1 Meteorology All at Sea

This chapter considers the importance of maritime exploration and surveying for the development of a culture of meteorology on board naval vessels. In his study of the whaler, explorer and magnetician William Scoresby, Bravo observes that exploration in the late eighteenth and early nineteenth centuries 'had become a much more specialised set of scientific practices that required training, the provision of expensive precision measurements, and new time-intensive methods of working and record-keeping'.[1] These methods and practices were extended to the investigation of the marine world. Reidy suggests that during the nineteenth century, 'the British Admiralty, maritime community, and scientific elite collaborated to bring order to the world's seas, estuaries, and rivers'.[2] The vast emptiness of the oceans was transformed 'into an ordered and bounded grid, inscribed with isolines of all kinds – tidal, magnetic, thermal, and barometric – in areas uncharted and on coasts unseen'.[3] Or at least that was the intention. The Royal Navy played a number of specific roles in the development of science, such as training personnel in scientific techniques useful to shipbuilding; carrying out surveying and navigation; and imparting knowledge through institutions such as the Royal Naval Academy at Portsmouth, the Greenwich Hospital, the Navy's domestic and overseas dockyards and the Admiralty's Hydrographic Office. Established in 1795, the Hydrographic Office gradually increased in importance,

[1] M. Bravo, 'Geographies of Exploration and Improvement: William Scoresby and Arctic Whaling (1722–1822)', *Journal of Historical Geography*, 32 (2006), 512–38, 519.

[2] M. S. Reidy, *Tides of History: Ocean Science and Her Majesty's Navy* (Chicago: Chicago University Press, 2008), p. 6. See also M. Deacon, *Scientists and the Sea, 1650–1900: A Study of Marine Science* (London: Academic Press, 1971); S. Millar, 'Science at Sea: Soundings and Instrumental Knowledge in British Polar Expedition Narratives, c.1818–1848', *Journal of Historical Geography*, 42 (2013), 77–87.

[3] Reidy, *Tides of History*, p. 6. See also E. J. Larson, 'Public Science for a Global Empire: The British Quest for the South Magnetic Pole', *Isis*, 102 (2011), 34–59; H. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge: The Belknap Press of Harvard University Press, 2005).

despite its remit being heavily circumscribed in its early years.[4] John Croker and John Barrow, the First and Second Secretaries to the Admiralty, respectively, resisted expansion of the Hydrographic Office due to financial retrenchment in the post-war years after 1815, Croker's scepticism of the value of hydrography, and the two men's commitment to the Royal Society as the Admiralty's scientific advisor. During this period, the connections between the Admiralty and the Royal Society were strong. Croker and Barrow took it in turns to sit on the Society's Council as Admiralty representatives, while the Admiralty appealed to the Royal Society for advice on its expeditions so frequently that the Society was treated almost like a standing committee.[5]

Since its establishment in 1714, the Board of Longitude had acted as a research department for the Admiralty, with a remit that extended beyond solving problems of navigation. However, in 1828, the Board of Longitude was abolished by Act of Parliament. In its place the Admiralty created an internal consultative committee, called the Resident Committee of Scientific Advice, which was made up of physicist and Egyptologist Thomas Young, Army officer and magnetician Edward Sabine and Royal Institution chemist Michael Faraday. By establishing the Committee, Barrow and Croker hoped to keep the Navy's interactions with men of science out of public view and to more effectively control whom it dealt with. The Resident Committee was criticised by Britain's scientific reform movement on the grounds of nepotism and patronage and was brought to an abrupt conclusion by the death of Young in 1829 and Sabine's posting to Ireland in 1830. Faraday was left as a sole and occasional advisor to the Admiralty, a role he fulfilled until the 1850s.[6] Croker's retirement from the post of First Secretary to the Admiralty in 1831 also created new possibilities for the pursuit of science in the Royal Navy.[7] In 1831, the Hydrographic Office became a separate department of the Admiralty, something Croker had prevented

[4] A. Webb, 'More Than Just Charts: Hydrographic Expertise within the Admiralty, 1795–1829', *Journal for Maritime Research*, 16 (2014), 43–54.

[5] M. B. Hall, 'Public Science in Britain: The Role of the Royal Society,' *Isis*, 72 (1981), 627–9; D. P. Miller, 'The Revival of the Physical Sciences in Britain, 1815–1840', *Osiris*, 2 (1986), 107–34; R. Cock, 'Scientific Servicemen in the Royal Navy and the Professionalisation of Science, 1816–55', in D. M. Knight and M. D. Eddy (eds.), *Science and Beliefs: From Natural Philosophy to Natural Science, 1700–1900* (Aldershot: Ashgate, 2005), pp. 95–112; A. Friendly, *Beaufort of the Admiralty: The Life of Sir Francis Beaufort 1774–1857* (New York: Random House, 1977), p. 247.

[6] On the scientific reform movement, see J. Morrell and A. Thackray, *Gentlemen of Science: Early Years of the British Association of the Advancement of Science* (Oxford: Clarendon Press, 1981).

[7] Friendly, *Beaufort of the Admiralty*, p. 247.

so as to limit the Office's autonomy.[8] The Admiralty Scientific Branch was also established in 1831, which was overseen by the Admiralty hydrographer and encompassed the Nautical Almanac Office, the Chronometer Office, the Astronomical Observatories at Greenwich and the Cape and the Hydrographic Office itself.

The naval administration also assisted scientific projects through the provision of indispensable resources, namely passage upon and use of a naval vessel as well as its well-equipped, disciplined and trained personnel. While financial and infrastructural resources were critical to major scientific projects, the Royal Navy's emphasis on order and discipline was arguably just as important. In theory, the daily regime on board ship lent itself well to ensuring regular and reliable scientific observations.[9] For John Herschel, the benefit of using naval ships as observational platforms was their capacity to act as 'itinerant observatories' and naval officers as ideal observers.[10] The necessity of a twenty-four-hour watch and the demands of the logbook promised to make the collection of routine and numerous observations more straightforward than in other settings. It was also assumed that naval discipline turned officers and crew into regulated instruments themselves, just like the precision devices they used daily.[11] Naval seamen were meant to be the meteorological equivalents of the 'obedient drudges' that the Astronomer Royal George Airy wanted to operate astronomical observatories like Greenwich – to treat their work and their ship in the same manner that astronomical technicians were expected to operate in an observatory setting.[12]

The Admiralty applied naval personnel to projects that utilised their familiarity with the latest mathematical, scientific and technical knowledge.[13] This was especially the case after peace with France in

[8] A. Day, *The Admiralty Hydrographic Service 1795–1919* (London: Stationery Office, 1967), p. 35.

[9] C. Ward and J. Dowdeswell, 'On the Meteorological Instruments and Observations Made during the 19th Century Exploration of the Canadian Northwest Passage', *Arctic, Antarctic, and Alpine Research*, 38 (2006), 454–64, 454.

[10] Quoted in Winter, '"Compasses All Awry"', 75.

[11] C. W. J. Withers, 'Science, Scientific Instruments and Questions of Method in Nineteenth-Century British Geography', *Transactions of the Institute of British Geographers*, 38 (2012), 167–79, 173. French commentators made similar assumptions about the capacities of their navy to collect meteorological information: F. Locher, 'The Observatory, the Land-Based Ship and the Crusades: Earth Sciences in European Context, 1830–50', *British Journal for the History of Science*, 40 (2007), 491–504, 498.

[12] Winter, '"Compasses All Awry"', 74.

[13] E. Behrisch, *Discovery, Innovation, and the Victorian Admiralty: Paper Navigators* (Switzerland: Palgrave Macmillan, 2022).

1815.[14] The prospects of peace 'presented an opportunity to those, both in the Navy and outside, who had ambitions to harness to the ends of science the resources of the new smaller, more professional and career-oriented service that developed as a result'.[15] After 1815, the Royal Navy experienced financial retrenchment and disarmament: many ships were decommissioned and thousands of enlisted men lost their jobs. Naval officers had greater political influence and so few of them were retired but perhaps 90 per cent of them found themselves without a role and on the half-pay list.[16] Croker defended the reduced Navy Estimates, while Barrow argued that the Navy's ships and personnel should be employed in global exploration, on the basis that 'exploration would increase scientific knowledge, that it would be a boon to national commerce, and above all that it would be a terrible blow to national pride if other countries should open up a globe over which Britain ruled supreme'.[17]

The Royal Navy and the Admiralty Hydrographic Office made numerous contributions to science, including geographical exploration of the Northwest Passage, the Antarctic Ocean and of Africa.[18] For naval officers interested in science, a position on one of these voyages of exploration was a choice appointment. These 'scientific servicemen' gradually took on much of the scientific work from civilians and many became Fellows of the Royal Society.[19] Naval personnel were part of the emerging division of labour in science in the nineteenth century. These scientific servicemen were most important as global data gatherers, passing information back to gentlemen savants for analysis in metropolitan centres, although some officers specialised in science and exploration themselves. They were supported by newly formed scientific societies, such as the Royal Geographical Society, which were comfortable about including military personnel in their ranks and benefited from their ability to collect data from locations around the world, pursue research programmes and to bring those programmes to the attention of government.

Evidence of the Admiralty's involvement in training sailors, supporting expeditions and collecting information on a global scale has led some historians to argue that in the first half of the nineteenth century, the Navy

[14] Reidy, *Tides of History*, p. 140.
[15] R. Cock, *Sir Francis Beaufort and the Co-ordination of British Scientific Activity, 1829–55*, Unpublished DPhil Thesis, University of Cambridge, 2003, pp. 7–8.
[16] C. Lloyd, *Mr. Barrow of the Admiralty: A Life of Sir John Barrow* (London: Collins, 1970), pp. 91–2.
[17] F. Fleming, *Barrow's Boys: A Stirring Story of Daring, Fortitude and Outright Lunacy* (London: Granta, 1999), p. 11.
[18] Friendly, *Beaufort of the Admiralty*, p. 289.
[19] Miller, 'Revival of the Physical Sciences'; R. Cock, 'Scientific Servicemen in the Royal Navy', pp. 95–112.

was the principal governmental subsidiser of science in Britain.[20] The Admiralty's support for a number of voyages of exploration was certainly justified on the grounds of national scientific prestige, but just as important were issues of commercial advantage and maritime safety. Rodger argues that the Royal Navy's growth and success were bound up with Britain's prosperity in overseas trade, while Webb suggests that matters concerning safety of life at sea were given priority over scientific interests.[21] Although self-interest is an obvious explanation for the position taken by the Admiralty in this regard, it is also likely that its thinking was shaped by the Royal Society's assumption that science should constitute a form of useful knowledge, an instrument of improvement and an aid to profitable and rational economic activity.

Cultures of Instrumentation on Voyages of Exploration

Voyages of exploration in the late 1810s and 1820s served to establish standards for the conduct of physical scientific inquiry at sea, particularly in relation to the use of philosophical instruments on board ships. The Royal Society had long offered advice to the Admiralty on the scientific aspects of its expeditions, viewed by government and the military as a 'state tool for consultation'.[22] The period from Ross's 1818 Arctic voyage to Foster's South Atlantic expedition in 1828 was a tumultuous one for the Society. Joseph Banks's reign as president of the Royal Society ended with his death in 1820. Successive presidents – Humphry Davy (1820–27) and Davies Gilbert (1827–30) – were caught up in wider contests over the character and direction of British science. Davy put the Royal Society on a course that aimed to satisfy both the remnants of Banks's 'Learned Empire' and the reformist intentions of the 'Cambridge Network'.[23] The changes experienced by the Society over this period were reflected in the composition and work of its committees. In the

[20] Friendly, *Beaufort of the Admiralty*, p. 289. For similar arguments see T. Levere, *Science and the Canadian Arctic: A Century of Exploration, 1818–1918* (Cambridge: Cambridge University Press, 1993); J. Ratcliff, *The Transit of Venus Enterprise in Victorian Britain* (London: Pickering & Chatto, 2008), p. 24.

[21] N. A. M. Rodger, 'From the "Military Revolution" to the "Fiscal-Naval" State', *Journal of Maritime Research*, 13 (2011), 119–28, 123; Webb, 'More Than Just Charts', 52.

[22] S. Waring, 'The Board of Longitude and the Funding of Scientific Work: Negotiating Authority and Expertise in the Early Nineteenth Century', *Journal for Maritime Research*, 16 (2014), 55–71, 57.

[23] D. P. Miller, 'Between Hostile Camps: Sir Humphrey Davy's Presidency of the Royal Society of London, 1820–1827', *British Journal for the History of Science*, 16 (1983), 1–47; R. M. MacLeod, 'Whigs and Savants: Reflections on the Reform Movement in the Royal Society, 1830–48', in I. Inkster and J. Morrell (eds.), *Metropolis and Province: Science in British Culture, 1780–1850* (London: Hutchinson, 1983), pp. 55–90.

early years of Davy's presidency in particular, increased use was made of scientific committees.[24] Over the course of the 1820s, scientific reformers, such as Herschel, Charles Babbage and Francis Baily, joined long-standing members like Thomas Young, Henry Kater and William Hyde Wollaston, all taking a greater role in the running of these committees. Miller notes that members of the reform group 'increasingly dominated public discussion of the most important objects of research for scientific voyages'.[25] Herschel in particular 'maintained an ambition to make the surveying voyages commissioned by Barrow on behalf of the Admiralty more "scientific"'.[26] The changes effected in this period had a direct bearing on the advice that the Royal Society provided to exploring expeditions.

During the final years of Banks's presidency, William Thomas Brande, one of the Royal Society's two secretaries, wrote to Barrow to supply the Admiralty with a list of instruments that the Society recommended for use on the two 1818 expeditions then heading for the polar regions, to be led by John Ross and David Buchan, respectively. These included compasses, barometers, magnetic instruments, bottom sampling and dredging equipment, chronometers, mercurial and sea thermometers, a Wollaston micrometer, artificial horizons, electrometers, hydrometers and apparatus 'for ascertaining the quantity of air in water'.[27] Four laboratory tents were added to protect the instruments during observations to be made onshore, along with two transit instruments, four 'Small Altitude Instruments', a water sampler and a tent for astronomical observations.[28]

In 1821, a 'Committee for suggesting Experiments and Observations to Mr Fisher, about to proceed to the Arctic Seas under the command of Capt. Parry', was established.[29] Herschel, William Hyde Wollaston and Charles Hatchett bolstered a core group made up of the president, the two secretaries – Brande and Taylor Combe – and Henry Kater and Thomas Young. The expedition astronomer George Fisher was invited to attend.[30] While the advice given to Ross in 1818 laid out in detail the instruments to be used on his expedition, that provided to Fisher was

[24] Hall, 'Public Science in Britain'. [25] Miller, 'Between Hostile Camps', 34.
[26] Waring, 'The Board of Longitude and the Funding of Scientific Work', 59.
[27] Copy of letter from W. T. Brande to J. Barrow, 29 January 1818, Archives of the Royal Society, CMB/1, p. 9.
[28] Anon, 'Committee for ascertaining the Length of the Seconds Pendulum', 26 March 1818, Archives of the Royal Society, CMB/1, p. 14.
[29] Anon, 'Hints of Experiments to be made in the Arctic Expedition ... of 1821', 12 April 1821, Archives of the Royal Society, CMB/1, pp. 26–31.
[30] G. W. Roberts, 'Magnetism and Chronometers: The Research of the Reverend George Fisher', *British Journal for the History of Science*, 42 (2009), 57–72.

more direct in the scientific agenda to be pursued, emphasising terrestrial physics. Twenty experiments were proposed. The majority focused on the effects of extreme cold on atmospheric chemistry, the behaviour of fluids (including mercury) and on humans, animals, food and different metals. Of particular interest was the freezing point of pure mercury and of different amalgams of mercury and other metals. This was significant because of its effect on the performance of the thermometer and barometer.[31] Other questions related to the operation and effects of the Aurora Borealis, and the investigation of sea temperature at different depths.

The advice supplied to Captain Henry Foster's 1828 voyage on the HMS *Chanticleer* to the South Atlantic was more comprehensive still. At this committee Davies Gilbert (now president), Herschel and Kater were joined by William Fitton, president of the Geological Society of London, Sabine and the Admiralty hydrographer Francis Beaufort. James Horsburgh, the East India Company hydrographer, and Captains Parry and Foster were present by invitation. In line with the interests of Herschel, Sabine and Beaufort, the principal objects of Foster's expedition were defined as the investigation of physical astronomy, the determination of the figure of the earth and the investigation of the law of the variation of gravity, along with inquiries into ocean currents, magnetism, the longitude of significant locations, natural history and meteorology. The committee noted that meteorological observations 'form a branch of inquiry of no small amount in this and all similar expeditions' and it recommended that 'regular observations of the Barometer, Thermometer, Hygrometer, and the direction and force of the wind should be daily made; and of the actinometer or other instruments proper for measuring the Solar and terrestrial variation, at favorable opportunities and at various levels'. The result, it was hoped, would be a better understanding of 'the probable former and future climate of different regions of the Earth[,] the permanence or variability of the Solar influence at different epochs, and the stability of the actual equilibrium of meteorological agents'.[32] In its findings, the voyage was judged a success and the results were later used by Royal Society reformers and members of the Astronomical Society to affirm the analytic importance of mathematics in accurate observation and experimental research.[33]

[31] Ward and Dowdeswell, 'On the Meteorological Instruments', 455.

[32] Anon, 'At a meeting of the Committee for considering and resolving on the most advantageous objects to be attained by Capt'n Foster in the course of his intended scientific Voyage', 28 January 1828, Archives of the Royal Society, CMB/1, p. 230.

[33] Miller, 'Revival of the Physical Sciences'.

The advice given to Foster was dwarfed, however, by that supplied to James Clark Ross for his 1839 voyage to the Antarctic Ocean as part of Britain's Magnetic Crusade (discussed further in Chapter 2). The committee convened to advise on the expedition was chaired by Herschel and included Beaufort, Sabine, John Ross, Michael Faraday, John Frederic Daniell, Peter Mark Roget, Charles Wheatstone and William Snow Harris.[34] The expedition was principally intended as an investigation into terrestrial magnetism, but other sciences were pursued, including study of the tides, the figure of the earth and meteorology. Meteorology was given greater emphasis than was necessary simply to correct the performance of the magnetic instruments.[35] The committee additionally advised on the instruments with which the naval expedition should be equipped. In terms of meteorology, these included actinometers, Lind's rain gauge, an Osler anemometer and spirit thermometers for operation in Antarctic temperatures below those at which mercury freezes and mercurial thermometers become ineffective.[36] Procedures were recommended for the verification of the instruments, especially when the expedition was far from fixed observatories on land.[37] Both of the ships – HMS *Erebus* and HMS *Terror* – were to carry standard barometers and thermometers against which others were to be compared. This was especially important when instruments were taken ashore, 'so as to detect and take into account of any change which may have occurred in the interval'.[38] The standards on one ship were to act as checks upon the other.

The passage of the *Erebus* and *Terror* from the tropics to the Antarctic presented an opportunity to investigate von Humboldt's claim that atmospheric pressure at the equator was uniformly 'less in its mean amount than that at and beyond the tropics', a phenomenon that was, in turn, believed to produce the trade winds.[39] The observation of changes in the barometer when approaching the line was therefore of great scientific

[34] Anon, Joint Committee of Physics and Meteorology, 1838–39, 19 June 1839, Archives of the Royal Society, CMB/284.

[35] Anon, *Report of the President and Council of the Royal Society on the Instructions to be Prepared for the Scientific Expedition to the Antarctic Regions* (London: Richard and John E. Taylor, 1839), p. 13; E. Gillin, 'The Instruments of Expeditionary Science and the Reworking of Nineteenth-Century Magnetic Experiment', *Notes and Records of the Royal Society*, 76 (2022), 565–92.

[36] Ward and Dowdeswell, 'On the Meteorological Instruments', 459.

[37] Joint Committee of Physics and Meteorology, 1838–39, 22 August 1839, Archives of the Royal Society, CMB/284.

[38] Anon, *Report … on the Instructions … for the Scientific Expedition to the Antarctic Regions*, p. 13.

[39] Anon, *Report … on the Instructions … for the Scientific Expedition to the Antarctic Regions*, p. 14

value, as was the observation of the local effects that continents or oceanic currents had on atmospheric pressure. Periods spent at high southern latitudes also presented opportunities to calibrate the instruments. For instance, Ross was asked to verify and to register the ships' standard thermometers at the freezing point of mercury whenever the opportunity arose. This was to be effected by placing four permanent marks on the tube of each standard thermometer, and Ross was 'requested occasionally to compare these marks with the degrees of the ivory scale'. A bottle of mercury was ordered to accompany each standard thermometer.[40] The scientific instructions presented to Ross contained, in his words, 'a detailed account of every object of inquiry which the diligence and science of the several committees of that learned body could devise'.[41] This report became a standard for subsequent scientific guides.

The deployment of philosophical instruments, and the supply of precise instructions for observations and experiments, was not alone enough, however, to guarantee reliable inscriptions. The directions provided to the captains of scientific expeditions were often aspirational in tone and susceptible to compromise when in the field. The robustness of the scientific outcomes of an expedition relied as much on 'immense chains of delegated trust and labour' as they did on detailed instructions, calibrated instruments and well-organised skeleton forms.[42] Instruments could not speak for themselves effectively. The determination of their accuracy relied on the person or persons operating them. Identifying and justifying who was to operate which instruments was a crucial matter in voyages of exploration. For John Ross's 1818 voyage to the Arctic, the Royal Society committee suggested to the Admiralty that Sabine was the 'proper person to conduct certain experiments', accompanied by a sergeant of artillery to 'take care of instruments'.[43] The committee also suggested the inclusion of Fisher – 'a Gentleman of considerable mathematical talent' – while Henry Kater reported that the naval officers John Franklin, Frederick Beechey and William Parry 'had been most assiduous in acquiring a due knowledge of the use of the Instruments to be employed in the Northern Expedition, and that he considers them fully competent to prosecute the required observations and experiments'.[44]

[40] Anon, Joint Committee of Physics and Meteorology, 1838–39, 22 August 1839, Archives of the Royal Society, CMB/284.
[41] J. C. Ross, *A Voyage of Discovery and Research in the Southern and Antarctic Regions, during the Years 1839–43*, Volume 1 (London: John Murray, 1847), p. xxvii.
[42] S. Schaffer, '"On Seeing Me Write": Inscription Devices in the South Seas', *Representations*, 97 (2007), 90–122, 113.
[43] 12 February 1818, Archives of the Royal Society, CMB/1.
[44] 26 March 1818, Archives of the Royal Society, CMB/1.

Despite the various controversies surrounding Ross's 1818 Arctic expedition, the Royal Society again recommended Sabine as a member of William Parry's 1819 Arctic voyage:

> It is of the opinion of this Committee that Capt'n Sabine has shown the greatest possible diligence in making the observations which were intrusted [sic] to his care and the greatest judgement and regularity in his method of recording them. And this Committee therefore suggests the propriety of recommending Capt'n Sabine to the Admiralty in the strongest manner, both as deserving every professional encouragement, and as a proper person to be again appointed to take charge of the Observations to be made in a new Expedition.[45]

The reiteration of instrumental and observational competence was crucial. The practices employed and the vagaries of the instruments' fate 'governed the status of the data they produced and the interpretations they suggested'.[46] The reputation of the observer was intrinsically linked to the data and the instruments: 'To question or doubt results or methodology was to question the character and morality of their creator.'[47]

Reforming Meteorology

After 1820, Royal Society committee members were increasingly chosen on the basis of expertise, whether intellectual or professional. This was also true in other respects, such as over the quality and use of the Society's meteorological instruments. The committee formed in 1822 to study this matter incorporated Thomas Young, William Hyde Wollaston and Henry Kater, together with Humphry Davy, Davies Gilbert, the secretaries Brande and Combe, Babbage and Herschel, as well as Luke Howard and John Frederic Daniell, included given their standing in meteorology and related fields.[48] Amongst other recommendations, the committee ordered the construction of new instruments for the Society, including two barometers from John Newman, of Lisle Street, London; these were, subsequently, the subject of experiments at the Society in December 1822.[49] The observational regime and the siting of the Society's instruments were also reviewed. At a meeting of the Society's Meteorological Committee in 1827, James South and Francis Baily, along with Beaufort and Herschel, complained about its recording forms and the quality and situation of its meteorological instruments.

[45] 18 March 1819, Archives of the Royal Society, CMB/1.
[46] Schaffer, '"On Seeing Me Write"', 112. [47] Waring, 'The Board of Longitude', 66.
[48] Anon, Committee for examining into the state of the Meteorological Instruments belonging to the Royal Society, 10 and 12 December 1822, Archives of the Royal Society, CMB/1.
[49] Anon, Committee for examining into the state of the Meteorological Instruments, Archives of the Royal Society, CMB/1.

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They argued that the 'local situation' of its headquarters at Somerset House did not allow for the production of 'any series of meteorological observations of material weight and importance in the present state of the science'.[50]

For Jankovic, '[w]hether fairly or not, early nineteenth-century commentators ... erupted with criticisms of a general lethargy that supposedly prevailed in the investigation of weather-systems, of the insufficiency *and* profusion of observations, of the public uselessness of the existing stock of facts, and of the imprecision of means for standardizing and using meteorological instruments'.[51] In his *Meteorological Essays*, John Daniell, Professor of Chemistry at King's College London, pointed to the Royal Society's meteorological observations as evidence of the poor science undertaken in England. He extended his criticism to the operations of overseas observatories, where, he claimed, there had been insufficient coordination of efforts, such that their 'labour and perseverance lose more than half their value by the want of a well-digested plan of mutual co-operation'.[52] Concerns about the level of training and expertise of meteorological observers similarly preoccupied William Whewell and James Forbes, the noted Edinburgh physicist, who argued that science should centre on precision observations and be conducted by trained personnel. Forbes expressed these arguments in his report on British meteorology to the 1832 British Association meeting in Oxford.[53] For Forbes, meteorological instruments 'have been for the most part treated like toys', while few of the numerous registers 'which monthly, quarterly, and annually are thrown upon the world' could be expected to afford information useful to the development of the science.[54] The situation was, in his view, so bad as to require 'a total revision upon which meteorologists have hitherto very generally proceeded'.[55]

This troubled history of meteorology at the Royal Society is important given discussions over the deployment of meteorological instruments on Admiralty ships. The review of the Royal Society's own instrumental practices was coincident with the Society's advice to captains and scientific officers on board exploring expeditions. The composition of the

[50] Anon, Minutes of the Meteorological Committee, 2 August 1827, Meteorological Committee Minutes and Letters 1830–1837, Archives of the Royal Society, DM/3.
[51] Jankovic, 'Ideological Crests', 24.
[52] J. Daniell, *Meteorological Essays* (London: Thomas & George Underwood, 1823), p. viii.
[53] J. D. Forbes, 'Report of the First and Second Meetings of the British Association for the Advancement of Science', *British Association for the Advancement of Science Second Report* (1833), 196–258.
[54] On the use, and misuse, of meteorological instruments, see J. Golinski, *British Weather and the Climate of Enlightenment* (Chicago: University of Chicago Press, 2007).
[55] Forbes, 'Report', 196–7. See also Jankovic, 'Ideological Crests', 24.

Society's committees on these issues was almost identical. It is reasonable to assume, therefore, that the reform of meteorology at the heart of British science was part of attempts to improve the conduct of science at sea. The difficulties experienced at the Royal Society illustrate the challenges inherent in the pursuit of an exacting instrumental regime. The committees established to advise Parry, Foster and others laid down scientific agendas and observational practices on the assumption that ships were floating observatories. At the same time, criticisms of the Society's own meteorological practices illustrated the challenges of meeting such demands when on dry land. When far away from instrument makers and scientific advisors, on board a moving ship in challenging conditions, operating personnel had no choice but to 'make up and mend ways of recording and transmitting what they reckoned worth noting'.[56]

Francis Beaufort and Instrumental Cultures on Hydrographic Ships

Scientific and exploring expeditions, such as those already discussed, helped establish precedents for the collection of information about terrestrial physics on board ships. The success of these and other voyages in the first half of the nineteenth century encouraged the belief that all military vessels might be employed as floating observatories. In his work on French arctic expeditions, Locher notes that the regular maintenance of the systematic naval watch offered real advantages to science, particularly if officers could be compelled to collect data in addition to the other observations they were required to undertake.[57] Naval officers received training in mathematics, navigation and astronomy and would have been comfortable operating relatively sophisticated precision instruments. For observations to be scientifically useful, however, they had to be made regularly, specific instruments had to be employed and full details had to be supplied about their constitution and conditions of use. Particular reduction protocols and computing methods had to be followed. The situation of an instrument and the state of the atmosphere around it had to be given consideration and recorded so that measurements could be reduced to a virtual common environment.

The weather was an inescapable part of life on board ship and the Admiralty required officers to keep a record of it. The 1808 edition of the Admiralty's *Regulations and Instructions Relating to His Majesty's*

[56] Schaffer, '"On Seeing Me Write"', 106.
[57] Locher, 'The Observatory, the Land-Based Ship and the Crusades', 498.

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Service at Sea required the ship's master to record in the logbook 'with very minute exactness' the state of the weather and the directions of the wind, along with other observations relating to navigation, and to the state of the ship and its provisions.[58] Any shifts in the wind that might affect the ship's course were to be recorded on the log board, while special care was to be taken during periods of fog. There was no compulsion to record meteorological observations for their own sake.[59] These were to be recorded on a pre-printed pro forma outlined in Appendix 25 of the *Regulations and Instructions*. There were, however, no explicit directions as to the manner in which the weather observations were to be recorded, and the space provided to do so was very small, especially when other essential information had to be noted. This attitude to the study of maritime weather was in contrast to the approach of other services. American navy surgeons had been keeping weather journals since 1814. The French navy had been analysing ships' logs for weather patterns to aid sailing since the 1720s, while Wilkinson claims that officers of the East India Company's ships employed a more sophisticated system of wind observations than their naval equivalents.[60]

The person who did the most to persuade the Admiralty that their ships' crews should take careful weather observations was Sir Francis Beaufort (1774–1857). Beaufort left school at fourteen to join an East India Company ship, the *Vansittart*, before transferring to the Fifth Rate Royal Naval ship *Latona* as an able seaman. During the Napoleonic Wars Beaufort served on fighting and surveying vessels and rose to the rank of captain by 1810. He gained his reputation as an excellent surveyor through his work on the Rio de la Plata and along the coast of Turkey. Beaufort replaced William Edward Parry as Admiralty hydrographer in 1829 after being overlooked for the post in 1823 by John Croker. He was appointed Knight Commander of the Bath in 1848 and eventually attained the rank of rear admiral. He held the post of Admiralty hydrographer until 1855. He died in 1857.

[58] Anon, *Regulations and Instructions Relating to His Majesty's Service at Sea* (London: Stationery Office, 1808), p. 192. In the Royal Navy, the ship's master was a naval warrant officer, trained in and responsible for the navigation of the ship. The completion of logbooks and remarks books was a legal requirement and officers were required to submit them to the Admiralty at the completion of a voyage, at which time they would be paid their salary. The logbooks and remarks books would constitute the complete record of a voyage. C. Wilkinson, 'The Non-climatic Research Potential of Ships' Logbooks and Journals', *Climatic Change*, 73 (2005), 155–67.

[59] See the section 'Lieutenant' in Admiralty, *Regulations and Instructions*, pp. 171–81.

[60] N. Courtney, *Gale Force 10: The Life and Legacy of Admiral Beaufort* (London: Review, 2002). However, see D. C. Agnew, 'Robert FitzRoy and the Myth of the "Marsden Squares": Transatlantic Rivalries in Early Marine Meteorology', *Notes and Records of the Royal Society*, 58 (2004), 21–46.

Beaufort has been credited with turning the Hydrographic Office into a world leader in maritime survey.[61] Alongside his formal responsibilities as Hydrographer, Beaufort had an informal role as liaison between British science and the state. Beaufort's interests in geophysics and exploration permitted his membership on the committees of many of Britain's most eminent scientific societies, including the Royal Society, the Royal Astronomical Society and the Royal Geographical Society. He was appointed head of the scientific branch of the Admiralty Board in 1831, a position that gave him administrative responsibility for the Greenwich and Cape Observatories and Admiralty Offices related to navigation.[62] He was close to the Cambridge reformers, with whom he found common cause in 'breaking the strangehold of heirs of that regime upon voluntary and government scientific institutions and also in the promotion of common interests in geophysical science'.[63] He worked closely with Airy in his role as Astronomer Royal, aided the work of John Lubbock and William Whewell on the tides and assisted Herschel and Sabine's campaign for magnetic observation voyages to Antarctica.[64] Beaufort also made full use of the resources and networks of the Royal Navy to supply willing volunteers spread across the world with scientific instruments and advice, and to facilitate the movement of valuable information and commodities, such as botanical specimens, back to Britain for analysis.

Beaufort's longest-held scientific interest was meteorology. He kept records of the weather in his diary as a teenager whilst serving on the frigate HMS *Aquilon* and continued to do so throughout his life. In 1806, while serving on the *Woolwich*, he laid out his own fourteen-point scale for the measurement of wind force (where 0 denoted 'calm' and 13 denoted 'storm'), as well as shorthand for the description of the weather.[65] Beaufort's early attempts at a wind scale did not eliminate the possibility that two observers could attribute different categories to the same strength of wind – how was one to distinguish between Beaufort's '4. gentle breeze' and '6. fresh breeze', for instance? His solution in the following year was to correlate wind force with the amount of sail a fully

61 Friendly, *Beaufort*, p. 248. 62 Day, *Admiralty Hydrographic Service*, pp. 47–8.

63 Miller, 'Revival of the Physical Sciences', 114.

64 G. S. Ritchie, *The Admiralty Chart: British Naval Hydrography in the Nineteenth Century* (London: Hollis & Carter, 1967). Day, *Admiralty Hydrographic Service*, p. 45. Severe cuts to the Hydrographic Office in 1847 and 1853 retarded the Hydrographic Office and Beaufort's ability to assist in other scientific schemes.

65 National Meteorological Archive, MET/2/1/2/3/540, MET2/1/2/3/541a and 541b. It is generally accepted now that Beaufort's wind scale was modelled on a system of observation developed by John Smeaton in 1759. Alexander Dalrymple, the Scottish geographer and first hydrographer of the Admiralty, is credited with passing Smeaton's ideas on to Beaufort so that they might be adapted for use at sea. See Friendly, *Beaufort*, p. 143.

rigged ship would carry.[66] The making, shortening, reefing or furling of sail were tasks crucial to the effective and safe operation of a ship prior to the age of steam. These tasks demanded cooperation amongst a large group of skilled sailors, all of whose movements were controlled through standardised instructions issued by an officer on deck.[67] The use of sail as a method of measuring the force of the wind was therefore an expedient way of turning an ingrained awareness of a subject to new ends. Turning part of the architecture of a ship into an instrument of science was also not without precedent. William Snow Harris conducted research into the effects of lightning strikes on over 200 naval ships and experimented with the use of lightning conductors, arguing that these 'may be considered as so many grand experiments on the gigantic scale of nature'.[68]

Beaufort's use of sail to measure wind speed was evident in the private diary he kept while in command of HMS *Blossom* and HMS *Frederiksteen* from 1810 to 1812. Now 'Gentle breeze' was ranked '3' and described as 'That which will impel a Man of War with all sail by the winds' at four to five knots. A 'Fresh breeze' was ranked '5', and described as 'That with which Whole S[ai]l_ royals, stays &c. may be just carried full and by'.[69] If it was challenging to differentiate the subtle differences in wind strength around the midpoint of the scale, Beaufort's nomenclature really struggled at the extremes. A storm, ranked 11 in Beaufort's 1810–12 diary, was defined as that which would blow away any sail. A hurricane, at the twelfth and final point on the scale, was defined simply as 'Hurricane!' Just as a ship's sails were unable to catch the wind in the event of a hurricane, so language seemed unable to capture a precise description of extreme weather.

As he developed his wind scale and weather notation, Beaufort agitated for better use to be made of ships' logbooks as effective textual instruments in the accumulation of knowledge about the wind and weather. Writing to his brother-in-law Richard Lovell Edgeworth in 1809, he noted:

> There are at present 1000 King's vessels employed. From each of them there are from 2 to 8 Log books deposited every year in the Navy office; those log books give the wind and weather every hour ... spread over a great extent of ocean. What better data could a patient meteorological philosopher desire? Is not the subject,

[66] Friendly, *Beaufort*, p. 144. The idea of describing wind strength in terms of sail carried was not new, and was referred to in Daniel Defoe's 1704 account *The Storm*.

[67] Anon, *Observations and Instructions for the Use of the Commissioned, the Junior and Other Officers of the Royal Navy* (London: C. Whittingham, 1804).

[68] W. S. Harris, *Remarkable Instances of the Protection of Certain Ships of Her Majesty's Navy from the Destructive Effects of Lightning* (London: Richard Clay, 1847).

[69] National Meteorological Archive, MET/2/1/2/3/540, MET2/1/2/3/541a and 541b.

not more in a scientific than a nautical point of view, deserving laborious investigation?[70]

Beaufort's appointment as Admiralty hydrographer provided him with the ideal platform from which to effect this vision. He and his officers used the Hydrographic Office as a centre for the collection of meteorological information and its surveying ships as mobile weather stations. In 1832, Lieutenant Alexander Becher, Beaufort's naval assistant, wrote an article in the *Nautical Magazine* entitled 'The Log Book', where he argued for better methods of the recording of the weather at sea.[71] Becher complained that the log contained too little space for the recording of the state of the weather given the mass of observations that officers had to record, and he advocated the system of abbreviated annotation that Beaufort had developed.[72] Beaufort encouraged the use of his meteorological schema amongst his surveyors. Probably the first surveying ship to employ it was HMS *Beagle* on its voyage to South America in 1831, captained by Robert FitzRoy. The Admiralty instructions that FitzRoy received noted that the ship's records of the wind should use Beaufort's wind scale and weather notation, as opposed to 'ambiguous terms … in using which no two people agree'. The guidance recommended that Beaufort's scale and notation be pasted on the first page of the logbook and the officer of the watch instructed to use the same terms.[73] They also gave guidance on when and how to read the barometers and thermometers on board ship.

Responses to Beaufort's meteorological plans for the Navy were generally positive but their uptake was uneven. In 1833, Beaufort received a letter from Admiral Sir George Cockburn, the commander-in-chief of the Navy's North America and West Indies Station at Bermuda, praising his system of wind and weather recording and noting that it was in general use there.[74] Herschel wrote to Beaufort

[70] Letter dated 9 December 1809, quoted in Friendly, *Beaufort*, p. 142.

[71] The *Nautical Magazine*'s aim was to collect and disseminate navigational and hydrographic knowledge with a view to the improvement of the Royal and Merchant Navy. Becher was the *Magazine*'s founder and editor. M. Barford, 'Fugitive Hydrography: The Nautical Magazine and the Hydrographic Office of the Admiralty, c.1832–1850', *International Journal of Maritime History*, 27 (2015), 208–26.

[72] Friendly, *Beaufort*, p. 146. Officers were obliged to note down all signals that were made and received, all changes of sail, 'all strange sails that are seen', any circumstances 'which may derange the order in which the Fleet is sailing', as well as 'all shifts of wind'. Anon, *Regulations and Instructions*, p. 173.

[73] 'Admiralty Instructions for the Beagle Voyage' is included in Appendix One of C. Darwin, *Voyage of the Beagle* (London: Penguin, 1989 [1839]), p. 396. John Herschel also employed Beaufort's wind scale at the Cape Observatory. Cock, *Sir Francis Beaufort*.

[74] G. Cockburn to Beaufort, 14 September 1833, UK Hydrographic Office Archives, LP1857/C.

in December 1835, saying that while visiting the Cape, Lord Auckland had volunteered his aid in establishing a proper system of meteorological and tidal observations in India, under his stewardship as Governor-General.[75] Beaufort also found support from the Admiralty Committee established in 1836 to organise the Navy's steam department, who were interested in adopting Beaufort's system on the Navy's fleet of steam vessels. Writing to the Committee in October 1836, Beaufort congratulated the Committee for the 'character of precision and utility' of the logbooks they proposed to use. In terms of records of the force of the wind, he asserted the value of his numerical scheme, urging them not to reduce the scale to six categories, worrying that such restrictions would encourage the use of fractions. Beaufort also complimented the Committee on their proposed column for the state of the sea, the observation of which could supplement evaluations of wind force.[76]

A year later, however, Beaufort was lamenting the quality of weather observations on board naval ships. In a letter to Captain Sir James Bremer, he wrote that 'once in the watch the officer generally inserts "Moderate and cloudy" or some one or other of those proverbial phrases, the ambiguity of which is quite laughable. I have tried a dozen persons and no two of them have agreed as to the expressions they would use to describe the state of the wind and weather.'[77] Although his own schema had been 'invariably adopted' by surveying vessels, only some of the admirals in general service had taken it up.[78] Even among his own surveying vessels there were inconsistencies in approach. While surveying off the coast of Sierra Leone in 1834 the crew on HMS *Ætna* collected various meteorological observations at 8am, noon and 4pm, but did not record wind force or direction, and made weather observations of the sort that Beaufort had been complaining about to Captain Bremer. Beaufort's attempt to regulate weather observation at sea suffered from the same problem as his wind scale. The use of terms such as 'variable airs', 'passing clouds' and 'pretty clear' in

[75] J. Herschel to Beaufort, 26 December 1835, UK Hydrographic Office Archives, LP1857/H.

[76] Letter from Beaufort to T. Baldock, 8 October 1836, UK Hydrographic Office Archives, LB/8. Baldock was one of three members of the Committee. Steam vessels eventually made the old correlations between press of sail and wind speed irrelevant. Cock, *Sir Francis Beaufort*.

[77] Letter from Beaufort to J. J. Gordon Bremer, 2 November 1837, UK Hydrographic Office Archives, LB/8.

[78] Bremer was twice commander-in-chief of British forces in China and it was Bremer who took formal possession of Hong Kong for Britain in 1841. W. R. O'Byrne, *Naval Biographical Dictionary* (London: John Murray, 1849), pp. 119–20.

Ætna's meteorological log demonstrated the insufficiency of language to represent weather at the mean.[79]

On the other side of the Atlantic HMS *Jackdaw* was working around the Bahamas and its commander, Lieutenant Edward Barnett, was making meteorological observations. The observations collected were much fewer than on *Ætna*, but this time wind direction and force were recorded using Beaufort's scale, along with weather observations using Beaufort's notation. Observations were taken at 9 am, noon, 3 pm, 6 pm and 9 pm.[80] *Jackdaw* was accompanied in the Bahamas by HMS *Thunder*, another hydrographic ship, which like *Ætna* and *Jackdaw* also kept a meteorological register separate from the logbook. While *Jackdaw* collected surface water temperature readings, *Thunder* made more comprehensive use of its marine and oil barometers. Readings were also taken at different times – at 4 am, 9 am, noon, 3 pm, 8 pm and midnight.[81] When Barnett took charge of HMS *Thunder* in November 1837 for another tour of North America and the West Indies, Beaufort wrote to him with detailed instructions. As with Bremer and FitzRoy, Beaufort provided Barnett with several copies of his wind scale and weather abbreviations and suggestions as to their use. He also asked the officer to record other interesting meteorological phenomena, to document the 'periods and limits' of the trade winds, monsoons and rains as they were encountered, and to pay full attention to the barometer and thermometer. In doing so, the ship would be adding to a stock of knowledge 'for the use of future labourers whenever some accidental discovery, or the direction of some powerful mind should happily rescue that science from its present neglected state'.[82]

Beaufort clearly felt that the malaise identified by Forbes in 1832 continued to plague meteorology at sea five years later. However, despite his explicit support for meteorological reform, Beaufort struck a pragmatic tone when in correspondence with his officers. He was forced to concede to Barnett that the hours of entry of meteorological information interfered with the officers' other activities while at sea. Noting that the data's 'future utility is so uncertain', Beaufort suggested that a fuller

[79] Anon, Hygronometrical Observations made on board His Majesty's Surveying Vessel *Ætna*, communicated to the Royal Society by Captain Beaufort, 1835, Archives of the Royal Society, AP/19/1.

[80] E. Barnett, *Jackdaw*'s Meteorological Register 1st January–1st November 1834, communicated to the Royal Society by Captain Beaufort, 1835, Archives of the Royal Society, AP/19/2.

[81] Anon, Meteorological Register. HMS *Thunder*. Between January 1st & June 30th 1834, communicated to the Royal Society by Captain Beaufort, 1835, Archives of the Royal Society, AP/19/18.

[82] Surveying instructions from Beaufort to Lieutenant E. Barnett of HMS *Thunder*, 9 December 1837, UK Hydrographic Office Archives, Miscellaneous Files.

record might only be possible due to some unforeseen detention in port, 'when a system of these observations might then be advantageously undertaken'.[83]

William Reid and the Law of Storms

In the late 1830s, Beaufort and Becher continued their campaign to improve meteorological observations on board Navy ships and were joined in their work by Lieutenant-Colonel William Reid (1791–1858), a British Army engineer. Reid served in the Peninsula and the Anglo-American wars and with the Ordnance Survey in Ireland, before being sent in 1832 as resident engineer to Barbados to assist in rebuilding government buildings after the devastating hurricane of August 1831.[84] Although Reid had harboured an interest in meteorology for some time, his residence in Barbados prompted him to study tropical storms. While there he familiarised himself with the work of other meteorologists who had worked on similar topics in different parts of the world. This included the writings of Colonel James Capper, of the East India Company. Capper published several works on tropical storms, including an 1801 paper *On the Winds and Monsoons*, which was based on his studies of records of eighteenth-century hurricanes that had affected the Coromandel and Malabar coasts of India. In it he argued that 'the velocity of the wind at any point was chiefly due to the velocity of rotation of a vortex of fluid, combined probably with a progressive motion'.[85]

Even more important to Reid was the work of William C. Redfield, an American transportation engineer based in New York, who published a number of papers in the 1830s on the characteristics of Atlantic storms.[86] Redfield had been informed by Benjamin Franklin's storm observations in the north-eastern United States. While in Barbados, Reid came across an 1831 paper by Redfield in the *American Journal of Science*, in which Redfield collated more than seventy sets of observations of the hurricane of 17 August 1830, to argue that these storms were whirlwinds rotating around a centre of low pressure, which moved forwards on curved tracks.[87] Reid was particularly impressed by the chart of

[83] Beaufort, Surveying Instructions to Barnett of HMS *Thunder*, p. 27.
[84] O. M. Blouet, 'Sir William Reid, F. R. S., 1791–1858: Governor of Bermuda, Barbados and Malta', *Notes and Records of the Royal Society*, 40 (1986), 169–91, 174.
[85] J. D. Forbes, 'Supplementary Report on Meteorology', *Report of the Tenth Meeting of the British Association for the Advancement of Science* (1841), 37–156, 109.
[86] J. R. Fleming, *Meteorology in America 1800–1870* (Baltimore: Johns Hopkins University Press, 1990).
[87] Anon, 'Redfield's Law of Storms:- Notice of Col. Reid's Work on Hurricanes', *The American Journal of Science and Arts*, 35 (1839), 182; W. C. Redfield, 'Remarks on the

the storm that Redfield included in his study.[88] Convinced that Mr Redfield's views were correct, Reid set about collecting more data on the wind direction of Atlantic storms, and laying down the data on large-scale charts so as to strengthen the argument that these storms conformed to the pattern of a 'progressive whirlwind'.[89]

Upon returning to England in 1836 Reid went on the half-pay list while assembling meteorological information, including storm data from the logbooks of Admiralty ships. He also initiated correspondence with Redfield, who encouraged Reid's emphasis on direct observation.[90] At the 1838 British Association meeting in Newcastle, Reid presented his own work on the subject, notably eight charts showing the path of storms at different latitudes. Although he claimed that his object was 'not to establish or support any theory, but simply to arrange and record facts', his report came out strongly in favour of the ideas of Redfield.[91] In doing so he supported Redfield's belief that a reliable system of meteorological physics should be 'grounded in direct observations'.[92] Reid also added his own embellishments, such as that the progressive rate of storms was never greater than that of the atmospheric currents; that a hurricane's destructive power was due to its rotatory velocity; and that its path traced out a parabola.[93]

Herschel, amongst others, spoke positively of Reid's work at the meeting, commending him for his judiciousness as an observer while urging him to advance a theoretical position, if only to incite debate and encourage the 'collision of intellect'.[94] Others argued against the theory that Reid's work supported. Alexander Bache, previously Professor of Natural Philosophy at the University of Pennsylvania, and from 1843 the superintendent of the Unites States Coastal Survey, spoke out against it and in support of a rival theory of James Espy, the director of the Joint Committee on Meteorology of the American Philosophical

Prevailing Storms of the Atlantic Coast, of the North American States', *American Journal of Science and Arts*, 20 (1831), 17–51.

88 Anon, 'On Storms', *Littell's Spirit of the Magazine and Annuals*, 2 (1838), 856–8.

89 W. Reid, *An Attempt to Develop the Law of Storms by Means of Facts, Arranged According to Time and Place, and Hence to Point out a Cause for the Variable Winds, with the View to Practical Use in Navigation* (London: John Weale, 1838), p. 3.

90 Fleming, *Meteorology in America*, p. 38.

91 Anon, 'A Report Explaining the Progress Made towards Developing the Law of Storms', *The Athanaeum*, 25 (August 1838), 594–6, 594.

92 Letter from Redfield to Reid, 26 March 1838, quoted in Fleming, *Meteorology in America*, p. 39.

93 Reid's contributions to Redfield's theory of storms were summarised in Charles Tomlinson's essay, 'The Law of Rotatory Storms', contained in J. Greenwood, *The Sailor's Sea-Book: Rudimentary Treatise on Navigation* (London: John Weale, 1850).

94 Herschel, quoted in 'A Report Explaining the Progress', p. 595.

Society.[95] Espy supported the centripetal theory of the German mathematician H. W. Brandes, proposing that the wind blew in all directions towards the centre of a storm, with the inward flow at the surface balanced by a corresponding outflow above a rising column of air.[96] While Espy's ideas gathered some support in America, they were largely rejected in Britain, where his theory was considered to be 'wholly contradicted by the facts'.[97]

Reid's research appeared in print in 1838, first in a long article entitled 'On Hurricanes' in the Corps of Royal Engineers' professional papers, and then in a nearly 600-page book on the subject, *An Attempt to Develop the Law of Storms*. The volume was in effect an extended demonstration of the validity of Redfield's theory. The first two chapters of the book discussed Redfield's storm observations, and then moved on in subsequent chapters to the storms that affected particular regions of the world, notably the hurricanes of the western Atlantic, the typhoons of the China Sea and the cyclones of the Indian Ocean. That a book on storms would focus on these areas was unsurprising, given the high incidence of storm events around the equator. It was also unsurprising that much of the discussion focused on islands under British control – Barbados, Mauritius, Antigua and Bermuda – or on those of significant commercial importance to the British, such as Macao. These were places where naval and merchant ships would visit on a regular basis. Weather data followed the paths of British ships and traced a geography of storms that conformed to the contours of Britain's imperial interests. Whether this was intentional or not, these were the places where a law of storms mattered most to British shipping.

Each chapter was a compilation of meteorological data from ships' logs and from observers on land, including both instrumental observations and anecdotal remarks. In the case of many of the storms, the data were traced out on large foldout charts appended at the end of the book. For instance, Reid's chart of the Great Hurricane of 10 October 1780 mapped the track of the hurricane across the Caribbean and then back across the Atlantic (Figure 1.1). Also included were the daily positions of various

95 C. Carter, 'Magnetic Fever: Global Imperialism and Empiricism in the Nineteenth Century', *Transactions of the American Philosophical Society*, 99 (2009), i–xxvi and 1–168. For a fuller discussion of the rival storm theories of Redfield and Espy, see Fleming, *Meteorology in America*; and Jankovic, 'Ideological Crests'.

96 J. Burton, 'Robert FitzRoy and the Early History of the Meteorological Office', *British Journal for the History of Science*, 19 (1986), 147–76, 148.

97 H. Piddington, *The Sailor's Horn-Book for the Law of Storms: Being a Practical Exposition of the Theory of the Law of Storms, and Its Uses to Mariners of all Classes, in all Parts of the World, Shewn by Transparent Storm Cards and Useful Lessons* (London: Williams and Norgate, 1848[1860]), p. 6.

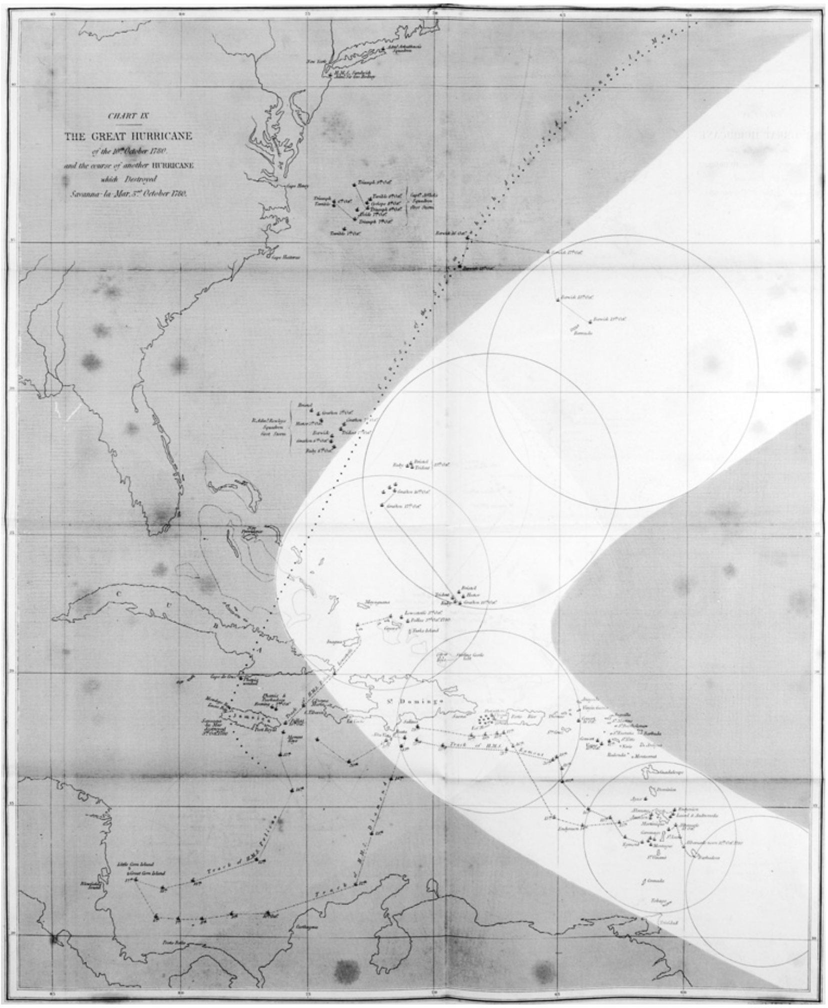

Figure 1.1 Chart of the Great Hurricane of 1780. (Source: Reid, *Attempt to Develop the Law of Storms*, Chart IV.)

ships that had supplied data, their movements between these points, and in several cases, the places where they had been wrecked or lost. Reid replicated this approach on many of his other charts. For him, the movement of those ships that encountered revolving storms was as important and useful as the information collected in their logbooks.[98]

[98] For a similar argument, see Sorrenson, 'The Ship as Scientific Instrument', p. 222.

Reid's epistemic authority was founded on the extent of the observations he had collected and their distribution across space, while that authority was bolstered by the cartographic representation of the observations. Reid argued that 'by collating a great number of reports of storms made at different places, as well at sea as on shore, the changes of wind in a separate storm are now understood'.[99] However, these charts were far from transparent representations of meteorological reality. Rather, they were opportunities to smooth out errors of observation and random fluctuations in the wind or barometric pressure. The charts revealed order that would otherwise have been concealed in tables of numbers, while retaining particular details, notably the positions and tracks of ships.[100]

The strongest endorsement for Reid's approach came from Henry Piddington in his *Sailor's Horn-Book for the Law of Storms*, published in 1848. Piddington was a merchant captain who had worked around India and China, and later became president of the Marine Court of Inquiry at Calcutta. In his *Horn-Book*, Piddington laid out the relations between scientific theory, proof and application, where the theory was 'the supposition that a thing always occurs according to certain rules, the proof or Law that it does and will always so occur, and the Application of that law to the business of common life'. According to Piddington, Reid's analysis of more than 2,000 logs and of some hundreds of storms had provided the proofs of the theory of storms developed by Redfield.[101] Reid's work certainly conformed to prevalent models for the pursuit of terrestrial physics in the first half of the nineteenth century (discussed further in Chapter 2), with its emphasis on the gathering of large amounts of global data. His graphical representations of storms were also part of a wider movement to present scientific ideas visually in the 1830s, such as by Herschel in astronomy and Sabine in studies of terrestrial magnetism. Lastly, Reid's implicit support of bold theorising and his ambition to identify the universal laws of nature meant that he was not merely a naïve military fact-gatherer – despite his own modest claims to be just that – but was supportive of a hypothetical-deductive method of the sort advocated by Herschel.[102] Indeed, Reid's

[99] W. Reid, *The Progress of the Development of the Law of Storms and of the Variable Winds, with the Practical Application of the Subject to Navigation* (London: John Weale, 1849), p. 2.

[100] T. L. Hankins, 'A "Large and Graceful Sinuosity": John Herschel's Graphical Method', *Isis*, 97 (2006), 605–33, 606; K. Anderson, 'Mapping Meteorology', in J. R. Fleming, V. Jankovic and D. R. Coen (eds.), *Intimate Universality: Local and Global Themes in the History of Weather and Climate* (Sagamore Beach: Science History, 2006), pp. 69–92.

[101] Piddington, *Sailor's Horn-Book*, p. 8.

[102] G. Good, 'A Shift of View: Meteorology in John Herschel's Terrestrial Physics', in J. R. Fleming, V. Jankovic and D. R. Coen (eds.), *Intimate Universality: Local and Global Themes in the History of Weather and Climate* (Sagamore Beach: Science History, 2006), pp. 35–68, p. 36.

charts were effective at holding these various demands in tension, while avoiding unnecessary philosophical controversy.

Piddington's claims that Reid's work added to the business of common life remind us that Reid conformed to another principle of science in the early years of the nineteenth century: that it should produce knowledge that was of use to society. Reid's charts had an obvious practical value: they spoke to non-scientific figures such as a sailor, navigator or harbour master – all of whom would be comfortable with the language of charts – as much as they did to the meteorologist. This was demonstrated in a review of Reid's book in the *London Saturday Journal*, where *The Law of Storms* was discussed alongside the 1839 edition of *Murphy's Weather Almanac*.[103] Both volumes were in the business of trying to predict atmospheric events, but while *Murphy's Almanac* was founded on 'vague, incoherent jargon' and grandiose claims, Reid's book proceeded on an altogether more cautious footing. The reviewer went as far as to say that if the theory of the circular and progressive motion of hurricanes be established as an actual fact, 'it may ultimately be turned to great "practical use in navigation"'.[104] Similarly, Piddington praised Reid for deducing the rules that would render Redfield's theory 'of practical utility'.[105] The *Edinburgh Review* predicted that 'no sailor will study these records of atmospherical convulsions, without feeling himself better armed for a professional struggle with the elements. The navigator, indeed, who may quit the shores of Europe for either Indies without Colonel Reid's book, will discover, when it is too late, that he has left behind him his best chronometer and his surest compass.'[106] Despite the full title of Reid's book, however, the amount of direct advice given to sailors who found themselves in the path of a storm was relatively slight. This was remedied in Reid's 1849 book *The Progress of the Development of the Law of Storms*, published by John Weale, which contained a chapter dedicated to heaving-to and sailing out of a revolving storm. The book's arguments were also more routinely illustrated by schematics, most notably Reid's hemispheric circles (Figure 1.2), which were designed to be cut out and placed on a marine chart so that they might 'serve to aid the memory whilst considering how the wind veers in whirlwind storms'.

[103] Patrick Murphy's *Almanac* caused a brief sensation in 1838 when it predicted successfully the coldest day of the year to be 20 January. Anderson, *Predicting the Weather*.

[104] Anon, 'Weather Almanacs and the Law of Storms', *The London Saturday Journal*, 1 (1839), 7.

[105] Piddington, *Sailor's Horn-Book*, p. 7.

[106] Anon, 'Review of Reid's *Law of Storms*, 1838, along with Redfield's articles on Atlantic storms in *Silliman's Journal, Blunt's American Coast Pilot and US Naval Magazine*', *Edinburgh Review*, 68 (1839), 406–30, 431.

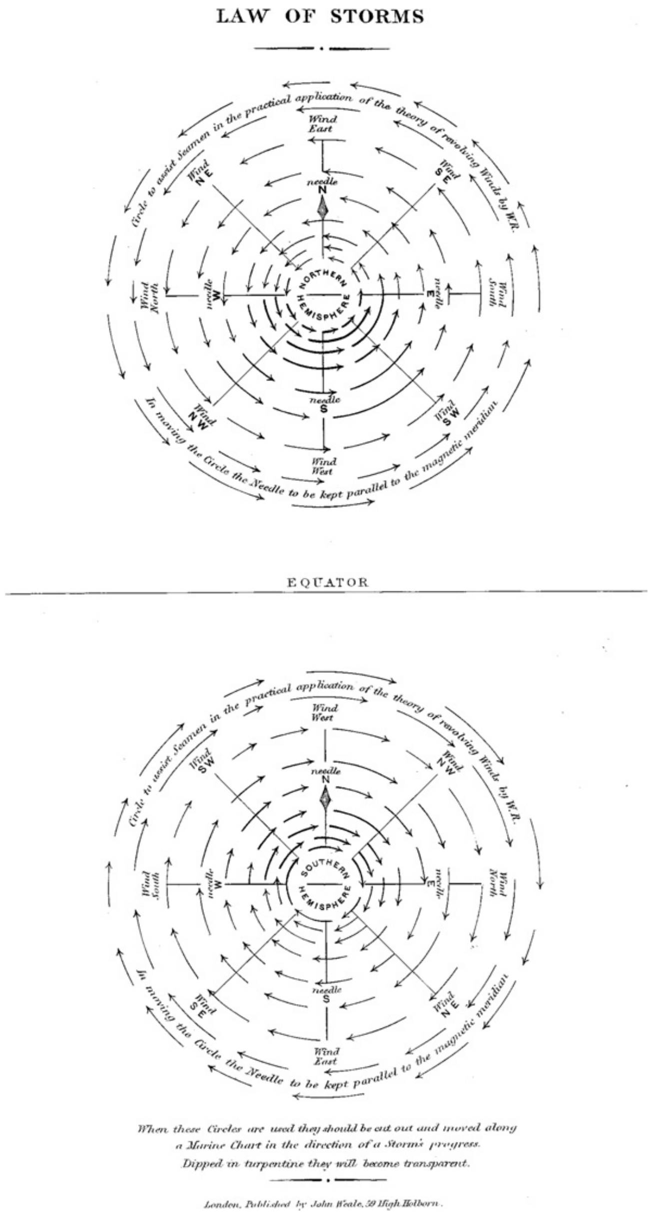

Figure 1.2 Hemispheric storm circles. (Source: Reid, *Progress of the Development of the Law of Storms*, facing p. 3.)

Reid, Beaufort and the Ship's Logbook

Reid's *The Law of Storms* went through several editions and was translated into various languages. In recognition of his scientific contribution Reid was made a Knight Companion of the Order of the Bath in 1838 and was elected Fellow of the Royal Society in 1839. His work and increasing prominence in the field of meteorology brought him into contact with Beaufort.[107] Reid wrote to Beaufort in May 1838 to draw the latter's attention to his work on storms. He lauded Beaufort's attempts to improve the quality of weather data collected in ships' logs and particularly his emphasis on wind speed and direction, with which a ship's position in a revolving storm could be ascertained. He also praised Beaufort's idea of inserting columns that showed a ship's track.[108]

Reid promoted Beaufort's wind force scale and weather notation in *The Law of Storms* and he petitioned the Admiralty to adopt Beaufort's meteorological additions to the logbooks of naval ships. Becher supported Reid's plan. In a memorandum of November 1838, Becher reiterated familiar criticisms of the current state of meteorological observations on board naval ships and acknowledged Reid's recommendation of Beaufort's schema, suggesting that Reid 'has evidently been enabled in his recent enquiry into Hurricanes to see the full value of it'.[109] Becher went on to argue that no seaman in command of a ship would ever go to sea without a barometer and that great advantage would arise from 'the observations of it being recorded in every weather, and in the event of storms or hurricanes occurring that the changes in its height during their progress and times of change should be carefully noted'.[110] Beaufort supported this, arguing in December 1838 that all officers who possessed a barometer 'should be permitted to observe it at least once in every watch'.[111]

Reid and Beaufort's joint campaign was a success. In December 1838, the Admiralty adopted Reid's proposal. On 3 January 1839, Reid wrote to Herschel in his role as chair of the Royal Society's Joint Committee of Physics and Meteorology, saying that 'it will be gratifying to yourself and all interested in Meteorology to know that the Lords Commissioners of

[107] Reid to Beaufort, 12 March 1838, UK Hydrographic Office Archives, LP1857/R.
[108] Reid to Beaufort, 9 May 1838, UK Hydrographic Office Archives, LP1857/R.
[109] A. Becher, Proposals for improving the Meteorological Registers in the Log Books of HM Ships, 14 November 1838, UK Hydrographic Office Archives, MB/3, pp. 91–3, on p. 91.
[110] Becher, Proposals, pp. 92–3.
[111] F. Beaufort, On inserting Meteorological Observations, according to Office Abbreviations, in the Logs of HM Ships, 5 December 1838, UK Hydrographic Office Archives, MB/3, p. 96

the Admiralty have ordered an addition to be made to the Log Books of Ships of War, to aid enquiry into the subject'.[112] Columns for the force of wind and appearance of the atmosphere were to be added to the logbook and were to be completed on an hourly basis. This instruction was reinforced in the 1844 edition of the *Admiralty Instructions*, where ships' captains were told to ensure that the logbook recorded, 'most carefully, all particulars relating to the situation of the Ship, along with the state of the weather, and the direction and force of the weather every hour'.[113] The *Admiralty Instructions* also included advice on the location and observation of the barometer on board ship, which reflected the Admiralty's decision in 1843 that all HM ships should carry one.[114] Courtney claims that it was the Royal Society's intervention that led to the formal issue of marine barometers to the naval fleet in 1843, a matter administered through the Hydrographic Office.[115] This development was reflected in the 1844 edition of the *Admiralty Instructions*, where captains were told to have the barometer 'carefully suspended in some secure and accessible part of the Ship' (and to note its location at the beginning of the logbook), and to make observations at 6 am, noon, 6 pm and midnight.[116] The British Association was quick to utilise this new development. In 1845, survey ships on the Home Station were ordered to assist the Association, which was interested in observing meteorological phenomena that affected the British Isles during the autumn. Officers were asked to keep registers of barometric observations during October and November using printed directions and blank forms issued especially, and were required to again do so in 1846.[117]

Interest in the value of meteorological instruments at sea spread beyond the survey fleet. In February 1847, Beaufort received a letter from Sir Henry John Leeke, flag captain of HMS *Queen*, a 110-gun first-rate ship of the line and the last sailing battleship to be completed before the widespread introduction of steam power.[118] Leeke wrote to Beaufort to promote the work of his Major of Marines David M. Adam, whose knowledge of the barometer and attention to changes in the weather had

[112] Letter from Reid to Herschel, 3 January 1839, Archives of the Royal Society, DM/3.
[113] Anon, *Admiralty Instructions for the Government of Her Majesty's Naval Services* (London: Stationery Office, 1844), p. 173.
[114] Day, *Admiralty Hydrographic Service*, pp. 56–7. Day notes that the barometers were supplied by the Hydrographic Office.
[115] Courtney, *Gale Force 10*.
[116] Anon, *Admiralty Instructions*, p. 173. What was meant exactly by 'secure and accessible' is not explained.
[117] Anon, 2 September 1845 and 6 October 1846, Circulars to Surveyors on the Home Station, UK Hydrographic Office Archives, LB/13 and LB/14.
[118] J. J. Colledge, *Ships of the Royal Navy: The Complete Record of all Fighting Ships of the Royal Navy from the Fifteenth Century to the Present* (London: Greenhill Books, 1970).

been of 'great use' to him on board. Adam was 'half a very clever scientific man', claimed Leeke, and he requested additional meteorological instruments to aid Adam.[119] Attached to Leeke's letter was one from Adam himself, addressed to Leeke although presumably targeted at Beaufort, forwarding his readings of the barometer, thermometer, wind direction and force, and weather while HMS *Queen* was at Plymouth Sound in November and December 1846. Adam requested a hygrometer, anemometer, rain gauge, electrometer and dipping circle, on the grounds that '[i]f there is one place where accurate knowledge of [the weather], is more useful than another, that place is a Man of War – on ship-board'. For Adam, instruments 'may give the young officers a scientific turn', and that the serious study of meteorology on a flagship could only lead to 'a more accurate knowledge of that science' throughout the fleet.[120] He promised the Admiralty Lords weekly or monthly meteorological reports in return. Columns for barometric and thermometric readings were added to the logbook, alongside those for wind and weather. The logbooks of naval ships, Reid later noted, were lodged and available for consultation at Somerset House.[121]

Interest in meteorological observation spread even further than the Navy's fighting ships. Reid appended a memorandum to his 1839 letter – written by Lord Glenelg, the Secretary of State for War and the Colonies – and addressed to all governors of British colonies on the subject of 'Keeping Journals of the Weather, and of noticing Meteorological phenomena generally'.[122] In it Glenelg also directed governors of British colonies, captains of ports, harbour masters and keepers of lighthouses to keep meteorological journals based on the principles of the logbooks of ships, and to submit them every half year to the Colonial Office, where they would be preserved in the library for future use. In the second edition of *The Law of Storms*, published in 1841, Reid drew attention to his success at persuading the Admiralty Lords and government ministers to adopt a keener interest in the weather at sea. He also noted that the inspector-general of the Coastguard had issued orders to revenue cruisers to keep hourly observations of the weather, and that the directors of the East India Company had instructed the governor-general of India to 'carry out

119 Letter from H. Leeke to F. Beaufort, 9 February 1847, UK Hydrographic Office Archives, LP1857/L.

120 Letter from D. Adam to H. Leeke, 30 January 1847, appended to the letter from Leeke to Beaufort, UK Hydrographic Office Archives, LP1857/L.

121 Reid, *The Law of Storms*, p. 542.

122 Lord Glenelg, undated, Memorandum respecting the Records to be kept of the state of the Weather, in the British Colonies, appended to letter from Reid to Herschel, 3 Jan 1839, Archives of the Royal Society, DM/3.

various suggestions on the subject of tracing the storm-tracks of the Indian seas'.[123]

For Reid, the Admiralty's willingness to support a plan that Beaufort had been promoting for some years was due to their interest in storm predictions. He noted that their lordships had ordered thirty copies of his book to be distributed among interested captains and commanders-in-chief of various stations, and that 'they would with pleasure afford any assistance in carrying on an enquiry so valuable to navigation and the interests of Humanity'.[124] Copies were also deposited in the Admiralty Library and at the Hydrographic Office. Reid's appeal for meteorological data to aid in the understanding of the behaviour of storms was clearly more persuasive than Beaufort's more general, inductive policy of meteorological observation and data gathering, and was illustrative of the priority that the Admiralty gave to fundamental matters concerning safety of life at sea over scientific interests.[125]

This sudden apparent enthusiasm for meteorology at the Admiralty and in government may also have been related to the decision in early 1839 to fund Ross's expedition to investigate terrestrial magnetism in the southern hemisphere and establish several overseas observatories, discussed earlier in the chapter and again in Chapter 2. Although meteorology and terrestrial magnetism were equally data-intensive, the coordination of magnetic research was, of the two, the 'most fully organized and most self-consciously directed toward answering questions of laws and causes'.[126] Its emphasis on theoretical explication, the use of precision philosophical instruments and the value of collective, international endeavour marginalised the individual observer in favour of a 'central scientific authority which would process all empirical information into mass data'.[127] The Magnetic Crusade set an important example for the conduct of meteorology, which was pursued during the crusade itself, while Reid's argument regarding the value of meteorological data gathering for ships caught in storms bore a close similarity to that made about the collection of magnetic data for improvements to navigation.[128] We will return to this theme in Chapter 2.

123 Reid, *The Law of Storms*, p. 542.
124 Reid to Herschel, 3 January 1839, Archives of the Royal Society, DM/3; Admiralty Rough Minutes, 6 January 1839, National Archives, ADM3/245.
125 Webb, 'More than Just Charts', p. 52.
126 G. A. Good, 'Between Data, Mathematical Analysis and Physical Theory: Research on Earth's Magnetism in the 19th Century', *Centaurus*, 50 (2008), 290–304, 301.
127 Winter, '"Compasses All Awry"', 87; Anderson, 'Mapping Meteorology'.
128 As noted on p. 29, a significant amount of effort was invested in the study of meteorology during the Crusade, and far more than was required to make the necessary adjustments to the magnetic and astronomical instruments. One of the five sections of the Royal

Bermuda as Island Laboratory

In late 1838, Reid was appointed governor of the Bermuda Islands, Reid surmising that Lord Glenelg had recommended him for the post on the basis of his scientific work.[129] The islands were of strategic importance to the Royal Navy and the British Empire. In 1818, the Royal Navy's North America and West Indies Station was formed when the two previous stations were combined.[130] Halifax had previously acted as headquarters of the North America Station and continued as the summer base for the new Station. Bermuda became the Station's winter headquarters and the main base of activities. It was also the site of the Royal Naval Dockyards and was well positioned to allow the Royal Navy to protect Atlantic trade routes and fisheries, to patrol for slave ships, transport troops and garrison colonial territory.[131]

As governor of Bermuda, Reid was in a position to develop his own meteorological inquiries and to assist Beaufort, and he made full use of his posting to achieve this. In doing so he positioned Bermuda as a scientific space in a number of different ways. First, Reid used the island as an archive, where he could both gather together and disseminate weather data from naval and merchant ships. Second, he treated the island as a laboratory for the testing of universal meteorological laws, a site where observational results were meant to be independent of the locale. Reid's treatment of Bermuda as an open-air weather observatory would have been reinforced by the activities of the island's temporary magnetic observatory, which was established in 1843 as part of the Hydrographic Office's contribution to the Magnetic Crusade. Reid observed the passage of a storm with Captain Barnett of HMS *Thunder* in October 1845, when Barnett was on the island to dismantle the observatory. Third, he defended his claims on the basis of an extended residence in the field, where his locatedness lent credibility to his claims. Coen has argued that a tension existed between the study of the atmosphere as laboratory and as fieldsite, but that these two approaches were in fact interdependent and impossible to isolate

Society's report was devoted entirely to meteorology. Anon, *Report … on the Instructions … for the Scientific Expedition to the Antarctic Regions.*

129 Blouet, 'Sir William Reid', p. 175.

130 Bermuda took over as the headquarters of the North America Station from Halifax, Nova Scotia. Rio had been the Navy's headquarters of the South America Station since 1808. F. Driver and L. Martin, 'Shipwreck and Salvage in the Topics: The Case of HMS *Thetis*, 1830–1854', *Journal of Historical Geography*, 32 (2006), 539–62.

131 K. Greer, 'Zoogeography and Imperial Defence: Tracing the Contours of the Nearctic Region in the Temperate North Atlantic, 1838–1880s', *Geoforum*, 65 (2015), 454–64.

fully.[132] Reid certainly employed both types of scientific space in his work at Bermuda.[133]

Bermuda was ideally situated to act as a weather archive.[134] In October 1839, Reid wrote to Beaufort, thanking him for new charts of Bermuda and to inform him that the island's collector of customs had been distributing his 'mode of recording the winds [sic] force by symbols' and that he had asked Reid to get him a further supply of the Admiralty order. Reid also offered to distribute these among the commanders of merchant ships who regularly docked there.[135] Early the following year, he wrote to Beaufort and to the Royal Society informing them that he had arranged for the editor of the *Bermuda Royal Gazette* to be supplied with meteorological reports from the island's central signal station at Government House. This system was effective, he claimed, because the newspaper was regularly transmitted to the Colonial Office and because it was popular amongst the commanders of ships and the owners of Bermuda shipping.[136] Reid had been getting masters of vessels coming into Bermuda to supply him with information from their logbooks on their courses sailed and the direction and force of the winds they had experienced. With the help of the customs office, he was laying the information down onto a chart so that 'we can judge of the best courses to steer'.[137]

Reid used this information to investigate the storms in the region. He pulled together large numbers of extracts from ships' logs documenting the incidence of a hurricane that passed over Bermuda on 11–12 September 1839 – a storm so severe that it had 'made the people here take up the subject of storms with some earnestness'.[138] The *Bermuda Royal Gazette* published a large number of the excerpts, with an introductory commentary that located the various ships in relation to the hurricane's path. The newspaper expressed the 'hope that by continuing the enquiry, the nature of the Bermuda Hurricanes and their Courses,

[132] D. R. Coen, 'The Storm Lab: Meteorology in the Austrian Alps', *Science in Context*, 22 (2009), 463–86, 465.

[133] C. R. Weld, *A History of the Royal Society* (London: John W. Parker, 1848), p. 444; Reid, *Progress of the Development of the Law of Storms*, p. 265.

[134] Mahony has developed a similar historical geography of island meteorology in his analysis of Mauritius: M. Mahony, 'The "Genie of the Storm": Cyclonic Reasoning ad the Spaces of Weather Observation in the Southern Indian Ocean, 1851–1925', *British Journal for the History of Science*, 51 (2018), 607–33.

[135] Letter from Reid to Beaufort, 17 October 1839, UK Hydrographic Office Archives, LP1857/R.

[136] Reid to J. Russell, 8 February 1840, Archives of the Royal Society, AP/24/16.

[137] Reid to Beaufort, 30 January 1840, UK Hydrographic Office Archives, LP1857/R; Reid to Russell, 8 Feb 1840, Archives of the Royal Society, AP/24/16.

[138] Reid to Beaufort, 17 October 1839, UK Hydrographic Office Archives, LP1857/R.

may be better understood'.[139] Reid went on to use the logbooks, newspaper reports and Central Signal Station records to update the second edition of *The Law of Storms*. He used the data to prepare a chart of the course of the hurricane, which demonstrated its curved track up from the tropic to Newfoundland, and showed the positions of the various ships that encountered it on 12 September.[140] He later reworked the chart in his *Progress of the Development of the Law of Storms* to illustrate his theory of the relationship between storms and sea-swell (Figure 1.3).

The chart was accompanied by an extended commentary, making up the entirety of Chapter IX, which imposed a loosely geographical narrative upon a range of source material. The chapter began with speculation on the origin of the storm. It then traced the storm's course, introducing extracts of reports of ships, their observations of winds and weather and the crews' responses to the storm, as they encountered it. Observations at Bermuda were also included, encompassing the nature of the sea-swell, barometer readings, wind force and direction, extracts from newspapers, the Central Signal Station weather tables, the behaviour of the tide and incidents of storm damage. As the storm progressed northwards, observations from other localities, such as St Johns, Newfoundland, the Gulf of St Lawrence and New York, were incorporated.

Reid's testimonial, narrative style reflected his commitment to first-hand observation as the basis for a science of storms. Reid's locatedness also formed part of the basis of his credibility as a meteorologist. He repeatedly legitimated his claims respecting storm activity with reference to his own extended residence on an island where Atlantic hurricanes could be experienced and studied and where others' observations could be procured. Crucially though, and in conformity with Herschel's position on the matter, he positioned his own observations at Bermuda as illustrative of processes that transcended place or region.[141] For instance, in a letter to the Royal Society in 1840, Reid noted: 'Since I have been in Bermuda, I have had no reason to doubt that Great Storms of wind, (which affect the Barometer) really revolve by a fixed law; but on the contrary, I have observed much to confirm this belief.'[142] Reid used his *Progress of the Development of the Law of Storms* to make similar virtue of his time on the island. For instance, he discussed Redfield's theory that a whirlwind diminished the pressure of the atmosphere at its centre, and supported the idea with the statement: 'My observations attentively made

[139] Anon, 'The Storm', *Bermuda Royal Gazette*, 24 September 1839, included in Reid's letter to Lord Russell, 8 February 1840, Archives of the Royal Society, AP/24/16. Descriptions of many of the storms were also reported in the *Nautical Magazine*.
[140] Reid, *The Law of Storms*, facing p. 444. [141] Good, 'A Shift of View'.
[142] Reid to Russell, 8 February 1840, Archives of the Royal Society, AP/24/16.

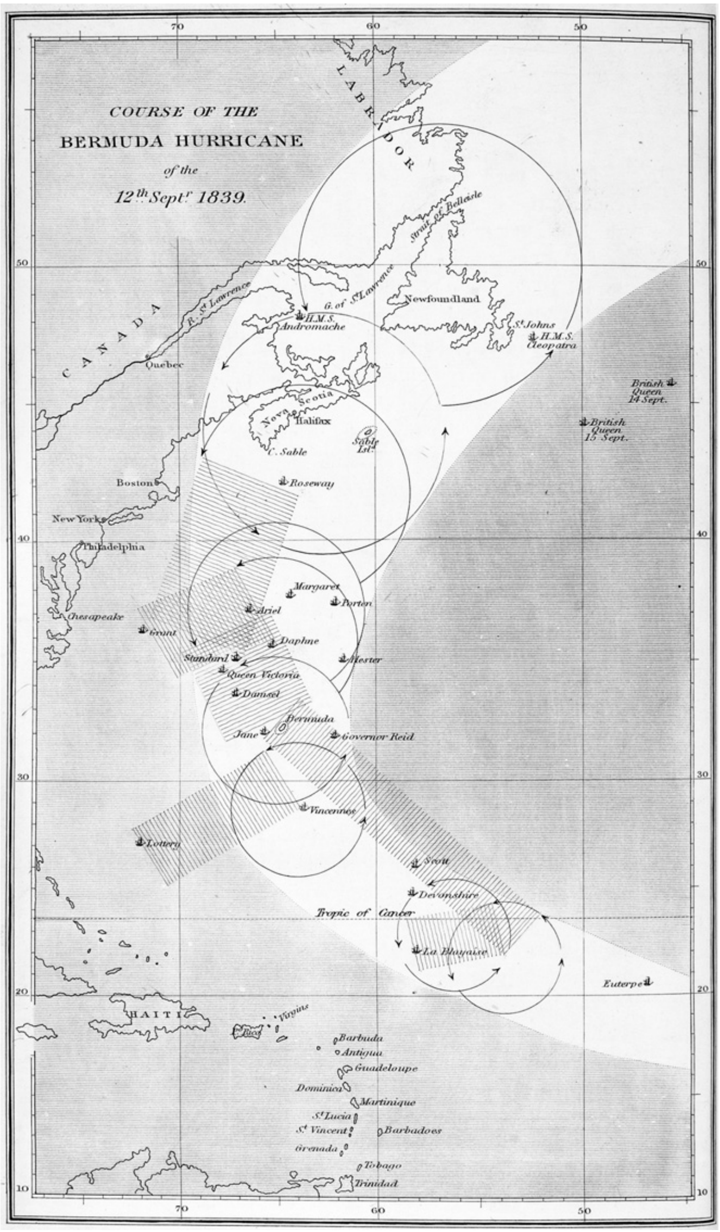

Figure 1.3 Chart of the course of the Bermuda hurricane of 1839. (Source: Reid, *Progress of the Development of the Law of Storms*, facing p. 39.)

for nearly eight years on the borders of the tropic in the Bermuda Islands, all tend to confirm the truth of this very important explanation.'[143] He defended one of his overarching suppositions on the same grounds: 'A residence of nearly eight years in the Bermudas, on the thirty-second degree of latitude, satisfied me that all the Bermuda gales, of whatever degree of force, in which the wind veers and the barometer falls, are progressive revolving gales; and I was struck when hearing the inhabitants call them "roundabouts."'[144]

Reid's regional maps of storms were used to the same end. As already noted, Reid had reworked his chart of the September 1839 Atlantic storm to illustrate his theory of the relationship between storms and sea-swell. Reid argued that 'great undulations' were raised by revolving storms along the radii of the whirlwind's circle, which then rolled straight onwards.[145] These undulations were illustrated on the chart using blocks of hatching and cross-hatching in places where sea-swells had been observed by ships. Reid also made reference to his own observations of the changing direction of the swell hitting Bermuda's shores. He came to the conclusion that '[s]ince storms obey fixed laws,' he claimed, 'and by their violence raise great undulations of the sea, these undulations probably conform to the same law'.

If Reid's researches were supported by his long residence at Bermuda, he continued to justify them on the grounds of maritime safety. Reid claimed that his extensive use of logbooks and the narratives of ships' captains helped 'seamen to study the application of the subject of revolving winds for themselves' and his advocacy of the use of barometers on board ships helped them to predict imminent changes in the weather.[146] The utility of this approach was demonstrated by several of the captains who had been caught in the 1839 hurricane. Bernard A. Ingham, the commander of the brigantine *Daphne*, experienced the storm en route from Bermuda to Halifax. He transmitted an extract of his private journal to the *Bermuda Royal Gazette* – his 'quota toward the development of the science of Storms' – that showed that he had been employing the wind and weather annotations advocated by Beaufort, and adopting Reid's advice regarding storm encounters.[147]

The utility of storm science to shipping was confirmed in Captain Robert Methven's account of a severe cyclone in March 1851 near Mauritius, which was published as the first in a putative series of

143 Reid, *Progress of the Development*, p. 19.
144 Reid, *Progress of the Development*, p. 2.
145 Reid, *Progress of the Development*, p. 32.
146 Reid, *Progress of the Development*, p. 17.
147 Letter from B. Ingham to Bermuda Royal Gazette, 7 October 1839, included in Reid's letter to Russell, 8 February 1840, Archives of the Royal Society, AP/24/16.

Narratives written by Sea Commanders – a series edited by Reid.[148] In the preface to Methven's account, Reid claimed that the captain had 'in a very striking manner applied the knowledge he had gained on the Law of Storms so as to keep his ship out of danger whilst a Hurricane was recurving South of the Island of Mauritius'.[149] Methven himself justified the study on the grounds that merchant shipping had expanded rapidly, while the pressures to move goods around the world had outstripped concerns about safety at sea.

Herschel's *Manual of Scientific Enquiry*

In the same year as Reid's *The Progress of the Development of the Law of Storms* was published by John Weale, John Murray published the *Manual of Scientific Enquiry*. The volume was commissioned by the Admiralty to provide naval officers while on foreign service with general instructions in various branches of science.[150] Beaufort was the guiding hand behind the volume while Herschel was the editor.[151] The *Manual* was part of a broader response to a growing mid-century demand from naval officers and other professional travellers for reliable guides to scientific observation.[152] Ward and Dowdeswell note that the *Manual* was effectively a reworking of the Royal Society's 1839 preparatory report for the Ross expedition to the Antarctic.[153] Like the expedition, the *Manual* positioned meteorology alongside and as an equal partner to other physical sciences, including astronomy, magnetism, tidology and statistics, as well as the natural and human sciences. The chapter on meteorology in the *Manual* was written by Herschel himself, beginning with the claim that there was 'no branch of physical science which can be advanced more materially by observations made during sea voyages than meteorology'.[154]

Alongside directions for the production of a routine meteorological log, Herschel urged naval officers to collect information on occasional atmospheric phenomena, such as squalls, storms, waterspouts, hurricanes and cyclones, even if there was no obvious place for them in the standard

[148] R. Methven, *Narratives Written by Sea Commanders, Illustrative of the Law of Storms, and of Its Practical Application to Navigation. No. 1. The Blenheim's Hurricane of 1851; with Some Observations of the Storms of the South–East Trade* (London: John Weale, 1851).
[149] W. Reid, 'Preface', no page, in Methven, *Narratives*.
[150] J. Herschel (ed.), *A Manual of Scientific Enquiry; Prepared for the Use of Officers in Her Majesty's Navy; and Travellers in General* (London: John Murray, 1849).
[151] Friendly, *Beaufort*, p. 264.
[152] See Withers, 'Science, Scientific Instruments and Questions of Method in Nineteenth-Century British Geography', for a discussion of this literature.
[153] Ward and Dowdeswell, 'On the Meteorological Instruments', 455.
[154] Herschel, 'Meteorology', in Herschel (ed.), *Manual of Scientific Enquiry*, p. 280.

entries of the register. Herschel urged officers to pay attention to these phenomena in all their phases, and to their connections to 'the state of the atmosphere preceding and subsequent, and especially every precursory appearance or fact which may have left on the observer's mind the impression of a *prognostic*'.[155] Although most familiar to medical practitioners, the application of the term prognostic to the study of meteorology was well established, used in a spate of studies in the eighteenth and nineteenth centuries.[156] The term did have some problematic connotations, given its association with folk readings of the sky and heavens, but Herschel argued that a careful study of storm prognostics, based on a large body of evidence, would in time serve to furnish the sailor with sufficient evidence and warning of an approaching hurricane. This was a position he was forced to defend publicly in 1860, after his apparent predictions of heavy floods and cold weather attracted widespread and unwanted attention. The study of past and current weather could provide indications of the future, Herschel argued, so long as the observer was credible, and their views were based on a body of trustworthy observations and on reasonable theoretical suppositions.[157] Herschel further clarified his thinking in a subsequent article in the evangelical and nonconformist periodical *Good Words*, where he dismissed folk prognostics of the weather as 'simple connotations' that displayed an ignorance of causes and modes of action, at the same time as he supported the idea of prediction of the weather a few hours into the future if based on 'an immense amount of perservering labour bestowed on daily and hourly records of the weather'.[158]

Herschel's chapter in the *Manual* also drew the reader's attention to the value of the work of Redfield, Reid and Piddington, 'which no navigator should go to sea unprovided with'.[159] These authors had shown hurricanes to be 'in the nature of vortices' which pursue a track that 'has a singular fixity of geographical situation and geometrical form'.[160] However, Herschel claimed that the habitual tracks of these storms remained 'imperfectly known', so that 'all of which tends to throw light upon this part of the subject is of the last importance to

155 Herschel, 'Meteorology', p. 316, original emphasis.

156 For instance, G. Adams, *A Short Dissertation on the Barometer, Thermometer, and Other Meteorological Instruments: Together with an Account of the Prognostic Signs of the Weather* (London: R, Hindmarsh, 1790); M. Waldeck, 'Natural Prognostics of the Weather', *Quarterly Journal of the Society for Literature and the Arts* (1827), 501–2; C. Clouston, *An Explanation of the Popular Weather Prognostics of Scotland on Scientific Principles* (Edinburgh: Adam & Charles Black, 1867).

157 Anderson, *Predicting the Weather*, p. 51.

158 J. Herschel, 'The Weather and Weather Prophets', *Good Words*, 5 (1864), 57–64, 57.

159 Herschel, 'Meteorology', p. 320.

160 Herschel, 'Meteorology', p. 319.

 https://doi.org/10.1017/9781009207225.002

navigation'.[161] Observations of the direction of the wind after the passage of a hurricane was also of interest to meteorologists, because it was still unclear whether hurricanes were constituted by the transfer of a mass of rotating air, or in the transient agitation of the air in situ.

Herschel's *Manual* became an essential component of the libraries of Royal Navy ships and an important point of reference to which potential weather observers could be referred. Beaufort routinely promoted its use and facilitated its uptake by others, on hydrographic ships and men of war, on packet and merchant vessels and at the stations of foreign consuls, where he recommended its use alongside Reid's *Law of Storms*.[162] The Admiralty's own advice was published in 1851, in the form of a pamphlet entitled *Remarks on Revolving Storms*.[163] Similar to Herschel's *Manual*, the Admiralty *Remarks* singled out Reid for special praise for collecting the facts and helping to develop the laws of storms. The *Remarks* also emphasised the value of storm prognostics alongside careful observation of the barometer, and, like Reid's *Law of Storms*, highlighted to ships' captains a geography of risk that focused on the West Indies, Madagascar and the China seas.

In spite of these guides, Beaufort remained concerned about the quality of meteorological observations at sea. In an 1852 Hydrographic Office memorandum on meteorological observation on board foreign and home men of war, Beaufort complained that '[m]uch valuable meteorologic information might undoubtedly be collected in H. M. ships if the officers could be induced with a sense of its importance – and could be induced to co-operate with zeal'.[164] Although the memo was partly addressed to the directors of the mail packet companies and to the Board of Trade and all foreign-going merchant ships, it was clear that Beaufort was frustrated at having to provide meteorological instructions and solicit information from naval ships more than thirteen years after the Admiralty had made the collection and inclusion of standardised weather data a formal component of the logbook.

Matters improved in 1853 when the Admiralty Lords decided that all HM ships should keep a meteorological journal separate from the logbook. In July that year Beaufort wrote to Sabine, the then de facto head of Britain's Magnetic Crusade, to discuss the shape of the proposed

161 Herschel, 'Meteorology', p. 320
162 F. Beaufort, Record of Observations by Foreign Consuls, 9 December 1851, UK Hydrographic Office Archives, MB/7.
163 Lords Commissioners of the Admiralty, *Remarks on Revolving Storms* (London: HMSO, 1851).
164 F. Beaufort, Meteorological Observations – General system of observing, 30 June 1852, UK Hydrographic Office Archives, MB/8.

journal, the hours at which observations would be made, the instructions that would be issued and the instruments to be used.[165] Sabine's reply urged caution due to wider developments and Beaufort quickly agreed 'on the propriety of waiting [sic] the result of Captain Beechey's mission before we decide anything'.[166] The mission to which Beaufort referred was an international maritime conference to be held in Brussels in August and September 1853 to devise a uniform system of meteorological observations at sea.

The 1853 Brussels Maritime Conference

In 1849 William Reid was appointed commanding Royal Engineer at Woolwich, having served as governor of Barbados until 1848.[167] He wrote to his former commanding officer Sir John Fox Burgoyne, Inspector General of Fortifications, to persuade him to organise meteorological observations at Royal Engineer stations overseas, the military branch responsible for operating Britain's colonial observatories. Burgoyne authorised the setting up of a network of observing stations, under the control of another Royal Engineers officer, Captain Henry E. James. James was head of the Edinburgh office of the Ordnance Survey. He had not played any significant public role in meteorology to date, but did have a professional interest in standards. In December 1851, James initiated a correspondence with Beaufort, outlining a way of calculating air pressure from wind speeds deduced from Beaufort's scale.[168] Burgoyne meanwhile wrote to the American government with a view to international cooperation on the subject of meteorological observation.[169] Matthew Fontaine Maury, director of the Naval Observatory at Washington, was one of the recipients of the proposal, who responded with the suggestion of an international conference to coordinate observations on land and sea.[170] Maury had been compiling data from ships' logbooks since the early 1840s and had produced global charts of wind and oceanic currents.[171]

165 Letter from Beaufort to E. Sabine, 25 July 1853, UK Hydrographic Office Archives, LB/19.
166 Beaufort to Sabine, 27 July 1853, UK Hydrographic Office Archives, LB/19.
167 Blouet, 'Sir William Reid', p. 181. Reid later became governor of Malta, which facilitated his study of the storms of the Mediterranean.
168 Letter from H. James to Beaufort, 24 December 1851, UK Hydrographic Office Archives, LP1857/J.
169 Anon, *Maritime Conference Held at Brussels for Devising a Uniform System of Meteorological Observations at Sea*, MS, 1853, National Meteorological Archive, Exeter.
170 Agnew, 'Robert FitzRoy', p. 25.
171 Reidy, *Tides of History*, p. 287; D. G. Burnett, 'Matthew Fontaine Maury's "Sea of Fire": Hydrography, Biogeography, and Providence in the Tropics', in F. Driver and

When consulted as to Maury's plans, the Royal Society noted that different nations already had their own standards for land observations but that a conference focusing on establishing a uniform international system of meteorological observation at sea would be useful.[172] Although organised by the US government, the maritime conference was held in Brussels in 1853, and chaired by Adolphe Quetelet. Ten nations were represented at the conference: Denmark, France, Great Britain, the Netherlands, Norway, Portugal, Russia, Sweden, Belgium and the United States.[173] Captain James and Captain Frederick W. Beechey, head of the Marine Department of the Board of Trade and previously one of Beaufort's hydrographic officers, were nominated as British representatives. Delegates committed to developing a plan of uniform observation and a form of register was duly adopted, including Beaufort's nomenclature for the force of the wind. James asked Beaufort to supply him with the meteorological forms used by the British Navy and the merchant service, having also asked Maury for the American equivalents, which he planned to compare in the hope of suggesting a uniform system for the two countries.[174] He later argued, having seen the forms, that 'the proposed uniform system between the two Governments *can* be very readily effected by a little giving and taking', whilst lamenting the numerous systems employed by different bodies within and between nations.[175]

Discussion strayed inevitably onto instrumentation. Delegates recommended that ships should carry thermometers and barometers, along with 'at least one good chronometer, one good sextant, [and] two good compasses'. Beechey argued that it was impossible to recommend the adoption of any particular instruments, let alone any specific instrument makers, given that different scales and standards were in use internationally. It was feared that any standardisation of instruments would 'interfere too abruptly with long established usages and long-established records, with which the observations now to be collected would require a reduction, before they could be compared'.[176] Each nation was left to

L. Martins (eds.), *Tropical Visions in an Age of Empire* (Chicago: Chicago University Press, 2005), pp. 113–36.

172 Agnew, 'Robert FitzRoy'.

173 J. L. Davis, 'Weather Forecasting and the Development of Meteorological Theory at the Paris Observatory, 1853–1878', *Annals of Science*, 41 (1984), 359–82.

174 James to Beaufort, 19 June 1852, UK Hydrographic Office Archives, LP1857/J. Worried that he would appear as an interloper in the meteorological field, James quickly appended the remark that 'Nothing can be done in this matter without the fullest concurrence of Professor Airy and yourself and I confine my ambition to the hope that I may be able to assist in promoting the object in view.'

175 James to Beaufort, 15 July 1852, UK Hydrographic Office Archives, LP1857/J, original emphasis.

176 Anon, *Maritime Conference held at Brussels*, p. 60.

use their own scales and standards, with the exception of the thermometer, where the centigrade scale was universally adopted (although this was not applied to the thermometer attached to the barometer), alongside any other scale currently in use. This was justified on the grounds of the possible *future* adoption of the centigrade scale – 'to accustom observers in all services to its use' – rather than its immediate use; the conference rejected the proposal that a separate centigrade column should be added to the meteorological register.[177] The conference also acknowledged the widespread use of barometers on board seagoing vessels of all types and their value as indicators of changes in relative pressure, but their use as recorders of absolute pressure was lamented: 'That an instrument so rude and so abundant in error, as is the marine barometer generally in use, should in this age of invention and improvement be found on board any ship, will doubtless be regarded hereafter with surprise.'[178]

In the aftermath of the conference, Maury acknowledged the compromises and faults inherent in the outcomes and recommendations but defended them nonetheless. In a letter to Lord Rosse, the president of the Royal Society, he explained that his support of the conference plan came:

> from the fact that with it we have in hand a grand experiment, it is an attempt to bring the sea by means of machinery already at work, regularly within the domains of systematic and scientific research, to change without cost, the common implements of navigation into philosophical instruments, and to convert the ships, for the safety of which these instruments are employed, into so many floating observatories, all cooperating together for the advancement of science, the good of mankind.[179]

There were several attempts to take forward this grand experiment in the 1860s, but these proved unsuccessful, due in part to the unstable political situation in Europe.[180] Several conferences on the topic were eventually convened in the 1870s. The first was held in Leipzig in 1872, followed by an international congress in Vienna in 1873.[181] In 1874, a private conference on maritime meteorology was held in London. The London conference set out to review participating nations' implementation of the recommendations of the 1853 Brussels conference, and to promote the recommendations of the 1872 and 1873 meetings: namely

[177] Anon, *Maritime Conference held at Brussels*, p. 14.

[178] Anon, *Maritime Conference held at Brussels*, p. 18. In relation to relative pressure, the conference noted the value of the aneroid barometer at sea but preferred the more delicate mercurial barometer given its ability to provide absolute results.

[179] Letter from M. Maury to Rosse, 27 July 1854, National Archives, BJ 7/4.

[180] Walker, *History of the Meteorological Office*.

[181] R.-J. Wille, 'Colonizing the Free Atmosphere: Wladimir Köppen's "Aerology", the German Maritime Observatory, and the Emergence of a Trans-Imperial Network of Weather Balloons and Kites, 1873–1906', *History of Meteorology*, 8 (2017), 95–123.

that '[t]horough uniformity in methods and instruments should be aimed at'; 'unity of measures and scales is desirable, and to this end the introduction of millimètres for the barometer and the Centigrade scale for the thermometer should be aimed at'; and that 'the importance of the co-operation of the Navies' should be promoted.[182] In its aims the conference was part of wider movements in the 1870s to effect a system of liberal internationalism; to foster economic and social progress; to popularise a language of progress; and in particular to establish international standards, such as the international gold standard and the Treaty of the Metre.[183] As with concurrent attempts to encourage the universal adoption of the metric system, however, the implementation of a single international system of marine meteorology was stymied by national rivalries and resistance to new measures and practices on board the ships of the various European navies.

Participants' responses at the 1874 meeting revealed differences of opinion on the aims and successes of the 1853 conference and over subsequent attempts to introduce a uniform international approach to the study of meteorology at sea. Brigadier-General Myer, chief signal officer in the US Army, reported that the United States had followed the Brussels plan. J. C. de Brito-Capello, the director of the Nautical and Meteorological Observations at the Lisbon Observatory, made a similar claim on behalf of Portugal. The Danish were also supportive, although Captain Hoffmeyer of the Danish Royal Meteorological Institute conceded that some compromises had been made, such as the use of aneroid barometers on smaller vessels where a mercurial barometer 'cannot appropriately be placed'. Other nations were less positive. Professor Buys Ballot, the Dutch meteorologist and the meeting's president, argued that the Brussels conference had 'asked for too many observations' and that the hours of observation were inconvenient. The French made similar complaints. The report of Captain Rikatcheff of the Imperial Russian Navy was perhaps the most pessimistic. The thermometers used on board Russian vessels had continued to use the Reaumur scale, without the recommended addition of the centigrade scale, because of worries that 'one would often be read instead of the other'. The barometers had not been compared since 1853 and the necessary corrections not been determined, due to the want of a dedicated office to do so.

182 Meteorological Committee, *Report of the Proceedings of the Conference on Maritime Meteorology held in London, 1874* (London: HM Stationery Office, 1875), p. 4.

183 M. H. Geyer, 'One Language for the World: The Metric System, International Coinage, Gold Standard, and the Rise of Internationalism, 1850–1900', in M. H. Geyer and J. Paulmann (eds.), *The Mechanics of Internationalism: Culture, Society, and Politics from the 1840s to the First World War* (Oxford: Oxford University Press, 2001), pp. 55–92.

Rikatcheff complained that meteorological observations obtained at sea were not discussed or utilised in his country, or shared with other countries. For Rikatcheff, 'You ought not to be astonished, Sir, if from these answers you see that the greater part of our Maritime Meteorological Observations lie dormant till now.'[184] Discussion of the various recommendations made at the 1874 conference was wide-ranging and conflicting. Disagreements remained over which scales to use when measuring temperature; to what degree of accuracy readings should be taken; what scale should be used to record wind force; how the labour of global meteorological study should be divided; what form the meteorological register should take; and how the resultant data should be dealt with, analysed and archived. The various formal conference resolutions reflected these differences.[185]

Conclusion

If we cannot bind [hurricanes] over to keep the peace, we may, at least, organize an efficient police to discover their ambush and watch their movements. If the bolts and bars of mechanism cannot secure our sea-borne dwellings from the angry spirit of the storm, we may at least track his course and fall into the wake of his fury.[186]

While efforts at international collaboration continued through the second half of the nineteenth century, British meteorologists sought to translate and adopt the recommendations of the conferences in a national context. Beechey reported on the outcomes of the 1853 conference to the British government and, in February 1854, the First Lord of the Admiralty, Sir James Graham, announced in the House of Commons that a new government department was to be formed, called the Meteorological Department, to be funded through the Board of Trade and the Admiralty. Its aims were to effect the recommendations of the Brussels conference; to collect and analyse meteorological observations taken at sea; to promote the observation of the weather on board ships; and, in the spirit of international cooperation, to convey reduced observations to the US Naval Observatory.[187] As discussed in the Introduction, the department's establishment was also a response to calls in the press for a force to police storms at sea. Robert FitzRoy was

[184] Meteorological Committee, *Report of the Proceedings. Appendix B*, quotes from pages, 28, 26, 31, and 32 respectively.
[185] In an attempt to encourage the more uniform pursuit of maritime meteorology, the 'Proposed English Instructions for keeping the Meteorological Log' were appended to the conference proceedings.
[186] Anon, 'Review of Reid', p. 432.
[187] Walker, *History of the Meteorological Office*, pp. 21–2.

appointed as the department's first director. FitzRoy's department began to supply instruments, instructions and registers to Royal Navy ships and British merchantmen, and to collect and compile weather logs.

It is possible to see the department as the most notable achievement of Beaufort and Reid's long campaign to promote the study of meteorology at sea, but such a reading should be treated with caution. The early, troubled, history of the department reminds us that meteorology in the nineteenth century continued to struggle to find its place in both the physical sciences and the public sphere. Perhaps the most significant criticism of the department was that levelled at FitzRoy's attempts to 'forecast' the weather (a term he coined), notably from Francis Galton, the African explorer, meteorologist and eugenicist.[188] In the aftermath of FitzRoy's death, Galton, the author of the 1866 government inquiry into the shortcomings of the department, labelled weather forecasting as unscientific, based on insufficient and poorly organised evidence, and indeed on a poor grasp of the physical laws involved. While Galton's report complimented the department on overseeing the provision of ships with instruments and registers, it was felt that too few registers had been collected and that there was insufficient global coverage.[189] FitzRoy had been distracted from his proper focus on meteorological statistics, Galton claimed, and had been diverted instead into 'the prognostication of weather'.[190] The report's criticism of FitzRoy's forecasts reflected anxieties about meteorology's supposed tendency towards the folk and the superstitious.[191] However, the deliberate comparison of Murphy's *Almanac* with Reid's *Law of Storms* in the *London Saturday Journal*, discussed earlier in the section titled 'William Reid and the Law of Storms', demonstrated that weather prediction could be countenanced under certain conditions. Herschel's discussion of storm prognostics and weather prophecy conveyed a similar sentiment and lent the approach significant intellectual weight. That Reid confined himself to the mapping of the behaviour of model storms, and did not attempt to predict the timing or location of particular storms in the future, further differentiated his work from the weather prophets.

Debates about storm prognostics were also in effect debates about meteorology's usefulness to the maritime world. Beaufort and Reid both played their roles as scientific servicemen, emphasising the public value of a maritime data-collection policy. However, it was the Army engineer's approach that proved more persuasive with the Admiralty. Beaufort argued for the construction of a large repository of basic information about the

[188] N. W. Gillham, *A Life of St Francis Galton: From African Exploration to the Birth of Eugenics* (Oxford: Oxford University Press, 2001).
[189] Burton, 'Robert FitzRoy'. [190] Walker, *History of the Meteorological Office*, p. 61.
[191] Anderson, *Predicting the Weather*, p. 124.

weather at sea, for use by a 'patient meteorological philosopher'. Reid's approach also placed great emphasis on the value of ships' logbooks for maritime meteorology, but it mirrored more closely the Royal Society's views on the usefulness of scientific knowledge, and spoke to the Admiralty's own interests in the safety of its ships. Reid's charts also successfully held in tension an inductive policy of data collection and the development of theory, while avoiding philosophical controversy.

If Beaufort and Reid differed over the ends of maritime meteorology, they also took somewhat different positions over the means by which it might be advanced. As Admiralty hydrographer, Beaufort laboured to turn naval ships into itinerant observatories and their crews into the equivalents of Airy's obedient drudges. As the chapter has demonstrated, Beaufort's maritime observatory experiment was not adopted quickly or universally across the British fleet. Sailors were not always good observers and ships often failed to conform to the model of the physical observatory. The weather routinely confounded the sailor's ability to describe it with sufficient accuracy, whether at the mean or at the extreme. Beaufort and his officers certainly aspired to bring order to the oceans, but their achievements were sporadic and geographically fragmented, while the scientific veracity of the results that were collected and preserved in the ships' logbooks was often open to question.

Reid benefited from Beaufort's campaign to turn ships' logs into weather diaries, but he went further in terms of the contribution that both ships and islands could make to the study of the atmosphere. Despite their wide geographical scope, Reid's charts were based on some very specific sites of inquiry. His work on storms relied on a handful of islands of strategic importance to Britain's Royal Navy and merchant marine, and functioned as important sites of observation and record keeping. Meanwhile, Reid treated ships not simply as floating observatories, but as meteorological instruments themselves. In his study of storm tracks, Reid was just as interested in the effects of a hurricane on the ships in and around its path as he was in the data collected on board. These ships left traces on the map, bearing mute and trustworthy witness to the actions of the atmosphere and ocean in a way that a barometer or an officer of the watch could not necessarily be trusted to do.[192] The ship produced an archive of the weather in its wake, while its paper trail could end up becalmed, languishing in Somerset House or in the offices of the Meteorological Department on Parliament Street.

[192] On similar practices of maritime surveying in Matthew Flinders' voyages of exploration, see S. Caputo, 'Exploration and Mortification: Fragile Infrastructures, Imperial Narratives, and the Self-Sufficiency of British Naval "Discovery" Vessels, 1760–1815', *History of Science*, 61 (2023), 40–59.