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Chapter 4

Economic Rationalization of Weather: Risk, Prediction, and "Normal" Weather, 1870-1930

Climate knowledge merged with larger efforts to govern climate in a manner specific to the development of industrial society. Chapter 3 demonstrated that commercial agriculture helped to wed climatology to government administration. In the process, the logic of climatology likewise changed the basic definition of climate towards a geographically delineated and temporally stable object. For climatic stability to haven taken shape, I argue, infrastructure had to be maintained, time had to be standardized, meteorological observations and reporting had to be disciplined, and authority to interpret weather patterns had to be monopolized. Representations of climate as stable thus rested upon "stability" across many social domains. The cacophony of atmospheric motion, in short, had to be rationalized.

To trace the rationalization of climate and weather knowledge, this chapter explores how meteorologists worked to assemble a vast array of material elements and human actions, made legible in standard units. Constructing a nationwide *data infrastructure* of weather observation was not simply a logistical issue. It succeeded through meteorologists' capacity to link their professional goals to state and economic interests. In turn, weather prediction served to rationalize weather as a set of economically legible elements, especially relevant to the domains of insurance, finance, trade, and public infrastructural investment.

Moving forward, the first issue addressed in this chapter is the difficulty government-centered meteorologists faced in securing the telegraphic circulation of weather observations, beginning with the origins of the U.S. Signal Service around 1870. Such a challenge involved a meteorological *technopolitics* (cf. Hecht 2011), which I define as struggles between those who would stabilize the meteorological data infrastructure and those who, for one reason or another, would subvert it or deny its significance to weather knowledge. The second issue addressed in the chapter is the social organization of "standard" time across geographic space, an invention required for meteorologists to develop a standard view of weather and an account of climatic stability. Third, the chapter focuses on the formation of *meteorological consumers* that adopted formal discourse regarding normal versus abnormal weather. Finally, the chapter shows that weather reporting and forecasting served to *economize* weather events, that is, make them fictitiously commensurable with dollars and cents. Weather was experienced in new ways as extreme and damaging, through which weather risk and "disaster" entered public consciousness and economic rationality (Bernstein 1998; Steinberg 1991). By contrast, for meteorologists, government, and the public, climate became the stable statistical-geographic background to a progressive, if tumultuous, socio-economic drama.

Technopolitics of the Meteorological Network

The 1870 legislation authorizing a national weather service initially mandated the development and distribution of storm warnings. The Signal Service of the War Department—not the Department of Agriculture—held the responsibility for organizing and issuing such warnings. Tracing the work of the Signal Service helps to show how post-Civil War science and government, even in a context of drastic demilitarization and state withdrawal (especially after Reconstruction), integrated weather into practices of government.

From Military Signals to Weather Data?

After the Civil War, "signaling," meaning practices and techniques of coding, making, displaying and interpreting visual and related signals (chiefly for military communication), tied the fate of Army Signal Service to the possibility of instituting national weather services. At the conclusion of the Civil War, Chief Signal Officer Albert Myer, whose method of signaling had become standard for Union forces, published a revised *Manual of Signals*. Myer was professionally invested in maintaining the organizational existence of the Signal Service, which his superiors threatened to decommission. Given this uncertainty, Myer mobilized his ties to War Department officials and meteorologists to defend the significance to national government of a corps of men trained in standardized signaling techniques:

> The actions of the late war, in which victory or defeat has sometimes hung upon the transmission of a signaled message, have rendered it certain that military signals will be used in the future military and naval operations, of our arms. They will be employed in the continued Indian warfares in the Interior. (Myer 1866:v)

Myer feared the loss of training facilities, trained signalmen, and the network of signal officers and materials that upheld not only his career but also the very relevance of signaling to government.

The issues that Myers faced in the postbellum military bureaucracy arose in relation to a previously separate problem in the burgeoning shipping industry. With a dramatic increase in rail and Great Lakes shipping tonnage, individuals connected to industrial production and trade experienced weather in new ways—specifically, as risks to the circulations of capital and of agricultural and manufactured goods. Weather became a business matter. Astronomer (and later Weather Bureau chief) Cleveland Abbe and scientist Increase A. Lapham were actively seeking funding from corporate entities, including the Chicago Board of Trade and the Bureau of Lake Underwriters, to commence a storm-warning system for the hazardous Great Lakes shipping routes. To this end, Lapham published his treatise, "Disaster on the Lakes," and calculated that for 1868-1869 alone there had been losses of over $7 million, 530 people, and 231 ships.[1]

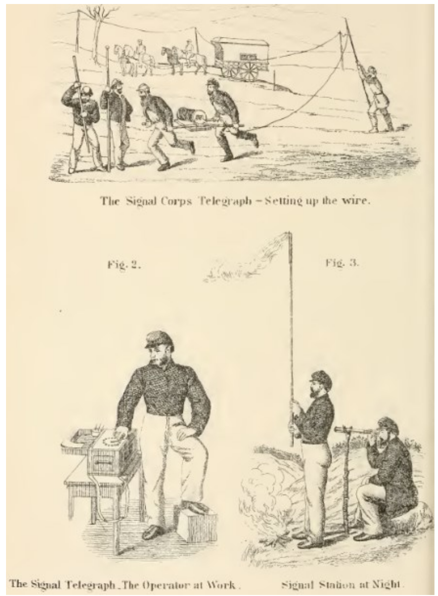


Figure 19. Albert Myer's 1866 Manual of Signals, Plate 28, depicting construction of a field-telegraph line and the process of signaling during the Civil War.

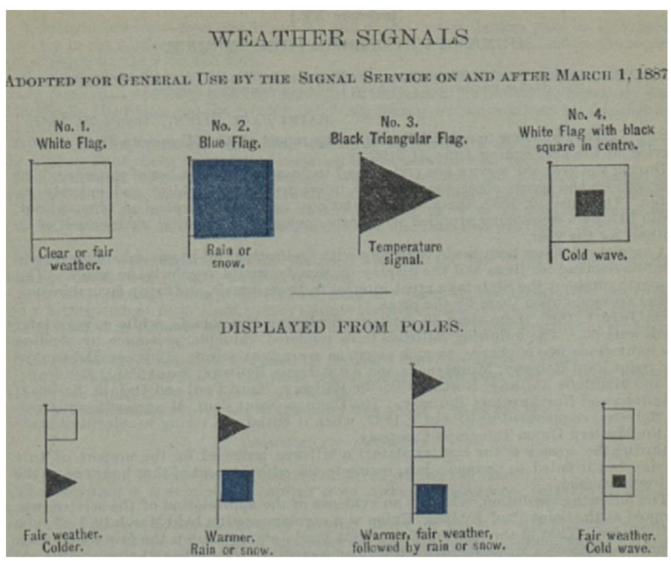


Figure 20. Signal Service "Weather Signals," resembling Myer's military signals and here promoted for use and display by railroad companies (Source: U.S. Signal Service 1887:99).

Albert Myer was able to link the problem of costly storms to the tools of military signaling (see Figures 19 and 20). He therefore successfully advanced the Signal Service as a relevant

[1] On Abbe's and Lapham's economic justifications for their efforts, see also Miller (1931), Craft (1999), and Fleming (1990).

government entity by addressing a problem that meteorologists sought to coalesce their profession around—namely, how storms form and move (Fleming 1990). In 1870, Congress authorized the Signal Service to function primarily as a weather service, initially on the Great Lakes and Atlantic Coast shipping routes, before extending such service to other areas and including regional forecasts relevant to specific crops and transport industries.

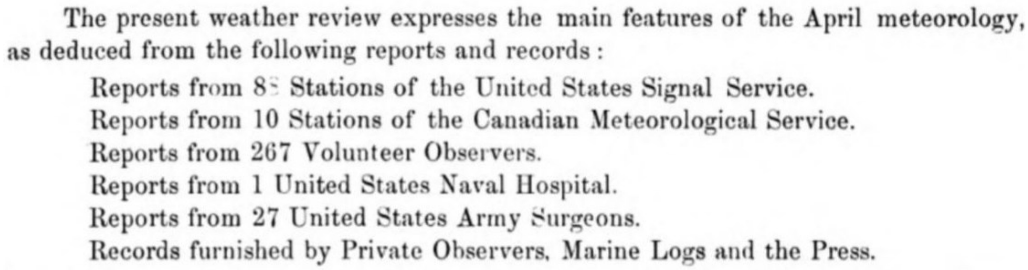
Economic historian Erik Craft (1999) argues that private corporations, shipping underwriters, and boards of trade were reticent, because of economic costs and benefits, to provide weather services for clients or the public. Yet producers, distributors, traders, investors, and meteorologists alike increasingly viewed weather as a fundamentally economic problem. Government investment in formal weather services, Craft (1998, 1999) also shows, resulted in dramatic increases in market efficiency, especially in the case of Great Lakes shipping and the financial facilitation of agricultural markets.

Bricolage Bureaucracy and the Rationalization of Action-at-a-distance

By the 1870s, meteorologists working for the Signal Service worked to establish a method for both collecting meteorological data and disseminating storm warnings they were now mandated to provide. To organize meteorological observation required that meteorologists mold the behavior of human observers and align physical infrastructure to their demands for standard meteorological data. In general terms, a fundamental struggle for those in government involves the mundane capacity to make orders across space and time. This is what Latour (1987) labels *action at a distance*. Such actions characterized Signal Service meteorologists' power over storms. To understand why this is so, let us consider the basic structure of weather observation, reporting, and forecasting.

In the early 1870s, the Signal Service began to utilize a diverse network of human observers who took instrument readings at established times and transmitted them, via telegraph, to the Signal Service Central Office in Washington, DC. There, signal officers and their staff interpreted the diverse weather reports and created the daily weather "synopsis and probabilities," later called the forecast. The forecast for the upcoming and following day could then be transmitted back through the telegraph network to diverse organizations, including especially local newspapers, regional boards of trade and exchange, railroads, and scientific, commercial, and farmers' organizations.

The difficulties in securing the data infrastructure that comprised the meteorological network in these terms were not solely technical. They also involved exercise of power over geographically dispersed human weather observers. Weather observation in the Signal Service and, later, the Weather Bureau, was a patchwork social process, forming something of a *bricolage bureaucracy*. Unlike an ideal-typical bureaucracy, the weather observers' assemblage consisted of diverse informants (as depicted in Figure 21) who often held divergent interests. For example, farmers were commonly "voluntary observers" (later classified "cooperative observers”); however, they were not always given to the systematic observation that Signal Service forecasters in Washington demanded.


The present weather review expresses the main features of the April meteorology, as deduced from the following reports and records:

Reports from 8[illegible] Stations of the United States Signal Service.
Reports from 10 Stations of the Canadian Meteorological Service.
Reports from 267 Volunteer Observers.
Reports from 1 United States Naval Hospital.
Reports from 27 United States Army Surgeons.
Records furnished by Private Observers, Marine Logs and the Press.

Figure 21. Description of observational record sources, as published in the Signal Service’s *Monthly Weather Review*, April 1876 Issue.

To shape observers’ behavior and link together the sprawl of weather observation, Signal Service agents strategically engaged local economic interests and existing organizations. For example, an early Signal Service (1872) manual, titled “Instructions to Observer Sergeants,” detailed how signal agents needed to first learn to construct effective instrument housing to assure “their protection from local influence.” After securing a recording station, each agent was ordered to, “as soon as practicable, put himself in communication with the board of trade, chamber of commerce, board of underwriters, and such other bodies as may desire to co-operate with this office in the efforts to make the service useful.” Forming “meteorological committees” within existing such organizations was to “be urged as a matter of special importance” for placing them in long-term, continual communication with the central Signal Office (U.S. Signal Service 1872:6). Subsequent records indicate vast success in such recruiting efforts, judged by the growing list of participating cooperative organizations listed as hosting weather stations in annual reports of the Chief Signal Officer. Yet the initial work in the field by signal agents was presumably tedious, especially because until the 1880s, the Signal Service lacked extensive educational resources that could standardize communication of meteorological knowledge and techniques.[2]

Even after Signal Service observers had been recruited, the bureaucratic structure and data-gathering strategies that Signal Service officers sought to implement faced challenges. How could a relatively weak organization control a nationwide network of people and instruments? On the one hand, national weather services were backed by a political ideology of civic democracy. “Cooperative” volunteers at times comprised over 90 percent of weather station personnel (Marvin 1896:556). Observers were therefore portrayed as “public-spirited persons [working] for the benefit of their communities” (Calvert 1931:iii). On the other hand, administrators needed to forge a delicate balance between such a vision of voluntary civic participation and a bureaucratic structure that could sustain expert rigor and social control.

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[2] On volunteers, see Marvin (1896) and U.S. Weather Bureau (1897); see *Monthly Weather Review* (USDA 1892:80-83) for a typical register of voluntary observers.

It is telling that meteorologists who initially sought to establish the official national weather service argued that the Department of War was the logical home for a storm-warning system. They made this argument in part based on the Department's existing capacity to facilitate telegraphic and manual (flags, etc.) signals across large geographic areas. Moreover, as the Congressional Resolution forming the weather service stated, "military discipline would probably secure the greatest promptness, regularity, and accuracy in the required observations" (reproduced in Raines 2011:43). This appeal to discipline had long marked a rationale that military organizations could best provide systematic weather observations, both in the United States and other countries (ARSO 1871:399; see Chapter 2), and it continued to be raised in the United States. In 1884, for example, a Signal Service historian (U.S. Signal Service 1884:3) argued, "An economic feature of the Weather Bureau is that it is a *military service*, and disciplined observations could not have been secured by a civil corps." Later retrospective accounts by meteorologists also attributed the evolution of weather services to "the application of discipline of military exactness" that coordinated observers, offices, and meteorological infrastructure "into an efficiently working machine" (U.S. Weather Bureau 1908:xvii).

For meteorologists to generate storm warnings and forecasts, the "machine" had to run continuously and efficiently. The meteorological order represented or mapped by the Weather Bureau was preceded by social order and secured by power relationships. To use Max Weber's (1978:957) terms, bureaucratic authority had to align roles and procedures in order to deliver "the files," in this case, the weather forecast. The Central Office in Washington was especially significant, for it operated as a national amalgamator of information, what Latour (1987) calls a "center of calculation." As one example, the 1883 "Regulations of Signal Officers," depicted strict attention to bureaucratic organization at the Central Office. Any communication "not necessary to the proper discharge [of] duties" was strictly prohibited. Office rules forbid the use of offices for visitors or "entertainment"; "unnecessary conversations," "private letters", and newspapers were "strictly prohibited" during office hours (U.S. Signal Service 1883). Thus, administrators at the Central Office created a space of formal discipline, which through its minute level of social control powered the larger "machine" of weather observation.

How the Signal Service Central Office spatially organized its national offices demonstrates a similar attention to order as a prerequisite to producing successful storm warnings and forecasts. By 1880, 110 enlisted signal service members staffed twelve units, or "rooms" of the Central Office in Washington, DC (Raines 2011:54). These rooms included one for correspondence and records; a telegraph room; a property room; a printing and lithographing room; a room devoted to the International Bulletin; an instrument room; a map room; an artisan's room; a station room; a fact room; a study room; and a central library (U.S. Signal Service 1878:429). Through the rationalization of space, the Central Office organized the action-at-a-distance that held the data infrastructure together. The Central Office alone could synchronize the work of the observers and forecast distributors. And the Central Office could calibrate instruments upon which all others were tested and measured. Only because of such coordination could meteorologists act faster than storms and warn people of anticipated weather.

Peripheral Visions: Making Official Weather

From the Central Office to local sites of weather observation and reporting, governmental order faced challenges about making representations of weather *official*, that is, flowing from an exclusive and impersonal authority. Although instruments could be standardized,[3] and the spatial organization of offices and equipment could be arranged to facilitate telegraphic communication, human observers, like the weather they were observing, still did not always behave as expected. One range of problems stemmed from observers' consistent temptation to forecast or predict the weather. Reflecting this concern, the 1872 "Instructions to Observer Sergeants on Duty at Stations" emphasized that "*observers must confine themselves strictly to the instructions issued from [the Central] office, and will not, under any circumstances, publish, or cause to be published, forecasts or predictions of the weather*" (p. 12). Creating one's own forecasts was not authorized: doing so would amount to a deliberate circumvention of the meteorological data infrastructure.

Meteorologists had an especially difficult time securing order at the peripheries of the observational network. As one example, in the 1873 Annual Report of the Chief Signal Officer, a field officer first reported possibly faulty results of river-gauge measurements, then raised the issue of a signal station in Cairo, Illinois, where the Ohio and Mississippi rivers converge, stating:

> The station has not been inspected since the date of last report. Sergt. Thomas L. Watson was relieved February 18, 1873, for neglect of duty, and was succeeded by Sergt. David Harnett, who left the station without authority, and was reduced [in] the ranks while absent. He was subsequently apprehended, tried, and found guilty of desertion, and is now serving out his sentence for that crime. Sergt. E. Garland was ordered to succeed him, and is now at the station. His reports are not promptly rendered, and it is intended to relieve him unless a change for the better is made (U.S. Signal Service 1873).

Capacity to control even the most "disciplined" state agents also proved difficult. Indeed, physical examination at the Signal Service training program, at Fort Myer, in Washington, D.C., included identifying physical characteristics of staff, evidenced by meteorologist Henry Cox's (1884) recollection of enrolling in the Signal Service: "I found this precaution was taken so that I could be more readily identified should I desert from the Corps." Lack of promotional

[3] Further research is needed in this case of what Bruno Latour labels *metrology*, the process by which standards allow scientists to "build their enlightened networks by giving the outside the same paper form as that of their instruments inside" (Latour 1987:251). The astounding array of instrument types in circulation among observers made the relationship of variously situated humans and instruments difficult to negotiate, much less coordinate. More specifically, from the 1870s onward, technological innovation in self-recording instrumentation involved complex relationships between inventors, patent-owning companies, human volunteer and salaried labor, and Weather Bureau officials in correspondence with the local and international meteorological data infrastructures. Instrumentation, especially the introduction of self-recording devices, has yet to be studied in this social context.

opportunities within the Signal Corps only made efforts to sustain a stable corps more difficult (Raines 2011).

Unreliability and limitations of human observation and labor also led to a rather steady replacement by self-recording instruments—making meteorological "observation" into what Carroll (2006) labels an "engine science" that could partially protect the data infrastructure from the limits and whims of human observers (see Figures 22 and 23).

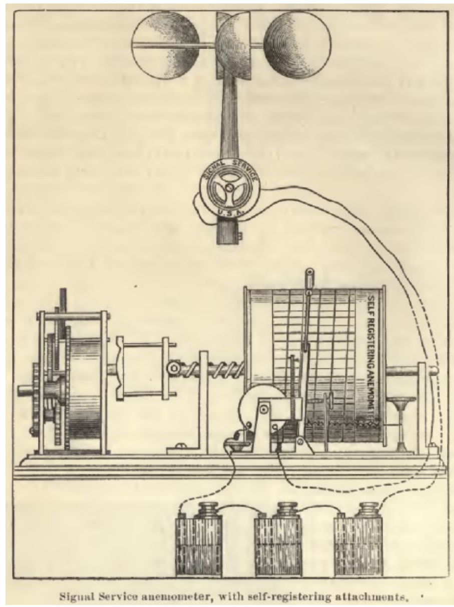

Figure 22. A anemometer with self-recording features (Source: U.S. Signal Service 1884:16).

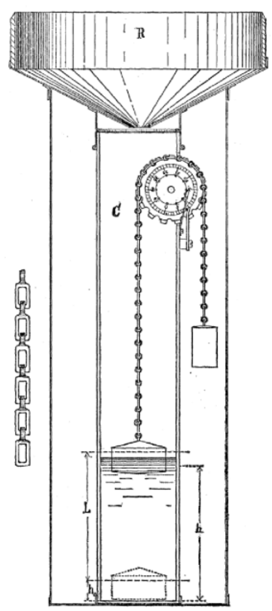

Figure 23. A "Self-Recording Rain-Gauge", which was attached to the "Signal Service standard gauge" already in use at stations. Source: Marvin (1888:98).

Meteorologists and associated actors faced challenges in designing and manufacturing self-recording instruments, followed by difficulties with inspecting and maintaining them to ensure valid results. Because of these ongoing problems, coupled with the limitations of human observers, the Weather Bureau purchased and implemented automated meteorological instruments almost as soon as they were invented.[4] However, humans remained critical to weather recording, and Bureau officials relied upon governmental and scientific authority to ensure compliance with established guidelines. This was especially significant in cases without formal enforcement mechanisms, notably, among volunteer observers. Thus, Bureau Chief Willis Moore (1903:3) implored observers not to transmit recordings beyond "plain facts" nor to falsify instrument recordings, reasoning that "attempt[s] to fill in missing records in a manner to make them appear as automatic and original, is liable to defeat the aim of scientific observation."

If one aspect of technopolitics involved the stable, regular transmission of meteorological data, another took shape at the limits of state authority and meteorological knowledge in the Far West. Recall that meteorologists in prior generations had connected their concerns regarding climate change and disease to the governmental problem of expanding state territoriality. At the close of the nineteenth century, the socio-technical network of signal officers and telegraphs similarly linked problems of meteorological observation to the governmental legibility of frontier society. Indeed, their observations were not simply meteorological: those tasked with meteorological observation also provided domestic surveillance and social-control measures, linking the meteorological network to a range of threats to socio-economic order. Fleming (2000b) describes how weather observers were charged with reporting to Washington on the status of railroad strikes and military confrontations with native tribes.

The telegraphic lines themselves could become a site of political contention and technopolitics, especially for Native Americans seeking to counter U.S. facilitation of white settlement and appropriation of land from native people. As the Annual Report of the Secretary of War in 1887 (U.S. Signal Service 1887:143) stated about Indian warfare and protection of settlers in the Southwest: "There can be no constructions more important for holding a frontier or protecting the first steps of advancing civilization than the telegraphic lines." The reporter outlined military tactics to protect war parties, military-signal posts, and commercial outposts from Native American attack. Often, as the report states and Raines (2011) identifies more broadly, Native Americans strategically cut telegraph lines. For U.S. officials, the problem could be circumvented through circuitous networking of telegraphic lines and mindful positioning of new lines and military divisions, as well as a capacity to deploy manual (non-electric) signaling in cases of telegraphic network interruption or failure. Therefore, the 1887 reporter (ARSO 1887:143-144) expressed the fundamental links between the "connection of military posts," the "incidental protections the stations [provide] frontier villages" to advance commercial interests,

[4] For examples of difficulties with self-recording instrumentation, see Annual Report of the Chief Signal Officer (1890:655): "Appendix 18: Report of Assistant Professor in Charge of the Instrument Division." See also Frank (1901) and U.S. Signal Service (1884:29-33). On the broader context of early computing technology, including that used to reduce climatological data after the 1880s, see Ager (2003) and Nebeker (1995).

and “the meteorological information” also tasked to the Service. One Signal Service report declared, “As an engine of civilization, the frontier telegraph rivals the railway, enabling the Government to throw an aegis of protection over the rapidly expanding wave of western emigration,” which the reporter argued was “facilitating, no doubt, the sale and settlement, as well as the material development of the public lands.” (U.S. Signal Service 1884:24-25). In broad terms, then, meteorologists worked to make “official” weather by calling into being a technopolitics of infrastructure, comprised chiefly by an array of human and non-humans variously aligned with the goals of meteorologists and allied state actors.

As in other periods and circumstances, efforts to establish meteorological order were co-produced with a specific kind of social order—a capitalist one. Following power relationships and social order along the telegraphic infrastructure is therefore instructive for understanding the general process of meteorological government. However, the material stability of the infrastructure was but one dimension of the larger process of rationalizing commercial activity through weather and climate knowledge. Meteorologists' efforts to stabilize space and time also encountered challenges but were equally important to a rationalized view of weather.

Stabilizing Time and Space

Until the mid-1880s, the United States had not yet achieved “standard time.” Time, for the purpose or record-keeping, scientific activity, or social coordination had previously been established by local observatories and later developed around the demands of “railroad time,” itself initially a company-specific patchwork of “times” (Bartky 2000; Zerubavel 1982). This situation presented a serious problem for meteorologists, whose capacity to organize action-at-a-distance relied upon temporally standardized measurement across space and time-sensitive data transmission. Without the coordination of time across space that would make weather legible, the network would fail in its purposes. Only through reimagining time in relationship to weather could observations make a national view of weather patterns and, by extension, of the temporally “fixed” dimension of climate.

The problem of standardizing meteorological observations across the United States was an immense challenge. Professor Maury[5] (1880), writing in *Popular Science Monthly*, captured the difficulty involved for meteorologists. He reported that “painstaking and indefatigable observers” were being “systematically vitiated” because of inconsistent observation methods and “the more fatal lack of uniformity in the hours of observation.” Maury compared the “synchronous” method, dominant in prior decades, through which each observer reported weather conditions at “his own *local* time,” to the “simultaneous” recording practices structured by what Maury (1880:291-292) termed “actual time.” Maury (p. 292) personified the problem of

[5] T. B. Maury (not to be confused with Matthew Maury addressed previously), was. according to Cleveland Abbe. a meteorologist employed by the Signal Service as a civilian professor to train the Service's corps of weather officers (see: www.history.noaa.gov/stories_tales/signal_abbe.html)

“local” versus “actual” time with reference to the maps that meteorologists produced to represent storms: “A weather-map based on such non-simultaneous reports, instead of faithfully mirroring the sky overhanging a continent, necessarily gives it rather a *wry* face.” Despite this challenge, Maury argued, synoptic visions of the globe were coming into view in a novel way, bringing forth “clarified conceptions of its massive yet orderly machinery,” what Maury discussed metaphorically as a “great steam apparatus” that must be “viewed as a whole,” for “its operations be clearly understood” (p. 305, 310). Time, as Maury and colleagues argued, had to be torn from its local and experiential contexts and reconfigured objectively with respect to nature’s “machinery.” But how could meteorologists accomplish such a feat?

One challenge for achieving standardized time was how to shape public attitudes to better align with the sort of diachronic time that organized meteorologists’ worldview. The progressive issue was to “to effect a complete reform in the popular mind as to the desirability and possibility of greater uniformity and accuracy, and especially to do away with the old conservative ideas as to the need of a local time” (Abbe 1893:38). To rectify this issue at a formal level, Abbe participated in the General Time Convention of Railroad Officials in 1883, which aimed to employ the Mean Time of London’s Greenwich Observatory to standardize time across railroads in the United States. The effort was successful, yet as Abbe (1893:39) recollected: “it was still necessary to induce towns, cities, states, and people to give up the old local and adopt the new standard times,” a task that meteorological and time-standard committees advanced primarily by mobilizing the popular press to “prepare the public for the change that was to come” (p. 39). The problem of aligning weather observation and related practices through a novel system of time was not a specifically American problem, meaning that U.S. meteorologists also had to contend with an array of international systems of time.

Meteorologists pursued time standardization projects at the international scale on the basis that understanding national weather would require knowledge of the atmosphere outside state-territorial borders. Albert Meyer had urged Congress, as early as 1872, to help facilitate “a grand chain of interchanged international reports, destined with a higher civilization to bind together the signal service of the world” (quoted in U.S. Signal Service 1884:19). As he reasoned, “the atmosphere is a unit, and to be understood must be studied as a unit…we must extend our investigation far beyond our territorial limits,” a view already partly materialized by 1875 in the *Bulletin of International Simultaneous Meteorological Observations*. The “unit” was, in practice, the territorial limits of Euro/American empires and territories, or, those parts of the Northern Hemisphere “so far as they have been placed under meteorological surveillance,” to use the words of one meteorologist (U.S. Signal Service 1884:19). In 1884, Cleveland Abbe represented the U.S. Signal Service at the International Meridian Conference in Washington, arguing that establishing standard time was critical to coordinating international meteorological activities. At the global scale, meteorology depended especially on colonial networks that held not only common interests in standardizing time, but also the infrastructural capacity to coordinate geographically disparate events, instruments, observers, and international standards.

Beyond shaping public opinion and aligning international data networks, a further challenge was how to ensure that technologies and people upheld the standardized time once it was formally established. In 1893, Abbe recollected his often-frustrated previous efforts to standardize time across the Signal Service. He (p. 38) referenced “the great annoyance caused by the uncertainties in the local standard of time used by our voluntary observers.” Despite clear directions posted on Signal Service documents, Abbe claimed, observers had not yet internalized a national standard time. The task of making time standard was likewise frustrated by difficulties in maintaining standardized instruments. Officers frequently monitored, tested and reconfigured instruments and recording practices throughout the entire Signal Service network, “the object being to assure ourselves that all regular stations throughout the country were employing a uniform standard, accurate to the nearest second” (Abbe 1893:38). To aid this effort, a kind of laboratory was set up at the Central Office to calibrate time across the network. The American Watch Company produced a contracted clock, kept “in a hermetically sealed brass case in order to obviate the influence of changing atmospheric pressure and any possible magnetic influence on the steel pendulum.” For additional protection from influence of “outside” weather, Abbe recalled, “A pier was specially prepared in the subbasement of the War Department in a room whose temperature variations were slight and were partly annulled by a self-controlling heating arrangement” (Abbe 1893:39; see also ARSO 1885:38-39). Only by these inventive means could meteorologists stabilize a “standard” time.

Once it was successful, synchronizing time provided opportunities for climatologists to revise existing accounts of climate and reconstitute diverse geographically local descriptions into a more uniform, national one. Alexander McAdie, for example, reduced and statistically interpolated local meteorological records for the period from 1877 to 1889 (McAdie 1891). He reported “corrections” for “time and locality” into his “Tables of Corrections to Hourly Temperature Readings to Reduce to True Mean Temperature” (McAdie 1891:x). Thus, McAdie effectively had to reconstruct national time in order to hold time constant, resulting in a new national model of climatic space. Such was the kind of work necessary to achieve “actual” time with respect to weather and climate.

Thus, meteorologists’ success in stabilizing the times of weather and the spaces of climate, from local to the global scales, depended on the powers that could coordinate the world based on one or another standard “unit.” Locher (2009) outlines a roughly parallel process in the case of French and international European storm warnings, which, like in the United States, had begun in the early 1870s. It became possible to speak about “the weather of France,” Locher shows, when it was represented on storm maps and reproduced though routine storm warnings. The technopolitics of meteorological knowledge thus gave way to a new view of the weather. In particular, “the weather” took the form of an extra-local, especially national, form of knowledge.

Like infrastructure and time, expertise regarding the nation’s weather proved difficult to centralize. Meteorologists eventually succeeded in providing a rationalized view of weather that could help govern the exigencies of weather risk so important to capitalist society. They did so in relation to consumers of weather information.

Monopolizing Meteorological Consumers and Publics

A prerequisite for the use of predictive knowledge is trust and authority in whomever can legitimately speak for anticipated weather. Authority is often won through struggle. Just such a struggle unfolded within the domain of weather prediction. Translating official predictive information into its public use was a long and arduous process, not an automatic one. To monopolize the authority to report and predict weather, government meteorologists had to invest significant resources into shaping how various public users consumed weather information. They also had to contend with alternative forms of predictive authority, namely popular weather forecasters (also called weather prophets) and folk weather knowledge.

Beginning in 1872, the Weather Bureau had provided "synopses and probabilities" regarding anticipated weather. At that time, official predictive statements began by offering a "synopsis" of recent and current weather in various locations, to which meteorologists attached the "probabilities," or forecasted weather, for the upcoming day or two. In official registers, the probabilities were later followed up with "facts," that could compare observed weather to the previously posted "probabilities" and hence verify their accuracy. In the 1870s and 1880s, meteorologists did not regularly call these activities "weather prediction" or "weather forecasting." However, the "official" meteorology of the Weather Bureau clearly penetrated many facets of social and economic life.

A report to the Chief Signal Officer from Robert B. Fulton, Director of the Mississippi Weather Service (ARSO 1889:109), provides an initial example of state success in forming a public around climate: "The study of the climatology of the State by this service has been appreciated by the public, and the results worked out have been freely used by public speakers and the press in setting forth the agricultural and other advantages of this State." Fulton argued such services permitted market specialization in Mississippi industry. Cold-wave warnings successfully tailored to the decision-making of farmers helped them to protect early-season fruits and vegetables and advance regional capacity for supplying seasonal products to Northern markets. Insofar as "the public is being educated to appreciate and understand the [Signal Service] aims and its methods," Fulton (ibid.) reportedly witnessed growth in routine public understanding of meteorology as a government service.

At the national level, the meteorologist and director of the Weather Bureau's Climatological Division Frank Bigelow (1899:7) claimed, a "system of mutual support" provided the "greatest value in establishing the weather service firmly among the necessary adjuncts of our modern life." He cited how agricultural societies, boards of trade and industries across the country successfully performed "missionary efforts in their respective communities" and "instruct[ed] them in the utility of the national service" in order to "interest the people in meteorology" (ibid.). Widening print media publication of daily Weather Bureau "probabilities" meant that a wider public, not only consumers of specialized warnings and crop-related "precautions," became consumers of weather information produced through Weather Bureau meteorology. At the subnational level, State Weather Services held as their mission "to educate people up to an appreciation of [the Service's] importance," and hence to "lead them on to become their own weather prophets," assisted by official predictions "sent on ahead of the storm" (Glidden 1895:4). Meteorologists who facilitated public anticipations of official forecasts thus advanced a general understanding of climate and weather that could be internalized in public culture roughly consonant with Weather Bureau discourse.

Although weather prediction remained partly decentralized through state-level Weather Services on the one hand, and international meteorological ambitions on the other, "national weather" at this time emerged as an object of observation, professional science, and public consciousness. By the 1880s, the Signal Office had organized formal meteorological education for officers, complete with standard curriculum and certification exams. Textbooks, primers, and popular scientific coverage of meteorology also covered and reflected the work of the Weather Bureau. According to the report of Bureau meteorologist Frank Bigelow (1899:83), "meteorology is extending rapidly throughout the common schools of the country as a required branch of instruction for every child." As he explained, "these changes have certainly resulted from the persistent propaganda of publications emanating from the Weather Bureau during the past thirty years." Bigelow (1899:84) argued that the provision of daily forecasts had created "obedience of navigators to the storm warnings," a "growing dependence of the railroads" on cold-wave warnings that threatened perishable goods. Routine forecasts, he continued, caused "gradual improvement" in the "great agriculturalist's care" to heed the frost warnings and embrace information on safe crop zones delineated by "normal or abnormal temperatures and rainfall."

Having assessed the widening use of meteorological science in public life, the meteorologist and textbook writer Douglas Archibald presented in 1897 an increasingly common narrative situating the field. The study of the atmosphere, he argued:

> "Is even now only just emerging from the stage of myth and speculation into that of fact and certainty. This desirable result has been chiefly attained by the disuse of vague speculation and the application of the known laws of physics. (Archibald 1897:5)

Archibald articulated a broad, positivist view of a transformation in meteorology from a form of knowledge based on myth and speculation to one rooted in the practical application of scientific laws. Notwithstanding such positive assessments and widespread public support for the national weather service, around the turn of the twentieth century, Weather Bureau meteorologists held unstable and contested jurisdiction over predictive weather knowledge.

The prospect of long-range weather forecasting was especially contentious because it required making predictive statements about weather that, to no small degree, could be incorrect. Only in 1908 did the Bureau officially begin issuing "weekly outlooks," at first experimentally and then in 1910 in a standard form of general "forecasts" (still primarily oriented to agricultural interests). As Anderson (1999) shows for Victorian-era forecasting broadly and Pietruska (2011) demonstrates for the Weather Bureau specifically, official meteorologists had to contend with competing cultural authorities, most prominently popular forecasters who rejected claims that

Bureau-centered knowledge was the only kind of forecasting useful to farmers, merchants, and the wider public.

The historic legacy of weather prophets who had rejected "official" meteorology loomed over the prospects of long-range weather forecasting. Henry Vennor, for example, had become famous in the late 1870s for successful storm predictions using non-standard methods, and he used this credibility to publish widely read almanacs and newspaper weather predictions (see, e.g., Vennor 1877). Vennor and many others like him both exploited and helped to unsettle the epistemic authority of the Weather Bureau, the officials of which remained circumspect of long-range forecasting techniques and outright despised public interest in popular prophets (Somerville 1979; Pietruska 2011).

Almanac writers, like Bureau officials, benefited from the capacity to easily circulate print media and to sell and publish monthly and seasonal forecasts (Sagendorph 1970). Like government bureaus, Vennor and later almanac writers maintained networks of correspondents and observers who formed the basis of forecasts and could allegedly verify successful seasonal predictions. These writers built expertise by developing proprietary or specialized techniques that could be mastered by the individual forecaster or that required insights into a specific geographic region. Almanacs, compared to government services, moreover, often readily drew upon folk weather lore and knowledge that resonated with subscribers. Non-Bureau weather prophets also successfully drew upon controversial (yet hardly rejected) scientific knowledge, including for example the effect of variable solar radiation on weather (e.g. sunspots; see Garriott 1903:30-34). Popular forecasters creatively synthesized science, folklore, and regional knowledge that often made it difficult for Bureau officials to demarcate their own scientific research from Moore (1904:3) derided as "pseudoscience."[6] Prediction was still labeled prophecy, and prophetic authority was anathema to meteorologists and state officials invested in rational-bureaucratic approaches to weather. Thus, the ideal-typical instability of charisma (Weber 1978:1114) could be resolved by forecasters appeals to science, correspondence networks, and other tools akin to those of formal government bureaus.

As one rejoinder to the problem of popular forecasting, Weather Bureau meteorologist Edward Garriott published a government Bulletin titled "Weather Folklore and Weather Signs" in an attempt to inform public audiences of the relative accuracy or danger of common or lay weather knowledge (Garriott 1903). He compiled hundreds of ancient proverbs and common sayings from around the country and measured their value. Using the language of science, he thus drew boundaries between valid facts and what he deemed useless "folklore." Meteorologists recognized that science could not abolish folk knowledge, including for example popular beliefs of lunar influence on terrestrial weather. Instead, Garriott reasoned that only by engaging folk knowledge could meteorologists overcome the problematic fact that "today, fakirs and charlatans

[6] Such boundary-making had long marked meteorology as a scientific enterprise, as indicated by what I analyzed as the formation of "rational accounts" of weather and climate in the eighteenth century. Espy (1841:vi) defended his meteorological work as holding the capacity to "penetrate mysteries heretofore thought inscrutable." Penetration of deductive philosophy, Espy claimed, would entail a "true system of meteorology" that "will be the death of superstition on this subject" (p. vii).

in the various professional and scientific fields, astrologers, fortune tellers, and long-range weather forecasters command, in civilized communities, a lucrative following" (Garriott 1903:29). The Bureau thus publicly put traditional knowledge to the test, hoping that under evaluation, folk beliefs could conform with scientific accounts of weather. This outcome could then bolster the position of the Bureau over its competitors, namely popular forecasters.

Furthermore, Bureau bulletins and reports issued routine warnings to the public against alternative forecasts. For example, New Jersey Section Director Edward McGann opened the January 1905 report of the Bureau's Crop and Climate Service with an article titled "Unreliable weather forecasters." He stated, "About this time of the year farmers are wont to receive almanacs from various sources and in them find forecasts the weather of each month of the year. Dire are some of [the] predictions." To such "fraud" he responded:

> It is the opinion of the leading meteorologists of the world that the public interests are injured by the publication of so called long range forecasts…The persistent efforts of certain men to foist their predictions upon the public for personal gain have reached such proportions that it is deemed advisable fairly and temperately to counteract the influence of those who it is believed are preying upon the credulity of the public.[7]

Pietruska (2011) shows how the Weather Bureau's reluctance to embrace official long-range forecasting efforts stemmed from officials desire to strongly separate predictive science from superstitious or self-serving prophesies. The "rambling" of "fake" forecasters and rainmakers, as Weather Bureau officials had labeled them (Garriott 1904; Moore 1905), persisted as a problem in the early twentieth century, because local oracles stood ready to trumpet their own expertise over the sometimes-inaccurate official forecasts and over the longstanding reticence at the Bureau to generate forecasts under conditions of uncertainty.

The epistemological battle around prediction, as an effort to stabilize official visions of the weather, can be compared to how the Signal Service had treated local weather knowledge just two decades prior. For example, in 1883, Signal officer Henry Dunwoody edited a large volume, titled *Weather Proverbs*. In tone and manner perhaps of his contemporaries' ethnological writings, Dunwoody and contributing authors described qualitative "popular weather prognostics" (Dunwoody 1883:9) that, they held, may have assisted Bureau efforts in the face of failure at prediction beyond a one- or two-day timeframe. Dunwoody especially drew upon scientific reasoning to assess popular plant- and animal-based behaviors as signs of upcoming weather. He worked to reinterpret these methods in the language of science. As an examination of Dunwoody's work reveals, the Signal Service understanding of popular

[7] Ironically, the article, which also appeared in *The Farmers Journal*, was heavily plagiarized by F.J. Walz, who wrote a 1905 article "Fake Weather Forecasts," in *Popular Science Monthly*. Walz, a Weather Bureau District Forecaster based in Louisville, Kentucky, sought to persuasively relinquish false "weather prophets," making direct appeals to public media: "Will not the newspapers, the great enlighteners and disseminators of truth and knowledge in the present age, help these investigators by discouraging and discountenancing the publication of weather predictions founded upon such baseless theories[?]" (Walz 1905:503, 513).

prognostication relied upon circulars that officers had distributed, imploring citizens to share predictive weather knowledge in their local contexts. Dunwoody then reported their results to enhance Weather Bureau forecasting efforts, concluding:

> Many of these sayings express in a crude form the meteorological conditions likely to follow, and have resulted from, the close observation on the part of those whose interests compelled them to be alert in the study of all signs which might enable them to determine approaching weather changes. (Dunwoody 1883:5)

Dunwoody's strategy was to deploy the power of the Bureau to integrate local "weather prognostics" that Bureau officials believed to be available throughout society. This strategy compares sharply to meteorologists' actions in the early twentieth century, when the relationship of government to local "fake" knowledge shifted through efforts to stabilize the monopoly of Weather Bureau over official representations of weather.

How did the Weather Bureau succeed in providing credible, long-range predictive knowledge? Only by rationalizing uncertainty, through the introduction of forecasts and delicately qualifying their predictive capacity with appeals to science, did weather forecasters eventually succeed in facilitating weather prediction beyond a one- or two-day period (Pietruska 2017). Under the direction of Bureau Chief Willis L. Moore, the Weather Bureau began issuing official long-term forecasts in 1908. Public understanding of weather forecasting as a legitimate effect of scientific advances helped meteorologists secure their role as the official spokespersons for future weather. Although the Bureau's authority over prediction remained open to criticism, by the time Willis Milham published his 1912 textbook entitled *Meteorology*, the age of "speculation," he optimistically argued, was finally ending (Milham 1912:3). Even though popular forecasters and public users continued to criticize meteorology as a profession, the Weather Bureau had garnered authority to police meteorological knowledge. For example, one federal statute, approved by Congress in 1909, made "counterfeiting weather forecasts" punishable by $500 fine and/or ninety-day imprisonment. Through legal and other strategies, meteorologists and the Weather Bureau enacted a professional closure on meteorology as a predictive science and a domain of official weather services.

Beyond eschewing the work of alternative weather prediction and securing a monopoly on long-range forecasting, the Weather Bureau intervened directly into public consumption of weather informationduring the first decade of the twentieth century. For example, in the March 1909 issue of the *Monthly Weather Review*, T.C. Maring discussed a bid for an "aesthetic" but "accurate" model "weather kiosk" (see Figure 24; see also Marvin 1909b, 1914).

Figure 24. A Weather Bureau Kiosk in Washington, DC, providing a public display of real-time instrument recordings (Source: MWR 1909:90).

Figure 25. A "Weather Bureau Exhibit at Panama-America Exhibition," showcasing meteorological instruments in San Francisco, February 1915 (Source: Alter 1915:453).

The kiosk was designed to facilitate public understanding of what Maring (1909:90) called "street weather" and to make visible the otherwise hidden mechanisms of weather-recording instrumentation. Other displays and demonstrations of Weather Bureau practices, for example at publicly attended international exhibitions (e.g., see Figure 25), complemented routine services and provided meteorologists with an opportunity to establish Weather Bureau expertise.

Although the success of "official" weather was not totalizing in its scope, the subsequent effects of meteorologists' rationalization of weather were far-reaching. For one example, in 1915, T. Morris Longstreth wrote a lengthy weather forecasting guide for a popular audience, called *Reading the Weather*. On the one hand, Longsreth grounded practical predictive techniques in science. He opened with a reflection on meteorologists' success in having "overwhelm[ed] the old, buttressed superstitions," specifically whereupon "at last Science established some sort of Weather Bureau in 1870" (Longstreth 1915:i, iii). On the other hand, the author took for granted that the daily life of his intended audience was often neither impacted nor guided by official weather forecasts emanating from the Weather Bureau. Thus, Longstreth reasoned, popular knowledge was called for and was plausibly endangered by the "quickening hand" of science (p. i). Science and non-science, for Longstreth and a larger public, did not need the boundary lines that Weather Bureau officials had constructed. Questioning the sole legitimacy of official weather forecasting, Longsreth compared the "anticyclone" of the "weather man" to common observations, and he noted that long-held beliefs about the behavior of pigs before a storm show that "the barnyard antedates the barometers as forecasters" (Longstreth 1915:20, 25). Although science and lay knowledge, for Longstreth, both testified to "our well-ordered atmosphere," his writings demonstrate that the tools of forecasting were not in the exclusive domain of official forecasters, opening the door to Longstreth's goal of cultivating a popular (but specifically masculine) "weather-wise" disposition: "An unconscious desire, a little conscious knowledge, and a good deal of experimentation with the cycle of the days, and you have a weatherman" (p. 64). Popular culture and official forecasting persisted as alternative, although compatible, bases for predictive weather knowledge. The advent of official forecasting did not absolutely monopolize nor rationalize weather knowledge, although popular knowledge had come to reflect the basic principles of a rationalized meteorological order.

Normalizing Weather

As we have seen, the Weather Bureau network—comprised of observers, telegraphy, instruments, and Central Office in Washington—provided meteorologists with opportunities to gain a novel official power to represent, map, and predict atmospheric patterns. Developing this power entailed integrating a bricolage bureaucracy and data infrastructure into weather reports and forecasts and monopolizing authority to create and interpret weather and climate information. The expanding, standardized meteorological network served to make legible, in standard units, not only weather phenomena but also time, space, and those social actors connected to the data infrastructure. As an effect of this network, meteorologists established official weather knowledge through their ability to link their authority to agricultural, transport, and other commercial interests, and by developing the technopolitics that could support them.

How does this historical instantiation of meteorological government relate to the dynamics of climate knowledge? Recall that the fundamental stability of climate was, by the 1870s, largely taken as given among scientists, thanks to the "positive climatology" heralded by Lorin Blodget and others in the previous two decades. In addition to observation-based storm warnings, weather prediction based on statistics and probabilities relied upon an assumed, stable climate. Thus, when climatologist Elias Loomis (1868) wrote in his widely circulated and frequently updated *Treatise on Meteorology* that weather prediction was "impossible," he qualified his judgment: "The climate of a country remains permanently the same from age to age…Assuming, then, the established constancy of climate, we can predict beforehand the probable character of any month of the year," however imperfectly (Loomis 1868:157, 158). If climate was considered to change, then the idea of weather prediction based upon synopses of historical climate records would crumble. But knowing future weather was simply too important, and rational anticipation of tomorrow's events was fast becoming the central occupation of the meteorological profession.

Meteorologists' successful *normalization* of weather thus represents the critical link between, on the one hand, the goal to make official weather, and on the other hand, the stabilization of climate. Establishing the binary—normality/abnormality—of climate and weather was a necessary step toward rendering climate a stable background. But actors' focus on weather as normal or abnormal was less embedded in debates about climate reality. Rather, it was concerned with how anticipating future weather could facilitate the rationalization of market-economic activity. Official weather and climate discourse were thus primarily oriented towards economic consideration of what was "normal" and "abnormal." Examples, drawn from the primary, widely distributed professional publication of the Weather Bureau, the *Monthly Weather Review* (henceforth *MWR*) from 1870 to 1920 reflects meteorologists' and their consumers' understanding of capricious (abnormal) weather set against (normal) climatic spaces.

Typical *MWR* and other Weather Bureau reports tabulated recent weather events on a vertical axis of geographical areas and a horizontal axis of weather parameters represented by "departures from normal." Reports, most typically in monthly timescales, designated such departures numerically in terms of "excess" and "deficiency," quantified as either absolute values or proportions (see Figure 26).

***Weather conditions of wheat, cotton, corn, and tobacco districts, etc.*—Continued.**

Districts and stations.	Departure from normal temperature and rain-fall.							
	For past seven days.				From January 1 to September 22—266 days.			
	Mean temperature.		Rain-fall.		Mean temperature.		Rain-fall.	
	Excess.	Deficiency.	Excess.	Deficiency.	Excess.	Deficiency.	Excess.	Deficiency.
Lake Region—Continued.	°*F.*	°*F.*	*Inches*	*Inches*	°*F.*	°*F.*	*Inches*	*Inches*
Detroit, Mich	......	18	......	.19	......	793	......	3.09
Port Huron, Mich	......	18	.05	......	......	524	......	7.47
Alpena, Mich	2	......	.37	......	......	516	......	5.37
Marquette, Mich	......	15	1.18	......	......	1380	1.43	......
Grand Haven, Mich	......	29	.99	......	......	1081	......	8.74
Milwaukee, Wis	......	24	......	.12	......	893	......	7.22
Chicago, Ill	......	30	.04	......	......	789	......	4.61
Duluth, Minn	1	......	......	.64	......	1298	......	1.41

Figure 26. Excerpt from the *Monthly Weather Review*, April 1889 (p. 142). Note columns identifying "excess" and "deficiency" of normalized values.

Pervasive discourse that organized routine *Monthly Weather Review* reports adhered to differentiating a "normal" value against any "abnormal distribution." For example, the April issue of 1877 (p. 4) provided an introduction to the month's weather across the United States, stating: "It is a most remarkable fact, as numerically shown, that, in every district of the United States east of the Rocky Mountains, the April temperature has been extraordinary low…. The only exception this abnormal distribution of temperature is on the Pacific coast." Appeals to abnormal and normal weather permeate interpretations of even records with comparatively short time series, especially over Western states and "new" territories. In August 1878, for example, one observer reported:

> A comparison with the averages for August, during the past seven years, shows that the temperatures have been from one to two degrees above normal throughout the Gulf and Atlantic States…but have been about normal in the Ohio, Mississippi, and Missouri valleys. On the Pacific coast, the monthly mean…is six degrees below average: at San Francisco it is about normal, and at Portland, two degrees above.

As another example, the Weather Bureau (1896:555) provided a tabular summary of relative humidity, for which "Normals are for a period of eight years, except for Los Angeles and Wichita, which are for seven years."

Granted, some reports may have been works-in-progress, especially in the last case, given that relative humidity was a newly systematized measure. Nevertheless, these evaluations demonstrate the central discourse by which meteorologists generally represented weather by reference to "deficiencies" and "excesses" of "normal" values, even in cases that clearly belied such designations.

Another relevant case is that of climate information regarding Puerto Rico, which did not host systematic Weather Bureau meteorological observations until 1898. Section Director Oliver Fassig reported in a 1911 article, titled "The normal temperature of Porto Rico," that Weather Bureau data confirmed a depiction of the island as holding an "equitable," "comfortable and healthful" climate. Fassig defended the evaluation, stating: "Carefully made daily temperature observations extending over a period of five years in the Tropics… will yield an average annual value which is within a fraction of the true normal value" (Fassig 1911:299). The tendency toward normal representations of weather and climate were strong enough to evaluate a climate with reference to a five-year time series that could approximate the "true normal value."

Condensed climatological summary of temperature and precipitation by sections, March, 1919.

Section.	Temperature.									Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.							Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.				Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.			In.	In.		In.		In.
Alabama	56.7	+0.5	Ozark	83	16	Florence	21	1†		7.23	+1.84	Bermuda	11.86	Eufaula	3.43
Arizona	49.3	−2.8	2 stations	93	31	Flagstaff	−1	1		0.80	−0.17	Henrys Camp	3.44	5 stations	0.00
Arkansas	53.2	+0.6	Pine Bluff	86	22	Dodd City	11	1		5.47	+1.05	Brinkley	11.66	Umpiers	0.98
California	49.0	−2.8	Indio	94	31	Madeline	−13	10		3.47	−1.27	Crescent City	12.24	2 stations	0.01
Colorado	33.2	−1.0	Lamar	82	19	3 stations	−26	10†		1.51	+0.17	Cascade	6.31	Hoyt	0.02

Figure 27. "Condensed climatological summary of temperature and precipitation by sections, March 1919," tabulating sections with reference to average value, "departure from the normal," and extreme values. (Source: MSR 1919).

In later decades, normal/abnormal weather was reified further, especially insofar as "climatological sections" (see Figure 18) were presented as units of analysis within which to measure "departures from the normal" (USDA 1919:193; see Figure 27). Meteorologists' attribution of normality therefore matched the basic representations of climate in terms of their stability.

Risk and the Economic Rationalization of Weather Events

To integrate weather and climate knowledge into capitalist society entailed that meteorologists establish normality and abnormality in their relationship to economic rationality. People had, for centuries, recognized that their ability to reliably anticipate weather held serious economic consequences. In economic terms, at their inception in the 1870s, weather warnings and climatology were profoundly successful in reducing losses and securing profits in agriculture, trade, finance, and shipping industries (Craft 1999). The economic import of the increasing rationalization of weather entailed a growing concern for making individual events legible in economic terms.

An important implication of meteorologists' efforts to represent normal weather was the parallel capacity to evaluate specific events with reference to statistical normalizations. In the "Introductory" section of the *MWR* 1876 April issue, as an early example, the author observed:

> The most noteworthy peculiarities of the weather are as follows: (1) The extraordinary and almost universal continuation of the cold weather, (2) The frequency, lateness, and destructiveness of the April frosts, (3) The lateness of the rivers and lakes in opening to navigation, [and] (4) The unusually high range of the barometer.

The meteorologists' use of evaluative language helped them bridge their technical expertise in constructing official weather reports with public experience in various localities. Bridging the official with the local was an important objective, because it could reinforce epistemic authority regarding weather knowledge. Evaluative knowledge of normal weather events thus fits Ian

Hacking's (1990:160) account of statistical normalization. Hacking (1990:ix, 160) shows that, as a word, "normal" only designated "usual" or "typical" beginning in the nineteenth century and was used thereby as an objective and neutral "bridge between 'is' and 'ought.'" So, how did meteorologists bridge the "is" of statistical normalization with the "ought" of evaluative climatic understanding and experience?[8]

In the *MWR,* meteorologists "normalized" weather though quantitative reductions of observer reports, although the accompanying scientific reportage of events and patterns routinely narrated experiences of how people and communities were impacted by specific events. In practice, such reportage involved interpreting meteorological records with reference to a reporters' or informants' sense of damage or "severity," an evaluation that extended beyond numerical representations of "excessive" and "deficient" values. For example, to address abnormal rainfall in the August 1876 (p. 6-7) issue of *MWR*, in a special section on "Drought," the author cites "deficiency" and "excessiveness" alongside observer reports of "cattle suffering," "streams dry and wells low," and other local experiences of severity:

> *Droughts*—Fla.: Mayport, ground very dry, season unusually sickly.
>
> Ill.: Riley, rain needed.
>
> Maine: Standish reports drought very severe, streams dry and wells low; West Waterville, driest August ever recorded.
>
> Mass: Amherst, vegetation scorched
>
> Texas: Corsicana, cotton crop greatly injured, and stock suffering from want of water.

Based on statistical and evaluative normalization of weather, meteorologists and those who came to rely upon their expertise could incorporate weather events into economic calculations. The stability of a normal climate could then form a foundation for evaluations of risk, damage, and other threats to an industrializing economy.

Just as stable climate "zones" had become markers of commercial investment strategies and government administration, weather "normals" and extremes became a language for evaluating economic risks and opportunities for profit. Henry Dunwoody (1894), who had organized a decade of state-level Weather Bureau reports to Washington, helped to articulate the central idea that the economic value of weather services, when compared to projected losses in the absence of such services, was so great as to be "fittingly expressed by the word 'incalculable.'" (Dunwoody 1894:124).

[8] To compare, the formal use of "climate normals" within the Weather Bureau has at times led climatologists to emphasize the technical/statistical (rather than experiential and evaluative) basis of what climatologists label "normal" (see, e.g. Landsberg 1955). A comparison to recent years that can illustrates the descriptive-evaluative context of climate "normals" established historically during the 1870-1920 period regards recent framings of "climate events" as indicating a "new normal" (given climate change). Recent examples include Gill (2017), Watts (2017), Schapiro (2016), and World Bank (2014).

Claims to incalculability notwithstanding, many interests became pinned to making weather events economically legible, that is, economized and subject to calculations about dollars gained and lost. Those interested in doing so could then collect on insurance and damage claims, financialize shipping, trade, or commodity markets, and defend the importance of weather services to national political economy. Dunwoody (1894:123) promoted the Weather Bureau's capabilities in these terms:

> The Weather Bureau can show in the case of the tropical hurricane of September 24-29, 1894, that 1,089 vessels, valued at $17,100,413, remained in port. In the hurricane of October 8-10, 1894, 1,216 vessels, valued at $19,183,500, heeded the warning…But for the warnings these vessels would probably have gone to sea, and it is but fair to presume would in such event have met with disaster.

Weather Bureau officials—ever in need of justifying their Congressional appropriations and public benefit—coordinated with boards of trade, emerging weather-related insurance companies, and financiers to make events commensurable with economic costs, losses, and benefits.[9]

By economizing weather events, meteorologists could not only facilitate economic-industrial expansion by rationalizing anticipations of weather that impacted market relations, they could also regulate disputes that involved "abnormal" or malicious weather events. "Disaster" thus took on a socio-economic meaning. Economic calculation of weather events, consisting of comparisons of "abnormal" to "normal" numerical figures, shaped evaluations of experienced events as well as future plausible extreme events. This power to interpret extremes could then shape appeals to the state by private entities or democratic publics, to protect against events that were simultaneously anticipated but unknown (Steinberg 1991, Levy 2014). Governing thus entailed new techniques for understanding, valuating, and managing weather as *risk*. The 1904 Annual Report of the Weather Bureau addressed the shifting legal definitions of nature and weather:

> The act of Providence, the legal term being *actus Dei*, is indeed the favorite argument heard in many trials whether it be the overflowing of a sewer through extraordinary rainfall or the cessation of building operations on account of prolonged wet weather or severe cold. In all such cases the weather man is needed. (USDA 1904:307)

The "weather man," who could take the authority of official weather knowledge into the legal domain, undercut prior assumptions of weather as natural, divine, or a matter of circumstance.

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[9] As Caliskan and Callon (2009:370) write, "the study of economization involves investigating the processes through which activities, behaviors and spheres or fields are established as being economic." More generally, commensuration is a social process, as Espeland and Stevens (1998:315) define it, "the expression or measurement of characteristics normally represented by different units according to a common metric." In capitalist society, then, as Polanyi and others have shown, the process of economizing nature involves the social and political process of valuating aspects of nature on terms commensurable with money (see also Bigger and Robertson 2017; Fourcade 2011).

Forms of “weather insurance” were also proposed in the early twentieth century (*MWR* 1916:44), expanding upon prior instantiations of seasonal insurance risk in weather-impacted industries and government disbursement of crop- and related insurance subsidies (Cronon 1991, Pietruska 2017). As the arbiter of weather events, including their costs, benefits, predicted probabilities and records, “the weather man” replaced Providence as the manager of the unanticipated future.

Supplementing God and circumstance, meteorologists in effect began to organize public experience of normal and extreme weather. Tragic disasters, which made clear the persistent, even increasing, vulnerability of human life to catastrophe, most notably cast this situation into view. In such cases, the alleged stability of climate “normals” confronts unexpected and unanticipated events. For example, in the 1900 Galveston hurricane (among the most costly and deadly disasters in U.S. history), the national public considered the Weather Bureau and especially local meteorologist Isaac Cline as partial saviors for issuing a storm warning. The warning helped residents to anticipate the storm’s significant flooding and severe weather. Residents of the island settlement of Galveston, along the Gulf Coast of Texas, were especially vulnerable to hurricane-induced storm surge. However, the local public and media also blamed Cline and the Bureau, insofar as Cline had rested confidently in the city’s safety from danger. In the decade prior, Cline had vocally criticized unfulfilled plans to build coastal fortifications to protect the burgeoning city’s wealthy properties from tropical cyclones—an expert position that failed him miserably in 1900 (Larson 1999; Pielke et al. 2008). More generally, extreme weather in the early twentieth century only further entwined the relationship of meteorology to the state, insofar as publics came to view weather and climate as domains that could, by the official discourse, be rationalized, predicted, and anticipated.

Public use of and engagement with official climate knowledge routinely involved meteorological experts settling matters of fact related to risk, responsibility, or economic damage and losses. As Weather Bureau Chief Marvin (1920:567) argued, in the case of the Bureau’s “Climatological Services” Division:

> The value of this work is incalculable. It affects and benefits the entire people…In New York City alone the weather records are brought into court by personal appearance of a Weather Bureau official more than 500 times a year. Several thousand certificates are issued annually over the seal and signature of the Secretary of Agriculture for court use...The economic value of the climatological work of the bureau is enormous.

Despite the increasing use of official climate knowledge, however, weather events continued to frustrate efforts at the normalizations necessary to economize risk. An example can be found in Hoffman’s (1901:24) proposal to sell tornado insurance to state and municipal governments. The business had yet to effectively transpire in a “scientific and profitable manner,” he claimed, because probabilistic statistics of tornado events (being geographically local and holding large year-to-year differences in damage costs) did not easily match the financial risk of insurance providers as evaluated by possible underwriters.

WINDSTORM INSURANCE RATES ON CITY PROPERTY, 1901.

	1 Year.	3 Years.	5 Years.
Indiana, Illinois, Michigan and Wisconsin..	$0.20	$0.40	$0.60
Missouri, Kansas, Iowa and Minnesota....	.25	.50	.75

Figure 28. Example of insurance rates charged per $100 of city property (Source: Hoffman 1901:36).

As Hoffman reported and Figure 28 demonstrates, crude attempts at setting values followed political-geographic boundaries as a basis for designating risk. Regardless of the limitations, climate knowledge—in the case of tornadoes, the settling of monthly rates and normalized distributions of storm paths—operated under the logic of possible financialization of weather and economic risk. Overall, meteorologists and those who relied upon official climate knowledge increasingly incorporated weather events not only into economic-productive activity but also into strategies to measure, arbitrate, and economize weather risk.

Conclusion

From the 1870s to the 1920s, weather—represented through a discourse of normal/abnormal phenomena and with reference to a "stable" climatic background—became a basically rationalized element of economic activity, governmental administration, and public consciousness. This development built on the capacity for climatologists and related experts to align their science with social actors interested primarily in commercial development and state administration, an alignment that produced a "stabilization" of climate as an unchanging, geographic category. The present chapter demonstrates a related development—that meteorologists faced challenges of "rationalizing" weather observation and prediction. This power over weather provided meteorological science a formal position within the state bureaucracy, without which infrastructure and knowledge about continental weather would have been impossible to establish. Through the institutional arrangements between formal government and the sprawling network of meteorological data infrastructure, meteorologists succeeded in forging weather that was both "national" and "official." Meteorologists charted their descriptions and predictions of weather with reference to normal and abnormal events. The technopolitics that had linked meteorology and the state thus undergirded a larger legibility project, through which weather and climate could enter economic government. Meteorologists co-produced evaluations of weather risk by translating atmospheric events into the language of economic costs, benefits, losses and financial risks. Although meteorologists may not have faced the moral resistance that Zelizar (1978) outlines for life insurance in the latter nineteenth century United States, meteorologists contributed to the basic social transformation of the era, namely the rationalization of American capitalism.

Overall, the stabilization of climate and the economization of weather fit hand in glove. Through official discourse about normal weather climatologists and meteorologists could carve up climates up in numerous ways geographically, but temporally, this practice was dependent upon rendering climate as stable—the normal background. Establishing the stability of climate and the normalization of weather was not simply a matter of statistical aggregation of data concerning an objective atmosphere "out there" in nature. Indeed, others advocated alternative methods for understanding, measuring and forecasting weather and climate. Local weather prophets had little use for the national view of weather. Indeed, it threatened their claims to knowledge. And medical climatologists were less concerned with understanding climates as geographically delineated and temporally stable. Such an understanding would have entailed relegating components of their work to medicine and the human sciences.

To forge a stable climate required the development of complex social relations and material associations. This forging process is visible in the politics surrounding meteorological infrastructure—what I called technopolitics—including diverse efforts to discipline weather observers, compete against alternative weather forecasters, co-produce state territorial governance, and designate official time, administrative space, and reported weather.

In the following two chapters, which comprise Part III, I turn to the transformations through which climatic *stability*, as the basic logic of climate knowledge and meteorological government, came unhinged. To account for the rise of concern, within science and government, with the *instability* of climate, I address how historical developments at the intersection of scientific disciplines, beginning around 1930, took hold of a new vision for governing climate by the time of World War II, which thereafter opened a space for scientific investigation into climate change. The rise of climate science, I argue in Chapter 5, depended upon state-science relations that fundamentally transformed the logic of meteorological government. By securing a new interdisciplinary and autonomous space, a "climate science" field could then, by around 1980, re-center knowledge and government around a major problematic of our time: is global warming governable, and if so, by what means? I take up this problematic in Chapter 6 through an analysis of climate security expertise, a recent instantiation of meteorological government that raises yet more questions about where climate science and government may be headed in the future.