Rulers of the Winds

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Conclusion

How did meteorology become a distinct branch of science? How did university professors manage to claim authority in a field that was closely tied to the sea and retained a strong practical orientation? The science of the weather emerged from astronomical and navigational concerns. It formed a compound in multiple senses. It evolved from a mixture of wind and ocean-current investigations, was carried out on land and at sea, and united naval officers and university professors in large-scale observation networks. It combined investigation with application, found expression in natural laws and weather forecasts, and served intellectual needs and public interests at the same time. The combination of state-of-the-art science and practical use gave the study of the weather its mass appeal in the mid-nineteenth century. It is remarkable that an ill-defined field of study could develop into a clear-cut academic science in a relatively short period of forty years between 1830 and 1870. As we have seen, the distinctive features in the shaping of meteorology as a science were the creation of networks of observation, the establishment of national institutes, the formulation of general laws of weather change, and the application of meteorological theories to public services under the leadership of academics.

Naval officers played an indispensable role in this process. As this study has shown, they personified the links among natural knowledge, power and profit. Knowledge of winds and currents meant control over sea lanes, and thus control over global trade routes and access to overseas territories. Acting as go-betweens, naval officers used their professional connections to forge global networks of data collection. The world's vast oceans and coastlines, the scene of imperial ambition and international trade, were their familiar playgrounds, their natural habitat, so to speak. Building on existing infrastructure and workforce, men like Maury, Jansen and Fitzroy carried out observations of a wide range of maritime phenomena and used these data to prepare reliable and accurate sea charts and sailing directions. They secured broad participation in the observation programs by advocating the benefits of maritime observations to the merchant navy, while using their connections to recruit observers. They standardized measurement procedures, coordinated the observations and developed methods to establish comparability of data. The cooperation between Jansen and Maury reached the pinnacle of its success with the organization of the first international maritime conference held in Brussels in 1853, when representatives of ten countries, nearly all naval officers, agreed upon a uniform mode of meteorological observation.

With their collective efforts in creating networks of observation, naval officers laid the groundwork for the establishment of institutes where investigations of the sea surface and the atmosphere could be organized systematically and according to standard procedures. Jansen, Maury and Fitzroy, who had a certain training in the exact sciences, hoped to advance the science of the sea and the atmosphere through their maritime investigations and thus obtain scientific credentials. In order to lend scientific status to their efforts, naval officers sought the cooperation of academics. In turn, university professors used their connections with naval officers to highlight the navigational, commercial and military benefits that could result from their astronomical, meteorological and other geophysical investigations. Professors like Kaiser, Buys Ballot, Bache, Henry, Whewell and Herschel used their alliance with naval officers to attract the attention of national governments and win support for the establishment and control of national scientific institutes. As we have seen, these forms of cooperation between naval officers and university professors were, in fact, bonds of convenience that helped each group to advance their own cause. Once the institutes were established, tensions mounted and competition revealed the vulnerability of these temporary alliances. Disagreements about tasks were commonplace at the nascent institutes, as was the case at the Dutch meteorological institute, the American Coast Survey and Naval Observatory, and the British Meteorological Department.

As this study has shown, the shaping of meteorology went hand in hand with intense boundary-work among university professors and naval officers that involved the cultivation of differences between analytical and practical work, the subordination of wind and current investigations to land meteorology, the creation of hierarchies at the departments, strategies of exclusion of non-academics from meteorological investigations and committees, and ultimately the assertion of scientific authority. The theories of atmospheric circulation of Maury and Fitzroy, for instance, were intensely criticized by elite men of science, mostly because their work associated science too much with commercial success and practical utility. Buys Ballot defined the maritime work of Jansen as practical and subordinate to his own theoretical and land-based meteorological investigations. In a similar manner, Bache downgraded the role of naval officers at the Coast Survey and Naval Observatory by depicting their work as based on experience and common sense. He promoted his own surveying practices as systematic and grounded in physical theories. When disputes needed to be settled, as was the case with Jansen and Buys Ballot, or at the U.S. Coast Survey, or in England when the Board of Trade had to decide about the future of the Meteorological Department, it was government authorities who accorded precedence to academics over naval officers. A comparison of the first international conference in Brussels, which was almost exclusively composed of naval officers, and the international meteorological congress in Vienna in 1873, which only admitted academically trained meteorologists provides a clear illustration of how meteorology had by then become the exclusive domain of academics.

By characterizing the work of naval officers as practical, excluding them from analytical work, marginalizing their role at the institutes, and denying them access to meteorological committees, academics defined the limits of scientific investigation, and established and secured their authority in meteorology. This history has sharply revealed the tense competition involved in the process of discipline formation that began in the 1830s, and yet did not end until after the turn of the century. In the 1870s, handbooks for meteorology had just begun to appear, but there was no examination for students or chair of meteorology at the universities. However, as we have seen, the general acceptance of Buys Ballot's wind rule marked a turning point for meteorology, as it provided the emerging science with a predictive law of its own. The ousting of Dove's law of turning restricted the science of the weather to the synoptic study of quantitative variables over short temporal intervals, thus separating meteorology from climatology. Created by a university professor, moreover, the wind law served as a reliable means of foretelling storms. It connected meteorology with practical utility, while keeping it firmly within academic bounds. Buys Ballot's wind law offered a means to give practical weather forecasting the credentials of authenticated science. Theory and prediction combined in the wind law gave meteorology the status of an exact science.

The claim to authority, increased differentiation and specialization in weather investigations, and their growing relevance in society are recurring themes threaded throughout this dissertation. These themes, indeed not unique to meteorology, continue to intrigue historians of science who seek to trace the origins of present-day scientific disciplines. The view has gained wider acceptance that the origins of modern science should rather not be sought in the early modern period during the so-called Scientific Revolution, but in the nineteenth century as a formative period for the emergence of modern disciplines. Some historians have introduced the phrase "the Second Scientific Revolution" so as to emphasize the greatness of nineteenth-century science matching the scientific accomplishments in the early modern period, but for good reasons the concept has not been taken up widely.[1] Although views range from "the very character of 'science' changed during the course of the nineteenth century," to "modern science was *invented* in the nineteenth century," there is no denial that science

[1] For a discussion of the term, see Steven G. Brush, *The History of Modern Science: A Guide to the Second Scientific Revolution, 1800-1950* (Ames, Iowa 1988); Andrew Cunningham and Perry Williams, "De-Centring the 'Big Picture': "The Origins of Modern Science" and the Modern Origins of Science," *The British Journal for the History of Science*, 1993, *26*:407-432; David Cahan, "Looking at Nineteenth-Century Science: An Introduction," in *From Natural Philosophy to the Sciences*, ed. Cahan (Chicago: University of Chicago Press, 2003), 3-15, on p. 3. Another more recent trend in historical scholarship is the frequent use of the phrase "history of knowledge" in favor of the "history of science," which could be interpreted as an affirmation of the view that the origins of "science" should be exclusively located in the nineteenth century. The history of knowledge, not strictly tied to a specific period, allows the inclusion of other distinct periods within its scope of research.

gained an unprecedented visibility in nineteenth-century society.[2] As we have seen, meteorology and weather forecasting significantly contributed to this visibility. Far from having diminished, science's potency has only increased, making it difficult today to imagine otherwise.

In their paper, "De-centering the 'Big Picture'," which thematized the "invention" of science, Cunningham and Williams explained the transition of natural philosophy as a dominant way of knowing nature to the rise of the modern sciences during the nineteenth century. They characterized this transition as a time when "the investigation of nature changed from a 'godly' to a secular activity." As they argued, people stopped using the term "natural philosophy" for the study of nature as God's universe and started "to speak of 'science' or 'the sciences' referring only to the sciences of nature." The period saw not only the "invention" of science, but also the invention of its values, aims and history. Cunningham and Williams sketched the shifts in scientific practice "in broad brush strokes" that included the creation of new disciplines like biology, geology, and new versions of physics and physiology; the creation of professional careers in science and the emergence of the salaried man in contrast to the preceding "gentleman amateur"; and a prominent role for organizations of science.[3] A decade later, the contributors of a volume appropriately entitled, *From Natural Philosophy to the Sciences*, made an attempt to elaborate these themes. Together, the case studies in the volume make the claim that institutionalization, specialization and the increased interrelationships of science with other aspects of society were distinctive features of nineteenth-century sciences.[4]

This history of meteorology, while in line with the triple theme of institutionalization, specialization and application, is illustrative of how individual branches of science developed. Government ministers

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[2] Cahan, "Looking" (cit. n. 1), p. 8. Cunningham and Williams, "De-Centring" (cit. n. 1), pp. 409-410. Emphasis is mine.

[3] Cunningham and Williams, "De-Centring" (cit. n. 1). For secularization and the transformation of natural philosophy to science, see pp. 422-424; for the invention of science's "aims, values and practice," see pp. 427-428.

[4] Cahan, "Looking" (cit. n. 1), pp. 8-15.

and heads of departments supported the establishment of national scientific institutions on the assumption that they could deliver material benefits to the state. Increasing differentiation in the investigations of the atmosphere and the sea surface paralleled the development of the hierarchical structure of the institutes, where subdivisions of work defined and classified the subjects of study. Academics actively cultivated distinctions between theoretical work, which they appropriated as the proper domain of scientists, and practical work, which they allocated to "practical men" such as naval officers, observers, instrument builders, and calculators. The rhetorical language employed in their writings served strategic purposes of enforcing these distinctions between practical investigations and higher intellectual pursuits. The creation of natural laws helped to further distinguish science from mere empirical knowledge. The visualization of acquired knowledge in charts, graphs and maps, furthermore, served as a means to communicate scientific results to wider audiences and enhanced science's visibility and relevance in society.

Finally, this study has identified a novel theme, the integration of meteorology with academia, that may be illuminating in the historiography of other areas of modern science, in that it suggests that the gradual domination of meteorology by academics was a general pattern discernible in other sciences as well. In the course of the nineteenth century, meteorology became increasingly tied to universities. Heads of meteorological institutions, positions that increasingly became the prerogative of professors, began to introduce requirements for access to research and positions. University credentialing served as a gatekeeping mechanism to exclude others from scientific investigations. Accuracy and reliability became watchwords in meteorological observations. Attempts to standardize research procedures and methods required further organization on national and international scales. At the same time, these attempts revealed the new limits of the scientific enterprise in a way that was painful to some of the traditional participants. Despite internal disagreements, academics presented themselves as a community by creating a scientific in-group with a distinct identity that shared similar backgrounds, qualifications, values and interests. Meteorology as a science was actively shaped and remolded in practice, not once but continually.

The increased identification of science with academia, the establishment of institutes, specialization, the creation of hierarchical divisions in scientific work, the creation of theories and laws, and visualizations of scientific results do not just stand on their own as exceptional episodes in the nineteenth century. All these points can serve as organizing categories in the historiography of science. Thinking along these lines is not only fruitful for the study of meteorology and other exact sciences, but also for the historical understanding of the wider spectrum of the sciences and humanities, as these points allow us to think more sharply about the origins of individual disciplines and how dividing lines between them were created.[5] These markers are useful in the study of the mechanisms of organization, combined effort and division in all academic fields, and pose questions as to how and why some fields began assuming a distinct place in the scientific landscape of the nineteenth century without taking their current form or their supposed coherence for granted. Science as an actively pursued enterprise, moreover, lends itself to be written down in compelling historical accounts of competition and cooperation, struggle and boundary making. When they are recounted in this way, not just historians, but anyone can relate to these histories. These illustrative episodes in science, having great appeal to the imagination, while grounded in empirical evidence at the same time, may provide the rich, multifaceted, unifying histories of science that we so dearly want.

[5] In 2015 an *Isis* Focus section was devoted to the discussion of a unified framework for the history of the sciences and humanities. In their contribution, Lorraine Daston and Glenn Most argued that the history of the sciences and humanities have much to gain by joining forces. One way to do so, as they propose, is by shifting the focus from the subjects of study to how they were studied. Lorraine Daston and Glenn W. Most, "History of Science and History of Philologies," *Isis*, 2015, *106*:337-390.