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ADVANCED REVIEW

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Forms of meteorological knowledge 1750–1850 in German countries and beyond

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Abstract

The complexity of atmospherical processes has always yielded a multitude of ways of knowing about the weather. What has been lacking in the historiography of meteorology so far is a way to formulate differences between forms of knowledge in a way that does not privilege modern scientific structures, but focuses instead on the epistemological category of causality. Using causality as ground of comparison for different knowledge claims, I shall argue, may enable researchers to investigate meteorological knowledge across time periods, perhaps even geographical regions, in a more symmetrical manner. This review demonstrates this approach as a means to organize a large set of historical meteorological writings from German countries between 1750 and 1850. Three distinct forms of knowledge (Semiotics, Physics, and Organics of the weather) during that time and in that region are suggested and will be described. While a bibliography with a national perspective from the 1880s was the basis for the selection of historical sources, such a setup proved awkward even to contemporaries. In addition, the bibliography came with a number of biases and shortcomings that will be critically reviewed.

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KEYWORDS

causality, forms of knowledge, Germany, history of meteorology, history of science

1 | INTRODUCTION

The weather is as shockingly mundane as it is infinitely complex—both in itself and in its effects on human life as well as the rest of the natural world. From military research to weather apps, from mathematical modeling to farmer's rules, sunscreen and the quality of the grape harvest—all are, or can be subject to meteorological and climatological expertise. Hence, a recent trend in the historiographical and sociological reflection of these sciences and their histories seems almost self-evident: Trying to distinguish and classify differences in how people try to know weather and climate that account for the different applications and investigative methods (e.g., Achermann, 2019; Feola, Geoghegan, & Arnall, 2019; Hall, 2019; Heymann, Gramelsberger, & Mahony, 2017; Hulme, 2015). All too often, however, such

compilations focus on the 20th and 21st centuries and the elaborate, yet historically specific scientific structures which developed in North America and Europe. For this reason, the characteristics used to distinguish ways of knowing tend to juxtapose traditional and scientific knowledge (Hall, 2019) or make use of categories like professionalization or the "character and significance of computational practices" (Heymann et al., 2017, p. 6–7). In both cases, such concepts cannot reasonably be applied to previous centuries. While reviewing a relatively sizable collection of published primary sources, I found a different benchmark helpful to organize and make sense of them: Distinguishable and recurring causal structures I define as a form of knowledge from this point on.

Other notions of knowledge differences popular in the historiography of science do not match the needs of such a study. The "episteme" that Foucault (2002 [1966]) introduced are too monolithic and the "thought styles" of Fleck (1981 [1935]) as well as the "paradigms" of Kuhn (1962) depend by their definition on the scientific institutions of the 20th century. More recent suggestions like "ways" (Pickstone, 2000) or "styles" (Kwa, 2011) of knowing grant more flexibility. They allow for more historical depth and changing combinations of different kinds of knowledge, although they are not entirely congruent with the forms of knowledge suggested here—as will be discussed presently. With any luck, other historians might find my proposition useful because it offers more potential to compare weather-related knowledge across time periods, possibly even regions.

The geographical focus of this review is on publications from the patchwork of German countries. Aside from diversifying the overwhelmingly Anglophone literature on the history of atmospherical sciences merely for the sake of completeness, such an analysis is compelling to a wider audience for two reasons. First, Gustav Hellmann's *Repertory of German Meteorology* (Hellmann, 1883) is a uniquely comprehensive (if not unproblematic) key to an abundance of historical texts. When focusing on underlying assumptions about the causality of the weather expressed in the texts, a distinct pattern emerged from which I derived a model of three forms of knowledge which I call Semiotics, Physics, and Organics of the Weather. As I will show, secondly, the historical sources transcended language boundaries with great ease, particularly in the 18th century. Once you consider all the developments abroad which German sources do reference, the emerging picture is much more European in scope. As far as this review suggested time frame is concerned, it covers the Enlightenment era, the tumultuous political upheavals and social changes of around 1800 and ends, roughly speaking, when the European nation states intervened into matters of weather observation. Especially the first 50 years are reasonably well researched for the British case (Golinski, 2007; 4, 2000), which is therefore the most important point of comparison. For the latter 50 years, Anderson (2005) offers insights into further British developments starting in the 1830s, whereas Fleming (1990) and Locher (2008) survey the better part of the 19th century for the US-American and the French case, respectively. While there was no lack of diligent weather observations in the 18th century, no one had yet managed to disentangle the causes and ways of the weather based on the produced data (Daston, 2008). The fact that there was not yet a state-sanctioned science created a more open, diversified field of knowledge claims in competition with one another. In addition, the success of Newtonian celestial mechanics by the mid-18th century was a powerful yardstick against which any upcoming science had to be measured.

2 | REVIEWING A FIELD OF KNOWLEDGE—A HISTORICAL BIBLIOGRAPHY AND ITS LIMITS

It is no simple task to review a field of knowledge in its entirety, both because the make-up and extent of this entirety are highly debatable and subject to historical change. One aspect that makes the German case uniquely suited to such an analysis is that contemporary historians of meteorology do not have to start collecting source material from scratch. On the other hand, they need to make peace with the inevitably flawed standards of objectivity guiding any compilation process. The climatologist and bibliophile Gustav Hellmann edited the comprehensive *Repertory of German Meteorology* (Hellmann, 1883) which outlined the corpus of sources relevant to his nascent scientific discipline at that specific point in time. Initially compiled to be part of an international bibliography of meteorological publications, Hellmann published it as a stand-alone after funding for the international project did not materialize. With utter tenacity, he collected information on meteorological publications, authors' biographies, where and for what time period weather observations had been conducted, as well as a survey of the history of observation networks. The benefits of such a resource for historians of science are obvious: If we trust Hellmann's entries to be reasonably well-researched, much of the bibliographical research on a panoply of meteorological topics is thus at hand, even conveniently accessible through an index. Two aspects, however, require critical reflection to reveal constraints on using the *Repertory of German Meteorology* as a gateway to the field of meteorological knowledge.

First, it is worthwhile to ponder what it is that constitutes a field of knowledge and what, therefore, is the object of such an analysis. The term "field" in this context is, of course, based on Pierre Bourdieu's. Whereas his notion of a "scientific field" depends on institutions and structures of the 20th century, his more general characterization of a field is arguably better applicable to earlier times. According to this, any social field is created and continuously shaped by the involved actors and their ability to accumulate various forms of capital (Bourdieu, 2004[2001]). To inspect and compare publications for notions of causality, of which some succeeded and others fell by the wayside, is only one facet of this. In a more thorough analysis, which lies beyond the scope of this review, more quantitative, bibliometric analyses could bolster the results or modify them. Beyond scientific literature, observational practice is another potential dimension of a field that eludes this review. Considering more recent Latourian approaches in history of science, the influence and agency of nonhuman actants like instruments, tables, even perhaps weather itself are another force to be reckoned with. In summary, to define additional layers of a field would probably modify or check the results of this review that is for now almost entirely based on published materials.

A second set of potential constraints revolve around the issues of how inclusive and comprehensive the *Repertory of German Meteorology* can possibly be. Hellmann (1883, p. xi) strove to ground his decisions on objective criteria, admitting—for the sake of overall completeness—texts that were in his opinion "outdated, irrelevant, and probably useless". Even so, all the publications he only came across by sheer accident convinced him that any bibliography, including his own, "are and must remain incomplete" (p. xi). Although Daston (2017, p. 5–6) has recently stressed the "opportunistic" nature of scientific archives, in the sense that they can adapt to different research questions, there are limits to anticipation. The implicit and explicit biases of the collectors render efforts at objectivity largely futile (Greetham, 1999).

While it is difficult to reconstruct Hellmann's implicit biases, he does explicate two problems which arose during the compilation process. One concerns the breadth of topics and disciplines involved in making sense of all the natural phenomena somehow related to the weather. Whereas he decided to include treatises on physics and physical geography, if they were relevant to meteorological questions, he excluded those on agriculture, forestry and medicine. In his view, their focus on "practical applications" (Hellmann, 1883, p. xii) failed to contribute anything original to the scientific discourse proper. The criteria an author had to fulfill to be counted as sufficiently German to make it into the *Repertory of German Meteorology* were a second cause for concern. When the collection was published in 1883, Germany had been a unified nation state only for a little over a decade. Many of its states had been independently ruled and very loosely associated in ever-changing Holy Roman Empire from the Middle Ages until 1806. They underwent various transformations and switching alliances following the upheavals of the Napoleonic wars and throughout the 19th century, before being unified under Prussian leadership in 1871. Strictly speaking, before that point, neither we nor Hellmann can speak of "German" as a nationality in any meaningful manner. The awkward criteria he arrived at came under immediate attack in the reviews, showing that they were by no means self-evident. Wladimir Köppen (1884), at the time head meteorologist of the *Deutsche Seewarte*, lamented that the most influential German-language journal at the time was not included because it was published in Austria.

Using the *Repertory of German Meteorology* as the basis for reviewing historical writings on meteorology forces us, to some extent, to accept and reproduce these problematic categories. If these limits are transparent and the results are taken with the necessary grain of salt, the damage is probably minimal. As a compilation of a multitude of historical texts roughly representative of knowledge production in a region of central Europa, it can still be useful—although it may reveal as much if not more about a meteorologist's retrospective view on the tradition of his discipline in the 1880s as it does about the earlier periods.

Although no historian by any stretch of the term, a great deal of historical judgment went into Hellmann's inventory of meteorological publications. This bolsters the more general claim that scientific publications do entail a significant amount of historiographical work by reviewing existing literature and placing contributions into the context of a given science's "imagined past" (Wilson, 2017, p. 814). Like a Russian doll, the review currently in front of you is an informed selection of Hellmann's sources, who himself reviewed and selected from among the publications he was aware of, a significant part of which based their claims on a sort of review themselves. The historicity and idiosyncrasies inherent to this process need not diminish the quality of research done in the history of science, as long as they are reflected upon, explicated and itself historicized (Badino, 2017). Continuously re-organizing, re-interpreting, and re-viewing sciences past is arguably what keeps writing the history of science engaging and relevant. Blind spots created by this historiographical method can be colored in and checked, for example, by way of, archival research as demonstrated in my dissertation (Richter, 2019a).

3 | CAUSALITIES OF THE WEATHER IN GERMAN COUNTRIES, 1750–1850

Compared to other regions, the field of weather knowledge in German countries has not yet been studied extensively. Some internationally visible research has been done on the remarkable observational network administered in the 1780s out of Mannheim, the Societas Meteorologica Palatina (e.g., Cassidy, 1985; Feldman, 1990; Khrgian, 1970; Lüdecke, 2005). Most of the publications available in German language privilege meteorological institutions (Körber, 1997; Wege, 2002), the history of the German disciplinary journal (Emeis, 2008) and early textbooks (Emeis, 2006). Early attempts, also by Hellmann (1914–1922, 1926, 1893–1904), to explore the history of meteorology and climatology there beyond its disciplinary structures remain highly informative.

When filtering all texts published between 1750 and 1850 out of the total number contained in the *Repertory of German Meteorology*, 3,100 individual entries remain. I do not suggest that the three forms of knowledge account for all of these. A substantial amount is concerned with measuring instruments, providing long tables of observational data or descriptions of more or less unusual weather phenomena—without voicing an explicit opinion on the weather's causality. Many of the remaining texts, I argue, belong to one of three distinct forms of meteorological knowledge: Semiotics, Physics, and Organics of the weather—the words being used in that sense throughout the following text, as also indicated by the capital initial. The first group, the Semioticists, dismissed the importance of actual causality of the weather in favor of empirical sign relations. The Physicists, on the other hand, envisioned a mechanical causality of all weather phenomena as results of intricately intertwined chains of events that they wanted to untangle via long series of instrumental observations. Finally, the Organicist view assumed an even more complex set of causes, dispersed throughout all kingdoms of nature and interacting with one another as part of one organized whole. That they all, in principle, subscribed to causality as what drove changes in the weather, shows the overall "analytical" spirit of that time period (see Pickstone, 2000, p. 83–105)—and also suggests the need to further differentiate types of causal thinking.

The following paragraphs cover the underlying causal structures in more detail and introduce some exemplary authors.[1] But before, a few clarifications can help to avoid misunderstandings. First, although names for these forms of knowledge follow contemporary usage as much as possible, they are not, in a strict sense, actor's categories but are heuristically motivated. The classification, second, primarily appreciates causality and does not distinguish by occupation or social standing—all groups are, therefore, socially heterogeneous in various degrees. The categories are ideal types and their existence does not imply that lines between approaches can always be drawn clearly. In fact, some publications contain more than one of the forms of knowledge or authors may occasionally change allegiance during their lifetime. These labels are supposed to aid analytical comparison, but retain a certain flexibility.

3.1 | Semiotics of the weather

The first group identified here continued the Ancient practice of interpreting weather signs (see Rochberg, 2004; Taub, 2003). Between 1750 and 1850 in German countries, however, this was rooted in a deeply Christian worldview of a natural world ordered by God. Particularly with regard to time passing, the Semioticists of the weather believed that all individual points in time were connected to one another in an unbreakable and immutable chain. For this reason, explained Adelbulner (1768), professor for mathematics and physics in Altdorf, it was possible to infer from signs in the present to signified events in the future. It was thus a misconception that changes in the weather were sudden. Instead, he continued, they came "step by step and mostly unnoticed" by humans (p. 22). Because other things in nature were less distracted by their reason and everyday matters, humans could make use of different natural signs (such as animals) or artificial signs (such as barometers) to predict impending weather changes.

To be clear, Semioticists did believe in underlying causes for resulting weather. It would be slightly misleading, therefore, to speak of them as acausal, as Janković (2000) has done for the closely related phenomenon of "Virgilian meteorology" in Great Britain. Although the goal was to empirically turn things with no immediately apparent connection to the atmosphere into signs for various possible weather events, a causal process within the atmosphere was never denied. In fact, the advantage of the Semiotics of the weather lay in the fact that one did not have *to know* the cause. As is depicted in Figure 1, Semioticists assumed that a certain cause A resulted in both an effect S and a later weather phenomenon W. If it held true that W would always follow S, then S was a sign for W—and knowing the actual cause A became irrelevant for making predictions. This made it possible, commented Adelbulner (1768, p. 22), to "listen in on nature" by "noticing certain changes in other things, from which we can conclude imminent weather changes".

That short-term, sign-based prognosis worked, was often attested to. The physicist Georg Wilhelm Munke (1837, p. 2082), for example, even admitted that of all weather signs, animals were "the most mysterious, yet most reliable", although he could not explain why they worked. This lack of transparency became troublesome to Semioticists because to provide empirical rules that worked without being able to explain why was increasingly regarded as unscientific. Over the course of the 19th century, then, the social status of Semiotic authors declined and ambitious attempts to collect empirical Semiotic data ended after the 1780s (Richter, 2019a).

According to later Semioticists, to insist on entangling all causal relationships before uttering predictions created a dangerous vacuum where forecasts were a practical necessity. The teacher Franz Wenzlaff in his published collection of weather signs (Wenzlaff, 1851, p. 2) blamed a continuing interest in superstitious prognostics of "vociferous calendar makers" (something he abhorred) on the failure of weather science to offer a competing prognostic tool. "Thus," he continued, "many who thirst for knowledge and who would have been content with half-sufficient information were turned against a thorough understanding of the weather" (p. 3). To fill this void, he and other Semioticists sought to collect different weather signs and distribute them in print.

The types of publications in which weather signs were predominantly gathered changed over time. The latter half of the 18th century was dominated by seasonal signs compiled in "natural calendars". In the 19th century, they turned increasingly toward catalogues of different signs, sorted either by sign or by signified (Richter, 2019a). While this does seem to reveal a taxonomical interest akin to that of natural history as stipulated by Pickstone (2000) and Kwa (2011), there are at least two unsettling points of friction. As opposed to plants or minerals, the weather is awfully difficult to collect and sort. Is the collection of supposed semiotic relationships in writing still comparable to the practices of natural historians? In addition, and more importantly, this different type of collecting nature was not performed for its own sake, that is to situate the weather within an all-encompassing system of nature, but to forecast weather in very specific instances. To the extent that it attributed an underlying meaning to these signs as representing an enlightened Christian natural order, it was certainly a kind of "world-reading" (see Pickstone, 2000, p. 33–59).

However, there is little evidence so far that Semiotics of the weather were actually used in agriculture. In addition, Semiotic authors did not reveal what kind of basis their prognostic rules had in the experience of actual farmers. A similar British case of a strong practice claim paired with unclear origins are the rules ascribed to an anonymous shepherd of Banbury (Golinski, 2007; Janković, 2000). A preliminary survey of edited German farmers' diaries yielded no lists of local weather signs (Richter, 2019a). Historians, therefore, should be more cautious than to simply accept the Enlightenment trope of a "fruitful mutual exchange [...] between popular and higher culture" (Casati & Ciardi, 1998, p. 568) as fact. In a similar vein, we ought to be more careful with claims such as Golinski's (2007) that the power structures of the field of meteorological knowledge were more even because the weather was accessible to everyone. In the German case, authors who published Semiotic texts were learned naturalists, priests, and teachers—not actual farmers. It is therefore necessary to find new ways of understanding the weather knowledge farmers may have had and circulated. Further analysis of ego-documents is one option, another would be to extend the pool of historical sources to documents relating to folk traditions and include nonwritten sources. Until then, historians need to restrict themselves to thinking of practice claims as a rhetorical strategy to legitimize their own knowledge claim.

3.2 | Physics of the weather

The causal structure that the Physicists of the weather ascribed to, as depicted in Figure 2, was more straightforwardly mechanical: A cause A resulted in effect B, which in turn became the cause for C and eventually resulted in a weather phenomenon W. The matter became complicated, however, because many such processual chains were interlinked and

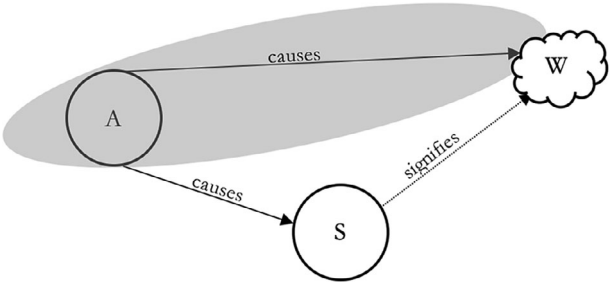

FIGURE 1 Causal structure of the Semiotic form of knowledge

unfolded at the same time. Nevertheless, authors such as the Baden administrator Böckmann (1778, p. 6) were convinced that "all the thousand seemingly disorderly changes" depended on "general causes, which produce effects according to general laws". If only the weather was observed by a multitude of observers over a wide area and for a long time, hoped he, meteorology could finally ascend to "the highest level of physical certainty" (p. 7). The Physicists borrowed the emphasis on extensive observations, quantification and natural laws from what they believed the genesis of Newtonian celestial mechanics to be. The editor of the first German encyclopedia of physical sciences, Johann Samuel Traugott Gehler, lauded observation networks such as the contemporary Societas Meteorologica Palatina. To him, they indicated that meteorologists were finally willing to "follow the path which astronomers laid out so admirably with their observations and their predetermination of the ways of the heavens—the path of tables" (Gehler, 1790, p. 206).

Because their role model was astronomy, the Physicists of the 18th century were particularly preoccupied with determining periods of weather based on the observational data—this, they hoped, would pave the way toward a natural law of weather akin to universal gravitation (e.g., Mayer, 1775). This form of knowledge is closely related to the trend Golinski (2007) described for Great Britain in the sense that it required continuous observation and aimed at rationalizing the complexities of the atmosphere by quantifying them. Rather than any of Kwa's (2011) styles, the "analytical" way of knowing described by Pickstone (2000) matches these Physics of the weather best because its adherents sought to derive insights into the mechanics of the atmosphere based on observing the precise changes in its elements.

In the second half of the 18th century, many Physicists were still open to including the movements of various heavenly bodies as causal factors in their period calculations, the moon being an object of particular fascination (Richter, 2019a). In German countries, first voices who seriously doubted the relevance of lunar influence on the earth's weather emerged around 1800 (e.g., Gronau, 1808; Heinrich, 1807; Kant, 1794). This was one of the key factors ushering in what I have called the "solar turn," that is reducing the extra-terrestrial causality of the weather to the sun alone (Richter, 2019a). Kämtz (1838, p. 257) summed up the general idea as follows: "the most important cause of all meteorological phenomena is the sun by virtue of the warming force of its rays". He and other leading figures of the Physics of the weather in the first half of the 19th century, like Alexander von Humboldt und Heinrich Wilhelm Dove, were most interested in daily, monthly and annual means of quantified measurements and their retrospective analysis. To speak somewhat anachronistically, their focus was mostly climatological. According to von Bezold (1892, p. 1), William Ferrel imported the general laws of mechanics and thermodynamics into meteorological thinking in the latter half of the 19th century, finally "loosening the grip" of climatology on weather science in German countries. Climatology was, of course, to become its own discipline from the 1880s onwards (Heymann, 2010), although Coen (2020) is correct in pointing out that contemporaries like Julius von Hann thought that meteorology and climatology were mutually dependent.

Focusing so enthusiastically on climatological means interestingly led the Physicists of the Weather in German countries to reject weather forecasts—in their view, it was unscientific to make predictions unless all processes in the atmosphere were understood and cast into natural laws. Even if the only cause of weather was the sun, its phenomena were still spread out over vast distances and happening everywhere at the same time (Dove, 1845; Kämtz, 1831–1836, vol. 1). Only if observations could be spread out, synchronized and transmitted quickly, might meteorologists begin to even consider thinking about forecasting (Mahlmann, 1850b). Although synoptic forecasting methods often proved highly controversial (e.g., Anderson, 2005; Hupfer, 2019), the reticence of these German authors seems extreme. Kämtz (1840, p. vii) insisted that a meteorologist was "nothing but a historian of the weather" whose only task was to "seek the laws of past events". Mahlmann (1850a) concurred and encouraged all meteorologists to dismiss even researching methods of forecasting. A proper meteorologist, in his view, should merely "collect observations, examine them critically, organize and compare them to reach more or less general results" (p. 154). This refusal to strive for practical application stood in stark contrast to the Semioticists, but also the earlier Physicists of the 18th century. In compliance with the Enlightenment ideal of utilitarian science, these authors readily assumed that their work, although complicated, was to eventually result in practical applications (e.g., Böckmann, 1781).

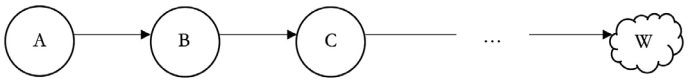

FIGURE 2 Causal structure of the Physicist form of knowledge

3.3 | Organics of the weather

A third and final form of knowledge marks a way of thinking about the weather as an integrated fragment of a larger organized entity or being. As Figure 3 illustrates, this means that causation of the weather did not follow a linear chain of causes and effects, but was instead the result of a back-and-forth between different parts of nature (A, B, C, D, E,...) continuously interacting with one another, only one of which (W) was the weather. A well-known branch of this form of knowledge is medical meteorology which pursued the correlation of medical and meteorological statistics in the 17th and 18th centuries (Janković, 2010). A handful of scientific societies organized observation networks to this end (e.g. Hannaway, 1972; Rusnock, 2002a, 2002b; Zuidervaart, 2005, 2006), often to no avail. Mendelsohn (2011) has shown that the Société Royale de Médécine, active in France between 1778 and 1793, developed an intricate system of questionnaires for their participants, which helped to standardize observations and convey (rather unsatisfying) "general observations" about weather and the state of health. Such projects of data-gathering as well as neo-hippocratic publications form a first, inductive branch of this form of knowledge in German countries between 1750 and 1850. Occasionally, this included experimental approaches as well, such as a series of chemical experiments by Sigismund Friedrich Hermbstädt (1822), aimed at finding substances emanating from the Baltic sea into the atmosphere. Hermbstädt wondered whether such parts of the sea breeze were responsible for its therapeutic qualities.

On a much more ambitious level argued a group of authors who were part of the so-called "Romantic" movement in science (see Beiser, 2006; Caneva, 1993; Cunningham & Jardine, 1990; Friedman, 2006). They followed different methods than the inductive Organicists, based on hypothetical anologies, but because they ascribed to the same underlying causal structure of the weather, I shall call them speculative Organicists. In an early publication on questions of nature, the philosopher Friedrich Wilhelm Joseph Schelling (1798) developed the idea that the failure of natural science to produce any laws in meteorology was the epitome of what was wrong with mechanical theories of nature more generally. In his view, speculating about the make-up of nature and the connections between plants, humans, minerals and the atmosphere *had to* precede empirical observations—otherwise they would just be meaningless piles of data. Schelling's friend, mineralogist and philosopher Henrik Steffens, as well as the medical doctor Johann Christian Reil wrote reports for the Prussian government in which they detailed how diseases in humans and animals mirrored deviations in the balance of the earth's atmosphere (Richter, 2019b). Steffens went particularly far in arguing for the atmosphere itself being alive and maintaining a mutually sustaining relationship with all other organic beings. These governmental files and the passages in Schelling, it should be noted, were not included in Hellmann (1883) and their omission, whether intentional or not, went uncommented. They are an example of what would go amiss if one reproduced the limits of the *Repertory of German Meteorology* without additional research.

Somewhat surprisingly, the substantial publications of at least two lesser known speculative Organicists were included. The botanist Karl Konstantin Haberle (Haberle, 1810–1812; Haberle, 1810–1811) and the chemist Karl Wilhelm Gottlob Kastner (1823–1830) mirror many aspects of Schelling's or Steffens' thoughts and exemplify some of the problems which adherents to this form of knowledge grappled with. Because of their belief that everything in nature was connected to everything else, the empirical side of the Organics of the weather tended to be impossibly extensive. The parameters to be observed, for example, as far as Haberle (1810) was concerned, far exceeded those of air pressure, temperature, wind direction and humidity. They included, among others still, tides, earthquakes, premature births, diseases, deaths, and sun spots. Their publications tended to be vague and rambling. Significantly, they also did not manage to organize a productive observation series, let alone prove any of their speculative hypotheses. The Prussian central government, initially intrigued by Steffens' and Reil's Organicist suggestions, underestimated the amount of personal and financial resources such observations would take and canceled a network it ran between 1817 and 1820 prematurely (Richter, 2019a).

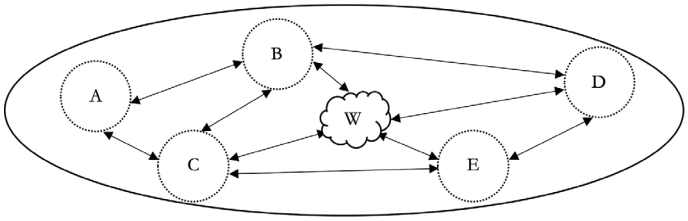

FIGURE 3 Causal structure of the Organicist form of knowledge

Despite this, Organicists were not a marginal phenomenon at all—in fact, at least two of the more influential Physicists of the weather had Organicist sympathies. Humboldt favored holistic, albeit more empirically based portraits of landscapes and their characters (Dettelbach, 1999). In addition, Dove's wind theory, popular from the mid-19th century onward, owes its dualism to Hegelian natural philosophy (Fritscher, 2005). The Organicists' preferred method of generating knowledge was by way of analogy between different parts of the natural world, reflecting sympathies for Kwa's "hypothetical" style (Kwa, 2011), although there was some variation in the extent in which they found this useful. Dove (1837), for example, ridiculed Schelling's idea that recurring daily variations in the barometer were earth's way of breathing. A different notion of theirs, on the other hand, is much more compatible with later ideas about meteorology: Because it is infinitely complex and evolving, perhaps there is no such thing as a recurrence of exactly identical states of the atmosphere, only a historical process (Dove, 1852). In this point, they diverged from the Physicists of the weather. Just like them, however, the speculative Organicists did not preclude applications of their knowledge, but feared that a practical motivation would distort their work in an untoward manner, eventually leading to falsehoods. To them, science was to be established for its own sake before, for example, medical advice could be given (Richter, 2019a).

4 | TRANSNATIONAL ENTANGLEMENTS

These discourses on forms of weather knowledge were neither restricted to German countries nor would they even have been possible without the reception of writings from abroad. Because so much more historiography on the development of meteorology and climatology covers the latter half of the 19th and especially the 20th century, they describe a time in which the existence of nation states is taken mostly for granted and national structures facilitate much of weather observations and research. Even then it was true that people, publications and the knowledge contained in them move across national boundaries with relative ease. Although transportation would have been a great deal more cumbersome, this was also the case for the preceding centuries. Even Hellmann (1883, p. ix) concluded that a comprehensive overview of the development of meteorological thinking that was restricted to the German nation alone was impossible "because it would only be comprehensible in relation to simultaneous developments in foreign countries". Indeed, such transnational entanglements became visible both in the numerous places where discussed authors originated and in the variety of places where aspects of a Semiotics, Physics, and Organics of the weather could be identified. Like the atmosphere itself, knowledge about the weather transgressed borders easily and often. The German sources investigated for this study reveal many instances of knowledge somehow imported from different places. One example from each form of weather knowledge may serve to illustrate this point.

In the case of Semiotics, a surprising number of German authors around 1800 celebrated the prognostic prowess Denis-Bernard Quatremère-d'Isjonval attributed to a particular weather sign: The house spider. Although he was of noble French origin, Quatremère fought for Republican forces in the Netherlands before he was incarcerated by Prussian troops. During the time he spent in prison, he took to observing spiders and published a rambling treaty on correlations he claimed to have established between changes in the behavior of spiders and changes in the weather (Quatremère-D'Isjonval, 1797). In a nutshell, increased activity by the spiders suggested fair weather ahead while withdrawal and inactivity signaled rain. This theory was embedded into a heroic story, in which Quatremère smuggled a spider-generated forecast (predicting a prolonged frost period) out of prison into the hands of the French Republican troops, eventually helping to facilitate their victory. As the two main benefits of his approach, Quatremère advertised a forecasting window of 10–14 days and the ubiquity of spiders. Whereas meteorological instruments were not affordable to the part of the population that depended on accurate forecasting for their livelihood, spiders were accessible everywhere at no cost. With the help of his guidelines, they could be easily read and interpreted. Many German authors who reported on this emphasized this egalitarian point (e.g., Anon, 1800). An anonymous translator prepared a German translation of the treatise (Quatremère-D'Isjonval, 1798) which reveals the political dimension of Quatremère's call for widely disseminated forecasting tools. He addressed his fellow Germans: "When do we rise from idle and unfruitful speculation to achieve a will, an action? While it may not yet work to engage with humans, we may begin by engaging with spiders" (p. v–vi). An astounding number of publications ensued in which Quatremère's theories were lauded and dispersed, often with surprisingly little skepticism (e.g., Günther, 1834; Schmidt, 1800; Stelzer, 1818; Weber, 1818). Currently, we do not know whether this was a German predilection, how his theories were received in his native France or whether they sparked discussions elsewhere. A brief attempt to identify similar enthusiasm in English-speaking contexts yielded few results. One English paper which mentions Quatremère's theories briefly (Lehmann, 1801–1802) was indeed translated from an earlier German publication. An anonymous author (Anon, 1798, p. 53) praised the

"important discovery of being able to rely on garden spiders, with as much, if not more confidence, than on the catgut or mercurial barometers". On the other hand, another commented (Anon, 1832, p. 690) on a different project of Quatremère's that he was known to be "a little deranged, but not mad enough to be confined".

As far as the speculative branch of Organics is concerned, it was perhaps the most Germano-centric approach of the group, with an important contemporary influence being the philosophers Schelling and Hegel. Certainly, the Romantic movement had scientific exponents in other regions as well (see Cunningham & Jardine, 1990). Indeed, one of the mentioned experts for the Prussian government personified a history of migration. Henrik Steffens was born in what is now Norway and studied mineralogy in Copenhagen before becoming enthralled with Schelling's natural philosophy and moving to Jena. Oscillating between Prussian and Danish centers of learning in his early years, he developed nationalist German attitudes later in his life (Bergner, 2016).

For the Physicists of the Weather in the latter half of the 18th century, it was an Italian priest and astronomer from Padua, Giuseppe Toaldo, who proved remarkably influential. Akin to Quatremère's story, Toaldo's success is clear from the sources but puzzling to historians on account of his bold claims (e.g., Sheynin, 1984). A treatise of his was prized by the Academy of Sciences in Montpellier and subsequently translated from the Italian original (Toaldo, 1775) into German (Toaldo, 1777). His main contribution to the field was to define 10 specific positions of the moon in relation to the earth he correlated with weather changes. How precisely the moon caused these changes, Toaldo left open. His approach can thus be characterized best as a somewhat updated astrometeorology which particularly emphasized the importance of the moon. Even though this was hardly a revolutionary approach at the time, German authors sang his praises. The entries for "meteorology" in the first German encyclopedia dedicated exclusively to the physical sciences (Gehler, 1790, 1795), devote a significant portion to him. The founder of the acclaimed observation network Societas Meteorologica Palatina, Hemmer (1778, p. 458) claimed that "no one has come closer" than Toaldo to discovering the "main sources of weather changes". To Hemmer, it was he who had first managed to "pick up the scattered pieces" of previous meteorological observations and put them together to form "a proper house of meteorology" (p. 458). When Hemmer had managed to enlist Toaldo as one of the observers of his own network, administered out of Mannheim, he boasted of this connection to the "famous founder of meteorological sciences", the "brightest star of the University of Padua" (Hemmer, 1783–1795, vol. 1, p. 40). A more critical evaluation came from Swiss doctor and botanist von Haller (1772), who pointed out that Toaldo had not proven anything except that the weather tended to change more often than it remained stable. Anglophone historiography has so far taken little notice of Toaldo's theories. He appeared as an advocate for lightning rods in Bertucci (2009) and in an overview of statistical methods in meteorology (Sheynin, 1984). Golinski (2007) and Janković (2000) do not mention him and indeed no contemporary translation of his work into English could be identified. A few more substantial treatments, perhaps unsurprisingly, were published in Italy (Bozzolato, 1984; Pigatto, 2000), although his impressive reception in Germany does raise the question if there was a wider distribution of his works that has so far been overlooked.

Thus, we have seen that the field of weather knowledge in German countries was permeable for publications, ideas, or people from abroad. The development of all three forms of knowledge stipulated here shows relations to or even dependency on publications translated into German or on migratory movements. A tentative hypothesis yet to be tested against comparable examples from different countries could be that a more decidedly national perspective on the relevant discourses only became a possibility in the sources of the second half of the 19th century—the existence and layout of the *Repertory of German Meteorology* supports this claim.

5 | CONCLUSIONS

This review of meteorological writings in German countries between 1750 and 1850 provides insights into a contested arena of at least three competing claims to knowledge: The Semiotics, Physics, and Organics of the weather. They did not evolve in succession, but rather co-existed in a diverse field. None of these emerged as inherently superior, but all wrestled with significant obstacles in the face of such a complex phenomenon as the earth's atmosphere. Each has aspects that seem strange to modern readers, like the Physicist's fascination with lunar atmospheric tides or the Organicist image of a breathing earth. On the other hand, it was not just the most obvious candidate for a predecessor, the Physics of the weather, that contributed to make Meteorology what it is today. The Semiotic insistence on practical use and the interconnectedness of the atmosphere with other parts of the natural world, as proposed in Organics, feature as well. In fact, because of their lack of practical commitments, the eventual triumph of the Physicists—if the establishment of the Prussian Meteorological Institute in 1847 is to be counted as such—is surprising. Apparently, the patronage

of Alexander von Humboldt (see Körber, 1997) and a more general interest in recording data for the purposes of nation-building, as witnessed in other countries (see Coen, 2018; Hupfer, 2019), outweighed practical concerns.

Introducing this way to characterize and organize historical publications on the weather was one aim of this review. A second one was to raise awareness about historiographical practices embedded also in this particular natural science. Exemplified by Hellmann's *Repertory of German Meteorology*, this has ambivalent consequences: While such a compilation is a fantastic asset for historians of science, it comes with baggage in the form of explicit or implicit biases. In addition to a dislike for what Hellmann perceived to be instances of applied knowledge, his national framing of publications was especially anachronistic. The many ways in which publications contained in the collection were still entangled with authors from what would become other nations show the failure of this approach to correctly mirror historical discourses. The stories of Quatremère-D'Isjonval, Toaldo, and Steffens are just a few examples of a publication culture as well as people that traversed borders with ease. The different modes and the extent of such movements and the knowledge transfer they entail we still know very little about. After a series of thorough studies of national developments, the time has come to shed the comfortable constraints of national archives and native tongues and make the history of meteorology and climatology as transnational as their object of inquiry.

Hopefully, this review resonates with historians of meteorology covering different regions and time periods. A focus on different modes of causality may begin a wide variety of new conversations on similarities and differences between theories and knowledge-based practices concerning the weather. Do they share assumptions about causality or do they differ vastly? How, for example, have weather signs evolved over time in various regions? Regarding the Organics of the weather, questions with a more cosmological dimension come to mind. What is the longer history of thinking about the earth as a living being of mutually sustaining parts? The earth-body analogy put forward by Kepler (1619) is an earlier example and reference point for the German Organicists, the Gaia Hypothesis of Lovelock (2016 [1979]) may likewise warrant attention. Finally, the search for natural laws in meteorology, the Physics of the weather, is equally in need of further historical analysis. What is the history of natural laws in meteorology and climatology? Were such claims contested and, if so, how? By whom?

It would be preposterous to assume that the three forms of knowledge presented for this specific time and region would be transferable easily (or at all) to other times and regions. More likely than not, other historical and geographical contexts will necessitate different means of distinguishing different bodies of knowledge. Perhaps even the prevalence of causal thinking was particular for the 18th and 19th centuries in Europe, and different epistemological categories might be necessary in other cases. The point is rather, to encourage other researchers to think about the epistemological categories which would best characterize their empirical material in the context of its own time. By collecting, comparing and evaluating the answers, we can achieve a way of thinking about differences in knowledge that more easily facilitates diversity and symmetry.

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CONFLICT OF INTEREST

The author has declared no conflicts of interest for this article.

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ENDNOTES

[1]The following text will include some translated passages from the original source material, most of which is in German. All translations were supplied by the author.

RELATED WIREs ARTICLES

The evolution of climate ideas and knowledge: The evolution of climate ideas and knowledge
Private diaries as information sources in climate research
Climate change and society in the 15th to 18th centuries

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