INTRODUCTION

THE DAWN OF IMPERIAL WEATHER

> Singapore is unusually favoured in the matter of climate. Situated close to the Equator, it nevertheless enjoys climatic advantages not shared by other places of the same latitude. The abundant rainfall tempers the fierce heat of the Tropics; and violent storms are unknown. There is no change of seasons; the island boasts an eternal summer, and is clothed with a perennial green. . . . Singapore should be one of the healthiest places in tropical latitudes and is so for Europeans . . . the effect of the eternal summer is somewhat relaxing and enervating to those who have come from temperate regions.[1]

This was how George Murray Reith—Presbyterian minister, historian, and author of the first comprehensive tourist guide to Singapore—described the island's climate. His view of the tropics was one commonly found in Western popular culture and scientific writing about tropical environments and, especially, nineteenth-century colonial Malaya.[2] Despite Reith's long experience in Singapore, his description was full of romanticisms and scientific inaccuracies, an idealized view of the tropical island. Singapore is in fact situated just one degree north of the equator so, while it does experience year-round high levels of heat, humidity, and rainfall, there are seasonal patterns dictated by the monsoon and also extreme weathers such as the Sumatra Squalls of June to November characterized by pre-dawn winds and heavy rains. There are also heat waves, regular floods and droughts, the latter phenomena at their worst when affected by the periodic cycles of the El Niño Southern Oscillation and the Indian Ocean Dipole. Of course, Reith would not have been privy to such science, but the vagaries of the local weather could have been understood experientially.

For the inhabitants of the Malayan Peninsula, the climate was everything. It contributed to ways in which homes and clothes were designed, the times of day at which work or play occurred, the types of flora and fauna and the foods they produced, including "all the rich-flavoured, coloured fruits . . . whose generous juices are drawn from the moist and heated earth, and whose flavours are the imprisoned rays of the fierce sun."[3] The climate also dictated the ritual year. The arrival of *phinisi*, for example, sailing vessels manned by the *Bugis* of the eastern Indonesian archipelago were an annual highlight. Coming to Singaporean shores before the northeast monsoon of late November each year, the Bugis traders would erect a colorful market of cloth, sarongs, and tropical birds on the beach.[4]

For the people who migrated to take advantage of the economic opportunities offered by the burgeoning colony, the endless sun, heat, and seemingly incessant humidity were not always as romantic as Reith described. Despite the brilliant colors and flavors, the constant heat and humidity sapped the strength of Western travelers and settlers. Writing in the 1830s, for instance, Captain Sherard Osborn of the British Royal Navy, notwithstanding his extensive experience in India and Southeast Asia, still noted how, at "the residences of the wealthy European merchants; all was as dreamy, sleepy, quiet, and picturesque as anyone could desire, and I am bound to say as hot, for there the bright equatorial sun was pouring down without shadow or breeze to take off its effects. The sepoy sentry seemed to be frizzling in his leathern shako and hideous regimentals, and the sensation I felt on regarding his scarlet coat was that he might at any moment burst into flames."[5] "It is hot—so hot!" also protested travel writer Isabella Bird in the 1870s, "one does long to take off one's flesh and sit in one's bones."[6] Australian miner turned planter Ambrose B. Rathbone, writing in the 1890s, would have agreed, groaning how "the climate is a moist, depressing heat which slowly but steadily undermines the European constitution."[7] Such are the Western ideas of the tropical climate with which historians are by now familiar.

Victor R. Savage wrote in the 1980s on the subject of outsiders' perceptions of Southeast Asia, views that were socially constructed and frequently based on the strangeness of the climate and environment.[8] There has since been a proliferation of literature on "tropicality," shining a light on colonial imaginaries and artistic representations of the tropical world.[9] Historians of medicine have shown how these perceptions went on to color Western views on race, the body, and health.[10] David Arnold's study of colonial India, for example, revealed starkly how British colonials conceptualized a distinct "tropical disease environment" that shared an intimate relationship with racist stereotypes of Indian people and created colonial anxieties about the possible effects of the tropical environment and climate on the European body.[11] As Edward Said observed in his critical 1978 text *Orientalism*, racism was a

fundamental component of a binary conception of temperate versus tropical that developed only in the West—in other words, the view reflected how Europeans believed the world was divided between the civilized and the other.

Reith was twenty-six when he was posted to the Straits Settlements, and during his lifetime, covering approximately eighty years from the 1860s into the 1940s, he witnesssed a confluence of ideas, where concepts such as tropicality and climatic determinism coexisted with new mathematical and statistical frameworks for understanding natural laws, the weather, and the atmosphere. Although many contradictions endured, especially in popular literature and imagery, scientists were beginning to nullify stereotypes of tropicality. This was an incredible time for the weather sciences. The focus in meteorology shifted from individual, local, and largely empirical studies undertaken by individuals and enthusiasts to international, visual, practical, and theoretical research performed by trained specialists at scientific institutions. It was a time of standardizing methods and instrumentation, large-scale data gathering, synoptic forecasting, and technological innovations such as radio and radiosonde, which were critical to advancing weather knowledge.[12] A key contention in this book therefore is to consider this alternative side of tropical thinking rather than to tread the already well-worn ground of the many prolific and influential historians who have written on tropicality in culture and in health.

BRITISH MALAYA AS A COUNTERPOINT IN THE HISTORY OF COLONIAL SCIENCE

Although the history of the development of the meteorological sciences in Britain has been well covered from many angles from the social and cultural to the scientific, this history has rarely been linked to Britain's tropical colonies, especially those in Southeast Asia.[13] By placing colonial Malaya at the heart of this story, in this book I intend to fill a gap in the historiography of meteorological science and to bring a history of science perspective to other areas of colonial development in the region, such as environmental management. This neglect, in some part at least, reflects the lack of attention paid by contemporaries to science—or indeed weather—in the region that has led to a paucity of records on these subjects.

During the nineteenth century, organizations and institutions including the Greenwich Royal Observatory, Kew Observatory, the Royal Society, and the British Association for the Advancement of Science (BAAS) were enthusiastic participants in the gathering of global weather information. At the very first meeting of the BAAS, for instance, members requested a report on the current state of meteorological science as a precursor to including this nascent field within their future work.[14] The BAAS and the Royal Society

drove a new scheme shortly thereafter to establish a series of observatories across the British Empire, including in Madras (1845) and Mauritius (1851), at which magnetic and atmospheric conditions could be studied.[15] Nonetheless, meteorology was not the prime concern of their subcommittees or the observatories. The science was subsumed under broader themes, which included the different disciplines of the mathematical sciences, light, heat, and sound. Meteorological studies were subservient to magnetic or astronomical research or were undertaken to provide a time and storm warning service for shipping rather than for meteorological research per se.[16] Certainly, the needs of the shipping industry were paramount to the British Empire, and thus the institutions most directly concerned with meteorology, notably the British Meteorological Office and its colonial counterparts, were set up with exactly this industry in mind, both at home and abroad.[17] Nineteenth-century imperial meteorology was concerned with forecasting weather events such as typhoons at sea that could affect trade or the monsoon that could affect agricultural and economic productivity on land.[18] Therefore, although the Straits Settlements incorporated the three major ports of George Town, Malacca, and Singapore, there were no cyclonic systems in the immediate vicinity, and explorers on early incursions into terrestrial Malaya suggested that the area did not suffer any extreme weathers. At the same time, it has been suggested by both contemporaries and historians that science in Malaya was behind that of other countries, as it was often left to individuals to champion rather than being a dedicated government or institution-sponsored effort.[19]

The claim of some historians that science and empire developed together has applicability to the weather sciences, but in Malaya, the perceived lack of extremes pushed the development of that science the other way. The establishment of meteorological networks and infrastructures across imperial geographies, the standardization of observational practice in ways specific to imperial and Western thinking, the use of meteorology in enhancing imperial productivity were all core characteristics of how this story played out in many other colonies.[20] But, the case of Malaya competes with the notion that British ways of doing and thinking were applied evenly across colonized regions and the concept of a homogenous imperial project is far too problematic to apply here.[21] Some of the authors of the latest work on the transfer of scientific knowledge suggest strongly that the colonial effort was neither linear nor uniform and that there was no single scientific colonial discourse or practice.[22] I am inspired by this line of thinking. In this book I therefore hold a question mark over the idea of science as a colonial tool and probe the equation of science and imperial control.

To establish an overseas settlement that would have commercial value, it was necessary for contemporaries to understand whether the climate would

be suitable for long-term European habitation—that is, would it be conducive to establishing commercial crops and healthy living? Some basic meteorological facts, such as annual averages of temperature and rainfall, were needed to determine the answers to these questions, and weather records made during exploratory missions or at the point of settlement were used to justify why an island or a harbor might be worth settling. Nonetheless, the Straits Settlements—unlike other British colonies including Hong Kong, Australia, or India—did not adopt a specialized observatory or institution until the 1920s. They also resisted much of the regulation and standardization pushed by bodies including the BAAS or the International Meteorological Organisation (IMO), despite the "calls of colonialism and modern science to know and to categorize, and in so doing, control environments."[23]

In meteorological historiography, it has also often been assumed that the observational networks linking imperial hubs and outposts were reflective of, and constituent to, imperial control. The observation stations, observatories, telegraphic lines, and flows of information collectively created a web that distinguished imperial lands and connected disparate areas in an imperial web. This network was reflective of which parts of the empire held the most value—stations emerged first in urban settlements, plantations, and botanic gardens—but although their locations mimicked the geography of power, in this book I also argue that the network did not exert power in and of itself. The network generated data, but the data's usefulness was limited by problems of accuracy, use, and scope. Arguably, these networks were just as reflective of the failures in the colonial system of control and surveillance as of their strengths. Either stations did not exist in areas that were too remote, or, just as Mark Frank argues in relation to Tibetan observational stations, many of the observational stations of the Malayan interior operated semi-independently, with few checks, being reliant entirely on the ability or the dedication of the staff who were present.[24]

Although the Malayan network could have been critical in providing the information for developing our understanding of the atmosphere as a global dynamic system, in the nineteenth century at least it was subject to human error, the information generated was full of chronological gaps, and the results were not applied to contemporary scientific studies of atmospheric weather conditions. The tropical weather remained by all accounts an imagined space in colonial science, and the Malayan example thus counters suggestions that meteorology was an organized and structured part of imperial state apparatus. The situation was perhaps more akin to what Martin Mahony has described as "faltering internationalism" where local circumstances and ambitions dictated the pace and scale of investment in knowledge making.[25] Thus, in this book I argue that colonial meteorology was less about purposeful science and the imperial project and more about trial, error, and accident.

RETHINKING COLONIALISM AND SCIENCE THROUGH THE WEATHER

The arguments laid out above position weather as a lens into colonial science and imperial functionality in the tropics. With this view I will show that the British government had a lack of interest in shaping Malayan meteorology and, although colonial officials dictated the key means of managing weather's extremes, from flood mitigation to drought protection, their role was largely reactive and, on occasion, inadequate. Often it was left to individuals or private enterprise to champion a cause. Following this line of reasoning, I provide a deep exploration of colonial era actors' attempts to know, manage, and control the previously unknown or the uncontrollable through information gathering, institutionalization, and infrastructural change from the standpoint of governmental, scientific, and technological responses to local weathers. I exclude the history of indigenous weather knowledge, unless this directly informed colonial modus operandi in this field.[26] This is not to downplay the importance of local knowledge or practices but to demonstrate that colonial science—in Malaya at least—was largely restricted and, although the day-to-day operations of meteorology relied almost exclusively on a local workforce, indigenous or traditional knowledge did not inform Western styles of meteorological science or the technological and engineered responses to extreme weather that were being practiced. This is markedly different from the experiences portrayed in some recent texts on the relationship of colonialism and local knowledge, in environmental histories of jungle commodities or bioprospecting, for example, or in the exchanges on climate with indigenous communities that have been described by Deborah Coen, Philipp Lehmann, or Thomas Simpson.[27] In Malaya, this dialogue was largely absent in the world of colonial weather science or environmental control.

In this argument I draw from the history of science—especially the history of meteorology—to think around the how and the why of weather knowledge within the tropical Malayan context. There have been recent studies undertaken on the environmental history of Malaya, but there have been no studies that foreground weather as a component in Singaporean or Malaysian history nor any that merged the history of colonial environments with the scientific history of weather and its extremes.[28] My premise is that these fields are not distinct and ought to be considered in their relationship to one another. Critically, I consider the weather as a catalyst for the development of science and land resources management, lending agency to the atmosphere in the shaping of colonial science and governance, showing how local circumstances often triumphed over global knowledge in the execution of science. Doing so foregrounds weather within a framework of

colonial interests, capacities, and capabilities, especially the state of science and technology, the desire to have a productive economy, and the realities of the environment.

Tropical weathers and landscapes presented extremes and uncertainties. These necessitated the acquisition of new knowledge to maintain settlers' quality of life and their economic resilience by controlling, or trying to control, nature. Nature dominated every aspect of life in the tropics, and it was almost impossible to tie it down. As the local writer Walter Makepeace was to note in the early twentieth century simply of the realities of indoor white-collar work: "the climatic and geographical conditions of Singapore affect the personnel of the firms that carry on business here (since practically every business man has to go on frequent leave) and the length of the life of the firms."[29] His viewpoint spoke only to the experience of the colonial European of course, but the challenges of creating a livable and workable environment in a tropical atmosphere often pushed the colonial government beyond its capacities. Solutions were frequently enacted at the expense of nature, which, ironically, often made managing the effects of the weather more problematic in the longer term. The deforestation needed to create new plantations, for instance, caused problems of soil degradation and erosion that, in turn, exacerbated the impacts of floods and droughts. This also began a long process of altering the indigenous landscape in ways that were never recovered.[30]

TEMPORALITY AND CONTEXT IN COLONIAL MALAYA

The focus here is on the multicultural ports and peripheries of Singapore and to a lesser extent George Town, Penang, the second-largest town of the Straits Settlements, although I also discuss Malaya more broadly. The temporal scope of the study is the nineteenth and the early twentieth century, during which time both the English East India Company (EEIC) and the British government had varying degrees of political and economic control over the Straits Settlements, the Federated Malay States, and the Unfederated Malay States. It was a time of sweeping social, economic, political, environmental, urban, climatic, technological, and scientific change.

The peninsula's strategic location between India and China enticed the British to challenge Dutch trade dominance in the East Indies by their settling Penang Island, which the British called Prince of Wales Island off the northwestern peninsula, and Singapore Island to the south. The ports of George Town, Penang, and Singapore were established through complex political negotiations with local rulers and force of personality. From the 1770s onward, the northeastern border region of Kedah was in turmoil because of a dynastic dispute and successive incursions from Bugis and Siamese factions. The sultan of Kedah, Sultan Muhammad Jiwa, sought military aid from the

FIG. 1. "Malay Peninsula," 1876. MPG1-1023, TNA.

EEIC in exchange for a monopoly on tin, pepper, and ivory, a practice that continued under his son Sultan Abdullah Mukarram Shah. Captain Francis Light of the EEIC saw opportunity in the situation and his eventual cessation of the site of George Town on Penang Island in 1786 began the direct intervention of the British into Malay territory that extended to the whole of Penang Island and Province Wellesley on the mainland.[31] The settlement at Singapore Island was established through a negotiation between Stamford

Raffles, then lieutenant-governor of Bencoolen, Major William Farquhar (who would become the settlement's first Resident), the Temenggong Abdul-Rahman of Johore and the sultan of Johor-Riau and Singapore, Hussein Mua'zzam Shah ibni Mahmud Shah Alam, between 1819 and 1824.[32] The settlement was originally governed from Bencoolen in Java from 1819 but it was placed under the control of the governor-general in India, via EEIC administration from 1826. It became the administrative capital of the Straits Settlements (which also included Malacca and Dindings) in 1826.

From the very beginning, the placid climate, along with the strategic position of the settlements, would be a boon. Exploitation of the peninsula's natural resources followed quickly, engendering the development of the major nineteenth-century trading entrepôts for the region—George Town and Singapore—and the transformation of land for commercial purposes. After the EEIC failed in the 1860s, the Straits Settlements became a Crown Colony and the opening of the Suez Canal in 1869, combined with the transition from sail to steam, created the conditions for trade expansion. The British extended their influence further into the mainland after the 1874 Pangkor Treaty began the British Residency system in Perak, leading the way to formalizing the Federated Malay States (comprising the agricultural states of Perak, Selangor, Negri Sembilan, and Pahang) in 1895. This opened these agricultural states to free trade and allowed the British to develop and control their commercial plantation agriculture. Early commercial enterprises exporting tin, gutta-percha, coffee, and pineapple were rapidly overtaken by the commercial success of rubber in the early 1900s.

All of this enacted a heavy toll on the environment, however. Mining and agriculture, urbanization, and infrastructure, deforestation, land-use change, alterations to watercourses and ecosystems, all meant that human and animal resilience in the face of extreme tropical weather declined. Local governments, planners, and engineers responded by trying to improve their knowledge of the weather and its dynamic interaction with the local environment, to create effective solutions so as to manage the most extreme of the weather's impacts on the towns and agricultural districts. The pace of man-induced environmental change was clear to contemporaries. Some began to question man's relationship with nature, especially regarding deforestation. They saw virgin forest give way to commercial monocrop plantations, soil erosion on denuded hill slopes, and rapid urban expansion. They recognized that barren hills and riverbanks led to an increase in the frequency and severity of land slips and floods and wondered, drawing from current scientific thought, whether the loss of natural habitat was causing changes to localized rainfall. They even theorized on whether urbanization was causing temperatures to rise.

Between the 1870s and the 1920s, anxieties increased as the El Niño

Southern Oscillation (ENSO) brought unusually extreme weathers to the British Empire across all of Asia. The ENSO is a cyclical atmospheric phenomenon. It has three main phases—neutral, positive, and negative, the latter two (known as El Niño and La Niña) result in low and high rainfall respectively. In Asia, these phases can induce devastating social impacts from droughts or floods.[33] Some phases can be stronger than others, such as the exceptional El Niño of 1877 or that of 1911. ENSO's interaction with the regional Indian Ocean Dipole (IOD), a three-phase climate oscillation that affects the temperature of the Indian Ocean, can also exacerbate the effects of the ENSO. The ENSO phenomenon was not identified formally until 1924 and the IOD not until the 1990s, so during the time covered in this study, observers identified patterns and speculated on whether human-induced environmental degradation or other phenomena such as sunspots caused this periodic extreme weather.

Ramachandra Guha has argued that the impacts of colonialism on the Indian environment, environmental destruction and climatic instability, attacked traditional sustainable and self-sufficient ways of living, leading to social dislocation and enhanced vulnerability. So too was the situation in Malaya.[34] Land-use change, imported engineering, population increases (especially of new urban inhabitants), and the rise of the technocrat divorced people from traditional ways of living with nature and altered the environment in ways that benefited the colonial class rather than the rest of society.

CLIMATE AND COLONIAL SCIENCE

Reliant as they were on a stable environment to maximize agricultural output and minimize outlay from damages, the colonial government officials were incentivized to increase their spending on mitigation measures but not to increase their research into understanding the atmosphere. Historians of science will be familiar with the concept of how scientific knowledge develops in site-specific places with site-specific needs.[35] Studies of the field, the lab, or the institution as the site of knowledge production have much applicability to the Malayan case as, although the colony was not a lab or an institution, it is plainly apparent that local weather and circumstances forced the balance of need, over knowledge, in managing the weather.[36] The tropical situation therefore offers new conceptual opportunities for us to explore how intemperate climates forced new ways and scales of practicing science and environmental management.[37]

However, this is not a story of progress toward a scientific apotheosis. The story of Malayan weather science and weather management is a story full of gaps, of failures, and of disinterest. Knowledge of tropical weather and its extremes remained largely undeveloped, despite advances in mete-

orological and climate sciences in the global North. In the first half of the nineteenth century, the sciences of tropical weather and of regional weather systems were a blank. Although there were efforts made to understand general information as to the typical weather of new settlements, such as the mean temperature and rainfall, from a scientific perspective these were limited to observations over short periods of time from occasional station points.[38] Observational and theoretical work was undertaken in the field of cyclonic storms of the Indian Ocean and the China Seas, mainly supported by mercantile and military interests, but the understanding of tropical monsoon systems or simply everyday weather in Malaya was largely absent.[39] Over the course of the century, theoretical and empirical knowledge about global climates shifted from thinking about climate as stable and localized to knowing it as a changeable phenomenon. These understandings developed largely outside of any empirical research in Malaya, however; the chief theory to impact on scientific thinking and practice was a shift in the knowledge of the scales at which weather, or climate, operated.[40]

In the early 1800s, colonial climates were measured at local scales. Military officers of the EEIC might record the weather in port or, occasionally, at a civic building or hospital. Other interested observers made single-site records within close distance to developing towns and their peripheries.[41] These records were rarely compiled for more than a year or so, in part because of the transient nature of the observers or their instruments—perhaps they were an EEIC officer who was posted to a new location—but also because it was supposed that there was no scientific reason to do so. The climate of the tropics was thought to be stable all year-round, year in, year out, and the peaks and troughs caused by the ENSO and IOD were not picked up on until much later, through a combination of lived experience and the availability of longer-term records across wider areas. As the Malayan interior was cleared for plantation, the number of station points built to make observations were extended outside of the urban settlements of Singapore, George Town, and Malacca. Patterns identified in the records were connected to contemporary theories coming out of Britain and Europe—Luke Howard's or Emile Renou's work on city heat in London and Paris respectively, for example—and it was also suggested that rainfall may have declined in areas where forests were cleared, an ancient theory reinvigorated during the 1800s and referred to as desiccation.[42]

As the century progressed, observers also began to develop a keener sense of climatic teleconnections across regions rather than just across localities or districts. A major drought in 1877–1878, for example, made meteorologists across Britain's Asian Empire—such as Henry Blanford, head of the newly established Indian Meteorological Department (IMD), and Charles Todd, the government astronomer in Australia—only too aware of the possibility

that climate might operate on regional or even global scales. Blanford, using synchronous instrumental weather observations gathered from a network of newly established regional stations, deduced that the "condition of excessive pressure prevailed over not only the Indo-Malayan region and Eastern Australia, but also the greater part if not whole of Asia, probably the whole of Australia and the South Indian Ocean." Todd similarly concluded that "there can be little or no doubt that severe droughts occur as a rule simultaneously," referring to reports from India, Singapore, and Batavia.[43] Such remarks were only possible because of the expansion of the observatory and station network across Asia and of collaboration between different nations in and around Asia from India, to China, to Hong Kong, the Philippines, and Japan, on matters of weather reporting and forecasting.[44] In this way, the scales of weather and its impacts metamorphosed from local weathers to regional climates and the enduring legacy of climate as a stable entity was transformed.

This new knowledge—especially that stable climates had natural or human-induced fluctuations—fed into the discussion of hydraulic management. Heavy rains or flash floods were a regular feature of tropical living, but extensive forest clearances, clean weeding practices on plantations, and mono-cropping laid the groundwork for intensifying soil erosion, runoff, and flooding. George Town, for example, was bounded by steep hills to the west, and it was clear to everyone that development on the hillside intensified soil erosion, and thus flooding and landslips, impacting on the public health of urban inhabitants, as well as causing regular damage to the urban landscape. Repeated droughts eventually forced the local government to improve the city's system of reservoirs and piped water, especially as urban populations rose.[45] Although hydraulic systems are almost as old as humanity itself, the colonial experience imposed foreign engineering structures into tropical environments, structures that often impinged upon the flow of nature or existing indigenous systems, in part to manage the imported ways of living that differed from extant means.[46] Controlling water required huge, expensive infrastructural investments, and it has been argued that the resultant hydraulic systems enabled colonial government officials to better utilize their colony's resources, protecting and enhancing economic productivity.[47] A close study of the development of hydraulic management in Malaya, however, reveals a more nuanced account, where infrastructures routinely lagged behind need.

By the early decades of the twentieth century, the frameworks, methodologies, and technologies available for thinking about, or managing, weather had expanded. In the scientific world climate was considered a teleconnected and global experience. Evolving communications technologies from telegraph to wireless and the transition from steam to air enabled meteorologists to gather data at temporally current, geographically broad, and infrastructurally embedded scales. Weather reports and forecasts were critical to im-

proving agricultural yields or to cultivating new areas and were essential to the nascent aviation industry.[48] Improving meteorological capacities at large scales also demanded international cooperation, agreement, and standards. But just as weather science expanded into these macroscales, urbanization and new technologies created the possibility of microclimates.

Over the 1920s and 1930s sociotechnical changes created artificial climates, which were distinct from anything known during the previous century. Whether it was an urban street heated by motor car pollutants, hard road surfaces, and increasingly concretized surroundings or an indoor space cooled by fans and later air-conditioning, modern living created new atmospheres and microclimates. The notion of indoor and outdoor space became gradually less fluid, as buildings were progressively closed off from the outside world, shuttered to keep in cooler airs generated by technical solutions rather than kept open to attract breezes. The introduction of electricity and refrigeration in combination with improved water management systems began the long and disjointed process whereby people who could afford it became divorced from their environment. During the period of this study, however, people still lived "in climates—amidst the particular fluxes of weather that they encounter in different places, visceral experiences which are interpreted through their imaginative worlds."[49] It would be a long time before the advance of technology would impact on people's lives evenly, if at all. Within the time frame of this book (and for many even longer still), money made the difference. Money determined whether you lived in cheap, housing prone to flooding, had insurance, or could afford any form of domestic cooling system. There was no clear chronological transition, and many of the same vulnerabilities that existed in early colonial societies endured. For some, modernization led to better standards of living and detachment from the climate, but for many, a reliance on wage labor and mass market commercialization lead to heightened social divisions and thus greater vulnerability to climatic shocks.

In this book I move through all these shifts in climatic experiences within the context of colonial Malaya. From the science of meteorology to weather management, from perceptions of tropical weathers to the creation of new microclimates, the weather infiltrated all aspects of life. As this story will show, studying weather science and weather management offers an alternative way into understanding colonialism and the environment.

THE FRAMEWORK OF IMPERIAL METEOROLOGY

The book is separated into three sections, each of which considers a different aspect of weather in colonial Malaya: the science of weather, changing weather, and controlling weather. Considered as a whole, they offer a long

view of change over time while facilitating in-depth insight into different areas of weather studies and human-climate interaction in colonial settings. The first section comprises an overview of the state of meteorological and climate science in the colony. I explore how tropical weather was understood by contemporary men of science and colonial officials, what their chief concerns were, and relatedly, how meteorology was practiced. In chapters 1 and 2, I explore the situation of Malayan meteorology from the 1820s until just after the conclusion of the Second World War. This was a significant transitional period in the history of meteorology globally, as well as in Malaya, with new communications technologies such as telegraph and radio increasing the speed and distance across which weather observations could be transmitted, new global institutions and standards, such as the IMO or the Beaufort Scale, new practices including mathematical modeling and theories to understand atmospheric phenomena such as cyclones. Nevertheless, revealed in both chapters is a strong theme of institutional disorganization and governmental disinterest in advancing the science in Malaya, especially in the nineteenth century, despite a growing global acknowledgment of its importance. These chapters constitute the contextual foundation for the remainder of the book.

From here onward, chronology gives way to theme. In Part II I dive deeper into the areas in which colonial officials held a particular interest, especially in response to ideas popularized in the later nineteenth century about the possibility of man-made climatic change. The focus in chapter 3 is on the desiccation "debate," an idea that had been around for centuries but which drew particular attention in the 1800s as colonial activities rapidly reshaped natural landscapes and European explorers asked questions about the desertification of African and central Asian interiors. This discussion hit a peak around the 1870s in connection to the question of whether forest clearances were decreasing rainfall, a critical concern for governments supervising plantation economies just as in Malaya. Weather records became the chief means to establishing patterns in rainfall and establishing norms and deviances.[50]

The government's desire to sustain and improve economic productivity was behind most of the main thrusts in environmental conservation or meteorological investment in the nineteenth century. Protecting the riches of the forests and jungles would provide woods for the railways and infrastructure, manufacturing, building, and furniture, and the resins, gums, and oils used in all types of products from medicine to food, dyes, and perfumes.[51] As Hugh Cleghorn, the conservator of forests in India, noted in 1861, the practice of forest clearances by unscrupulous contractors, traders, and natives needed to be stopped for the "public good" because they were laying waste to "useful material" and resources "valuable to science."[52] These were all materi-

als that colonial officials wanted to exploit themselves. By the first decades of the twentieth century, tropical forests were seen as a source of everyday materials, such was their significance in global commodities markets.[53] As early as the 1870s, it was also thought necessary to protect the forests in order to protect rainfall in a country that depended on its plantations for its wealth. These fears resulted in first conserving areas of forestland, such as Nathaniel Cantley's proposals to conserve large swathes of Singapore's jungle in the 1880s, and second, improving the network of meteorological observation stations across the country so as to enable sufficient density and breadth of records for detecting changes in rainfall.[54]

Conversely, however, in chapter 4 I show that studying temperature was conceived of very differently from studying rainfall, despite the plentiful depictions of the heat in contemporary literature (travel writing) and the concern of medical establishments for human (European) health in hot weather. Most weather records kept across the nineteenth century comprised temperature as well as rainfall measurement. Yet there was little coordinated research on tropical temperature (outside of medical literature) within the Straits Settlements. In this chapter, therefore, I explore some of the possible reasons for this incongruity but also draw attention to the irony that, while temperature research per se was not considered a subject for meteorological science, there was a limited but steadily mounting discourse on urban heat.

The discussion on urban heat in Malaya was quite clearly influenced by scientific research coming out of Europe on how urbanization increased heat but was provoked by the lived experience of urbanization. Keeping cool was a priority for Europeans unused to the tropics, so the idea that the growing towns might be worsening the situation caught contemporaries' attention. Unlike the desiccation discussion, the urban heat discussion was more of a scientific curiosity than a concern, unlike today. Urban heat may have made things less comfortable, but small temperature differences were not considered serious enough to affect human health or have a drastic impact on productivity, unless there was an exceptional heat wave. Also, at the time that increasing development, concretization, and motor cars were making urban living hotter, corresponding coping technologies were being introduced to cool things down, such as the electric fan and, later, air-conditioning. Modern science was providing the technological solutions to improve lived experiences through controlling the climate, even if it could not—yet—make it rain.

Controlling the climate is thus the theme that binds the third and final part of the book. Part III is an interrogation of the conceptualization of imperial control. Using weather—an inherently unstable and unpredictable phenomenon—means a reevaluation of the relationship between colonialism and power. The story of how, and how far, British colonial officials at-

tempted to manage the weather's extremes—in an age where science was hoped to be the answer to living, and profiting, within precocious environments and atmospheres—is telling of this relationship.[55] In particular, Part III draws attention to two aspects to this story. First, and in keeping with the themes of the previous chapters, it points to inaction, or inability, in the colonial government's response to the weather. Second, it looks at how managing weather proved to be a reflection of, and driver for, the social divisions inherent in colonial society.

Chapter 5 is an exploration of flooding. Malaysia and Singapore have a high annual rainfall that is spread relatively evenly throughout the year, but from November to January monsoon surges can cause severe rainfall events, and during May and June there is a high incidence of flash flooding because of the phenomenon known locally as Sumatra Squalls. These squalls, when combined with a high tide, mean that low-lying coastal areas are easily flooded and, when combined with La Niña heavy rains, can cause rivers to burst their banks and mountainous areas to experience devastating landslips. Flooding was a serious problem for the expanding settlements and for the agricultural land of the colony. My argument, however, is that although basic precautions such as seawalls or embanking were established early on in British rule in new urban settlements, more extensive initiatives tended to be put in place reactively, rather than because of forward planning. This was especially the case before the 1920s and outside of the towns. Even when solutions and schemes were proposed, they were quite flagrantly aimed at protecting the town's civic and business interests over and above the town's poorer inhabitants. Any given scheme's inception and realization was frequently hampered by a lack of funds, resources, and disagreement at the top levels over what ought to be done and how. Far from the notion of control, local governments were compelled into taking measures because of the recurrence of costly disasters, a growing complaint culture among citizens, and a changing sense of expectations of the role of government in the twentieth century.

With the focusing on the converse extreme of drought, chapter 6 is an exploration of the colony's quest for sustainable and potable water, especially in the emergent towns, as it was discovered that Malaya was not always the persistently wet environment that was first assumed. Rapidly rising urban populations demanded ever more complex infrastructures and technologies to conserve and distribute water. This chapter continues the theme of omnishambles, arguing how schemes to conserve or enhance Malaya's urban water supply were reactive, were underfunded, and suffered considerable implementation delays. Notwithstanding, securing a constant and abundant water supply for harbor activities and shipping was vitally important to the economic survival of the ports of Singapore and George Town, and ensur-

ing an adequate and healthy water supply for urban inhabitants was considered a moral imperative. Thus, larger reservoirs and ever more elaborate and expensive means of drawing water to the towns, especially Singapore, became a focus of engineers from the 1910s to the 1930s. Feats included the monumental Johor-Singapore Causeway, which in addition to its function as a land crossing, contained waterpipes linking Singapore to a reservoir at Gunong Pulai on the Malayan peninsula.[56] Over time, the improved availability of long-term weather observations, especially from the 1870s onward, invited contemporaries to investigate the seeming regularity of extreme drought periods, to have data to underpin water usage projections in line with population and industry needs, and to scientifically plan the capacities required for flood mitigation schemes.

However, the more that nature was "controlled" for some, the more others became vulnerable during periods of climatic instability. Indigenous communities such as the *Orang Laut* (sea people) survived by coexisting with the ocean's natural rhythms, or *Jiwa Laut* (spirit of the sea), and the *Orang Asli* (original people) had free rein of the jungle's incredible resources.[57] As their lifestyles and communities were gradually subsumed by the progression of infrastructure and the transformation of land from swamp and forest to plantation and town, they, like the large migrant communities of unskilled workers and laborers who had immigrated to the towns and plantations, had less recourse to traditional ways of living with water. These people were at most risk from living in poor quality housing on cheap land that was easily flooded, having limited access to fresh water supplies to manage through a drought.

Finally, in chapter 7 I consider climate control at the micro-level. Instead of looking at how unpredictability was managed, I explore how the predictable specter of heat and humidity could be managed through the introduction of cooling technologies. This process was immersed within an era of technological optimism whereby scientific expertise was considered part of the solution for resolving the problem of the climate, not through massive geoengineering schemes or climate modificationbut through small-scale changes in homes, offices, institutions, and places of entertainment. Wholly reliant on the pre-introduction of electrification, air-conditioning was symbolic of modern, clean, and healthy living. While the process of cooling Malaya was not a government-managed initiative, it was still an issue of managing and living within a tropical climate; cooling technologies were embedded within colonial-era socioeconomic structures and were largely imported from the West. Their advent and adoption presaged a new way of distinguishing between rich and poor, with cooling technology becoming a marker of wealth and better living standards. Just as the focus in chapters 5 and 6 is on socio-environmental injustices during flooding and drought,

the focus of chapter 7 is on how cooling technologies were socially discriminating. Early air-conditioning was available only in spaces that charged an entry fee, such as cinemas or dance halls; domestic air-conditioning units were out of most people's price range. Thus, this chapter is an exploration of climate control as a form of sociotechnical imaginary, achieved by the few while imagined by the many, shedding light on how colonial-era aspirations to modernity were restricted to time, space, and person.[58]

Overall, in this book my aim is to speak to readers of environmental and scientific history. As such, the study is located at the intersection of both fields and may therefore seem incongruous to readers firmly situated in either one or the other. My aim, however, is to illuminate how the climate crosses disciplinary borders as well as national ones and how, when used as the means of interrogation, climate reveals the relationship of colonialism, science, and society.