**Log Books and the Law of Storms: Maritime Meteorology and the British Admiralty in the Nineteenth Century**

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## Abstract

This paper contributes to debates about the relationship between science and the military by examining the British Admiralty's participation in meteorological projects in the first half of the nineteenth century. It focuses on attempts to transform Royal Naval log books into standardized meteorological registers that would be of use to both science and the state. The paper begins with a discussion of Admiralty Hydrographer, Francis Beaufort, who promoted the use of standardized systems for the observation of the weather at sea. It then examines the application of ships' logs to the science of storms. The paper focuses on the Army Engineer, William Reid, who studied hurricanes while stationed in Barbados and Bermuda. Reid was instrumental in persuading the Admiralty to implement a naval meteorological policy, something the Admiralty Hydrographer had struggled to achieve. The paper uses the reception and adoption of work on storms at sea to reflect on the means and ends of maritime meteorology in the mid-nineteenth century.

## Introduction

Over the last 25 years or so it has become increasingly common for historians and historical geographers of science to investigate science's role in the expansion of European power over space.[2] The temporal focus for much of this work has been the eighteenth and nineteenth centuries, a period that was notable for the number of state-

sponsored voyages of exploration that were dispatched from Europe.[3] As many of these voyages were ocean-going, it has become common for scholars to argue that the ship was re-styled as a floating instrument of science, or as an itinerant observatory.[4] Ships that were part of voyages of exploration along with those that performed more mundane surveying duties were packed with scientific equipment, while their crews were trained in "the languages of instrumental precision and calculation' and even in "the theoretical explanation and systematic ordering of what was discovered'.[5] As Bravo notes, exploration in the late eighteenth and early nineteenth centuries 'had become a much more specialised set of scientific practices that required specialised training, the provision of expensive precision measurements, and new time-intensive methods of working and record-keeping.'[6]

Historians and geographers of science have argued that expansionist nations invested in and supported scientific inquiry to such an extent because they 'required a scientific understanding of the spatial relations of their territories'; that science helped imperial nations 'create ordered spaces in the natural world', such that those spaces could be more effectively traversed, governed and exploited.[7] This investment extended to 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'.[8] 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'.[9] The willingness of European governments and military to commit resources of people, equipment and money to voyages of exploration would seem to bear this argument out.

This paper contributes to debates about the relations between science and the maritime world by examining the British Admiralty's participation in meteorological projects in the first half of the nineteenth century. The paper traces the hesitant emergence of a culture of meteorology in the Royal Navy, at a time when there remained significant ambiguities about the place of science on ships at sea. The Admiralty Hydrographer, Francis Beaufort, was instrumental in negotiating a place for meteorology on naval ships, but the paper demonstrates that he struggled to persuade the Admiralty of the value of his inductive approach to the collection of weather information, and to persuade sailors to employ a sufficiently precise language to record both normal and extreme weather at sea. It took an Army Engineer, William Reid, to convince the Admiralty to adopt their Hydrographer's recommendations regarding the collection of wind and weather data. Reid used ships' log books and the plotting of the ships' movements themselves to develop William Redfield's theory of revolving storms. His use of maps and charts imposed order on a mass of data spread over a large geographical area. In doing so he overcame the limits of language and helped to more effectively recast meteorology as a science that was useful to the maritime world. Reid's charts explained the science of storms to the naval officer in familiar terms, such that a storm's potentially catastrophic effects could be avoided. The arguments Reid, Beaufort and others made for a science of storms and study of weather at sea were later supported by a series of manuals and international congresses on maritime meteorology. In developing a historical geography of storm science, the paper contributes to wider debates about data collection and theory development in the first half of the nineteenth century; about

contemporary tensions over forecasting and weather prognostics; and about relations between science and the military.

**Science at sea**

The British Admiralty played a number of roles in the development of science. The Royal Navy trained personnel in scientific techniques useful to ship building, surveying and navigation, and imparted 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. Having been established in 1795, the Hydrographic Office gradually increased in importance as the Royal Navy assumed its self-appointed role as surveyor of the world's oceans and coasts. However, in its early years its remit was heavily circumscribed.[10] 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 skepticism 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.[11]

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 Thomas Young, Edward Sabine and 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 criticized 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 adviser to the Admiralty, a role he fulfilled until the 1850s.[12] 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.[13] In 1831 the Hydrographic Office became a separate department of the Admiralty, something Croker had prevented so as to limit the Office's autonomy.[14] 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 onboard ship lent itself well to ensuring regular and reliable scientific observations.[15] For the astronomer, 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.[16] The necessity of a 24-hour watch and the demands of the log book 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.[17] Naval seamen were meant to be the meteorological equivalents of the 'obedient drudges' who helped to operate astronomical observatories, and to treat their work and their ship in the same manner that astronomical technicians were expected to operate in their observatory.[18]

The Admiralty applied naval personnel to projects that utilized their familiarity with the latest mathematical, scientific, and technical knowledge. This was especially the case after peace with France in 1815.[19] 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".[20] 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 specialized 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 was the principal governmental subsidizer of science in Britain.[21] 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.[22] Although self-interest is an obvious explanation for the position taken by the Admiralty in this regard, it is also likely that their 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. Lastly, it is important to note that the quality of the science that was actually undertaken was questioned at the time. Waring notes that John Herschel "maintained an ambition to make the surveying voyages commissioned by Barrow on behalf of the Admiralty more 'scientific', demonstrating that what scientific activity and investigation there was in this period was not effectively established".[23] During Barrow's period as Second Secretary to the Admiralty, the role of scientific activity on board naval vessels was ambiguous, especially when it came to the operations of a surveying vessel or a man-of-war.

The next section of the paper examines the Admiralty's engagement with one particular scientific agenda, that of the study of weather at sea. It traces attempts to impose a culture of scientific observation of the weather on naval ships and demonstrates

that meteorology was an ambiguous activity onboard navy vessels and was adopted unevenly by naval personnel.

**Meteorology at sea**

The weather was an inescapable part of life onboard 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 Service at Sea* required the ship's Master to record in the Log-book "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.[24] These were to be recorded on a pre-printed proforma 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.

The ship's lieutenants were also required to observe the weather. 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.[25] 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 analyzing 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.[26]

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 14 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.

Beaufort has been credited with turning the Hydrographic Office into a world-leader in maritime survey.[27] 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.[28] 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".[29] 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 Edward Sabine's campaign for magnetic observation voyages to Antarctica.[30] 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 14-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.[31] Beaufort's early attempts at a windscale 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-rigged ship would carry.[32] 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.[33] The use of sail as a method of measuring the force of the wind was therefore an expedient way of turning an in-grained 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".[34]

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.[1] _ royals, stays &c. may be just carried full and by".[35] If it was challenging to differentiate the subtle differences in wind strength around the mid-point 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' log books 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, not more in a scientific than a nautical point of view, deserving laborious investigation?[36]

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.[37] 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.[38] 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 log book and the officer of the watch instructed to use the same terms.[39] They also gave guidance on when and how to read the barometers and thermometers on board ship.

Responses to Beaufort's plans 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.[40] John Herschel wrote to Beaufort 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.[41] Beaufort also found support from the Admiralty Committee established in 1836 to organize 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 log books 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. [42]

A year later, however, Beaufort was lamenting the quality of weather observations onboard 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".[43] Although his own schema had been "invariably adopted" by surveying vessels, only some of the Admirals in general service had taken it up.[44] 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 windscale. The use of terms such as "variable airs", "passing clouds" and "pretty clear" in *Ætna*'s meteorological log demonstrated the insufficiency of language to represent weather at the mean.[45]

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 9am, noon, 3pm, 6pm and 9pm.[46] *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 log book. 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 4am, 9am, noon, 3pm, 8pm and midnight.[47] 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".[48]

Here Beaufort was echoing prevalent concerns about the state of British meteorology more generally. John Frederick Daniell, Professor of Chemistry at Kings College, London, had pointed to the Royal Society's meteorological observations as evidence of poor science in England in his *Meteorological Essays*.[49] Daniell extended this 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."[50] At a meeting of the Meteorological Committee of the Royal Society in 1827, James South, Francis Baily, Francis Beaufort and John Herschel complained about the Society's recording forms and about the quality and situation of its meteorological instruments. These sentiments were mirrored in James D. Forbes' paper, "Report on the Recent Progress and Present State of Meteorology", given to the 1832 Oxford meeting of the BAAS.[51] Forbes' evaluation of British meteorology was damning, suggesting that 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. The situation was so bad that Forbes insisted upon "a total revision upon which meteorologists have hitherto very generally proceeded".[52]

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.[53] Noting that the data's "future utility is so uncertain", Beaufort suggested that a fuller record might only be possible due to some unforeseen detention in port, "when a system of these observations might then be advantageously undertaken".[54]

**William Reid and the law of storms**

In the late 1830s, Beaufort and Lieutenant Becher continued their campaign to improve meteorological observations onboard 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.[55] Although Reid had harboured an interest in meteorology for some time, his residence in Barbados prompted him to study tropical storms. While there he familiarized 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".[56]

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.[57] 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 70 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.[58] Reid was particularly impressed by the chart of the storm that Redfield included in his study.[59] 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".[60]

Upon return to England in 1836 Reid went on the half-pay list while assembling meteorological information, including storm data from the log books of Admiralty ships. He also initiated correspondence with Redfield, who encouraged Reid's emphasis on direct observation.[61] At the 1838 British Association for the Advancement of Science 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.[62] In doing so he supported Redfield's belief that a reliable system of meteorological physics should be "grounded in direct observations".[63] 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.[64]

John 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".[65] 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 Society.[66] 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.[67] 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".[68]

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, 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.

***Figure 1.*** *Chart of the Great Hurricane of 1780. Chart IV in Reid, 1838,* Attempt to Develop a Law of Storms.

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 10th October 1780 mapped the track of the hurricane across the Caribbean and then back across the Atlantic (figure 1). Also included were the daily positions of various 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 log books.[69]

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".[70] 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.[71]

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 two thousand logs and of some hundreds of storms had provided the proofs of the theory of storms developed by Redfield.[72] Reid's work certainly conformed to prevalent models for the pursuit of terrestrial physics in the first half of the nineteenth century, with its Humboldtian 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 Edward Sabine in studies of terrestrial magnetism. Lastly, Reid's implicit support of bold theorizing 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.[73] Indeed, Reid's 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*.[74] 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"".[75] Similarly, Piddington praised Reid for deducing the rules that would render Redfield's theory "of practical utility".[76] 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."[77] 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 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".

***Figure 2***. *Hemispheric storm circles. From Reid, 1849,* Progress of the Development of the Law of Storms, *facing p. 3)*

**Reid, Beaufort and the ship's log book**

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.[78] 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.[79]

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 log books 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 onboard 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".[80] 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".[81] Beaufort supported this, argued in December 1838 that all officers who possessed a barometer should be permitted to observe it at least once in every watch".[82]

This 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 the Admiralty have ordered an addition to be made to the Log Books of Ships of War, to aid enquiry into the subject".[83] Columns for the force of wind and appearance of the atmosphere were to be added to the log book 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 log book 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".[84] The *Admiralty Instructions* also included advice on the location and observation of the barometer onboard ship, which reflected the Admiralty's decision in 1843 that all H.M. ships should carry one.[85] Columns for barometric and thermometric readings were added to the log book, alongside those for wind and weather. The log books of naval ships, Reid later noted, were lodged and available for consultation at Somerset House.[86]

Reid appended a memorandum to his letter, written by Lord Glenelg, the Secretary of State for War and the Colonies, addressed to all governors of British colonies on the subject of "Keeping Journals of the Weather, and of noticing Meteorological phenomena generally".[87] 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 log books 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 various suggestions on the subject of tracing the storm-tracts of the Indian seas".[88]

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 30 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".[89] 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 behavior 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.[90]

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 an expedition to investigate terrestrial magnetism in the southern hemisphere, along with several overseas observatories, as part of the "magnetic crusade".[91] Herschel and Beaufort, along with Edward Sabine, and others, had been heavily involved in lobbying the government and the Admiralty for their support for the project. 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".[92] Its emphasis on theoretical explication, the use of precision philosophical instruments and the value of collective, international endeavour, marginalized the individual observer in favour of a "central scientific authority which would process all empirical information into mass data".[93] 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.[94]

**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.[95] 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.[96] 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.[97]

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. Thirdly, 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 fully.[98] Reid certainly employed both types of scientific space in his work at Bermuda.[99]

Bermuda was ideally situated to act as a weather archive. 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.[100] 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.[101] Reid had been getting masters of vessels coming into Bermuda to supply him with information from their log books 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".[102]

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 the 11-12th September 1839 – a storm so severe that it had "made the people here take up the subject of storms with some earnestness".[103] 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, may be better understood".[104] Reid went on to use the log books, 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 the 12th September.[105] 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 3).

***Figure 3.*** *Chart of the Course of the Bermuda Hurricane of 1839. From Reid, 1849,* Progress of the Development of the Law of Storms, *facing p. 39)*

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, including the nature of the sea swell, barometer readings, wind force and direction, extracts from newspapers, the Central Signal Station weather tables, the behavior 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 field 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 field observations at Bermuda as illustrative of processes that transcended place or region.[106] For instance, in a letter to the Royal Society in 1840, Reid noted that: "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."[107] Reid used his *Progress of the Development of the Law of Storms* to make similar virtue of his time on the island. For instance, Reid discussed Redfield's theory that a whirlwind diminished the pressure of the atmosphere at its centre, and supported the idea with the statement that "My observations attentively made 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".[108] 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.""[109]

Reid's regional maps of storms were used to the same end. As noted above, Reid had reworked his chart of the September 1839 Atlantic storm to illustrate his theory of the relationship between storms and sea-swell (see figure 3). Reid argued that "great undulations" were raised by revolving storms along the radii of the whirlwind's circle, which then rolled straight onwards.[110] 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 "Since 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 log books 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.[111] 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.[112]

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 *Narratives written by Sea Commanders* – a series edited by Reid.[113] 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".[114] 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* and the 1853 Brussels Maritime Conference**

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.[115] Beaufort was the guiding hand behind the volume while Herschel was the editor.[116] 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.[117]

The chapter on meteorology in the *Manual* was written by Herschel, 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".[118] 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, water-spouts, hurricanes and cyclones, even if there was no obvious place for them in the standard 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 preceeding and subsequent, and especially every precursory appearance or fact which may have left on the observer's mind the impression of a *prognostic*".[119] 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.[120] 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 publically in 1860, after his apparent predictions of heavy floods and cold weather attracted wide-spread 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.[121] Herschel further clarified his thinking in a subsequent article in the religious magazine, *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".[122]

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".[123] 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".[124] 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 navigation".[125] 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 Naval 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*.[126] The Admiralty's own advice was published in 1851, in the form of a pamphlet entitled *Remarks on Revolving Storms*.[127] 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 emphasized 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 onboard foreign and home men of war, Beaufort complained that "Much 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".[128] 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 13 years after the Admiralty had made the collection and inclusion of standardised weather data a formal component of the log book.

Matters improved in 1853 when the Admiralty Lords decided that all H.M. ships should keep a meteorological journal separate from the log book. In July that year Beaufort wrote to Edward Sabine, then de facto head of Britain's "magnetic crusade", to

discuss the shape of the proposed journal, the hours at which observations would be made, the instructions that would be issued, and the instruments to be used.[129] 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".[130] 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.

In 1849 William Reid was appointed commanding Royal Engineer at Woolwich, having served as Governor of Barbados until 1848.[131] He wrote to his former commanding officer, Sir John Fox Burgoyne, Inspector General of Fortifications, to persuade him to organize meteorological observations at Royal Engineer stations overseas, the military branch responsible for operating Britain's colonial observatories. Burgoyne authorized 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.[132]

Burgoyne wrote to the American Government with a view to international cooperation on the subject of meteorological observation.[133] Lieutenant 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.[134] Maury had been compiling data

from ships' log books since the early 1840s and had produced global charts of wind and oceanic currents.[135]

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 observations at sea would be useful, to which Maury acceded.[136] Although organized by the US Government the conference was held in Brussels, and chaired by Adolphe Quetelet, the Belgian astronomer and statistician. 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. 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.[137] 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.[138]

Ten nations were represented at the conference: Belgium, Denmark, France, Great Britain, the Netherlands, Norway, Portugal, Russia, Sweden and the United States. Their 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. They also recommended the adoption of accurate instruments – most notably barometers and thermometers – that had been compared with recognized standards and had their errors accurately determined. While it was desirable to have all observations recorded using the

same scales, this was seen as too complicated to effect and so each nation was left to use their own scales and standards, with the exception of the thermometer, where the centigrade scale was universally adopted. 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.[139]

Maury acknowledged the compromises and faults inherent in the conference plan but defended it 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.[140]

Maury's letter to Rosse was his response to the British Government's request for advice from foreign governments on the establishment of a meteorological department. The initial purpose of this new department was to collect and digest the meteorological observations being collected at sea, to promote the study of meteorology amongst merchant shipping, to enforce the standards set at the Brussels conference and to

communicate reduced observations to Maury in Washington. Robert FitzRoy was appointed as its first director.

**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.[141]

The establishment of the Meteorological Department of the Board of Trade in 1854 was one response to the *Edinburgh Review's* call for a force to police storms at sea. It is possible to see the Department as the most notable achievement of Beaufort's 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 mid-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 leveled at Fitzroy's attempts to "forecast" the weather (a term he coined). In the 1866 government inquiry into the shortcomings of the Department, in the aftermath of Fitzroy's suicide in 1865, the report's author, Francis Galton, labeled weather forecasting as unscientific, based on insufficient and poorly organised evidence, and on a poor grasp of the physical laws involved. Fitzroy had been distracted from his proper focus on meteorological statistics, Galton claimed, and had been diverted instead into "the

prognostication of weather".[142] The report's criticism of Fitzroy's forecasts reflected anxieties about meteorology's supposed tendency towards the folk and the superstitious.[143] However, the deliberate comparison of Murphy's *Almanac* with Reid's *Law of Storms* in the *London Saturday Journal*, discussed earlier, 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. Indeed, the future of meteorology itself was tethered to its public utility to a degree that was probably unique in the sciences at the time. Beaufort and Reid both played their roles as scientific servicemen, emphasizing 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 weather at sea, for use by a "patient meteorological philosopher". Reid's approach also placed great emphasis on the value of ships' log books 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 paper has demonstrated, the study of the weather onboard naval ships 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. In this regard it is difficult to agree entirely with the sentiment summarized by Reidy in the introduction. 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' log books 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 onboard. 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. 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 Office on Parliament Street.

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[1] School of Geographical and Earth Sciences, East Quadrangle, University of Glasgow, Glasgow, G12 8QQ, UK. Many thanks to Les Hill for reproducing the figures. Thanks to Felix Driver, Rebekah Higgitt, Simon Schaffer, Richard Staley, Charles Withers, Bernard Lightman, H. Floris Cohen and three anonymous referees for their generous comments on earlier versions of this paper; to Megan Barford for sharing her research with me; and to the archivists at the UK Hydrographic Office, Royal Society, National Archives, and the Meteorological Office for helping me with my research.

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

[14] Archibald Day, *The Admiralty Hydrographic Service 1795–1919* (London: Stationary Office, 1967), p. 35.

[15] Catharine Ward and Julian Dowdeswell, "On the Meteorological Instruments and Observations Made during the 19th Century Exploration of the Canadian Northwest Passage," *Arctic, Antarctic, and Alpine Research*, 2006, *38*:454–464, on p. 454.

[16] Herschel referred to naval ships as "itinerant observatories" in his 1845 British Association for the Advancement of Science (BAAS) speech. Quoted in Alison Winter, ""Compasses All Awry": The Iron Ship and the Ambiguities of Cultural Authority in Victorian Britain," *Victorian Studies* 1994, *38*:69–98, on p. 75.

[17] Charles W.J. Withers, "Science, scientific instruments and questions of method in nineteenth-century British geography," *Transactions of the Institute of British Geographers*, 2012, *38*:167–179, on p. 173. French commentators made similar assumptions about the capacities of their navy to collect meteorological information: Fabian Locher, "The observatory, the land-based ship and the crusades: earth sciences in European context, 1830-50," *Brit. J. Hist. Sci.*, 2007, *40*:491–504, on p. 498.

[18] George Airy used the term "obedient drudges" to describe the technicians at Greenwich Observatory. Winter, "Compasses All Awry," p. 74.

[19] Reidy, *Tides of History*, p. 140.

[20] Randolph Cock, *Sir Francis Beaufort and the co-ordination of British scientific activity, 1829-55*, unpublished DPhil thesis, University of Cambridge, 2003, pp. 7–8.

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

[22] N.A.M. Rodger, "From the 'military revolution' to the 'fiscal-naval' state," *J. Mar. Res.*, 2011, *13*:119–128, 123; Webb, "More than just charts," p. 52.

[23] Sophie Waring, "The Board of Longitude and the Funding of Scientific Work: Negotiating Authority and Expertise in the Early Nineteenth Century," *J. Mar. Res.*, 2014, *16*:55–71, on p. 59.

[24] British Admiralty, *Regulations and Instructions Relating to His Majesty's Service at Sea* (London: Stationary 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 log books 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 log books and remarks books would constitute the complete record of a voyage. Clive Wilkinson, "The non-climatic research potential of ships' logbooks and journals," *Climatic Change*, 2005, *73*:155–167.

[25] See the section "Lieutenant" in Admiralty, *Regulations and Instructions*, pp. 171–181.

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

[27] Friendly, *Beaufort*, p. 248.

[28] Day, *Admiralty Hydrographic Service*, pp. 47–8.

[29] Miller, "Revival of the Physical Sciences," p. 114.

[30] G.S. Ritchie, *The Admiralty Chart: British Naval Hydrography in the Nineteenth Century* (London: Hollis & Carter, 1967). Day, *Admiralty*, 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.

[31] Private weather diary of Francis Beaufort 1805-12, Archive Z11.E-Z10.B, Archive of the Meteorological Office, Devon (hereafter MO). It is generally accepted now that Beaufort's windscale was modeled 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.

[32] 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*.

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

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

[35] Private weather diary of Francis Beaufort 1805-12, Archive Z11.E-Z10.B, MO.

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

[37] 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. Megan Barford, "Fugitive Hydrography: The Nautical Magazine and the Hydrographic Office of the Admiralty, c.1832-1850", *International Journal of Maritime History*, 2015, *27*: 208–226.

[38] 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". Admiralty, *Regulations and Instructions*, pp. 173.

[39] "Admiralty Instructions for the Beagle Voyage" are included in Appendix One of Charles 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*.

[40] Admiral Sir George Cockburn to Beaufort, 14 September 1833, Incoming letters C601–995, Archives of the UK Hydrographic Office, Taunton (hereafter UKHO).

[41] John Herschel to Beaufort, 26 December 1835, Incoming letters H300-669, UKHO.

[42] Letter from Beaufort to Lt Thomas Baldock, 8 October 1836, Letterbook 8/HH8, UKHO. 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*.

[43] Letter from Beaufort to Sir J.J. Gordon Bremer, 2 November 1837, Letterbook 8/HH9, UKHO.

[44] 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. William R. O'Byrne, *Naval Biographical Dictionary* (London: John Murray, 1849), pp. 119–120.

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

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

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

[48] Surveying instructions from Beaufort to Lieutenant Edward Barnett of HMS *Thunder*, 9 December 1837, Miscellaneous Files, UKHO.

[49] Katherine Anderson, *Predicting the Weather*: *Victorians and the Science of Meteorology* (Chicago: Chicago University Press, 2005).

[50] John Daniell, *Meteorological Essays* (London: Thomas & George Underwood, 1823), p. viii.

[51] James D. Forbes, "Report on the Recent Progress and Present State of Meteorology," *British Association for the Advancement of Science Second Report* (London: John Murray, 1832), pp. 196–258.

[52] Forbes, "Report," pp. 196-7. See also Vladimir Jankovic, "Ideological crests versus empirical troughs: John Herschel's and William Radcliffe Birt's research on atmospheric waves, 1843-50," *Brit. J. His. Sci*., 1998, *31*:21–40, on p 24.

[53] On the barometer, see Jan Golinski, *British Weather and the Climate of Enlightenment* (Chicago: University of Chicago Press, 2005).

[54] Beaufort, Surveying Instructions to Barnett, p. 27.

[55] Olwyn Mary Blouet, "Sir William Reid, F.R.S., 1791–1858: Governor of Bermuda, Barbados and Malta," *Notes Rec. Roy. Soc.*, 1986, *40*:169–191, on p. 174.

[56] James D. Forbes, *Supplementary Report on Meteorology*, from the Report of the British Association for the Advancement of Science for 1840 (London: Richard and John E. Taylor, 1841), p. 109.

[57] James R. Fleming, *Meteorology in America 1800-1870* (Baltimore, Johns Hopkins University Press, 1990).

[58] Anon, "Redfield's Law of Storms:- Notice of Col. Reid's Work on Hurricanes," *The American Journal of Science and Arts*, 1839, *35*:182; William C. Redfield, "Remarks on the prevailing Storms of the Atlantic coast, of the North American States," *Amer. J. Sci. Arts*, 1831, *20*:17–51.

[59] Anon, "On Storms," *Littell's Spirit of the Magazine and Annuals*, 1838, *2*:856–58.

[60] William 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.

[61] Fleming, *Meteorology in America*, p. 38.

[62] Anon, "A Report explaining the Progress made towards developing the law of Storms," *The Athanaeum,* 1838, 25 August:594–6, on p. 594.

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

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

[65] Herschel, quoted in "A Report explaining the Progress", p. 595.

[66] Christopher Carter, "Magnetic Fever: Global Imperialism and Empiricism in the Nineteenth Century," *Transactions of the American Philosophical Society*, 2009, *99*: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".

[67] Jim Burton, "Robert FitzRoy and the Early History of the Meteorological Office," *Brit. J. His. Sci*., 1986, *19*:147–176, on p. 148.

[68] Henry 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.

[69] For a similar argument, see Sorrenson, "The ship as scientific instrument," p. 222.

[70] 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* (John Weale, London, 1849), p2.

[71] Thomas L. Hankins, "A "Large and Graceful Sinuosity": John Herschel's Graphical Method," *Isis*, 2006, *97*:605–633, on p. 606; Katherine Anderson, "Mapping Meteorology," in *Intimate Universality: Local and Global Themes in the History of Weather and Climate*, eds., James R. Fleming, Vladimir Jankovic and Deborah R. Coen (Sagamore Beach: Science History Publications, 2006), pp. 69–92.

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

[73] Gregory Good, "A Shift of View: Meteorology in John Herschel's Terrestrial Physics," in *Intimate Universality*, pp. 35–68, on p.36.

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

[75] Anon, "Weather Almanacs and the Law of Storms," *The London Saturday Journal*, 1839, *1*: 7.

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

[77] 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*, 1839, 68: 406–430, on p. 431.

[78] Reid to Beaufort, 12 March 1838, Incoming Letters R1-R300, UKHO.

[79] Reid to Beaufort, 9 May 1838, Incoming Letters R1-R300, UKHO.

[80] Alexander Becher, Proposals for improving the Meteorological Registers in the Log Books of HM Ships, 14 November 1838, Minute Book 3/HH11, UKHO, pp. 91–3, on p. 91.

[81] Becher, Proposals, p. 92–3.

[82] Francis Beaufort, On inserting Meteorological Observations, according to Office Abbreviations, in the Logs of HM Ships, 5 Dec 1838, Minute Book 3, UKHO, p. 96

[83] Letter from Reid to John Herschel, 3 January 1839, Minutes of the Meteorological Committee, Domestic MSS Volume III, RS.

[84] British Admiralty, *Admiralty Instructions for the Government of Her Majesty's Naval Services* (London: Stationary Office, 1844), p. 173.

[85] Day, *Admiralty Hydrographic Service*, pp. 56-7. Day notes that the barometers were supplied by the Hydrographic Office. On barometers at sea and at Britain's harbours in the mid-nineteenth century, see Sarah Dry, "Safety networks: fishery barometers and the outsourcing judgement at the early Meteorological Department," *Brit. J. His. Sci*, 2009, *42*:35–56.

[86] Reid, *The Law of Storms*, p. 542.

[87] 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, RS.

[88] Reid, *The Law of Storms*, p. 542.

[89] Reid to Herschel, 3 January 1839, RS; Admiralty Minute, 6 January 1839, ADM3/245, National Archives, Kew.

[90] Webb, "More than just charts", p. 52.

[91] On the magnetic crusade see John Cawood, "The Magnetic Crusade: Science and Politics in Early Victorian Britain," *Isis*, 1979, *70*:492–518; John Cawood, "Terrestrial Magnetism and the Development of International Collaboration in the Early Nineteenth Century," *Annals of Science*, 1977, *34*:551–587; Granville Allen Mawer, *South by*

*Northwest: The Magnetic Crusade and the Contest for Antarctica* (Edinburgh: Birlinn Limited, 2006).

[92] Gregory A. Good, "Between Data, Mathematical Analysis and Physical Theory: Research on Earth's Magnetism in the 19th century", *Centaurus*, 2008, *50*:290–304, on p. 301.

[93] Winter, "Compasses All Awry," on p. 87; Anderson, "Mapping Meteorology".

[94] 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 Society's report was devoted entirely to meteorology. Royal Society, *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).

[95] Blouet, "Sir William Reid," p. 175.

[96] 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", *J. Hist. Geogr.*, 2006, *32*:539–62.

[97] Kirsten Greer, "Zoogeography and imperial defence: tracing the contours of the Nearctic region in the temperate North Atlantic, 1838-1880s," *Geoforum*, 2015, forthcoming.

[98] Deborah Coen, "The Storm Lab: Meteorology in the Austrian Alps," *Science in Context*, 2009, *22*:463–486, on p. 465.

[99] 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. Charles Richard 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.

[100] Letter from Reid to Beaufort, 17 October 1839, Incoming Letters R1-R300, UKHO.

[101] Reid to Lord John Russell, 8 Feb 1840, AP/24/16, RS.

[102] Reid to Beaufort, 30 January 1840, Incoming Letters R1-R300, UKHO; Reid to Russell, 8 Feb 1840, RS.

[103] Reid to Beaufort, 17 October 1839, UKHO.

[104] Anon, "The Storm," *Bermuda Royal Gazette*, 24 September 1839, included in Reid's letter to Lord Russell, 8 February 1840, RS. Descriptions of many of the storms were also reported in the *Nautical Magazine*.

[105] Reid, *The Law of Storms*, facing p. 444.

[106] Good, "A Shift of View."

[107] Reid to Russell, 8 Feb 1840, RS.

[108] Reid, *Progress of the Development*, p. 19.

[109] Reid, *Progress of the Development*, p. 2.

[110] Reid, *Progress of the Development*, pp. 32.

[111] Reid, *Progress of the Development*, p. 17.

[112] Letter from Bernard Ingham to Bermuda Royal Gazette, 7 October 1839, included in Reid's letter to Russell, 8 Feb 1840, RS.

[113] Robert 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).

[114] William Reid, "Preface," no page, in Methven, *Narratives*.

[115] John 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).

[116] Friendly, *Beaufort*, p. 264.

[117] See Withers, "Science," for a discussion of this literature.

[118] Herschel, "Meteorology," in *Manual*, ed., Herschel, p. 280.

[119] Herschel, "Meteorology," p. 316, original emphasis.

[120] For instance, George 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, pp. 501-2; Charles Clouston, *An Explanation of the Popular Weather Prognostics of Scotland on Scientific Principles* (Edinburgh: Adam & Charles Black, 1867).

[121] Anderson, *Predicting the Weather*, p. 51.

[122] John Herschel, "The weather and weather prophets", *Good Words*, 1864, pp. 57-64, on p. 57.

[123] Herschel, "Meteorology," p. 320.

[124] Herschel, "Meteorology," p. 319.

[125] Herschel, "Meteorology," p. 320

[126] Francis Beaufort, Record of Observations by Foreign Consuls, 9 December 1851, Minute Book 7, UKHO.

[127] Lords Commissioners of the Admiralty, *Remarks on Revolving Storms* (London: HMSO, 1851).

[128] Francis Beaufort, Meteorological Observations – General system of observing, 30 June 1852, Minute Book 8, UKHO.

[129] Letter from Beaufort to Edward Sabine, 25 July 1853, Letter Book 19, UKHO.

[130] Beaufort to Sabine, 27 July 1853, Letter Book 19, UKHO.

[131] Blouet, "Sir William Reid," p. 181. Reid later became Governor of Malta, which facilitated his study of the storms of the Mediterranean.

[132] Letter from Henry James to Beaufort, 24 December 1851, Incoming Letters, J1-J299, UKHO.

[133] Anon, *Maritime Conference held at Brussels for Devising an Uniform System of Meteorological Observations at Sea*, MS, 1853, MO.

[134] Agnew, "Robert Fitzroy," p. 25.

[135] Reidy, *Tides of History*, p. 287; D. Graham Burnett, 'Matthew Fontaine Maury's "Sea of Fire": Hydrography, Biogeography, and Providence in the Tropics', in F. Driver and L. Martins, eds, *Tropical Visions in an Age of Empire* (Chicago: Chicago University Press, 2005), pp. 113-136.

[136] Agnew, "Robert Fitzroy."

[137] James to Beaufort, 19 June 1852, Incoming Letters J1-J299, UKHO. 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 [the Astronomer Royal] and yourself and I confine my ambition to the hope that I may be able to assist in promoting the object in view."

[138] James to Beaufort, 15 July 1852, Incoming Letters J1-J299, UKHO.

[139] Anon, *Maritime Conference*, p. 14.

[140] Letter from Matthew Maury to Lord Rosse, President of the Royal Society, 27 July 1854, BJ 7/4, National Archives, Kew.

[141] Anon, "Review of Reid," p. 432.

[142] Malcolm Walker, *History of the Meteorological Office* (Cambridge: Cambridge University Press, 2012) p. 61.

[143] Anderson, *Predicting the Weather*, p. 124.

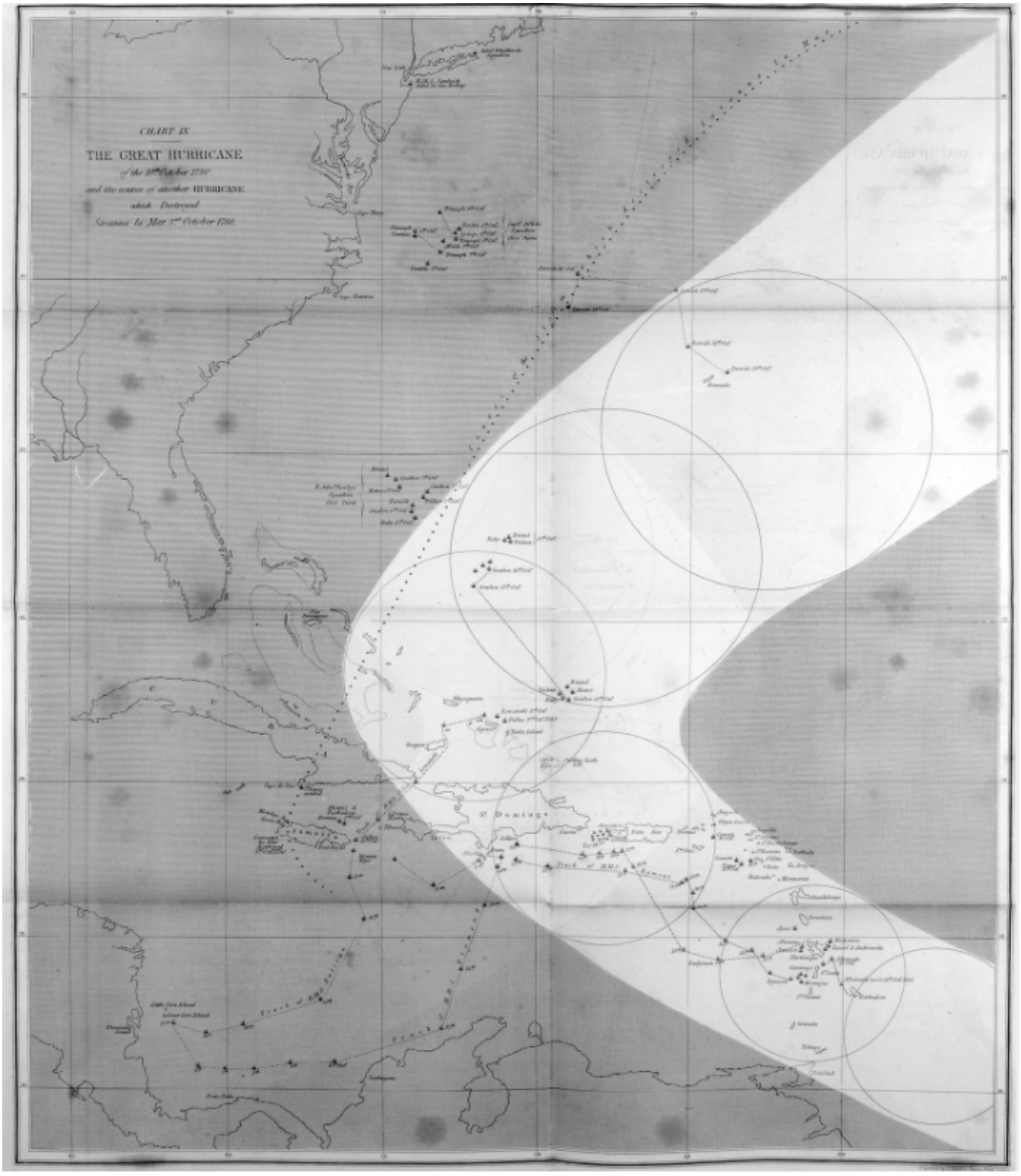
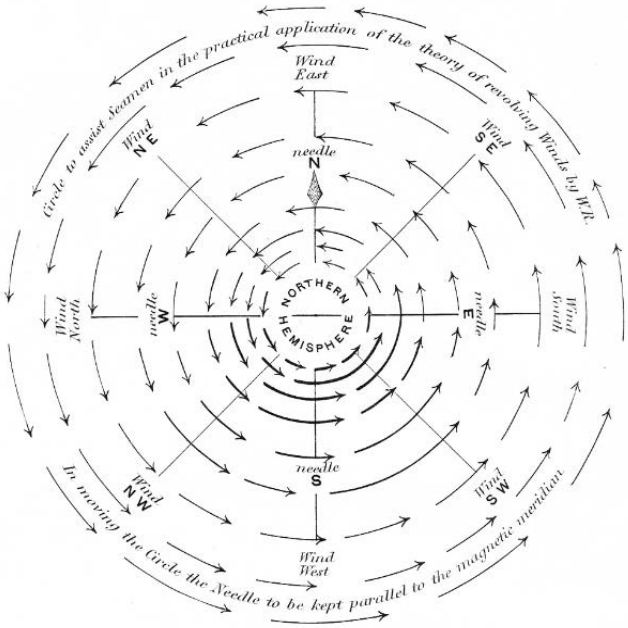


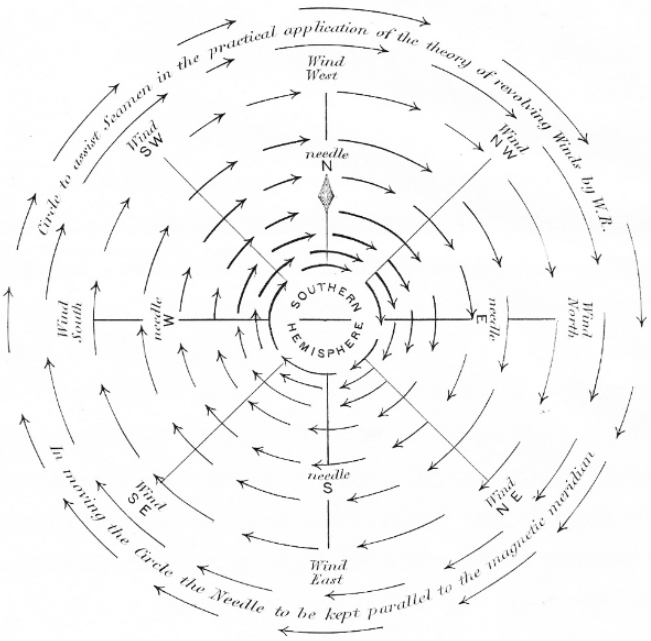
CHART IX.
THE GREAT HURRICANE
of the 10th October 1780
and the course of another HURRICANE
which Destroyed
Savanna la Mar 3rd October 1780.
St Domingo

Figure 1

# LAW OF STORMS




EQUATOR




*When these Circles are used they should be cut out and moved along a Marine Chart in the direction of a Storms progress. Dipped in turpentine they will become transparent.*

*London, Published by John Weale, 59 High Holborn.*

Figure 2

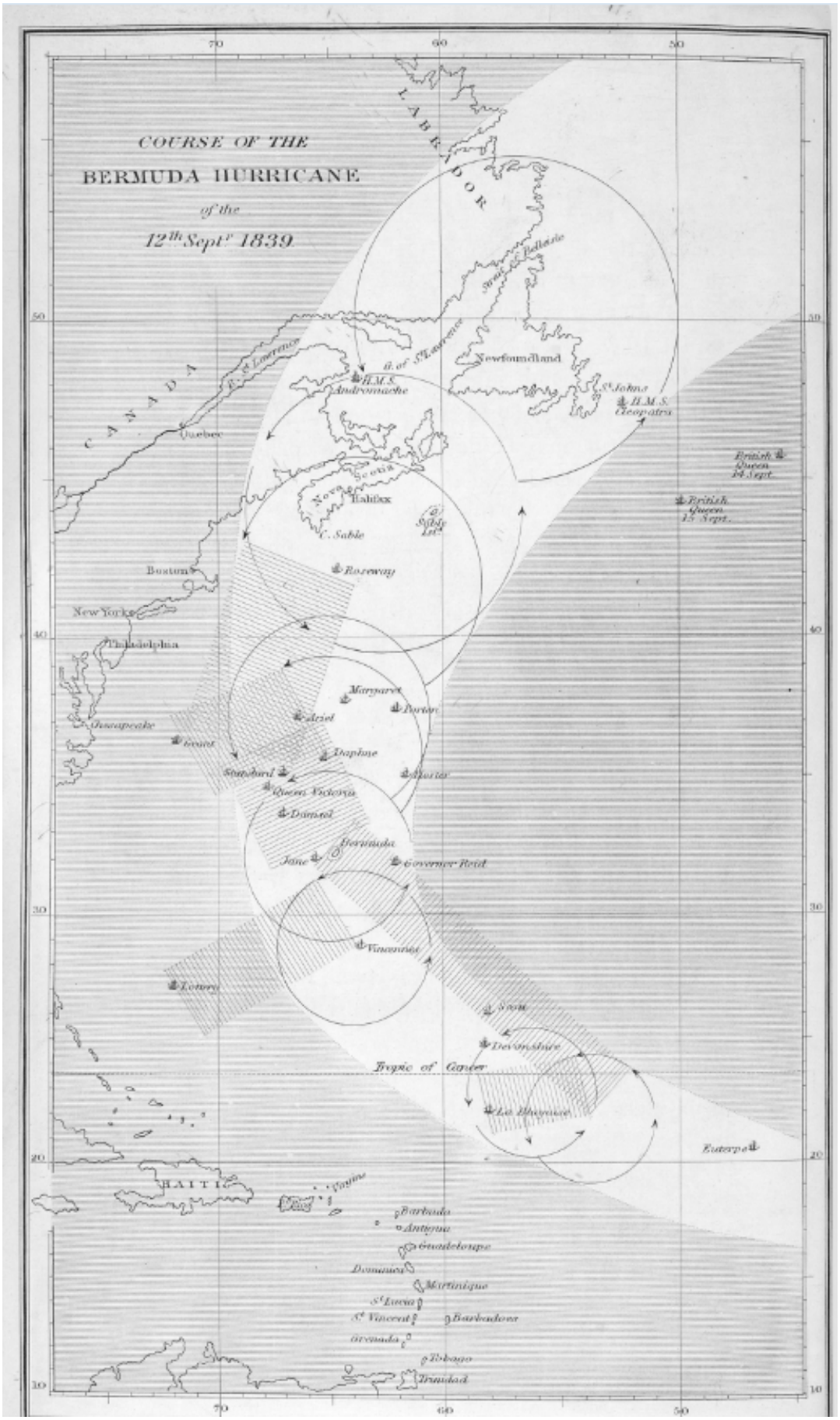

COURSE OF THE
BERMUDA HURRICANE
of the
12th Septr 1839
LABRADOR
CANADA
Quebec
Newfoundland
St. Johns
H.M.S. Andromache
H.M.S. Cleopatra
Halifax
C. Sable
Boston
New York
Philadelphia
Chesapeake
Margaret
Portia
Thaphne
Queen Victoria
Diamond
Bermuda
Governor Reid
Vincennes
Levant
Leo
Devonshire
Tropic of Cancer
Europa
HAITI
Barbuda
Antigua
Guadeloupe
Dominica
Martinique
St Lucia
St Vincent
Barbadoes
Grenada
Tobago
Trinidad
70
60
50
40
30
20
10

Figure 3