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Kerby C. Alvarez

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The scientific endeavors of the Observatorio Meteorológico de Manila in the nineteenth century brought about major changes in colonial science in the Philippines. The observatory pioneered the modern study of weather, climate, and natural hazards through the use of instruments and apparatus it invented and produced. This article explores how, through its programs and projects, the observatory operationalized colonial science, particularly meteorology, to promote a new understanding of weather and natural phenomena and create new avenues for public engagement.

KEYWORDS: OBSERVATORIO DE MANILA · COLONIAL SCIENCE · JESUITS · METEOROLOGY · METEOROLOGICAL INSTRUMENTS

The nineteenth century witnessed major developments in science. Colonizers and colonial territories acquired scientific knowledge and technologies from different countries in Europe, particularly from France and Germany. The second half of that century saw the emergence of a new mentality concerning science, particularly regarding the use and essence of scientific instruments. During this period instruments flooded major economic and academic centers and secured the recognition of science as a primary epistemological framework in achieving societal progress (Camba 2010, 120). As Michael Adas (1989, 263) argues, the introduction of such key instruments allowed Europeans to imagine and explore the natural world of their colonial territories. Advancements in the sciences and mathematics heightened the colonizers' valuation of accurate enumerations and estimates in their political and economic endeavors (ibid.). The colonizers applied scientific knowledge to advance production, communications, and military technology in their respective colonies in Asia (ibid., 269). In addition, colonial expansion promoted the rapid transmission of new scientific ideas among colonies and between colonizer and colony over a large area of the world (Grove 1995, 7).

In analyzing the development of science in the Philippines, Warwick Anderson (2007, 288–89) argues for a nonlinear perspective. Nevertheless, colonial science played a vital role in the development of colonial societies. Centuries of scientific expeditions and research endeavors bore fruit in the establishment of colonial institutions catering to specific economic needs. As a "dependent science . . . based primarily upon institutions and traditions of a nation with an established scientific culture" (Basalla 1967, 613), colonial science in the Spanish colonies, for example, received greater attention than other colonial endeavors, given that most metropolitan governments aimed at mechanizing modern forms of knowledge production to sustain and/or salvage the economies of their peripheral territories. Robert Peckham's (2016, 7) analysis of colonial medicine sums up important uses of colonial science for the colonizers: "it functioned as a means of integrating colonized peoples into the institutions of the modern state [and it] served to standardize behavior and practice, making indigenous societies more tractable."

Although this phenomenon intensified the colonizers' control over their colonies, it also paved the way for the spread of "formalized" and localized sciences and the establishment of scientific institutions (Chambers and Gillespie 2000, 230). Global and local colonial dynamics suggested the creation of "colonial science" in the peripheral territories, in contrast to the usual structure of knowledge production wherein ideas originated from European countries and moved to their colonies.

Colonial science gained strength as seen in the rise in the number of practicing scientists whose education and work were buttressed by external scientific tradition and reinforced by their local colonial experiences (Basalla 1967, 614). At this point science was equated not only with knowledge production but also with the instruments, techniques, and services used in the production of this knowledge (Raj 2007, 10). Colonial science was categorically, for a period of time, meant for development, manifested both in the rise of ideas and institutions and the growing eagerness among sectors to attain specific social reforms. Colonial science was a domain of knowledge strategically designed to pursue the growth of colonies in the ways that empires perceived science as serving their respective economic interests. Although it was widely accepted that manifestations of ethnoscience were present in colonial societies, meteorological science, which was founded on the pragmatic and empirical character of knowledge, was indeed a colonial legacy.

This study presents a history of the Manila Observatory, known in the nineteenth century as the Observatorio Meteorológico de Manila, in the context of the era of instrumentation and institutionalization in colonial sciences.[1] This scientific agency enhanced the instrumentation of sciences in the archipelago: the *observatorio* (observatory) pioneered the use of new and up-to-date observation and recording instruments, marking a major development in the understanding of weather and atmospheric phenomena in the nineteenth century. Under the initiative and supervision of the Jesuit scientists of the Ateneo Municipal de Manila, it was established and grew as a private institution. Its designation as the state's official meteorological agency decades after its creation expanded the scope of its scientific work and gave it the mandate to further enhance its meteorological studies as well as the communication of weather knowledge for the benefit of the government and of the public in general.

To chart the scientific endeavors of the Manila Observatory that brought about major changes in colonial science in the Philippines, this study explores the idea of colonial science as seen in the programs and projects of the observatory, such as the introduction of a new way of reading the weather through numerical calculation and prediction of atmospheric disturbances, the purchase and use of instruments from Europe along with the promotion of local inventions, the observatory's service to the commercial sector, and its engagement of Filipinos in scientific work and activities. Colonial science, specifically meteorology, served as a mechanism not merely to subjugate people but also to protect the commercial industry as well as enable the seemingly left-out colony in the Pacific to serve as a model of scientific development. As a "colonial laboratory" the observatory was a source and repository of modern scientific knowledge. At the same time, it signaled a shift in colonial science from the "laboratory" to the "public," that is, from colonial scientific works perennially confined in laboratories to scientific activities serving the interest of select public sectors.

Meteorology as Challenge to Religious Views of the Weather

The evolution of weather reading in the Spanish Philippines can be understood diachronically. A thematic link between the dominant religious views, local knowledge, and the number- and instrument-based weather reading can be constructed to facilitate a clearer understanding of the phenomenon of science at the time the observatory was established in the second half of the nineteenth century.

Documentary sources suggest people understood weather phenomena and natural hazards from a religious perspective (de los Reyes 1889; Manila Observatory Archives [MOA] n.d.; Selga 1936). Novenas and church accounts evoked the religious perspective in understanding natural hazards and disasters; prayers and rituals begged the heavens for fair and good weather (Bankoff 2004). In some parts of Luzon people prayed to venerated beings known as *pintakasi* or patron saints such as San Vicente Ferrer, San Ramón Nonato, and San Isidro Labrador (Vidal 1904, 48–49; Pardo de Tavera 1960, 76–77; Palacio 1934). In this perspective disasters were attributed to God's wrath (Bankoff 2003; Camba 2010; Abejo 2005).

Many communities relied on local forms of knowledge to predict and anticipate possible threats or effects of certain environmental threats (de los Reyes 1889; Malay and Malay 1955). Narratives of disasters showed a frequently devastated archipelago.[2] Viewed from different perspectives—religious, cultural, economic, and political—these disasters revealed the social grammars of societies (Hoffman and Oliver-Smith 1999, 1). Natural hazards in the Spanish Philippines exposed the underlying contexts and problems that people faced before, during, and after such calamities.

John Bowring (1963, 44), the nineteenth-century English traveler, observed how atmospheric disturbances distressed the islands: "violent hurricanes produce fearful devastations; typhoons cover the coasts with wrecks, inundations of rivers and excessive rains destroy the earth's produce." Emphasizing the destructiveness of typhoons, Greg Bankoff (2003, 41; 2007a, 157) argues that "the loss of life and property caused by tropical cyclones and their epiphenomena such as landslides, storm surges and floods are greater than any natural hazard in the Philippines." The occurrence of typhoons can be attributed primarily to the archipelago's geographic location and atmospheric patterns. These typhoons cause severe destruction to properties: dwellings, crops, domesticated animals, and infrastructures (Bankoff 2007b, 285). Aside from damages to life and property, they also engender extreme fear that prevents people from protecting themselves from such events. Miguel Selga, former director of the Philippine Weather Bureau (1926–1948), even coined the term "tifonitis" to describe the widespread fear among people in the archipelago due to the frequency or extraordinary intensity of typhoons in 1934 (Bankoff 2003, 174–75; 2007a, 179).

Drawing from these details, we can infer that people regarded as apparently novel the scientific mindset of understanding the seemingly unpredictable sky. Colonial science, through meteorology, became a mechanism that challenged the prevailing notion that the atmosphere was under the control of spirit beings. Through the observatory's efforts, these views changed. Some sectors of the public, who were aware of the observatory's scientific activities, gradually appreciated the precise prediction and calculation of weather patterns.

Jesuit Meteorology: Seeds of Colonial Science Education

The introduction of meteorological science, which coincided with the return of the Jesuits in the Pacific, signaled the propagation of new forms of scientific knowledge and appreciation manifested through the use and invention of instruments. The Jesuits' passion in meteorology, rooted in their engagement with progressive scientists and institutions in Europe, paved the way for new scientific advancements to spread throughout the archipelago. Natural hazards that occurred in the Philippines tested the Jesuits' knowledge of meteorology, but at the same time helped develop a new understanding of the natural environment and threats to the people's lives.

These Jesuit initiatives in science can be attributed to their advocacy of spiritual and scientific development by establishing schools, universities, and observatories (Udias 2003). The Jesuits' scientific research reflected their conviction about divine responsibility. As a well-known Jesuit scientist, Pierre Teilhard de Chardin (1968, 201), explains:

> Why is it of such importance that we Jesuits share so fully in man's research that we permeate and impregnate it with our faith and our love for Christ? Why? Simply because (if what I have just been saying make sense) in the nature that surrounds us, research is the form in which the creative power of God is hidden and operates the most intensely. Through our research, now being, a further increase in consciousness emerges in the world.

Udias (1996, 2308) adds:

> Scientific works offered Jesuits a forum in which they could aid human progress. For a religious order that had made education its principal work, dedication to the natural sciences was essential . . . Jesuits displayed an implicit and even explicit interest in science to show its harmony with religion. . . . Jesuit scientific work was exercised as part of their "apostolic spirituality." The fundamentally dynamic nature of the apostolic spirituality of Jesuits and the emphasis that they place on Christian service channels the religious sentiment outward and into worldly activities that are not usually associated with the religious life. It is natural that this mentality directed and continues to direct Jesuit attention to modern science.

The Jesuits fulfilled their commitment to science through the establishment of scientific agencies in different parts of the world. Among these agencies four were focused on meteorological undertakings, specifically on tropical hurricanes: Belen in Cuba, Tananarive in Zimbabwe, Zikawei in China, and Manila in the Philippines (ibid., 2309). The objectives of the Jesuits' project of establishing a network of observatories in mission lands may be summarized into two: (1) to institutionalize their passion for science, particularly in astronomy and meteorology; and (2) to study the nature and tracks of *huracanes* (hurricanes) and *tifones* (typhoons) in the Caribbean and the Pacific (Saderra Masó 1915, 24). In Europe and in the Antilles Frs. Angelo Secchi, Esteban Perry, and Benito Vines were among the Jesuit scientists who became popular in this work.

Modern scientific knowledge from Europe became a valuable content in colonial educational systems prevalent during the nineteenth century. Some secondary and tertiary educational institutions included the natural sciences in their curricula. Foremost among these institutions were the Universidad de Santo Tomás of the Dominicans and the Ateneo Municipal of the Jesuits. The Dominicans taught science with particular focus on *vita contemplativa* (contemplative life), emphasizing learning as a means to prepare for reflection on divinity with strict enforcement of theological doctrines (Anderson 2007, 291). The Jesuits introduced new approaches in mathematics and physics to their curricula and taught applied and practical scientific ideas and concepts. Aitor Anduaga (2014, 520) argues that the missionary and educational tasks the Spanish government entrusted the Jesuits reinforced the latter as investigators and professors of science, and not mere functionaries committed to the dissemination of Catholic teachings that used science as stimulus.

Education became the primary means of imparting scientific knowledge. Filipinos who entered the said schools were introduced to scientific concepts and ideas that later proved to be helpful in their critical analysis of social problems as well as in developing Enlightenment ideas such as nationalism, political reforms, and anticlerical sentiments (Anderson 2007, 297). These Filipinos were labeled *ilustrados*—students educated in science, reason, and rationality. Most of them went to Europe to obtain advanced degrees; foremost among them was José Rizal, who pursued medical studies in Madrid in Spain.

In Europe Rizal saw a setting where people engaged in science. He witnessed new landscapes of knowledge—sceneries that enriched his passion for scientific education. Rizal considered scientific reasoning a tool, which he believed was obtainable through education, to emancipate Filipinos from mental imprisonment caused by Spanish rule and subjugation. He also believed that science and reason would instill patriotism among Filipinos (ibid., 298). Rizal's ideas reflected, in general, an appreciation of colonial science in the nineteenth century. As an ilustrado who had access to premierquality education at that time, he experienced the different ways teachers in formal schools taught science. Rizal's academic training introduced him to the colonial science advanced by the Jesuits of the Ateneo. Despite this training, he was apparently frustrated about how science was taught.

Rizal's critique on the state of science and scientific education in the Philippines during his time can be seen in some episodes of his two novels, *Noli me tangere* (1889) and *El filibusterismo* (1891).[3] Emphasizing the allegory of the instruments and the mysterious cabinet in *El filibusterismo*, he showed his desire for Filipino engagement in modern science. We can surmise that his narrative of annoyance stemmed from his apparent awareness of the Jesuits' scientific work at the observatory, especially that of his former teacher Fr. Federico Faura, as well as his exposure to the much wider world of modern science in Europe. As discussed later in this article, the observatory would serve as a space that allowed a select group of Filipinos to be involved directly in the colonial science of meteorology.

Beginnings of Instrumentation: The Observatorio, 1865–1883

Meteorology in most colonies in the second half of the nineteenth century evolved out of waves of knowledge and the pressing need for societies to adapt to the vast challenges of sea trade. Governments and the private sectors of different colonial territories ventured into supporting meteorology that would provide accurate weather observations and forecasts necessary for managing trade and shipping activities on the high seas in order to avoid business losses caused by typhoons.

In several nineteenth-century colonial territories in Asia, meteorological observatories provided numerically calculated and scientifically processed weather-related information that mercantile shipping and trade found very useful. Kevin MacKeown (2011, 9, 11) states:

> The role of observatories in the colonial expansion of Western powers into Asia is not a simple linear history. All the major colonial powers devoted effort to some aspects of the physical sciences usually associated with an observatory and established suitable institutions in that part of the world. . . . The historical importance of all the observatories in that part of the world lies almost entirely in the advances achieved by their pioneering staff in understanding such meteorological phenomena, and in weather forecasting.

We can argue that, as far as the trend in Europe was concerned, academics and universities facilitated the transfer of scientific developments to the colonies, oftentimes through transcontinental and transoceanic exploratory expeditions (Raj 2007, 15). In the eighteenth century Spain made great strides in meteorology. Observatories in Madrid and Cádiz were founded for the use of the naval force; economic societies and medical academies contributed to meteorology, primarily through applications in agriculture and biomedical research (Anduaga 2012, 31–44). The establishment of the Real Academia de Ciencias y Artes de Barcelona, which was meant to initiate the political, economic, and cultural modernization of Spain, proved to be one of the highlights of eighteenth-century science in the peninsula (ibid., 49–51).

In the nineteenth century, however, Spain made few scientific advances, while the rest of Europe saw the fruits of the eighteenth-century Scientific Revolution in fully institutionalized networks that made science more relevant in societal progress (Chambers and Gillespie 2000, 223). As Europe became decentralized, so did science (ibid.). In their attempt to modernize society through science, Spain and its remaining colonies in the 1850s, in effect, were colonized by the scientifically advanced countries and consequently failed to develop a firm scientific, technological, or industrial base of their own (Elena and Ordoñez 2000, 72). Spain's active borrowing of technologies from neighboring countries in Europe resulted in a "reverse colonization," even as the Philippines became highly dependent on external domains and affairs and was controlled by Anglo-American institutions (Fast and Richardson 1987; Legarda 1999).

Due to the lack of scientific initiatives in the home country, modern developments failed to spread to the periphery. In this context, people and institutions in the colonies took the initiative as in the Observatorio del Ateneo Municipal de Manila. The institution studied local weather and natural hazards, relied heavily on instruments and expert Jesuit scientists from Europe, and functioned as a modern scientific agency.

The Jesuit scientists of the observatory pioneered the use of several instruments in the Philippines. On the one hand, they bought instruments from Europe that had been invented by both private individual scientists and fellow Jesuits, with the bulk of the money coming from private donors. On the other hand, the Jesuits of the observatory crafted their own instruments designed for the precise measurement of meteorological conditions and

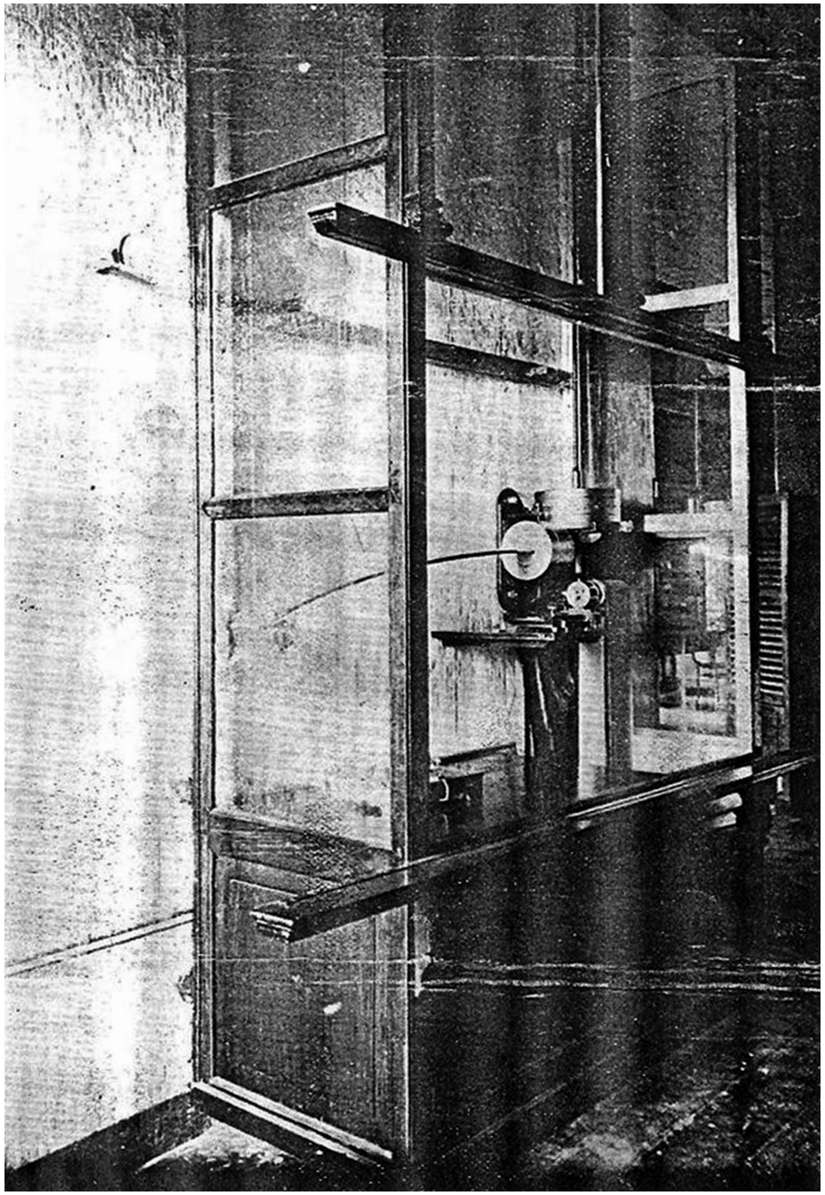

Fig. 1. Secchi's Meteorógrafo Universal

Source: Saderra Masó 1915, 155

disturbances in the archipelago. On their return to conduct missions in the Philippines the Jesuits became one of the major forces behind the modernization of the colony through science.

The beginnings of colonial meteorology in the archipelago can be traced back to the experiments conducted by the Jesuit scientists of the Ateneo Municipal de Manila, Frs. Francisco Colina and Jaime Nonell (Schumacher 1965, 258). In January 1865 Father Colina put instruments such as a thermometer, hygrometer, a barometer that used oil instead of mercury, and an anemometer made of cloth and twine in an abandoned pigeon house. Twice or thrice a day, he recorded all-weather data from his improvised gadgets. The two scientists conducted a meteorological study of a typhoon that hit Manila and its nearby communities in September of that year and published it in the *Diario de Manila* (ibid., 259). This initiative attracted the attention of merchants who immediately saw the value for trade of meteorological studies.

The businessmen approached and asked the superior of the Jesuits in the Philippines, Fr. Juan Vidal, to encourage the Jesuits of the Ateneo to continue studying the weather and issuing notes and warnings to seafarers (ibid.). Business owners expressed their interest in supporting the Jesuits, and gave monetary support for the purchase of additional instruments (ibid.). Dutch Consul to the Philippines Van Polanen Petel, Maximo Paterno, and Ramón Genato signified their intention to donate funds (Saderra Masó 1915, 27). According to Colina, the observatory could further support the traders if they could acquire new instruments from Europe, such as Secchi's *meteorógrafo universal* (universal meteorograph that recorded simultaneously several meteorological conditions), which cost 5,000 Spanish dollars (Schumacher 1965; Repetti 1948). This instrument enabled the continuous recording of meteorological observations day and night (Schumacher 1965, 259). The Manila businessmen were able to come up with the necessary amount. In 1867, before disembarking in Spain, Colina went to Paris to personally request Secchi to make a copy of his instrument for the use of the Jesuits in Manila (Repetti 1948; Saderra Masó 1915).

In June 1866 a young Jesuit scientist from Madrid, Fr. Federico Faura, arrived in Manila to teach at the Ateneo and continue the work of Colina and Nonell (Repetti 1948, 2). He studied mathematics and physics in Rome before he went to the Philippines to assume the observatory's directorship, a post he held until 1871 (ibid., 13). The meteorógrafo universal (fig. 1) arrived from Europe, together with additional instruments such as the *barómetro de mercurio sistema Fortín* (Fortin system mercury barometer to measure atmospheric pressure), *termómetro de máxima y mínima de Negretti y Zambra* (Negretti & Zambra maximum and minimum thermometer), *psicrómetro de Saussure* (Saussure psychrometer to measure moisture content or relative humidity of the air), *pluviómetro* (pluviometer or rain gauge), *vaporimetro* (atmometer or evaporimeter to measure the rate of water evaporation), *veleta* (weather vane to determine wind direction), and anemómetro (anemometer to measure wind speed) (Schumacher 1965; Saderra Masó 1915).

One of the Ateneo Municipal's buildings in Anda and Santa Lucia streets in Intramuros housed the observatory, which published weather notes and typhoon warnings in several newspapers such as the *Diario de Manila*. It also compiled the meteorological data gathered in the laboratory, some of which saw print in publications such as the *Baguios y Collas* (Tropical Cyclones and Squalls), *Hoja del Boletín de Observaciones Meteorológicas* (Bulletin Newsletter of Meteorological Observations), and the *Boletín del Observatorio de Manila* (Bulletin of the Manila Observatory) (Saderra Masó 1915; Sola 1903).

The observatory undertook pioneering studies in Philippine weather while continuously accumulating funds to purchase new instruments from Europe. From 1872 to 1877 its collections from the Ayuntamiento de Manila and city businessmen amounted to P7,572 (Schumacher 1965, 261). These funds allowed the observatory to procure additional instruments such as barometers, psychrometers, Dolland meridian telescopes, Elliot magnetometers (to measure the magnitude and direction of a magnetic field), Dover Dip needles, Isaac chronometers, and seismometers (to detect seismic impulses), which formed part of its inventory when the observatory transferred to its new site in Ermita in 1877.

In 1882 Father Faura published his compilation of studies and research notes on tropical typhoons in the Philippines in the *Señales Precursoras de Temporal en el Archipiélago Filipino* (Storm Warning Signals in the Philippine Islands), which contained information about typhoons, recent studies, and precautionary measures in the event of a typhoon landfall (Saderra Masó 1915, 54). In the Exposición Colonial Universal held in Amsterdam the following year, Faura presented his book together with his invention, the *barómetro aneroide* (aneroid barometer), to delegates from different scientific institutions in Europe and Asia (ibid., 61; Faura 1886). This aneroid barometer was made specifically to replace the traditional mercury barometers in order to address the need for better numerical reading and recording of atmospheric pressure in the archipelago (Faura 1886, 2–3). Faura received wide praise for his invention. The Sociedad Económica de Amigos del País, an organization of intellectuals, merchants, and businessmen that promoted agricultural development through modern scientific knowledge, awarded Faura a medal (Saderra Masó 1924; Schumacher 1965).

The observatory also participated in the Exposición Filipina de Madrid in 1887 and the Exposición Universal de Barcelona in 1888, where it received highest praise and honors (Saderra Masó 1915, 97–98).

The Observatory and the Private Sector in Manila and Hong Kong

The observatory under Faura's directorship was active in conducting weather studies. Their support of the maritime and trading sector in Manila became very important for the seafaring industry centered in the capital. From 1879 to 1882 the observatory issued fifty-three typhoon warnings, a feat that captured the attention of more traders in the capital as well as businessmen from Hong Kong (Sola 1903, 10–11).

The scientific and professional relationship between the observatory and the Hong Kong Observatory was shown in the sharing of information through telegraphic transmissions; donations, particularly from Hong Kong merchants to the observatory in Manila; and the exchange of meteorological instruments and inventions between the two colonial cities. Relations between the Jesuit scientists in Manila and the Hong Kong Observatory started in the early months of 1880. The successful establishment of submarine cable between Manila and Hong Kong prompted the merchants from Hong Kong to petition Gov. John Pope to request from the Spanish governor-general in Manila daily weather bulletins and typhoon warnings (Schumacher 1965; Saderra Masó 1924). The benefits of telegraphy as a new mode of communication offered merchants, bankers, investors, and ship owners a progressive avenue for information flow (Wenzlhuemer 2013, 85), in which Hong Kong merchants and traders had shown great enthusiasm since 1871.

The Manila-based newspaper *El Comercio* reported in 1880 that Hong Kong traders collected HK$350 to be donated to the observatory for the purchase of new instruments; several Hong Kong companies spearheaded the donation (Zhu 2012, 172–73). In 1880 a report published in *El*

Comercio indicated that one such company, the Hong Kong Shanghai Banking Corporation, donated a considerable amount to the observatory to improve weather forecasting through the use of up-to-date instruments (ibid.). A pamphlet filled with weather notes and advisories for seafarers, titled *Señales de mal Tiempo* (Signs of Bad Weather), provides a sample of a typhoon warning.

It can be observed that from its creation in 1865 until before its transformation into an official government institution the observatory relied heavily on donations from the business sector to purchase equipment and instruments abroad. The group, composed of local and foreign merchants (Spaniards, Chinese, Americans, and other European nationalities), pledged and gave a significant amount of money for the observatory to function as an advanced scientific center dedicated to seafaring and weather forecasting. Anduaga (2014, 504–5) points out that the creation and development of the observatory was made possible by the existence of an "exogenous" commercial element—the colonial society's economic sector, which surfaced the importance of weather forecasting vis-à-vis meteorological science research for public use.

This factor also became prominent when donations were sought for the maintenance and improvement of the Manila Observatory (ibid., 505). The list of donors for the construction of the observatory's building in Ermita in 1877 included local traders (probably Spanish and Chinese mestizos), foreign nationals, and some companies (Saderra Masó 1915). Their donations ranged from P10 to P1,000. English merchants from Hong Kong signified their intention to donate to the Jesuits for the purchase of supplementary apparatus and the improvement of its edifice in Ermita (Saderra Masó 1924, 101).

The observatory received financial donations not only from private individuals and companies but also from the government. In the same year it obtained a grant from the colonial government for the construction of a separate terrestrial magnetism laboratory (Repetti 1948, 8–9). At this point, we see that the observatory had gained traction among merchants and diplomatic officials because of its work and support for the commercial sector as a weather watchdog. In August 1898, during the days when American military forces attacked Manila, several officials from the consular offices of Germany, Great Britain, France, and Japan visited the observatory and assessed its condition; they requested American troops to be cautious in conducting operations in the observatory's vicinity (ibid., 15).

As we have seen, the public service of the observatory as an institution of colonial science crossed the critical lines of the international trading sphere in Manila at that time. One reason for this achievement was its status as a private institution rendering public service to the commercial sector. At the same time, the observatory was gaining bureaucratic momentum to be recognized as an official colonial service institution. Interestingly, the observatory expanded its scope of service and became open to foreign support without endangering its status as a Jesuit scientific center.

Institutionalization: The Observatorio as a Government Agency, 1884–1899

Because of meteorological data collection, public storm warnings, and specific research projects, the observatory gained credit for being an agency that helped in developing the colony. Through the observatory the Spanish colonial state further realized the value of science in facilitating "modern" programs for the economy.

In 1880 a commission was formed and tasked to recommend the creation of a state meteorological service (Saderra Masó 1915, 74). This commission, named the Junta de Meteorológica de Filipinas, convened from September to October 1880 to discuss the creation, structure, and mandate of the Servicio Meteorológico de Filipinas (ibid., 74–75). The junta was composed of the Commanding General of the Navy, who served as chair; the director of the observatory, Father Faura; the Inspector General of Public Works; the Navy Frigate Commander; the superior of the Philippine Augustinian Province; the Captain of the Port of Manila; the Chief Magistrate of Manila; and the Inspector General of Telegraphs (ibid., 74). The junta put into place an "institutional triad" composed of the Spanish Navy, the Jesuits, and the telegraphic agency (Anduaga 2014, 507).

One of the junta's major recommendations was to set up a network of *estaciones secundarias* (secondary stations) in several provincial capitals and ports that would be selected on the basis of the availability of telegraphic lines to Manila (Saderra Masó 1915, 74). The junta identified several such areas: Tayabas, Punta Santiago in Batangas, Punta Restinga in Cavite, Cabo Bolinao in Pangasinan, Laoag in Ilocos Norte, Aparri in Cagayan, Ilagan in Isabela, Central Caraballo mountains, San Isidro in Nueva Ecija, Daet and Nueva Cáceres in Ambos Camarines, and Albay (ibid.). After almost a year,

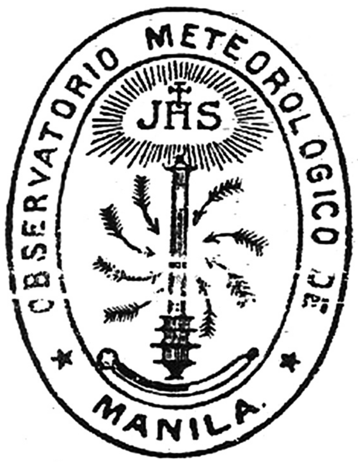

Fig. 2. Seal of the Observatorio Meteorológico de Manila, 1884

Source: Saderra Masó 1915, title page

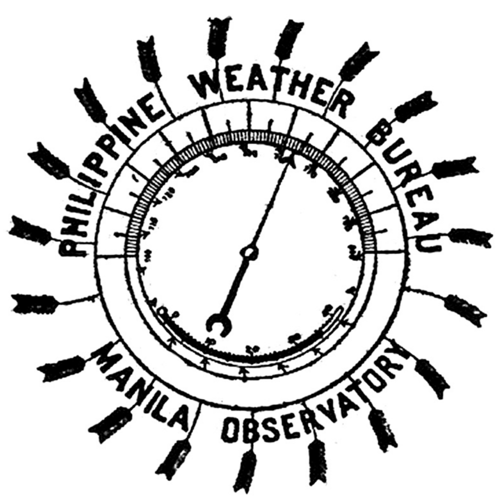

Fig. 3. Seal of the Philippine Weather Bureau, 1915

Source: Algué 1904, title page

Gov.-Gen. Fernando Primo de Rivera sent an *expediente* (dispatch) to the Ministerio de Ultramar (Ministry of Overseas Affairs) to seek approval for the establishment of a state meteorological service (ibid., 76).

After almost two years of dealing with the taxing bureaucratic structure between the Philippines and Spain, the observatory received an official notice from Madrid pertaining to its restructuring under the colonial government. On 28 April 1884, the king issued a royal decree, coursed through the Ministro de Ultramar Rafael Aguirre de Tejada, that formally established the Servicio Meteorológico de Filipinas (Saderra Masó 1915; Repetti 1948). The decree stipulated that the Observatorio Meteorológico del Ateneo Municipal would become the Observatorio Meteorológico de Manila. The new state meteorological service was placed under the Dirección General de Administración Civil de las Islas Filipinas (General Board of Civil Administration of the Philippine Islands) (NAP 1885–1897, S54). Based on the original proposal sent in 1882, thirteen secondary stations were to be established and required to send daily, weekly, and monthly reports to the central station in Manila.

The official seal of the observatory (fig. 2) showed two improvised instruments: a vertical mercurial barometer and a thermometer. The seal also depicted the circulation of wind currents in a tropical hurricane or typhoon. This pictorial symbol of instruments to identify the observatory was incorporated later in the 1915 seal of the Philippine Weather Bureau, which used a modern circular-shaped aneroid barometer (fig. 3).

Following the decree, the newly established state meteorological agency remained under the Jesuits' supervision. The superior of the Jesuit Philippine Province recommended to the government nominees for the positions of director and assistant director of the observatory (ibid., S54b). Whoever was appointed director would then recommend nominees for the staff positions to be filled: *observadores* (observers), *calculistas* (calculators), *mecánicos* (mechanics), *delineantes* (draftsmen), *alumnos* (apprentices), and *ordenanzas* (messengers) (ibid., S54-b–S55).[4] Those designated to the secondary stations needed to submit reports to Manila on a regular basis and were thus required to be skilled in using telegraphic machines (ibid., S55).

The agency received a budget approved by the civil government (table 1). It included funds for the salaries of officials and staff and allocations for administrative expenses. During its first year of operation the agency's budget came from the state *presupuestos* (appropriations) and in its succeeding years

Table 1. Annual budget of the Observatorio Meteorológico de Manila based on the 1884 royal decree

BUDGET ITEM	BUDGET (PHILIPPINE PESOS)
PERSONNEL	
Director	1,500
Assistant Director	1,000
Central observatory staff (total)	2,054
Secondary stations staff (total)	1,872
Subtotal	6,426
INSTRUMENTS	
Purchase of instruments	1,500
Building and instrument maintenance	1,000
Subtotal	2,500
OPERATING EXPENSES	
Printing expenses	1,500
Mailing and courier expenses (secondary stations to central)	1,000
Mailing and courier expenses (central to secondary stations)	432
Subtotal	2,932
TOTAL	**11,858**

Source: NAP 1885–1897, S54

from local government units. Since the agency was devolved locally in its succeeding years, two-thirds of the budget came from local units.

Work at the *Estaciones Secundarias*

From 1884 to 1887 estaciones secundarias were established in the areas indicated in the royal decree; aspects such as the telegraphic line system, the erection of buildings, and the hiring of staff were considered important to enable the additional stations to function necessarily. Father Faura personally managed the construction of edifices (Saderra Masó 1915, 82–83). Each station was equipped with the necessary instruments, such as the Fortin bucket barometer, the maximum and minimum thermometer, psychrometer, atmometer, pluviometer, the Robinson anemometer, and anemoscope or weather vane (ibid.). Father Faura distributed copies of a manual that he wrote, the *Instrucción práctica para el uso de los instrumentos Meteorológicos de las Estaciones Secundarias de las Islas Filipinas* (Practical Instructions in the Use of Meteorological Instruments of Secondary Stations in the Philippine Islands), to guide the staff deployed (ibid.). The manual contained detailed orders and instructions, particularly on sending reports and messages to the central station in Manila thrice daily (6 am, 10 am, and 4 pm) (ibid.). On a daily basis the staff recorded the measurements indicated in the instruments and the weather elements observed, such as temperature, rain, cloud formation, wind velocity, and relative humidity.

In 1884 the king issued a royal decree creating the Comisión Agronómica de Filipinas, an agency tasked to spearhead the development of modern agriculture through theoretical and practical pedagogy and scientific approach to cultivation and harvesting (US Philippine Commission 1901, 9). Several *estaciones agronómicas* (agronomic stations) were established: the Granja Modelo de Luzon in San Pedro de Magalang, Pampanga; the Estación Agronómica de Albay in Tabaco, Albay; and the Estación Agronómica de Ilocos in Vigan, Ilocos Sur. These stations conducted research and offered public training in modern agricultural systems. In particular, their training programs included a series of lectures on the influence of weather and climate on agriculture, one of which was the course *Nociones de Cultivo General* (Ideas on General Cultivation). This course contained forty lectures on the science of agriculture, vegetation, agronomy, irrigation, plant breeding, fertilizers, climate, and atmospheric conditions (NAP 1892, S68–S72).

The three agronomic stations received support from the observatory. Aside from being posted for routine work at the estaciones secundarias, observatory employees were sent to several agronomic stations to lend meteorological instruments and teach their usage. Most of the time, observatory personnel were sent to help and support the work in several specialized agricultural and model farms. One example was the work done by Toribio Jovellanos at the agronomic station, as mentioned in a report by the station director in Tabaco, Albay (ibid., S65–S66). Based on the reports from Ilocos and Albay in 1890 and 1892, respectively, agronomic stations had obtained several meteorological instruments, some of which were instruments from or recommended by the observatory (table 2).

Table 2. List and quantity of meteorological apparatuses used in the agronomic stations in Ilocos (1890) and Albay (1892)

ESTACION AGRONÓMICO DE YLOCOS	ESTACION AGRONÓMICO DE ALBAY
actinómetro de Arago (Arago actinometer), 1	abrigo o facistol para termómetro sistema Montsouris (shelter box or lectern for Montsouris system thermometer), 1
anemómetro de Dr. Rovinson (Dr. Rovinson anemometer), 1	anemómetro de Robinson (Robinson anemometer), 1
barómetro de Fortín (Fortin barometer), 1	barómetro de Fortín (Fortin barometer), 1
barómetro de P. Faura (Faura barometer), 1	escala para correcciones barómetricas (barometric corrections scale), 1
baroscopio indicando los cambios de tiempo (borescope indicating time changes), 1	escala psicométrica (psychrometric scale), 1
boleta giratorio de zinc de dos metros (two-meter rotated zinc sheet), 1	espejo para fijar la dirección de las nubes (mirror for cloud direction observation), 1
brújula con Meridian (meridian compass), 1	higrómetro de Daniell (Daniell hygrometer), 1
brújula prismática (prismatic compass), 1	higrómetro de Saussure (Saussure hygrometer), 1
cajas con discos de papel para el anterior aparato (instrument boxes with paper discs), 2	pluviómetro (rain gauge), 1
campanillas tembladores en armadura de hierro caja de caída (shaker bells in iron armor drop box), 2	psicrómetro de Augusto (August psychrometer), 1
escala psychrometrica (psychrometric scale), 1	termómetro de bola negra (black ball thermometer), 1
espejo para determinar la dirección de las nubes, modelo numero mediano (medium-sized mirror model for cloud observation), 1	vaporímetro de Pichi (Pichi evaporimeter), 1
hilo de cobre cubierto de seda (silk covered copper wire), 1 kilo	
pilas de Lechanche perfeccionadas de placas aglomeradas (agglomerated plate Lechande batteries), 6	
pluviómetro de Glashier (Glashier rain gauge), 1	
psicrómetro de August (August psychrometer), 1	
sal amoniaco para la alimentación de las pilas (ammonium salt for battery power), 1 kilo	
termómetro máximo de Negretti y Zambra (Negretti y Zambra maximum thermometer), 1	
termómetro máximo de Casella (Casella maximum thermometer), 1	
termómetros botánicos (botanical thermometers), 4	
termómetros de mercurios divida a 1/5 (mercury thermometers in 1/5 intervals), 4	
termómetro de mínima de Negretti y Zambra (Negretti y Zambra minimum thermometer), 1	
termómetro de mínima de Casella (Casella minimum thermometer), 1	
termómetro para la radiación terrestre (terrestrial radiation thermometer), 1	
vaporímetros de Piche (Piche evaporimeters), 2	

Sources: NAP 1890, 1892

Native Staff of the Observatory

Although Rizal was frustrated about scientific pedagogy and the apparently limited access to instruments despite their presence in the Philippines, a look at the observatory's work reveals quite the contrary. Not to be dismissed is how the observatory, in fact, proved to be a training ground for Filipinos in the field of science. The observatory hired employees who were perceived to be proficient in mathematics and arithmetic, competent in mechanics and drafting, and skilled in operating a telegraphic machine.

Given the extent of the decree that made the observatory a government agency, how was its scientific work propagated to other sectors of colonial society? For the observatory's new work to be operationalized, its human capital had to be developed. Filipinos were employed in and designated to several key positions. Except for the Jesuit scientists who served as officials, almost all employees of the observatory were Filipinos. They occupied the positions indicated in the royal decree of 1884: observadores, calculistas, mecánicos, delineantes, and ordenanzas. Filipino employees did the extended work of the observatory (table 3). They handled the instruments, gathered and received data outside the central station, operated the telegraphic machines, and wrote and kept records of the collected data.

The individuals who occupied the positions listed above, we can surmise, were chosen based on their technical abilities. With its procedural and methodical work the observatory needed to hire personnel who were capable of tasks that involved numerical and mechanical observations, computations, and assessments. In this instance science was taught, learned, and applied in the context of work and employment in the observatory. The Jesuit Fathers served as experts in the field, and they involved native personnel in the observatory's rigorous and tedious work and activities. Notable for their diligence were observatory personnel like Toribio Jovellanos and Cesario Dulueña. Jovellanos was part of Faura's team that, together with Fr. Isidro Battlo, facilitated the establishment of secondary stations from 1884 until 1887 (Saderra Masó 1915, 82–83). Dulueña became part of the first expeditions in Mindanao to undertake studies in terrestrial magnetism (Repetti 1948, 27). Both Jovellanos and Dulueña served in the observatory from its early years until the American regime, when the agency was reorganized into the Philippine Weather Bureau (MOA 1915; Repetti 1948, 27).

The royal decree indicated the salaries for the different positions. For example, in the presupuesto of September–October 1896 the Filipino

Table 3. Filipino Staff of the Observatorio Meteorológico de Manila, 1887–1895

STAFF	POSITION(S) HELD	DATE OF EMPLOYMENT
Laureano Algarra	Ordenanza	1 April 1889
Gregeorio Basa	Observador Tercero Observador	1 May 1887 1 May 1888
Domingo Bello	Ordenanza	6 July 1891
Cornelio Camantigue	Ordenanza	1 January 1888
Juan de la Cruz	Calculista Primera Calculista	1 May 1887 1 May 1888
Juan de la Cruz y Bautista	Segundo Calculista	20 February 1895
Miguel de la Cruz	Ordenanza	8 October 1895
Cesario Duluena	Segunda Calculista Cuarto Observador	7 July 1888 1 September 1894
Hermenegildo Eugenio	Ordenanza	14 December1894
Quintin Gomez	Observador Cuarto Observador Tercero Observador	1 May 1887 1 May 1888 26 August 1896
Cesario Jovellanos	Segundo Observador	1 May 1888
Toribio Jovellanos	Primero Observador	1 May 1888
Celestino Laforteza	Delineante	27 December1887
Emiliano Layoc	Auxiliar	14 December 1894
Basilio Lindo	Segundo Mecánico	27 December 1887
Francisco Non	Auxiliar	20 February 1896
Perfecto Paulino	Segundo Delineante	5 August 1893
Carlos Punsalang	Calculista	1 May 1887
Gregorio Quizada	Ordenanza	27 December 1887
Francisco Rivera	Segundo Mecánico	18 July 1894
Mariano Salafranca	Primera Calculista	14 September 1894
Cesario Ubaldo	Mecánico	27 December 1887

Source: NAP 1885–1897, 1887–1896, 1890–1891

staff of the central observatory received the following monthly salaries: P75 (P900 per year) for primero observador, P56.25 (P675 per year) for segundo observador and primera calculista, and P18 (P216 per year) for segundo calculista, segundo delineante, and segundo mecánico (NAP 1885–1897, S126–128b, S139–S141b). Mecánicos, delineantes, ordenanzas, and those working in the estaciones secundarias received salaries ranging from P8 to P22.50 (P96 to P270 per year) (ibid.). Based on the annual salary scale for colonial officials and employees whose services were engaged starting 1890, the annual salaries of the director, assistant director, and primero observador were classified as that of oficial tercero de administración and oficial cuatro de administración (Huetz de Lemps 2006).[5] The salaries of segundo calculistas, segundo delineantes, segundo mecánicos, mecánicos, delineantes, and ordenanzas also coincided with the standard salaries given to aspirantes a oficiales (officer candidates), ayudante segundo (second assistant), and ayudante tercero (third assistant) (ibid.). In relation to the salaries of local professional employees and workers during the 1890s, the staff of the observatory received a relatively higher income. In Jim Richardson's (2013, 400–401) study, Katipunan members who were government employees, clerks, agents, tobacco factory, and printing press workers received P15 to P25 per month.

Instruments and the Public

Another milestone for the observatory was its promotion of the use of instruments among certain segments of colonial society. With support from the commercial sector in Manila the observatory was able to afford the high cost of purchasing instruments abroad. Specialized devices bought from Europe were used exclusively in the observatory. Only scientists and staff members assigned to run certain instruments or to undertake work using these instruments had direct access to them. The continued purchase of instruments from Europe enabled the observatory to serve the public as the leading scientific institution in the Spanish Philippines during the last decades of the nineteenth century. They acquired a significant number of apparatuses used for direct observation and recording (table 4).

Meanwhile, instruments made by the Jesuit scientists were marketed locally and abroad. Four years after it was presented to the scientific community, Faura's aneroid barometer (fig. 4) was made available to the public as an instrument for forecasting possible typhoons and other weather disturbances (Schumacher 1965, 263). This instrument was considered the graphic expression of Faura's laws on typhoons laid down in his publication, the *Señales Precursoras* (ibid.). The description and instructions on the use of the instrument were detailed in a pamphlet, *El barómetro aneroide aplicado a la previsión del tiempo en el archipiélago Filipino* (The Aneroid Barometer Utilized in Weather Forecasting in the Philippine Islands) (Saderra Masó 1915, 96). Merchants and traders, collectors, and affluent people sought the barómetro aneroide until Fr. José Algué launched the new version of this instrument—his improvisation of the apparatus known as *barociclonometro* (fig. 5)—onto the market (ibid.). Local merchants bought functioning

Table 4. List and quantity of instruments of the Observatorio Meteorológico de Manila, 1886

DIRECT OBSERVATION INSTRUMENTS	RECORDING INSTRUMENTS
abrigo para termómetros e higrómetros (shelter box for thermometers and hygrometers), 1	anemógrafo de Beckley (Richard anemograph), 1
bomba de aspiración, con camara para comparar aneroides (suction pump with camera for aneroid comparison), 1	anemoscopio-anemógrafo de Richard (Richard anemoscope-anemograph), 1
fotográmetros Franceses (French photogrameter), 2	barógrafo de Richard, para las estaciones de segundo orden en Luzon, varios (Richard barograph for secondary stations in Luzon), several
fotopolarímetro de M.A. Cornu (M.A. Cornu photopolarimeter), 1	barógrafo de Sprung-Fuess (Sprung-Fuess barograph), 1
grandes barómetro (huge barometers), 2	clino-anemógrafo de Garrigou-Lagrange (Garrigou-Lagrange clino-anemograph), 1
nefoscopios de Fineman (Fineman nephoscope), 2	electrómetro Thompson (Thompson electrometer), 1
polímetro de Lambrecht (Lambrecht multimeter), 1	heliógrafo Richard (Richard heliograph), 1
psicrómetrógrapo de aspiración de Lambrecht (Lambrecht suction psychrometrograph), 1	heliógrafo universal de Whipple-Casella (Whipple Casella universal heliograph), 1
termohygroskop y wettertelegraph de Lambrecht (Lanbrecht thermohygrometer and weather telegraph), 1	higrometrógrafo de Richard (Richard hygrometrograph), 1
termómetro de Kuchler (Kuchler themometer), 1	el meteorógrafo universal de P. Secchi (Universal meteorograph of Fr. Secchi), 1
termómetro magistrales de máxima y minima (master maximum and minimum thermometer), 1	pluviógrafo Casella (Casella rain gauge), 1
termómetro normal (standard thermometer), 1	pluviógrafo Richard (Richard rain gauge), 1
	psicrografos de Richard, varios (Richard psychographs), several
	termógrafos de Richard, varios (Richard thermographs), several

Source: Saderra Masó 1915, 89–90

Fig. 4. Faura's barómetro aneroide currently displayed at the Manila Observatory Library and Archives

replicas of Faura's barómetro and Algué's barociclonometro used primarily as seafaring instruments. Some wealthy families used them as decorative house displays.

A lawyer from Batangas, Polo Santiago Pantaleon,[6] through an email written by his granddaughter, Julia P. Agoncillo (2014), offers an interesting account of their Faura barometer:

> When we put up our law firm in 1981, I thought of hanging the barometer in my office as a conversation piece. Before that, however, I had already seen the object lying around in the house of my father-in-law, Manuel M. Legaspi, in San Jose, a town in the province of

Nueva Ecija. And so hanging the barometer occasioned a discussion of why it was in the house of Manuel in the first place. All my father-in-law said was that his father, Anastacio Aguinaldo Legaspi, brought the barometer to San Jose. Anastacio is a direct descendant of Baldomero Aguinaldo, brother [sic: cousin] of Gen. Emilio Aguinaldo. Baldomero had been given the barometer by his brother [sic: cousin]. Baldomero then gave it to his son Anastacio, who brought it with him when he moved to San Jose from Cavite, where his family was originally from. Anastacio Legaspi and his wife, the parents of my father-in-law Manuel, permanently moved to San Jose in the 1950s. According to Manuel, Gen. Emilio Aguinaldo brought the barometer from Hong Kong, where he had been in exile for some time.

This narration suggests that indeed the Jesuit scientists' inventions were available in the market abroad as these inventions contributed to the merchants' knowledge about the weather, particularly in assessing and preparing for possible typhoon occurrences in the seas.

Fig. 5. Algué's barociclonometro

Source: Saderra Masó 1915, 161 and MOA 1937

The transfer of the observatory to its new site and edifice in Ermita in 1886 created a more vibrant space for scientific research, given its numerous spacious rooms for offices and instruments. At the time of its transfer, the observatory's collection consisted of instruments used for atmospheric and temperature observation and reading (Saderra Masó 1915, 89). The bulk of the instruments distributed in different parts of the building consisted of weather vanes, anemometers, pluviometers and pluviographs, thermometers, and actinometers (to measure terrestrial and solar radiation) (ibid., 90).

The 1893 Columbian Exposition in Chicago featured some of the instruments the observatory had obtained for its laboratories. This international exposition included scientific lectures that featured meteorological instruments such as anenometers, thermographs, snowfall recording apparatuses, and different types of thermometers (Faura and Algué 1894, 23–24). The exposition also featured exhibits that showed advancements in instrument use and application. Instrument categories such as *presión atmosférica* (atmospheric pressure), *temperatura de aire* (air temperature), *corrientes aéreas* (airstreams), *meteoros acuosos* (aqueous meteors), and psicrómetros composed the exhibit that had on display barometers, barographs, thermometers, telethermometers, anenometers, anemoscopes (wind direction indicators), and pluviographs (ibid., 69–103).

Fathers Faura and Algué admitted that inventions in general and the use of recording instruments in particular had opened new horizons in the science of meteorology (ibid., 115). They added that experimental meteorology had changed since Secchi's meteorograph was presented to the scientific community and featured at the universal expositions held to popularize inventions—the 1867 and 1878 expositions in Paris and the 1873 exposition in Vienna (ibid.). Faura and Algué were very optimistic that their report on the Columbian exposition would inspire the youth to pursue studies in meteorology (ibid., 115–16). The popularization of instruments and the rise of recording tools prompted the quick recognition of meteorology as an indispensable pillar of colonial development. Indeed, the number of instruments that the observatory had acquired at the time of the Columbian exposition was at par with the global trend.

Conclusion

Colonial science benefited empires in the eighteenth and nineteenth centuries, when empires pursued the advancement of European scientific knowledge and traditions for practical and economic application in their respective colonies. Colonial science served as a point of convergence for local and foreign experts and the public and for governments, institutions, and private sectors.

This article's discussion of the institutional history of the Observatorio Meteorológico de Manila is framed within the view of colonial science as a valuable mast for the development of economy and society in general. At the outset the work of the Jesuits aimed to promote science in their schools. Subsequently the business sector came to appreciate the Jesuits' contributions as experts in the field. The "instrumentation" of scientific observations of the weather and the institutionalization of the observatory's work and service created a specific space for meteorological science to grow and prosper in the Spanish Philippines. The linkages between the Jesuits, the colonial government, and the traders and merchants resulted in meteorology capturing the minds of strategic quarters of colonial society. In the process the Jesuits' initiatives transformed meteorology from being a private science confined to experiment rooms to a new wave of public science, which promoted the colony's progress and economic development.

The institutionalization of colonial meteorology under colonial state auspices integrated Filipinos into the scientific transformation of the archipelago. The observatory's employment of Filipinos as staff members put them at the center of colonial science and modern technical knowledge. Ranging from record keeping to operating instruments the tasks of these Filipino staff of the observatory were integral to the practice of colonial meteorology, even if they and their roles have not been assessed and recognized in mainstream historiography.

Moreover, through the observatory's work, a wider section of colonial society gained access to modern scientific knowledge, with the maritime and trading sectors benefiting directly from the observatory's work, particularly the inventions of Fathers Faura and Algué. The very presence and work of the observatory made the public appreciate the value of meteorology as a science, which emerged at a critical juncture in Philippine colonial history. As a result, while colonial science might have functioned to integrate colonized peoples into state institutions and effect greater control over them, the case of the Observatorio Meteorológico de Manila showed that colonial science could benefit society and help advance scientific thinking and the public's engagement with social endeavors related to science and society.

Notes

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1 Camba (2010) uses the terms "instrumentation" and "institutionalization" in discussing "science discourse" in the Philippines during the American colonial period. He argues that the "Period of Instrumentation" began in the second half of the nineteenth century, which was realized through the Jesuits' scientific activities pertaining to meteorology and seismology. Further he states that infrastructure building and promotion of technology by the American colonial government "institutionalized" science discourse in the archipelago as manifested in a variety of mental and technological boundaries and by different sectors of society. This study shows that institutionalization started in the late nineteenth century.

2 For a detailed description of the effects of storms on certain towns and provinces for the years 1844 to 1864, see unpublished "Meteorological Notes" in Selga n.d., such as "El baguio del 5 de Mayo de 1850 en Zambales," "El baguio del 15 de Octubre de 1856 en Bohol y Surigao," "El baguio del 4 de Noviembre de 1864 en La Union," "El baguio del 9 de Noviembre de 1849 en Abra," "El baguio del 6 de Diciembre de 1849 en Samar," "El baguio del 13 de Noviembre de 1844," "El baguio del 24 de Noviembre de 1853 en Negros," "El baguio del 24 de Septiembre de 1855 en Abra," and "El baguio del 27 de Octubre de 1856 en la provincia de Manila" available at the Manila Observatory Archives.

3 In *Noli me tangere* Rizal demonstrated how science was treated in colonial society through the conversation between Tasyo and the *gobernadorcillo* (town chief), in which the former expressed his disappointment over the latter's inaction on his proposal to procure *pararrayos* (lightning rods) to prevent fire caused by lightning bolts that hit houses and edifices, particularly during storms (Rizal 1996, 75–76). In *El filibusterismo* Rizal dedicated a chapter to discuss the status of science and its pedagogy. In chap. 13, "La Clase de Física" (A Class in Physics), he described how physics was taught in the University of Santo Tomas. Guillermo (2011) provides a noteworthy discussion on Rizal's views on science and the native capacity to learn it.

4 Available documentary sources indicate that all employees hired by the observatory were male; no names of women appeared on its *presupuestos* (budget appropriations).

5 The list is reproduced in Huetz de Lemps 2006, 389–90. Special thanks to one of the reviewers for providing a copy of this list.

6 Polo Santiago Pantaleon is a descendant of Emilio and Baldomero Aguinaldo.

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Kerby C. Alvarez is assistant professor, Department of History, College of Social Sciences and Philosophy, University of the Philippines Diliman 1101, Quezon City. He is pursuing a Doctorate in History, Art and Archaeology (HISTAR) at the University of Namur (Belgium). A recipient of the ARES-CCD Scholarship Grant of the government of the Kingdom of Belgium, he is part of the project "Local Adaptation, Resilience, and Interpretation of Socio-Natural Hazards and Environmental Management in the Philippines." His research interests include environmental history, history of meteorology, and history of natural hazards and disasters (typhoons, earthquakes, and volcanic eruptions). He is also doing research on the local history of his hometown, Malabon (Tambobong). <kcalvarez@up.edu.ph>