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A question of scale: Making meteorological knowledge and nation in Imperial Asia

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Introduction

This special issue of *History of Meteorology* explores processes of making, communicating, and embedding modern meteorological knowledge in late nineteenth and early twentieth century imperial Asia. Its focus is on the institutionalisation of meteorology in key nation-building activities such as developing agricultural services, synoptic mapping to predict storms, and participation in scientific organisations and initiatives. Collectively, the essays explore the intersection of local, regional, and international scales and processes in generating new forms of state-sponsored meteorological practices and institutions, though complex multi-layered networks involving different actors and modes of information flow across multiple scales. In so doing, they reveal the dynamism and mobility of people, objects, inscriptions, information, careers, ways of knowing, and so on across space and place. They build from the paradigm that mastering the means of understanding and—significantly—making use of the weather in Asia involved working with manifold modes of meteorological knowledge drawn from multiple origins.

Thanks to the efforts of many scholars in the history of science, it is now generally accepted that knowledge is not produced within national borders but shaped by global trends, local information and needs, and relationships between scientific organisations and people, often across vast geographic and cultural regions and traditions.[1] In the history of meteorology, however, such trends have only more recently been explored.[2] The scholarship has generally been Western in theme and, although often ground-breaking in its own right, perspectives and explorations of meteorological practices have been primarily confined to European or

[1] Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650–1900* (Basingstoke: Palgrave Macmillan, 2007); David N. Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago, IL: University of Chicago Press, 2003).

[2] Deborah R. Coen, *Climate in Motion: Science, Empire and the Problem of Scale* (Chicago University Press, 2018); Martin Mahony and Angelo Matteo Caglioti, "Introduction to Relocating Meteorology," *History of Meteorology* 8 (2017): 1–14; Zhenghong Chen, Guifang Yang, and Robert A. L. Wray, "Shiyan Tao and the History of Indigenous Meteorology in China," *Earth Sciences History* 33, no. 2 (2014): 346–60; Masumi Zaiki and Togo Tsukahara, "Meteorology on the Southern Frontier of Japan's Empire," *East Asian Science, Technology and Society* 1, no. 2 (2007): 183–203; Vladimir Janković, "Science Migrations: Mesoscale Weather Prediction from Belgrade to Washington, 1970–2000," *Social Studies of Science* 34, no. 1 (2004): 45–75; A. Udías, *Searching the Heavens and the Earth: The History of Jesuit Observatories* (Dordrecht/Boston/London: Kluwer Academic Publishers, 2003).

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American contexts.[3] Whilst this collection of essays does not seek to overturn this trend, it does aim to delve a little deeper into Asian stories to reveal meteorological science as a more globally-distributed scientific practice, ultimately demonstrating the complex origins of its adoption and modernisation in Asia.[4] Although Western imperialism did play a significant role in facilitating and distributing knowledge in Asia, the binary disjunct that Western narratives have raised has obscured the fact that modern meteorology was the sole property neither of Western actors nor of colonial needs. Asian interests and demands, public opinion, and Asia-based scientists and scientific networks were critical. Western-centric narratives have also left gaps in considering how Asian imperialism drove scientific endeavour, despite the similarity of motives behind using meteorology as a state-advancing tool. Japan, for example, began its own program modernisation in the mid-nineteenth century, establishing research stations and observatories across the country and, after expanding overseas, undertook the same process in Taiwan, Korea, and Manchuria. The first formal observatory in Taiwan, for instance, was established in 1896 by the Japanese authorities and, by the 1920s, the Japanese had also established a meteorological department at the imperial university for weather monitoring and forecasting. During the twenties and thirties, they became strong leaders in the field of Asian agricultural meteorology and gained recognition in tropical storm science (Fujiwara Sakuhei), atmospheric science (Wasaburo Oishi), and urban heat science in Osaka and Tokyo.[5] Elsewhere, during the short-lived Japanese occupation of countries such as Singapore and Hong Kong, observatories and meteorological facilities were taken over and weather records held secret as part of the war effort.

Rising interest in, and support for, meteorology reflected pragmatic concerns of governance and exploitation of space. Trade and exploration were vulnerable to weather conditions, shaping access, extraction, and transport of commodities,[6] and it was a matter of scientific and mathematical perspicuity to use climatic theories in making decisions about geographical, material, and political conquests of new territories. Meteorology and mathematical climatology were used in planning to help increase nations' profits by either lowering costs of extraction and transport or raising labour productivity. For European traders, imperialists, and settlers, newly-discovered climates possessed the economic virtue of literally saving labour by *producing* commodities, from foodstuffs to timber to minerals to humans. Climates thus acquired a tangible value extracted by means of observation and prediction. For instance, in a feat of foolhardy mathematical brilliance, Jean Pierre Purry, a Swiss wine merchant turned colonial adventurer, determined an arithmetic formula for the "best" climate

[3] Jamie L. Pietruska, "Hurricanes, Crops, and Capital: the Meteorological Infrastructure of American Empire in the West Indies," *The Journal of the Gilded Age and Progressive Era* 15, no. 4 (2016): 418–45; Deborah R. Coen, "Imperial Climatographies from Tyrol to Turkestan," *Osiris* 26, no. 1 (2011): 45–65; Gregory T. Cushman, "Humboldtian Science, Creole Meteorology, and the Discovery of Human-Caused Climate Change in South America," *Osiris* 26, no. 1 (2011): 16–44;

[4] On ways in which the "gaze/scale" has been constructed, Tsing writes: "We describe the landscape imagined within these claims rather than the culture and politics of scale making." Anna Tsing, "The Global Situation," *Cultural Anthropology* 15, no. 3 (2000): 327–60, 330. See also: Louis Lebel, Po Garden, and Masao Imamura, "The Politics of Scale, Position and Place in the Governance of Water Resources in the Mekong Region," *Ecology and Society* 10, no. 2 (2005): 18–37; Greg Mitman, Michelle Murphy, and Christopher Sellers, "Introduction: A Cloud over History," in *Landscapes of Exposure: Knowledge and Illness in Modern Environments* (Osiris Vol. 19), eds. Greg Mitman, Michelle Murphy, and Christopher Sellers (Chicago: University of Chicago Press, 2004), pp. 1-17; Erick Swyngedouw, "Excluding the Other: The Production of Scale and Scaled Politics," in *Geographies of Economies*, eds. Roger Lee, and Jane Wills (London: E. Arnold, 1997), 171–80.

[5] An overview of Japanese UHI developments can be found in: Takeshi Sekiguti, 'Progress of Climatology in Japan', *Bulletin American Meteorological Society* 35:0 (1954): 428-32 and Masatoshi Yoshino, 'Development of Urban Climatology and Problems Today,' *Energy and Buildings* 15-16 (1990/91): 1-10.

[6] Timothy Sweet, *American Georgics: Economy and Environment in Early American Literature* (Philadelphia: University of Pennsylvania Press, 2002).

on Earth and persuaded the British government to fund colonization of the American Carolinas (with disastrous consequences for Swiss settlers maladapted to swamps and malaria).[7] Asian state and district leaders were doing the same thing internally, tracking rainfall patterns to boost agricultural yields and monitoring harvest and blossoming seasons in Korea, China, and Japan.

A century later, environmental and climatological sciences drew legitimacy from institutional grounding. Imperial powers led the way on the global table, as did Jesuit activities across the Americas and in Asia. Understanding and putting to use the knowledge of newly-discovered weather patterns, unfamiliar seasonal changes, extremes of heat, winds, rains, unusual ocean currents and tides, convective storms, and non-routine events such as hurricanes and droughts—not to mention the medical conditions associated with the physiological and epidemiological qualities of non-European atmospheres—called for institutional means of information monitoring and delivery.[8] Institutional initiatives geared towards investment and organization of meteorological knowledge in non-European geographies thus became the norm among colonial governments and were made available to colonial promoters, traders, prospectors, botanists, and physicians. Weather charts, as Simon Naylor puts it, followed interests and geographies that "conformed to the contours of Britain's imperial interests".[9] Similarly, the colonial interest in North American climates, as Anya Zilberstein has recently demonstrated, expressed real concerns with their impact on settler demography, labour productivity, prospecting for raw materials, and health in places unfamiliar to Europeans.[10] Likewise, Jesuits in Asian entrepôts such as Shanghai and Manila demonstrated a keen interest in scientific innovation—in methods and instruments especially—in demonstrating the use of meteorology for improving local agriculture, for reducing risks in trading expeditions, and improving scientific education in the East. This was reflected in the establishment of Jesuit observatories and established institutional networks and research centres across the region[11] The Jesuit practices were also rooted in long-established ties with their counterpart meteorological observatories in South America, Africa, and China, and in strong collaborations across the typhoon-affected China Seas region.

Authors in this volume provide further evidence that the development of meteorological activities in imperial settings served as a risk-hedging pursuit intended to optimize weather-sensitive activities by means systematic monitoring, communication, and prediction of meteorological conditions and seasonal changes. Our authors demonstrate an evolving system of practical knowledge developed in parallel to infrastructures of commerce and commodities markets: shipping informed new monsoon research, farming spurred work in forecasting, resource extraction depended on seasonal anomalies, and merchant navigation depended on weather bulletins and warning systems. For example, British Indian officials' concern over revenue-depleting droughts raised questions about the possibility of developing methods to

[7] Vladimir Janković, "Climates as Commodities: Jean Pierre Purry and the Modelling of the Best Climate on Earth," *Studies in History and Philosophy of Modern Physics* 41 (2010): 201–207.

[8] Morten A. Skydsgaard, "It's Probably in the Air: Medical Meteorology in Denmark, 1810–1875," *Medical History* 54 (2010): 215–36; Vladimir Janković, *Confronting the Climate: British Airs and the Making of Environmental Medicine* (New York: Palgrave Macmillan, 2010); David Arnold, *Colonizing the Body: State Medicine and Epidemic Disease in Nineteenth-Century India* (Berkeley: University of California Press, 1993).

[9] Simon Naylor, "Log-Books and the Law of Storms: Maritime Meteorology and the British Admiralty in the Nineteenth Century," *Isis* 106, no. 4 (2015): 771–97.

[10] Anya Zilberstein, *A Temperate Climate: Making Climate Change in Early America* (Oxford: Oxford University Press, 2016).

[11] Aitor Anduaga, 'Spanish Jesuits in the Philippines: Geophysical Research and Synergies between Science, Education and Trade, 1865-1898', *Annals of Science*, 71:4 (2014): 497-521.

determine the regularity of monsoon onset. Likewise, Asian states adopted and adapted modern meteorological methods, often cherry-picked to suit local circumstances and weathers.[12]

This collection shows how meteorology operated across a multiplicity of scales yet, despite this fluidity, in many respects formed its own knowledge space that underpinned and transcended imperial interests. The essays all present assessments of how meteorology was embedded within the national development strategies of both "home" and "foreign" environments within imperial Asia. They explore how knowledge was communicated, constituted, represented, and articulated across networks of people and institutions within these contexts and also show how meteorology still operated at transnational scales. Scales thus conceived can be geographic and corporeal, or perceptive and representative. The essays also collectively emphasise hybridity in the knowledge exchanges that took place within the spaces of meteorological science, even within colonial space, rather than presenting a dual or binary construction of Eastern or Western practices that met somewhere in the middle. The papers span the Japanese and European imperial periods in nineteenth- and early twentieth-century Asia. They showcase the research of relatively early-career scholars whose work engages with the need to re-locate the spaces and places of meteorology and, in particular, seeks to re-evaluate meteorological science within Asian geographical perimeters and social frameworks.[13]

Seeing Across Scales: Local Needs, National Interests, Global Reach

Kae Takarabe shows how meteorology in Japan developed at place-specific as well as national scales with some of the first institutionalised efforts to collate instrumental weather observations at the regional headquarters of the Kaitakushi (Hokkaido Development Commission), several years before the establishment of the Tokyo Observatory. Ostensibly an office dedicated to settle and develop what was then considered a wild and uncultivated island, the Kaitakushi quickly realised the importance of climatic information to achieving this task. This was never a solely Japanese story, however. Kiyonaru Kuroda, the man in charge of the Kaitakushi, actively sought input from key figures on the emergent American meteorological scene to advise and inform scientific direction in Hokkaido. This initiated a process of international knowledge exchange through the movement of people, information, methodologies, and instruments to and from Japan and the US through the Smithsonian Meteorological Project. The Project's first secretary, Joseph Henry, was a firm supporter of open communication in science, believing that science would not progress if it was confined within national borders. Intellectual exchange across transnational settings was vital to advancing scientific endeavours. The Smithsonian was not only a hub and dissemination point for scientific research, Takarabe argues, but also dealt with very practical elements of the science, orchestrating the methodologies for collecting, tabulating, and broadcasting weather data in two-way exchanges.

A large proportion of the early meteorological efforts in Hokkaido were connected to agriculture, as indeed was the case in many parts of the world. It is perhaps surprising, then, that agricultural meteorology has received so little attention within the history of meteorology and the history of science more broadly. Two of the essays in this collection (Takarabe, Parolini) connect with this important subject, shedding light on its role in improving imperial capacities and national development. Giuditta Parolini directly addresses national and international scales, rooting her discussion in the meetings and correspondences of the

[12] Chen et al, "Shiyan Tao and the History of Indigenous Meteorology".

[13] Mahony and Matteo Caglioti, "Introduction to Relocating Meteorology".

International Meteorological Organisation's (IMO) technical commission on agriculture. This commission operated for thirty years from the 1910s onwards, with brief disruptions during each World War. The commission operated as a melting pot for scientific exchange with members who actively contributed to the knowledge-making process. Parolini argues that members' interests were diverse and transnational in scope with participants drawn from almost forty nations as far afield geographically and culturally as Argentina, China, Egypt, and Japan. Whilst a large number of the members were trained in Europe or in the US, their working experiences and nationalities went far beyond Western borders, their personal participation in commission activities and daily jobs enabling cross-fertilisation of embryonic macro- and micro-agricultural, ecological, and meteorological ideas. This dynamic was essential not only to furthering scientific research but also to economic success in producing and sustaining commodities and crops, especially for emergent and imperial economies. First-hand experience of working with "new" plants in "foreign" environments to produce worthwhile cash crops was an important road to successfully developing commercial agricultural capabilities.[14]

Takarabe also explains how the invention, movement, and purchase of scientific instruments (for example, barometers) offer a different way of conceptualising the traditional centre-to-periphery colonial framework for knowledge dispersal. She notes how the Americans, via the Smithsonian Project, were requested by their Japanese counterparts to send meteorological instruments to the country in aid of burgeoning agriculture but also how instruments were developed or adapted locally. Her observations connect with an important yet small strand in the history of meteorology on the movement of instruments and objects across global scales.[15] However, they also invented, manufactured, and exported their own designs which were then sold back into the international market. Thus the instrument market operated across multidirectional channels, over international borders, and within Japan itself. The movement of people was also important in this process of exchange, offering a channel to transfer both information and instruments. Takarabe's account highlights the movement of people between the US and Japan. These were not just short official visits to build political relationships, but often entailed the long-term placement of people in one country or the other, to work at respective meteorological and agricultural institutions as staff and advisors. These people were corporeal conduits through which cross-cultural as well as scientific knowledge was shared between the two nations.

Parolini points to how knowledge operated across disciplines as well as national borders. She describes agricultural meteorology as an essentially multi-disciplinary phenomenon. Meteorologists did not work alone, but in close association with botanists, geographers, and statisticians to manage the complexity of the task at hand. Knowledge-making in this case was just as unlikely to operate as a single field as it was to operate within geographic perimeters. Local knowledge was just as important, perhaps even more so, in the successful colonisation of tropical regions. Yet international contexts allowed the dissemination of ideas between experts in ways that could not be matched locally. The resultant flows of information between East, West, and back again, were evolving and dynamic. They enabled the hybridisation of different forms of knowledge in their application to new environments and the development of new perspectives and working theories in agricultural

[14] Joseph M. Hodge, "The Hybridity of Colonial Knowledge: British Tropical Agricultural Science and African Farming Practices at the End of Empire," in *Science and Empire: Knowledge and Networks of Science Across the British Empire, 1800–1970*, eds. Brett M. Bennett and Joseph M. Hodge (Basingstoke: Palgrave Macmillan, 2011), 208–31.

[15] Simon Naylor and Simon Schaffer, "Nineteenth-Century Survey Sciences: Enterprises, Expeditions and Exhibitions: Introduction," *Notes and Records of the Royal Society* 73, no. 2 (2019): 135–47; Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge: Harvard University Press, 1988).

ecology through trial, error, and the application of multiple fields of study. Thus knowledge-making might be viewed here as something resembling a crosshatch stretching across the globe, intersecting at manifold points, scales, and across multiple layers.

Beth Cullen and Christina Leigh Geros conceptualise scale as an interconnected feature of evolving monsoon science as improved ways of understanding local and regional weather patterns emerged over the late nineteenth century. In some ways, this understanding also connected to the scale of the British Empire itself, and the establishment of linked magnetic and meteorological stations across wide areas. In British India, they argue, weather maps reflected changing perceptions of scale in geographic and conceptual terms. The early maps, such as those created by Henry Blandford in the 1880s, mirrored the extent of British control in the region, as the maps directly reflected data points then established by, or available to, the British imperial meteorological network. This only changed as the scientific understanding of the monsoon advanced alongside the ability to collect deep oceanic data, enabling a far broader and significantly more dynamic picture to evolve. By the early twentieth century, they argue that a pan-oceanic view of weather had developed, enabling scientists to unfold new thinking spaces far beyond the more static pictures of the previous era. More than this, the maps evolved multidimensionally, vertically as well as horizontally, reflecting man's incursion upwards into the atmosphere as well as across the lithosphere and hydrosphere. The collation of upper-air data developed alongside exploratory missions into higher altitudes, using balloons and kites to further the empire's reach metaphorically and physically.

Cullen and Geros' maps can be viewed as visual representations of colonial knowledge-making about weather, weather science, and India. This particular form of knowledge potentially ran roughshod over traditional indigenous understandings of the same climatic phenomenon that the British sought to make comprehensible. Cullen and Geros explore how the monsoon has been conceptualised within evolving scientific and chronological frames that cut across geographic, though not necessarily national, borders. Their lens is also colonial and Western, hemmed in by British (and, to a lesser extent, American) imperial ambitions, contemporary scientific networks, and trading routes. Their account perceives of scale as at once global, national, and local, operating within a worldwide forum yet bounded by domestic interests and homegrown science. Their account argues that weather maps emerged not only as a useful tool but as a way of rendering the intangible tangible. This of course connected with the nineteenth-century, predominantly Western method of doing meteorology; that is, by collecting and systematising weather information alongside the integration of increasingly sophisticated theory and prevision.[16] The weather map—often created around imperial shipping trajectories and trading routes[17]—therefore said perhaps more about colonial lenses and mindsets than about the weather itself, offering one way to understand the values of a particular time, place, and culture. As Mike Hulme has argued, climate is best understood as a cultural construct, viewed through its tools, practices, and artefacts.[18] In other words, weather and climate are not atmospheric givens but realms of experience that are made to correspond to forces of nature that affect the human world through science.

[16] Katherine Anderson, *Predicting the Weather: Victorians and the Science of Meteorology* (Chicago: University of Chicago Press, 2005); James R. Fleming, *Meteorology in America, 1800–1870* (Baltimore: John Hopkins University Press, 1990).

[17] Naylor, "Log-Books and the Law of Storms".

[18] Mike Hulme, "Climate and Its Changes: A Cultural Appraisal," *Geography and Environment* 2 (2015): 1–11, doi: 10.1002/geo2.5.

Marlon Zhu's lens is also set within an imperial landscape, but he shows how British scientific authority was circumscribed by the nationalities and allegiances of the key actors in his story. He explores how the nineteenth-century English language presses available in the China Seas region helped shape perceptions of the role and responsibilities of meteorological science through their reporting of controversies between some of the contemporary key players in weather science. Honing in on two specific disputes, the first between the Jesuit fathers who ran the Manila Observatory and William Doberck, their counterpart at the Hong Kong Observatory, and the second between the US Weather Bureau and its counterpart in the UK, Zhu argues that the press played an important role in presenting and representing both arguments. In the Asian case, the press represented the interests of the international inter-port mercantile community whose ideas were firmly set against Doberck personally, tarnishing and misrepresenting the dispute to favour Manila. Zhu offers a tantalising glimpse into the soft power of the multi-national merchant community who, through appropriation of the English-language news channels, exerted their influence on the direction and outcome of disputes critical to the livelihood of people living under the threat of typhoons in China, Hong Kong, and the Philippines. The typhoon dispute, though essentially developed out of personal antagonisms, sheds light on the ways in which scientific knowledge and, critically, perceptions of scientific knowledge were fashioned and directed via the intervention of sundry competing interests operating across different scales.

Indeed, interest in regional typhoon forecasting was essentially localised to the China Seas region, yet it affected trade across the world and attracted international commentary. Meteorology was critical to the successive Spanish and American regimes' navies, enabling their respective militaries to safely navigate and patrol local waters in the China Seas. Trading interests were also protected by accurate forecasting, at which the Manila Observatory Jesuits excelled. If any further argument was needed as to the science's importance, the occupation of the Philippine Weather Bureau by the Japanese during World War II as a critical institution ought to leave no doubt. Integrated into new agricultural initiatives and disaster risk-management and reduction, the Philippine science also had a broad-spectrum remit beyond seafaring. In agriculture, the Weather Bureau's inquiries by this time interconnected with all major aspects of developing a modern agriculture department, including crop and animal disease research, harvest yield and productivity, irrigation and hydraulic management, even the health of farmers themselves. In managing disaster, the Bureau aided the government with forecasting floods, typhoons, and droughts, and even with research into seismic and volcanic activity. It managed all these processes through a network of registering stations and research outposts all linked to the central Bureau and observatory by telegraph, cable, and post, with operations enhanced by locally-developed and imported instruments. As a maturing nation with one of the highest number of natural disasters in the world, agriculture and disaster management were critical to successful national development.

In the ports and mercantile communities of the China Seas, Zhu argues, meteorological sovereignty was tantamount to national sovereignty, with the arguments between Manila, Shanghai, and Hong Kong centred in on older national and international interests and affiliations. Meteorology became caught up in a race for supremacy, a desire to be the first observatory to control and head the scientific services for the region, representing in many ways the race to power and antagonism between different colonial and non-colonial powers in the regions. A similar theme emerges in Cullen and Geros' account of the establishment of the Indian Meteorological Department (IMD) in 1875. Concerned with centralising the study of the climate in one place, this was not a question of geographic convenience, but a way of imposing British dominance on weather science across the region. The IMD was intended to

be the hub of a network that crisscrossed India, Burma, and eventually the Far East, linking centre to periphery and providing active information channels. This network mirrored, in some respects, the cartographic representations of the atmosphere, soon to be rendered into synoptic charts, a new view and perspective on the monsoon region and a way of asserting (British) order onto the unstable monsoonal atmosphere.

Understanding the monsoon was critical to agricultural fortunes in India and many parts of Southeast Asia. Pressure to better forecast the monsoon in order to protect agricultural industries, Cullen and Geros argue, led directly to the expansion of data collection and more investment in the science from the 1880s. After three serious drought-connected famines between 1896 and 1902, pressure only increased as revenue and population both decreased in Britain's "jewel in the crown". In French Indochina, the subject of Parolini's research, improving the ability to forecast macro- and micro-climatological changes was critical to local farmers and to national agricultural output. Indeed, climatology may have benefitted more than meteorology, she argues, given that the long-term (say annual) perspective of the climate was more important than daily weather in managing farming operations. At the same time, the sheer pace at which the meteorological and climatological station networks grew, reflected in many ways the grip of French power on the region. Growing from fewer than thirty stations in 1925 to more than five hundred in only seven years, people from all backgrounds, local, foreign, missionaries, and plantation workers, as well as hospital, agriculture, and forestry officers, were drawn into the meteorological fold.

One of the recurring concerns across these essays is the role of meteorological expertise in economic activities. In Indochina, and in Hokkaido where the Japanese were investing heavily in pioneering agricultural development, meteorology was a critical component in successfully developing agricultural strategies. It could even be argued, as Parolini does in her article, that this relationship worked both ways: agriculture acted as a/the catalyst for the creation of a systematic weather network. Protection of imperial trade and shipping was also a formidable catalyst for meteorological investment in typhoon-inflicted Asia. For the Spanish Jesuits in Manila and for Britain's officials stationed in Hong Kong, finding a workable method of predicting the onset and intensity of an incoming typhoon was paramount. This situation was also reflected in India where the monsoon had the potential to change agricultural fortunes, and thus determine the health and stability of the region's populace. Weather maps were produced as result of the extreme climatic situation that colonial officials found themselves in, a way of controlling or taming nature through the imposition of orderly systems. Geros and Cullen show that Matthew Fontaine Maury's monsoon charts featured new elements that gave them an advantage in optimizing maritime routes, transport costs, speed of travel, and, eventually, resource use. Through cartographic visualisations, the monsoon the became an object of trade, with ocean currents and winds turning into market internalities, part of a "vast and reliable machine" with "revenue-boosting advantages". Those involved in meteorological research considered meteorological monitoring a "subject of the greatest importance from an economic standpoint". In Parolini's study of Paul Carton's (1891–1969) meteorological work in French Indochina, the logic of agro-capitalism becomes apparent in the state's programme to determine the type of crops most suited to local terrain and climate, and the economic value of weather research and observations becomes the precondition for the growing network of farm weather stations. By investigating the relationship between plant ecology, soil types, radiation, and humidity, agroecology served the French state and business interests in providing the practical information needed for the cultivation of *hevea*, tea, coffee, and rice. Carton advocated meteorology as an aid for industrial agronomy and farm management, believing that a combination of weather, soil, and ecological data was more useful to the farmer than weather

bulletins and short-term weather forecasts. Furthermore, Zhu sees a further dimension in the mobility of colonial capital related to maritime security. As the rivalry in issuing typhoon warnings escalated between the Manila and Hong Kong Observatories, daily newspapers enabled merchants to judge their accuracy first-hand by publishing of the warnings from both institutions—and, in addition to being consumers, these merchants also became juries on the value of the respective weather services. The use of warnings, as Takarabe's investigation into the adoption of Smithsonian methods of weather observation in Meiji Japan acknowledges, testifies to the state's increasing recognition of the public, agricultural, and industrial value of meteorological research and networks. Interestingly, the Americans brought their Smithsonian Programme to the Philippines, as they did in Japan, essentially a Western approach to systematic and standardised meteorology. One could argue, however, that this system was not specific to the West but was already practiced—just under different names and styles—by the nineteenth-century Asians. Thus the particularly interesting elements of this scientific crucible were that neither system was indigenous to a region but had developed conterminously as direct result of contemporary scientific networks and knowledge sharing, as well as the pressures of practical necessity.

Weather and atmosphere gained scientific status in proportion to their relevance to government, trade, markets, and—more generally—to an institutional approach of managing environmental vulnerability. Trivially a matter of everyday experience, weather commanded scientific and public interest especially when the scientific practitioners could demonstrate its value in commercial and public life. While such knowledge may appear to have emerged out of disinterested inquiry into the quantifiable properties of the aerial fluid governed by universal laws, in reality it was a practice—a working knowledge—in which information about the likelihood of monsoons, typhoons, and other hazards became relevant to the extent that it provided rational grounds for maximizing insurance, security, foresight, and profit-making activities.