Rulers of the Winds

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Chapter 2

Dutch Skies, Global Laws: The British Creation of "Buys Ballot's Law"[1]

Given the prominent role of laws of nature in modern science, it seems appropriate to ask what it takes for an empirical regularity to be crowned with this privileged designation "law." Unlike philosophers, whose reflections on natural laws have filled many volumes, historians have mostly ignored this question.[2] This is even more surprising as the question is arguably largely an empirical one. Historical contingencies have always played a role in the allocation of the label "law." Originally, when the concept was linked with the seventeenth-century rise of the mechanical or corpuscular philosophy as well as the concept of a divine lawgiver, the label was usually reserved for the so-called laws of motion.[3] However, it did not take long before the designation

[1] A shortened version of this chapter was published in *Historical Studies in the Natural Sciences*. A. Achbari and F. van Lunteren, "Dutch Skies, Global Laws: the British Creation of 'Buys Ballot's law'," *Historical Studies in the Natural Sciences*, 2016, *46*: 1–43.

[2] For a general overview of the philosophical literature on "laws of nature," see, for example, John W. Carroll, "Laws of Nature," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (Spring 2012 edition), http://plato.stanford.edu/archives/spr2012/entries/laws-of-nature/ (accessed 11 Aug 2014). Historians have mostly discussed the introduction of the concept of laws of nature in the early modern period; see John Henry, "Metaphysics and the Origins of Modern Science: Descartes and the Importance of Laws of Nature," *Early Science and Medicine*, 2004, *9* (no. 2): 73–114; Lorraine Daston and Michael Stolleis, eds., *Natural Law and Laws of Nature in Early Modern Europe: Jurisprudence, Theology, Moral and Natural Philosophy* (Burlington, VT: Ashgate, 2008); Friedrich Steinle, "The Amalgamation of a Concept: Laws of Nature in the New Sciences," in Friedel Weinert, ed., *Laws of Nature. Essays on the Philosophical, Scientific and Historical Dimensions* (Berlin: Walter de Gruyter, 1995), pp. 316–68.

[3] For the precedent being created by Descartes, cf. Henry, "Metaphysics" (cit. n. 2), p. 97. In this regard even Newton followed Descartes, at least in his *Principia* (1687), where he did not speak of either Kepler's laws or a law of gravitation, but only of "laws of motion." See Curtis A. Wilson, "Kepler's Laws, So-Called," *Newsletter of the Historical Astronomy Division of the American Astronomical Society*, 1994, *31*: 1–2.

was broadened to include many other regularities, such as Newton's law of universal gravitation and Kepler's laws of planetary motion.

In the nineteenth century the number of laws rapidly increased as they came to be seen as the hallmark of science, and especially of the more exact sciences that made predictions possible. In Victorian Britain, John Herschel and William Whewell clearly stressed the primacy of laws as the goals of research in their authoritative writings on the nature of science, and in this respect they were echoed throughout the Victorian era. Thus, Herschel emphasized in his *Preliminary Discourse of the Study of Natural Philosophy* that "we must never forget that … laws, not insulated independent facts, … are the objects of enquiry to the natural philosopher."[4] And in the concluding paragraph, he stated that "science … refers all its advances to the discovery of general laws."[5] Whewell was no less explicit: "our knowledge of nature is our knowledge of laws."[6]

Yet, not all empirical or theoretical regularities, mathematical or otherwise, were actually designated laws. So, what was it that made a natural regularity a *law* in the eyes of nineteenth-century authorities? Instead of suggesting a general answer to this question, the study of one particular case in this chapter shows how an empirical generalization came to be called a "law." The law in question is Buys Ballot's law, which describes the relationship between the wind direction and the spatial distribution of atmospheric pressure. Its importance was enhanced by the scarcity of such general principles in this burgeoning discipline.

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[4] John F. W. Herschel, *A Preliminary Discourse on the Study of Natural Philosophy* (London: Longman, Rees, Orme, Brown and Green, 1831), pp. 13–14.

[5] *Ibid.*, p. 360; For laws in terrestrial physics, see Gregory A. Good, "A Shift of View: Meteorology in John Herschel's Terrestrial Physics," in *Intimate Universality: Local and Global Themes in the History of Weather and Climate*, ed. James Roger Fleming, Vladimir Jankovic, and Deborah R. Coen (Sagamore Beach, MA: Science History Publications/USA, 2006), p. 37.

[6] W. Whewell, *Astronomy and General Physics Considered with Reference to Natural Theology* (London: William Pickering, 1839), pp. 3, 11. As Michael Ruse put it: "Whewell saw a scientific theory, in ideal, as being composed of universal statements, or *laws*." M. Ruse, "William Whewell: Omniscientist," in *William Whewell: A Composite Portrait*, ed. M. Fisch and S. Schaffer (Oxford: Clarendon Press, 1991), p. 88.

In the early nineteenth century the status of meteorology was ambiguous. Lacking a strong theoretical foundation for its mostly empirical practice, it could hardly boast scientific credentials. Endless readings of thermometers and barometers by individual observers had done little to uncover the underlying principles of the daily weather conditions. In 1831, John Herschel wrote of meteorology "as one of the most complicated and difficult, but at the same time interesting, subjects of physical research; one, however, which has of late begun to be studied with a diligence which promises the speedy disclosure of relations and laws of which at present we can form but a very imperfect notion." Fifteen years later Buys Ballot still spoke of "a science which hardly deserves that name" and "which rarely succeeds in connecting its results."[7] The model to be emulated was physical astronomy, where Newton's law of gravitation, combined with his laws of motion, allowed for precise predictions.[8]

The diligence Herschel discerned was, indeed, very present. Meteorology participated in the general boom of terrestrial physics. In the wake of the vigorous campaign by the German traveler and polymath, Alexander von Humboldt, for worldwide measurements of terrestrial magnetism, atmospheric pressures, temperatures, winds, tides, and ocean currents, several governments and scientific societies started to invest large sums of money in such Humboldtian endeavors. In many cases practical interests of trade, public health, and agriculture combined with theoretical ambitions, the ultimate ambition being the discovery of fundamental laws.[9]

Buys Ballot's law was actually not the first so-called meteorological law. During the first half of the nineteenth century, the Berlin professor of physics, Heinrich Dove, had suggested that as a rule the direction of

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[7] Herschel, *A Preliminary Discourse* (cit. n. 4), pp. 328–29; C.H.D. Buys Ballot, *Toespraak over de noodzakelijkheid eener veelzijdige beoefening van wetenschap* (Utrecht, Kemink en Zoon, 1846), p. 37.

[8] Herschel, *A Preliminary Discourse* (cit. n. 4), pp. 265–273.

[9] For Humboldtian Science, see Susan F. Cannon, *Science in Culture* (New York, 1978), pp. 73–110; J. Cawood, "Terrestrial Magnetism and the Development of International Collaboration in the Early Nineteenth Century," *Annals of Science*, 1977, *34*:551–87; W. H. Brock, "Humboldt and the British: A Note on the Character of British Science," *Annals of Science*, 1993, *50*:365–72.

the wind changes in a clockwise direction in the Northern hemisphere. This rule came to be known as Dove's law or the "law of the turning of the wind" (in German, *Drehungsgesetz*). This law was often confused with the so-called law of storms, which stated that in the Northern hemisphere cyclones are characterized by an anti-clockwise motion of the air around an area of low pressure. Both laws were eventually subsumed under Buys Ballot's law. In fact, Dove's law traversed the opposite path from a general law to a local rule. It was eventually seen as a consequence of the eastward motion of depressions through Northern Europe, resulting in the indicated change of direction of the winds at points south of the center of a depression.[10]

It was only around 1870 that meteorology could claim a more durable law, the one that we still designate as Buys Ballot's law. Its canonization took approximately ten years. In the process, which was far from straightforward, a local rule of thumb, dating from 1857, was generalized, transformed, and elevated to the status of law. In studying this process, this chapter hopes to shed light on two deceptively simple questions: why was it named a *law*, and why *Buys Ballot's* law? As we shall see neither of these questions allows for a simple answer. Buys Ballot was not the first to propose that winds blow at right angles to pressure gradients; he was reluctant to generalize his local findings and did not speak of a law, largely as he was unable to fully grasp its underlying cause.[11] He did encourage others to verify his rule at other geographical locations, but he had a hard time in drawing attention to his work outside of the Netherlands.

The story of Buys Ballot's law is profoundly geographical in many respects. Buys Ballot used the safe and speedy crossing of Dutch ships to far-away places to solicit government support for his meteorological endeavors. As we will see, it took the full area of the Dutch territory to find a relationship between winds and pressure distribution. Both the

[10] The gradual eclipse of Dove's law is the topic of the next chapter.

[11] Well-known precedents, to a smaller or larger extent, among several others are Humphrey Lloyd, "Notes on the Meteorology of Ireland," *Transactions of the Royal Irish Academy*, 1856, *22*: 411–96, esp. on p. 461; and William Ferrel, "Essay on the Winds and the Currents of the Ocean," *Nashville Journal of Medicine and Surgery*, 1856, *11*: 7–19.

size and the flatness of the country, expressed in its very name, were particularly helpful in creating an almost ideal atmospheric laboratory. And it took a geographical expansion of the observational network to other areas beyond the Dutch borders to expand the local rule into a global relationship. Place and scale are essential in the establishment of a meaningful atmospheric relationship based on observation of fickle weather conditions.[12]

But the creation of the law was as much a social as an intellectual and geographical achievement. For Buys Ballot, expanding his rule required expanding his network and his international reputation, but it is doubtful whether this in itself would have sufficed for its eventual transformation into a law. On the one hand, meteorology was a highly competitive field, and rivalry among the competitors was strong. On the other hand, even general acceptance would not automatically turn a rule into a law. The eventual transformation into a law appears to have resulted at least partly from specific British concerns at a very specific moment, namely the need to provide scientific credentials to meteorology and, more particularly, to the practice of storm warnings in the wake of institutional changes. In this particular case, then, the use of the term "law" seems to have been at least partly strategic.

This chapter discusses Buys Ballot's meteorological aims and endeavors, the institutionalization of Dutch meteorology, the first formulation of the Dutch wind rule in 1857, its application in the Dutch practice of storm warnings, and Buys Ballot's persistent, though unsuccessful, attempts to draw attention to the rule abroad. It also discusses the emergence of the British Meteorological Office, headed by

[12] For another exemplary instance of a progression from the local study of atmospheric phenomena to an international meteorological project on a global scale, see: Deborah R. Coen, "Scaling Down. The 'Austrian' Climate between Empire and Republic," in *Intimate Universality: Local and Global Themes in the History of Weather and Climate*, ed. James Roger Fleming, Vladimir Jankovic, and Deborah R. Coen (Sagamore Beach, MA: Science History Publications/USA, 2006), pp. 115–40. For a general overview of the role of geographical elements and, more generally, the spatial turn in the history of science, see David Livingstone, *Putting Science in its Place: Geographies of Scientific Knowledge* (Chicago: University of Chicago Press 2003). For the spatial aspects of Humboldtian science see Simon Naylor, "Introduction: historical geographies of science—places, contexts, cartographies," *British Journal for the History of Science*, 2005, *38*: 9–10.

Captain Robert Fitzroy, the controversial British practice of storm warnings, and finally the institutional changes and the resulting social pressures that resulted in the British espousal of Buys Ballot's work.[13] Two polarities permeate this story. Firstly, there is the tension between the aim to uncover the underlying principles of the weather, and thereby turn meteorology into a true science, and the practical needs and interests of seafarers, primarily interested in swift and safe voyages across the oceans. Secondly, there is a tension between the widely perceived need for cooperation and the strong rivalry between the participants, who cherished their own pet theories and who competed for leadership in this new, burgeoning field.

Buys Ballot and the Foundation of the Dutch Meteorological Institute

During his student days at the University of Utrecht, Buys Ballot had both an omnivorous appetite for knowledge and lofty aspirations. It was only with great reluctance that he gave up his philological studies to focus on the sciences. In his youthful ambition he developed a general scheme that aimed to account for all physical and chemical processes in terms of the attractive and repulsive forces operating between point-like material and ether particles, and the resulting vibratory motions. His level-headed supervisors dissuaded him from publishing his speculative ideas.[14] As he would later confide to the Dutch chemist Jacobus van 't Hoff, it was the resulting disillusionment that made him take up meteorology "as a plaything."[15] Although his ambitions were as strong as ever, he learned to be more careful in the future. After he obtained his doctorate in 1844, he did not look for a position. As a man of independent means, he chose to continue his studies with the Utrecht mathematician Richard van Rees. The

[13] For British debates on meteorological predictions, see Katharine Anderson, *Predicting the Weather: Victorians and the Science of Meteorology* (Chicago and London: University of Chicago Press, 2005).
[14] J. P. van der Stok, "Levensbericht C.H.D. Buys Ballot," *Jaarboek der Koninklijke Nederlandsche Akademie van Wetenschappen*, 1899, 59–100, on pp. 67–68.
[15] E. van Everdingen, *C.H.D. Buys Ballot 1817–1890* ('s-Gravenhage: D.A. Daamen, 1953), p. 32.

following year he solicited the university board for an unpaid lectureship. For the next two years he taught geology, mineralogy, and "theoretical chemistry." Meanwhile he analyzed large sets of meteorological observations made in several places in Holland over several decades in the hope of finding some meaningful patterns in the fluctuating temperatures in so far as they differed from the daily and annual variations.[16] His interest in meteorology was strongly connected to the new Humboldtian wave. Already as a student he had assisted Van Rees in a series of meterological measurements as part of an international meteorological project, initiated by Herschel and taken over by the Belgian mathematician Adolphe Quetelet.[17]

In 1847, he was appointed extraordinary professor of mathematics at Utrecht University. By then he had consulted several friends and colleagues about his plans to establish an observatory for meteorology and terrestrial magnetism. He rented a small house on the ramparts of the city and borrowed some instruments from the physical cabinet. Additional instruments were designed and built by his friend and former fellow student Krecke, who agreed to take care of the measurements. These measurements effectively started in 1848.[18] The project involved the creation of a Dutch network of observers in different parts of the country who would read their instruments thrice a day at fixed points in time, in accordance with a protocol established at Utrecht. Buys Ballot undertook the processing and publication of all the assembled data.[19]

In addition to his disappointing experiences in physical theorizing, there were positive factors informing his choice for a large meteorological research project. As he stressed on several occasions, in spite of numerous observations the field was still in its infancy. Theoretical foundations had not been developed or, to put it

[16] *Ibid.*, pp. 56–58.
[17] F. van Lunteren, "De oprichting van het Koninklijk Nederlands Meteorologisch Instituut: Humboldtiaanse wetenschap, internationale samenwerking en praktisch nut," *Gewina*, 1998, *21*:216 –243, on p. 219.
[18] *Ibid.*, pp. 229–30; Richard van Rees to Adolphe Quetelet, 18 Jul 1849, CAQ, Collection 2095.
[19] C.H.D. Buys Ballot, "Iets over de meteorologische waarnemingen aan het observatorium te Utrecht," *Algemeene Konst- en Letterbode*, 1848:379–84.

differently, the field still awaited its Newton.[20] As Buys Ballot told his students in 1846, anyone looking for fame would be well advised to turn to a branch of science as yet hardly deserving that name. A "lucky find" could bring about a revolution.[21] In this respect Buys Ballot shared the view held by other leading figures in science. John Herschel, for example, noted in 1831 that "meteorology, one of the most complicated but important branches of science, is at the same time one in which any person who will attend to plain rules, and bestow the necessary degree of attention, may do effectual service."[22] As late as 1867, a leading figure in British meteorology, George Symons, would remark, "When this Newton of Meteorology is to arise, we know not."[23]

In the late 1840s Buys Ballot considered the time ripe for such a breakthrough. His optimism was partly inspired by the swift developments in electric telegraphy. The telegraph would enable a rapid exchange of meteorological data collected at widespread locations.[24] Moreover, Alexander von Humboldt had paved the way for a science of meteorology by pioneering worldwide depictions of average thermometric and barometric conditions, so-called isotherms and isobars. The next step, already initiated by Heinrich Dove, was to measure disturbances or deviations from these mean values and to find the laws regulating such disturbances. The ultimate goal was to emulate the predictive capacity that characterized all exact sciences, above all astronomy.[25]

With regard to the future prospects of weather predictions, Buys Ballot did not share the notorious scepticism of François Arago or, for

[20] Van der Stok, "Levensbericht" (cit. n. 14), p. 65.
[21] Buys Ballot, *Toespraak* (cit. n. 7), p. 37.
[22] Herschel, *A Preliminary Discourse* (cit. n. 4), p. 133.
[23] George J. Symons, "Reviews: *Sunshine and Showers: their Influence throughout Creation: A Compendium of Popular Meteorology*, By Andrew Steinmetz," *Symons's Monthly Meteorological Magazine*, 1867, *2*:33–34, on p. 34.
[24] Van Everdingen, *Buys Ballot* (cit. n. 15), p. 53.
[25] Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Oxford University Press, Clarendon Press, 1982), p. 513.

that matter, of his former tutor Van Rees.[26] Yet, as he was well aware, the current Dutch practice of extended series of measurements at a single location would not bring this goal nearer. As Buys Ballot stressed time and again, only simultaneous measurements across a large area would lead to progress. Such measurements required large-scale collaboration, preferably across international borders. A Dutch network would not suffice. To further international cooperation, Buys Ballot and Krecke visited several European meteorologists in the summer of 1851. Some of them agreed to exchange meteorological data with Utrecht.[27]

The following year Buys Ballot published his plea for a European network with Dove's Berlin as the center. Further expansion should result in a worldwide net of observatories. Once that was in place, "trade and agriculture would reap the same fruit, as was now harvested by broad navigation."[28] In private he hoped for a leading role for himself.[29] Such a role, however, required institutional backing and preferably some kind of public sanction. So far the observatory had been little more than a private enterprise, partly funded by grants from local societies. To secure the project in the long term and, more importantly, to obtain the authority enabling him to operate on the international stage, Buys Ballot needed the Dutch state to adopt his observatory and turn it into a national institute. In the summer of 1852 he turned to the Minister of the Interior, Johan Rudolph Thorbecke.[30]

In his request for government support, Buys Ballot immediately played his trump card. As a seafaring nation and the center of a colonial empire, the Netherlands would benefit considerably from improved knowledge of maritime winds and currents.[31] Such knowledge would drastically reduce the length of ocean voyages. In this

[26] C.H.D. Buys Ballot, *Les changements périodiques de température* (Utrecht: Kemink & Fils, 1847), pp. 116–117.
[27] Van Everdingen, *Buys Ballot* (cit. n. 15), p. 59.
[28] C.H.D. Buys Ballot, *Meteorologische waarnemingen in Nederland 1851* (Utrecht: Kemink & Zoon, 1852), p. ii.
[29] Van der Stok, "Levensbericht" (cit. n. 14), p. 75.
[30] Van Everdingen, *Buys Ballot* (cit. n. 15), pp. 63–64.
[31] H. G. Cannegieter, *Koninklijk Nederlands Meteorologisch Instituut 1854–1954* ('s-Gravenhage: Staatsdrukkerij- en Uitgeverijbedrijf, 1954), pp. 27–28.

regard he referred to the *Sailing Directions*, based on large numbers of ship's logs, collated by Matthew Fontaine Maury, the superintendent of the Naval Observatory in Washington. If Dutch navy and merchant ships made their logs available through the mediation of a national institute, Maury promised to provide them with his latest sea charts and sailing directions.[32]

Buys Ballot's connections in seafaring circles probably dated from early 1850. He found a strong ally in the Dutch naval officer Marin Henry Jansen. The latter lobbied the Minister of the Navy on behalf of Buys Ballot, requesting that the Dutch professor would receive the logbooks of Dutch warships.[33] The following year Jansen met Maury in Washington, which resulted in a lifelong friendship. Jansen became a staunch supporter of Maury's project, which effectively cemented his alliance with Buys Ballot.[34] In a sense, they were thrown into each other's company. Being a sailor himself, Jansen could overcome the distrust that many sailors held against the pretences of university professors. As a naval officer he could, moreover, mediate with the Minister of the Navy. Most importantly, Maury's program promised concrete short-term results. In turn, Buys Ballot's university chair conferred the necessary scientific status on their joint enterprise.[35]

Although Thorbecke was sufficiently impressed by Buys Ballot's plea to promise an annual subsidy, it is doubtful whether he would have allowed the creation of a state institution. The liberal statesman strongly favored private initiative and therefore restraint in government involvement in scientific affairs. But his government was brought down in early 1853, and his successor Van Reenen eventually supported the foundation of a Dutch meteorological institute.[36] What probably tipped the scales was the Brussels international conference on maritime

[32] Van Everdingen, *Buys Ballot* (cit. n. 15), pp. 62.
[33] *Ibid.*, p. 60.
[34] In the previous chapter, the collaboration between Jansen and Maury has been discussed in detail.
[35] The terms upon which Maury's *Sailing Directions* were furnished to the Dutch merchant ships were confirmed in Jansen's later correspondence with Maury. Marin Jansen to Matthew Maury, 28 Jul 1852, RNO, LR, Box 11; Matthew Maury to Marin Jansen, 7 May 1853, RNO, LS, vol. 9.
[36] Van Everdingen, *Buys Ballot* (cit. n. 15), pp. 63–66.

meteorology, organized by Maury, which aimed to establish a uniform system of measurements as well as the expansion of Maury's enterprise. The Netherlands was represented by Jansen. His report of the meeting to the Minister of the Navy helped secure support for the establishment of the state institute.[37]

In January 1854, Buys Ballot's observatory was expanded and formally transformed into the Royal Dutch Meteorological Institute. Buys Ballot was appointed superintendent, supervising two departments, one for terrestrial meteorology, headed by Krecke, the other for maritime meteorology, run by a naval officer. The first of these was Jansen himself, who was deeply disappointed by the arrangement. Firstly, he detested his subordinance to Buys Ballot. Secondly, he deplored the establishment of the maritime department in the inland town of Utrecht, rather than in a seaport. To aggravate the situation, Jansen and Buys Ballot strongly disagreed about the prescribed measurements to be taken. Jansen repeatedly upbraided Buys Ballot for his ignorance of nautical matters. Within a year the Minister of the Navy intervened and Jansen was replaced by another officer.[38]

Storms, Warnings, and Barometer Readings

Maury's initiatives, particularly the Brussels conference, also spurred other European states to create or support meteorological institutes. Britain established a government office in 1854 under the auspices of the Board of Trade's Marine Department, which was to collect and process meteorological data. Known as the Meteorological Department, the office was headed by naval officer Robert Fitzroy,

[37] *Maritime Conference held at Brussels for devising an uniform system of meteorological observations at sea. August and September 1853* (Brussels, 1853), p. 58; Minister of the Navy to Marin Jansen, 24 Jun 1853, NA, Ministry of the Navy, Box 2274.

[38] Van Everdingen, *Buys Ballot* (cit. n. 15), pp. 67–72. The correspondence among Jansen, Buys Ballot, and the Minister of the Navy throughout 1854 is kept at the Utrecht Archives, KNMI, Box 1199.

who received the title of Meteorological Statist.[39] The French acted more slowly. Not until 1859 did the French government delegate the implementation of the Brussels arrangement to the hydrographical service of the Ministry of Marine, the *Dépôt de la Marine*.[40]

The Brussels conference was not the only incentive to meteorological initiatives at the time. The Crimean War likewise enabled the advocates of the field to press home the need for greater collaborative efforts. In March 1854, Britain and France formally declared war on Russia, and in September allied forces besieged the city of Sevastopol, home of the Russian Black Sea fleet. A violent storm on November 14th of that year ruined the Allies' camps and sank several of their battle ships. Originating in the Atlantic, the storm that hit the allied troops had progressed across Europe for several days before arriving at the Black Sea. Had there been a telegraph line connecting Crimea to Western Europe, a warning might have reduced the losses.[41]

At least this was the claim made by Urbain Le Verrier, the astronomer who found Neptune. He had succeeded Arago as director of the Paris Observatory, now renamed the Imperial Observatory. While reorganizing the observatory, Le Verrier developed ambitious plans for its Meteorological Department. These plans involved the collection of simultaneous observations by telegraph as well as telegraphic storm warnings. His plans were endorsed by the government, although their implementation had to wait for several more years.[42] The use of a meteorological network for collecting data and passing on warnings had also been envisaged by Joseph Henry at the Smithsonian Institution in Washington.[43]

In both the American and French schemes, the warnings were to be based upon information about actual storms and their projected

[39] Anderson, *Predicting the Weather* (cit. n. 13), pp. 108–109; Edward Sabine to Matthew Maury, 13 Jan 1854, RNO, LR, Box 13.
[40] Fabien Locher, *Le savant et la tempête: Étudier l'atmosphère et prévoir le temps au XIXe siècle* (Rennes: Presses Universitaires de Rennes, 2008), pp. 148–151.
[41] James Burton, "History of the British Meteorological Office to 1905" (PhD dissertation, Open University, 1988), p. 39.
[42] Locher, *Le savant* (cit. n. 40), pp. 33–39.
[43] James Rodger Fleming, *Meteorology in America, 1800–1870* (Baltimore: Johns Hopkins University Press, 1990), p. 145.

trajectories. More ambitious, but also more controversial, methods were proposed by the end of the 1850s in both Britain and the Netherlands. In these plans, warnings were not to be based only on storms already observed, but on storm predictions as well. In the past, such predictions had faced the censure of critics like Arago. In 1846, for instance, Arago remarked, "However science may advance, worthy philosophers who care for their reputation will never venture to predict the weather."[44] Fitzroy and Buys Ballot, however, did not share this scepticism, the first basing his optimism on his many years of experience as a sailor, the second on simultaneous meteorological observations.[45]

Buys Ballot proposed an empirical basis for a Dutch warning system in 1857, when he presented a brief note at the Amsterdam Academy in which he related the force of the wind in Holland to the distribution of pressure.[46] By the mid 1850s his network of meteorological stations encompassed Groningen and Den Helder in the north of the country, Maastricht and Vlissingen in the south, and Utrecht and Nijmegen in the middle, covering the entire area of the country. Observations over five successive years had shown that neither the height of the barometer at a single location, nor its rapid rise or fall provided a sufficient indication of the prospect of strong winds. The best indication stemmed from the differences in the barometer readings:

> The difference between simultaneous absolute readings or deviations from the normal reading gives the most certain indication, even when one pays attention to places not too far apart. For out of a thousand times when, within the confines of the Netherlands, this difference at eight in the morning was less than two millimetres, the force of the wind never increased

[44] "Jamais, quels que puissent être les progrès de la science, les savants de bonne foi et soucieux de leur réputation ne se hasarderont à prédire les temps." Arago's remark is quoted in Van der Stok, "Levensbericht" (cit. n. 14), p. 77; and in Anderson, *Predicting the Weather* (cit. n. 13), p. 40.

[45] Buys Ballot, *Les changements* (cit. n. 26), pp. 116–117; Burton, "History" (cit. n. 41), pp. 39–42.

[46] *Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen: Afdeeling Natuurkunde*, 1857, *7*:75–77.

> beyond thirty kilograms per square metre within twenty-four hours, and out of two hundred times when the difference was more than four millimetres, the wind attained a greater strength fifty times.[47]

Buys Ballot immediately went on to spell out the practical consequences of these results. As he stressed, given this strong correlation it would be desirable to use the telegraph each morning to inform all Dutch harbors of the barometer readings at Groningen in the north of the country and Maastricht in the south so as to enable ships to anticipate storms. Only at a later stage did Buys Ballot add some comments on the direction of the wind:

> The direction was or always became easterly (between NE and SE), when the reading was higher in Groningen and Den Helder than in Maastricht. And always west or south west, when higher at Maastricht than at Den Helder, almost without exception.[48]

This early note was a far cry from what later became known as Buys Ballot's law. In this brief note there was no attempt to generalize these local rules of thumb, nor any endeavor to explain them. The counter-intuitive relationship between the direction of the wind and the pressure gradient did not receive any comment and was evidently judged to be of secondary importance.

Buys Ballot seemed more concerned about the practical consequences than about the theoretical underpinnings of his wind rule. In October 1859, he consulted Eduard Wenckebach, Inspector of the telegraphic service in the Netherlands, to discuss the practicalities of his newly invented system of storm warnings. According to his rule, strong winds could be expected when the difference between the barometric readings at the northern and southern stations in the country was more than four millimeters. When storms were

[47] *Ibid.*, p. 76.
[48] *Ibid.*, p. 76.

approaching, he proposed to send warnings to the main harbors containing information on the readings taken at Groningen and Maastricht, and the direction of the winds in the next 24 hours. The message was in the following form: "[barometer reading taken at Maastricht] [direction of the wind] [barometer reading taken at Groningen] [difference in barometer readings] or for example 51.8 WSW 45.-6.8."[49]

By the end of the month, he adjusted his plan and proposed to issue daily weather reports early in the morning to telegraph clerks in major seaports. By instructing the clerks about the rule of barometric differences and the expected direction of the wind, they could decide themselves whether storm warnings were needed and whether safety measures should be taken. In addition, Buys Ballot suggested that the weather reports be published on notice boards as well for the public to view.[50] In the following months Buys Ballot submitted his proposal to the Ministry of the Interior and the Ministry of the Navy. On May 21, 1860, the Minister of the Interior decided in favor of the proposal, and the Dutch telegraphic system of weather reporting and storm warning was in full operation by June 1st.[51]

In his 1857 note to the Dutch Academy, Buys Ballot had announced a more extensive publication in the Academy's *Proceedings* on his wind rule.[52] This promise never materialized. He did, however, in 1860 publish a pamphlet accompanying the introduction of the telegraphic weather reports in June of that year. Entitled *A few rules for forthcoming weather change in the Netherlands*, the brochure aimed at the general public rather than his professional colleagues. It started with an extensive explanation of the working of the mercury barometer, including instructions for its manufacture. Basing his comments on statistical data assembled during the three previous years, he subsequently offered several indications for forthcoming rain and,

[49] Buys Ballot to Eduard Wenckebach, 19 Oct 1859, KNMI, Box 682.
[50] Buys Ballot to the Minister of the Interior, 31 Oct 1859, KNMI, Box 682.
[51] J. Schröder, "Excerpt from Resolution by the Minister of the Interior, dated 21 May 1860," cited in C.H.D. Buys Ballot, *Eenige regelen voor aanstaande weersveranderingen in Nederland* (Utrecht: Kemink & Zoon 1860), pp. 75–76.
[52] *Verslagen* (cit. n. 46), p. 77.

once again, for the force and direction of winds. It is here that we find the classic phrasing of what was to become Buys Ballot's law:

> The rule for the direction of the wind is therefore as follows: if one places oneself in the direction of the wind with one's back towards the place from where it arrives, then one will have the place of lowest pressure on the left side, just as in the case of hurricanes.[53]

Although this rule still only referred to local conditions in the Netherlands, the analogy with hurricanes suggested its wider application. The anti-clockwise motion of the air around the center of a hurricane, itself a center of depression, in the northern hemisphere was known at the time as the "law of storms."[54] Buys Ballot's comparison of these phenomena suggested that weaker winds might behave in a way similar to extremely strong winds.

The analogy also suggested an explanation as to how the wind deviates from its direction toward the region of lowest pressure. As he pointed out, a volume of air approaching from the south would tend to end up east of the point of lowest pressure because of the greater longitudinal speed of the air at lower latitudes, resulting in a spiraling motion. For a similar reason, air coming from the north would pass the point of minimum pressure to the west. However, he could not see why air coming from either east or west would deviate from a straight trajectory. He therefore presented his explanation with some reservations.[55]

As he pointed out, several others before him had tried to account for the circulatory motion of storms:

> Many attempts have been made, to find the reason for this property of hurricanes. The explanations, however, appear

[53] Buys Ballot, *Eenige regelen* (cit. n. 51), p. 50.
[54] Pauline Halford, *Storm Warning: The Origins of Weather Forecast* (Gloucestershire: Sutton Publishing, 2004), pp. 38–43.
[55] Buys Ballot, *Eenige regelen* (cit. n. 51), pp. 55–56.

> somewhat artificial, so that it appears as if one could prove the opposite in the same manner. When it happens occasionally, that a fact is known through observation, before theory leads one to suspect it, it easily happens that one forgets the required circumspection in reasoning.…[56]

Buys Ballot's caution manifested itself throughout the booklet. As he stressed there repeatedly, accurate weather predictions would require information on the distribution of meteorological variables over a complete hemisphere, not only at sea level, but also along the vertical axis. Lacking such data, all one could do for the time being was to "resort to … general rules, or even make do with more local and therefore partial indications."[57] These would only allow one to guess the weather for the following day or at best the next few days. Such predictions were probable rather than certain, but they could still prove to be useful. And useful they seemed to be. Since its foundation several more Dutch cities had requested to be part of the weather reporting network.

Dissemination of the Rule

Buys Ballot's wind rule did not immediately garner the international recognition he craved, notwithstanding the unflagging zeal with which he promoted his work abroad. He published his work in foreign journals, visited foreign conferences, and actively engaged in correspondences with several foreign meteorologists and institutions.[58] Above all Buys Ballot hoped to encourage his colleagues abroad to test the validity of the wind rule in areas beyond the reach of his stations. Hopefully such measurements would transform his local rule into a general principle.[59] However, as we shall see, arousing interest in his empirical results as well as the conclusions he drew from those results,

[56] *Ibid.*, pp. 54–55.
[57] *Ibid.*, p. 34.
[58] Van Everdingen, *Buys Ballot* (cit. n. 15), p. 97.
[59] Buys Ballot to the Minister of the Interior, 27 Dec 1859, and 29 Jun 1860, KNMI, Box 682.

proved to be extremely difficult. The wind rule was either not understood or deliberately ignored by foreign meteorologists, who either were sceptical about meteorological predictions or cherished rivaling schemes or principles.

In 1857, Buys Ballot published a note almost identical to the one he had presented at the Amsterdam Academy, in the French Academy's *Comptes Rendus*.[60] Very soon he started a correspondence with Le Verrier about the use of the telegraph for the collection of meteorological data.[61] In the spring of 1860, Le Verrier informed Buys Ballot about the preparatory steps taken in France to create a storm warning system based on simultaneous observations carried out at French ports. The Frenchman invited Buys Ballot to exchange barometric readings taken at Den Helder, Texel, and Groningen in return for those taken at Brest, Le Havre, and Paris.[62]

The French observations were a welcome addition to Buys Ballot's studies of barometric differences, so he accepted the offer. Le Verrier's letter also prompted Buys Ballot to induce the Dutch Minister of the Interior to adopt his storm warning system before the Frenchman introduced his. Buys Ballot confided to the minister that the French proposals for telegraphic transmission of observations resembled his own. The only difference was that the French were still not in a position to "understand the value of [barometric] differences above the actual readings." Nevertheless, "time was pressing" if the Dutch wished to gain credit.[63] In hindsight, there was no reason to worry, for the first French storm warnings were not dispatched until 1863.[64]

With regard to his attempts to disseminate the wind rule, Buys Ballot's contact with Le Verrier was of little use. The Frenchman stuck to his own storm warning system based on telegraphic transmission of information about actual storms. In this respect, Buys Ballot found a

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[60] C.H.D. Buys Ballot, "Note sur les rapports de l'intensité et de la direction du vent avec les écarts simultanées du baromètre," *Comptes rendus hebdomadaires des séances de l'Académie des Sciences*, 1857, *45*:765–768.
[61] Locher, *Le savant* (cit. n. 40), pp. 43–47.
[62] Buys Ballot to Le Verrier, 11 Apr 1860, KNMI, Box 682.
[63] Buys Ballot to the Minister of the Interior, 9 Apr 1860, KNMI, Box 682.
[64] Locher, *Le savant* (cit. n. 40), p. 56.

far more useful intermediary in Maury. The latter constantly referred to the wind rule in all his major publications as well as in his *Sailing Directions* accompanying his *Wind and Current Charts* from 1858 onward. Like Buys Ballot himself, Maury consistently presented the rule as a local one, referring to the Dutch situation. And like Buys Ballot, he emphasized the predictive value of barometric measurements for the force of the wind, rather than its direction. As he put it both in his *Explanations and Sailing Directions to accompany the Wind and Current Charts* (1859) and in his *Physical Geography of the Sea and its Meteorology* (1860): "Professor Buys Ballot has discovered, practically, the numerical relation between the force of the wind and given barometric differences for certain places in Holland."[65]

Two factors may help to account for Maury's support. Firstly, the Dutch were by far the greatest foreign contributor to his *Wind and Current Charts*.[66] Secondly, Maury still hoped to expand his meteorological network by including land-based observations. He had tried to utilize the weather reporting network founded by Joseph Henry in 1849, under the authority of the recently established Smithsonian Institution. However, Henry denied Maury access to his database, because of the latter's poor scientific qualifications and the allegedly speculative nature of his publications.[67] In the late 1850s, Maury attempted to organize a second international conference that would also include land measurements. However, his efforts were to no avail.[68]

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[65] M. F. Maury, *Explanations and Sailing Directions to accompany the Wind and Current Charts*, 8th edn., vol. 2 (Washington: Cornelius Wendell, 1859), p. 453; M. F. Maury, *The Physical Geography of the Sea and its Meteorology*, 8th edn. (London: Sampson Low, Son & Co, 1860), pp. 430–431.

[66] Scott D. Woodruff et al., "Early Ship Observational Data and Icoads," *Climatic Change*, 2005, *73*:169–194, on p. 170.

[67] Katharine Anderson, "Mapping Meteorology," in *Intimate Universality. Local and Global Themes in the History of Weather and Climate*, ed. J. R. Fleming, V. Jankovic, and D. R. Coen (Sagamore Beach, MA: Science History Publications, 2006), 69–91, on p. 75.

[68] Matthew Maury to Adolphe Quetelet, 12 Dec 1853, CAQ, Collection 1761; Adolphe Quetelet to Matthew Maury, 27 Feb and 7 Aug 1857, RNO, LR, Box 19; 17 May and 26 Jun 1860, Box 26; 3 Oct 1860, Box 27; Marin Jansen to Matthew Maury, 8 Mar 1854, RNO, LR, Box 13; 20 Aug 1858, Box 21.

The only promising solution in this regard came from his correspondence with Buys Ballot. The wind rule had kindled Maury's interest, and he was encouraged to verify its validity in the United States. He used his connection with the Dutch professor to gain support for the establishment of his own network of land observations that could eventually serve as the foundation for an American system of storm warnings.[69]

In May 1858, a petition was presented to the U.S. Senate requesting funding for a project "to ascertain whether Professor Ballot's rule by which the approach of storms may be foretold is applicable to the [area of the great] lakes."[70] In December of that year, the senate voted against the petition. It did, however, authorize the Secretary of War "to provide for taking meteorological observations at the military stations and other points in the interior of the continent, and for giving notice on the northern lakes and seaboard of the approach and force of storms."[71] Like the French, the Americans put more confidence in reporting about actual storms than in providing storm predictions.

Buys Ballot regarded Maury's support for his rule as a mixed blessing. As much as he welcomed any support, Maury's lack of scientific credentials and the careless way in which he expressed himself endangered Buy Ballot's reputation as a man of science. In a letter to the Belgian astronomer, Quetelet, he toned down the claims of discovery that Maury attributed to him. He confessed that he had not made progress in foretelling the emergence of strong winds with the degree of certainty that Maury claimed. He distanced himself from

[69] Maury, *Explanations* (cit. n. 65), p. 453; Maury, *Physical Geography* (cit. n. 65), pp. 430–431. Robert Hatton to Matthew Maury, 3 Mar 1858, RNO, LR, Box 20. Hatton wrote to Maury: "I have just read, in the intelligences your communication on the subject of the application of Prof. Buys Ballot's alleged meteorological discovery, to the navigation of our lakes."

[70] *Journal of the Senate of the United States of America*, 35th Cong., 1st sess., 6 May 1858, 421. In June 1859, Buys Ballot was still under the impression that the senate was considering the petition. Buys Ballot to the Minister of the Interior, 3 Jun 1859, KNMI, Box 682.

[71] *Journal of the Senate of the United States of America*, 35th Cong., 2nd sess., 22 Dec 1858, 1127.

Maury's exaggerated style of writing and argued that he "always remain[ed] cautious not to state more than [he could] demonstrate."[72]

Buys Ballot preferred the approbation of his fellow professors, especially of the leading authority at the time, Heinrich Dove in Berlin. In 1860, he offered a paper on his wind rule to the Berlin-based journal, *Annalen der Physik*, in which he had published several earlier papers. Unfortunately, and much to his surprise, his contribution was rejected by the editor, Johann Christian Poggendorff, a close colleague of Dove.[73] The wind rule happened to rival Dove's own law of winds, and Buys Ballot cast doubts on the latter's validity. In turn, Dove adopted a critical attitude toward Buys Ballot's wind rule. There can be little doubt that this was the main reason behind Poggendorff's otherwise surprising step.[74]

Three years later, in 1863, nearly ten years after the Brussels conference, Dove organized a conference on land meteorology at the annual meeting of the Swiss *Naturforscher Verein* in Geneva. He invited leading meteorologists from several countries including Austria, Italy, Spain, and France. This seemed a perfect opportunity for Buys Ballot to make his wind rule more widely known among his fellow researchers and so he eagerly accepted the invitation. Unfortunately, he was among the very few meteorologists to do so and the conference failed to acquire an international character, leaving Buys Ballot disappointed at the absence of several savants whom he had wished to consult.[75]

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[72] Buys Ballot to Adolphe Quetelet, 30 Jul 1860, CAQ, Collection 561. Quotation in original language: "Vous verrez que je ne suis pas encore autant avancé dans la prédiction des vents forts que M. Maury m'a fait l'honneur dans sa lettre adressée à vous…. Je n'ai pas écrit de cette manière à M. Maury, car j'ai toujours soin de ne plus affirmer que je ne puisse démontrer."

[73] C.H.D. Buys Ballot, "Beiträge zur Vorhersage von Witterungserscheinungen, namentlich von Windrichtung und Windkraft," *Archiv für die Holländischen Beiträge zur Natur- und Heilkunde*, 1864, *3*:85–99, on p. 95.

[74] Anders O. Persson, "Hadley's principle: Understanding and Misunderstanding the Trade Winds," *History of Meteorology*, 2006, *3*:17–42, on p. 29.

[75] Robert Henry Scott, "The international Meteorological Committee," *Nature*, 1902, *66*:608–609; C.H.D. Buys Ballot, *Suggestions on a Uniform System of Meteorological Observations* (Utrecht: The Industry, 1872), pp. 1–2.

Of all foreign countries, England was in a practical sense the most relevant to Buys Ballot. As weather systems tend to move from west to east across the Atlantic toward Europe, he set great store by the exchange of simultaneous barometric observations with the British stations. Access to these data would also enable him to test his rule across a wider area and issue warnings at Dutch ports even further in advance. Before the Dutch storm warning system was established, he had indeed requested the Minister of the Interior to bring his wind rule to the attention of the British Board of Admiralty.[76] Because of the advantageous geographical location of these stations, Le Verrier was interested in the British observations as well.

However, Buys Ballot received no response from England despite his frequent attempts to inform the Meteorological Department and the Royal Society about his method.[77] In August 1863, an opportunity availed itself to make his wind rule known to a scientific audience at the annual meeting of the British Association for the Advancement of Science (BAAS) held at Newcastle. At this meeting Buys Ballot explained his system of forecasting based on his many years of making observations in the Netherlands and most of all on his wind rule:

> More accurately, … the wind will be at nearly right angles with the direction of the greatest difference of pressures. When you place yourself in the direction of the wind, … you will have at your left the least atmospheric pressure…. When the difference of pressure of the southern places above the northern is not above four millimetres, there will be no wind of a force above 30 lbs. on the square metre. [A]t the places [of the greatest difference of observed pressures], there also the force of the wind will be generally stronger.[78]

[76] Buys Ballot to the Minister of the Interior, 12 Nov and 27 Dec 1859, KNMI, Box 682.
[77] Buys Ballot to the Minister of the Interior, 3 Jun 1859, KNMI, Box 682.
[78] C.H.D. Buys Ballot, "On the System of Forecasting the Weather pursued in Holland," in *Report of the Thirty-Third Meeting of the British Association for the Advancement of Science* (London: John Murray, 1864), pp. 20–21.

He also felt emboldened to add a few rules for the prediction of the amount of rainfall and the appearance of thunder. His confidence was partly fed by a favorable paper of a merchant shipper, who compared Buys Ballot's observations and signals with those of Fitzroy, and who had tested both against the actual state of the weather for seven months from August 1861. Buys Ballot's predictions based on four stations were as accurate as Fitzroy's, who received observations from twenty stations.[79]

One can well imagine that Buys Ballot should wish to engage in some form of discussion with Fitzroy. In the midst of widespread skepticism about forecasting, both men had developed a method for storm predictions and had established a warning system in their countries. Yet, strangely enough, no traces of correspondence are to be found between Fitzroy and Buys Ballot. Although the latter frequently mentioned Fitzroy's name in his letters, and constantly strove to draw the attention of several British institutes to his warning system, the two men never seem to have come into contact with one another.[80] Tellingly, Fitzroy did not mention Buys Ballot's wind rule in any of his publications.

To understand the cold shoulder received by the Dutchman, we need to take a closer look at the events that took place at the British Meteorological Department in the period 1860–1870. These events will also make it clear how Buys Ballot's wind rule, which initially served as a method for storm warnings in the Netherlands, was transformed into a scientific principle enabling weather predictions in general, and eventually came to be accepted as a law of nature.

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[79] F. H. Klein, C.H.D. Buys Ballot, and A. Adriani, *The foretelling of the weather in connection with meteorological observations by F.H. Klein together with a description of the telegraphic warning system introduced in The Netherlands, June, 1860, as proposed by the director of the Royal Netherlands Meteorological Institute Professor Dr. Buys-Ballot* (London: Benjamin Pardon, 1863), pp. 25–29.

[80] Buys Ballot to the Minister of the Interior, 3 Jun, 12 Nov, and 27 Dec 1859, KNMI, Box 682.

The British Meteorological Department

In 1863, the same year when Buys Ballot visited the annual BAAS meeting in Britain, Fitzroy published a book on his latest theories of atmospheric circulation. He had supervised the British Meteorological Department for almost a decade and felt it was time to explain his method of forecasting in a work entitled *The Weather Book*.[81] The British storm warning service had come into operation in February 1861, following the Dutch system by nine months. With Fitzroy directing the warning system, the department had outgrown its original tasks.

Officially the department was commissioned (1) to supply instruments, instructions, and registers to Mercantile Marine and Navy ships, and (2) to compile statistical records from the completed registers of marine meteorological observations.[82] Once the compilation of marine data had become routine, Fitzroy turned to other projects. He designed a barometer and wrote a manual for its use. He began a practice of loaning barometers to fishing villages along the British coasts. He made adjustments to Maury's abstract log for oceanic data in what he thought was a form more suitable for mariners. In addition he devised new diagrams named "wind stars" to help seafarers understand Maury's wind charts more easily.[83]

Fitzroy's activities beyond his official brief brought him into conflict with the director of the Marine Department of the Board of Trade, Frederick W. Beechey.[84] When the latter died, Fitzroy applied for the vacancy in 1857. Unfortunately, he was passed over for the post. Instead the position was filled by his former junior officer, Bartholomew Sulivan, who had a brilliant record from the Crimean War. Yet out of respect for his former commander, Sulivan kept his

[81] Robert Fitzroy, *The Weather Book: A Manual of Practical Meteorology*, 2nd edn. (London: Longman, Green, Longman, Roberts, & Green, 1863), p. 172.
[82] Burton, "History" (cit. n. 41), p. 32.
[83] Anderson, *Predicting the Weather* (cit. n. 13), pp. 109–10.
[84] Halford, *Storm Warning* (cit. n. 54), pp. 91, 105.

overall control of the Meteorological Department to a minimum, leaving Fitzroy's hands free to pursue his own program.[85]

In 1857, Fitzroy began constructing synoptic charts based on simultaneous meteorological observations that he received from coastal stations. He hoped to use these charts to understand the movement of atmospheric disturbances over the British Isles. His ultimate aim was to establish a system of storm warnings with the use of the electric telegraph. In the same year, a standard work on the nature of storms was published by Heinrich Dove. Fitzroy could not wait to read *Über das Gesetz der Stürme* and pressed for a translation. He anticipated that Dove's theories might provide an explanation of the weather patterns that he could not understand by looking at his charts. The translation was eventually carried out in 1862 by Robert Henry Scott, who had been a student of Dove's in Berlin.[86]

In the meanwhile, Fitzroy lobbied for a telegraphic warning system and found support at the annual meeting of the British Association in Aberdeen. Herschel, the great scientific authority of the time, backed the idea of communicating the progress of an actual storm by means of the telegraph. The devastating storm of October 1859, which wrecked the iron-clad ocean steamer, the *Royal Charter*, as it tried to reach Liverpool at the end of a voyage from Australia, immediately gave a sense of urgency to Fitzroy's proposal. On June 6, 1860, the President of the Board of Trade authorized the Meteorological Department to prepare a system of storm warnings, which was operational by February 1861.[87]

Fitzroy's warning service was based on several elements, including changes in barometric readings and indications of strong winds along the path of an actual storm, and integrated Dove's theories of middle latitude circulation of air masses consisting of a northerly cold and dry air stream and a southwesterly warm and moist air current. Storms resulted from the conflict between these air currents.[88] To decide

[85] Anderson, *Predicting the Weather* (cit. n. 13), p. 108.
[86] Halford, *Storm Warning* (cit. n. 54), p. 113; Burton, "History" (cit. n. 41), p. 35.
[87] Burton, "History" (cit. n. 41), pp. 41–44
[88] *Ibid.*, p. 35; Anderson, *Predicting the Weather* (cit. n. 13), p. 89.

whether to issue a storm warning, Fitzroy made forecasts for separate districts based on the observations that were carried out at thirteen stations around Britain. In addition Fitzroy received a report of six observations from the continent by Le Verrier, whose storm warning scheme still had not been approved by his government. Fitzroy sent five British observations to Paris in return.[89]

The observations gave Fitzroy an idea of the expected surface winds. When storms were likely to occur, he sent a telegram to the observation station in question. The message contained a list of places with the words "North Cone" or "South Cone," as indications of a storm from a northerly or southerly direction, and "Drum," indicating cyclonic or veering winds. On receipt of the message by the station clerk, a signal was hoisted on a staff that was visible to sailors from all directions.[90] The Secretary to the Admiralty authorized the cautionary signals for a one-year experiment as long as Fitzroy took on the responsibility for them.[91]

In August 1861, Fitzroy exceeded his brief by issuing forty-eight-hour weather forecasts to several daily newspapers. He saw no harm in publishing routine forecasts as he had already made them to decide whether storm warnings were necessary. They were thought useful for the general public, and added hardly any cost to the warning system anyway.[92]

There was broad support for Fitzroy's warning system from the seafaring community, which made ample use of the warnings. When the secretary of the Board of Trade, Thomas H. Farrer, expressed his concern about the rising costs of the department and asked the council of the Royal Society its opinion about warnings and forecasts, the Society responded by quoting Herschel, who had been a supporter of telegraphic warnings. As far as forecasts were concerned, the Society found the query irrelevant on the grounds that the warnings involved

[89] Burton, "History" (cit. n. 41), p. 43.
[90] Anderson, *Predicting the Weather* (cit. n. 13), pp. 112–114.
[91] Halford, *Storm Warning* (cit. n. 54), p. 173.
[92] *Ibid.*, pp. 176–177.

no extra cost.[93] However, the forecasting service began to generate strong criticism from many sides. According to Fitzroy, ship owners were critical of his forecasts because of loss of revenue when their captains refused to set sail after a warning had been given.[94] Then there were those who had no confidence in Fitzroy's scientific method.[95]

In 1863, Fitzroy felt it necessary to justify his method to a broader audience in *The Weather Book*. Much depended on the reception of this work. Fitzroy, who lacked formal scientific training, hoped that the book would demonstrate his skills as an experienced practitioner and someone who had mastered the theories of Heinrich Dove. He explained the nature of storms in middle latitudes according to Dove's collision of polar and equatorial air currents. He also described the gyratory movement of the storm as the result of currents displacing each other around a point of low pressure. Furthermore, he proposed a new principle that he claimed had resulted from years of observations. His investigations had led him to believe that "the entire mass of atmosphere in [the middle] latitude, has a constant, a perennial movement toward the east…."[96]

This proposition actually refers to the geostrophic wind, a flow of air that blows in the northern hemisphere with lower pressure to its left and higher pressure to its right. Although Fitzroy was close to arriving at a general rule, the proposition lacked the simplicity and practicability of Buys Ballot's wind rule. In addition to his claims, Fitzroy offered a controversial explanation for atmospheric circulation. In a separate chapter in *The Weather Book*, he explained how air masses seemed to behave like tides in the ocean following a cyclic pattern under influence of the effect of the moon and the sun. He named this the "lunisolar" effect. [97]

Fitzroy had high hopes that his lunisolar theory would find favor with gentlemen scientists and would become the guiding theory of

[93] Burton, "History" (cit. n. 41), pp. 50, 251 (note 155); Anderson, *Predicting the Weather* (cit. n. 13), pp. 122–123.
[94] Halford, *Storm Warning* (cit. n. 54), p. 175.
[95] Burton, "History" (cit. n. 41), p. 49.
[96] Fitzroy, *Weather Book* (cit. n. 80), pp. 107, 173.
[97] *Ibid.*, pp. 206, 244–56.

atmospheric circulation. In fact, the year 1863 was a record year for meteorological theories. Fitzroy, who is likely to have been well informed of the latest developments in the field, had probably struggled to have his book ready for publication before the end of the year. As mentioned earlier, Buys Ballot presented his wind rule to the British Association in the summer of 1863. Another contender, Francis Galton, Charles Darwin's nephew, published a work entitled *Meteorographica*.

This book, which presented the results of Galton's survey of weather observations, contained a series of maps depicting the state of the weather over Europe for the whole month of December 1861. Unlike Fitzroy, who had strong objections to the use of isobars on maps, Galton's maps presented isobarometric curves connecting areas of equal pressure. Fitzroy questioned the accurateness of these lines because there were insufficient points of measurement.[98] Yet Galton actually made a discovery by the use of isobars. Besides centers of low pressure with winds spiralling inward, or cyclones, as they were called, his maps revealed centers of high pressure. They showed winds blowing outward, away from these high-pressure areas in a clockwise direction. He named these areas anti-cyclones.[99]

Compared to Fitzroy's lunisolar theory and Galton's theory of atmospheric circulation, Buys Ballot's rules were far more appropriate for storm warnings. The rules, which had been obtained empirically by observations carried out over a long period of time, described the movement of atmospheric systems in an efficient way. At the same time, they indicated the direction *and* the force of expected winds, the combination of which made them particularly useful for storm warnings. Furthermore, they required no difficult calculations, and they could therefore be applied simply and quickly.

In 1863, Fitzroy faced other challenges besides dealing with competing theories. James Glaisher, the secretary of the British Meteorological Society, announced his intention to establish the Daily Weather Map Company, a venture with the objective of making a

[98] Halford, *Storm Warning* (cit. n. 54), pp. 187–88.
[99] Francis Galton, *Meteorographica: or Methods of Mapping the Weather* (London: MacMillan, 1863), p. 7.

profit from the publication of weather maps.[100] Although the undertaking failed, it must have had an impact on Fitzroy's performance at the Meteorological Department. There were obviously others, perhaps even with better qualifications, who wished to or could take over his job.

In addition, Fitzroy's one-year trial of storm warnings was evaluated by the Wreck Department of the Board of Trade. His duties were also discussed in the House of Commons. The rising costs of the department, which were mainly caused by the growing number of logbooks that needed to be processed and the use of the telegraph for the warnings, were a matter of debate in parliament.[101] With so much tension and deteriorating health to cope with, Fitzroy needed a break. He put all his hopes on the reception of his *Weather Book*. However, he received a devastating critique from John Herschel, the one person whose opinion meant most to Fitzroy.[102] In the following months he was tormented by other, personal problems. In April 1865, he committed suicide.[103]

An Investigation, the Ordeal, and a New Office

Fitzroy's tragic death has been the subject of different historical interpretations. It has been related to his mental health, religious views, financial difficulties, and scientific work.[104] Whatever the main cause, it came as a blow to the authorities under whose guidance his job description as head of the Meteorological Department had been outlined in the first place. As Katharine Anderson argues, in contemporary Victorian society Fitzroy's suicide was attributed in the first place to his controversial forecasting work. In the press he was portrayed as a "gentleman fraud" who could not cope with the morality and the responsibility that were considered appropriate for

[100] Anderson, *Predicting the Weather* (cit. n. 13), p. 98.
[101] *Hansard's Parliamentary Debates*, 3rd series, HC Deb 12 May 1864, vol. 175, cols. 401–402.
[102] J. M. Walker, *History of the Meteorological Office* (Cambridge: Cambridge University Press, 2012), p. 50; Halford, *Storm Warning* (cit. n. 54), pp. 199–200.
[103] Anderson, *Predicting the Weather* (cit. n. 13), pp. 119–120.
[104] *Ibid.*, p. 120; Burton, "History" (cit. n. 41), pp. 53–54.

science. Fitzroy was guilty of the three deadly sins of "practical science, popular prophecy, and suicide." By committing these, he had compromised his integrity and had discredited the scientific claims of the Meteorological Department.[105]

In the months following Fitzroy's death, his former assistant Thomas Babington took over his duties until matters were settled. This temporary solution was suggested by the Royal Society in response to an inquiry by the Board of Trade.[106] However, a more fundamental decision regarding the future of the department had to be made. Therefore, the Board of Trade pressed for a committee to investigate the management and the affairs of the department. The Royal Society nominated Galton as chairman of the committee.[107] The other two supervising institutes, viz. the Board of Trade and the Admiralty, nominated secretary Thomas H. Farrer and Staff Commander Frederick J. Evans, respectively.

The report of the Galton Committee was presented to Parliament on April 13, 1866. The outcome of the investigation was a dismissal of Fitzroy's method of forecasting. The committee considered his method too individualistic and empirical. The daily forecasts were made "provisionally [without making] notes or calculations."[108] The observations and the preparation of charts were "not carried on by precise rules; and [were] not established by a sufficient induction from observed facts."[109] Neither was the method "capable of being stated in

[105] Anderson, *Predicting the Weather* (cit. n. 13), p. 120–123; see, for instance, R. I. Murchison, "Anniversary Address," *The Journal of the Royal Geographical Society*, 1865, *35*:cviii–clxxxvii, on p. cxxxi.

[106] In response to Thomas H. Farrer's letter, Sabine, the president of the Royal Society, recommended that storm warnings be continued. As far as regular forecasts were concerned, the President and the Council of the Royal Society "decline[d] expressing any opinion." Quoted in "Correspondence between the Board of Trade and the Royal Society in Reference to the Meteorological Department," *Proceedings of the Royal Society of London*, 1865, *14*:306–317, on p. 316.

[107] *Report of a Committee Appointed to Consider Certain Questions Relating to the Meteorological Department of the Board of Trade* [also known as *Galton Report*] (London: Eyre and Spottiswoode, 1866), p. vii.

[108] *Ibid.*, p. 20.

[109] *Ibid.*, p. 42.

the form of Rules or Laws."[110] As such, the committee opted for the termination of regular forecasts on the grounds that there was "no scientific basis" for them.[111] The storm warnings, however, were thought "too important, too popular, and too full of promise of practical utility" to be ended. Instead, the committee suggested to retain them in a modified form.[112]

As for the future of meteorological research, the committee recommended to split the Department into two separate branches, one governmental office for the distribution of instruments and the collection of observations, and another scientific branch for the reduction and tabulation of figures. In addition, the committee decided that the work of the department should be carried out "under the direction of a scientific body" instead of a government department. Therefore it advised that the Royal Society or the British Association take over the management of the new Office by the appointment of a committee.[113] It also recommended an investigation into "the laws which govern the changes of weather in the British Isles … [so] as to enable Meteorologists to place the practice of foretelling weather on a sound basis."[114]

Clearly the committee took the view that the time of uncontrolled forecasting experiments was over. To prevent the public from "confus[ing] real knowledge with ill founded pretences," the committee decided that measures needed to be taken to bring these risky activities under strict control by the members of the scientific community. A division of labor into two branches of meteorology would make a clear distinction between what was considered practical work such as collecting data, and scientific procedures such as reducing and analyzing these data. The report of the Galton committee was distributed across Europe and reached Buys Ballot in the Netherlands. It must have been frustrating for him to read the piece, especially the claim that "no competent meteorologist believe[d] the science to be …

[110] *Ibid.*, p. 20; also quoted in Walker, *History* (cit. n. 102), p. 63.
[111] *Report of a Committee* (cit. n. 107), p. 24.
[112] *Ibid.*, p. 38.
[113] *Ibid.*, p. 40.
[114] *Ibid.*, p. 37.

in such a state as to enable an observer to indicate day by day the weather to be experienced for the next 48 hours."[115] As has been shown, Buys Ballot had in fact formulated a ground rule for foretelling weather changes in the Netherlands.

The final remarks of the report in particular disturbed the Dutch professor. Within two months after its publication, Buys Ballot wrote a slightly irritated letter to the secretary of the British Association. He asked whether the committee was "right to say p. 43 that it was Admiral Fitzroy … who gave the first impulse to this branch of inquiry for foretelling, or forecasting storms, who induced men of science and the public to take an interest in it? When a better system has been introduced a year before in the Netherlands."[116]

Since 1859, Buys Ballot had frequently requested the Dutch Minister of the Interior to inform the British of his warning service, because he thought that the measures taken in Holland could be of use in Britain as well. He repeated this message in the following years.[117] In 1863, he visited England and gave a lecture about his wind rule at the annual meeting of the British Association. Two years later he wrote a paper for *The Civil Engineer and Architect's Journal*.[118] In his letter to the secretary of the *British Association* in 1866, he asked why his wind rule was "not refuted" then, if the committee had found it faulty.[119] In the race to formulate a theory of weather systems, it seems that no British scholar involved in the competitive field of meteorology wished to pay attention to a Dutch professor who claimed to have found a local wind rule.

While Buys Ballot became more agitated, the British daily weather forecasts stopped being issued as of June 1866.[120] It looked as if the recommendations of the Galton committee were being implemented.

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[115] *Ibid.*, p. 24.
[116] Buys Ballot to the Secretary of the British Association, 3 Jun 1866, KNMI, Box 684.
[117] Buys Ballot to the Minister of the Interior, 12 Nov and 27 Dec 1859, KNMI, Box 682. Buys Ballot to the Minister of the Interior, 16 Feb 1864, KNMI, Box 684.
[118] C.H.D. Buys Ballot, "On Meteorological Observations as made in Holland," *The Civil Engineer and Architect's Journal*, 1865, *28*:245–246.
[119] Buys Ballot to the Secretary of the British Association, 3 Jun 1866, KNMI (cit. n. 116).
[120] Burton, "History" (cit. n. 41), p. 65; Halford, *Storm Warning* (cit. n. 54), p. 229.

The following August, Buys Ballot visited England again to give a lecture about his method of storm prediction at the annual meeting of the British Association.[121] He still believed that his system could be of use in Britain. After all, the British system of storm warnings was seen as lacking a sound basis and that was precisely what he could provide.

Consequently, he travelled to Nottingham to convince the members of the scientific community at the meeting of the British Association once again that he had in fact found a sound basis for forecasting weather changes. There he contacted Galton and, presumably, explained to him the principles on which the Dutch system of warnings rested. In Buys Ballot's own words, "I communicated a paper on the subject to the British Association at the Newcastle meeting (1863), and I wonder that my system has not been adopted in England, the more so because I recommended it to Mr. Francis Galton in August last (1866)."[122] Buys Ballot was truly amazed that no one paid attention to his plea to adopt the Dutch system in the United Kingdom.

It is hard to prove that Galton deliberately ignored Buys Ballot's suggestions. He may have had several reasons for not adopting Buys Ballot's system of storm warnings, but it is not implausible that the British official who was involved in deciding the future of the Meteorological Department, wanted a role for himself and to be the first in Britain to provide a sound basis for the cautionary signal system. In his book on meteorology, *Meteorographica* (1863), he came very close to defining a general rule for the direction of the winds.[123]

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[121] C.H.D. Buys-Ballot, "On the Method adopted at Utrecht in discussing Meteorological Observations," in *Report of the Thirty-Sixth Meeting of the British Association for the Advancement of Science* (London: John Murray, 1867), p. 16.

[122] In a letter to the editor of the *Proceedings of the Literary and Philosophical Society of Manchester*, Buys Ballot wrote about his encounter with Francis Galton. The greater part of the letter is cited in Buys Ballot, "On Storm Warnings," *Proceedings of the Literary and Philosophical Society of Manchester*, 1867, *6*:83–84.

[123] Galton's isobarometric maps showed the following "universal fact … throughout the entire month [of December 1861]. It is that on a line being drawn from the locus of highest to the locus of lowest barometer; it will invariably be cut more or less at right angles, by the wind; and, especially, that the wind will be found to strike the *left* side of the line, as drawn *from* the locus of highest barometer." Galton, *Meteorographica* (cit. n. 99), p. 7.

Yet, to be able to give storm warnings, one has to forecast the *force* of the winds as well.

Finally, on October 27, 1866, the Royal Society came with an official reply to the report of the Galton committee. Most of the proposals were adopted. The council endorsed the plan to split the Meteorological Department into two separate branches for the collection and the reduction of data. It also supported the proposal to have the duties of the first branch performed by a governmental office, while it considered it best that the other branch was placed under the supervision of a scientific committee. The council, however, disagreed with the Galton committee on the subject of storm warnings. On this issue it stated:

> [T]he President and Committee do not concur in the recommendations that the issue of storm warnings should be placed under the superintendence of the scientific body under whose direction the meteorological observations are discussed. At present these warnings are founded on rules mainly empirical. In a few years they may probably be much improved by deductions from the observations in land meteorology, which will by that time have been collected and studied. The empirical character may thus be expected to give way to one more strictly scientific, in which case the management of storm warnings might be fitly undertaken by a strictly scientific body. It must not be forgotten that storm warnings did not originate in any recommendation of the Royal Society. If their present continuance be deemed of sufficient importance by the Government, it must be for them to consider the means of carrying them on.[124]

With this statement the Royal Society finally made explicit its stance on forecasts and warnings. The council advised against the continuance of forecasts as well as storm warnings under its direction. If the British

[124] *Report of the Meteorological Committee of the Royal Society, For the Year ending 31st December 1867* (London: Eyre and Spottiswoode, 1868), p. 57.

government wanted a weather service, it should take it on. When asked to give its opinion in the past, the Royal Society had only responded in the most cryptic terms. Moreover, it had turned a blind eye to Fitzroy's activities, which often went beyond his assigned duties. However, in the aftermath of the admiral's death, the Royal Society declined to take responsibility for the issue of storm warnings, which the council essentially saw as a public service. Since the Galton committee had decided that the warnings lacked a sound scientific basis, the Society distanced itself from the entire issue. It rather supported the idea of reshaping the Meteorological Department as a center for the collection and analysis of meteorological data. No more and no less.

With this decision the issue of warnings came to a sudden end on December 7, 1866. The telegraph agents who received the warning messages were barely informed of the termination of the service. On that same day Babington, who had remained loyal to Fitzroy since the establishment of the office, resigned.[125]

On January 21, 1867, the Meteorological Department was reorganized and renamed as the Meteorological Office. Just as the Galton committee had recommended, the office was divided into two branches. Captain Henry Toynbee was appointed head of the marine branch and became responsible for the distribution of instruments and the collection of marine observations. Balfour Stewart, the director of Kew Observatory, where land observations were taken, was appointed head of the "scientific" branch and secretary to the scientific committee, which oversaw its activities. He became responsible for the calibration of instruments and the reduction and analysis of the observations. Robert Henry Scott was appointed director of the Meteorological Office in overall charge of both branches.[126]

Not surprisingly, the president of the Royal Society, Edward Sabine (1788–1883), was very careful in his choice of the new director. To avoid the repercussions of the previous choice, he preferred a clerkish

[125] Burton, "History" (cit. n. 41), pp. 67, 83. The circular issued by the Board of Trade which announced the suspension of the warning service had just appeared on 29 Nov 1866; "Circular of the Board of Trade," 29 Nov 1866, KNMI, Box 685.
[126] *Report of the Meteorological Committee* (cit. n. 124), pp. 5–6.

superintendence rather than an obstinate and enterprising personality like Fitzroy. Although Scott had a degree in physics and had studied under Dove in Berlin, he had no experience in meteorology. Except for the translation of Dove's works, he was devoid of any scientific ambition, which could play an adverse role in his appointment.[127] Besides, any change he might want to make in the program of the Office needed to be referred to the Royal Society Meteorological Committee, of which Galton was a member and which was chaired by Sabine.[128] Above all, Scott was a close family friend of Sabine and his executor.[129] In every respect, Scott was the perfect candidate. On February 7, 1867, he took office.

Breaking through the Impasse

At the start of 1867, the crisis over the future of the Meteorological Department appeared to have been resolved by the final decision of the Royal Society. Yet, what the Society had not anticipated was a storm of protest that resulted after the discontinuance of the warning service. The protesters were of diverse backgrounds. Ship owners and seamen argued that Fitzroy's cautionary warnings had worked well and helped save lives, whether scientific or not. Underwriters, marine boards, and chambers of commerce were supporters of the warning service because of its commercial value.[130] Some men of science likewise denounced the cancellation of warnings.

Most scathing in his criticism was the naturalist and politician William Henry Sykes, member of the Royal Society, Member of Parliament, and former president of the Royal Statistical Society. He vigorously campaigned for the resumption of the storm warning service, both in the House of Commons and at the 1867 meeting of the British Association. There he dismissed the arguments employed by the Meteorological Committee, for example, that Fitzroy had based his

[127] Burton, "History" (cit. n. 41), pp. 71–72.
[128] *Report of the Meteorological Committee* (cit. n. 124), p. 5.
[129] Walker, *History* (cit. n. 102), p. 72.
[130] Halford, *Storm Warning* (cit. n. 54), pp. 233–234; Anderson, *Predicting the Weather* (cit. n. 13), p. 128.

conclusions "mainly on empirical data" as "a pedantic affectation of science." The Committee, he sneered, proposed the establishment of several additional observatories so that at the end of fifteen years it "expected to be able to predict storms on philosophical data, not on empirical data."[131]

The journal of the Manchester Literary and Philosophical Society became one of the hotbeds of criticism. The secretary of the society, Joseph Baxendell, stated:

> [T]he recommendation of the President and Council of the Royal Society, … is a retrograde movement, opposed to the true interests of the science of meteorology, and likely, if acted upon, to retard its progress. It is therefore to be hoped that the Board of Trade will reconsider their decision, and not … discontinue a system which, on grounds of humanity and commercial economy, has met with the general approval of the country, and is, moreover, so likely to contribute materially to the advancement of a popular and highly-important branch of science.[132]

It is striking that Buys Ballot also found his way into the journal. He wrote a letter to the editor and explained once again that he had established a system of warnings grounded on an empirical rule: "*It is a fact above all doubt* that the wind that comes is nearly at right angles to the line between the places of highest and lowest barometer readings. The wind has the place of lowest height at its left hand."[133] He went on to emphasize that the Dutch warning service preceded Fitzroy's by nine months. But, he argued, "It is not only a right of priority that I claim; … I think my system is much better."[134] He explained that he had contacted Galton to inform him about his system

[131] Walker, *History* (cit. n. 102), pp. 83–84.
[132] Joseph Baxendell, "On the Recent Suspension, by the Board of Trade, of Cautionary Storm Warnings," *Proceedings of the Literary and Philosophical Society of Manchester*, 1867, *6*:41–48, on p. 45.
[133] Buys Ballot, "On Storm Warnings" (cit. n. 122), p. 83.
[134] *Ibid.*, p. 83.

in August of the previous year, and that he had received no response. Therefore, he invited British meteorologists to visit Utrecht and see for themselves how the system worked.[135]

The letter shows Buys Ballot's persistence in making his system known to the British public. Yet, it is also remarkable to observe how the Royal Society's stance toward the issue of storm warnings—that it could only be continued when it was placed on "a strictly scientific" footing [136] —had affected Buys Ballot's warning system in the Netherlands. In the last part of the letter, Buys Ballot announced that he was about to introduce a new instrument to the Dutch system. He had devised what he called an *aeroclinoscope*, an apparatus with a movable arm that indicated the greatest difference in barometrical measurements taken at northern and southern stations in the Netherlands.

By launching this instrument, Buys Ballot presumably sought to give his warning system a more scientific character in order to win the approval of the Royal Society or the British Association. Moreover, he was careful not to end up in the same pitfall as Fitzroy. Since the crisis over their continuation in Britain had begun, he had become reluctant to issue official warnings.[137] What better way to give warnings than by an instrument that allowed the public to decide for themselves whether or when a gale was coming? It should be said, however, that the aeroclinoscope could hardly be called an instrument, as it was not a measuring device. [138] Nevertheless, through this "instrument" Buys Ballot could provide weather information without putting himself at risk of being held responsible for the accuracy of the warnings.

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[135] *Ibid.*, pp. 83–84.

[136] *Report of the Meteorological Committee* (cit. n. 124), p. 57.

[137] C.H.D. Buys Ballot to the Minister of the Interior, 8 May 1867, KNMI, Box 685.

[138] At first glance the launching of the aeroclinoscope could be seen as an example of the 19th-century ideal of letting "nature speak for itself." However, unlike self-registering instruments, the aeroclinoscope was not a measuring but a signaling apparatus. After receiving telegrams, which contained barometric readings, telegraph clerks at the Dutch ports placed the movable arm of the aeroclinoscope in position to indicate the pressure gradient. On the ideal of mechanical objectivity, see Lorraine Daston and Peter Galison, "The Image of Objectivity," *Representations*, 1992, *40*:81–128, on p. 81.

In a letter to the Dutch Minister of the Interior, Buys Ballot wrote, "I knew that human nature would be inclined, despite warnings against it and despite having been warned against it by Admiral Fitzroy, to view a cautionary sign as a prediction. People would decide and people have decided: a sign, therefore a storm, no sign, therefore no storm. They refrained from investigating the course of deviations. They were satisfied with: it has not proved correct, without finding out in what case it has not come true."[139]

It seems that Buys Ballot's letter to the editor of the journal of the Manchester Literary and Philosophical Society speeded things up at last. In less than two weeks, John Herschel, whose attention had been attracted by the letter, sent a reply to the journal. He explained how in 1863, he had come across a phenomenon that is typical of November gales in Britain. He had observed that the direction of the wind was always perpendicular to that of advancing hurricanes that accompany the "great November wave."[140] When reading Buys Ballot's letter, it had struck him that the Dutch meteorologist wrote about the same phenomenon in general terms. He concluded from the letter that this was "no special peculiarity of the November gales [as he assumed], but a general one."[141] He further wondered whether Buys Ballot's wind rule, or "feature" as he referred to it, applied to the southern hemisphere as well, but in the reverse direction (!).[142]

The reply generated an exchange of letters between Herschel and Buys Ballot.[143] A French naval captain, named Bourgois, incidentally

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[139] Buys Ballot to the Minister of the Interior, 8 May 1867, KNMI (cit. n. 137).

[140] J.F.W. Herschel, "On Barometric Waves, February 5th 1867," *Proceedings of the Literary and Philosophical Society of Manchester*, 1867, *6*:91–93, on p. 91. Herschel's theory of atmospheric waves stemmed from 1843. Vladimir Jankovic, "Ideological crests versus empirical troughs: John Herschel's and William Radcliffe Birt's research on atmospheric waves, 1843–50," *The British Journal for the History of Science*, 1998, *31*:21–40; Good, "A Shift of View" (cit. n. 5), p. 50.

[141] Herschel, "On Barometric Waves" (cit. n. 140), p. 92.

[142] Herschel asked, "[W]ould it not be worthwhile to enquire whether the condition as to the wind having the barometric minimum (the trough of the wave) on its left hand is not reversed in the southern hemisphere?" *Ibid.*, pp. 92–93.

[143] Unfortunately in the letter book of incoming letters of the KNMI, which are kept at the Utrecht Archives, only a reference is made to Herschel's letter. Buys Ballot replied

got involved in the discussion when reading a translation of the open letters in a French weekly journal.[144] Bourgois, who investigated the daily weather reports of the French observatory, verified the wind rule empirically. Although he added nothing new to the rule, his contribution to the discussion is noteworthy, for he combined Buys Ballot's principle and Galton's cyclones and anti-cyclones in a comprehensible account.[145]

Also, Bourgois went one step further than Herschel in generalizing Buys Ballot's rule. Whereas Herschel referred to the wind rule as a "general feature," Bourgois defined it as a "law of nature."[146] This seems to be the first instance of Buys Ballot's wind rule being attributed the status of a law. No matter how gratifying such an evaluation was for the Dutch professor, he still hoped to win acceptance from his learned colleagues, for his warning service had already earned the support of naval and commercial shipping.[147]

Pleased by these developments, Buys Ballot sent a reply to the editor of the French *Revue Maritime* and suggested how the rotation of the earth caused the winds in the northern hemisphere to blow clockwise around the center of a low-pressure area and anti-clockwise around the center of a high-pressure area. He also described the reverse phenomenon in the southern hemisphere. Despite his claim of having formulated a theory for the rotation of the wind, Buys Ballot was still unable to explain the deflection of the wind to the east or west of areas of low pressure. Apparently, he was not aware of the coriolis force and he had made no progress since his 1860 brochure. Yet, he could not

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on 2 March 1867. The content of this letter is not given. KNMI, 685 Letter book of letters sent, 1854–1889.

[144] "Le vent et le baromètre; lettres de Sir J. Herschel et de M. le capitaine de vaisseau Bourgois," *Revue Maritime et coloniale*, 1867, *19*:927–929, on p. 927–928.

[145] *Ibid.*, 928–929.

[146] Bourgeois wrote: "le fait signalé par M. Buys-Ballot à Sir J.W. Herschel, et que ce savant météorologiste anglais considérait, dès l'année 1863, comme un cas particulier *d'une loi générale de la nature* [emphasis added], a plus de généralité encore qu'il ne semble le supposer." *Ibid.*, p. 928.

[147] Klein et al., *The foretelling* (cit. n. 79), pp. 15–16.

refrain from pointing out again that it was "in the Netherlands, where … the rule ha[d] been found."[148]

It is clear that Herschel's approving reference to the wind rule was an important factor in its dissemination in Britain. For years Buys Ballot had tried to attract the attention of the British scientific community to his findings. Although the rule was merely referred to as a "general feature," Buys Ballot had finally found a receptive audience. Another factor that worked to the Dutchman's advantage was the general wave of protests against the suspension of the English warnings. The critique in the *Proceedings of the Literary and Philosophical Society of Manchester* took on a more accusatory form:

> [N]o confidence could … be placed in the so-called "Scientific Committee," which [has] shown itself to be utterly regardless of public opinion and feeling, and quite unfitted to carry out efficiently the duties which had been so ably and so usefully discharged by the late Admiral Fitzroy. [The committee] has not hesitated to divert funds … to the furtherance of schemes and scientific crotchets which are altogether uncalled for … and which, have certainly no interest whatever for the general public.[149]

Halfway through 1867, even members of parliament complained about the suspension of the public weather service. The president of the Board of Trade (the Duke of Richmond), who furnished an annual sum for the warning system, threatened to withdraw the allowance.[150] Alarmed by this prospect, the Royal Society Meteorological Committee had to make a quick decision. It had landed itself in an awkward predicament. On the one hand, it refused to give storm warnings,

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[148] "[C]'est aux Pays-Bas qu'on en a trouvé non-seulement la règle, et non pas d'une manière simplement empirique, mais selon une théorie confirmée depuis par l'expérience." Buys Ballot to Paul Dupont, editor of the *Revue Maritime et Coloniale* in Paris, 10 Apr 1867, KNMI, 685 Letter book of letters sent, 1854–1889.
[149] Joseph Baxendell, "Storm Warnings," *Proceedings of the Literary and Philosophical Society of Manchester*, 1867, *6*:178–179.
[150] Burton, "History" (cit. n. 41), p. 86.

because the Royal Society found them scientifically unjustifiable. On the other hand, the committee could not do without funding.

In the midst of public protests and under pressure from the president of the Board of Trade, there seemed to be no way out for Scott, the director of the Meteorological Office, other than to restore the storm warnings. However, how could the office retain its credibility if the service were reinstated while there was still no agreement on a method or a principle to place the storm warnings on a "strictly scientific basis"?

The Meteorological Office chose a cautious approach. In July the office instituted an enquiry into the practice of storm warnings in other countries. Replies were received from France, Holland, Austria, Italy, and Norway. This time it was not Buys Ballot who responded, but one of his assistants, J. E. Cornelissen. In a brief reply, he explained the theory behind the Dutch wind rule, the warning procedure, and the use of the aeroclinoscope.[151]

Finding himself in a quandary, Scott was desperate to find a basis for storm warnings. In retrospect, the Dutch wind rule was precisely what he needed. In August he travelled to the Netherlands to visit the meteorological institute at Utrecht to see for himself how the Dutch warning system operated.[152] When he returned to England, he started an investigation to test the correctness of the wind rule. To this end he used old records of daily weather reports dating from Fitzroy's time and started collecting observations in October 1867.[153]

Meanwhile, under the weight of public criticism, the Meteorological Committee changed tack and finally agreed to provide, free of charge, telegraphic information about storms already in progress to ports and fishing villages in the British Isles. Yet, instead of using the term "storm warnings," the committee referred to the practice as "intelligence of

[151] J. E. Cornelissen to R. H. Scott, 12 Aug 1867, cited in *Report of the Meteorological Committee* (cit. n. 124), pp. 71–72.
[152] R. H. Scott to J. E. Cornelissen, 24 Aug 1867, KNMI, Box 1463.
[153] R. H. Scott, *Report of an inquiry into the connexion between strong winds and barometrical differences: presented to the Committee of the Meteorological Office* (London: Eyre and Spottiswoode, 1869), p. 4.

facts" or "notices of serious atmospherical disturbances."[154] Information about wind direction stopped being issued, and therefore the cone disappeared from the storm warning arsenal. Fitzroy's drum was reintroduced, but was hoisted for a shorter period of 36 hours instead of 72.[155]

In May 1868, Scott presented his results to the Royal Society Meteorological Committee. Buys Ballot's rules had held reasonably well, if not perfectly so. A difference of 0.6 inch in the barometer readings of two stations was followed by a storm in 60 percent of cases, whereas more than 70 percent of all storms were preceded by such differences. With regard to the direction of the wind, the rule did even better. In more than 90 percent of the cases it was seen to have correctly predicted the direction.[156] Although Scott presented the inquiry as "purely tentative," he nevertheless interpreted his results as a "*prima facie* confirmation" of Buys Ballot's work. Significantly, throughout the paper he consistently spoke of Buys Ballot's rules as a "law."[157] Moreover, he attributed the law to Buys Ballot, although he was aware that others had made similar suggestions before him. The main reason he credited the law to Buys Ballot was because the latter had "been the person who has insisted on its importance as a means of *foretelling* wind, both as to direction and force."[158]

Indeed, the way Scott rephrased the law, it was changed into a predictive claim. At the same time, however, his phrasing ignored the force of the wind, in contradiction to the title of his report:

> If any morning there be a difference between the barometrical readings at any two stations, such as Groningen and

[154] Thomas Farrer issued a circular on 30 Nov 1867. *Report of the Meteorological Committee* (cit. n. 124), p. 19.
[155] *Report of the Meteorological Committee* (cit. n. 124), p. 19; Anderson, *Predicting the Weather* (cit. n. 13), p. 129.
[156] Scott, however, did allow for an arc of 135 degrees with regard to the right direction so as to allow of veering of the wind during 24 hours. Scott, *Report of an inquiry* (cit. n. 153), pp. 7, 11, 15.
[157] *Ibid.*, p. 17. See also on page 3: "The Principle, which I shall call, throughout this Report, the Law…."
[158] *Ibid.*, p. 4.

> Maastricht, a wind will blow on that day in the neighbourhood of the line joining those stations, which will be inclined to that line at an angle of 90° or thereabouts, and will have the station where the reading is lowest on its left-hand side.[159]

That same year, Scott also discussed "Buys Ballot's law" on several other occasions, among them his Friday lecture at the Royal Institution and in a small booklet on the use of the barometer. His subordinate at the Meteorological Office, marine superintendent Henry Toynbee, followed suit by referring consistently to "Buys Ballot's law" in another non-official report for the Meteorological Committee on isobaric curves. [160] More importantly, likewise did the Meteorological Committee of the Royal Society in its official *Report, For the year ending 31st December 1868*, which was presented to Parliament. The report ended with: "[The] conclusions are very encouraging as general results, inasmuch as they afford a very strong corroboration of the value of the law as the foundation of a practical principle for the issue of cautionary telegrams."[161]

The explicit and consistent use of the term "law" by these parties was hardly accidental. A law, rather than a rule of thumb, would provide the scientific backing needed to legitimatize the practice of storm warnings. As we have seen, the Galton report rejected Fitzroy's method of weather forecasting for not being based on meteorological laws, and advised the search for such laws so as "to place the practice of foretelling weather on a sound basis."[162] Precisely the fact that Buys

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[159] *Ibid.*, p. 3.
[160] R. H. Scott, "On the Work of the Meteorological Office, Past and Present," *Notices of the Proceedings at the Meetings of the Members of the Royal Institution of Great Britain*, 1866-1869, *5*:535–547, on pp. 542–543; H. Toynbee, *Report to the Meteorological Committee of the Meteorological Office on the use of isobaric curves and a line of greatest barometric change in attempting to foretell winds; with some practical suggestions for seamen and a few remarks on Buys Ballot's law* (London: Eyre and Spottiswoode, 1869).
[161] *Report of the Meteorological Committee of the Royal Society, For the Year ending 31st December 1868* (London: Eyre and Spottiswoode, 1869), p. 18.
[162] *Report of a Committee* (cit. n. 107), p. 37.

Ballot's set of rules lacked the exact nature of, say, Newton's law of gravitation reveals the strategic nature of the term.

During the following years, Buys Ballot's law was tacitly introduced in the British system of storm warnings, in spite of the previous announcement that the new storm warnings would not have a predictive character, but would only be based on the registration of existing storms. In this respect the situation remained delicate. However, the reintroduction of the cone in the storm warnings of the Meteorological Office, which signalled the expected direction of the wind,[163] could be viewed as an indication that Buys Ballot's predictive rule was being used in the warning system. It was only in 1876, in a report of the Meteorological Committee, that Scott openly discussed the principles on which British storm warnings were based. At the top of the list was the "Law known as Buys Ballot's." As Scott emphasized, "The intelligent application of this principle to wind motion … has been the chief point in which modern meteorology offers a contrast to prior investigations into the science." He was, however, quick to add that these principles were "only announced with very great diffidence."[164]

After the acceptance of Buys Ballot's wind rule as a natural law by the British Meteorological Committee, the label "Buys Ballot's law" rapidly gained wide currency and appeared in a variety of European and American journals and publications. Within a few years of the publication of the British Report, French, Italian, and German versions of the expression could be encountered.[165] The earliest instances of

[163] Walker, *History* (cit. n. 102), p. 86.

[164] Robert H. Scott quoted in "Report of the Meteorological Committee to the President and Council of the Royal Society on the Work done in the Meteorological Office since their appointment in 1866 to December 31, 1875," *Proceedings of the Royal Society of London*, 1876, *24*:189–210, on p. 200.

[165] The law appeared, for instance, as "Das Gesetz von Buys Ballot" in C. Jelinek, "Über den Zusammenhang zwischen Stürmen und barometrischen Unterschieden," *Zeitschrift der Österreichischen Gesellschaft für Meteorologie*, 1869, *4*:331–339, on p. 331; as "loi de Buys Ballot" in R. H. Scott, "Institution Royale de la Grande Bretagne," *Revue des Cours Scientifiques de la France et de l'Étranger*, 1868–1869, *6*:595–601, on p. 599; as "die niederländische Regel von Buys-Ballot" in a paper in the Prague-based journal by A. Nowak, "Dr. Prestel's Windgesetz," *Lotos. Zeitschrift für Naturwissenschaften*, 1869, *19*:153–161, on p. 155; as the "law of Buys Ballot" in Albert

these usually concerned translations of papers or brochures by Scott, Toynbee, or the Secretary of the Scottish Meteorological Society, Alexander Buchan. The rapid spread testifies to the increase in interest in both meteorology and storm warnings in several states. It also testifies to the shift in authority in this burgeoning field from naval officers to academic scientists, who were far more eager for scientific foundations for their practices.[166]

This shift became markedly visible at the international meteorological conference held at Vienna in 1873. Whereas the previous international conference in Brussels had been dominated by naval officers, the Vienna conference was almost exclusively attended by academic scientists. With the canonization of the law, Buys Ballot was firmly established as a meteorological authority. In 1873, he was unanimously chosen to preside over the Vienna conference, with Scott acting as its secretary.[167] In a field as hotly contested as meteorology, their mutual interests had resulted in a rare feat of symbiosis, crowned by a law that still bears the name of its most vociferous prophet.

Conclusion

As we have seen, Buys Ballot played a secondary role in the elevation of his local rule to a global law. Despite his international orientation, expressed from the very first moment of the publication of his wind rule in the French *Comptes Rendus*, he initially failed to gain foreign recognition for his discovery or to induce others to verify his rule in

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J. Myer, "The winds and their law," *Annual Reports of the Secretary of War* 1 (Washington DC, 1871), 344–347, on pp. 345–346; as "Buys-Ballot'sche Gesetz" in Prestel, "Ergebnisse der Beobachtungen und Erfahrungen betreffend die Sturmwarnungen und die Sturmsignale," *Jahresbericht der Naturforschenden Gesellschaft in Emden*, 1873, *58*:1–8, on p. 8; as "legge di Buys Ballot" in A. Gianjacopo, "Sul Clima di Mantova," *Atti e Memorie della Reale Accademia Virgiliana di Scienze, Lettere ed Arti* (1874), 54–64, on p. 60; and as "ley de Buys Ballot" in P. Benitos Viñes, *Apuntes relativos a los Huracanes de las Antillas* (n.p., 1877), 121.

[166] For the shift in authority in marine meteorology, see Azadeh Achbari, "Building Networks for Science: Conflict and Cooperation in Nineteenth-Century Global Marine Studies," *Isis*, 2015, *106*: 257–282.

[167] *Report of the Proceedings of the Meteorological Congress at Vienna* (London: Eyre and Spottiswoode, 1874).

other regions. Nor could he provide an adequate theoretical foundation for his rule. Therefore, it remained unclear whether the rule applied beyond the Dutch borders.

His fellow meteorologists did not recognize or ignored the importance of the empirical generalization. Those who did support the rule were engaged in naval and commercial shipping, and lacked the scientific authority that could give weight to their opinion. Meteorology was fraught with conflicting concerns and objectives. Views about what it should entail shifted back and forth between those who saw it as a public resource concerned with practical results such as storm predictions and those who regarded it as primarily a scientific field that aimed for general laws, a physics of the atmosphere. Moreover, members of the latter group were inclined to regard each other as competitors rather than as collaborators.

In the course of the transformation of the wind rule into a law, Buys Ballot did his utmost to interest several foreign parties in his Dutch findings. Yet, eventually it was Scott who contributed to the general acceptance of Buys Ballot's wind law by claiming a verification of the rule in the region encompassing the British Isles, by highlighting the role of Buys Ballot in its conception, by stressing its utility in foretelling storms, and by a consistent use of the word "law." The backing of the Royal Society, moreover, provided the required authority for propagating these views abroad.[168] At this point scientific interests and practical considerations converged under the pressure of public opinion.

Given the prevalent tensions and rivalries in meteorology, Scott's generosity toward the Dutch professor comes across as an anomaly. The general acceptance of Buys Ballot's law, however, can largely be attributed to Scott's efforts. Unlike other meteorological investigators, Scott had no pet theory of his own. As we have seen, increasing public pressure had turned the suspension of the British storm warning system into a pressing impasse, and he was badly in need of a principle to sanction and reinstate the service at the Meteorological Office. Buys

[168] Jelinek, "Über den Zusammenhang" (cit. n. 165), pp. 331–339; Scott, "Institution" (cit. n. 165), pp. 595–601; *Fortschritte der Physik*, 1873, *25*:882–901, on p. 884.

Ballot's wind rule provided him with a way to save face and restore the reputation of his department, which had been damaged by the awkward handling of the Fitzroy affair. Most importantly, Buys Ballot's "law" offered a means to make meteorology scientific rather than merely empirical. Predictive sciences are generally equated with exact sciences based upon laws.[169]

Why did Buys Ballot receive the sole credit for the law, or differently phrased, why did the law end up being called "Buys Ballot's" law? Scott certainly was not the only contemporary commentator to observe that Buys Ballot had been preceded by several others who had expressed similar results. Apart from Scott's own role in this attribution, three additional factors need to be singled out. First, as we have seen, Buys Ballot indefatigably promoted his rule in lectures, publications, and correspondence, both in the Netherlands and abroad. Although it took almost ten years before the international meteorological community was willing to take his rule seriously, when they did, Buys Ballot was the name that immediately sprang to mind. Second, as Scott pointed out, Buys Ballot promoted his rule as a method for predicting storms, and in this respect he certainly was unique. As the issue of storm warnings was at the center of public interest, this approach ascertained a higher visibility. Finally, the phrasing itself was attractively simple: "if a person stands with his back to the wind, the low pressure area will be on his left." This at least was the plausible explanation for the general attribution of the law to Buys Ballot given by the anonymous author of an article on the use of the barometer on board ships, published in 1871 in a German maritime journal.[170]

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[169] Such a strategic use of the term "law" may not have been exceptional. Three decades later, in a similar move, geneticists would introduce the term "Mendel's laws" for similar purposes, distinguishing the new quantitative and experimental science of genetics from qualitative and speculative biology, marked by the absence of laws. A similar message may also have been at the root of William Bateson's coinage "genetics," its ending being modelled after "mathematics" and "physics," and unlike that of "biology" and "geology." Bateson notoriously coined the term "genetics" in 1905 in a letter to Adam Sedgwick; see B. Bateson, *William Bateson, F.R.S., Naturalist: His Essays and Addresses together with a short Account of his Life* (Cambridge: Cambridge University Press, 1928), p. 93.

[170] "Der Barometer an Bord," *Hansa. Zeitschrift für Seewesen*, 1871, *8*:197–198, on p. 198.

Later in life Buys Ballot admitted that he had put too little effort into the theoretical elaboration of his wind rule.[171] By then he was familiar with the work of the American meteorologist William Ferrel, who had published a general derivation of the fact that all moving objects on the surface of the earth, whether particles of atmospheric air or of ocean water, are deflected to the right in the Northern hemisphere and to the left in the Southern hemisphere, due to the axial rotation of the earth. Ferrel, moreover, had published this paper almost a year before Buys Ballot put forward the first intimations of his rule. Unfortunately, Ferrel had published his "Essay on the Winds and the Currents of the Ocean" in a rather obscure journal, the *Nashville Journal of Medicine and Surgery*.[172] In the 1870s, Ferrel and several of his compatriots pointed out that Buys Ballot's law was simply a consequence of Ferrel's more general work. Some even remarked that "Buys Ballot's law" was actually a misnomer. On the one hand, the "law" was little more than an empirical rule, and on the other hand, it ignored the precedence of Ferrel.[173]

In the mid-1880s, Buys Ballot approached Ferrel and suggested to rename the law by adding Ferrel's name to, and even before, his own name, thereby acknowledging Ferrel's priority. Ferrel, however, graciously declined the offer. It seems appropriate to end this paper with his magnanimous response:

> I cannot but admire your great generosity in proposing to connect my name with yours, and even to put mine first, in designating the law known as Buys Ballot's law. The law has been too long and too well known by the latter designation to change it now, if there was any occasion for it. But there is really none. No one doubts its being an original discovery with you and first promulgated by you, and if, as frequently happens

[171] Van der Stok, "Levensbericht" (cit. n. 14), p. 75.
[172] Ferrel, "Essay on the Winds" (cit. n. 11), pp. 7–19.
[173] See, for instance, the remark by Cleveland Abbe: "The present writer has previously called attention to the fact that *Buys-Ballot's* law, as enunciated by him, is simply a rule." Cleveland Abbe, "Physics of the Globe," *Annual Record of Science and Industry*, 1879, *8*:91–210, on p. 173.

in new discoveries, others may have similar ideas about the same time, this is no occasion, why the name of the law should be changed.[174]

[174] William Ferrel to Buys Ballot, 25 Jul 1886, KNMI, Box 1508; also quoted in Van der Stok, "Levensbericht" (cit. n. 14), p. 75.