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ROBERT FITZROY AND THE MYTH OF THE 'MARSDEN SQUARE': TRANSATLANTIC RIVALRIES IN EARLY MARINE METEOROLOGY

by

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SUMMARY

Marine data (especially in meteorology) are often grouped geographically using a set of numbered 10° latitude–longitude squares known as Marsden squares, which are usually attributed to William Marsden, Secretary of the Admiralty (and Vice-President of The Royal Society), who supposedly invented them early in the nineteenth century. Available records suggest that this system was in fact probably invented by Robert FitzRoy soon after his appointment as head of the British Meteorological Office in 1854. FitzRoy felt that early English work in marine meteorology was being ignored, notably by the American Matthew Fontaine Maury, who had pioneered the collecting of marine meteorological data from ship's logs. A desire to undo this wrong led FitzRoy to emphasize earlier (though abortive) British projects by A.B. Becher (in 1831) and by Marsden (probably in the 1780s), both of which involved grouping marine data geographically, though only over limited areas. FitzRoy's treatment of this earlier work seems to have created, much later, the belief that Marsden had invented the system of 10° squares. Given both Maury's and FitzRoy's desire to demonstrate priority in this field, it is ironic that the first clear proposal to collect and group data from ship's logs was made by the American (and British) natural philosopher Isaac Greenwood in 1728.

Keywords: William Marsden; Robert FitzRoy; Matthew Maury Fontaine; Isaac Greenwood; marine statistics; meteorology

INTRODUCTION

Increasing concern over long-term climate change has led to increasing interest in recovering and using older meteorological data, to obtain the longest possible span of measurements. A notable effort has been the conversion into digital form of marine meteorological data to form COADS, the Comprehensive Ocean–Atmosphere Data Set. These efforts in turn have resulted in more attention being paid to the historical development of such data collection—unfortunately not always with complete historical accuracy. For example, a recent summary of the COADS project[1] identifies the following (among others) as important events in the history of marine meteorology:

1805 Francis Beaufort introduced codes for recording wind force.

1831 Secretary of the Admiralty William Marsden proposed latitude–longitude 'squares' to facilitate handling and analysis of ships' weather records.

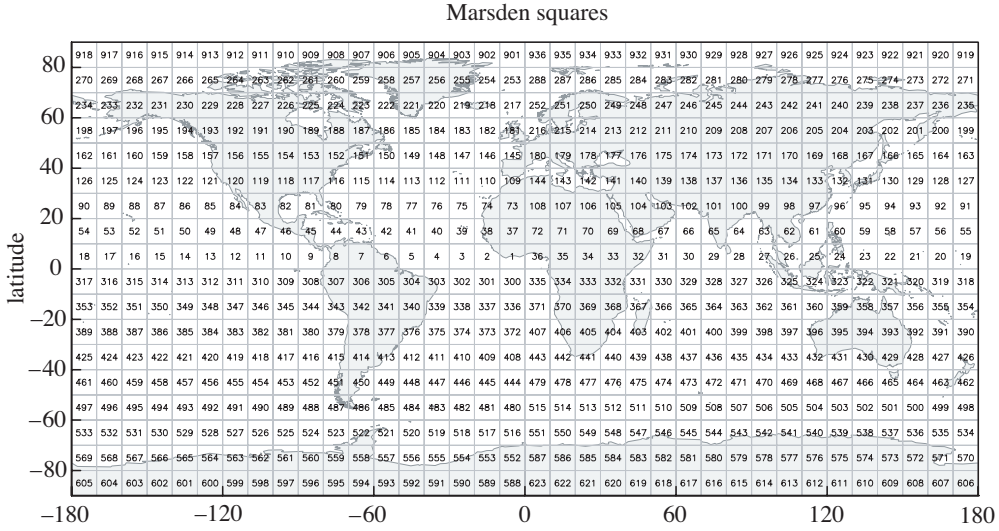

Figure 1. The modern system of 'Marsden squares'. The original numbering scheme did not extend beyond 80° latitude, north or south.

1853 Brussels Maritime conference 'for devising an uniform system of meteorological observations at sea'.

The second event refers to a system of organizing data by spatial location; as shown in figure 1, the Earth is divided into 10° squares of latitude and longitude, and each square is assigned a number, so that all data in 'Square 3', for example, must be in a region in the central Atlantic Ocean. This, one of many ways of parcelling the surface of the Earth into labelled areas, is particularly common in marine meteorology and some other areas of oceanography; in recognition of their introduction by Marsden in 1831 the squares are known as Marsden squares.

However, while the first and third of the events listed above actually happened,[2] the second never did: this system of squares was not introduced in 1831, or by Marsden. To be fair to the authors of the COADS paper, this error is quite common (being enshrined, for example, in glossaries of meteorology), although it should be said that the best scholarly treatments[3] do provide a more careful, though still incorrect, account by giving Marsden the credit at an earlier date. While it is perhaps not that interesting that there is such an error (as shown by Stigler's Law of Eponymy: no eponym honours the actual discoverer[4]) finding the source of error turns out to throw light on the rivalries that existed at the start of marine meteorology, especially between its practitioners in England and in the USA.

William Marsden

To start, who was William Marsden (figure 2)? Although he was indeed secretary of the Admiralty, and active in The Royal Society, his scholarly achievements were not primarily in the sciences or related to the Navy. Fortunately he wrote an autobiography, edited

Figure 2. Portrait of William Marsden FRS in 1794, by George Dance.
(National Portrait Gallery, number NPG 4410.)

and published after his death by his widow, with additions from his letters.[5] He was born in 1754 to a prosperous Anglo-Irish merchant family. After a standard classical education, he decided to forgo university training and instead followed his brother in the service of the East India Company, at their outpost at Fort Marlborough, on the west coast of Sumatra. He arrived in 1771, returning to England in 1779 to live as an independent scholar in London, almost immediately joining the intellectual life of the capital by being introduced to Sir Joseph Banks at one of the latter's 'philosophical breakfasts', at which he became a well-known presence.[6] His first scholarly publications were, typically, one to the Society of Antiquaries on Sumatran languages, and one to the *Philosophical Transactions of The Royal Society* on a case (in Sumatra) of a large dieoff of fish.[7] In 1783 he published *The history of Sumatra*: a comprehensive treatise on all facts connected with that island, natural, social, linguistic and historical.[8] In the same year he was elected FRS. By his own account, most of his subsequent efforts were devoted to studying languages, of which he possessed an amazing range, although he was good friends with men interested in the natural sciences, such as the hydrographers Alexander

Dalrymple and James Rennell. Indeed, it was Rennell who was asked to approach him in 1795 with an offer to become Second Secretary of the Admiralty, which he did almost at once, abandoning his scholarly pursuits for bureaucratic ones.[9]

Marsden remained at the Admiralty for just over 12 years, becoming First Secretary in 1804 and resigning in 1807: because this entire period (except for the one-year Peace of Amiens in 1802–03) was one of war between France and Britain, his job was anything but a sinecure. By his own account he rarely left London, or after his appointment as First Secretary the Admiralty building, a few official trips excepted; his request for resignation mentioned the effect of constant indoors work on his health. However, his official duties did not prevent him from becoming Treasurer of The Royal Society in 1802 and Vice-President in 1803, both positions that he held until 1810. After resigning from the Admiralty he returned to scholarly work, publishing a new edition of his *Sumatra*, a Malay grammar, and an edition of Marco Polo. But most of all he collected: manuscripts and books on all languages, and an extensive collection of coins; collections that, as he aged, he carefully deposited at King's College and the British Museum. He died, after a series of strokes, in 1836.

This biographical summary makes plain, of course, that the most common account of Marsden squares cannot be correct, if only because Marsden was no longer at the Admiralty in 1831. His autobiography indicates an interest in meteorology, as in other kinds of natural history: his letters often include notes of unusual weather or high or low temperatures, even including the statement that he did not yet possess self-recording instruments.[10] But with the exception of one rather cryptic footnote (discussed below) there is no mention of any systematic collection of data such as that implied by the system of Marsden squares.

The birth of nautical meteorology

In the introduction I have followed current usage and referred to 'marine meteorology', meaning meteorology over the oceans. However, it needs to be understood that, for many of the workers described here, the motivation for collecting data lay not in improving our understanding of the atmosphere but rather our ability to use it. Until the latter half of the nineteenth century most ships used sails, so the winds were the motor of commerce, and of war. A better term for these early efforts would thus probably be 'nautical meteorology'.

Certainly, improving the navigator's knowledge of the winds was the avowed purpose of the first successful collector of marine meteorological data, Matthew Fontaine Maury (1806–73) of the US Navy. In 1842 Maury was appointed head of the Navy's Depot of Charts and Instruments, a chronometer-rating facility and chart-distribution centre set up in 1830. His qualifications were that he was not suited to sea duty because of an injury and that he was one of the few naval officers with any indication of an interest in science, having written a manual of navigation. In 1844 he was made Superintendent of the Depot, which became known as the US Naval Observatory; he remained there until his resignation to join the Confederacy upon the outbreak of the American Civil War in 1861.[11]

Maury had a strong interest in improving navigation, and was, compared with other naval hydrographers, in the unusual position of having no responsibility for charting his country's own coastline, because this was then, as it had largely been since 1807 and remains today, the responsibility of a civilian agency, then called the United States Survey of the Coast.[12] And the US Navy, like many others, then depended very largely on the Hydrographic Office of the British Admiralty to provide charts of all other coasts. Maury turned instead to compiling meteorological data from logbooks, initially those from prior Navy voyages; an effort that seems to have begun soon after his 1842 appointment and by 1847 had advanced to the point that the Observatory was able to issue the first 'Wind and current chart', showing the winds in the North Atlantic. Maury tried to get naval and merchant shipmasters to provide him with observations, initially with little success; but once his charts were available he arranged that they would be provided free to anyone sending him data. This incentive, aided by the reputation that Maury's methods developed for reducing sailing time, greatly increased the volume of data submitted to the Observatory, which is reflected in the growth in successive editions of Maury's charts and of his *Sailing directions*, a book summarizing and describing his results.[13]

In 1851 the British Royal Engineers proposed to supplement their meteorological measurements in the British Empire through cooperative measurements with the USA. This proposal was sent through channels in the US government to interested officials, one of whom was Maury. Easily fired to enthusiastic plans, he proposed in response an international conference to coordinate observations on land and at sea. In turn, the British government requested the advice of The Royal Society, which reported (in May 1852) that because different nations already had their own standards for land observations, and because there had been a meeting of European observers at Cambridge in 1845, another general conference seemed inappropriate. The report did, however, agree that a conference focusing on observations at sea would, following Maury's success, be worth having, and that Britain, as the leading maritime power, should certainly be involved in it. Maury adopted this modification to his proposal, and (after some further delay) in June 1853 had the US government invite representatives of other governments to a conference for standardizing the reporting of marine meteorological data. This conference was held in Brussels from 23 August to 8 September 1853, and during it the delegates (all except two of them naval officers) agreed on a standard form, which naval vessels could use to report data. The chairman was the Belgian astronomer and statistician A. Quetelet, but the main leadership seems to have come from Maury and from Captain Frederick W. Beechey, one of the two British delegates, who was in the Marine Department of the Board of Trade.[14]

The Meteorological Department, and Robert FitzRoy

Having sent two delegates to the Brussels conference, the British government seems to have felt some responsibility to set up an organization to collect and collate marine meteorological data, although action was delayed by the onset of the Crimean War. It seems that after a few months of indecision it was decided to house this organization,

called the Meteorological Department, within the Marine Department of the Board of Trade, providing funding through that department and through the Admiralty; the plan to create the department was announced in Parliament on 6 February 1854, with funding announced in June 1854. The head of the new department had the title of Meteorological Statist, with a staff of three; the actual appointment was not made until December 1854, though backdated to 1 August of that year. The appointee was Captain Robert FitzRoy.[15]

FitzRoy is now almost solely known as the captain of HMS *Beagle* on a surveying voyage to South America and around the world in 1831–36: a voyage famous because of the naturalist invited by FitzRoy, the young Charles Darwin. This voyage, during which he was promoted to captain, was the high point of FitzRoy's naval service, which had begun with his entry into the Royal Naval College in 1818 at the age of 12. Given the huge surplus of officers in the post-Napoleonic Royal Navy, he could not have expected regular employment, and so became (through connections) MP for Durham. In 1843 he abandoned this when he was appointed Governor of New Zealand, then newly annexed to the British Empire by the Treaty of Waitangi. Given the difficulties posed by land-hungry Pakeha, well-armed and martially skilful Maori, and a home government unwilling to supply much financial or military support, this was not an easy colony to administer, and FitzRoy was not a success, being recalled less than two years later, amid much questioning of his tendency to ignore instructions and not inform the government of his actions. In the following years he had commanded Woolwich dockyard and the experimental steam warship HMS *Arrogant*, but resigned from active service in 1850 and was subsequently little employed.[16]

The planned office would have to collect data from vessels of both the Royal Navy and the Merchant Marine, and FitzRoy had worked with both groups, having while in Parliament sponsored a bill for the examination and registration of masters on merchant vessels.[17] His career also showed him to have a greater interest in science and technology than most Navy captains did; he had been elected FRS in May 1851.

The first sign that FitzRoy was involved comes from a letter from Col. Edward Sabine to FitzRoy on 5 November 1853, only two months after the Brussels conference; the letter itself is uninformative, but was annotated 'Maury' by FitzRoy, who on the same day wrote a very rough, and probably private, memorandum on the possible organization of a marine meteorological organization. Additional letters between October and December 1853 show that consideration was also given to housing the activity at the Royal Observatory at Greenwich, or having it done by Lyon Playfair (1818–98), who was much favoured for various governmental functions. By January it seems that Sabine, at any rate, had decided that FitzRoy would head the office, though it was not until 3 February 1854 that FitzRoy wrote to him agreeing to head it.[18]

Once appointed, FitzRoy set to work with characteristic energy. Part of his job was to issue forms (and standard instruments) to cooperating ships; but clearly it would be some time before these new observations could approach what Maury had collected. FitzRoy therefore turned to doing what Maury had done at first, collecting data from existing logbooks. However, his manner of doing so was influenced by his doubts about Maury's originality, in ways that eventually led to the myth of the Marsden square.

Plagiarized squares. I. Maury the plagiarist of Becher

The first sign of these doubts comes in a memorandum that FitzRoy wrote on 8 November 1854, expressing his beliefs about earlier data collected by the Admiralty but not acknowledged by Maury:[19]

> From the commencement of Sir Francis Beaufort's duties as Hydrographer to the Admiralty—he instructed the officers employed in marine surveying to collect information respecting winds—currents—tides—and generally, all meteorological as well as hydrographic subjects.
>
> His intention was—as he expressed it to me in 1831—to produce useful results from the accumulation of facts which he anticipated: but I have since often heard that the limited means at his disposal impeded the execution of his object.
>
> As a commencement, however, his principal assistant (then Lieut. A.B. Becher RN) had authority to prepare a set of large books—for tabulating observations—and one of these was partly filled with notices of winds.
>
> Lieut. Becher divided a chart of the Ocean into squares of so many degrees each, and numbered them to correspond with the books he had arranged.
>
> Pressure of other duties hindered the continuation of this work—which, in its nascent state, was shown [known?] to Lieut. Maury, a few years subsequently, before he had undertaken his own great work.
>
> Lieut. Maury's Sailing Directions and Charts—although too diffuse and bulky for convenient use, have in a great measure realized the intentions expressed by Sir Francis Beaufort in 1831.
>
> In connection with the deep-sea soundings (so often urged by the Hydrographer) it may be mentioned that a 'Sounding Line' (so like that called 'Brooks's' by Lieut. Maury, that the one is almost a duplicate of the other) was suggested to Sir Francis Beaufort in writing—and talked of in his office—half a year before one appeared in the United States.

For the first half of 1831 FitzRoy was in London after the *Beagle*'s first voyage, and was probably in regular communication with Beaufort; but after June 1831 he was engaged in outfitting the *Beagle* at Plymouth and would have been only rarely present at the Admiralty, so his knowledge might well have been somewhat imperfect. What is striking is his conviction that this early work must have been known (or shown—the writing is unclear) to Maury, and that the latter was also (implied by the last paragraph) guilty of copying the idea of a detachable-weight sounding lead from British sources. At the time of starting his meteorological efforts in the 1840s, Maury had visited England only (very briefly) in 1827; his next visit was in 1853 *en route* to the Brussels conference. Given the private nature of the 1831 work (discussed below), it seems impossible that he could have seen it, and very unlikely that he would have known of it. However, FitzRoy's belief that Maury did not adequately acknowledge his (mostly British) predecessors in nautical meteorology seems to have developed into a somewhat obsessive desire to highlight earlier developments, and an unfounded assumption that these perhaps lay behind Maury's work.

It is worth noting two sides to this: FitzRoy often had too much concern to see that credit was given correctly, but he was not alone in believing that Maury fell short in this area. The best-known example of FitzRoy's concern for correct attribution was his response to the draft introduction to one of Darwin's books reporting on Darwin's work on the *Beagle* voyage: FitzRoy wrote to Darwin, clearly very upset that Darwin did not even mention the assistance he had received from the *Beagle*'s officers—and, perhaps,

that Darwin seemed to give Beaufort more credit than FitzRoy for his presence on the voyage. But while FitzRoy may have been unusually sensitive about the attribution of credit, others besides himself felt that Maury performed poorly in this area. For example, in November 1850 Joseph Henry wrote to Maury to express his displeasure about Maury's incorrectly attributing a discovery about the Gulf Stream to Navy personnel rather than to earlier work by the Coast Survey; the ensuing exchange caused Henry to remark that Maury was 'rather I think indefinite in his views of scientific ethics.'[20]

What was actually done in 1831 was explained in a letter to FitzRoy by A.B. Becher on 20 November 1854, presumably in response to a request by FitzRoy along the lines of his memorandum. Alexander Bridport Becher (1796–1865) was the chief Naval Assistant in the Hydrographic Office from 1823 to 1864, being brought in originally to organize, catalogue and distribute the charts. He wrote several navigational tracts and began the issuance of bottles whose tracks could be used to determine currents, and thereby the compilation of current charts based on these.[21] His reply[22] indicated that he would indeed forward books of meteorological data, which he had started compiling 'in the year 1831 for the investigation of the winds, the weather, and the currents of those seas bounded by the shores of Asia in the North, and extending from the Cape to Australia in the South', with 'a volume for each month of the year', these books being 'supplied … by the Admiralty'. He went on to describe his method:

> Taking a chart of the whole of the ocean I divided it into squares or spaces of two degrees of latitude and longitude, which were numbered consecutively up to about 1400. Then for each of the twelve months of the year I prepared a book, each page of which was numbered in the same consecutive manner as the squares on the sheet, and was thus destined to receive the statements of the wind and weather experienced by ships in passing through the space on the sheet that was assigned to it. Thus you will perceive, that for each square on the chart there were assigned twelve pages (one in each book) to receive the statements of the meteorological observations throughout the year made by ships passing through that square. … As the pages of each of these books became filled, it was my intention to have taken a chart of the ocean for each book and to have transferred from them a digested statement, expressed in symbols, of their contents, into each square of latitude and longitude to which they belonged; thus shewing throughout the whole chart, by the contents of one book, the mean state of the wind and weather for one month of the year.

He went on to note that such a chart would have provided 'a fair approximation to the limits of the monsoons, their direction and extent, the periods and limits of the calms as well as those of the trade winds, the land and sea breezes, the district of calms and hurricanes…'. But unfortunately

> I soon found out that I had embarked on a work far beyond my powers of execution; and that what I had undertaken, for mere useful amusement, in the leisure hours left from office, was really one that would give employment to a staff of persons, who need have nothing else to do. Under these circumstances the books were laid aside for future amusement in more propitious times, and the Nautical Magazine has occupied those leisure hours, if not with the same advantage to Seamen, at least with the approval of the Nautical world.

Becher's reference to the *Nautical Magazine* is to the periodical, still being published, that he edited (with partial support from the Admiralty and the Mercantile Marine Fund) starting in 1832. Initially this included notices of updates to Admiralty charts but also a variety of articles on nautical subjects (including the first public announcement of the

Beaufort scale). It is easy to imagine that this task, done out of office hours, would have used up any time he might have spent on compiling logbook data, even for the limited area of the Indian Ocean.[23] A covering letter from Beaufort confirmed that, aside from providing the blank books, the Admiralty had no official involvement in Becher's initiative, contrary to FitzRoy's belief. Becher at least was not unhappy with Maury, writing that 'It is gratifying to me to … find that the subject has been looked upon in the same important light … by the Seamen of the United States; and to see Lieut. Maury, supported by that government, taking it up in earnest.'

However disabused FitzRoy may have been about the official nature of Becher's efforts, he still wished to point out the primacy of British efforts, and so opened his first report, from the Meteorological Department, dated 23 May 1855,[24] with a historical review.

> In 1831 the first systematic endeavour to collect and discuss meteorological observations made at sea was commenced at the Hydrographical Office of the Admiralty, and from that time all surveying ships were ordered to make them regularly.
>
> Pressure of other duties, and the limited extent of the means applicable by the Hydrographer, prevented a continuance of the collection which was then begun in twelve large volumes (one for each month) prepared, in the first instance, for the Indian Ocean, as being less known than the Atlantic.
>
> The useful plan of the dividing the ocean into squares—affording the means of grouping and averaging observations, as well as identifying spaces of sea, like provinces of land—was then originated at the Admiralty.

In his 1855 report FitzRoy goes on to explain the method used in the Meteorological Department for organizing data:

> The surface of the globe is supposed to be divided into squares of ten degrees each. Beginning at the meridian of Greenwich, on the Equator, the numbers go westward until the same meridian is regained, then on the next circle, northwards, between the parallels of ten and twenty degrees of latitude—and so on, omitting the ten degrees space of latitude around the Pole.
>
> From the first meridian, the squares south of the Equator are numbered from 300, in a similar manner, but southwards to the eightieth southern parallel. Thus distinguished by numbers not exceeding 600—all those below 300 being north of the Equator—the locality of each frequented square may soon become fixed in the mind of the navigator, and serve (like provinces on land) to recall spaces to the mind, rather than points indicated only by latitude and longitude.

Comparison with figure 1 (or other descriptions) shows that this is just the system of numbering now known as 'Marsden squares', though the modern version includes the Arctic band as well. The novel aspect of this is the assigning of numerical designations to each square—and FitzRoy's final sentence shows he was aware of how useful this feature was. It seems entirely possible that this idea was devised by FitzRoy himself, though perhaps owing something to Becher's labelling of squares with numbers. Certainly it would have been somewhat characteristic for FitzRoy not to claim the credit for his own idea. He may not have thought that it was as important as his other innovation, described below, namely an improvement of Maury's methods of displaying wind data.

Plagiarized squares. II. Enter William Marsden

On 11 March 1857 FitzRoy produced his second report on the work of the Meteorological Department: a much longer account, and actually published.[25] As with his 1855 report, it opened with a historical summary—but one revised from the earlier version:

> 3. In the early part of this century, while Mr. Marsden was Secretary of the Admiralty, the want of collected and combined information respecting the ocean was so often felt by that able public servant that he suggested a plan for arranging, or grouping, all that could be observed in certain convenient divisions of the seas. He then proposed the method of squares as suitable and convenient in practice. (*See* Appendix).
>
> 4. In 1831 a systematic commencement of a collection and discussion of Meteorological observations made at sea was undertaken at the Hydrographical Office of the Admiralty, upon a similar principle; but pressure of other duties, and the limited extent means then applicable, impeded a continuance of the collection which was scarcely more than commenced.
>
> 5. Twelve large volumes (one for each month) prepared for the Indian Ocean, as being less known than the Atlantic, are now in this office, with their corresponding charts subdivided into numbered squares.
>
> This useful arrangement, dividing the ocean into squares, which affords the means of grouping and averaging observations, as well as identifying spaces of sea like provinces of land, was thus originated at the Admiralty.

It is not clear what FitzRoy's source of information was for his assertions about Marsden, but they can hardly have been based on any records from the Admiralty because it was not until more than a year later (March 1858) that FitzRoy seems to have searched for such records. A letter from Becher to FitzRoy (19 March 1858) reported that the Admiralty records of Marsden's time were not properly indexed, but that Becher had found nothing in them to suggest such a plan by Marsden. Becher had also read through Marsden's *Memoir*, without finding anything relevant. He closed by suggesting that FitzRoy investigate possible records at The Royal Society.[26]

This FitzRoy either did immediately or had already done, since he received a letter from Edward Sabine dated 20 March 1858, and enclosing material passed on by Marsden to him around 1828. Sabine's letter states that this material was copied by his wife from manuscripts lent by Marsden, but this cannot be strictly true, because the four items enclosed are in two different hands. There are two translations of articles by Semyns on the causes of land and sea breezes, and of the trade winds, both translated by Marsden at the request of Alexander Dalrymple; one of these is in a fine copperplate script, the other in a much more irregular hand, written with a broader pen.[27] This more irregular hand and pen are present in a third item, a single sheet of instructions for a 'Capt. Stoddart' on observing the wind and surf on the Malabar coast of India.[28] The fine copperplate script was also used for a paper, entitled 'Plan for Experimental Lists of Prevailing Winds in the Tropical and neighbouring Latitudes', which describes Marsden's proposed procedure for compiling wind information; this seems to have been the basis for FitzRoy's claims.[29]

Marsden's description does not in fact suggest that he undertook such a project, but is more in the nature of a proposal of how this could be done.[30] The first step would be to set up a table from 36° S to 36° N, and for all longitudes; Marsden suggests that this

could occupy a piece of paper 90 inches by 15 inches, if each degree occupied a $\frac{1}{4}$-inch square. Perhaps quickly realizing the impracticality of this scheme, he immediately offers the alternative of a book, opened lengthways, with north latitudes on one page and south on the other, and a limited range of longitudes for each page, and 'there must be one set for every one, two, or three months of the year'. Then

> As many ships journals as possible must be inspected and memorandums made of the winds found at each season of the year in the various Latitudes and Longitudes within 36° N and S which such ships happened to pass through … These must be entered in the Tables at their proper divisions and when a sufficient number are procured at any one spot the general result or medium at that month or season (discretion being used in extracting such medium) is to be transferred to the charts and the medium may again be estimated which will afford a close approximation to the truth.

The next step was to put indicators of wind direction on a chart, squared in latitude and longitude, and if these directions agreed in a given region, to draw a line around them, so that 'in time the whole chart will be formed into little compartments, each containing the prevailing wind in such particular space, at any given time of year'. There is, again, no indication that he proceeded far in this task; although this summary proposal is accompanied by a long list of meteorological observations, all are taken from printed accounts of voyages.

An obvious pair of questions about this document are when it was written, and whether it had any relationship to Marsden's Admiralty service. Some good evidence on the first point is provided by the translations from Semyns, assuming that these were done at about the same time. Because these translations were not mentioned in the first edition of Marsden's *History of Sumatra* (1783) but were explicitly referenced in the second edition of 1784 (in a note pointing out that Marsden had not been aware of them at the time of writing the first edition), they must have been made in 1783 or 1784.[31] The date '1784' is also written on the note to Capt. Stoddard mentioned above, though not as a heading. Certainly the trajectory of Marsden's interests is also consistent with all this natural-science material being produced relatively early in his career, rather than later. It is perhaps worth noting that although Marsden had the best of all opportunities to change the collection of meteorological data while Admiralty Secretary, he did not do so; the new edition of regulations for the Royal Navy published during his tenure (and going out over his signature) did not require any change in logkeeping procedure from what had been customary.[32] It should, however, be noted that FitzRoy seems to have remained convinced that Marsden's work must have been done at the Admiralty, because he repeated this in later writings. The importance he attached to Marsden's work is perhaps shown by the tone of another letter from Becher, sent of 23 March 1858, saying that

> It was never my desire to set aside Mr. Marsden's claims to priority in the subject of discussing Met'l observations on a method similar to my own, although I was unsuccessful in finding any record or proof of it.

Clearly FitzRoy was still very concerned about who did what first.

Later use of squares

FitzRoy's own method of data compilation was through what he called 'data books': volumes in which specific types of data were entered, arranged by the numbered system of 10° squares. Because this arrangement involved much recopying if data were to be grouped by month or season, it was abandoned after FitzRoy's death, being replaced briefly by a system using cards devised by Francis Galton, and then by another system of data books (one book for each month and square) set up by Captain Henry Toynbee (1819–1909), who was Marine Superintendent at the Meteorological Office starting in 1867. Toynbee's system seems to have lasted until the whole procedure was converted to Hollerith punched cards in 1921.[33] Through all this the system of 10° squares remained unchanged. But it is notable that in Meteorological Office publications up to 1900 the squares are simply referred to as either (for example) 'Square 3' or 'Ocean Square 3'.[34] The first reference I have seen in which Marsden's name is attached is in the first volume (1924) of the *Marine Observer*, the journal published by the Meteorological Office for participants in the marine observing programme. In this, a 'Marsden chart' shows the numbered squares, with the number of observations for the year in each square. How this usage arose is not clear, and perhaps not very interesting. It seems likely to have been caused by the misleading phrasing of FitzRoy's 1857 report quoted above, in which the words '*See* Appendix' are so placed as to suggest to any but the wariest reader that what is described in the Appendix would be what was done by Marsden—though in fact it is the system of 10° squares described in the 1855 report; FitzRoy's repetition of his historical account in his *Weather Book* (*op. cit.*, note 29) is similarly misleading. In the earliest discussions of the history of marine meteorology[35] Marsden's work and that done in 1831 are kept separate; their subsequent conflation seems to be an error propagated in secondary accounts.

Summarizing the winds: a comparison of methods

Given the general lack of attention given to meteorology in histories of statistics, it may be worthwhile to consider how these early workers imagined summarizing how the winds blew—something almost proverbially variable. It is probably not surprising that the first investigators confined themselves to regions in which the winds were thought not to vary: the belts of trade winds and monsoons. This restriction applied to the first such summary, Edmond Halley's map of 1686, which showed the winds between (very nearly) 30° N and 30° S.[36] Although Marsden, a century later, also restricted himself to 'the winds between the tropicks' (though taking this more expansively, to be 36° N and 36° S), his approach is interesting (for its date) in its explicitly statistical nature: he imagines extracting some kind of average value from varying observations. (In proposing to display the results on a map he was ahead of his contemporaries but behind Halley.) Given that statistical reasoning at this date is more usually associated with error theory, it is interesting that he would propose to find 'the general result or medium … (discretion being used in extracting such medium)'. He seems to have had pretty clearly in mind the need to produce some kind of summary value, although perhaps not exactly the arithmetic mean (in any case not an obvious choice for a vector quantity).[37]

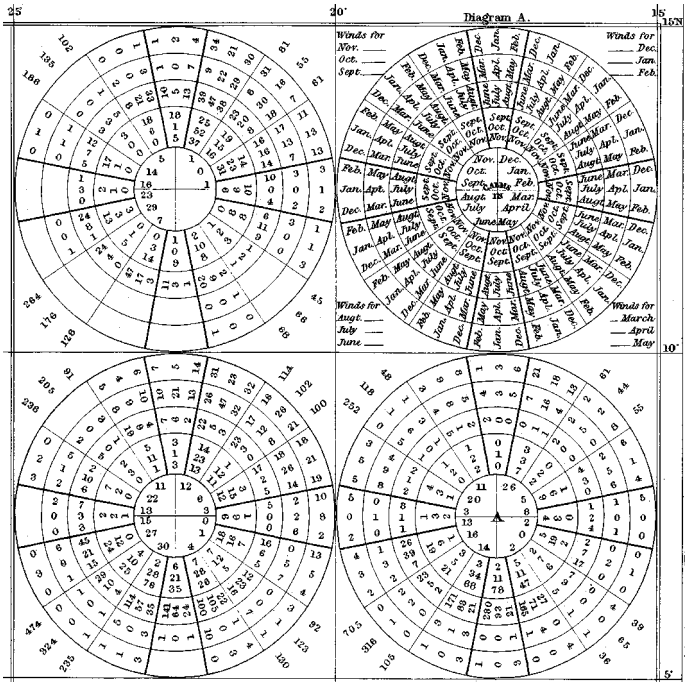

Figure 3. Maury's presentation of the distribution of wind direction, as used on his 'Pilot Charts', here taken from Plate V of Maury's *Explanations and sailing directions* (note 13). The numbers show, for each 5° square, the number of observations of a particular direction during each month, as illustrated by the square in the upper right.

Becher's 1831 proposal has the same restrictions as earlier ones, in showing only means (though for each of 12 months) in the tropics only. Maury's depictions have a much broader coverage, and a more complete presentation: they show the actual distribution of winds rather than a summary value, and attempt to do so for the whole ocean. Maury's first charts showed actual ship tracks, with, next to each track, small symbols to indicate the direction and force of the wind; the season was indicated by the colour used. Of course, once many data had been accumulated in an area this display became badly overcrowded. Maury therefore began producing, in 1849, what he termed 'Pilot Charts'. In these, the distribution of wind directions with a 5° square of latitude and longitude were displayed by giving the number of observations in a kind of circular table, different radii corresponding to different months (figure 3). Any observations made within the square area were assigned to that square: an obvious idea now, but, to judge from the explanations of it that appeared in these early treatments, not so obvious at the time—and at least novel enough for FitzRoy to wish to emphasize British priority in using such a system.

FitzRoy also saw a problem with Maury's charts, one that he quickly moved to correct. Maury reported the actual number of observations within a square, by month and direction; but such numbers could not be interpreted as they stood: 100 observations in a much-frequented region might mean relatively few occurrences. One of FitzRoy's first activities in the Meteorological Department (along with collecting existing data and issuing instruments) was to convert the data on Maury's Pilot Charts into a graphical form

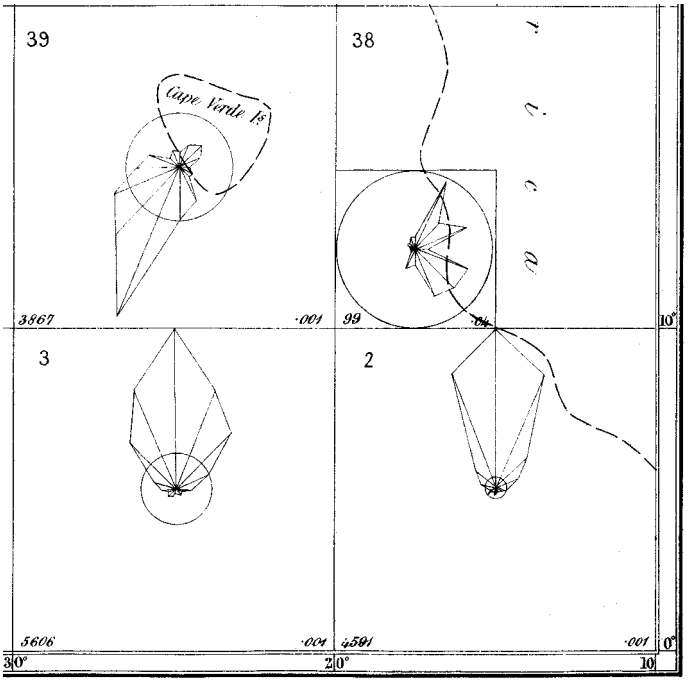

Figure 4. FitzRoy's presentation of the distribution of wind directions, from the first edition of the Wind Charts published by the Board of Trade: a portion of the chart for the North Atlantic (published August 1855), showing the distribution of wind direction for the summer months. Note the 10° square number in the upper left corner of each square: the first appearance of this system in print. The 'stars' show the distribution of winds and the size of the circles the relative proportions of calms. The dotted lines show, approximately, the Cape Verde Islands and the coast of Africa.

that, while preserving the information about distributions, could more easily be understood. This led to the first maps on which the 'Marsden square' numbers appear, the 'Board of Trade Wind Charts'.

On these charts (figure 4), the data in Maury's 5° squares were aggregated into 10° squares and quarterly intervals; the maximum number was scaled to half the side of the square, and the other values were scaled in proportion to give radial lines in the directions of the 16 points of the compass. Connecting the ends of these gave a polygonal figure showing the distribution of winds, which FitzRoy called a 'wind star'.[38] In the end, 11 charts were produced between August 1855 and March 1856, and issued in a portfolio. FitzRoy sent an example to Maury, who although appreciating the method did not change his own procedure—even though he understood the need for normalizing the wind distributions, because he took this step in his own development of suggested sailing routes. Exactly the same criticism of Maury's Pilot Charts was made in an evaluation by a committee of the US National Academy in 1863—although with no apparent awareness of FitzRoy's maps.[39]

FitzRoy and Maury: later interaction

Given FitzRoy's belief that Maury had given insufficient credit to, and perhaps plagiarized from, earlier workers, it is interesting to examine their later interactions. In some striking ways their careers and attitudes were remarkably similar (figure 5). They were born less than a year apart, but certainly to very different backgrounds: FitzRoy to the British aristocracy, Maury to a struggling farm family in Virginia. However, both had settled on a naval career, and as a result had travelled to parts of the world then little visited: they were in Tahiti seven years apart, and in early 1834 both were near Cape Horn.[40] Within their respective navies each stood out as especially dedicated to scientific pursuits, and each was also dedicated to using meteorology to assist mariners—a dedication perhaps connected to both of them being extremely pious even by the standards of the time.[41] Both published popular books based on their work that contained unorthodox ideas and were not enthusiastically received by the scientific establishment; and that same establishment argued strongly against continuing the projects they had started, after each had left that project.[42]

Whatever FitzRoy's concerns about Maury's behaviour their professional interactions were at least cordial on FitzRoy's side; and Maury was extremely open with him on matters both personal (Maury's battles with a Naval board which had put him on the inactive list) and professional (on FitzRoy's behalf, Maury organized American observers for a synoptic weather observation exercise in June 1859).[43] Despite this, FitzRoy remained unhappy with Maury's insensitivity to his predecessors, writing to Herschel in 1858:

> Entirely do I subscribe to your (private and strictly confidential) opinion of Lieut. Maury. He has collected facts (aided by a *large* staff). … He has given good sailing directions—and has duly trumpeted—according to the fashion—(however unworthy) of the day: therefore—in America—he has a large reputation among men of my cloth—who have not heard of old Dampier—Cook—Finders—Dalrymple—Horsburgh etc etc as *educated* men in England have generally. Maury's adoption of other men's ideas—and nonrecognition of their origin is sad.[44]

FitzRoy's feelings were thus apparently shared by at least some English men of science, which might explain why Maury, who received many awards and medals from foreign governments, and developed a number of influential friends in England, nevertheless received no governmental recognition there.[45]

FitzRoy's feelings towards Maury acquire a special importance when one comes to the final, and closely linked, parallelism in their lives: both ended their scientific careers by committing suicide. In Maury's case the suicide was only professional, when in April 1861 he followed many other Southern officers out of the Union forces and into the Confederate ones. In late 1862 he went to England to develop electric mines, and to assist in purchasing and outfitting vessels for the Confederate Navy, not an easy task in an officially neutral Great Britain. At this time he renewed his acquaintanceship with FitzRoy (who earlier in that year had thought it likely that Maury was dead), although since Maury lived in Manchester and FitzRoy in London they would not have had many occasions to see one another. They did have a dispute in February and March 1864. Maury seems to have published (in a French journal) a letter critical of FitzRoy's weather-forecast efforts, to which FitzRoy responded in his annual report in April 1864; they also seem to have corresponded privately on this.[46]

Figure 5. Portraits of (*a*) Robert FitzRoy and (*b*) Matthew Fontaine Maury, from albumin prints of photographs taken by Ernest Edwards for the series *Portraits of men of eminence in literature, science, and art, with biographical memoirs*. The memoir for FitzRoy is on pp. 53–56 of volume 3 (Alfred Bennett, London, 1865); statements in it show that it was probably written in the winter of 1864–65. The entry for Maury is on pp. 109–118 of volume 2 (Lovell Reeve, London, 1864); judging from the location of each entry in its volume and the number of entries published each year, his photograph would have been taken about 8 months earlier.

By this time others besides Maury had begun to criticize FitzRoy's efforts to forecast the weather; and FitzRoy, as on two earlier occasions, responded to this stress by developing nervous symptoms, probably of depression.[47] These symptoms were severe enough that in early 1865 he largely set his work aside, moved from London to the suburb of Lower Norwood, and placed himself under the care of a local physician starting on 18 April. But on 27 April he heard that Maury, then staying with the Rev. Francis Tremlett at the latter's rectory in Belsize Park, was planning to leave England. Tremlett invited FitzRoy to come to say farewell to Maury. This troubled FitzRoy greatly and he initially planned to refuse the invitation. On Saturday 29 April he vacillated and eventually spent the afternoon and evening in a visit, returning from it extremely restless and upset. The next morning he got up, went to shave, and cut his throat. It is poignant to consider how FitzRoy's emotions, already easily troubled, must have been affected by a meeting with Maury, whom he may have in some ways admired, but certainly in some ways disdained—and whom, at that moment, he is unlikely to have envied.[48]

The earliest proposal to collect marine data

Given the interest that Maury showed in defending his own originality, and FitzRoy's desire to find an earlier British example of the collection of data from ship's logs, it is ironic to realize that there was a much earlier precursor to all the examples above—and that this precursor was both British and American, because Massachusetts was a British colony when he wrote. Nor was his proposal (like Marsden's and Becher's) unpublished: indeed, it was printed in the *Philosophical Transactions of The Royal Society of London* in 1727. The author was Isaac Greenwood (1702–45), the first Professor of Natural Philosophy at Harvard University.[49]

Greenwood's interest in meteorology led him to import the first barometer to North America; but it also led him to respond to the request, made by James Jurin in 1723, for the collection of meteorological data.[50] Having travelled between Boston and London in 1721, Greenwood had become familiar with nautical practice, and realized that standard shipboard recordkeeping provided a wealth of data on the weather and especially the winds:

> There was a general Account of the *Weather* for every Day, during the Passage of the Ship on the Voyage … if there is any Defect in this Article, it is abundantly made up in another Column, which is a far more exact Register of the *Direction of the Winds* than was ever kept *ashore*, being an account thereof to every two Hours in the Day. … As for the *Degree* or *Strength* of the Wind, there are also sufficient data in all Sea-Journals to determine it. … Lastly, there is a daily Account inserted of the *Latitude* and *Longitude* of the Ship.

He went on to say that since there was 'a great Variety of these *Marine Observations* already made' it would be 'no difficult matter' for the Royal Societies of London and Paris to collect these, though he recognized the concern that 'the Work will be very much protracted, and require some considerable Application and Care'. He suggested that log-books be collected specifically from ships of the Royal Navy, and hoped that 'the trading Interest' would be willing to contribute, given that the large number of voyages, producing data 'in order to conduct a Ship safely thro' the Ocean' would enable much more complete coverage of the ocean than would for some time be available on land.

Pointing out that the winds at sea are unobstructed by the terrain, Greenwood argued that a collection of wind data would be more accurate than on land, and would provide information on which winds occur where, and at what times; which places and times have regular winds and which do not; and, more practically:

> … were we able to define the more frequent and reigning Winds of every Climate … the Probability of Voyages might then be calculated in the same manner as that of other Chances, [so] the Sailor might then better know to order his Course, so as to arrive with the most probable Dispatch to his Port.
>
> It may not be impossible also, from a protracted Series of *Sea Observations*, … to make a very probable Judgement of the reigning Winds of the several *Seasons of the Year*, … which if it could once be obtained, we should have nothing more uncertain in *Navigation*, than that it was a *Doctrine of Chances*, which might be mathematically calculated.

Although this view of how a collection of wind data might be used for navigational planning is vague, it certainly seems to suggest a probabilistic, and indeed almost statistical, approach to the relation between wind data and setting a course: a remarkably advanced position for its time.

And, like every other practitioner of nautical meteorology, Greenwood proposed a method of tabulating the data by squares of latitude and longitude: in this case, in a table with an overall heading for each day, subdivided into squares by 1° of latitude and longitude, and space in each square in which to enter the wind direction, wind strength, and weather for several times of the day. Greenwood's experience at sea also seems to have come into play in his statement that the 'Strength of the Wind may … be judg'd of from the Effects it produces, or the Motion it communicates to the Ship': the exact basis of the Beaufort scale until the replacement of sail by steam.

Conclusion

It will be clear from the examples given here that Greenwood's idea was not developed, and indeed seems to have been totally forgotten. It is difficult not to conclude, given the existence of his, Marsden's and Becher's proposals to collect wind data from ships' logs, that in some ways this idea was a commonplace one.[51]

However, that the idea was commonplace in some ways brings into sharper focus the contribution of Matthew Fontaine Maury: not just to think of collecting and compiling weather data from logbooks, but actually to get the resources to be able to do this—and on an ever-larger scale, thanks to his ability to distribute free charts and books in return for contributed data, a procedure followed to this day by similar agencies. It is thanks to Maury's entreprenurial abilities that we have such a legacy of marine data from the 1840s and after.

Ever since the work of William H. Goetzmann and especially Susan Faye Cannon, historians of science have referred to the large-scale gathering of data (usually quantitative) about the Earth as 'Humboldtian science',[52] and certainly any of the efforts described here would fit that heading—even though some of them preceded Humboldt. Maury, for one, was consciously a follower of Humboldt—even if many of his scientific contemporaries would have scoffed at the comparison. But here again, Maury's success in creating what many others had talked of highlights a key aspect of Humboldtian science: with rare exceptions (Humboldt himself being one) it demanded resources that only the state could provide; and, before the nineteenth century, few if any states had the resources, still less the desire, to provide them.[53] Humboldtian science was as much a creation of the Industrial Revolution, with its increase in national wealth, as of the ideas of any investigator.

Acknowledgements

I thank Margaret Deacon for alerting me to the existence of Barlow's calendar of the Met. Office papers, Anita McConnell for pointing out the source for figure 5, and Katherine Anderson, Andrew S. Cook, Eric Mills, and Deborah Day for comments and suggestions. I especially thank the interlibrary loan librarians at the Scripps Library for dealing with some very non-standard requests, and acknowledge the benefit I have had from the collections (in both meteorology and exploration) donated to the UCSD library by the late Kenneth Hill.

NOTES

1 S.D. Woodruff, R.J. Slutz, R.L. Jenne and P.M. Steurer, 'A comprehensive ocean-atmosphere data set', *Bull. Am. Meteorol. Soc.* **68**, 1239–1250 (1987).

2 Although the first is misdated: trivially, in that Beaufort first devised his scale in 1806, and more seriously, in that it was not promoted publicly until 1832. See Alfred Friendly, *Beaufort of the Admiralty: the life of Sir Francis Beaufort, 1774–1857* (Hutchinson, London, 1977), Chapter 13.

3 Notably Margaret Deacon, *Scientists and the sea, 1650–1900: a study of marine science* (Ashgate, Aldershot, 1997), p. 290. The 1831 date is given in, for example, D.H. McIntosh, *Meteorological glossary* (HMSO, London, 1972), perhaps derived from P.G. Parkhurst, 'Ocean meteorology: a century of progress', *Marine Observer* **25**, 16–21 (1955); another example is P.J. Meade, 'The history of the World Meteorological Organization, with special reference to oceanography', *Marine Observer* **43**, 25–31 (1973).

4 Stephen S. Stigler, 'Stigler's Law of Eponymy', *Trans. N. Y. Acad. Sci.* (2) **39**, 147–157 (1980).

5 William Marsden, *A Brief Memoir of the Life and Writings of the Late William Marsden, Written by Himself, with Notes from His Correspondence* (privately printed by J. and L. Cox and Sons, London, 1838).

6 So much so that Marsden reports that when he accepted his post at the Admiralty, King George III commented that Banks would certainly miss having Marsden at these events.

7 William Marsden, 'Account of a phenomenon observed upon the island of Sumatra', *Phil. Trans. R. Soc. Lond.* **71**, 383–385 (1781). His subsequent publications in *Phil. Trans.* were two papers and a note, all on chronology.

8 William Marsden, *The History of Sumatra, Containing an Account of the Government, Laws, Customs, and Manners of the Native Inhabitants, with a Description of the Natural Productions, and a Relation of the Ancient Political State of that Island*, 3rd edn. (Longman, Hurst, Rees, Orme & Brown, London, 1811).

9 See Marsden, *op. cit.* (note 5), pp. 53–54, 71, 78 and 85. Christopher Lloyd, *Mr. Barrow of the Admiralty* (London: Collins, 1970) and F.B. Wickwire, 'Admiralty secretaries and the British civil service', *Huntington Library Q.* **28**, 235–254 (1965) describe the activities of the Admiralty Secretaries—although one falls largely after, and the other before, Marsden's tenure. Why Marsden was appointed is not clear; although he must have had some 'interest' (that is, a patron), it is not clear who this might have been. He and his brother had, in 1784, set up an agency for handling remittances from the East Indies; from this he may have gained a reputation for organizational ability.

10 Marsden's widow supplemented his memoir by notes from his memorandum books; many of these notes include statements of temperatures on particular days. The comment about 'self-registering' instruments is on p. 145 and refers to a period between 1810 and 1820.

11 There are many biographies of Maury. Frances L. Williams, *Matthew Fontaine Maury, scientist of the sea* (Rutgers University Press, New Brunswick, NJ, 1963) is the most thorough and scholarly, if sometimes overly hagiographical. Robert V. Bruce, *The launching of modern American science: 1846–1876* (Alfred A. Knopf, New York, 1987) sets Maury in the context of the overall state of American science; James Rodger Fleming, *Meteorology in America: 1800–1870* (The Johns Hopkins University Press, Baltimore, MD, 1990) describes contemporary American meteorology in more detail, although giving little attention to Maury's work. Steven J. Dick, in 'Centralizing navigational technology in America: the U.S. Navy's Depot of Charts and Instruments, 1830–1842', *Technol. Culture* **33**, 467–509 (1992) and in *Sky and ocean joined: the U.S. Naval Observatory, 1830–2000* (Cambridge University Press, 2003) describes the formation and early development of the depot. The second reference discusses, in much detail, the establishment of the Naval Observatory and its operation under Maury, although more with reference to Maury's astronomical research than to meteorology. The best evaluations of Maury and his relationships within the American scientific community are John Leighly, 'M.F. Maury in his time', *Bull. Inst. Oceanogr. Monaco, Numéro Spéc. Congr. Int. Hist Oceanogr.* **1**, 147–159 (1968)

and Mark Rothenberg, 'Observers and theoreticians: astronomy at the Naval Observatory, 1845–1861', in *Sky with ocean joined: Proceedings of the Sesquicentennial of the U.S. Naval Observatory* (ed. S.J. Dick and L.E. Doggett) (Washington, U.S. Naval Observatory, 1983), pp. 29–43.

12 Hugh R. Slotten, *Patronage, practice, and the culture of American science: Alexander Dallas Bache and the U.S. Coast Survey* (Cambridge University Press, 1994) describes the Coast Survey most fully; Thomas G. Manning, *U.S. Coast Survey vs. Naval Hydrographic Office: a 19th-century rivalry in science and politics* (University of Alabama Press, Tuscaloosa, 1988) describes various unsuccessful attempts, mostly after the period covered here, to shift coastal mapping to the US Navy (which did supply personnel to the Coast Survey). The US Naval Hydrographic Office did not undertake mapping of other countries' coasts until a rather tentative beginning in 1872.

13 Williams, *op. cit.* (note 11), Chapter 10, is still the only thorough description of Maury's program in nautical meteorology. J. Lyman, 'The centennial of pressure-pattern navigation', *Proc. US Naval Inst.* **74**, 309–314 (1948) and Marc I. Pinsel, 'The Wind and Current Chart series produced by Matthew Fontaine Maury', *Navigation* **28**, 123–137 (1981) provide summaries, the latter having good illustrations of the various chart types. Maury's own account of progress towards his charts is M.F. Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, 3rd edn (C. Alexander, Washington DC, 1851), pp. 22–26.

14 Williams, *op. cit.* (note 11), Chapter 11, describes the events leading to the Brussels conference, although her account should be supplemented by the description in Fleming, *op. cit.* (note 11), pp. 107–109, which shows the extent to which Maury ignored existing work in the USA, notably the programme run by the Smithsonian Institution under Joseph Henry; and by J. Burton, 'Robert FitzRoy and the founding of the Meteorological Office', *Br. J. Hist. Sci.* **19**, 147–176 (1986), which describes the original British initiative. The Royal Society report is S. Hunter Christie, 'The reply of the President and council to a letter addressed to them by the Secretary of State for Foreign Affairs, on the subject of the cooperation of different Nations in Meteorological Observations', *Abstr. Pap. Present. R. Soc. Lond.* **6**, 188–192 (1852); the 1845 conference it refers to is described in 'Proceedings connected with the magnetic and meteorological conference, held at Cambridge in June 1845', *A. Rep. Br. Assoc. Advmt Sci.*, 1–73 (1845). As the title suggests, this was in fact devoted almost entirely to geomagnetic measurements. Williams suggests that the Royal Society report suggested a more limited conference in part because of a request from Henry to Edward Sabine (1788–1883), then Treasurer of The Royal Society. However, the published letters between Henry and Sabine for this period discuss only the exchange of scientific journals: see Sabine to Henry, 19 March 1852, and Henry to Sabine, 7 May 1852, in Nathan Reingold (ed.) *The papers of Joseph Henry* (Smithsonian Institution Press, Washington DC, 1998), vol. 8, pp. 297 and 315. The results of the Brussels conference were published as *Maritime Conference Held at Brussels for Devising a Uniform System of Meteorological Observations at Sea: August and September 1853* (printed by Hayez, Brussels, 1853). This includes the detailed minutes of the meetings, which show the importance of suggestions by Maury and Beechey—and, incidentally, that the dynamics of committee meetings have changed little in 150 years.

15 Burton, *op. cit.* (note 14) and J.M.C. Burton, 'The history of the Meteorological Office to 1905' (PhD thesis, The Open University, 1989) are the best references on the founding and early history of the Meteorological Office; see also R.P.W. Lewis, 'The founding of the Meteorological Office, 1854–55', *Meteorol. Mag.* **110**, 221–227 (1981). Unfortunately much of the archival material for this period was not readily available when these accounts were written; it was transferred to the Public Record Office only later. Derek Barlow, *Origins of meteorology: an analytical catalogue of the correspondence and papers of the first Government Meteorological Office, under Rear Admiral Robert FitzRoy, 1854–1865, and Thomas Henry Babington, 1865–1866; of the successor Meteorological Office from 1867, primarily during its first two years under the Scientific Committee appointed by The Royal Society; and of Registers of Instruments issued by*

the successive Meteorological Offices from 1854 up to c. 1915 (Public Record Office, Kew, 1996) is an enormously thorough calendar of these papers, using an elaborate referencing scheme. I have in general relied on Barlow's descriptions of these documents. I reference them as Bnnnn, where nnnn is Barlow's internal item number; I also give the PRO piece number, which is usually in group BJ 7. If I have consulted the original documents I place Barlow's item number in square brackets.

16 H.E.L. Mellersh, *FitzRoy of the Beagle* (Rupert Hart-Davies, London, 1968), and the *Dictionary of national biography*, are the main sources for FitzRoy's biography—other than the *Beagle* voyage, for which there is a vast literature; one particularly relevant book is Richard Darwin Keynes (ed.), *The* Beagle *record: selections from the original pictorial records and written accounts of the voyage of H.M.S.* Beagle (Cambridge University Press, 1979), because it reproduces some of FitzRoy's letters during the voyage. Michael Lewis, *The Navy in transition, 1814–1864; a social history* (Hodder & Stoughton, London, 1965) describes the difficulties faced by Royal Navy officers. Paul Moon, *FitzRoy: governor in crisis, 1843–1845* (David Lang, Auckland, 2000) covers FitzRoy's New Zealand governorship in great detail, although the military situation is described better by James Belich, *The New Zealand wars and the Victorian interpretation of racial conflict* (Auckland University Press, 1986). The University of California library holds a bound volume of various short works by FitzRoy, one of which is a printed 'Memorandum: private and confidential' dated 15 March 1852. On the cover is written, in FitzRoy's hand, '*60* copies—to be sent to 4 Norland Square—when finished. Robt FitzRoy March 18/52.' This is a short biography of FitzRoy, covering some episodes for which there is no other evidence; though it is in the third person, its style—with its frequent use of dashes—is clearly FitzRoy's own. It seems to be a *curriculum vitae*, to be circulated to prospective employers, because near the end it states '[H]is sole object now is to follow up his own proper profession as soon as he can obtain employment in command of a ship. … He is free to undertake any service.'

17 Jane H. Wilde, 'The creation of the Marine Department of the Board of Trade', *J. Transport Hist.* **2**, 193–206 (1956).

18 Sabine to FitzRoy, 5 November 1853 (B0122, BJ 7/112); FitzRoy memorandum, 5 November 1853 (B0123, BJ 7/113). Letters from G.B. Airy to R.E. James of the Royal Engineers (13 October 1853: B0119, BJ 7/109) and to Beechey (11 November 1853: B0124, BJ 7/114) indicate that Airy was originally willing to take on the meteorological work, but then changed his mind. Beaufort's assistant John Washington wrote to FitzRoy on 10 January 1854 (B0139, BJ 7/122) offering the facilities of the Hydrographic Office, and stating that he viewed the idea of Playfair collecting data as 'a farce'. Maury, in writing to Sabine on 16 March 1854 (B0012, BJ 7/65), acknowledges a letter of 13 January 1854; because he says that he 'anticipates much from FitzRoy' it seems that Sabine, at least, was by then assuming that FitzRoy would head the meteorological effort. FitzRoy's letter agreeing to do so (B0143, BJ 3/78) contains the odd postscript that he reserved 'other topics and *private* feelings'.

19 PRO BJ 7/149 [B0189].

20 FitzRoy's letter to Darwin, 16 November 1837, is reprinted in *The correspondence of Charles Darwin* (ed. Frederick Burkhardt and Sydney Smith) (Cambridge University Press, 1986), vol. 2, pp. 57–58. For the Henry comment, see Reingold, *op. cit.* (note 14), pp. 126–128.

21 Biographical information on Becher comes from L.S. Dawson, *Memoirs of hydrography*, pp. 48–49 (Cornmarket Press, London, 1969, reprint of the original 1885 edition), and A. Day, *The Admiralty Hydrographic Service, 1795–1919* (HMSO, London, 1967), pp. 35–36 and 57. The bottle chart is illustrated in Anita McConnell, *No sea too deep: the history of oceanographic instruments* (Adam Hilger, Bristol, 1982), pp. 137–138. Pages 50–59 of this work, which describe the development of the detaching-weight (Brooke) sounder, do not support FitzRoy's belief that it had been previously invented in England.

22 Also in BJ 7/149 *op. cit.* (note 19).

23 The number of 2° squares in the Indian Ocean (north of 34° S) with more than 50% ocean is just under 900, according to the detailed land–sea data of C.K. Shum, B.E. Schutz, J.C. Ries and

B.D. Tapley, 'Digitized global land-sea map and access software', *Bull. Geod.* **61**, 311–317 (1987)—which uses, and was my introduction to, Marsden squares. Extending the system of squares to (say) 40° S would make the total only about 1050, so it is not clear how Becher got to 1400 squares.

24 This report was suppressed by Beechey, apparently in part because he feared it would offend Maury; FitzRoy saved a few copies and distributed them privately. A copy is available in the library of the Meteorological Office, Bracknell. For the suppression, see FitzRoy to Maury, 19 September 1855, B0030, BJ 7/77, and FitzRoy to Lord Stanley (President of the Board of Trade) 24 April 1856, B0776, BJ 9/1, p. 118.

25 Report of the Meteorological Department of the Board of Trade, Parl. Papers, 1857 Session 2 [2234] XX.283.

26 BJ 7/385 [B0846]. This also includes the Sabine, Marsden and Becher materials referred to in the rest of this section.

27 The translated articles are M. Semyns, 'Bericht wegens de eigenschappen der land on zee-winden: waaijende langs de kusten van't eiland Java wel inzonderheidt te Batavia. Volgens eene veeljaarige bevindinge', *Verh. Holl. Maatsch. Wet. Haarlem* **2**, 413–418 (1755) and M. Semyns, 'Verhandeling over de natuurlijke oorzak der algemeene en beurthoudende pasaat-winden of moussons', *Verh. Holl. Maatsch. Wet. Haarlem* **3**, 183–222 (1757); Marsden does not give the exact reference, but it is clear that these (which references I take from *International bibliography of meteorology: from the beginning of printing to 1889* (ed. James R. Fleming and Roy E. Goodman) (Diane Publishing, Upland, PA 1994)) are the ones referred to.

28 Surf was a particular interest of Marsden's; in *History of Sumatra* (*op. cit.*, note 8), pp. 34–39, he notes that this term is not known in English and describes the very large and regular breakers on the west coast of Sumatra, which he contrasts with the large but irregular waves on the Atlantic coast of Ireland. It is possible that the instructions were to Capt. Joseph Huddart, an East India captain with scientific interests; if so, this would have been written in spring 1780 or late 1783/early 1784, at which times Huddart was in England but preparing to voyage to India; see William Huddart, *Unpathed waters: account of the life and times of Joseph Huddart FRS* (Quiller Press, London, 1989). (I owe this reference and suggestion to Andrew S. Cook.)

29 When FitzRoy repeated the historical summary from his 1857 report in Robert FitzRoy, *The weather book: a manual of practical meteorology*, p. 49 (Longman, Green, Longman, Roberts and Green, London, 1863), he added a footnote 'General Sabine has the documents', to his comment about Marsden—although Sabine had not in fact returned them. After FitzRoy's death Sabine wrote to the new head of the Department, Babington, requesting the return of the materials, but perhaps because Sabine misstated the materials as a memoir by Alexander Dalrymple, Babington was unable to locate them (Sabine to Babington, 25 Aug 1866, BJ 7/55; Babington to Sabine, 28 Aug 1866, B2190, BJ 7/865).

30 On p. 32 of his *Memoir* (*op. cit.*, note 5), Marsden refers to a period 'when my attention was directed to the subject of the winds, &c. prevailing between the tropics', as the context for a note on land and sea breezes on the SW coast of Sumatra.

31 The footnotes making these points are on pages 21 and 24 of the third edition (*op. cit.*, note 8). I have not seen the second edition, but the notes are present in the French translation of it: William Marsden, *Voyage a l'isle de Sumatra, où l'on décrit le gouvernement, le commerce, les arts, les loix, les coutumes et moeurs des habitans; les productions naturelles, et l'état politique du pays; Traduit de l'anglois par J. Parraud, sur la 2. ed.* (Buisson, Paris, An II [1793 or 1794]).

32 *Regulations and Instructions Relating to His Majesty's Service at Sea*, pp. 193–195 and Form 25 (W. Winchester & Son, London, 1806), describes the logs to be kept by the Master (and forwarded to the Admiralty); their layout is essentially that of the standard East India Company log in use since 1761, or indeed of earlier logs, as described by D.W. Waters, *The art of navigation in England in Elizabethan and early Stuart times* (Yale University Press, New Haven, CT, 1958), pp. 203, 282–294, and W.C. May, 'The logbooks used by ships of the East India Company', *J. Inst. Navig.* **27**, 116–118 (1974).

33 H.T. Smith, 'Biographical notes of some leaders of marine meteorology, V. Captain Henry Toynbee', *Marine Observer* **1**, 74–75 (1924) and H.T. Smith, 'Marine meteorology, history and progress', *Marine Observer* **2**, 33–35, 90–92, 173–175 (1925) summarize the nineteenth-century processing methods of the Meteorological Office. The most detailed account of the difficulties with FitzRoy's system, and of Galton's proposed replacement, is in Francis Galton, Thomas H. Farrer and Frederick J. Evans, 'Report of a Committee to consider certain questions relating to the Meteorological Department of the Board of Trade', pp. 7–11, Parl. Papers 1866 [3646] LXV.329. M.C. George, 'An annotated bibliography of some early uses of punched cards in meteorology', *Bull. Am. Meteorol. Soc.* **26**, 76–85 (1946) describes the adoption of punch-card methods by the Meteorological Office; as pointed out by C.C. Bates, 'Marine meteorology at the U.S. Navy Hydrographic Office—a resume of the past 125 years and the outlook for the future', *Bull. Am. Meteorol. Soc.* **37**, 519–527 (1956), he overlooks their use by the US Hydrographic Office in the 1890s: see *The treatment of marine meteorological data with special reference to the work of the United States Hydrographic Office* (US Hydrographic Office Publication 113, Washington DC, 1897), which is so early that Hermann Hollerith is personally thanked for providing the illustrations. This document also makes clear that the US Office continued to use Maury's grouping by 5° squares.

34 Galton *et al.* (*op. cit.*, note 33), who can be assumed to have taken their terminology from the Meteorological Department, call them (p. 7) 'Ten-degree Squares' and include a global map of them as their Appendix 4.

35 Such as H.T. Smith, *op. cit.* 1925 (note 33).

36 Edmond Halley, 'An Historical Account of the Trade Winds, and Monsoons observable in the Seas between and near the Tropicks, with an attempt to assign the phisical cause of said winds', *Phil. Trans. R. Soc. Lond.* **16**, 153–168 (1686).

37 The *OED* indicates that 'medium' was not unusual as a synonym for 'mean' at this period. O.B. Sheynin, 'On the history of the statistical method in meteorology', *Arch. Hist. Exact Sci.* **31**, 53–95 (1984) brings together a number of early comments, although in somewhat undigested form; he points out that for temperature at least, a preferred summary value was halfway between the maximum and minimum; this might have been in part because it was much easier to compute than the arithmetic mean. An early example not noted by Sheynin is Richard Kirwan's *An Estimate of the Temperature of Different Latitudes* (London: J. Davis, 1787), which lists a number of 'mean' temperatures; on p. 5 Kirwan attributes the use of means to Tobias Mayer's *Opera Inedita*; more precisely, this is the article (of 1755) 'A more accurate definition of the variations of a thermometer'. See *Tobias Mayer's Opera Inedita: the First Translation of the Lichtenberg Edition of 1775* (transl. Eric G. Forbes) (Macmillan, London, 1971), pp. 53–61. Both Kirwan and Mayer draw the analogy with the 'mean motions' of astronomy, with Kirwan saying that Mayer showed 'the necessity … of first finding the mean of certain large periods, as months and years'. This would seem to reflect the idea of eliminating actual variations, not just errors, which are usually taken to be the only kind of variation treated statistically before the nineteenth century; see Stephen M. Stigler, *The history of statistics: the measurement of uncertainty before 1900* (Belknap Press of Harvard University Press, Cambridge, MA, 1986). However, neither Mayer not Kirwan indicate whether their 'mean' is the arithmetic mean, or some other summary value. See also R.L. Plackett, 'Data analysis before 1750', *Int. Statist. Rev.* **56**, 181–195 (1988).

38 The procedure is summarized in R. FitzRoy, 'Wind charts of the Atlantic, compiled from Maury's pilot charts', *A. Rep. Br. Assoc. Advmt Sci.* part 2, 39–40 (1855), and on the charts, 12 of which were issued in a portfolio in 1856. The originality of FitzRoy's wind stars was questioned by A.F. Osler, 'An account of the self-registering anemometer and rain-gauge erected at the Liverpool observatory in the year 1851, with a summary of the records for the years 1852, 1853, 1854, and 1855', *A. Rep. Br. Assoc. Advmt Sci.*, 127–142 (1855), who pointed out that he had used the same type of display in A.F. Osler, 'Report on the observations recorded during the years 1837, 1838, 1839, and 1840 by the self-registering anemometers erected at the Philosophical Society, Birmingham', *A. Rep. Br. Assoc. Advmt Sci.*, 321–347 (1840); Plate 4 of this last is clearly a wind

star. Another precedent for a polar plot of wind distribution, although drawn as a smooth curve, was a figure by the French engineer Leon Lalanne (1811–92), who provided a graphical representation of wind duration as part of his appendix to Ludwig F. Kaemtz, *A Complete Course of Meteorology. With Notes by Ch. Martins and an Appendix, Containing the Graphic Representation of the Numerical Tables, by L. Lalanne. Translated, with Notes and Additions, by C.V. Waker* (H. Baillière, London, 1845); for information on Lalanne, see Gilles Palsky, *Des chiffres et des cartes: naissance et développement de la cartographie quantitative française au XIXe Siècle* (Ministère de l'enseignment supérieur et de la recherche, Comité des travaux historiques et scientifiques, Paris, 1996), pp. 102–109, and T.L. Hankins, 'Blood, dirt, and nomograms: a particular history of graphs', *Isis* **90**, 50–80 (1999).

39 FitzRoy sent an example of wind stars to Maury in a letter of 19 Sep 1855 (B0030, BJ 7/77); Maury's response, terming them 'beautiful' is Maury to FitzRoy, 30 October 1855 (B0034, BJ 7/80). Maury's use of normalized distributions is on pp. 112–116 of Maury, *op. cit.* (note 13). The National Academy report (made in response to a request for evaluation from the US Navy Bureau of Hydrography) is F.A.P. Barnard, W. Chauvenet A. Caswell, J. Winlock, B. Pierce, J.E. Hilgard, J.F. Frazer, J.D. Dana and J.H. Alexander, 'Report of the committee of the National Academy of Sciences appointed to examine the "Wind and Current Charts" and "Sailing Directions" issued from the National Observatory', *A. Rep. Natl Acad. Sci.* **1**, 98–112 (1863).

40 In February and March 1834 Maury was going around Cape Horn, returning on USS *Potomac* from patrol duty in South America; Williams, *op. cit.* (note 11), pp. 99–100. At this time HMS *Beagle* was surveying southern Tierra del Fuego. Maury visited Tahiti in 1829 aboard USS *Vincennes*; *Beagle* visited in 1835.

41 FitzRoy's adherence to Biblical literalism led him to defend the Noachian flood in his *Narrative* of the *Beagle*'s voyage (text reproduced in Keynes, *op. cit.* (note 16), pp. 368–382), and his denunciation of his former shipmate's theory of evolution at the Oxford BAAS meeting in 1860 is well known. Maury's popular writings, notably Matthew F. Maury, *The Physical Geography of the Sea* (Harper, New York, 1855; reproduced by Harvard University Press, Cambridge, MA, 1963), is replete with theological and Biblical arguments for particular features of the Earth, to an extent that troubled even contemporary reviewers, as summarized in John Leighley's introduction to the 1963 reprint.

42 The books are FitzRoy's *Weather Book* (note 29) and Maury's *Physical Geography* (note 41). The negative report on FitzRoy's work was Galton *et al*. *op. cit.* (note 33); that on Maury's publications was Barnard *et al.*, *op. cit.* (note 39). It should be noted that the request for review of Maury's efforts came from Charles Henry Davis, and the National Academy committee was empanelled by Alexander Dallas Bache of the Coast Survey. Both had been bitter antebellum rivals of Maury (Bruce, *op. cit.* (note 11), Chapter 13), so this report could hardly have been positive—although its criticisms seem sound. As pointed out by Burton, *op. cit.* 1986 (note 14), the statistical analysis used by Galton to argue the uselessness of FitzRoy's forecasts was itself flawed.

43 See Maury to FitzRoy, 1 December 1857 (B0052, BJ 7/89) and 15 March 1859 (B0071, BJ 7/97), and observations sent by Maury to FitzRoy, June 1859 (B0078, BJ 7/101).

44 FitzRoy to Herschel, 4 May 1858, quoted from J.M.C. Burton, *op. cit.* (note 15), p. 32; the original is in the Herschel correspondence in The Royal Society Archives, Hs 7.252. It should be noted that Herschel was in conflict with Maury over the driving force of ocean currents, with Maury favouring density differences and Herschel wind stress; see Deacon, *op. cit.* (note 3) , pp. 292–294. It is somewhat ironic that the view from America was just the converse, with Joseph Henry writing to Sabine on 8 July 1861, 'Maury, sustained by the puffing he was constantly receiving from England, arrogated to himself all the science of the country …' (quoted from Fleming, *op. cit* (note 11), p. 110, note 92).

45 Barlow, *op. cit.* (note 15), Section 31, describes a series of letters in early 1865 (BJ 7/850) between Maury's friend, the London minister Francis Tremlett, and Sabine and others of The Royal Society, in which Tremlett attempted to get support from the Society for a testimonial for Maury, something Sabine firmly declined to do.

46 Williams, *op. cit.* (note 11), Chapter 20, covers Maury's Civil War work in England; see also Warren F. Spencer, *The Confederate Navy in Europe* (University of Alabama Press, University, AL, 1983), Chapter 5. FitzRoy's guess is in a letter of 26 July 1862 (BJ 9/11 p. 71, B0095). Maury's 1864 letter is not listed in Williams' bibliography of his writings. FitzRoy's response to this is in Appendix G (dated 25 February 1864) to the 1864 'Report of the Meteorologic Office of the Board of Trade', Parl. Papers 1864 [3334] LV.125. In this FitzRoy says that Maury wrote 'discouraging such forecasts as are now drawn in France and England', which he attributed to Maury's lack of awareness of what FitzRoy had accomplished, 'owing perhaps to his own able mind having lately been unavoidably engrossed by lamentable internecine war'. Barlow, *op. cit.* (note 15), describes a memorandum of 24 February 1864 (BJ 7/775, B1879) from FitzRoy to his assistant deploring Maury's article, which suggests that Maury had not warned him of it. This dispute might have been related to the French programme (following FitzRoy) in weather forecasting, described by John L. Davis, 'Weather forecasting and the development of meteorological theory at the Paris Observatory', *Ann. Sci.* **41**, 359–382 (1984). The summary of a letter from Maury on 30 February 1864 (*sic*), in the register of letters received (B2003, BJ 9/12 p. 70) suggests that Maury's concerns were to do with forecasting, given the 'insular position' of FitzRoy's network. This was not an unfair comment, given that exactly this point was made later by the Meteorological Office in defence of its poor forecasting capabilities: see R.H. Scott, *Weather charts and storm warnings*, 3rd edn (Longmans, London, 1887).

47 The first occasion was while in command of the *Beagle* in 1834, when FitzRoy had temporarily relinquished command and gone under the care of the ship's surgeon, writing to Beaufort, 'I am in the dumps' (Keynes, *op. cit.* (note 16), pp. 238–239). The second was in 1850, while in command of HMS *Arrogant*; according to his privately printed memorandum of 1852 (*op. cit.* (note 16)), having 'fairly tired himself out—Captain Fitz Roy was obliged to yield to the effects of fatigue—and anxiety about home affairs—conjoined; which had unnerved him, for a time' although a 'week's change of air only, with absolute rest, sufficed to make him feel himself a different person'. The only professional evaluation of FitzRoy's psychological problems is by the psychiatrist John Bowlby, *Charles Darwin: a new life* (Norton, New York, 1991), p.154 and note, who proposes a diagnosis of unipolar depression, with a possibly enhanced propensity because of the death of FitzRoy's mother when he was young.

48 A detailed account of FitzRoy's last days, by his widow, is in Mellersh, *op. cit.* (note 16), pp. 282–284; see also the report of the inquest in *The Times*, 4 May 1865 (page 14, col. D). Some authors (for example Barlow) have suggested that the visit to Maury would have reminded FitzRoy of his own lack of success, compared with Maury's reputation. But by this time the news had arrived in England of General Lee's surrender of the Army of Northern Virginia to General Grant, of the fall of the Confederate capital at Richmond, and of the assassination of President Lincoln. So Maury's future, as a leading member of the Confederacy, was anything but good: he was a man without employment and indeed without a country, who in fact spent the next four years promoting an unsuccessful colonization scheme in Mexico, and a training course on mine warfare in England, before returning to Virginia; see Williams, *op. cit.* (note 11), Chapters 21 and 22. That FitzRoy's state of mind was such as to be easily upset is shown by testimony at the inquest and by a letter from Col. Henry Edmund Austen to Babington (FitzRoy's assistant), 2 May 1865, (BJ 7/46), who says that when he told FitzRoy on 27 April that he would be moving from Norwood, FitzRoy became 'quite oppressed'.

49 Isaac Greenwood, 'A new method for composing a natural history of meteors', *Phil. Trans. R. Soc. Lond.* **35**, 390–402 (1727). L.G. Simons, 'Isaac Greenwood, first Hollis professor', *Scr. Math.* **2**, 117–121 (1934) and H.H. Frisinger, 'Isaac Greenwood: pioneer American meteorologist', *Bull. Am. Meteorol. Soc.* **48**, 265–267 (1976) provide biographical information on Greenwood (although neither notes the originality of his proposal in 1727). Greenwood became Professor in 1728, being discharged in 1738 for habitual drunkenness.

50 The importation of the barometer is described by W.E.K. Middleton, *The history of the barometer* (The Johns Hopkins University Press, Baltimore, 1964), Chapter 12. Jurin's request is James

Jurin, 'Invitatio ad observationem Meteorologicas communi consilio instituendas', *Phil. Trans. R. Soc. Lond.* **32**, 422–427 (1723), the background to which is discussed by Andrea Rusnock, 'Correspondence networks and the Royal Society', *Br. J. Hist. Sci.* **32**, 155–169 (1999).

51 As another example, from someone who might later have acted upon it, Friendly, *op. cit.* (note 2), p. 142, quotes from a December 1809 letter from Francis Beaufort to Richard Lovell Edgeworth, '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?'

52 William H. Goetzmann, *Army exploration in the American West, 1803–1863* (Yale University Press, New Haven, CT, 1959) and Susan Faye Cannon, *Science in culture: the early Victorian period* (Science History Publications, New York, 1978) are the first two discussions (with somewhat different meanings and spellings). A good recent summary of the literature on this topic—as well as a thorough examination of the activity in practice—is Michael S. Reidy, 'The flux and reflux of science: the study of the tides and the organization of early Victorian science' (PhD thesis, University of Minnesota, 2000).

53 Reidy, *op. cit.* (note 52), makes exactly this point: William Whewell could envisage a coordinated campaign to measure tides, but being (merely) a Fellow of Trinity College could not make this happen; to do so required the commitment of Francis Beaufort and the Hydrographic Office—itself an entity that, before the nineteenth century, the greatest naval power in the world had seen no need for.