Summary

This dissertation is a study of how meteorology developed into a well-defined and widely acknowledged branch of science in the period between 1830 and 1870. Meteorology was shaped in a context of cooperation and conflict between men of science and naval officers in their search for professional opportunities. This study offers an answer to the question: How did university professors establish their authority and manage to dominate the science of the weather? 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. 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 until now understudied, role in the forging of national and international maritime observation networks. As this study shows, furthermore, the emergence of these networks involved many countries across both sides of the Atlantic. The gradual institutionalization of meteorology and its integration with academia resulted from changing alliances among university professors, naval officers, and governments of maritime nations.

Five distinctive features characterize the emergence of meteorology as a distinct field: the creation of global networks of observation, the establishment of national institutes, the formulation of general laws of weather change, the application of meteorological theories to public services, and the establishment of international organizations. Chapter 1 shows how naval officers in search for fast and safe navigation routes took the initiative to forge global networks of marine observations and played an influential role in the establishment of national institutes of meteorology. In order to lend scientific status to their efforts, they 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 investigations. They used their connections with naval officers in order

to attract the attention of the state and obtain support for the establishment of institutes of meteorology where investigations of the sea surface and the atmosphere could be organized systematically and according to standard procedures. The partnership between naval officers and university professors embodied the fusion of practical utility and scientific interest. As this chapter shows, these alliances were, in fact, bonds of convenience. Once the institutes were established, tensions mounted and competition revealed the vulnerability of these temporary alliances. Neither side agreed to a subordinate position at the institutes. In most cases it was government authorities who accorded precedence to academics over naval officers.

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 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. Competing wind theories prevented him from finding support for his empirical generalization. As this chapter shows, the general acceptance of Buys Ballot's law can largely be attributed to the decisions of the Royal Society. The Meteorological Office under the authority of the Royal Society was badly in need of a principle to sanction and reinstate the suspended British storm warning system. The acceptance of Buys Ballot's wind rule as a general law offered a means to give meteorology the status of an exact science and it provided the Royal Society with a way to restore the reputation of the Meteorological Office.

Chapter 3 studies the emergence and decline of the "law of turning" of the Berlin professor of physics, Heinrich Dove, which served as the theoretical basis of an overall model of weather change that dominated meteorological thinking in Europe from the 1830s to the 1870s. The law of turning described the regular clockwise turning of the wind direction around the compass whenever barometric pressure dropped

and rose again. This chapter shows 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. Two factors are singled out. In the first place, this chapter shows that synoptic meteorology, while it became a dominant tool in weather investigations in the late 1860s, played an important role in this transformation. Synoptic weather maps showed at a glance how the movement of winds in general and in storms related to the pressure distribution, and thus obeyed Buys Ballot's law. Secondly, it is shown how Dove's theory of the deflection of winds based on latitudinal differences in the earth's rotational velocity was dismissed and superseded by William Ferrel's mathematical equations of motions of air on a rotating earth when they became known in Europe in the mid 1870s. As Dove's law of turning was stripped of its theoretical layers, it also lost its scientific relevance and was reduced to a local rule that said that the wind in middle latitudes changed its direction more often clockwise than anti-clockwise. With the replacement of the turning law by the wind law, Buys Ballot ousted Dove from his leading position as Europe's premier weather scientist.

Chapter 4 shows how authority is more easily lost than gained. It looks into the role that Buys Ballot played at the international meteorological congress held in Vienna in 1873. At this meeting Buys Ballot's leading position became manifest in his appointment as president of the permanent meteorological committee. However, his presidency was hardly more than a ceremonial position without real influence. A major theme during the discussions at the international meeting was how to obtain exactness of meteorological observations that were carried out at different stations. Buys Ballot offered two direct solutions to the problem of exactitude: synchronous measurements and the principle of deviations. On both these points he was disappointed badly. While the first proposal was impractical to carry out, the meteorological assembly at Vienna questioned the validity of the second proposal. The majority of the participants dismissed his proposed methods and standards of observation and analysis as outmoded. While determination of measurement errors was

once a standard practice to obtain reliable results, statistical data analysis was increasingly being replaced by exact experiments and improved instrumentation as ways to produce precision measurements in the exact sciences. The discussions at the meteorological congress in Vienna reflected the shift from the traditional mid nineteenth-century research of meteorological averages to the study of the geographically bound dynamics of the weather from the 1870s onwards. This chapter illustrates that Buys Ballot as an advocate of the former tradition in meteorology was as much a transitional figure as was Dove before him.

In conclusion, this dissertation has shown how the shaping of meteorology went hand in hand with boundary-work among university professors and naval officers that involved the cultivation of differences between analytical and practical work, the creation of hierarchies at the departments, strategies of exclusion of non-academics from meteorological investigations and committees, and finally the assertion of scientific authority. This history of meteorology is illustrative of how individual branches of science developed in the course of the nineteenth century in a process that has been characterized as a period of transition of natural philosophy, or the study of nature as God's universe, to the rise of modern sciences. This study has identified the increased identification of science with academia as a novel theme that can be added to the themes of institutionalization, specialization and the increased interrelationships of science with other aspects of society that are generally viewed as distinctive features of modern sciences.