furthermore, he thought it was a "waste of labor of computation" to systematically rid them of errors "even if we had funds available," much less publish them for international consumption. His lack of faith meant U.S. meteorologists would have little access to, much less use, for this data.[17]

III

Marvin was completely out of touch with the trend toward "international cooperation . . . between practically all the leading nations of the world" in marine meteorology during the 1920s.[18] In fact, there were dozens of meteorologists outside the United States who were interested in data provided by the AGS-SIO network.

The Pan-Pacific Science Congress, an international meeting modeled after the Pan-American Science Congress, provided the main conduit for the rapid dispersal of scientific understanding of the El Niño phenomenon during the 1920s. It is rather simple to explain how: both Vaughan and McEwen were intimately involved with their organization, beginning with the Pan-Pacific Science Congress held at Honolulu in 1920. In 1926 at the Third Pacific Science Congress in Tokyo, at Vaughan's behest, McEwen presented a summary of Robert Cushman Murphy's work "on the currents and temperatures of the coastal waters of western South America and their inter-relations with the heavy rains in Peru". This presentation highlighted Murphy's uncertainty whether "El Niño" was a "restricted coastal" phenomenon or a hemispheric "surface movement of colossal extent".[19]

Dutch colonial scientists in Java provided an answer to this question. When he returned to Batavia (now Jakarta) after attending the Tokyo meeting, the director of the Netherlands East Indies Royal Magnetic and Meteorological Observatory passed on Murphy's observations to his colleague Hendrik Petrus Berlage, Jr. (1896-1968), the son of a prominent Dutch socialist architect. Berlage had just taken over this colonial institution's meteorological program from Cornelis Braak. Braak had been working for several years to use the Southern Oscillation, a quasi-cyclic variation in atmospheric pressure over the South Pacific, to make seasonal precipitation forecasts for the Netherlands East Indies. While heading the Indian Meteorological Service, Sir Gilbert Walker had first identified the Southern Oscillation when using statistical correlations between global meteorological phenomena to try to predict the Indian monsoon. Murphy's work on the 1925 El Niño filled in a crucial piece of the puzzle both Walker and Braak had been trying to solve. Berlage made the crucial connection between Peruvian events and climate anomalies on the other side of the Pacific. He somehow obtained Víctor Eguiguren's 1894 chronology of precipitation anomalies in northern Peru, and he determined that they correlated almost exactly with the six-to-seven year cycle in the "east monsoon" since 1864. He announced his results at the 1929 Pacific Science Congress held in Batavia to showcase Dutch colonial science.[20]

Berlage's discovery had immediate consequences for international El Niño research. Gerhard Schott (1866-1961), the director of Deutsche Seewarte in Hamburg, happened to be in attendance at the Batavia congress. (Deutsche Seewarte was the central node of an elaborate, systematic observation network based on data provided by German "ships of opportunity," and probably the foremost oceanographic research institution in the world at the time.) During his trip home across the Pacific, Schott took a detour to Peru explicitly to find out more about the El Niño phenomenon. In 1931, he authored a fundamental study of anomalies in the Peru Current that posited a physical explanation of El Niño as an oceanographic phenomenon. It was quickly translated into Spanish and published in Peru.[21] Inspired by Berlage's progress, McEwen returned to his seasonal forecasts with renewed vigor, though with declining success, and Vaughan even tried to lure the meteorologist Horace R. Byers, one of Carl-Gustaf Rossby's earliest disciples at MIT, to help with this work at SIO. If Byers had accepted Vaughan's offer, Scripps might have become a center for marine meteorology almost four decades before SIO finally hired its first real meteorologist, Jerome Namias, to work on this exact problem. Meanwhile, the Compañía Administradora del Guano in Peru hired Erwin Schweigger, a German fishery scientist, to work on oceanographic problems; his work over the next three decades established the main empirical foundation for subsequent El Niño studies in Peru.[22]

IV

In conclusion, the idiosyncracies of these networks linked to foreign enclaves laid down many of the channels and boundaries for future scientific investigation of what we now call the El Niño-Southern Osciallation (ENSO) phenomenon. H. P. Berlage's ability to integrate himself into the transnational network founded by Robert Cushman Murphy put him in the position to be the first to posit a physical relationship between these two major climatic phenomena. Over thirty years later, the great Norwegian-American meteorologist Jacob Bjerknes (1897-1975) was able to formulate a plausible physical mechanism for these phenomena because he was able to negotiate a much larger, yet basically similar set of international scientific networks. In fact, U.S. tuna fishermen, a sort of moving enclave in the eastern tropical Pacific, played a pivotal role in attracting Bjerknes to investigate the El Niño phenomenon in the first place. Bjerknes profited greatly from Berlage's decision to devote the rest of his life to investigations of the Southern Oscillation, though Bjerknes decided to name his theory the Walker Circulation after the original discoverer of the Southern Oscillation. Berlage continues to receive much less credit than he deserves for his fundamental work, partly because he remained attached to the same old approach toward meteorological cycles he helped develop in the colonial context years after other climate scientists had relegated it to the dustbin of science history.

Perhaps this essay only makes the rather bland observation that foreign economic and political penetration established a beachhead for meteorology and oceanography in Peru. But I think this story of the internationalization of El Niño research says something more about the creation and transfer--or production and trade--of scientific knowledge. Modern science co-evolved with modern global networks of trade and influence characterized by immense concentrations of wealth and power. I think one of the keys to understanding the association between science and global economic and political prowess is to understand the relation of science to foreign enclaves, especially in post-colonial societies. Certainly, a key to understanding the history of El Niño is to understand the international networks involved in its invention as a scientific concept.

Endnotes

[1] Camilo N. Carrillo, "Estudios sobre las corrientes oceánicas y especialmente de la corriente de Humboldt", *Boletín de la Sociedad Geográfica de Lima*, 2 (1892): 72-111; Víctor Eguiguren, "Las lluvias en Piura", *Boletín de la Sociedad Geográfica de Lima*, 4 (1894): 241-257; Federico A. Pezet, "La Contracorriente 'El Niño' en la costa norte del Perú", *Boletín de la Sociedad Geográfica de Lima*, 5 (1896): 457. Besides appearing in the *Report of the 6th International Geographical Congress*, London, John Murray, 1896, the latter was abstracted in *Annalen der Hydrographie und Maritimen Meteorologie*, 23 (1895), p. 466. See also Leoncio López-Ocón Cabrera, "El nacionalismo y los orígenes de la Sociedad Geográfica de Lima", in *Saberes andinos: Ciencia y tecnología en Bolivia, Ecuador y Perú*, ed. Marcos Cueto, Lima, Instituto de Estudios Peruanos, 1995, pp. 109-125.

[2] On the significance of place in the production of scientific knowledge, see Steven Shapin, "Placing the View from Nowhere: Historical and Scoiological Problems in the Location of Science", *Transactions of the Institute of British Geographers*, n.s., 23 (1998) *1*: 5-12. On the "place" of science in the field and colonial context, see Henrika Kuklick and Robert E. Kohler, eds., "Science in the Field", *Osiris*, 2d ser., 11 (1996); Roy MacLeod, ed., "Nature and Empire: Science and the Colonial Enterprise", *Osiris*, 2d ser., 15 (2000).

[3] Robert Cushman Murphy, "Equatorial Vignettes: Impression of the Coasts of Peru and Ecuador, 1925", *Natural History*, 25 (Sept.-Oct. 1925), *5*: 431-449; idem, "Oceanic and Climatic Phenomena along the West Coast of South America during 1925", *The Geographical Review*, 17 (1926), *1*: 26-54; idem, *Oceanic Birds of South America*, New York, American Museum of Natural History, 1936, vol. 1, pp. 25-29.

[4] Murphy, "Oceanic and Climatic Phenomena", *op cit*, passim; E. Willard Berry, "Meteorological Observations at Negritos, Peru, December, 1924, to May, 1925", *Monthly Weather Review*, 55 (Feb. 1927), *2*: 75-79, p. 76.

[5] Murphy, "Oceanic and Climatic Phenomena", *op cit*, pp. 26 n. 1, 32 fig. 2; Erwin Schweigger, "Los fenómenos en el mar de 1925 a 1941 en relación con observaciones meteorológicas efectuadas en Puerto Chicama", *Boletín de la Sociedad Geográfica de Lima*, 59 (1942), *3*: 247-258, 59 (1942), *4*:267-316, pp. 247-250.

[6] Murphy only referred to Lavalle in a footnote directing readers to "an important tabulation" of meteorological data that provided "further illustration of the normal temperature relations" on the guano islands; Murphy "Oceanic and Climatic Phenomena", *op cit*, p. 26, 32, 35 n. 9; idem, "Recent Oceanic Phenomena along the Coast of South America", *Monthly Weather Review* 53 (Mar. 1925), *3*: 116-117, p. 117; cf. Murphy, "Fenómenos oceánicos y climatéricos en la costa occidenta de Sur-América durante el año 1925", trans. José Antonio de Lavalle y García, *Boletín de la Compañía Administradora del Guano* (Lima), 2 (Mar. 1926), *3*: 137-179, *Boletín de la Sociedad Geográfica de Lima*, 43 (1926), *2*: 87-125. On the role of the Compañía Administradora del Guano as a promoter of science in Peru, see Gregory T. Cushman, "The Lords of Guano: Scientists and the Management of Peru's Marine Environment, 1890-1973", Ph.D. diss., University of Texas at Austin, forthcoming.

[7] John K. Wright to T. Wayland Vaughan, 2 July 1926, Scripps Institution of Oceanography (SIO), Office of the Director, Vaughan, (AC 11) Scripps Institution of Oceanography Archives, University of California, San Diego, La Jolla, CA, box 1, fol. 22 [hereafter, Vaughan papers box:folder].

[8] Isaiah Bowman to David White, 15 June 1926, Vaughan papers 1:21.

[9] Vaughan to W. W. Campbell, 10 Aug. 1926; G. W. Littlehales, "Program for Initial Researches in the Pacific Ocean", 16 Jan. 1922; Vaughan to F. R. Lillie, 10 Nov. 1927, Vaughan papers 1:23, 1:1, 1:38; Elizabeth N. Shor, "The Role of T. Wayland Vaughan in American

Oceanography", in *Oceanography: The Past*, ed. M. Sears and D. Merriman, New York, Springer-Verlag, 1980, pp. 127-137.

[10] Vaughan to Crosley, 16 Mar. 1927, Vaughan papers 1:29; William E. Ritter and George F. McEwen to Melville Klauber, 9 Nov. 1918; Beecher [Sterue?] to Ritter, "List of Names of Persons to Whom Seasonal Forecasts Have Been Mailed", 16 Dec. 1918; Vilhelm Bjerknes to Vaughan, 30 Sept. 1924, SIO, Biographical Files, (AC 5) SIO Archives, box 10, fol. 346, 347 [hereafter, SIO Biographical Files box:folder]; Vaughan to Ralph J. Chandler, 23 Mar. 1926; Vaughan to R. G. Sproul, 7 Apr. 1926, Vaughan papers 1:18, 1:19. Cf. Richard H. Grove, "The East India Company, the Australians and the El Niño: Colonial Scientists and Ideas about Global Climatic Change and Teleconnections between 1770 and 1930", in *Ecology, Climate and Empire: Colonialism and Global Environmental History, 1400-1940*, Cambridge, UK, White Horse Press, 1997, pp. 125-141; Lewis Pyenson, *Empire of Reason: Exact Sciences in Indonesia, 1840-1940*, Leiden, E. J. Brill, 1989, ch. 3; Robert Marc Friedman, *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology*, Ithaca, NY, Cornell University Press, 1989.

[11] Vaughan to Galbraith, 22 May 1926; Vaughan to David White, 28 May 1926; D. McD. Le Breton to Vaughan, 5 June 1926; Vaughan to Bowman, 11 June 1926; A G. Howe to SIO, 20 July 1926; A. J. Hepburn to SIO, 8 Dec. 1926; Bowman to Vaughan, 7 Mar. 1927; Vaughan to Bowman, 15 Mar. 1927; Charles Gordon Davy to Vaughan, 16 Apr. 1929, Vaughan papers 1:20, 1:21, 1:22, 1:29, 2:58.

[12] R. L. Walker to Vaughan, 19 Nov. 1926, 26 Apr. 1927, 12 Nov. 1927; I. H. Mayfield to Vaughan, 29 May 1929, 10 June 1929, 14 June 1929, 4 Sept. 1929; D. Cook to Vaughan, 26 Nov. 1928, 14 Jan. 1929, 8 July 1929, 13 May 1929, Vaughan papers 1:25, 1:30, 1:38, 2:58, 2:61, 2:53, 2:55, 2:58.

[13] Vaughan to Littlehales, 11 June 1926; Vaughan to Pedro C. Sánchez, 23 Sept. 1926; Sánchez to Vaughan, 5 Oct. 1926; A. W. K. Billings to T. W. Vaughan, 7 Feb. 1931, Vaughan to A. W. K. Billings, 9 Feb. 1931, Vaughan papers 1:21, 1:24, 1:25, 2:76.

[14] Howe to Director of Naval Intelligence, 2 May 1927; J. S. Abbott to Jefe de Estado Mayor General, 28 May 1927, Vaughan papers 1:30; Nicolás Zavala y Zavala to Director del Material, 3 June 1927, Vaughan papers 1:31.

[15] Bowman to Vaughan, 15 June 1926, Vaughan papers 1:21.

[16] Vaughan to T. H. Morgan, 16 June 1928; Vaughan to Henry B. Bigelow, 25 Oct. 1928; Vaughan to W. W. Campbell, 9 Apr. 1930; Vaughan to Waldo Schmitt, 19 Dec. 1933; Schmitt to Vaughan, 22 Dec. 1933, Vaughan papers 1:48, 1:52, 2:66, 2:97.

[17] C. F. Marvin to Vaughan, 8 Dec. 1927, Vaughan papers 1:40.

[18] Vaughan to Members of the Advisory Board on SIO, 19 June 1928, Vaughan papers 1:48.

[19] Vaughan to Bowman, 11 June 1926, Vaughan papers 1:21; Murphy, "Oceanographic Work Originating in the New York Region during 1925-1926", in *Proceedings of the Third Pan-Pacific Science Congress, Tokyo, October 30th-November 11th 1926*, Tokyo, National Research Council of Japan, 1928, vol. 1, pp. 219-220. See also, Philip F. Rehbock, "Organizing Pacific Science: Local and International Origins of the Pacific Science Association", in *Nature in Its Greatest Extent: Western Science in the Pacific*, ed. Roy MacLeod and Philip F. Rehbock, Honolulu, University of Hawaii Press, 1988, pp. 195-221.

[20] *Committee on the Physical and Chemical Oceanography of the Pacific: Reports of the Chairman, T. Wayland Vaughan*, n.p., n.d. [Tokyo, 1926], George Francis McEwen Papers, (MC 21) SIO Archives, box 8, fol. 1, f. 8-9, 19, 21-22; H. P. Berlage, Jr., "Arguments for the Existence of a Seven-Year Cycle in the Meteorological Elements of the Stations in or Near the Pacific

Ocean", in *Proceedings of the Fourth Pacific Science Congress, Java, May-June 1929*, Batavia, Bandoeng, 1930, vol. 2A, pp. 11-16; Pyenson, *Empire of Reason*, ch. 3.

[21] Gerhard Schott, "Der Peru-Ström und seine nördlichen Nachbargebiete in normaler und anormaler Ausbildung", *Annalen der Hydrographie und Maritimen Meteorologie*, 59 (1931): 161-169, 200-213, 240-252; idem, "La corriente del Perú y sus límites norteños en condicionales normales y anormales", *Boletín de la Compañía Administradora del Guano*, 9 (Mar.-Apr. 1933), *3-4*: 65-117; idem, "Conferencia del Profesor Gerhard Schott, del Observatorio Marítimo de Hamburgo: La circulación general de los océanos", *Boletín de la Sociedad Geográfica de Lima*, 49 (1932), *3-4*: 107-114.

[22] Horace R. Byers to McEwen, 7 Nov. 1930, SIO Biographical Files 11:351; on Schweigger, see Cushman, "The Lords of Guano", op. cit.