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Heat and colonial weather science in the Straits Settlements c. 1820-1900

Fiona WILLIAMSON
Singapore Management University, fwilliamson@smu.edu.sg

Beyond Tropicality: heat and colonial weather science in the Straits Settlements c. 1820-1900

Abstract

Historical explorations of tropical heat in a colonial context have largely focussed on two interconnected spheres: colonial perceptions of place and body or, the implications of heat on different bodies in medical thought and practice. This paper seeks to move the discussion towards a history of colonial scientific thought about heat as component of weather and of escalating nature-induced hazards, studied in the observatory or meteorological department. A central theme is to think about heat in its relationship to nascent meso-scale atmospheric knowledge, meteorological theory and, as a by-product of urbanisation and land-use change. In so doing, it conceptualises the scientific understanding of heat as essentially responsive, embodied within science as result of how heat was prioritised within a local context and in the contemporary understanding of human-induced climatic change. The paper works thus across the disciplinary boundaries of history of science and environmental history to highlight an underexplored aspect of the Straits Settlements' past: the scientific history of urban heat.

Introduction

The direction of this article is influenced by recent intersections between environmental history and the history of science, especially the ways in which embodied history (habitus) have drawn attention to the importance of place in grounding the history of science. Some of this literature has seen environmental or climatic factors as an historical explanation for the development of science, situating practice in locality and materiality as basis for the construction of scientific knowledge.[1] This frame for understanding the development of knowledge has been especially apparent in the field of natural science history from the 2000s, whereby the role of place (lab/field) has been considered in some depth. There has been less attention to place as a methodological lens in histories of meteorology until relatively recently. One of the main ways this angle has developed is through consideration of the formative role of the weather in shaping science.[2] Early work in this field tended to be framed socio-culturally, such as Vladimir Janković's *Reading the Skies* which considered the embodiment of locally based weather knowledge as a formative part of English culture or slightly later, technology-oriented studies such as Jim Fleming's *Fixing the Sky* or Kristine Harper's *Making it Rain* which explored how weather – or the desire to manage it – led to scientific research and development.[3] Certainly,

[1] Kohler, Robert E. (2006), *All Creatures: Naturalists, Collectors and Biodiversity, 1850-1950*, Princeton: Princeton University Press; Schiebinger, Londa (2004), *Plants and Empire: Colonial Bioprospecting in the Atlantic World*, Cambridge, Mass.: Harvard University Press; Kohler, Robert E. (2002), *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology*, Chicago: Chicago University Press; Soojung-Kim Pang, Alex (2002), *Empire and the Sun: Victorian Solar Eclipse Expeditions*, Stanford: Stanford University Press; Dorn, Harold (1991), *The Geography of Science*, Baltimore: John Hopkins University Press.

[2] Rouphail, Robert M. (2019), 'Cyclonic Ecology: Sugar, Cyclone Science, and the Limits of Empire in Mauritius and the Indian Ocean World, 1870s-1930s', *Isis* 110/1: 48-67; Johnston, Sky Michael (2019), 'Weathering Early Modern Germany: Vernacular Meteorology, Pastoral Theory, and Communal Life in the Long Sixteenth Century UnPub. PhD Thesis, University of Southern California; Raby, Megan (2017), *American Tropics: The Caribbean Roots of Biodiversity Science*, Chapel Hill: University of North Carolina Press.

[3] Janković, Vladimir (2001), *Reading the Skies: A Cultural History of English Weather, 1650-1820*, Chicago: Chicago University Press; Harper, Kristine (2017), *Making it Rain: State Control of the Atmosphere in Twentieth*

the history of climate and climate science offer both methodological and conceptual opportunity for new ways of exploring the relationship of climate, environment and science. Post-colonial history has also seen several investigations of tropical environments and scientific practices that relate to the weather. Some of the best studies have investigated the science of climatic thought, especially in light of the fast-paced environmental destruction that colonial development wrought on tropical habitats.[4] Others have explored how new spaces (observatories, registering stations and weather networks) advanced colonial meteorological science and, arguably, colonial power, in different regions.[5] Bringing in the colonial setting has offered new pathways into understanding the interface of politics, power, science and environmental/climatic change. The latest trends in this area focus on how extreme weathers instigated scientific paradigm shifts for example, particularly in thinking around how atmospheric phenomenon linked to localised environmental changes and in revealing early understanding of atmospheric teleconnections across borders and regions.[6] This latter area is where the concerns of this paper lie.

There have been several excellent studies of the science of heat, such as that of temperature and thermometry by Hasok Chang, alongside many studies of the history of thermodynamics within the history of science.[7] Within the colonial context there have also been many explorations of tropical heat, health, and the body, often framed within the context of medicine and the imperial gaze.[8] In this article however, I think about heat solely within the bounds of

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Century America, Chicago: Chicago University Press; Fleming, James R. (2010), *Fixing the Sky: The Checkered History of Weather and Climate Control*, New York: Columbia University Press. See also: Hochadel, Oliver and Nieto-Galen, Agusti (2018) eds., *Urban Histories of Science: Making Knowledge in the City, 1820-1940*, London: Routledge.

[4] Craciun, Adriana and Terral, Mary (2019), eds., *Curious Encounters: Voyaging, Collecting, and Making Knowledge in the Long Eighteenth Century*, University of Toronto Press; Slonosky, Victoria C. (2018), *Climate in the Age of Empire: Weather Observers in Colonial Canada*, American Meteorological Society; Coen, Deborah R. (2018), *Climate in Motion: Science, Empire, and the Problem of Scale*, Chicago: University of Chicago Press; Zilberstein, Anya (2016), *A Temperate Empire: Making Climate Change in Early America*, New York: Oxford University Press; Cushman, Gregory T. (2011), 'Humboldtian Science, Creole Meteorology, and the Discovery of Human-Caused Climate Change in South America' *Osiris* 26: 19-44; Grove, Richard (1998), *Ecology, Climate and Empire: The Indian Legacy in Global Environmental History*, New Delhi: Oxford University Press.

[5] Frank, Mark (2021), 'Frontier Atmosphere: observation and regret at Chinese Weather Stations in Tibet, 1939-1949', *British Journal for the History of Science*, 54/3: 361-380; Bickers, Robert (2016), 'Throwing light on natural laws': meteorology on the China coast, 1869-1912,' in Robert Bickers and Isabella Jackson, eds, *Treaty Ports in Modern China: Law, Land, and Power*, London: Routledge, pp. 179-200; Zaiki, Masumi and Tsukahara, Togo (2007), 'Meteorology on the southern frontier of Japan's empire: Ogasawara Kazuo at Taihoku Imperial University*,' East Asian Science, Technology and Society: an International Journal*, 1: 183–203.

[6] Gooding, Philip, ed., *Droughts, Floods, and Global Climatic Anomalies in the Indian Ocean World*, London: Palgrave, forthcoming; Grove, Richard and Adamson, George (2018), '*El Niño in World History*, London: Palgrave Macmillan.

[7] Chang, Hasok (2004), *Inventing Temperature: Measurement and Scientific Progress*, Oxford: Oxford University Press; James, F. (1982), 'Thermodynamics and Sources of Solar Heat, 1846–1862', *The British Journal for the History of Science*, 15/2: 155-181. doi:10.1017/S0007087400019154.

[8] For example: Pols, Hans (2018), 'Health and Disease in the Tropical Zone: Nineteenth-century British and Dutch Accounts of European Mortality in the Tropics', *Science, Technology & Society* 23/2: 324-329; Anderson, Warwick (2017), 'Coolie Therapeutics: Labor, Race, and Medical Science in Tropical Australia', *International Labor and Working-Class History* 91: 46-58; Beattie, James (2011), *Empire and Environmental Anxiety: Health, Science, Art and Conservation in South Asia and Australasia, 1800-1920*, Palgrave Macmillan; Arnold, David (2006), *The Tropics and the Traveling Gaze: India, Landscape and Science, 1800-1856*, Seattle and London: University of Washington Press; Arnold, David (2003), 'Introduction', in David Arnold, ed., *Warm Climates and*

the nascent study of meteorology and extreme weather. The discussion is framed as a history of colonial scientific thought about the weather, especially in relation to the human potential for altering the weather or for creating hazards, as studied in the field, the observatory, or the meteorological department. A central theme is to think about heat's place in nascent meso-scale atmospheric knowledge, meteorological theory and, by extension, in its relationship to human civilisation, in this case, urbanisation and land-use change. In so doing, it sees contemporary tropical heat research as an essentially responsive science, resulting from how heat was perceived within its local context albeit informed by the wider studies that were available at the time. The history of heat studies within meteorology should, like most sciences, also be considered non-linear. While this article highlights certain developments in a chronological order, their embodiment within scientific infrastructure, place or thought was never teleological but discrete and scattered across time, often in response to particular atmospheric events that affected society and environment or, in many cases, as result of individual researcher's interests.

It is also worth raising that there are several problems innate in the study of temperature in the Straits Settlements. First, much of the work that related to atmospheric temperature change on a macro or micro-scale during the period of study was not undertaken in the tropics. Eunice Foote, John Tyndall and Svante Arrhenius' studies of carbonic acid, for example, worked within an energy budget model, to explore the possibilities of global temperature rise or decline.[9] But this work relied on the premise of a globally teleconnected atmosphere and the acceptance of this concept into mainstream meteorology. Temperature in meteorology was rarely considered a changeable component of large climatic systems, instead tending to be conflated with latitudinal studies of mean global averages. Julius von Hann, for example, considered to have written one of the more influential texts on meteorology for the late nineteenth and early twentieth century, explored the principle of an energy budget deducted through statistical description, connecting climatic fluctuation to historic or cyclical time scales, much as astronomers Annie and Edward Maunder or geologist Louis Agassiz had theorised before him.[10] Thus von Hann gave little credit to the possibility of temperature change per se, conceiving of it more in readily explainable scales. Such ideas lay at the root of the difference between atmospheric studies and the field of meteorology and lasted until at least the early-twentieth century, with the latter predominantly remaining a statistical exercise until the demand for better weather forecasting – driven by commercial and military aviation needs - became more urgent. This was compounded by various practical hindrances in the study of meteorology too. Meteorological thermometry did not really develop until radiation and the

Western Medicine: The Emergence of Tropical Medicine, 1500-1900, 2nd edn., Amsterdam-Atlanta, GA; Livingstone, David (2002), 'Tropical Hermeneutics and the Climatic Imagination', *Geographische Zeitschrift* 90/2: 65-88; Harrison, Mark (1999), *Climates and Constitutions: Health, Race, Environment and British Imperialism in India 1600-1850*, New Delhi: Oxford University Press; Kennedy, D. (1990), 'The perils of the midday sun: climatic anxieties in the colonial tropics', in J. M. MacKenzie, ed. *Imperialism and the Natural World*, Manchester: Manchester University Press, pp. 118–140.

[9] Jackson, Roland (2019), 'Eunice Foote, John Tyndall and a question of priority', *The Royal Society Journal of the History of Science: Notes and Records* 74: 105-118.

[10] Edwards, Paul N. and Bowker, Geoffrey C. (2010), *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*, MIT Press, pp. 62-6.

transfer of heat energy was better understood and, even in the early 1800s, the 'fixed point' for calibrating thermometers was still creating debate.[11] The inability to make frequent and wide coverage upper-air observations until the advent of an aviation industry in the 1930s – especially in the tropics - also meant that temperature research was literally grounded, reliant on terrestrial datasets which were few and far between outside the US and Europe until the late nineteenth century. As Russell McCormmach explains, the understanding of heat developed in tandem with the technological ability to measure it.[12] The ways in which meteorology was practiced prior to the Second World War reflected these practical considerations whereby the nascent field was largely divided into three camps: forecasters who aimed to improve weather predication accuracy; theoretical meteorologists who grounded deductive knowledge in mathematical law and physics and, empiricists who induced weather laws from data analysis, rather than the mechanics of physical qualities.[13] At the same time, tropical temperature readings and studies were often by-product of other interests, such as magnetism, health, or agriculture, rather than a research topic for its own sake.

Second, there were specific local circumstances preventing more in-depth research. In the British Straits Settlements, heat was assumed to be a relatively stable feature of the climate across the year and, where no resources were being placed into meteorological research beyond basic statistical correlations – mostly for medical research on the relationship of disease and extreme weather - research on temperature per se was underdeveloped. While knowledge of global scale radiative or climatic forcings which might affect temperature were spreading throughout scientific circles, in the Straits Settlements temperature change was more often spoken of as temporary and always on local scales, responsive to specific environmental destruction and deforestation. In many respects, this was in line with the dominant narratives of the day that thought about climate at near scales, a commonly enough accepted trajectory of thought derived from Theophrastus writings on climate, which endured even through reinvention by polymath scholars such as Eduard Brückner or Peter Kropotkin.[14] Until at least the 1930s, statistical and descriptive accounts of weather were the norm in the Straits Settlements, as elsewhere, and the idea of a teleconnected climate was anomalous because of the difficulty in establishing universal laws for a changeable ephemera.

With these caveats in minds then, the resources for this article were drawn from the national archives and libraries of Singapore, Malaysia and the United Kingdom for records pertaining to local meteorology, including local and regionally produced natural science journals, scientific and pseudo-scientific papers, official colonial government publications – such as

[11] Chang, *Inventing Temperature*, Chap. 1. A comprehensive introduction to the history of the thermometer is: Knowles-Middleton, W. E. (1966), *A History of the Thermometer and its use in Meteorology,* Baltimore: John Hopkins University Press.

[12] McCormmach, Russell (2004), *Speculative Truth: Henry Cavendish, Natural Philosophy, and the Rise of Modern Theoretical Science,* Oxford: Oxford University Press, p. 81.

[13] Edwards and Bowker, *Vast Machine*, p. 62.

[14] von Storch, Hans and Stehr, Nico (2000), 'Eduard Brückner's Ideas: Relevant in his time and today', in N. Stehr and H. von Storch, *Eduard Brückner: The Sources and Consequences of Climate Change and Climate Variability in Historical Times*, Springer Netherlands, pp. 1-24; Prince Kropotkin (1904), 'The Desiccation of Eur-Asia', *The Geographical Journal* 23/6: 772-734.

gazettes and medical reports, alongside actual weather observations and commentaries on climatic and environmental change. In addition, to explore the global contexts of local knowledge, sources relating to the state of British meteorology in the tropics more broadly are also included, for instance the letters and papers of the Royal Society and the records of the British Association for the Advancement of Science relating to tropical research in what were then British colonies.

Taking the Straits Settlement's Temperature

The British colonies known as the Straits Settlements were established between 1786 and 1824. The first known British-made observations of temperature were made at Penang in the 1780s, Malacca in 1809 and in Singapore from 1820 to 1824, largely convergent with the history of British incursion into and down the Malayan peninsula.[15] These early measurements were made using instruments that had been brought to the region on the English East India Company (EEIC) ships, repurposed during their sojourn in port to extend knowledge of the local weather. This was considered useful in ascertaining the potential for long-term European settlement. Interestingly, temperature and wind were prioritised over rainfall, despite the usefulness of precipitation data in establishing plantations. This may have been due to purely practical, rather than scientific considerations, as rain gauges were not used on marine voyages. The British government seemed to have lacked foresight in sending complete sets of meteorological instruments for permanent residence in these early forays, possibly due to the expense and very delicate nature of specialist observational equipment at this time.

These early Straits Settlements temperature observations generated much excitement in the scientific community. They were snapped up by David Brewster - a mathematician and physicist and then editor of the *Edinburgh Journal of Science* - to better determine the mean temperature of the equator. Brewster was especially interested in the Straits Settlements' observations as they represented the closest data to the equator that were then available. Previously he had been relying for his calculations of tropical and global climates on meteorological readings undertaken in Batavia and Ceylon.[16] These records were also made continuously over whole, rather than partial, years, opening a door into studying seasonal shifts, an area that had previously relied on anecdotal evidence rather than data. Determining the mean temperature of the tropical heat of the equatorial zone was a prominent scientific problem that had been broached in the 1820s by Alexander Von Humboldt and Henry Atkinson.[17] The problem revolved around establishing mean temperatures at different latitudes

[15] Farquhar, William (1826), 'Appendix I: Thermometrical Registers', *Transactions of the Royal Asiatic Society of Great Britain and Ireland* 1/2: 585-86; Monckton Coombs, John (1826), 'Appendix II: Thermometrical Registers', *Transactions of the Royal Asiatic Society of Great Britain and Ireland* 1/2: 586-98; British Library (hereafter BL), India Office Records (hereafter IOR), G/34/1 Bengal public proceedings, unrecorded papers 726, Instructions from the government at Bengal to Capt. A. Kyd to Survey Penang, Jerajal and Phuket, 11 April 1787: Observations made by Captain Francis Light, 1786.

[16] Brewster, David (1828) 'XII-On the Mean Temperature of the Equator, as deduced from Observations made at Prince of Wales Island, Singapore and Malacca', *Edinburgh Journal of Science* 8: 60-7.

[17] Atkinson, Henry (1826), 'XVI – On Astronomical and other Refractions: with a connected Inquiry into the Law of Temperature in different Latitudes and at different Altitudes', *Memoirs of the Astronomical Society of London* 2: 137-83; Humboldt, Alexander (1827), 'XIX-Observations of the Mean Temperature of the Equatorial Regions', *Edinburgh Journal of Science* 6: 136-144.

while determining an increase or decrease in temperature at various heights. Something of a dispute had ensued between all three men, as they arrived at slightly different conclusions for an estimated mean temperature of the equator, with Atkinson accusing Humboldt of making an error and vice versa. The observations from the Malayan peninsula were therefore critical to resolving this disagreement. Brewster used the datasets to update and challenge his peer's work while simultaneously adding new knowledge on tropical weather to the global understanding of climate.[18]

The quest to establish mean temperatures positioned the Straits Settlements within a geographically diverse dialogue, hinged on individuals who shared and debated their scientific knowledge in scholarly mediums. Brewster's ideas, for example, were published not only in the scholarly *Edinburgh Journal of Science* in the late 1820s but, disseminated to the reading public in the *Singapore Chronicle*, a locally produced newspaper, in abridged form. This enabled local actors to become aware of such ideas and, as we shall see, use them in their own studies. Nonetheless, there was little direct engagement in the question of temperature until the late 1840s, although there was interest in the climate in general from other fields. Weather observations were often added as addenda to the extensive natural history and ethnographic studies conducted by enthusiasts, for example, to which much time and effort was devoted in the local presses and journals. William Farquhar, for example (who had signed off on but probably not actually made the 1820s Singapore observations),[19] was interested personally in climate only so far as it related to local flora and fauna. The same could be said for the prolific Nathanial Wallich, who gathered one of the most extensive collections of regional plant specimens then known but spent little time considering the local climate beyond its role in producing regionally specific species.[20] Temperature was also noted as a means of establishing the purported 'healthiness' of the new colony's environments.

From the 1840s, things began to change. The interest in tropical diseases and the effects of heat on the (usually European) body had inspired new observational datasets and correlative studies undertaken for the sake of medical research, with the Medical Department later fully taking the main responsibility for meteorology from the late 1860s.[21] During the same decade, the interest in terrestrial magnetism also resulted in the opening of an observatory in Singapore. Managed by Lieutenant Charles Elliot and operating between 1841-45, the purpose of this observatory

[18] Werner, Anja (2014), 'Networks of Knowledge in the Sources of the 1826 Essai Politique sur I'ile de Cuba', *HiN- Alexander von Humboldt im Netz* XV/28: 59-67.

[19] The 1820s Singapore readings are usually attributed to English East India Company Bengal Native Infantry officer Charles Edward Davies.

[20] Bastin, John and Guan, Kwa Chong (2010), *Natural History Drawings: the Complete Williams Farquhar Collection, Malay Peninsula, 1803-1818,* Singapore: Editions Didier Millet; Arnold, David (2008), 'Plant Capitalism and Company Science: The Indian Career of Nathaniel Wallich', *Modern Asian Studies* 42/5: 899-928.

[21] Little, Robert (1848), 'An Essay on Coral Reefs as the cause of Blakan Mati Fever etc, Part I: On the medical Topography of Singapore, particularly its Marshes and Malaria', *Journal of the Indian Archipelago and Eastern Asia* III/VIII: 449-71; British Library (hereafter BL): MSS EUR D157. John Caswall, *Observations on the Medical Topography of Singapore* (1830), ff. 2, 6, 22-4; Ward, T. M. and Grant, J. P. (1830), 'Contributions to the Medical Topography of Prince of Wales Island or Pulo Pinang', in *Official Papers on the Medical Statistics and Topography of Malacca and Prince of Wales' Island…&c*, Pinang: Government Press, pp. 1-58.

was to study magnetism in conjunction with the simultaneous observations being made in other parts of the British Empire, including Tasmania, Simla, and Madras but temperature observations were made in conjunction.[22] This was the first time that temperature was monitored locally in any meaningful or coherent scientific way. Elliot and his assistants had noted it religiously, hourly, every 24 hours, alongside daily readings of pressure and general remarks on the weather and, although their aim was not to study weather per se, the value of the data lies more in the studies that were to come after that utilised this information, especially those that thought about the possibilities of climatic change. As an aside, today, this dataset is one of the best resources to detail Singapore's historic climate in an era before large scale deforestation and urbanisation.

Environmental Change and Temperature Change

The observatory was closed in 1845 due to government funding cuts and, after this, there were very few temperature observations made for the next two decades.[23] Nonetheless, there were several studies undertaken that noted the potential for deforestation to change the local climate that utilised the observatory's readings. The most notable was probably the 1848 paper published by James Logan in his own *Journal of the Indian Archipelago and Eastern Asia*. The paper derived from a lecture Logan had given for the Asiatic Society of Bengal two years previous. During his visit to Penang island, Logan had witnessed large scale destruction to its virgin forests – especially on the hill slopes – for agriculture and for charcoal. He raised the concern, citing direction from Alexander Von Humboldt and Jean-Baptiste Boussingault, that such destruction would 'prove the great influence in tropical regions of forests … in … diminishing local temperature'.[24] Logan also worked from contemporary examples of environmental destruction in other parts of the world, such as the Cape de Verde Islands (modern Republic of Cabo Verde) that now suffered a 'sultry atmosphere and dreadful droughts' owing to forest destruction.[25] The droughts that he predicted the Malay Peninsula might suffer as result of local deforestation would contribute to increasing heat, he argued, through the exposure and drying out of the deforested hill slopes. In such circumstances, he warned of the dire consequences of watercourses drying out 'amidst a universal aridity'. Logan's work drew directly from the understanding of climate change that was prevalent in many agricultural economies at that time, known as desiccation theory. It is no coincidence that this theory – despite having been known for centuries – achieved a pinnacle of discussion in the mid-nineteenth century, as rapid colonial development acted as a microcosmic lens into environmental destruction. The steady conversion of virgin jungle into plantation, infrastructure and town expansion had already elicited much comment by the 1860s in the

[22] For more on this project, see: Williamson, Fiona (2015), 'Weathering the British Empire: meteorological research in the early nineteenth-century Straits Settlements', *The British Journal for the History of Science* 48:3: 475-492; (1841) *Report of the Tenth Meeting of the British Association for the Advancement of Science, August 1840*, London: J. Murray, p. 428; (1846) *Report of the Fifteenth Meeting of the British Association for the Advancement of Science, June 1845*, London: J. Murray, pp. 3-.4

[23] BL, IOR F/4/2026, 91387 ff. 34, 7 January 1843.

[24] Logan, J. R. (1848), 'The Probable effects on the climate of Pinang of the continued destruction of its hill jungles', *Journal of the Indian Archipelago* 2: 534-6, 534.

[25] Ibid., 535.

Straits Settlements.[26] During the same period, the development of commercial news agencies and steam-driven faster postal services had enabled the faster and richer expression of news and scientific communication on such matters enabling local actors to engage more directly with these ideas.[27]

It was no great leap to make a connection between purported temperature changes with urbanisation, as well as with deforestation. John Crawfurd, a medical doctor, amateur scientist and previously British Resident at Singapore, had noted an urban and peri-urban temperature increase as early as 1855. Crawfurd had dedicated some early part of his research to understanding the temperature of the island, arguing - based on comparison of annual averages from across the British Empire - that it fell far lower than other areas with the same tropical latitude. He also noted however, that over twenty years, the temperature had increased. This change was, he contested, 'ascribable no doubt, to the increase of buildings, and to the country having been cleared of forests for several miles inland from town, the site of the observations'.[28] He went on to note how the lower maximum (in the shade) of the older observations made by one Mr Thomson (82.3°F as compared to 86.7°F at Crawfurd's time of writing) that would have been affected by 'the nearness of the forest to the town', which would have caused a 'greater degree of coolness'. Yet, he was also concerned as to why the annual minimum was in fact higher than the time at which he was writing.[29] He thus postulated that the forests may have had a dual effect, while bringing down the maximum, they had also 'hindered the free circulation of air and consequent evaporation'.[30]

His observations and concerns, as elsewhere in the colonies, grew from witnessing first-hand unchecked deforestation as plantation farming, mining and urbanisation had intensified.[31] The discussion reached a peak in the Straits Settlements after 1865, when Alexander Maingay, a Malacca based surgeon and amateur natural historian, had published his views on the issue in a government report. Just as Logan had done in 1848, Maingay claimed that 'the ruin of the forest … involves … a general elevation of the temperature, with an increasing prevalence of

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[26] Ward, T. M. (1830), 'Contributions to the Medical Topography of Prince of Wales Island, Or Pulo Pinang', in T. M. Ward and J. P. Grant, *Official Papers on the Medical Statistics and Topography of Malacca and Prince of Wales Island and on the Prevailing Diseases of the Tenasserim Coast*, Pinang: Government Press, pp. 60-117, 61. Sourced from the Wellcome Collection online: https://wellcomecollection.org/works/uhqkbwe2.

[27] Legg, Stephen (2014), 'Debating the Climatological Role of Forests in Australia, 1827-1949: A Survey of the Popular Press', in James Beattie, et al., *Climate, Science, and Colonisation: Histories from Australia and New Zealand*, New York: Palgrave Macmillan, pp. 119-136, 119.

[28] Dennys, N. B. (1894), *A Descriptive Dictionary of British Malaya*, London: London and China Telegraph Office, p. 351. Originally written by John Crawfurd in 1856.

[29] The observations made by the mysterious 'Mr Thomson' are possibly those that were published in *The Singapore Free Press and Mercantile Advertiser* during the 1830s. This series ran from 1833 to 1840. 'Mr Thomson' was likely the local notable J. T. Thomson, surveyor, engineer and explorer who wrote extensively on local culture, landscape and climate in the mid-nineteenth century, amongst his other many other achievements in mapping and urban infrastructure. See, for example: Thomson, J. T. 1849. 'General Report on the Residency of Singapore, drawn up principally with a view of illustrating its agricultural statistics', *Journal of the Straits Branch of the Royal Asiatic Society* Vol. III: 618- 628.

[30] Ibid., p. 352.

[31] For more on this within the wider imperial story, see: Grove, Richard (1997), *Ecology, Climate and Empire: Colonialism and Global Environmental History, 1400-1940*, Cambridge: White Horse Press.

long droughts'.[32] The report resulted in a heated debate enacted through the medium of the local press. Many different – often anonymous – authors weighed in with congratulations or disagreement over the report, some thinking it was high time that deforestation was addressed to limit further changes to rainfall, others seeking other explanations for climatic changes, if they agreed there had been any at all.[33] Despite these differences, by the late 1870s, the possibility that deforestation might be affecting the local weather had become an influence on government policy.[34] One catalyst for this abrupt shift was an extended drought that swallowed the majority of 1877, affecting not only the health of the colony but creating an unbearable 'great heat'.[35] The causes of the drought had elicited much concern. We know today that the lack of rain that year was influenced by a protracted El Niño event that had created drought conditions across much of the world.[36] However, the El Niño Southern Oscillation (ENSO) and the regional and global atmospheric teleconnection was not then understood by contemporary scientists, leading to speculation that land-use change might have instigated the drought locally. As a consequence, large areas of remaining virgin and secondary forest across Singapore island were reserved during the 1880s.[37]

At around the same time, Allan Maclean Skinner had also explicitly linked a perceived rise in temperature and an increasing prevalence of droughts to 'the spread of buildings' as well as the loss of forest cover.[38] Skinner was a colonial civil servant without any formal training in meteorology but he had an excellent grasp of meteorological matters and a strong grounding in contemporary theory.[39] He also had access to what were by that time fourteen years of continuous weather records from the Straits Settlements and comparative tables furnished by the Director of the Batavia Observatory for 166 registering stations in the Eastern Archipelago; through which he explored connections between human-induced climatic change, sunspot activity and heat. Skinner worked with the by then commonly accepted theory that sunspot activity had an approximate eleven-year cycle and, that this activity correlated with changes in rainfall, storm activity and temperature across the globe. Drawing from the work of men including Joseph Baxendell, Piazzi Smyth, George Airy and Wladimir Köppen among others, he postulated that in tropical latitudes, heatwaves generally fell the year before maximum

[32] Maingay, Alexander C. (1865), 'Report on the Timber and Forest Conservancy of Malacca, 20 August 1865', *Straits Settlements Government Gazette*, 1 September 1865, pp. 387-8, 388.
[33] For example: Editorial, *The Singapore Free Press and Mercantile Advertiser*, 28 September 1865, p. 2.
[34] CO276-10: Copy of Colonial Engineers Minute on Survey, dated 27 August 1878, *Straits Settlements Government Gazette*, 3 October 1879, p. 893.
[35] Anon, 'The Stamford Road Stream', *Straits Times Overland Journal*, 12 May 1877, p. 9; Anon, 'Victoria Street Drain', *Straits Times Overland Journal*, 21 July 1877, p. 9.
[36] Allan, Robert J., Gergis, Joëlle and D'Arrigo, Rosanne (2020), 'Placing the AD 2014-2016 "protracted" El Niño into a long-term term context', *The Holocene* 30/1: 90-105.
[37] CO276-10: McNair, J. F. A. 'Report by the Colonial Engineer on the timber forests in the Malayan Peninsula, 21 June 1879', Straits Settlements Government Gazette, 3 October 1879, pp. 893-903; National Archives of Singapore (hereafter NAS), Map of the Island of Singapore. Annexure to Report on the Forests of the Straits Settlements, 1882 by Nathanial Cantley; media image no: 20050000974 - 0093_TM000020_000028_TM
[38] Skinner, Allan M. (1883), 'Straits Meteorology', *Journal of the Straits Branch of the Royal Asiatic Society* 11/12: 245-259.
[39] Gullick, J. M. (1991), 'William Maxwell and the Study of Malay Society', *Journal of the Malaysian Branch of the Royal Asiatic Society*, 64/2: 7-46, 20; Choy Chee Meh née Lum (1995), 'History of the Malaysian Branch of the Royal Asiatic Society' *Journal of the Malaysian Branch of the Royal Asiatic Society, Sheppard Memorial Issue* 68/2: 81-148, 126.

sunspot activity and, that the 'regularity and magnitude of the temperature wave are most strongly marked in the topics'.[40] While he remained only half convinced of the desiccation argument as it affected rainfall, he was more certain of the impact of tree loss and urbanisation on temperature, which change he argued was most marked during periods of sunspot activity. The eleven-year solar cycle that he had correctly identified in the Straits Settlements also had interconnections with ENSO but as already been noted, this latter phenomenon was not yet understood.[41]

Global and Local

The movement of colonial officials across the British Empire interested in, or actively working on, areas that interconnected with the study of the weather; the transmission and dissemination of scholarly works into the libraries and presses of the Straits Settlements and, the gradual adoption and publication of locally and regionally produced scholarly journals, were all critical to the understanding of anthropogenic land-use change and temperature rise. Within the British context, from the first studies of urban temperature (undertaken in Canterbury, England) by James Six, inventor of one of the first effective thermometers that enabled readings of minimum and maximum temperature in 1780 to those of Luke Howard in London three decades later, ideas of how environmental change affected temperature were brought away from the more widely known and ancient concept of desiccation and became more focussed on the urban environment as a separate component of study.[42] Following, or around the time of Howard's specifically urban research, multiple studies that connected human activity and climate changes were conceived, coterminous to work that sought to establish the laws of tropical weathers. Ideas like Howard's were taken up by several European contemporaries including Emilien Renou in his study of Parisian temperatures in the mid 1800s, arguing that there was at least a one-degree difference between city and country, though his work was concerned more with making meteorological observations accurate, than for studying the impact of urbanisation of heat per se.[43] German astronomer and Berlin-based meteorologist Victor Kremser also pioneered early work in the field. Ostensibly interested in how air and wind moved through cities, he considered how buildings changed air circulation and affected humidity and heat from the 1880s.[44] Likewise, scientists, urban planner, and doctors in

[40] Skinner, 'Straits Meteorology', 248.

[41] Lin, Yong-Fu, Yu, Jin-Yi, Wu, Chau-Ron and Zheng, Fei (2021), 'The Footprint of the 11-year Solar Cycle in Northeastern Pacific SSTs and its Influence on the central Pacific El Niño', *Geophysical Research Letters* 48/5: https://doi.org/10.1029/2020GL091369

[42] Royal Society (hereafter RS), L&P/7/240 Paper, 'Of an improved thermometer' by James Six, read to the Royal Society 28 February 1782; RS, L&P/8/89, ff. 89r-91v, 94r-v. Letter, 'Variation of local heat as determined by a special thermometer' from James Six to Francis Wollaston, read to the Royal Society 10 June 1784; Turner, G. L. E. (1981), 'Eighteenth Century - The Construction of a Thermometer. By James Six. Prefaced by an Account of His Life & Works and the Use of His Thermometer over Two Hundred Years by Jill Austin & Anita McConnell. London: Nimbus Books, 1980, pp. 28 Xiv 64 Xxiv" *The British Journal for the History of Science* 14/1: 90–91. doi:10.1017/S0007087400018355. On Howard's urban studies, see: Mills, Gerald (2008), 'Luke Howard and *The Climate of London', Weather* 63/6: 153-7.

[43] Renou, E., (1855), 'Temperatures Differences between City and Country', *Annuaire du Bureaux Centrale Météorologique de France* 3/79, revised 1868. See Helmut Landsberg 'The Urban Climate', p.7.

[44] See, for example, Kremser, V (1908), 'The Influence of Large Cities upon Humidity', *Meteorologische Zeitschrift* 25: 206-15; Kremser, V. (1909), 'The Results of Wind Measurements recorded over many years in Berlin', *Meteorologische Zeitschrift* 26: 259-265.

America, such as Charles Caldwell, or Frederick Law Olmstead, noted the urban temperature increase and worked toward solutions for improving thermal comfort and health within city spaces.[45] This 'modern' research intersected with what was by now several centuries old ideas concerning urban ventilation, pollution and health, adding new impetus to the growing discourse on urban design, especially the importance of open space and green space in the city.[46]

It is clear from their published work that the officers of the English East India Company, such as Lieutenant Charles Elliot, responsible for establishing and running Singapore's first observatory, were well-versed in such theory, as too were subsequent civic officials such as Logan, Crawfurd or Skinner. They brought with them scientific training and amateur interest in the research that had been underway in Europe, Britain, America and elsewhere on urbanisation and temperature, combined with a keen understanding of matters of desiccation and forest loss. They also had diverse histories serving across the colonies before being stationed on the Malayan peninsula, bringing experience of differing atmospheres and environmental exigencies. Thomas Newbold is an excellent example. Originally of the Madras Light Infantry under the East India Company, his posts took him between India and the Straits Settlements, the latter for three years from 1832. He was a member of, and contributor to the Asiatic Society, the *Madras Journal of Literature and Science* and was eventually elected Fellow of the Royal Society.[47] Very well aware of the work of Boussingault and his peers,[48] Newbold had made a connection between deforestation, drought, heat and climate change during his time spent in late 1830s India, drawing from the local knowledge of inhabitants.[49] Newbold was already a well-known name on the British Asiatic journal circuit on this subject by the time Logan or Crawfurd began publishing their own thoughts on the matter.

The widespread proliferation of scientific or semi-scientific opinion pieces and articles re-printed in shorter form in the newspapers, of which several dailies and weeklies were available as early as the 1830s (including the *Singapore Free Press and Mercantile Advertiser* from 1835 and *The Straits Times* from 1845) also meant that the reading public could access globally available scientific research and debate. This was abundantly clear in the 1860s, when the heated debate over the causes – natural or otherwise – had ensued over desiccation in the local press after the release of Maingay's forest report mentioned previously or, in 1907, for instance, when the press had reproduced a British lecture on the 'effects of civilisation on climate' which, echoing Howard's claims almost a century earlier, noted how 'the presence of buildings … will raise the temperature of the locality, whilst the influence of the warmth arising from a large

[45] For more on this early history, see: Jankovic, Vladimir and Hebbert, Michael (2012), 'Hidden climate change – urban meteorology and the scales of real weather', *Climatic Change* 113: 23-33.
[46] See, for example: Howard, Ebenezer (1902), *Garden Cities of Tomorrow*.
[47] 'Biographical memoir of Captain. T. J. Newbold' (1887), *Journal of Straits Branch of the Royal Asiatic Society*, 19: 143-152.
[48] Newbold, T. J. (1851), 'On the temperature of the springs, wells and rivers of India and Egypt, and of the sea and table lands within the tropics; with a few remarks on M. Boussingault's mode of ascertaining the mean temperature of equinoctial regions', *Proceedings of the Royal Society of London*, Vol. 5: 502-3.
[49] Newbold, T. J. (1839), 'Notice of River Dunes on the Banks of the Hogri and Pennaur', *Madras Journal of Literature and Science*, Vol. 9: 309-10.

number of fires must not by any means be overlooked'.[50] After 1874, the establishment of the Raffles Public Library and Museum had also made scientific books and journals available to the middle-classes. The library acquired a range of new books and journals annually, prioritising educational, non-fiction subjects, among which were many books relating to the sciences and natural history.[51] Many such volumes on natural history were published locally and included sections on the climate of the peninsula, as too did many Asia-focussed journals that featured Straits Settlements based authors, including Logan's *Journal of the Indian Archipelago and Eastern Asia* of course but also the different branches of the Royal Asiatic Society, including the Straits Branch.[52] This ensured that the latest scientific ideas and debates were accessible to the reading public in Singapore and beyond.

Conclusions: A Halting Start and into the Modern Era

Despite all the early interest in the 1800s, serious scientific research was not really undertaken on urban heat – tropical or otherwise - until the 1920s and 1930s. Publications emanated from the pens of researchers on the towns of the American tropics and in Asia, Japan lead the way with major studies on Tokyo and Osaka in the 1930s.[53] It was Albert Kratzer's *Das Stadtklima* (1937) that was to prove a pivotal moment in urban heat studies more broadly however. He put forward a really defined concept of urban climate as 'meso-climate' comprised of micro-climatic zones, such as industrial or residential, or on a smaller scale still, streets, parks and squares.[54] Kratzer's climate scales are commonly understood today as the three fundamental tenets of a UHI: local scale (similar buildings in a district); microscale (urban canopy) and mesoscale (total urban boundary layer).[55] Yet, despite all this, it was to be the 1960s before the first comprehensive UHI study of any of the by now *ex*-colonies of the Straits Settlements would be undertaken.[56] This may have had much to do with the lack of a dedicated climate or meteorological research facility in Malaya until 1929. Even then, the new service' focus was on providing weather forecasting services for the burgeoning commercial and military aviation industry, rather than on climate studies per se. Developing airline routes across Asia and into

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[50] 'Can man change climate?', *Eastern Daily Mail and Straits Morning Advertiser,* 11 January 1907, p. 6.

[51] In 1889, for example, the library acquired 38 volumes of natural history books: Annual Report of the Raffles Library and Museum for 1889, published in the *Straits Settlements Government Gazette*, 1 May 1890.

[52] The precursor of the contemporary *Journal of the Malaysian Branch of the Royal Asiatic Society*.

[53] Sargent Visher, Stephen (1922), 'Local Climates in the Tropics', *Bulletin of the American Meteorological* Society 3/9: 119-121. An overview of Japanese works can be found in: Sekiguti, Takeshi (1954), 'Progress of Climatology in Japan', *Bulletin of the American Meteorological Society* 35: 428-32. Sekiguti neglects however to mention some important research under his summary of urban climate by, for example: Sasakura, K (1931), 'On the temperature difference in and out of Tokyo city', Geographical Review of Japan 7:551-559; Hatakeyama, H. (1932), 'The Temperature Distribution in and around Tokyo', *Journal of the Meteorological Society of Japan*, 11/10; Arakawa, Hidetoshi (1937), 'Increasing air temperatures in large developing cities', *Beiträge Geophysik* 50: 3-6; Hakoda, A. and Kinka, T. (1939), 'On micro-airmass of Osaka and its Neighbourhood', *Journal of the Meteorological Society of Japan, 2nd Series*, 17: 425-434; Kita, T. (1939), 'Town climate of Tokyo,' *Journal of the Meteorological Society of Japan, 2nd Series*: 155-161.

[54] Kratzer, Albert (1956), *Climate of Cities*, trans. 2nd ed., p. 1.

[55] Roth, Matthias (2013), 'Urban Heat Islands' in Harindra Joseph Shermal Fernando, ed., *Handbook of Environmental Fluid Dynamics*, Vol. 2, CRC Press/Taylor and Francis Group, pp. 143-159, 144.

[56] Nieuwolt, S (1966), 'The Urban Microclimate of Singapore', *The Journal of Tropical Geography* 22: 30-37. For a good overview of subsequent UHI research for Singapore, see: Roth, Matthias and Chow, Winston T. L. (2012), 'A Historical Review and Assessment of Urban Heat Island Research in Singapore', *Singapore Journal of Tropical Geography* 33: 381- 97.

Europe, ones that could protected from the frequent and severe local storms and squalls, was paramount.

Ironically too, as Kratzer's ideas were becoming mainstream, the colony (as elsewhere) was already on a downward spiral in managing urban heat through increasing urbanisation and removal of many green spaces to accommodate motorcars. Reminiscing about how Raffles' Place (the past and present heart of Singapore's central business district) had looked in 1901 for instance, local inhabitant Edwin Brown noted that it had transformed from an attractive, green spot shaded by 'flame-of-the-forest trees', where men would sit for their lunch and horses and carriages would shelter 'while the "mems" did their shopping', into a 'glaring whiteness … with its motor cars parked in orderly ranks in the centre'.[57] This was also the same decade that air-conditioning was mass introduced across the Malayan peninsula. While it would still be decades before anyone except the rich could afford domestic air conditioning units in their homes – mostly it was commercial enterprises such as cinemas, dancehalls, or government-run institutions like hospitals that invested in the new technology - the introduction of air-conditioning marked a technological tipping point in an age of 'progress'. This 'progress' would usher the regions' towns into the age of the Anthropocene and, contribute to the growing problem of urban heat now, and in the future.

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[57] Brown, Edwin A. (1935), *Indiscreet Memories: 1901 Singapore through the eyes of a colonial Englishman*, reprinted 2007, Monsoon Books, p. 42.