Rulers of the Winds

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Introduction

Forming a boundless duo, the air and water that envelop the earth are closely connected. They interact continually, exchange energy and mass, and affect each other's appearance. Weather and water conditions, having the potential to wreak havoc or bring harmony, have sparked the imagination of generations and continue to do so, whether in works of art, literature or science. Being in constant movement, winds and currents resist easy conceptualization. How were these fluids in perpetual motion "tamed," how did they come within the grasp of science? Understanding wind and ocean circulation and their driving forces was a matter of importance in the nineteenth-century world of global navigation, maritime commerce and colonial expansion. Knowing the phenomena of the oceans and the atmosphere was a shared interest of seafaring nations that enthused different groups to engage in the widespread collection of, what we now would call, "big data" about sea currents, winds, air pressures, temperatures, and water levels. Cooperation and information exchange were key to assure a large database of field observations. Despite an increasing awareness of the need for international cooperation, the studies of the atmosphere and the ocean's surface were a contested field. While the investigation of winds and currents had the potential of delivering navigational, commercial and strategic military benefits to the states, they could also help build careers and reputations. The stakes were high. In the emerging science of the atmosphere and in the study of ocean currents, naval officers and university professors struggled for authority.

In the early nineteenth century, studies of the weather and the sea surface were intertwined with astronomy and navigation. At astronomical observatories weather investigations were carried out for the purpose of calculating the refraction of light in the earth's atmosphere. At sea, astronomical tools and methods such as the lunar-distance method, or the angular measurement of the moon and other celestial bodies, were used to calculate time and determine the exact location of a ship. Equally crucial to navigation was knowledge of wind patterns and surface ocean currents as ships often moved away from their planned course by the effects of set and drift. Sea captains turned these effects to their advantage by using and sharing their experiences of favorable winds and strong sea currents when they charted their course and set sail. As many of them came to realize, preparing and improving charts of these natural pathways could be a profitable undertaking. Naval officers encouraged their fellows and merchant seamen to keep records of weather and ocean observations on their journeys. The systematic study of these phenomena was expected to result in better charts and finding safer and faster navigation routes, which in turn helped to reduce the costs of shipping. These practices attracted the attention of national governments. Ministers and department heads were induced to fund projects that could improve maritime security and commerce. Professors of astronomy, mathematics or physics, who saw career opportunities in these research activities as well, were swift to offer their scientific services to marine departments, which they claimed were better suited for these complex investigations. In a climate rich in potential and seething with competition, it was not uncommon for practical concerns to clash with intellectual ambitions, for instance when the primacy of marine or land-based observations was discussed.

This dissertation deals with the question of how, from these broad-ranging investigations of maritime and atmospheric phenomena, a new branch of science crystallized: meteorology. How did the science of the weather, which initially had been subordinate to astronomy, develop into a field of its own? Who were the individuals involved in the process? How did they manage to carve out a well-defined and widely acknowledged research area where they could establish their authority? The modern science of meteorology was fairly quickly put into practice and applied to a system of storm prediction enabled by the emergence of the electric telegraph. The field remained closely connected to the sea. The sustained practical orientation of nineteenth-century weather investigators raises questions about what impact the growing practice of weather and storm forecasting had on the formation of the science. How did storm warnings influence the relationship among professors and naval officers that was at times collaborative and at other times intensely rivalrous? Controversy marked the science as storm and weather theorists of every stamp vied for dominance. What kind of standards did they set themselves? How was expertise achieved, authority established? By the 1870s, academically trained men had gained complete control over meteorology. However, this outcome was not at all obvious to the contenders at the time. In short, how did university professors come to define and dominate the science of the weather?

This dissertation offers a history of the making of a science in the context of cooperation and conflict between men of science and the military in their search for professional opportunities in a world that saw rapid growth and improvement of travel, transport and communication. It scrutinizes how global networks of data collection were forged, meteorological institutions were established, theories about weather change were developed, and international meteorological committees were founded. It seeks to shed light on processes of partnership and of vying for authority in the creation of scientific knowledge of the weather. This story shows how constant maneuvering was involved in meteorological theories getting disseminated and ultimately becoming accepted or being discarded. It explains, for instance, how the creation of the still-current law of atmospheric surface circulation, the "law of Buys Ballot", resulted from contingent social, institutional and geographical factors rather than from its inherent persuasive qualities.

Historiography and Theory

In the historiography of meteorology, emphasis is usually placed on research carried out by men of science and scientific institutes in British and American contexts.[1] Katharine Anderson's *Predicting the Weather*,

[1] Malcolm Walker, *History of the Meteorological Office* (Cambridge: Cambridge University Press, 2011);
Katharine Anderson, *Predicting the Weather: Victorians and the Science of Meteorology* (Chicago and London: University of Chicago Press, 2005); Pauline Halford, *Storm Warning: The Origins of Weather Forecast* (Gloucestershire: Sutton

which is set in Britain, offers a gripping history of the Victorian science of meteorology and weather forecasting as the scenery of controversies about the authority of science and the public role of the emerging weather scientist. By looking into debates about whether meteorology should serve scientific or public interests, she reveals how Victorian elite scientists defined the function of the science of meteorology and attempted to dismiss forecasting as a non-scientific practice.[2] This dissertation moves the focus away from elite scientists and scientific institutes and traces the history of the systematic study of the weather and the sea surface by combining the point of view of university professors with that of naval officers, who played a major, though understudied, role in the forging of national and international maritime observation networks. This study, furthermore, shows their influential role in the establishment of meteorological institutes, which in the historical literature is often taken for granted. The development of maritime and meteorological observation networks involved many

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Publishing, 2004); Vladimir Jankovic, *Reading the Skies: A Cultural History of English Weather, 1650-1820* (Chicago: University of Chicago Press, 2000); Mark Monmonier, *Air Apparent: How Meteorologists Learned to Map, Predict, and Dramatize Weather* (Chicago: University of Chicago Press, 2000); James Rodger Fleming, *Meteorology in America, 1800–1870* (Baltimore: Johns Hopkins University Press, 1990); James Burton, "History of the British Meteorological Office to 1905" (PhD dissertation, Open University, 1988). Among the few exceptions is a somewhat older study of the history of the cyclone theory in multiple geographical contexts by Gisela Kutzbach, *The Thermal Theory of Cyclones: A History of Meteorological Thought in the Nineteenth Century* (Boston: American Meteorological Society, 1979); A. Kh. Khrgian, *Meteorology. A Historical Survey* Vol. I Second Edition Revised and Edited by Kh. P. Pogosyan (Jerusalem: Israel Program for Scientific Translations 1970); and James Roger Fleming, Vladimir Jankovic, and Deborah R. Coen ed., *Intimate Universality: Local and Global Themes in the History of Weather and Climate* (Sagamore Beach, MA: Science History Publications/USA, 2006). Fabien Locher's *Le savant et la tempête: Etudier l'atmosphère et prévoir le temps au XIXe siècle* (Rennes: Presses Universitaires de Rennes, 2008) is one of the few studies of the history of French meteorology. For the early organization of Dutch meteorological networks see Huib J. Zuidervaart, "An Eighteenth-Century Medical-Meteorological Society in the Netherlands: An Investigation of Early Organization, Instrumentation and Quantification. Part 1," *British Journal for the History of Science*, 2005, *38*:379–410; and "An Eighteenth-Century Medical-Meteorological Society in the Netherlands: An Investigation of Early Organization, Instrumentation and Quantification. Part 2," *British Journal for the History of Science*, 2006, *39*:49–66.

[2] Anderson, (cit. n. 1), pp. 2-3.

countries across both sides of the Atlantic and, as we shall see, the initiative and much of the resources deployed in the research projects came from the navy and merchant marine.

This thesis, moreover, treats the investigations of the atmosphere and ocean currents, research activities carried out by academics as well as naval officers, not as separate fields, but takes them together as the hybrid practices of investigation and application that they initially were.[3] The advantage of this approach is that it elucidates the sensitivities involved in the division of tasks at the nascent meteorological institutes. Close examination of what went on at the institutes shows, for instance, that accepted values and norms in science did not always mesh with actual attitudes and practices. It reveals how distinctions were made between who should perform the practical work and who could pursue developing theories and formulating general rules of weather change.

The, once again, hybrid investigations of the weather and the sea, which included such varied phenomena as winds, currents, tides and magnetic variation, did not fall within the disciplinary boundaries that we are now accustomed to. Susan Faye Cannon has grouped the nineteenth-century investigations of the physical properties of the earth, ocean, and atmosphere under the term "Humboldtian science." Named for the famous Prussian explorer and naturalist, Alexander von Humboldt, this type of science involved the accurate measurement of widespread and interconnected natural phenomena on a global scale by the use of sophisticated instruments and the application of theories and

[3] A similar attempt is made for astronomy and related sciences pursued at nineteenth-century observatories in the volume *Heavens on Earth. Observatories and Astronomy in Nineteenth-Century Science and Culture*. In their introduction, the editors argue that nineteenth-century observatories were concerned with more than just astronomy, which was part of a larger group of "observatory sciences," including "cartography, geodesy, meteorology, and to an extent physics and statistics. While universities and academies tended to split science along disciplinary lines, … [this volume is] a first attempt to investigate [the coexisting scientific] pursuits at the observatory as a coherent whole." David Aubin, Charlotte Bigg, and H. Otto Sibum, "Introduction: Observatory Techniques in Nineteenth-Century Science and Society," in eds. David Aubin, Charlotte Bigg, and H. Otto Sibum, *Heavens on Earth. Observatories and Astronomy in Nineteenth-Century Science and Culture* (Durham and London: Duke University Press, 2010), p. 2.

tools to eliminate measurement errors. The aim was to find hidden laws in nature that could be written in mathematical form.[4] As Cannon has argued, Humboldt did not invent all aspects of "Humboldtian science."[5] Over the years, historians of science have refined the rather plastic concept of "Humboldtian science" to include additional characteristics such as a mania for mapping averages that revealed the harmony and "equilibrium of forces" in nature, an aesthetic sensibility towards nature, an all-encompassing synthesis of nature's elements in a graphic form that was at once attentive to local variation and global regularity, and the representation of phenomena in images that integrated artistic expression with scientific rigor.[6]

If we look at the main characters in this story, they all show, to a greater or lesser extent, traces of Humboldt's influence in their investigations. Humboldtian science, however, is not used here as a classificatory term to include or rule out specific research practices or practitioners. Such an approach would not be a fruitful exercise in any case. Instead, and more importantly, Humboldtian science serves as a heuristic means to take a closer look at nineteenth-century studies of the weather and the sea at once without applying our accepted categories to them. As historian Slotten has repeated Cannon's well-chosen words, the concept allows us to avoid "conventional ways of looking at the history of science as developments in discrete special subjects, each with its continuous comprehensible internal history."[7] In fact, the notion of "Humboldtian science" can serve as a foil to

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[4] Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Science History Publication, 1978), chapter 4, esp. pp. 104-105.

[5] Cannon, (cit. n. 4), pp. 77, 96.

[6] Michael Dettelbach, "Humboldtian Science," in N. Jardine, J. A. Secord and E. C. Spary, *Cultures of Natural History*, 287-304, on pp. 295-298; Joan Steigerwald, "Figuring Nature/Figuring the (Fe)male: The Frontispiece to Humboldt's *Ideas Towards a Geography of Plants*," in Ann B. Shteir and Bernard Lightman, *Figuring it Out. Science, Gender, and Visual Culture* (Hanover and London: University Press of New England, 2006), 54-82, on pp. 69-71; Lorraine Daston, "The Humboldtian Gaze," in Moritz Epple and Claus Zittel ed., *Science as Cultural Practice Vol I: Cultures and Politics of Research from the Early Modern Period to the Age of Extremes* (Berlin: Akademie Verlag, 2010) 45-60, on p. 55.

[7] Hugh Richard Slotten, *Patronage, Practice, and the Culture of American Science. Alexander Dallas Bache and the U.S. Coast Survey* (Cambridge, Cambridge University Press, 1994), p. 114; Cannon, (cit. n. 4), p. 104.

historicize the emergence of autonomous fields and professional distinctions that were made between academics, or "men of science" as the academically trained members of the scientific elite came to call themselves, and so-called "practical men" from the mid-nineteenth century onwards.[8] The gradual transformation of Humboldtian study of the properties of the atmosphere and the sea into a more specialized and institutionalized form took roughly forty years between the 1830s and 1870s, which is precisely the time span of this dissertation. As we shall see, the shaping of the science of the weather involved intense "boundary-work," including the cultivation of differences in types of work, the subordination of one kind of investigation to another, the creation of hierarchies, strategies of exclusion, and the claim to authority.[9]

Since Cannon's study, Humboldtian science is strongly associated with Victorian Britain. The Magnetic Crusade, a vast global network of observatories for investigation of the magnetic properties of the earth, and William Whewell's international tide experiment, are two of the best examples of global Humboldtian scientific undertakings, both of which got off the ground in Britain. John Cawood's much-cited paper on the so-called Magnetic Crusade examined the intricate links between Victorian science and politics.[10] In *Tides of History*, Michael Reidy tells the fascinating history of how the British-led international study of the tides, or more appropriately the Tidal Crusade, helped Britain to master the world's seas, while showing at the same time how Whewell as the originator of the tidal program created space for the modern "scientist." Reidy's close examination of Whewell's writings reveals how the Cambridge professor established the authoritative role

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[8] 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); and Cannon, (cit. n. 4), p. 34. Throughout this dissertation, terms and labels that were used by the historical actors themselves have been adopted. See also footnotes 3, 5, 8 and 128 of chapter 1.

[9] The concept of boundary-work is derived from Thomas F. Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review*, 1983, *48*:781–795.

[10] John Cawood, "The Magnetic Crusade: Science and Politics in Early Victorian Britain," *Isis*, 1979, *70*:492-518.

of the scientist which also supported his inductive model. Whewell used a rhetorical language that placed the scientist above calculators, instrument makers, and observers, whose contributions to the investigations he classified as subordinate.[11]

In *Fathoming the Ocean*, Helen Rozwadowski shifts the focus from the British context and investigates the Humboldt-inspired physical geography of the American naval lieutenant, Matthew Maury among other nineteenth-century attempts to study the ocean floor.[12] This dissertation aligns itself with the work of Reidy, Rozwadowski, Anderson, and Cawood, while widening the scope to include broader transatlantic connections that were vital to the establishment and maintenance of networks of maritime meteorological observation and reciprocal exchange of ideas. The meeting between the Dutch naval officer, Marin Jansen, with Matthew Maury, serves as a first point of entry into the web of alliances among different groups that got involved in the investigations of winds and currents. The close examination of the organization of the first international maritime conference in Brussels in 1853 allows us to look into how professional connections were established among naval officers, men of science and state officials, and how entrepreneurial plans were made for the systematic study of the ocean's surface and the atmosphere.

Scope and Structure

The time frame covered in this dissertation stretches from the 1830s to the 1870s, the period that paralleled the transformation of the wide-ranging investigations of the atmosphere and the sea into meteorology as a distinct branch of study. As will be explained, this period also coincides with the evolution of two careers that changed the substance of meteorological science profoundly. One of these is that of Christopher Buys Ballot, a Dutch professor, who plays a prominent

[11] Michael Reidy, *Tides of History. Ocean Science and Her Majesty's Navy* (Chicago and London: University of Chicago Press, 2008).
[12] Helen M. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge, Mass.: Belknap, 2005), esp. on pp. 31-32, and 79.

role in this story. As we shall see, his findings in meteorology challenged and eventually eclipsed the authority of the Berlin professor of physics, Heinrich Dove.

As founder of the Dutch meteorological institute and as discoverer of a wind rule that was to become a widely accepted scientific law – a suspenseful history that has, oddly enough, not been examined before – Buys Ballot is ideal for close study in the history of weather investigations. Because of his strong international orientation, he had many connections outside the Netherlands. His correspondence with fellow investigators of the weather and others involved in the projects offers a vivid view of nineteenth-century scientific culture. Besides the already mentioned expert in meteorological theory, Heinrich Dove, and the naval officers, Matthew Maury and Marin Jansen, the community of weather investigators was made up of men like Robert Fitzroy, Francis Galton, William Redfield, Alexander Buchan, Henrik Mohn and others, who will all make their appearance in this story. As we shall see, they all had their own pet theories of the rules of weather change, which made nineteenth-century meteorology an overly competitive field.

The reader will find that the work of French meteorological investigators is only covered in broad outlines in this dissertation. Abrupt changes of directorship and staff at the observatory in Paris caused major interruptions in the state of the investigations. For instance, when the astronomer, Urbaine Leverrier, was appointed as head of the Paris observatory by Napoleon III as successor of the republican Francois Arago, he had to witness the departure of a cohort of trained staff who were loyal to their former director and unwilling to serve under Leverrier. As a result meteorology at the observatory lacked a firm base of research to build on. Leverrier's authoritarian personality, furthermore, brought him often into conflict with newly recruited meteorological researchers at the national institute causing them to leave prematurely, while they could have contributed to progress in the science. In a period when the Netherlands and Britain were making great advances in putting meteorological theories into practice at their newly operating storm warning services, France still lacked its own warning system and, for a long time, the French ministry of marine relied on British warnings for its ships.[13] The ramifications of the disrupted hierarchical organization of the national observatory had its inevitable effects on the state of meteorology in France. Since the studies of French weather investigators had relatively little impact on the debates over wind and storm theories elsewhere in Europe, France plays a smaller role in this story than would be expected of a nineteenth-century maritime power.[14]

This history of nineteenth-century meteorology takes place in the contexts of the Netherlands, United States, Britain and the German-speaking regions. The story is structured in four chapters that stand on their own, but taken together also constitute a narrative unity. The episodes in this story will take us from the Naval Observatory in Washington D.C. across the seas and Dutch colonial territories over to Buys Ballot's home town, Utrecht, westwards to the meteorological department in London, and back eastwards to the meteorological institute in Berlin among other places, to finally arrive at the international meteorological congress held in 1873 in Vienna.

The first chapter examines the alliance between professors and naval officers in establishing networks for marine and meteorological data collection on board ships. It shows how university professors teamed up with naval officers in forging networks of marine observations, in order to attract the attention of the state and obtain support for the establishment of national institutes of meteorology. The partnership embodied the fusion of practical utility and scientific interest. This chapter investigates the combined efforts of the U.S. Navy lieutenant Matthew Maury and the Dutch naval officer Marin Jansen in organizing the 1853 International Maritime Conference in

[13] John L. Davis, "Weather forecasting and the development of meteorological theory at the Paris Observatory, 1853-1878," *Annals of Science*, 1984, *41*:359-382, on pp. 363-364, 367. J. Babinet was among those who left the observatory when Leverrier was appointed. E. Liais, Q. P. Desains, and E. Marie-Davy left the institute before the end of their term. For the history of meteorology in France, also see Locher, (cit. n. 1).
[14] Kutzbach, for instance, ascribes the insignificant impact of Henri Peslin's thermal theory on meteorology in France to its hostile reception by the established French meteorological authorities, Urbaine Leverrier, Edme Hippolyte Marie-Davy and Hevré Faye. Kutzbach, (cit. n. 1), p. 88. See also Davis, (cit. n. 13), pp. 379-380.

Brussels, which aimed to develop a worldwide system of uniform atmospheric and marine observations. To carry out their plans they sought the cooperation of professors. As will be shown, however, the alliance between naval officers and academics proved to be only temporary. Once the meteorological institutes were established, tensions between them mounted and led to serious conflicts with long-lasting implications affecting the hierarchical structure of the institutes and meteorological science in general.

Chapter 2 focuses on the creation of "Buys Ballot's wind law." It explains how a rule of thumb, which was first used for the prediction of strong winds in the Netherlands, was transformed into the widely acknowledged meteorological law that relates the direction and force of the wind to the surrounding atmospheric pressure field. Buys Ballot, the creator of the law, actively lobbied for ten years in the international arena for his wind rule. Despite his successful implementation of the wind rule as a basis for the first storm warning system, he failed to interest foreign weather investigators in his work. His large network of associates could not help him to get his wind theory accepted. This chapter shows how general skepticism towards predictions and competing wind theories prevented Buys Ballot from finding support for his ideas. As this chapter further shows, entirely contingent events eventually resulted in the transformation of the wind rule into a wind law, which appeared to be the remedy to the problems of an ailing British meteorological department.

While the second chapter deals with the *creation* of a meteorological law, Chapter 3 examines the *decline* of the first law of the winds. The so-called "law of turning" of the Berlin professor of physics, Heinrich Dove, served as the theoretical basis of an overall model of weather change that dominated meteorological thinking in Europe for forty years. Dove developed an active interest in weather and climate in the late 1820s. From the study of precise observations of local winds, air pressures, temperatures, and humidity, he discovered the regular clockwise turning of the wind direction around the compass whenever barometric pressure dropped and rose again. In the spirit of Humboldt, he collected and collated large sets of meteorological data from hundreds of different places over long periods of time and succeeded in extracting mathematical laws from them. As Humboldt's protégé, he emulated the practice of charting global average temperatures in monthly isothermal maps in the late 1850s. Dove's model of weather change and storm generation was imbued with holistic notions of interdependence among different atmospheric phenomena. Although he was a prominent figure in nineteenth-century studies of the weather, his research has as yet not been thoroughly examined. This chapter investigates why the "law of turning," which was part of standard training in the science of the atmosphere, was suddenly replaced by Buys Ballot's wind law. While the local Dutch wind rule became widely accepted as "Buys Ballot's wind law" in 1868, the "law of turning" fell into discredit at around the same time. As we shall see, the replacement of the "law of turning" by the wind law reflects a metamorphosis of meteorological science in the 1870s from the holistic study of local periodic changes in weather phenomena into the "synoptic" study of simultaneous atmospheric observations over a wide region mainly focused on storm and weather forecasts.

The last chapter looks into the role that Buys Ballot played at the international meteorological congress held in Vienna in 1873. The aim of the meeting was to develop a uniform system of observations. The major issue at stake was how to obtain reliable and precise observations that were carried out at different places by different observers and with different instruments. Buys Ballot, who was by then widely known as the creator of the wind law, was appointed as president of the permanent meteorological committee. In this chapter I show how he used his position at the congress to actively promote two solutions to the problem of exact observations. With these solutions, which he borrowed from the astronomer Gauss and his one-time patron, Dove, who had turned into his rival, he hoped to make meteorological observations more accurate. However, instead of succeeding in finding support for his program, Buys Ballot eventually pushed himself to the margins of meteorology, which by the 1870s was beginning to be classified as a physical science. Explained in present-day terms, meteorology began to be viewed as a science that benefitted more from mathematical and physical modeling than from a spatial-temporal statistical approach. This episode marks the end of the "cult of averages" in meteorology and the beginning of a new type of weather research.[15]

Although it would take another forty to fifty years for nineteenth-century meteorology to begin to resemble the modern university discipline, the study of the harmonious oscillations of atmospheric phenomena based on averages had by the 1870s gradually turned into a science of actual observations of the atmosphere. What was once part of a Humboldtian unifying form of knowledge was shaped into a separate differentiated and specialized branch of science. As we shall see, this transformation was inseparable from boundary-work and the claim to authority.

[15] The phrase "cult of averages" is derived from Lorraine Daston's "The Cult of the Average" where she argued that Humboldt used the method of averages as a way of integrating nature's variation into a whole, for example in his isotherm map of global annual temperature averages. Daston, (cit. n. 6), pp. 54-55.