VU Research Portal

Rulers of the Winds
Achbari, A.

2017

document version
Publisher’s PDF, also known as Version of record

Link to publication in VU Research Portal

citation for published version (APA)

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:
vuresearchportal.ub@vu.nl

Download date: 05. Jul. 2021
Chapter 3

Mastering the Winds: How a Local Rule Supplanted a General Law in the Science of the Weather

Not in his wildest dreams did Christopher Buys Ballot expect to topple Heinrich Dove from his position of authority, but that is what happened. At least, this is the argument of this chapter. In the mid nineteenth century, Dove was widely known as the creator of the “law of turning,” which served as the theoretical foundation of the emerging science of the atmosphere. In the 1870s, however, Buys Ballot ousted Dove from his position. His wind rule, which had first served as a practical rule for the creation of the first storm warning system in 1860, acquired the status of a natural law in 1868 and replaced Dove’s law. In fact, Dove’s general law and Buys Ballot’s local rule followed opposite paths. While Buys Ballot’s wind rule was transformed into a general law of nature, Dove’s “law of turning” was reduced to a local rule and it was subsumed under this newly established wind law. Buys Ballot’s leading position became manifest in his appointment as president of the permanent meteorological committee at the international congress of Vienna in 1873. At around the same time, Dove’s teaching fell into discredit.

Dove is now almost completely forgotten, his “law of turning” having been eclipsed by “Buys Ballot’s wind law,” which today still serves as a school example of a scientific law.

---

1 A shortened version of this chapter will be revised and resubmitted to the journal *Historical Studies in the Natural Sciences*.
symmetry in the demise of Dove’s “law of turning” and the rise of “Buys Ballot’s wind law” is a notable omission in histories of meteorology. In fact, there is in general little historical discussion of the “law of turning,” except for Gisela Kutzbach’s monograph on The Thermal Theory of Cyclones. But while she addresses the turning law in the context of Dove’s theory of storms, she only briefly discusses Buys Ballot’s wind law. Furthermore, she does not link the decline of Dove’s law with the concurrent general acceptance of Buys Ballot’s law.5

In this standard history of the development of the thermal theory of storms, Kutzbach discerned a new direction in European meteorological thought in the 1870s which marked a clear break from “the ‘old’ meteorology” associated with Dove. The new turn in meteorology was represented by British and Norwegian weather scientists, Alexander Buchan, William Clement Ley, Henrik Mohn and Cato Guldberg among others.6 As Kutzbach argued, their systematic investigations of simultaneous weather observations and the source of energy in storms were decisive for the development of the thermal theory of cyclones. This theory was in turn essential for the emergence of the polar front theory of cyclones, which is seen as one of the most important events in early twentieth-century meteorology.7 To show

---


6 Kutzbach, Thermal Theory (cit. n. 3), pp. 88, 120.

7 Ibid., pp. 1, 5.
how great the difference was between “the ‘old’ and the ‘new’ meteorology… that no compromise appeared possible,” Kutzbach cited a fragment from Mohn’s textbook of meteorology in 1875:

The readers who are acquainted with the presentation of older meteorological textbooks, will find that the presentation of various subjects in this book differs from earlier ones. Wherever such deviations from older points of view occur, I would like to recommend that the reader examine the reasons for these contrary views and then choose between them rather than attempt to reconcile them; for this cannot be done.  

This striking discontinuity in nineteenth-century meteorology makes it the more pertinent to ask how Dove’s meteorology that was labelled “old” in the 1870’s related to the general acceptance of Buys Ballot’s law in the same period. But before turning to this question, this chapter examines what exactly was the “law of turning.”

Dove’s “law of turning” is analysed in the context of the early nineteenth-century enthusiasm for the collection of large data sets about the weather. Unlike his predecessors, Dove moved beyond collecting and tabulating data. He believed that the mathematical analysis of large collections of atmospheric observations could uncover meaningful patterns and causal relationships among the phenomena that he studied. The success of his approach manifested itself in the discovery of a regularity in changes of wind direction. He succeeded

---

8 Kutzbach, Thermal Theory (cit. n. 3), p. 89. The quote is from H. Mohn, Grundzüge der Meteorologie (Berlin: Reimer, 1875), pp. vii–viii.

9 The nineteenth-century enthusiasm for large numbers is the subject of The Rise of Statistical Thinking by Theodore Porter. In this book he argues that meteorology was a field of importance for the transmission of statistical methods to the natural sciences. He refers to an 1850 paper of Buys Ballot, which testifies that in meteorology “consideration of variation as well as averages could be seen as genuinely important.” Further on in the text, it will be shown that statistical methods were introduced in meteorology even earlier. Theodore M. Porter, The Rise of Statistical Thinking 1820–1900 (Princeton: Princeton University Press, 1986), p. 116. The paper in question was C.H.D. Buys Ballot, “On the great importance of Deviations from the mean state of the atmosphere for the science of meteorology,” The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science, 1850, 37, no. 3:42–49.
moreover to express the found regularity into a mathematical law that became the first law in the science of the atmosphere. Reviews of Dove’s “law of turning” in German publications are examined to see how his work was assessed and how he advanced his career in meteorology.

The following part of this chapter shows that Dove developed a theory of storms while he engaged in discussions with his academic peers. Dove’s theory of storms, which he also proclaimed as a law, differed from the concurrent “law of storms” stating that storms in the northern hemisphere spiralled anti-clockwise around an area of low pressure. The discussions took place in British journals, for the “law of storms” was of half British origin. By looking into these discussions, it is shown that although Dove’s theory of storms was not generally accepted, he nonetheless assumed a position of authority in British academic circles. It appears that he was praised by the Royal Society, not so much for his storm theories, but for his global temperature maps. For the construction of his maps, Dove used a graphical technique borrowed from the famous globetrotter, Alexander von Humboldt. The latter had pioneered the use of isotherms on maps that displayed lines of equal yearly average temperatures on the globe. Dove improved on the isotherm maps by depicting monthly temperature variations across the latitudes.10

Dove’s theory of storms and his “law of turning” together made up an overall model of weather change that dominated meteorological teaching in many parts of Europe for decades. The next part of this chapter discusses how his investigations of periodic changes in temperature, pressure and wind direction inspired Buys Ballot’s meteorological program. By focussing on the distribution of atmospheric pressure instead of the distribution of temperature, Buys Ballot’s research plan slightly differed from Dove’s program, but as it is

---

10 The nineteenth-century trend of collecting “Big data” about nature initiated by Humboldt was accompanied by innovations and growth of statistical visualizations to which he also contributed. The graphical innovations were so influential that the period 1850–1870 has been called the “Golden Age of Statistical Graphics.” Michael Friendly, “The Golden Age of Statistical Graphics,” Statistical Science, 2008, 23, no. 4:502–535, on pp. 516–517. On Humboldt’s maps, see p. 510.
shown, he did not question his established methods and theories. He was, in fact, known as Dove’s best supporter. He was once even called “the best defender” of the “law of turning.” However, while pursuing Dove’s meteorological programme in the Netherlands, Buys Ballot discovered a wind rule of his own that challenged the “law of turning.”

The final part of this chapter discusses how Buys Ballot’s wind law eventually ended up replacing Dove’s “law of turning” without actually contradicting it. The replacement of the turning law by the wind law appears to have been primarily the result of the evaluation of Buys Ballot’s wind law in publications by the exponents of the “new” meteorology.

**Heinrich Dove and the Creation of the “Law of Turning”**

In early nineteenth-century German regions, bureaucrats and administrators collected numerical facts about the weather as part of their task to inventory the natural, financial, and population resources of their states. This practice originated in cameralism that fused commercial activities like mining, forestry, and metallurgy with natural science. The collection of data about the weather rooted in the cameralist belief of using natural knowledge for the common good and was directly linked to the state’s agricultural and public health concerns. However, the data that statists and naturalists collected often ended up in neatly arranged tables without expressing relevant information about the phenomena under study. Labels like “Tabellenstatistiker” or “tabellenknechte” were coined for statistical enthusiasts who hoarded and tabulated data, but who lacked the skills or the interest to draw meaningful conclusions from the numbers.

---


12 The strong connection between natural science and cameralism has been demonstrated by Andre Wakefield, *The Disordered Police State: German Cameralism as Science and Practice* (Chicago: The University of Chicago Press, 2009), pp. 24–25.

13 The obsession with reducing natural phenomena to numbers and statistics is described in the *Göttingische gelehrte Anzeigen*, 1806, 1, no. 84:833–840, on p. 834. I thank Ida Stamhuis for bringing sneering terms like “tabellenstatistiker” (table statisticians), “tabellenknechte” (table servants) and “tabellenfabrikanten” (table
Ephemerides for instance, resulting from years of observation by the Mannheim meteorological network called the Societas Meteorologica Palatina were widely praised, but these long tables of periodic atmospheric statistics as such did not yield insights into processes determining weather.14

In 1844 German weather investigations received a boost when the director of the Statistical Bureau developed the plan to establish a full-fledged meteorological institute in Berlin as the centre of a Prussian network of weather stations. To this end he sought the cooperation of Humboldt, the explorer of international standing, who agreed to use his position at the court of Frederick William IV to obtain support for the plan.15 He drew up a blueprint for the measurements to be carried out and recommended his friend Wilhelm Mahlmann for the management of the institute.16 Mahlmann had translated Humboldt’s scientific treatise on the results of his expedition to Central Asia in 1829 from French into German. He was also known for his own climatological studies.17

As soon as the king gave his approval to the plan in 1846, Mahlmann was recruited to begin the preparatory work.18 He began with the inspection of existing meteorological stations and the search

---

18 Körber, Die Geschichte (cit. n. 15), pp. 11–12.
for new locations to make observations. The preparatory journey took approximately one year. The Prussian network comprised 35 stations, all of which Mahlmann was ordered to visit annually. In 1847 the central institute in Berlin was officially established and Mahlmann was appointed as its director. But before reaching the stage of processing the data that had been collected, he died during one of his field trips to Breslau in 1848. In the next year Heinrich Dove was appointed as his successor.

Dove had studied physics in Breslau, where he also attended courses in philosophy, astronomy and history. As a young student, he was impressed by the lectures of Heinrich Wilhelm Brandes (1777–1834) who ignited his enthusiasm for meteorological studies. Much to his delight Brandes praised him as one of his best students and engaged him in his investigations of meteors. In the spring of 1824 Dove travelled to Berlin to attend lectures in physics and mathematics. Paul Erman, who had been told about this brilliant student by Brandes, welcomed him at the faculty and in his home.

Dove obtained his doctorate in 1826 from the university of Breslau with a thesis on changes of the barometer, and he received his habilitation from the university of Königsberg in the same year with a dissertation on the distribution of heat on the globe. He worked at this university as a private tutor until 1828, when he was appointed extraordinary professor in physics. Despite the financial worries that marked his early career, he was very productive. His investigations of local weather conditions led him to the discovery of a general meteorological rule in 1827.

His first publication began with the sentence “changes in wind direction seem to be so arbitrary … that people have given up trying to

---

21 Dove, “Dove” (cit. n. 16), pp. 53–54.
find any regularity in them.”

He claimed to be the first to offer a general theory of weather change. By studying simultaneous readings of the barometer and observations of wind direction in Königsberg, Dove discovered that the wind direction always shifted clockwise “through the complete wind rose,” whenever barometric pressure dropped and rose again. Over a period of twelve days, he had observed that the wind shifted from west to northwest, northeast, east, southeast, south, and west again. Although the turning of the wind occurred most noticeably in winter, he observed the phenomenon during the other seasons as well.

The turning of the wind led Dove to believe that all winds in the area where he made his observations, were whirlwinds. Next he tried to establish whether the phenomenon of the turning of the wind was observed elsewhere as well. He was able to get hold of some rare observations that had been made by Francis Bacon in London and by Wilhelm August Lampadius in Freiburg. These natural philosophers had independently observed the phenomenon of the clockwise turning of the wind. Dove concluded that this was not just a local phenomenon.

He subsequently analysed published records of the weather from different places in Europe. From the comparison of series of pressure, temperature and humidity records with wind observations he noticed “a regular cycle of changes” in the occurrence of different weather conditions, which concurred with different wind directions. Changes in pressure, temperature and humidity seemed to be the effect of the turning of the wind, or so he concluded. The periodic cycle of changes was most clearly noticeable in the observations that were carried out in Paris from 1816 until 1825. About the turning of the wind he said: “There are, I believe, few phenomena in meteorology, which reveal

---

themselves with such compelling clarity from relatively short series of observations.”

By using the method of least squares and an interpolation method borrowed from the astronomer Friedrich Bessel, on his data sets, Dove was able to obtain an approximate law of atmospheric pressure as a continuous periodic function of the wind direction in the form

\[ b(x) = a + c \sin x, \]

where \( b \) was the pressure, \( x \) the wind direction in degrees, and \( a \) and \( c \) constants that he determined empirically. Similarly he obtained approximate laws of temperature and humidity as periodic functions of the wind direction. He published the results of his investigations in the Berlin-based journal, *The Annalen der Physik*, in 1827. In the course of two years he published another four papers, which together constituted a general theory of weather change.

In the second and third paper Dove explored the relationship between precipitation and changes in air pressure and temperature. In the fourth paper he argued that the weather in Europe was determined by two dominant air currents, one from the southwest and the other from the northeast. He believed that the turning of the wind was the product of the collision between these two alternating air currents in opposite directions, which displaced one another and brought about a circular movement in wind direction. The change of direction of the wind seemed to depend, according to Dove, on the location of the observer relative to these currents. From observations of wind direction made in several places in Europe located between the southwest and the northeast streams, he concluded that winds changed their direction clockwise. However, in Asia, located east of the northeast current, the winds turned anti-clockwise. In addition, he inferred from available observations that winds in the southern hemisphere turned in the

---

26 Ibid., pp. 553–556.
29 Dove, “Über den Zusammenhang” (cit. n. 28); Dove, “Über das Gewitter” (cit. n. 28).
direction opposite to that in the northern hemisphere.\textsuperscript{30} In the fifth paper, he suggested that storms in middle latitudes were whirlwinds that followed the path of the southwest air current and were characterized by a barometric minimum. The direction of a storm’s rotation, he hypothesized, must then be in accordance with the found regularity in the turning of the wind, beginning from the southwest and turning clockwise. Storms in the southern hemisphere rotated in the direction opposite to that in the northern hemisphere.\textsuperscript{31}

Dove’s publications added to his reputation as a promising scholar and helped him gain an invitation to the meeting of the German Association for the Advancement of Science and Medicine in Berlin in September 1828. The meeting was organised in honour of Humboldt, who had recently returned to the Prussian capital. Humboldt was truly impressed by the meteorological studies of Dove, so much so that he invited the researcher who was 34 years his junior to Abraham Mendelsohn-Bartholdy’s mansion to take part in carrying out magnetic observations in the iron-free cabin that stood in the garden.\textsuperscript{32}

Dove’s stay in Berlin was not only promising on a professional level. In fact, the real reason behind his visit to the city, according to one of his biographers, was to propose to Louise von Etzel, the daughter of a well-known geographer. He had become acquainted with her when he stayed at Paul Erman’s house a couple of years before. Louise was Erman’s niece. At Christmas in 1828 they became engaged and Dove asked for a transfer to the university of Berlin. Although he received no salary for the first two semesters and had to manage with a meagre income thereafter, he was happy with his appointment as an extraordinary professor in physics in 1829.\textsuperscript{33}

Meanwhile a paper appeared in the \textit{Annalen der Physik} in response to Dove’s theory of the turning of the wind. The author of the paper, Joakim Schouw, a Danish professor of botany, questioned the general

\textsuperscript{30} Dove, “Über mittlere Luftströme” (cit. n. 28), pp. 585–587, 590.

\textsuperscript{31} Dove, “Über barometrische Minima” (cit. n. 28).


\textsuperscript{33} Dove, “Dove” (cit. n. 16), pp. 56–57.
validity of the turning of the wind. One of Schouw’s arguments was that Dove’s conclusions were based on too few observations to make such general claims. In order to test the validity of the rule for the Atlantic Ocean, Schouw had consulted three naval officers with scientific training on this matter. One officer strongly disagreed with Dove. Another claimed that the wind turned clockwise in most cases, especially from east to south to northwest. The third officer agreed with Dove, but questioned the relevance of the rule.34

Schouw’s main objection to Dove’s theory was based on the meteorological observations that had been made ten times a day over a one-year period at Apenrade, a Danish seaport, by a colleague named Neuber. These observations showed different results. Of 1100 observations of changes in the direction of the wind, 559 changes were clockwise. In Schouw’s view the difference was not sufficient to produce any reliable evidence.35 From the analysis of these observations, he drew a different conclusion, namely that the wind tends to turn in the direction from which the winds blow most frequently. A south wind usually turns into a west wind, because west winds are more common than east winds. However, a north wind also turns into a west wind, for the same reason. While the wind turns clockwise in the first case, it turns counter-clockwise in the second.36

In his response to Schouw, published in the Annalen der Physik in 1829, Dove appeared to be offended. He brushed aside Schouw’s first objection, based on the observations made by the three naval officers, by arguing that out of the three statements, two were in agreement with his theory. In response to Schouw’s conclusion based on the observations made in Apenrade, Dove remarked that he had already discussed in his earlier work how the intensity of the southwest and northeast air currents are not always equal, which causes the wind to turn back through the wind rose, a phenomenon that he called “zurückspringende Wirbel.” He stated that, when this happens, “the

36 Ibid., p. 550.
wind turned more often anti-clockwise between SW and NW, seldom between NW and NE, and more often between ENE and ESE, than between SE and SW.” He argued that if Schouw believed long-term observations would produce better results, then he should collect these himself, for Schouw had longer series of observations at his disposal. Dove added that “a person can cast doubt on everything, but doubt itself is no refutation.” The final blow he delivered to Schouw was his remark that “there are always opposing views to be found concerning meteorological phenomena by people who do not fully engage in these studies.”

It is remarkable that Dove made such blunt statements, without actually responding to Schouw’s relevant criticism. Instead of producing doubt, his criticism seemed to have made Dove more confident of his case. Previously he had described the phenomenon in more cautious terms such as “a regular cycle.” For his approximate law of atmospheric pressure he had used the word “Formel.” In his response to Schouw however, he proclaimed the phenomenon of the turning of the wind for the first time as the “law of turning” (Gesetz der Drehung).

He defended his law on the basis of three arguments. First, he claimed that Bacon and Lampadius had also witnessed the phenomenon in the areas where they lived. Secondly, the turning of the wind was part of an overall model of weather change. The rise and fall of the barometer corresponded with a fall and rise in temperature respectively and the turning of the wind through the wind rose. In this respect, Dove considered three possible scenarios:

1.) the direction of the wind changed clockwise,
2.) the direction of the wind changed counter-clockwise,
3.) there was no law of turning of the wind direction.

38 Dove, “Einige meteorologische Untersuchungen” (cit. n. 23), pp. 558, 564.
Based on his observations from Königsberg and Paris, Dove concluded that for Europe the first scenario had to be the correct one. To question the “law of turning” implied that the entire model was criticized, while the observations confirmed the theory completely. Dove used the same holistic reasoning for his third and last argument. Precipitation also corresponded to a change in wind direction. In the case of precipitation and a turning of the wind direction from south through west to north, there was always a rise in the barometer and a fall in temperature. Precipitation and the turning of the wind direction from north through east to south, was accompanied by a fall in the barometer and a rise in temperature. With these peremptory arguments Dove laid claim to a natural law.40

His approach met with approval in German academic circles. In 1830 a professor in natural philosophy and chemistry, Karl Kastner, published a handbook of meteorology. Kastner, who reported the discussion about the turning of the wind, decided in favour of Dove and acknowledged the theory as a law.41 He did so without producing substantive arguments and it is doubtful whether Dove attached much importance to Kastner’s support. If anything, Dove criticized him for having included Schouw’s criticism in the book. As he put it, “[Schouw’s] reasoning is of such a kind, that I am surprised it has been included in a Handbook for Meteorology.”42

Another German professor in physics, Ludwig Kämtz, however, was undecided. In the first volume of Lehrbuch der Meteorologie, which he published in 1831, Kämtz gave a general survey of the arguments used by Dove and Schouw. Although he offered more examples, which confirmed the phenomenon of the turning of the wind in other places in Europe and the United States, he explicitly referred to it as Dove’s hypothesis. Referring to Schouw’s study of the Apenrade observations, he concluded that the wind patterns in Denmark deviated from those observed elsewhere in Europe. He closed the section with the

40 Ibid., pp. 55–61.
suggestion that “in order to determine whether Dove’s hypothesis corresponds with nature or not, it now only comes down to a great deal of simultaneous observations not only of the direction, but also of the force [of the wind], not only in Europe, but also in other parts of the world.” Thus, he refrained from settling the dispute between Dove and Schouw, which continued in the following years. Dove’s carping led Schouw to complain a last time in the *Annalen der Physik* in 1833, but he saw no point in wasting more words on the subject after that.

A headmaster of a Berlin gymnasium, Johann Galle, investigated Dove’s hypothesis for Danzig, based on observations made over a 15-year period (1813–1827). The observations revealed a strong regularity of changes in barometer readings with corresponding changes in the direction of the wind. The barometer rose with west winds and fell with east winds. The turning of the wind was “the most plausible conclusion” to be drawn from the results, Galle argued. At the same time, however, he left the door open for alternative explanations. In addition, he did not generalize the findings beyond the locations where observations had been carried out, but assumed the validity of Dove’s wind rule only for the region between Danzig and Paris.

The above-mentioned physics teacher, Mahlmann, also engaged in the debate on the turning of the wind. In 1835 he published a translation of a report of the first and second meetings of the British Association for the Advancement of Science (BAAS) at York and Oxford in 1831 and 1832 respectively. The report had been written by the Edinburgh professor of natural philosophy, James D. Forbes. On his own account, Mahlmann added a section in which he reported on contemporary investigations into meteorological topics in the German states. Of all German physicists who made a contribution to the study

---

of the weather, he praised Dove as “someone who with outstanding 
insight formulated a hypothesis of the turning of the wind and related 
it to other atmospheric changes such as changes in the barometer.” 
Although acknowledging the need for barometer observations from 
more locations, he commended Dove’s law by stating that “this 
hypothesis here [is] one of the most important that meteorology possesses at the moment ....”

The general tenor of the responses to Dove’s theory was positive, 
but the majority of reviewers suggested that more extensive barometric 
and wind observations were needed. While these endorsements helped 
Dove to earn a reputation as an expert in meteorological studies, they 
did nothing to improve his financial situation. He still had the same 
position and salary as when he began to work as an extraordinary 
professor in Berlin. In order to get by he had to take additional 
teaching positions at the Friedrich Wilhelm Gymnasium, the Artillery 
and Engineering School and the Military College. A few years would 
pass before his financial situation improved. Around 1842 he received 
invitations to work at the universities of Dorpat, Bonn, Freiburg and 
Jena, but he rather preferred to be an extraordinary professor in the 
centre of the Prussian state than a full professor on the fringes. 
Although he declined the offers, he managed to negotiate a higher 
salary. In 1845 he became a full professor at the University of Berlin.

In the period up to 1845 Dove had a heavy teaching load. His 
working week consisted of about 24 to 30 hours of lectures in optics 
and acoustics, electricity and magnetism, theory of colour, and 
meteorology at several institutes. His lectures on meteorology were 
the most popular and drew crowds of listeners. In spite of the 
workload he was able to publish a book on meteorology in 1837. The

46 W. Mahlmann, Abriss einer Geschichte der neueren Fortschritte und des 
47 Dove, “Dove” (cit. n. 16), p. 58.
48 Hans Neumann, Heinrich Wilhelm Dove. Eine Naturforscher-Biographie (Liegnitz: 
49 Heidrun Siebenhühner, “Altmeister der Meteorologie. Der Physiker Heinrich 
publication of the work coincided with his appointment as a member of the prestigious Prussian Academy of Sciences.\textsuperscript{50}

The book, entitled \textit{Meteorologische Untersuchungen}, was actually a compilation of Dove’s meteorological investigations of the past years, which synthesized his theories into a full model of weather analysis. In addition to his first set of papers, which dealt with his discovery of the turning of the wind, he included a chapter elaborating on this phenomenon. This chapter was a revision of a paper that had appeared in the \textit{Annalen der Physik} in 1835.\textsuperscript{51} Here, he labelled the phenomenon of the turning of the wind once again as the “law of turning,” even though almost all those who had discussed his previous papers referred to it as a hypothesis that needed more empirical evidence.\textsuperscript{52} Dove was indifferent to these arguments. In fact, he drew an analogy between the “law of turning” and Kepler’s laws of planetary motion in astronomy. He probably hoped that the analogy would fortify his claim, although he admitted that Kepler’s laws and his own law had very different aims. Whereas Kepler’s laws described the motion of planets around the sun, the “law of turning” aimed at determining the force that caused a continuous cycle of changes in temperature, pressure and humidity, which were mutually dependent on each other.\textsuperscript{53} He then proceeded with an explanation of his law by offering both a theoretical and an empirical underpinning of the phenomenon.

Dove explained the turning of the wind theoretically by pointing to the rotation of the earth, an idea, which he borrowed from the British natural philosopher George Hadley (1685–1768).\textsuperscript{54} In 1735 Hadley had proposed the rotation of the earth as an explanation of the trade winds. He had argued that temperature differences between the equator and

\textsuperscript{50} Dove, “Dove” (cit. n. 16), p. 60.
\textsuperscript{52} Heinrich Wilhelm Dove, \textit{Meteorologische Untersuchungen} (Berlin: Sander’schen Buchhandlung, 1837), pp. iii, 129.
\textsuperscript{53} \textit{Ibid.}, p. 122.
higher latitudes produced a circulation of the atmosphere consisting of a closed loop with rising air near the equator and sinking air near the poles. Polar air masses moved toward the equator close to the surface of the earth. Because of the rotation of the earth and differences in its latitudinal speed, these northerly winds appeared as northeast winds or trade winds in the northern hemisphere, and southeast winds in the southern hemisphere. The closed loop of air circulation necessarily entailed a return flow of warm air masses from the equator to the poles higher in the atmosphere, which deflected due to the earth’s rotation and blew as southwest winds in the northern hemisphere and northwest winds in the southern hemisphere.\footnote{Anders O. Persson, “Hadley’s Principle: Understanding and Misunderstanding the Trade Winds,” History of Meteorology, 2006, 3:17–42, on p. 28. Dove, Meteorologische Untersuchungen (cit. n. 52), pp. v, 245–247.}

Although a closed circulation of air between the equator and the poles does not actually exist in the earth’s atmosphere, the “Hadley cell” is still used in a simplified three-cell model, together with the Ferrel cell and the polar cell, for explaining the cellular circulation of the atmosphere from the equator to latitudes near 30°, between latitudes 30° and 60°, and between latitudes 60° to the poles respectively.

Dove used Hadley’s principle to explain the turning of the wind by referring to the rotational velocity of the earth, which increases from zero at the poles to its highest value at the equator. He argued that southerly winds deflect sideways due to this difference in velocity. Dove explained that, when a volume of air is, by some cause, set in motion from north to south, then air coming from close to the point of observation will appear as a north wind. The air volume from further away will lag behind the rotation of the earth because of its slower rotational speed and will appear to the observer as a northeast wind. Air from still further north will appear as an easterly wind. “To an observer … the vane will thus have gradually turned from north through north-east to east.”\footnote{Dove, Meteorologische Untersuchungen (cit. n. 52), p. 126.}
Hadley’s principle as applied to the northern hemisphere only explains the deflection of a southward surface wind from north to northeast and the deflection of a high-atmosphere northward wind from the equator to southwest. According to Dove, the turning of the wind through the other directions of the wind rose was caused by the succession of polar air currents by equatorial currents, which first appeared to the observer as east winds, then shifted to southeast and south winds as equatorial air currents displaced polar currents. He applied a similar reasoning to the rest of the wind cycle, viz. the turning of southerly winds to westerly and northerly winds. Differences in the earth’s rotational speed at various latitudes accounted for the deflection of the equatorial air flow from the south into southwest and west winds. And again, by the displacement of the equatorial air flows by polar air flows he explained the shift of the wind through the rest of the wind rose, from west to northwest to north. Dove extrapolated the same reasoning to the southern hemisphere to argue that winds there turned in the reverse, anti-clockwise direction throughout the wind rose.\(^{57}\)

There are a number of discrepancies between Dove’s theoretical argument and Hadley’s principle. While in Hadley’s model northeast trade winds blow at the surface with concurrent southwest winds returning at higher levels, creating a closed loop, Dove’s two air currents succeed and displace one another at the earth’s surface. According to Hadley’s principle the general movement of the air was triggered by temperature differences at different latitudes. This difference, which caused an imbalance of density of atmospheric air, produced a circulation to restore the balance. Dove’s model, however, failed to explain the mechanism that set polar and equatorial currents in motion. It only accounted for every turn of the wind through the wind rose, without explaining the cause for the circulation of the atmosphere in the first place.

In an earlier paper, Dove had suggested that the study of temperature distribution on the earth’s surface would provide the

answer.\textsuperscript{58} Here, however, he remained silent on the subject. Instead he provided empirical evidence for the validation of the turning law, which he deduced from his observations of the wind direction from September 26 until October 6, 1826 in Königsberg. These were the same results that he had published in his first paper. He repeated his earlier discovery of the wind cycle in a clockwise direction and the concurrent changes in weather conditions. New to his empirical evidence was a substantial list of accounts of the observed phenomenon in other places in Europe and North America over a period of 300 years. The earliest account was from Francis Bacon, but the list contained names of several other renowned men of science. Observations from a few places in the southern hemisphere suggested the anti-clockwise turning of the winds south of the equator.\textsuperscript{59}

With a theoretical underpinning loosely modelled after Hadley’s principle, and a full list of empirical evidence, Dove regarded the principle of the “law of turning” as explained and established. Shortly after the publication of his meteorological treatise, he presented the preliminary results of his investigations of the distribution of heat on the earth’s surface at the meeting of the Prussian Academy in Berlin on May 3, 1838. He hoped to discover the rules for atmospheric circulation by studying temperature differences at various latitudes.

To the members of the Academy he explained his choice by stating that physical quantities such as temperature, pressure and air humidity were not evenly distributed on the globe. Changes in temperature, air humidity, and pressure at one location corresponded with changes in these quantities elsewhere on the earth’s surface. An increase in barometric pressure at one place, caused a decrease of pressure at another place, but could, for example, also cause an increase of temperature there. From his earlier discovery of a regular cycle of change in wind direction, which corresponded with changes in temperature, pressure and humidity, Dove distinguished two halves in the wind rose, which showed a clear contrast in all weather conditions. A “rise [in pressure for example,] on one side of the wind rose

\textsuperscript{58} Dove, “Über mittlere Luftströme” (cit. n. 28), p. 596.
\textsuperscript{59} Dove, Meteorologische Untersuchungen (cit. n. 52), pp. 130–155.
corresponded to a drop [in air pressure] on the opposite side.” Dove explained that he had already defined “the periodic cycle of each of the three main [atmospheric] instruments” (thermometer, barometer and hygrometer). What needed to be done was investigating how these periodic cycles corresponded with each other and with the turning of the wind. This research would reveal the interplay between the northeast polar air flow and the southwest equatorial air flow, which Dove believed shaped the weather at different locations in Europe.60

He pictured the air flows as fields that moved across the latitudes. Their “intensity” (Mächtigkeit) increased as they approached each other and collided. “Irregular” or “non-periodical” changes in temperature, pressure or humidity occurred when the polar air flow displaced the equatorial air flow or vice versa. These non-periodical changes were, so to speak, deviations from the mean distribution of atmospheric quantities at a certain moment in time. Dove assumed that the mapping of the simultaneous distributions of temperature, pressure and humidity across the globe would reveal the contours and the direction of the polar and the equatorial air current. Compiling a so-called synoptic map of the air currents, however, required that “all atmospheric relations were equally defined.” To start with, he set out to investigate the distribution of temperature on the globe and reserved the study of air pressure and humidity for a later date.61

Dove’s Law of Storms

In 1837 Dove began publishing an annual review called Repertorium der Physik in close cooperation with his colleagues and friends from Königsberg and Berlin. In the third volume published in 1839, he discussed the latest works on meteorology. In addition to his own book, he listed numerous other works on meteorology. Among them

61 Ibid., pp. 288–289. The term “synoptic” for the graphical depiction of various meteorological quantities on one single map was coined in 1858 by Robert Fitzroy. Halford, Storm Warning (cit. n. 5), p. 124.
were two papers that explicitly dealt with the nature of storms.\textsuperscript{62} This topic attracted Dove’s attention so much that he abandoned his original research agenda for the time being. Although the collection of temperature observations and analysis of the distribution of heat on the globe had been Dove’s main interest, he became involved in the study of storms.

William C. Redfield was one of the authors of a paper on storms. He was an American self-made entrepreneur who ran a transport company. In 1821 he became interested in the study of storms, when a storm known as the “Great September Gale,” hit the city of New York.\textsuperscript{63} The author of the other paper, a lieutenant-colonel of the British Royal Engineers, William Reid, became interested in the study of hurricanes while he was on a military mission in the West Indies. He had arrived in Barbados in 1831 immediately after a great hurricane that had killed about 1400 people within seven hours. Years later he recalled how he was led to the study of hurricanes when he was employed there for two and a half years surrounded by ruined buildings.\textsuperscript{64}

Redfield had set up a personal data collecting system with coastal stations and sea captains who sailed to and from New York. He gathered information about wind patterns from the logbooks that were kept on board ships. These logbooks, which contained information on the prevailing winds and precipitation on a daily basis, formed a great source for studying the paths of storms. By combining these observations with barometric readings, he concluded that atmospheric pressure was lowest at the centre of a storm and increased outward. In a paper published in 1831 in the \textit{American Journal of Science} Redfield suggested that storms and hurricanes were whirlwinds and advanced in


the same direction as the general air current of the region in which they occurred.65

As a result of the publication of this paper Reid became acquainted with Redfield and began collecting observations himself. The results of his investigations confirmed Redfield’s view that storms were “progressive whirlwinds, their manner of revolving being always in the same direction.”66 In August 1838 Reid presented his results to the Annual Meeting of the BAAS held at Newcastle. In the same year he published a work entitled An Attempt to develop the Law of Storms, which summed up the general conclusions of his and Redfield’s investigations:

a.) storms generally move in straight or curved lines towards the north pole in the northern hemisphere, and towards the south pole in the southern hemisphere;

b.) storms rotate counter-clockwise in the northern hemisphere, and clockwise in the southern hemisphere;

c.) when a storm passes, the change in wind direction to a stationary observer depends on his position with respect to the axis of the vortex. The wind changes its course in the opposite direction on either side of the axis – viz. if the wind veers on one side, it backs on the other side of the axis.67

In addition to these general rules, the work contained simplified drawings of storms and practical guidelines for sailors to manoeuvre a ship out of instead of into these vortices (Figures 1 and 2).68

---

66 Reid, “A Statement” (cit. n. 64), p. 22.
68 Ibid., pp. 426–427.
Figure 1. Diagram of a passing storm from west to east, from W. Reid, *An Attempt to develop the Law of Storms* (London: John Weale, 1838). The arrows indicate the turning of the wind around the area of low pressure in reverse directions in the northern and southern hemisphere. Notice that the wind changes its course in opposite directions on either side of the storm’s axis.

Figure 2. Diagram of a ship in a storm in the northern hemisphere, from W. Reid, *An Attempt to develop the Law of Storms* (London: John Weale, 1838).
The American professor in natural science, James Espy, was an outspoken opponent of the rotatory storm theory of Reid and Redfield. Espy propounded an alternative convective theory of storms, arguing that air rushed from all directions towards the centre of a storm forming a rising column of air and flowing out over the top of the storm. He modelled his theory on an older idea originating from Brandes, Dove’s former mentor. In Britain Espy’s centripetal model was criticized, whereas Reid’s book was enthusiastically received by John Herschel and James Forbes among others.\textsuperscript{69}

In his journal Dove merely mentioned the title of Reid’s publication without going into detail on storm theories. A year later, however, in September 1840, he sent a letter to the editor of the Philosophical Magazine, in which he claimed the credit of having first formulated a law of storms. He referred to his earlier paper, “On Barometric Minima,” in which he claimed to have stated that “the storm which accompanies a great depression of the barometric column is a vast whirlwind, which in the northern hemisphere proceeds from S.W. to N.E.”\textsuperscript{70} In fact, in the original paper he made no general claims about the dynamics of storms. He had only stated that “every seafarer would confirm the experience that storms are whirlwinds” and “since … all strong storms in our surroundings are southwest storms, the turning has to be SW, NW, and so on.” He drew this conclusion from his investigation of a storm that had occurred on December 24, 1821.\textsuperscript{71}

In the original paper Dove was notably vague on the rotation of the whirlwind itself, but only wrote about the clockwise turning of the wind from SW to NW. Referring to hurricanes in the southern hemisphere Dove stated: “almost all hurricanes in the southern


\textsuperscript{71} Dove, “Über barometrische Minima” (cit. n. 28), p. 597.
hemisphere studied by me move in the opposite direction, namely SW. S. E." These remarks strongly suggest that Dove did not distinguish between the rotation of a storm itself and the turning of the wind in the vicinity of a passing storm. According to his description, storms rotate clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere. In reality the opposite is the case. Also, he had obviously not noticed (or at least, not mentioned) the turning of the wind in reverse directions on opposite sides of a storm’s axis.

In the letter to the editor of the *Philosophical Magazine*, however, Dove argued that the rotation of whirlwinds in the northern hemisphere was counter-clockwise, “after the order of the letters S. E. N. W.”, but at the same time he noted that the wind vane veered from southeast to southwest and west to an observer on the southeast side of the December storm track – a claim that closely resembled Reid’s third conclusion and that served to re-establish the law of (clockwise) turning of the wind. As Kutzbach also noticed, Dove’s law of the turning of the wind was a phenomenon observed from the point of view of a stationary observer at a given place. In contrast to Reid and Redfield’s theory of storms, his model of the wind’s circulation did not apply to the centre of a storm. Thus, his point of view was different from theirs. Dove’s statements in his letter, however, strongly suggest that he tried to reconcile his theories with theirs, while also claiming that he actually discovered the “law of storms” first. Furthermore, Dove accused an anonymous reviewer of Reid’s book of having trivialized his own contribution to the law of storms.

---

72 Ibid., p. 598.
73 According to James Forbes, the third conclusion of Reid and Redfield, viz. the wind turns in reverse directions on opposite sides of the storm track, was an “essential exception to Dove’s law of turning,” which demanded a regular, clockwise turning of the wind in the northern hemisphere, no matter the position of a stationary observer with respect to the storm. Forbes, “Supplementary report on Meteorology” (cit. n. 69), p. 110.
75 Ibid., pp. 369–370. According to Kutzbach, the different perspectives, namely Dove’s point of view from a single location versus Reid and Redfield’s point of view from the storm’s centre, often led to confusion about the direction of the wind’s circulation. Kutzbach, *Thermal Theory* (cit. n. 3), pp. 74, 81.
The British polymath, David Brewster, who admitted that he was the author of the anonymous review in the *Philosophical Magazine*, found it necessary to state that “Professor Dove’s name is not even once mentioned in that Review, nor his labours in any way referred to.” He further remarked:

Had I been disposed to enter into any discussion respecting the earliest discovery of the rotatory character of storms, I should certainly not have awarded the honour to Prof. Dove, but to the late Colonel James Capper, of the East India Company’s service. We agree with General Reid in giving the merit of first suggesting the theory to Colonel Capper; but we must at the same time claim for Mr. Redfield the greater honour of having fully investigated the subject, and, apparently, established the theory upon an impregnable basis.\(^{76}\)

Brewster was right. He had not mentioned Dove’s name in his anonymous review.\(^ {77}\) In fact, Dove had referred to the wrong journal. In another English review that Dove meant to cite, the author spoke of his theory of storms as “speculation – for it is no more.”\(^ {78}\)

Dove did not leave it at that and quickly published a paper entitled, “On the Law of Storms,” in the *Annalen der Physik* barely two months after his letter to the *Philosophical Magazine* in 1840. He used the storm of December 24, 1821 as a case study to discuss existing theories of the movement of storms and to point out again that he had discovered the “law of storms” first. Brandes had developed his centripetal theory of storms by comparing observations of wind direction and barometer readings carried out at multiple places in Europe on December 24 and 25, 1821. Dove re-examined Brandes’s


\(^{77}\) Brewster’s anonymous and untitled review was the article published in *The Edinburgh Review, Or Critical Journal*, 1839, 68, no. 138:406–432.

records in order to test which storm theory, the rotatory or the centripetal theory, matched the observations best.\textsuperscript{79}

He composed two diagrams showing the path of a rotatory and a centripetal storm across Europe (Figures 3 and 4). He then deduced from the diagrams the sequence of wind direction for places above and

under the storm track. It should be noted that it was only at this point that Dove began to mention the opposite turning of the wind on either side of the storm track. Moreover, his diagram of the rotatory storm (Figure 3) bears a suspiciously close resemblance to Reid’s systematic map of a storm (Figure 2), which strongly suggests Dove’s appropriation of their storm model.

He argued that, according to the centripetal theory, the wind should turn “from ENE through E, ESE, SE, SSE, S, to SSW” for a location on the southeast side of the storm track. On the northwest side of the storm track the wind should change counter-clockwise beginning in the NNE and turn to the WSW. However, if the storm were a whirlwind rotating counter-clockwise, the wind should turn clockwise on the southeast side of the storm track beginning from the SSE and turning to the WNW. On the northwest side of a rotating whirlwind, the wind should turn counter-clockwise beginning from the ESE and turning to the NNW. From a re-examination of Brandes’s data Dove concluded the centripetal model to be incorrect. His assessment of Reid’s and Redfield’s work was laudatory, but he could not resist pointing out again that his own discovery of the rotatory movement of storms had preceded theirs.

What is more, he emphasized that whereas Reid and Redfield had investigated the movement of storms empirically, he was able to provide a theoretical explanation of the “law of storms,” which he based on the notion of the rotation of the earth. Remarkable in Dove’s reasoning are the exceptions to his so-called laws. He stuck, for instance, to the clockwise turning of the wind direction as a regular occurrence in middle latitudes, but he claimed that the change in wind direction deviated from its regular turning cycle in extreme cases when there were strong winds or storms. These deviations were “a reliable

---

80 Ibid., p. 10.
82 Ibid., p. 10–11.
83 Ibid., p. 15.
84 Ibid., pp. 16–21, 35
indication of very changeable weather.... In case of a passing whirlwind for instance, the wind vane turns from NW to W and SW [counter-clockwise] on the northwest side of a storm track [in the northern hemisphere], whereas the wind direction normally changes according to the “law of turning” from SW to W and NW, viz. exactly in the opposite direction.”  

Although Dove refuted the centripetal theory, he did not claim that all storms were rotatory. Some storms began as strong winds from a steady direction, but changed into whirlwinds in temperate zones. He also provided practical rules for avoiding storms just as Reid had done earlier.  

Dove’s paper did not yield the result that the author hoped to achieve. In the years following the publication of his paper, there was no general agreement on the dynamics of storms and Dove again turned to the study of temperature distribution on the earth’s surface.  

In 1848 he published a book consisting of temperature tables and observations of global heat distribution. The book, which was based on an impressive amount of temperature data collected at about 700 stations worldwide, was a precursor of his atlas of monthly isotherms published a year later. He dedicated the atlas to Humboldt in honour of the first isothermal maps depicting climate zones in the year 1817. Humboldt celebrated Dove’s accomplishments and called him “the founder of modern meteorology.” When Mahlmann passed away shortly after, Dove, who was seen as his natural successor, was appointed director of the Prussian meteorological institute.  

Dove’s global temperature maps also attracted much attention from leading British men of science, who praised him for his remarkable achievement. Due to the support of Edward Sabine, who presented

---

85 Ibid., p. 35.  
86 On storms on a straight path or “gales,” see Ibid., p. 22. On practical rules to avoid storms, see Ibid., pp. 37–38.  
87 On the course of the storm controversy, see Jankovic, “Ideological crests” (cit. n. 69), pp. 26–28.  
89 Dove, “Dove” (cit. n. 16), pp. 61–62.
Dove’s results at the BAAS meeting in Swansea in 1848, the association ordered 500 copies of the maps. Dove’s relationship with Sabine stemmed from the early 1840s, when the latter had asked him for advice on the extension of a network of weather stations in the British colonies. At the invitation of Sabine, Dove attended the annual meeting of the BAAS in Cambridge in 1845, where a long and close friendship began between the two. At this meeting Dove also met Sabine’s wife, who translated his book into English. A few years later the Royal Society awarded Dove the prestigious Copley Medal for his maps, which Sabine received on his behalf. At that point, Dove had reached the pinnacle of his career and was regarded as Europe’s premier weather scientist.

The “Altmeister” Challenged

In 1846 Dove found another supporter for his “law of turning.” In the prime of youth, Buys Ballot, who had recently received his doctorate and was working as lecturer in mathematics and chemistry, defended Dove’s “law of turning” in the Annalen der Physik. Observations of wind direction carried out over a period of forty years confirmed the clockwise turning of the wind direction in the Netherlands. In 1850 Buys Ballot published a report discussing the state of play in meteorology in the period 1845 until 1847. He did so at the request of the editors of Die Fortschritte der Physik, an annual report of published

---


physics papers compiled by the newly established Berlin Physical Society. This society originated from an informal discussion group led by the professor of physics, Gustav Magnus. The six founders were young scholars and lecturers, who felt the need for a new open society for physics that allowed unfettered discussion, free from academic constraints.93

Wilhelm Mahlmann was actually meant to write the report on meteorology, but as he passed away, the ever-keen Buys Ballot who had just been appointed extraordinary professor in mathematics at the university of Utrecht, became a foreign member of the society and took on the task.94 In fact, it would have made more sense if, instead of Buys Ballot, Dove had written the meteorological report. As Mahlmann’s successor at the meteorological institute, he was already responsible for the publication of an annual report. Dove, however, declined membership of the society and as “Älterer” (senior) he kept himself aloof from the society.95 Clearly there was a generation gap between Dove, “the founder of modern meteorology,” and the Young Turks of the Physical Society.

Buys Ballot opened the report with the announcement of a prize competition held by the Society of Arts and Sciences in Utrecht, which “fully characterize[d] the new meteorological period developed by Dove.” He claimed that after Dove’s achievement of defining the “formula” for periodic changes in temperature, pressure and wind direction, it was time to find the rules of “non-periodical changes” by looking at the deviations from the mean values at different places at the same time. He believed that these non-periodical changes were somehow directly related to atmospheric disturbances. A gold medal and a prize of 80 Prussian silver coins awaited the one who succeeded

95 Schreier et al., “Geschichte” (cit. n. 93), p. 44.
in carrying out the task.” In the Netherlands no one had responded to Buys Ballot’s call in 1847, and therefore he tried his luck in Prussia. In the end, he hoped to be able to discover rules of weather change. In this respect, he claimed that “the barometer is of greater value for a correct understanding of atmospheric change than the thermometer.”

In his obituary of Buys Ballot in 1890, the German physicist von Bezold referred to the same statement so as to show that he differed from Dove from early on in his belief that the distribution of air pressure, not temperature, gave a better indication of likely weather changes. “But … [as von Bezold quoted Buys Ballot], “everyone shall certainly sow and plough under his [Dove’s] direction, and he himself shall soon reap a rich harvest.” Indeed, Buys Ballot may very well have had a different opinion than Dove, but he was careful never to openly question his theories. In fact, he praised Dove as Humboldt’s successor. As he put it:

Different phases can be distinguished in meteorology since it has emerged as a science. The first begins with Humboldt, … [who discovered] the regularities in the mean state of the atmosphere and its distribution on the globe. The founder of the second phase is Dove, who after following in the footsteps of Humboldt began studying the deviations from the mean state…. One has to investigate the deviations from the rules in order to find the rules of the deviations. The use of self-registering instruments and the electrical telegraph … will mark the third phase, when we shall be able to predict meteorological conditions.

---

Buys Ballot’s strategy, if that is what it was, was surely the right one. A contemporary of Dove said of him that “he was ‘the nicest person under the Sun, kind, amiable, and obliging,’ but that he could be very unpleasant to anyone who ‘meddled with or criticized’ his ‘law of turning’ or his ‘storm law’.”

Another contemporary spoke of Dove’s theory with the words: “to doubt it [the ‘law of turning’] was heresy.”

Dove appears to have been pleased with the Dutch support for his ideas, so much so that he visited Buys Ballot at the Utrecht observatory in the spring of 1851. His visit enabled Buys Ballot to compare his barometer with Dove’s calibrated travel barometer, from which he concluded that his device showed a minor deviation of 0.03 millimetre at the most, an error that could easily be ignored. In the following summer Buys Ballot travelled to Berlin to meet with Dove again. This visit gave him the opportunity to view the Prussian meteorological institute and to become familiar with Dove’s research procedures.

In the next volume of the *Fortschritte der Physik* Buys Ballot discussed Dove’s studies of “the non-periodical changes of temperature distribution on the globe.” He ended the report with a call to Dove, whom he called “the father of modern meteorology,” to use “his influence to centralise the meteorological investigations” carried out in Europe. Just a couple of months before Buys Ballot had appealed to Adolphe Quetelet in Brussels to use his position as director of the Belgian Academy of Sciences to organise and preside over an international meteorological conference in order to bring unity to the measurements that were carried out in the surrounding countries.

---

100 The quote is from Karl Vogt and is cited in Neumann, *Dove* (cit. n. 48), p. 10.
103 Buys Ballot wrote the report in July 1850, but the volume itself was published two years later because of some practical editorial problems, which are described in G. Karsten, “Vorberigt,” *Die Fortschritte der Physik im Jahre 1848*, 1852, 4:v–x, on p. v.
105 Buys Ballot to Quetelet, 29 Mar 1850, CAQ, Collection 561.
repeated his call for an international meteorological meeting to Karl Kreil at the Imperial Academy of Vienna in 1852.\(^{106}\)

Clearly Buys Ballot was convinced that the combination of simultaneous observations carried out at widespread stations and the use of the electrical telegraph would significantly advance the science of meteorology and enable weather prediction in the future. He had already established an observatory in Utrecht and he had created a network of observers to take meteorological measurements at several stations in the Netherlands. His requests to Dove, Quetelet and Kreil served to gain access to observations carried out abroad. However, he was not solely interested in amassing trans-border records.

His ideal was to obtain daily readings of wind direction and simultaneous observations of thermometric and barometric deviations from their respective mean values carried out in a uniform manner at as many stations in Europe as possible so as to study the relationship between these quantities. He wanted to find the rules of non-periodical changes in temperature, pressure and wind direction in the same way as Dove had found and defined the rules of periodical changes in these quantities.\(^{107}\) Yet, he understood that such a scheme would entail great costs and would overburden the observers. So he settled for observations carried out over intervals of five days and demanding less precision.\(^{108}\) As he explained to Quetelet, he aimed to prompt observers at widespread stations in Europe “to publish their data in a standard form [so as to be able] to compare the measurements.” He made suggestions for an efficient and economical way of publishing the data sets so that a person interested in monthly averages or daily values would only have to purchase that part of the published data sets.\(^{109}\)

Although he openly appealed to Dove to take the lead in meteorology by centralising the observations at the Prussian institute,


\(^{109}\) Buys Ballot to Quetelet, 29 Mar 1850, CAQ, Collection 561.
he may have had his own plans at this point. In July 1852, a year after his visit to Berlin, Buys Ballot wrote a letter to the Dutch minister of internal affairs, Thorbecke, in which he pressed for the Utrecht observatory to be granted the status of an official meteorological institute, fully supported by the state. In the letter he confided to the minister that Utrecht could become the centre of a European network of meteorological observations. He took into account that London or Berlin had the best credentials for becoming the centre of the network. As he explained to the minister, the greatest number of grants to meteorological and geomagnetic projects were issued in England. Dove in Berlin had the best credentials to become Humboldt’s successor. The Utrecht observatory, however, was “exceptional” compared to the other stations, for it had demonstrated that it was the place where “the most observations had been collected and published … in a most commendable form [and] as quickly as possible after the onset of changed meteorological conditions.” In 1854 Buys Ballot’s plans came to fruition and the Utrecht observatory became the Royal Dutch Meteorological Institute.\(^{110}\)

In the following years Buys Ballot collected and analysed series of temperature and barometric measurements and readings of wind direction and force. In 1854 he published a paper in the *Annalen*, which was aimed at encouraging observers to comply with certain procedures so as to facilitate the amalgamation of data.\(^{111}\) It is an interesting text for two reasons.

Firstly, Buys Ballot explained the relevance of keeping records of deviations from the mean values of temperature and pressure instead of keeping track of absolute values. He explained how a phrase like “yesterday, it was two degrees warmer,” meant so much more than “yesterday it was minus 16 degrees.” Deviations were a better means of gauging the state of the weather than absolute values. They also helped to neutralise measurement errors in the records of observations that


could be caused by uncalibrated instruments. As he explained, keeping
and publishing records of deviations, viz. differences between absolute
readings of the thermometer and barometer and the respective mean
values calculated over longer periods, made it possible to compare
observations that were carried out with different instruments, by
different observers at different places.\footnote{Ibid., pp. 560–562.}

Secondly, he presented a new method for the graphical depiction of
simultaneous weather phenomena on synoptic maps, offering a
retrospective view of synchronized weather observations. He admitted
that readers might be surprised that he of all people should suggest a
graphical method. His great role model Dove was unfavourably
disposed towards synoptic mapping.\footnote{Dove’s objection to synoptic mapping is also mentioned in Tor Bergeron, “Synoptic
473, on pp. 445, 447; and in Kutzbach, \textit{Thermal Theory} (cit. n. 3), p. 89.}
As Dove had argued, compiling
a map of simultaneous observations of pressure, temperature, humidity
and wind direction required that the interdependent relationships
among these quantities were determined and he found the time not ripe
enough to take all quantities into account.\footnote{Dove, “Über die nicht periodischen Änderungen” (cit. n. 60), p. 289.}
He had just been able to
map temperature deviations from their monthly means for a number of
places in North America and Europe.\footnote{H. W. Dove, \textit{Die Verbreitung der Wärme auf der Oberfläche der Erde erläutert
durch Isothermen, thermische Isanomalen und Temperaturkurven} (Berlin: Dietrich Reimer, 1852).}

Buys Ballot claimed that he himself had always shown a preference
for “the numbers themselves over their graphical representation,” but
he believed nonetheless that maps could provide “an overview” of
meteorological conditions.\footnote{Buys Ballot, “Erläuterung einer graphischen Methode” (cit. n. 111), pp. 559, 563. On
page 563 Buys Ballot described how his maps offered a bird’s-eye view of simultaneous
weather phenomena without using the term “synoptic,” which was coined later by
Fitzroy. See note 61.}
He stated that he had already started
drawing abstract maps, depicting daily readings from a dozen stations
in Europe, which were plotted on the maps by their initial letters. Near
the dots he marked the deviations from the normal temperature in
numbers and the wind direction with arrows. At the tail end of the
arrows he drew arcs in order to show how the wind had changed its direction in the course of a day (Figure 5).\cite{buys-ballot-1852}

Figure 5. Buys Ballot’s abstract map of winds changing their direction, from C.H.D. Buys Ballot, *Meteorologische waarnemingen in Nederland 1854* (Utrecht: Kemink & Zoon, 1855), appendix.

Buys Ballot had been experimenting with maps since 1852. His first maps depicted temperature distributions and were published in the yearbook of the Utrecht observatory (Figure 6).\cite{buys-ballot-1854} To draw these maps he had hired an assistant, whom he paid himself. In time, however, he had to give up publishing them because of a lack of buyers. Nonetheless, he believed that the maps could help reveal the rules of weather change. His beliefs were congruent with the contemporary notion that weather conditions resulted from the movement of warm and cold currents of air. In the paper published in the *Annalen*, he

\footnotesize

\cite{buys-ballot-1852} Buys Ballot, “Erläuterung einer graphischen Methode” (cit. n. 111), pp. 563–564. Two examples of these weather maps were published as an appendix in C. H. D. Buys Ballot, *Meteorologische waarnemingen in Nederland 1854* (Utrecht: Kemink & Zoon, 1855), no page number.


155
mentioned that he intended to add deviations of barometric values to the maps.\textsuperscript{119}

Figure 6. Buys Ballot’s maps of temperature distributions, from C.H.D. Buys Ballot, *Meteorologische waarnemingen in Nederland 1852* (Utrecht: Kemink\& Zoon, 1852), plate 2.

These steps were decisive for Buys Ballot’s investigations. His synoptic maps of the winds, for one thing, showed that winds at different locations did not turn in the same direction. In the course of a day, local winds were shown to turn in either direction, some with and some against the clock.\textsuperscript{120} Furthermore, the maps depicting barometric readings were instrumental for Buys Ballot in finding the relationship

\textsuperscript{119} Buys Ballot, “Erläuterung einer graphischen Methode” (cit. n. 111), p. 567. I have not been able to find Buys Ballot’s maps depicting barometric deviations and wind directions at the Utrecht Archive or in his publications in the period from 1854 to 1857. Buys Ballot’s biographer van Everdingen, who had seen these maps, wrote that he found them very peculiar without explaining himself further. Everdingen, *Buys Ballot* (cit. n. 110), p. 80.

\textsuperscript{120} Buys Ballot, *Meteorologische waarnemingen* (cit. n. 117).
between air pressure and winds. Instead of studying long tables of sequential measurements of multiple meteorological quantities, looking at his maps may have helped him to visually notice the connection between large barometric differences and the occurrence of strong winds. In their biographies of Buys Ballot, both Cannegieter and van der Stok pointed to the significance of synoptic mapping for his discovery of the relationship between air pressure and winds. As van der Stok states, “A link was found in the chain of causality when Buys Ballot started adding barometric readings to synoptic maps that depicted simultaneous observations of wind direction and force for many places.” He also noticed that Buys Ballot offered proof of his wind law based on statistical evidence not until three years after his discovery.  

In one of Buys Ballot’s letters that was published in a report in 1874 we find an interesting testimony of how he drew his maps:

The distribution of pressure, temperature, humidity, &c., should be given on one special chart (a), and the wind condition on another chart (b). If both charts were drawn on thin paper, we might compare (b) for the 2nd, 3rd, and 4th of a month with (a) of 1st, 2nd, 3rd, 4th, 5th of the same month. They would show, for I have proved this without possibility of contradiction more than 15 years ago, that (b) is more dependent upon (a) than (a) upon (b), so that the conditions of wind for one day are regulated by the conditions of pressure of a previous day.  


Buys Ballot made his discovery about wind behaviour public in the October meeting of the Royal Academy of Science in Amsterdam in 1857. He explained that when the difference in air pressure in the northern and southern part of the country amounted to 4 millimetres or more, this usually gave rise to strong winds in the next 24 hours, whereas smaller differences of 2 millimetres were followed by weak winds. He had also found a regularity in wind direction in relation to the pressure gradient. Winds from the east blew when pressure was higher in the north; and they blew from the west when pressure was higher in the south of the country. At the meeting Buys Ballot suggested using these wind rules, which predicted the direction and force of approaching strong winds and storms, to establish a system of storm warnings at the Dutch harbours.123

He sent a similar note to the French journal *Comptes rendus*. However, in the French report he explicitly added that “one can better judge the wind from the barometer than from a wind vane.”124 Anders O. Persson, the author of a recent paper on Hadley’s Principle, interpreted this statement as casting doubt deliberately on the merit of Dove’s law.125 The statement indeed appears to argue that the best indications of approaching strong winds are changes in the distribution of air pressure, not the turning of the wind. Buys Ballot’s discovery provoked only indirect reaction from the German professor in the following years.

In the same year when Buys Ballot proclaimed his wind rule, Dove published a monograph on his law of storms entitled *Über das Gesetz der Stürme*, in which he repeated the results of his meteorological investigations over the past thirty years. He included a chapter on the turning of the wind, which contained a massive number of accounts

125 Persson, “Hadley’s Principle” (cit. n. 55), p. 29. Kutzbach argues that Dove’s views had no impact on meteorology in France. Apparently, Buys Ballot must have thought that he could afford making this statement in a French paper. Kutzbach, *Thermal Theory* (cit. n. 3), p. 15.
affirming his “law of turning” in both northern and southern hemispheres. In cases where observations of wind direction did not show a clear confirmation or refutation of the “law of turning,” such as in the report by the Dane Schouw, Dove repeated Buys Ballot’s by then no longer relevant statement in the Annalen from 1846: “the evidence that Prof. Dove has derived from the pressure, temperature and humidity readings, is all the finer, the more it was originally hidden.”

To a reader this sounds like a vague argument to strengthen the “law of turning,” but Dove claimed that although the wind did not always behave regularly, the turning of the wind did at least correspond to regular changes in the barometer, thermometer and hygrometer, which he hoped was a compelling underpinning of the regularity in the turning of the wind. Dove’s monograph had probably preceded Buys Ballot’s 1857 note. Nonetheless, Dove would repeat this statement in his future writings. His silence on Buys Ballot’s wind rule was telling. He was not pleased.

In the following three years Buys Ballot used the wind rule as a practical tool to establish a system of storm warnings along the Dutch coast, which was implemented in June 1860. In that year he submitted a paper on the discovery of his wind rule to the Annalen der Physik, but against all expectations, it was rejected. This must have been a slap in the face for Buys Ballot. In a paper published in 1864 he explained the principles of the wind rule and added: “much to my surprise the report which I sent to prof. Poggendorff for his Annalen der Physik in 1860

---

was not accepted.”

It is no coincidence that he wrote this paper in German and published it in a journal that aimed to popularize results of Dutch investigations in German-speaking states. He probably hoped to receive some form of acknowledgement of his discovery.

In 1861 Dove published a new book on his law of storms entitled *Das Gesetze der Stürme in seiner Beziehung zu den Allgemeinen Bewegung der Atmosphäre*. The work did not differ much in content from his earlier monograph. However, the change in title from *Über das Gesetze* to *Das Gesetze*, showed Dove’s persistence in claiming priority of discovery of a storm law. By that time, he was definitely aware of the Dutch wind rule, but he used Buys Ballot’s 1846 statement again in order to promote his own “law of turning.” Buys Ballot’s wind rule was not mentioned at all. What made matters worse was the fact that he dedicated the work to Robert Fitzroy, the naval officer and a competitor of Buys Ballot. Both men were directors of a meteorological institute and they had simultaneously developed a system of storm warnings in their respective countries. While Buys Ballot had always spoken with great admiration for Dove, he was bypassed and his wind rule was completely ignored in Dove’s book.

Dove’s move explains Buys Ballot’s astonishment about the rejection of his paper in a journal that was edited by a close friend of Dove. However, Dove’s behaviour toward Fitzroy was not really surprising, for the latter was a great supporter of his work. As editor of a series of *Meteorological Papers*, Fitzroy had published a paper consisting largely of a translation of Dove’s *Über das Gesetze der Stürme*.

---


133 On the friendship between Dove and Poggendorff, see Dove, “Dove” (cit. n. 16), p. 57.
in 1858. He also used Dove’s theory of two air currents as a basis for his storm warning system, whereas Buys Ballot indirectly challenged Dove’s “law of turning” by presenting a wind rule of his own as a principle for predicting the force and direction of strong winds.

In 1863 Dove organised a conference on meteorology at the annual meeting of the Swiss Naturforscher Verein in Geneva. After the first international maritime meeting held in Brussels in 1853, which had led to the establishment of a number of meteorological institutes in Europe, many people involved in the field of meteorology called for a second conference in order to establish cooperative programmes in land meteorology. However, for a variety of reasons the actual organisation did not get off the ground. The Crimean War was a major obstacle at first, but political sensitivities did not help either. Eventually Dove succeeded in aligning himself with a number of people and invited leading meteorologists from several countries including Austria, Italy, Spain, and France to the Swiss meeting. Buys Ballot, who had every reason to feel sad about Dove’s disregard, did attend the meeting. Unfortunately, very few foreigners participated and the conference failed to acquire an international character. Years later Buys Ballot recalled his disappointment about the absence of several

---

134 Walker, *History of the Meteorological Office* (cit. n. 14), p. 37. The paper in question was the *Third Number of Meteorological Papers, Compiled by Rear-Admiral R. Fitzroy, F.R.S., Published by Authority of the Board of Trade* (London, 1858).

135 On Fitzroy using Dove’s theories for his storm warning service, see Burton, “History of the British Meteorological Office” (cit. n. 5), p. 48.


137 In June 1860 the American naval officer, Matthew Maury wrote to Quetelet and complained that it was difficult to choose a president for the proposed meeting. In his words, “if we take an Englishman as president, the French are offended. On the other hand, John Bull will take umbrage at a French president.” Maury to Quetelet, 6 Jun 1860, CAQ, Collection 1761. A couple of months later, the Dutch naval officer, Marin Jansen, suggested to Quetelet “to keep England away from the negotiations and to organise a continental conference without them.” Jansen to Quetelet, 23 Nov 1860, CAQ, Collection 1391.

138 “Über den Meteorologen-Congress zu Wien,” *Zeitschrift der Österreichischen Gesellschaft für Meteorologie*, 1872, 7, no. 17:297–298, on pp. 297–298; Neumann, *Dove* (cit. n. 48), p. 15. Unfortunately, I have not been able to find any sources on the reason why the British were absent.
meteorologists whom he had wished to consult. His attendance seemed to have had no effect on his souring relationship with Dove, who remained silent on his discovery.

**Turning Point**

After the Swiss conference, Buys Ballot concentrated his efforts on finding support for his wind rule in Britain, but he had a hard time convincing his fellow meteorological investigators of the significance of his theory. It took Buys Ballot almost ten years to have his wind rule tested and accepted in Britain after its formulation in 1857. Fitzroy, for example, never mentioned Buys Ballot’s wind rule in any of his publications. Dove, in contrast, was seen as the leading meteorological theorist at the time. His theories were much cited and served as a basis for the British system of storm warnings under Fitzroy’s direction.

In 1864 Herschel praised Dove’s investigations in a written lecture on the emerging practice of weather predictions in England and abroad. In that paper he warned against “weather prophets,” who ventured to predict the weather, often months in advance, based on absurd claims such as a “rainbow in the morning” or “sheep turn[ing] their tails to the south-west.” He argued that “the progress of [meteorology] and its whole aim [was] to supersede the endless detail of individual cases by the announcement of easily remembered and readily applicable laws.” He considered the “law of the rotation of the winds … (from east round by south, west, and north in the northern hemisphere, and reversely in the southern)” as the only “meteorological law of universal applicability,” and acclaimed Dove’s

---

140 How Buys Ballot’s wind rule was eventually accepted has been discussed in the previous chapter.
insight for connecting it “with that great fact which underlies so many other phenomena – the rotation of the earth on its axis.” Herschel was not alone. Francis Galton, who coined the term anti-cyclones for areas of high pressure, also spoke with admiration for Dove’s “law of gyration,” which he valued as “so fertile in result.”

It could be argued that the British’ ignoring Buys Ballot’s discovery was related to his challenging the “law of turning,” and thus Dove’s leading position in that country. However, the period 1865–1868 marked a turning point for the valuation of both Buys Ballot’s wind rule and Dove’s “law of turning.” The turn of events following Fitzroy’s suicide in 1865, his disqualification as a trustworthy investigator of the weather, and the suspension of the British storm warnings in 1866, created a more favourable atmosphere for Buys Ballot to disseminate his wind rule in Britain.

Fitzroy’s death led the president of the Royal Society, Edward Sabine, to ask Dove for advice regarding the practice of storm warnings. Dove replied by informing Sabine that the Prussian storm warnings were “in general accordance with the methods followed in England.” Telegrams containing observations carried out in Berlin, including at least readings of “the height of the barometer, … and the general appearance of the sky, … viewed in connexion with the whole local character of the weather” were sent to the Baltic ports. He further remarked: “we leave to authorities at the ports, … a discretionary power of showing warnings, in so far as they may be able to form a judgment from the telegrams which we send them.”

It is not particularly clear from the letter how the Prussian system of storm warnings operated, though it is obvious that Dove, unlike Fitzroy, was much too cautious to put his credibility on the line by issuing storm warnings himself. He left the decision to the clerks at the ports to hoist a warning signal. As he put it, “I wished to introduce the

---

145 This episode has been discussed in the previous chapter.
system gradually…. Advances in meteorology are based on long continued labours; we seem now to want to take it by storm.”¹⁴⁷ Further on in the text, he argued that

The idea that all storms are cyclones is indeed given up by most, and I have lately been taking some pains to contribute thereto. The introduction of the word “cyclonoid” means nothing more than that for a given case it is wished to leave the matter undecided. It is a retrograde step.¹⁴⁸

These statements show how Dove was struggling to keep up with the latest developments in meteorology. The last remark even demonstrates how his theories were by then completely off the mark.¹⁴⁹ As he explained himself:

The small pecuniary resources of our Meteorological Institute, which now includes ninety seven stations, do not permit me to publish the daily means…. I think that … I have brought some questions nearer to a solution. But I have to do this work by myself, and, overcharged as I am with official duties, I do not think I shall long be able to continue to master it.

He added:

I had long proposed to myself to write from my own point of view a pamphlet “how to observe” in meteorology, but when one has, as I have constantly, to give lectures in the day, and hold examinations in the evening till nine o’clock, much that has been contemplated is left undone….¹⁵⁰

¹⁴⁷ Ibid., pp. 317–318.
¹⁴⁸ Ibid., p. 318.
¹⁴⁹ In the 1860s people involved in meteorology generally agreed that all storms rotated inwards to an area of low pressure in a counter-clockwise direction. Dove, however, believed that some storms followed a straight path. Dove, “Über das Gesetz der Stürme” (cit. n. 79), p. 22.
For someone with his heavy teaching tasks, his loss of grip on recent meteorological developments seems excusable.

In the 1870s the future director of a German marine service called the Norddeutsche Seewarte, Georg von Neumayer, noted that Dove failed to train students in meteorology, who could have given his ideas youthful and independent support in later years. One of his biographers wrote: “it is somewhat mysterious that Dove, who had many students around him, did not make use of their strengths so as to expand his institute and advance meteorology. It seems as if Dove did not entrust his deeply cherished tasks to others.” He hired his first assistant as late as 1866.

When Buys Ballot’s wind rule was transformed into a wind law in 1868, it permanently superseded Dove’s “law of turning.” Buys Ballot, however, did not exactly rejoice at this victory. In 1885 he complained to a colleague with the words, “my rule has cost me the favour of my patron Dove. He had called me the best defender of his law of turning ... but then I was to prove just the opposite.” As one of his biographers has written, Buys Ballot was “at first a champion of Dove’s ‘law of Turning’ with all the passion of a young enthusiast, so much so that he was called his best supporter, but soon he had to abandon the ‘Altmeister’ and to demonstrate that air usually moved not with the sun, but against the sun in the northern hemisphere.”

In 1868 Robert Henry Scott, Fitzroy’s successor at the London meteorological department, elevated Buys Ballot’s wind rule to the status of a natural law. He tested the wind rule for Britain and confirmed its validity in a report that he presented to the meteorological committee of the Royal Society. The report was accompanied by a set of synoptic maps showing pressure and wind

152 Neumann, Dove (cit. n. 48), p. 44.
153 Günther and Dannbeck, “Die Vorgeschichte” (cit. n. 11), on p. 417.
154 Van der Stok, “Levensbericht” (cit. n. 121), p. 73. As we have seen, the wind law did not contradict the “law of turning.” The confusion about the direction of the wind’s circulation is due to the different points of view (the centre of a low pressure area versus the point of view of a stationary observer of a passing depression), which was also noticed by Kutzbach, Thermal Theory (cit. n. 3), pp. 74, 81. See also note 75.
observations carried out at seventeen British stations. The maps showed how the direction and force of the winds corresponded with local pressure differences. In his report he only implicitly referred to Dove’s “law of turning” by claiming that “the wind, especially in storms, seldom blows for many hours consecutively from the same point, but either veers (changes direction clockwise) or backs (changes direction anti-clockwise), the former motion being much more usual than the latter.”\textsuperscript{155} Put in a nutshell, Scott thus minimized the “law of turning,” Dove’s chief discovery in meteorology, to a subordinate clause without naming the originator. It is interesting to notice that “Dove’s law of turning” was placed in parentheses in a German summary of Scott’s report.\textsuperscript{156} Perhaps the author of the summary felt he could not leave out a theory that had been the lynchpin of meteorology for forty years.

Another book that was published in 1868 discussed the two laws. However, Alexander Buchan, the author of the book, modified the “law of turning” according to his own interpretation so as to retain its currency. As the secretary of the Scottish Meteorological Society he presented a paper to the Royal Society of Edinburgh in 1865, which discussed his studies of eleven storms occurring in Europe in the months of October, November, and December 1863. For his investigations he had collected data from stations in Scotland, England, Ireland, Scandinavia, Russia, and continental Europe. A set of fourteen weather maps accompanied his published paper depicting isotherms, isobars, arrows representing the direction and force of the wind, and letters indicating the state of the sky with respect to rain, cloud, and fog. His synoptic maps were among the most complete of all contemporary weather maps (Figure 7).\textsuperscript{157}

\textsuperscript{157} Kutzbach, \textit{Thermal Theory} (cit. n. 3), p. 69.
Figure 7. Buchan’s synoptic weather map of Europe, from Alexander Buchan, “Examination of the Storms of Wind which occurred in Europe during October, November, and December 1863,” Transactions of the Royal Society of Edinburgh, 1867, 24:191–206. Solid lines represent isobars; dashed lines isotherms; winds are represented by arrows; C denotes clouds; B, clear or fair skies; F, fog; R, rain at 8 a.m., r, rain during the past 24 hours.
These synoptic maps showed a general pattern in winds and storms. Unaware of Buys Ballot’s wind law, Buchan offered a model that combined his theories with Galton’s description of cyclones and anti-cyclones, while it at the same time reconciled the rotatory storm theory of Reid and Redfield with the centripetal theory of Espy. As the following quote shows, he viewed this discovery as a general wind law:

Every one of the storms on each day presented the winds under the same conditions, ... whirling round the area of low barometer in a circular manner, in a direction contrary to the motion of the hands of a watch, with a constant tendency to turn inwards towards the centre of lowest barometer. The wind in storms neither blows round the centre of least pressure in circles... nor does it blow directly towards that centre. It takes a direction nearly intermediate, approaching, however, more nearly the direction and course of the circular curves than of the radii to the centre. To this general rule none of the eleven storms any day offered an exception.... This blowing of the wind from a high to a low barometer, and with a force generally proportioned to the differences of the pressure, would appear from these storms to be the most important law concerned in regulating the movement of the wind ...the wind was always observed gently *whirling out of the area of high barometer*, in the direction of the motion of the hands of a watch — being the opposite direction to that assumed by the wind when it blows round and in towards an area of low pressure.  

Two years later he developed his conclusions in further detail and published them in the *Handy Book of Meteorology*. The second edition of the book showed marked differences from the first, indicating that in

---

the meantime Buchan had become aware of the wind rule of Buys Ballot. One of the interesting differences is his explanation of the causes of winds.

In the first edition, all winds were viewed as being “caused directly or indirectly by changes of temperature, … [giving] rise to two currents of air … [that] continue to flow till the equilibrium is restored.” In the second edition, however, the phrase was changed into “all winds are directly caused by differences of atmospheric pressure.” This shift of view reflects the switch from Dove’s theories to Buys Ballot’s wind law. For forty years Dove’s two-currents model had dominated the field of meteorology, but Buchan questioned his theory of atmospheric circulation arising from the interference of two currents, and offered an alternative theory that was based on Buys Ballot’s wind law.

Buchan credited Buys Ballot with having discovered the spirally inward course of the wind “from the region of high towards … the region of low pressure … [with] the area of lowest pressure to the left hand of the direction towards which it is blowing.” He also credited Galton with coining the term anti-cyclone for an area of high pressure. On the relation between barometric differences and the force of the wind, he adopted Buys Ballot’s exact phrasing. He argued that these insights demanded a revision of the theory of storms for:

The spiral rotation, instead of the purely circular rotation, of the winds in storms, completely alters the whole complexion of the question of the theory of storms … we are forced to the conclusion that from a large area within and about the centre of the storm a vast ascending current must arise into the upper regions of the atmosphere; and arriving there must flow away over into neighbouring regions.

---


From these considerations, Buchan suggested that “the general movements of the atmosphere over the globe and in storms, are due to the same physical causes acting in the same way.”

He then went on to test Dove’s theory that “storms are produced by the mutual lateral interference of two currents of air flowing in opposite direction.” From his charts he concluded that “no other movement of the wind is observable than the spirally in-moving currents of air towards the area of least pressure,” and stated: “the facts of the storms of the 1st and 2nd January 1855 do not, so far as I can see, offer any support to the theory of the simple mutual interference of currents generating storms.” He ended his discussion with:

… as regards the specific conditions out of which those great atmospheric disturbances take their origin, we know little or nothing … we urge the extension of the field of observation, so that synchronous charts … might be constructed, which would supply the information desiderated – viz., trustworthy facts, in place of vague and unsatisfactory theorisings.

Thus he refuted Dove’s storm theory in favor of Buys Ballot’s wind law, which applied to storms and winds in general.

Elsewhere in the book, Buchan discussed the “law of turning,” but like Herschel, he gave his own interpretation of what the law entailed. Buchan saw the shifting of the wind, more frequently going clockwise than anti-clockwise as an established fact that had been noticed long ago by Bacon. What he attributed to Dove was that he had “from Hadley’s principle, propounded the law of rotation of the wind, and proved that the whole system of atmospheric currents, the permanent, periodical, and variable winds, obey the influence of the earth’s rotation.” Thus, he credited Dove not for discovering the turning of the wind, but for linking it with the earth’s rotation. On the deflection

---

162 Ibid., p. 282.
163 Ibid., pp. 288–291.
164 Ibid., p. 232.
of westerly and easterly winds, Buchan remarked: “since they continued in the same latitude, [they] would have blown in the same direction, if they had not been disturbed by contiguous currents. Hence in a storm the whole system of winds rotates round the centre.” In other words, Buchan explained the bending of northerly and southerly winds to the right in the northern hemisphere as an effect produced by differences in the earth’s rotational velocity across latitudes in accordance with Hadley’s principle. On east-west motions of air, he adopted Dove’s supplement to Hadley’s principle, namely that contiguous northerly and southerly currents affected easterly and westerly winds, and caused them to deviate from their paths.

In 1872 another British meteorologist discussed Buys Ballot’s wind rule. In his widely read book on *The Laws of the Winds Prevailing in Western Europe*, William Clement Ley, presented the results of his synoptic statistical investigations of storms. Like Buchan, he dismissed Dove’s theory of storms in favour of the generality of Buys Ballot’s wind law. It is interesting to note that he mentioned Dove’s storm theory together with that of Fitzroy. He selected statements about storms from their published papers that were similar, and dismissed them as “erroneous.” As he concluded, the “whole theory according to which the varying types of atmospheric circulation are regarded as resulting from the mutual collision, impact, overlapping, and diversion of the primary currents, is gravely interfered with by the universality of (Buys) Ballot’s law.” Finally, he explained the deflection of winds from a straight path as an effect of “an attracting force” under the influence of the earth’s rotation without making any references to Dove’s “law of turning.”

In the period up to the mid 1870s, most models of atmospheric circulation were based on the notion of latitudinal differences in the earth’s rotational velocity. However, not everyone was satisfied with this model. For Buys Ballot, for instance, it remained unclear why

---

westerly and easterly winds deviate from their course. While Ley attributed the deflection of winds to “an attracting force,” he could not fully grasp its properties. The one exception was the American schoolteacher, William Ferrel, who had quite independently offered a correct mathematical model in 1856 that explained the deflection of winds from all directions on the earth’s surface as an effect of a force acting on the wind and producing a deflection to the right in the northern, and to the left in the southern hemisphere. Unfortunately his work was unknown to men of science in Europe at the time.

The force recognized by Ferrel is also known as the Coriolis force named for the French mathematician Gustave de Coriolis. The force causes moving objects from all directions to deflect to the right of their intended path with respect to a counter-clockwise rotating reference frame, and to the left with respect to a rotating reference frame in the opposite direction. The magnitude of the Coriolis force is proportional to the latitude and the speed of the wind. It has maximum effect for motions that are perpendicular to the axis of the earth’s rotation, so is strongest at the poles, and it has no effect for motions that are parallel to the earth’s axis, thus zero at the equator. Furthermore, the force increases as the wind speed increases. Therefore, the Coriolis force affects all motions of air, from north, south, east or west.

Only in the mid 1870s did Ferrel’s results become known in Europe. The director of the American Weather Service, Cleveland Abbe, and the editor of the prestigious Meteorologische Zeitschrift, Julius Hahn, reportedly publicized his papers. Had Buchan known about Ferrel’s work and the effect of the Coriolis force, he would perhaps not have mentioned Dove at all in his book, for the last remnant of Dove’s complex of meteorological theories, namely his explanation of atmospheric circulation due to the latitudinal differences in the earth’s rotational velocity and the succession of contiguous air currents, was wrong.

169 Buys Ballot, Eenige regelen (cit. n. 120), p. 54.
One aspect of Buchan’s general atmospheric circulation remained unexplained. The pressure gradient force opposed by the Coriolis force acting on air currents produces a net force that causes winds to flow parallel to isobars, but what causes the wind to turn spirally inward toward the centre of a depression near the ground? In 1872 the Norwegian meteorologist Henrik Mohn and his colleague Cato Guldberg proposed a mathematical model that explained why winds cut across isobars on a slant moving from higher to lower pressure. Near the earth’s surface, friction causes the wind to slow down, which weakens the Coriolis force, while the pressure gradient force retains its strength. Therefore, the net force acting on the wind is directed toward the centre of a depression. Over land the angle at which the wind crosses the isobars is usually between 25 and 50 degrees. By the time the Guldberg-Mohn balance was generally accepted as a subordinate factor to Buys Ballot’s law for use near the ground, all of Dove’s theories had become obsolete and were replaced by the wind law.

Conclusion

Dove’s “law of turning” was the first law for weather change written in a mathematical form. This approximate law of atmospheric pressure as a continuous periodic function of the wind direction eventually proved to be nothing more than a local rule describing the clockwise change in wind direction caused by prevailing westerly storms in most parts of mainland Europe. As meteorologist Persson explains, “since most of continental Europe was south of this [main storm] track it was easy to find confirmations of the ‘law’ from seamen, weather amateurs, renowned philosophers and scientists.” Buys Ballot’s wind law, on the other hand, followed an opposite path by first being used as a local and practical rule for the Dutch system of storm warnings in 1860, but gaining wide acceptance as a universal law of nature that relates the

---

173 Guldberg and Mohn published a series of papers from 1876 onwards in which they explained their mathematical equations. Kutzbach, Thermal Theory (cit. n. 3), p. 100.
direction and force of surface winds to the distribution of surrounding air pressures. Despite attempts to rename the Dutch law into the more neutral “baric wind law,” the term “Buys Ballot’s law” has been in use since it was introduced.\(^\text{175}\)

The striking inverse relation between Dove’s “law of turning” and “Buys Ballot’s wind law” was a starting point in this chapter to find out how the wind law superseded Dove’s “law of turning.” As we have seen, Dove’s law derived its authority for a long time from being the only rule of general atmospheric circulation in meteorology based on large sets of empirical data. It was created, furthermore, by a professor in physics and put in a mathematical form obtained by sophisticated astronomical methods of least squares and interpolation. Dove had elucidated the law both empirically and theoretically. Other competing meteorological theories of the time, in contrast, had been obtained only empirically, and usually by people engaged in naval and commercial shipping. When the “law of turning” was questioned on the basis of contradicting empirical evidence such as by Schouw, or when it was challenged by Reid and Redfield’s “law of storms,” Dove defended his law by pointing to its theoretical foundation based on Hadley’s principle of the rotation of the earth on its axis.

He proclaimed the superiority of the turning law, moreover, by arguing that it was part of a complex model of weather change consisting of two currents of air. The polar air flow from the northeast and the equatorial air flow from the southwest shaped the conditions of the weather in their interaction. The model explained how the alternate replacement of the two air currents caused the winds to change their direction clockwise; and brought about corresponding changes in temperature, pressure, and humidity, which also corresponded with the occurrence of precipitation. Although Dove hoped to be able to draw maps of the interaction between the two air currents in the future, he dismissed the synoptic method of depicting the various elements on one single map, because he believed that the interdependent relationships among the atmospheric quantities were

\(^{175}\) The term baric wind law was introduced in 1878. Kutzbach, *Thermal Theory* (cit. n. 3), p. 18.
not yet determined. The lack of synoptic maps made it difficult to convey an unambiguous idea of Dove’s model of atmospheric circulation. His abstruse language and the modifications to his theories over the years did not help either. Despite the intricacy of his model, however, it served for a long time as the only established theory of weather change.

When Buys Ballot launched his wind rule, he promoted it as a practical rule to use locally for the prediction of strong winds in the Netherlands. Although he presumed that his wind rule applied to wider areas and gave a better indication of approaching winds and storms than Dove’s “law of turning,” he was cautious not to openly challenge the latter’s theories. His own wind rule was based on empirical evidence and lacked a theoretical underpinning. Unlike Dove who had explained the deflection of winds in a circular motion due to latitudinal differences in the earth’s rotational velocity and the succession of two air currents in opposite direction, Buys Ballot was unable to explain why winds according to his rule did not flow directly from high pressure areas to low pressure areas, but deflected from their course to the right. Compared to Dove’s turning law, his rule also lacked a mathematical expression. He offered proof of his wind rule, based on statistical grounds, three years after his discovery. He had noticed the rule from his synoptic maps, which he began to draw in the early 1850s. Initially he was among the few to compile them, but he successfully propagated their use for storm predictions. His efforts resulted in the establishment of the first warning system in the Netherlands in 1860. With the establishment of storm warnings and weather forecasting services elsewhere in Europe and the U.S., synoptic maps acquired wider practical applicability.176

Synoptic meteorology, while it became a dominant tool in weather investigations in the late 1860s, played an important role in the replacement of Dove’s “law of turning” by “Buys Ballot’s wind law.” In the synoptic studies of Scott, Buchan and Ley, Buys Ballot’s wind rule obtained the status of a natural law and subsumed the “law of storms.” Scott’s maps of simultaneous observations of winds and pressures

176 See also Kutzbach, Thermal Theory (cit. n. 3), p. 65.
verified the wind rule in Britain. He was, furthermore, the first to call Buys Ballot’s wind rule a law. Buchan and Ley subsequently refuted Dove’s theory that storms resulted from the collision of two air currents in favour of the wind rule, which they also referred to as “Buys Ballot’s law.” Buchan’s synoptic maps of European weather 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.

Ley ended his analysis of synoptic investigations with the same conclusion, but for one aspect. While Buchan made a feeble attempt to hold on to Dove’s “law of turning” as the principle that explained the deflection of winds from a straight path, Ley did not mention Dove’s law in his book. He listed Dove’s theory of storms together with other theories, which he claimed to be “erroneous,” or had “fallen to pieces.”

Furthermore, he attributed the deflection of winds from their course to “an attracting force” without mentioning Dove’s “law of turning.” His choice of words clearly shows that he found Dove’s views no longer authoritative in meteorology. In Britain they were generally associated with Fitzroy’s investigations. As a supporter of Dove, Fitzroy propagated the two-currents model as the basis for his storm warnings and weather forecasts. The loss of Fitzroy’s scientific respectability on account of his suicide therefore, also affected Dove’s scientific reputation.

As a result of the synoptic investigations of Scott, Buchan and Ley, Dove’s meteorological edifice of weather change gradually eroded. A process, which began with Dove’s theories being increasingly associated with Fitzroy’s controversial weather forecasts, got worse when his mechanical model of storms based on the notion of the collision of two air currents was refuted. The general acceptance of Buys Ballot’s wind law, while subsuming the “law of storms,” further challenged the integrity of Dove’s complex model of atmospheric circulation. It fell permanently in discredit when his theory of the deflection of winds based on latitudinal differences in the earth’s rotational velocity was dismissed. As we have seen, Dove’s explanation for the deflection of winds was superseded by Ferrel’s theories when

they became known in Europe in the mid 1870s. His mathematical equations of motions of air on a rotating earth were further elaborated by Mohn and Guldberg shortly after. 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.

The phrase “law of turning,” however, did not disappear from weather books overnight. One publication took into account that it had served as a principle in the science of the weather for many years.178 The author, Scott, who played an important role in the creation of Buys Ballot’s law, referred to Dove’s rule one last time while remarking that it lived on in the sailors’ proverb:

“When the wind is against the sun, trust it not, for back it will run.”179

---
