US Weather Bureau Chief Willis Moore and the Reimagination of Uncertainty in Long-Range Forecasting

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ABSTRACT

This article examines competing modes of knowledge production in the context of long-range weather forecasting in the United States at the turn of the twentieth century. The US Weather Bureau, a newly constituted civilian organisation in 1891, sought to build its institutional reputation based on authoritative short-term 24-hour forecasts by discrediting the popular and ubiquitous 'weather prophets' who made long-range predictions. Chief Willis L. Moore, at the helm of the Weather Bureau from 1895 to 1913, initially condemned long-range forecasting as superstition and quackery inherently inferior to professional meteorological expertise. But the Weather Bureau, which began issuing its own weekly forecasts in 1908, reimagined long-range forecasting to accept the very indeterminacy it had formerly denounced, thereby rationalising the uncertainty of weather prediction into its weekly forecasts and into its vision of modern scientific meteorology.

KEYWORDS

US Weather Bureau, Willis Moore, weather prophets, weather forecasting, professionalisation, science and the public, knowledge production, uncertainty, prediction

Environment and History **17** (2011): 79–105
 doi: 10.3197/096734011X12922359172970

INTRODUCTION

In 1901, US Weather Bureau Chief Willis L. Moore published *Moore's Meteorological Almanac and Weather Guide, for The Farmer, the Horticulturalist, the Shipper, the Mariner, the Merchant, the Tourist, the Health-Seeker, and for those who Wish to Learn the Art of Weather Forecasting*. But Moore's was not the kind of almanac this diverse readership would have expected: it did not showcase seasonal predictions, but rather tables of retrospective weather data, the highest and lowest monthly temperatures on record at each Weather Bureau station across the country.[1] The bulk of Moore's almanac contained articles depicting weather forecasting not as an art but as a technological and scientific enterprise driven by the bureaucratic orchestration of simultaneous and standardised weather observations, their telegraphic transmission and the professional expertise of government meteorologists who translated observational data into short-term forecasts. But in his entry on long-range forecasting, Moore proclaimed that 'no scientific man' – only 'charlatans' – dared to predict the weather a week or month ahead of time. Accurate long-range forecasts, Moore declared, were but a meteorological 'dream'.[2] In this article I examine how the Weather Bureau reimagined long-range forecasting in its attempt to achieve that elusive dream in the early twentieth century.

From the establishment of the federal government's national weather service under the auspices of the US Army Signal Service in 1870, traditional methods of long-range forecasting, including almanacs and weather folklore, posed an epistemological threat to professionalising government meteorological science, a threat recognised by journalists and weather bureaucrats alike. This confrontation between two competing modes of knowledge production about the natural world intensified at the turn of the twentieth century, when the Weather Bureau, which had been reconstituted as a civilian organisation within the US Department of Agriculture in 1891, came under the leadership of Willis Moore, who launched a vigorous campaign to discredit long-range weather prophets as purveyors of 'meteorological soothsaying'.[3] Moore worked tirelessly to shape public opinion of not only private weather prophets but also professional government forecasters in the decade before the Weather Bureau began issuing its own long-range forecasts in 1908.

Soon after Moore took the helm of the Weather Bureau in 1895, long-range weather prophets became his vehicle for distancing forecasting from prophecy, science from superstition and quackery, professional meteorological expertise

1. Sarah Strauss, 'Weather Wise: Speaking Folklore to Science in Leukerbad', in *Weather, Climate, Culture*, ed. Sarah Strauss and Benjamin S. Orlove (New York: Berg, 2003), 44.
2. Willis L. Moore, *Moore's Meteorological Almanac and Weather Guide* (Chicago: Rand, McNally, 1901), 53.
3. 'How "Fake" Weather-Forecasters Fool Farmers,' *New York Times* (hereafter *NYT*), 11 Dec. 1904.

from lived experience and observation and, ultimately, ideals of modern scientific progress from what he deemed ignorant reliance on weather folklore or false forecasts. But as it reinvented weather forecasting as a modern scientific practice, the Bureau actually embraced the very uncertainty it had formerly condemned as the chief liability of weather prophecy: following its turn-of-the-century public relations campaign against long-range weather forecasting, the Weather Bureau began to issue its own weekly forecasts in 1908. I argue that the Bureau's re-imagination of long-range forecasting rationalised the uncertainty of weather prediction: in the late nineteenth century, the Bureau viewed the uncertainty of long-range forecasting as a liability in a science of accuracy and a hallmark of amateur meteorology, vernacular weather wisdom and, at its worst, quackery, but by the close of the first decade of the twentieth century, the Bureau had accepted uncertainty as an unavoidable characteristic of long-range forecasting, a fundamental aspect of a science of probability.

As historian Katharine Anderson has observed in her study of Victorian meteorology, weather prediction was 'poised between divination, opinion, and calculation', and 'weather forecasts were both experiment and prophecy'.[4] Here I focus on the Weather Bureau's late nineteenth- and early twentieth-century endeavours to relegate calculation and divination to separate realms, to establish and police a rigid boundary between experiment and prophecy. All late nineteenth-century weather forecasters were termed 'weather prophets', both the weather service's military and civilian personnel trained in government or academic settings and the self-taught private prognosticators who commonly employed forecasting traditions based on natural signs and weather folklore. This article illuminates the turn-of-the-century moment when the meanings of *forecaster* and *prophet* diverged and, more precisely, the way in which the Weather Bureau redefined professional scientific forecasting as the opposite of vernacular prophecy.[5]

4. Katharine Anderson, *Predicting the Weather: Victorians and the Science of Meteorology* (Chicago: University of Chicago Press, 2005), 15, 19.

5. In her analysis of the public construction of individual and institutional scientific reputation in early Victorian weather prophecy and the subsequent administration of weather science in Britain, Katharine Anderson argues that categories of 'respectability' and 'propriety' are more historically useful for understanding the production of scientific knowledge in the public sphere than are rigid retrospective distinctions between genuine science and pseudoscience, or between popular and institutional contexts for scientific work. Like Anderson, I am concerned with the public reception of meteorology and what she terms the nineteenth-century 'public theatre of science' but here I focus explicitly on the US Weather Bureau's construction and policing of a rhetorical boundary between science and quackery as a tool for building its institutional reputation in the late nineteenth and early twentieth centuries. Katharine Anderson, 'The Weather Prophets: Science and Reputation in Victorian Meteorology', *History of Science* **37** (1999): 180, 203.

PROPHETS AND PROBABILITIES

At 7 a.m. on Sunday, March 11, 1888, US Army Chief Signal Officer Adolphus W. Greely issued the national weather service's daily weather map with the following twenty-four-hour forecast: 'Fresh to brisk easterly winds, with rain, will prevail to-night, followed on Monday by colder brisk westerly winds and fair weather throughout the Atlantic states.'[6] But the following morning brought a powerful blizzard that buried the east coast in up to four feet of snow and turned New York City into a 'wilderness', where winds reaching seventy miles per hour pushed snow into drifts that towered up to 35 feet high. Virtually all trains in New Jersey, New York, Connecticut and Massachusetts sat immobilised and businesses, schools and the New York stock exchange shut down. High winds and heavy ice pulled down most telegraph lines along the east coast, plunging Hartford, Boston, and Providence into unfamiliar isolation, leading one journalist to remark, 'It is hard to believe in this last quarter of the nineteenth century that for even one day New York could be so completely isolated from the rest of the world as if Manhattan Island was in the middle of the South Sea.'[7] As New York dug itself out in the following days, reports surfaced of corpses huddled in doorways. In all, over three hundred storm-related deaths were reported on land and almost one hundred at sea. The storm ended on March 14, 1888, but its legacy as the most severe blizzard in American history has lasted to the present day.[8]

Chief Signal Officer Greely published a *National Geographic* essay shortly thereafter that offered a detailed meteorological analysis of how and why the storm's course, intensity and precipitation had defied accurate prediction. The blizzard was anything but typical, Greely argued, 'a somewhat unusual class of storm on a very grand scale'.[9] Although the weather service had issued general warnings, the public was unprepared for the storm's intensity. On Sunday, March 11, Boston weather service officials had displayed cautionary signals, but, as the *Boston Globe* put it, 'the thought of the morrow brought no suggestion of such a storm' and a subsequent *New York Times* editorial faulted the weather service for allowing the storm to arrive 'absolutely unheralded'.[10]

6. National Oceanic and Atmospheric Administration, 'US Army Signal Service Daily weather map, March 12, 1888, 7 A.M.' NOAA Central Library US Daily Weather Maps Project, http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_ weather_maps.html Accessed 4 November 201.
7. 'Crushed Under the Snow', *NYT*, 14 Mar. 1888; 'Cut Off', *Boston Daily Globe*, 13 Mar. 1888; A. W. Greely, 'Great Storm off the Atlantic Coast of the United States, March 11-14,' *National Geographic* 1, no. 1 (1888): 38-39; 'Blasted', *Boston Daily Globe*, 14 Mar. 1888; 'In a Blizzard's Grasp', *NYT*, 13 Mar. 1888. Quotations in 'Cut Off', *Boston Daily Globe*, 13 Mar. 1888; 'In a Blizzard's Grasp', *NYT*, 13 Mar. 1888.
8. 'Blasted', *Boston Daily Globe*, 14 Mar. 1888; Mary Cable, *The Blizzard of '88* (New York: Atheneum, 1988), 1-2; Mark Monmonier, *Air Apparent: How Meteorologists Learned to Map, Predict, and Dramatize the Weather* (Chicago: University of Chicago Press, 1999), 2.
9. Quoted in Cable, *The Blizzard of '88*, 178.
10. 'Cut Off', *Boston Daily Globe*, 13 Mar. 1888; Editorial, *NYT*, 26 Nov. 1888.

Credit for accurately predicting the blizzard of 1888 went instead to affluent Connecticut farmer Horace Johnson, who predicted in a New York newspaper that 'a disastrous blizzard would occur between March 12 and 15'.[11] Johnson's forecast launched his fifty-year career as the 'Sage of Middle Haddam' and the 'oracle of Connecticut'. 'Uncle Horace', as he was also known, developed a loyal following among local farmers, even though he did not rely on the same natural signs (e.g. thickness of corn husks, pumpkin rinds or animal fur; colour and shape of a goose's breastbone; livestock's relative restiveness) commonly associated with farmers' weather predictions. Johnson, self-taught in meteorology and astronomy, told an interviewer in 1916 that his 'prophecies are the result of years of scientific research' into planetary motion and its ostensible relation to atmospheric conditions.[12] Despite Johnson's characterisation of his work as similar in nature to the federal government's professional scientific meteorology, his prediction of the blizzard of March 12, 1888 was fundamentally different from the Weather Bureau's twenty-four hour weather 'Probabilities' in that it was a long-range forecast issued well in advance of the storm.[13]

Long before Horace Johnson forecast the blizzard of 1888, American almanacs and newspapers regularly featured long-range weather predictions based on periodicity, planetary meteorology, lunar phases and the weather of saints' days and other holidays.[14] Newspapers frequently mentioned a menagerie of

11. 'Another Blizzard Predicted', *NYT*, 19 Mar. 1888. For newspaper accounts that credit Johnson with accurately forecasting the blizzard, see 'Another Blizzard Predicted,' *NYT*, 19 Mar. 1888; '"Old Reliable" up in Connecticut', *Baltimore Sun*, 16 Dec. 1890; 'Big Blizzard Coming', *Boston Daily Globe*, 28 Jan. 1892; 'Editorial Points', *Boston Daily Globe*, 17 Sep. 1903; 'Will Destroy New York', *NYT*, 30 May 1907; 'Sage of Middle Haddam', *Boston Daily Globe*, 2 Jun. 1912; 'A Visit to the Prophet Who Predicted the 1888 Blizzard', *NYT*, 16 Jul. 1916; 'Horace Johnson, Noted Weather Sharp, Dead', *Boston Daily Globe*, 21 Jan. 1917.

12. 'A Visit to the Prophet Who Predicted the 1888 Blizzard', *NYT*, 16 Jul. 1916.

13. Reports of just how far in advance Johnson predicted the blizzard varied from one to three weeks to two to six months. 'Horace Johnson, Noted Weather Sharp, Dead', *Boston Daily Globe*, 21 Jan. 1917; 'A Visit to the Prophet Who Predicted the 1888 Blizzard', *NYT*, 16 Jul. 1916; 'Another Blizzard Predicted', *NYT*, 19 Mar. 1888; 'Editorial Points', *Boston Daily Globe*, 17 Sep. 1903; 'Will Destroy New York', *NYT*, 30 May 1907; 'Sage of Middle Haddam', *Boston Daily Globe*, 2 Jun. 1912.

14. The first almanac entirely devoted to long-range forecasting, *Vennor's Weather Almanac*, appeared in 1877. Canadian geologist and ornithologist Henry Vennor began his rise to fame in the United States on the basis of the long-range weather predictions he published in annual almanacs and American newspapers between 1877 and 1885. Drawing both public adulation and ire for his forecasting of an entire year's worth of weather, Vennor quickly came to embody vernacular weather expertise in the American popular imagination. By the end of the century, Vennor had a host of well-known colleagues who circulated their prognostications in almanacs and newspapers: John H. Tice, W. T. Foster, and Rev. Israel R. Hicks, all of St. Louis, A. J. DeVoe of Hackensack, Levi Beebe of the Berkshire Valley, and William H. Sears of Plymouth, to name a few. Robb Sagendorph, *America and Her Almanacs: Wit, Wisdom & Weather, 1639–1970* (Boston: Little, Brown, 1970); Scott Somerville, 'A *Vennor*able Weather Prophet', *Chinook* (Spring 1979): 36—37; E. B.

non-human weather prophets, often with headlines that played on a rivalry between scientists and seers: 'A Sort of Gopher Weather Bureau at Santa Ana', 'Woodchuck as a Seer', 'Tree Frog a Weather Sharp; One Animal Whose Meteorological Reputation Science Has Not Damaged'.[15] In addition to the groundhog, whose shadow foretold a longer winter, other animals predicted – through their migratory patterns, behaviour, and appearance – long-term as well as short-term weather trends.[16] And numerous 'goosebone weather prophets' consulted the breastbone of a goose born the previous spring: dark spots on the bone presaged cold weather, lighter spots milder, with different sections of the bone corresponding to December, January, February and March. Such weather lore, almost always characterised as a rural phenomenon, encompassed flora as well as fauna: the thickness of corn husks indicated the severity of winter; the appearance of skunk cabbages announced the start of spring; and late flowering of goldenrod signalled late frost.[17]

Alongside the long-range signals of goosebone and goldenrod travelled the short-term weather forecasts of the US Army Signal Service, the institutional home of the national weather service from its creation in 1870 until Congressional order transferred it to the US Department of Agriculture in 1891. The national weather service was constructed atop the increasingly dense post-bellum telegraphic communications network, a sprawling web of poles and wires that linked 'island communities' together through instantaneous transmission of

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Garriott, *Long-Range Weather Forecasts* (Washington, DC: Government Printing Office, 1904), 36.

15. 'Southern California News', *Los Angeles Times*, 30 Jan. 1896; 'Starts His Winter Nap', *Chicago Daily Tribune*, 17 Dec. 1899; 'Tree Frog a Weather Sharp', *Washington Post*, 9 Jun. 1907.

16. The ranks of non-human weather prophets included, among others, moles (the depth of their holes indicated the severity of winter), frogs (who sought the refuge of water when inclement weather was imminent), wild geese (which the Connecticut farming community considered the sign of an early spring), yellow-billed cuckoos (whose cry announced a coming storm), caterpillars (whose colouring in late fall indicated the pattern of the coming winter), and fish (who refused to bite if a storm loomed and went to deeper water when cold weather was coming). 'The Mole as Weather Prophet', *Washington Post*, 24 Dec. 1905; 'Frogs as Weather Prophets', *Los Angeles Times*, 30 Jul. 1899; 'Tree Frog as Prophet', *Boston Daily Globe*, 14 Jul. 1907; 'Frog is a Weather Prophet', *Washington Post*, 9 Aug. 1908; 'Signs of an Early Spring', *Chicago Daily Tribune*, 9 Apr. 1899; 'Wild Geese Flying North', *Washington Post*, 5 Feb. 1913; 'Picture to Paint', *Boston Daily Globe*, 21 Aug. 1904; 'Caterpillar as a Weather Prophet', *Atlanta Constitution*, 29 Jan. 1905; 'Fishes as Barometers', *Washington Post*, 16 Sep. 1906; 'Fishes Know Weather', *Boston Globe*, 25 Nov. 1906.

17. 'Goosebone Markings', *Reading (PA) Cor. Philadelphia North American*, in *Washington Post*, 30 Dec. 1906; 'Hard Winter, Says Goose,', *Philadelphia Ledger*, in *Atlanta Constitution*, 26 Dec. 1911; Edward B. Garriott, *Weather Folk-Lore and Local Weather Signs* (Washington, DC: Government Printing Office, 1903), 40; 'Vegetable Weather Prophet', *Washington Post*, 3 Oct. 1897; 'Signs of an Early Spring', *Chicago Daily Tribune*, 9 Apr. 1899; 'Dandelion as a Barometer', *Boston Daily Globe*, 11 Jul. 1909; 'The Goldenrod as a Weather Prophet', *Atlanta Constitution*, 13 Sep. 1910.

news and market information from far-flung corners of the nation.[18] Indeed, late nineteenth-century government weather forecasting was based not on theoretical models of atmospheric change but rather the geographical projection of weather observations from west to east by 'the telegraph [that] enabled knowledge to outstrip the storms'.[19] Throughout the late nineteenth century, weather service personnel and volunteer observers across the country used standardised meteorological instruments to record thrice- or twice-daily synchronous observations of temperature, barometric pressure, wind speed and direction and cloud conditions, which they then transmitted by telegraphic cipher to Washington, D.C. headquarters, where a team of clerks and the chief forecaster translated the flurry of local weather reports into maps and then the daily 'Synopsis and Probabilities', a summary and twenty-four hour forecast that projected observed surface conditions forward in both space and time. The 'Probabilities', officially defined by the Signal Service as 'announcements of the changes, considered from the study of the charts … as probably to happen within the twenty-four hours then next ensuing', were then transmitted to newspaper offices, boards of trade and commodity exchanges, the halls of Congress, scientific institutions both at home and abroad and back to Bureau substations, each of which relayed the forecast by telegraph to towns and villages within fifty to one hundred miles.[20]

As the federal government's daily twenty-four hour forecasts circulated among a public that read seasonal forecasts in almanacs and nature alike, newspapers often dramatised an epistemological divide between urban and rural ways of knowing the weather. In a 1908 article on vernacular weather prediction, the *New York Tribune* imagined a debate between a 'rural interpreter' and a sceptical 'city man' who dismissed natural weather signs as superstitious nonsense.[21] But the distance between rural and urban modes of apprehending the weather was in fact far narrower than the *Tribune* suggested. Rural Americans – hardly rooted in anti-modernism or protective localism – had sought since mid-century access to a government-sponsored weather information network. In the mid-1850s, Virginia and New York agricultural societies petitioned the House Committee on Agriculture for the adaptation of Navy Lieutenant Matthew Fontaine Maury's pioneering work in maritime meteorology to a land-based system. Throughout the 1870s the Signal Service acknowledged steadily increasing demand for a rural weather service, and by the mid-1880s, the National Grange and other

18. Robert H. Wiebe, *The Search for Order, 1877–1920* (New York: Hill and Wang, 1967), xiii.

19. N. S. Shaler, 'The Future of Weather Foretelling', *Atlantic Monthly*, Nov. 1880, 645. On the centrality of telegraphy to late-century storm tracking and forecasting, see Monmonier, *Air Apparent*, xi.

20. Monmonier, *Air Apparent*, 7; Edmund P. Willis and William H. Hooke, 'Cleveland Abbe and American Meteorology, 1871–1901', *Bulletin of the American Meteorological Society* **87** (3, 2006): 317; quotation in Chief Signal-Officer, *Annual Report of the Chief Signal Officer to the Secretary of War for the Year 1874* (Washington, DC: Government Printing Office, 1874), 90.

21. 'Some Popular Weather Signs', *New York Tribune*, in *Washington Post*, 1 Nov. 1908.

agrarian organisations had intensified the call for improved access to the Signal Service network.[22] In 1886, two bills proposing to extend the weather service further into the countryside were introduced in the House, and the hearings revealed a broad and unified base of discontent with the current reach of the weather service: as Robert Beverly, the President of the National Agricultural Congress, testified, 'There has not been an agricultural meeting of any society state or local in the last two years that has not called for this bill. Everyone has called for it.'[23] The Grangers, state and country agricultural societies and local farmers' clubs who petitioned Congress and the US Army for a rural weather service sought to link the countryside to the urban meteorological 'centre of calculation' so that they might protect their crops from frost, hail and snow and thus mitigate their economic risk in a national market.[24] And these agrarian demands for improved access to the Signal Service's network of ostensibly modern and scientific weather information were entirely consistent with what historian Charles Postel has recently characterised as the business- and market-oriented politics of the Farmers' Alliance and the Populist movement more broadly.[25]

The economic value of weather forecasts and the type of risk they mitigated varied according to their temporal and geographical reach. The Signal Service's first storm-warning system proved immediately valuable for Great Lakes shipping companies, which faced a greatly reduced risk of losing vessels to uncertain weather.[26] The value of short-term forecasts in the countryside proved harder to measure in the late nineteenth century. The Signal Service faced the perennial problem of disseminating timely and relevant weather predictions to the

22. Jefferson County Agricultural Society, 'Petition for the adoption of Lieutenant M. F. Maury's system of meteorological observation', Feb. 1856, and New York State Agricultural Society, 'Petition for the adoption of Lieutenant M. F. Maury's system of meteorological observations', Feb. 1856, folder 'Adoption of Lieutenant M. F. Maury's System of Meteorological … Feb. 14 to Feb. 28, 1856', HR 34A-G1.1, House Committee on Agriculture, Records of the United States House of Representatives, RG 233, National Archives I, Washington, DC; US Department of War, *Annual Report of the Secretary of War* (Washington, DC: Government Printing Office, 1871), 272, 398-99; US Department of War, *Annual Report of the Secretary of War* (Washington, DC: Government Printing Office, 1877), 162–67; Robert Beverly, A. J. McWhitter, and M. C. Ellzly, 'Petition to General W. B. Hazen,' 1884, folder 'Benefits to Agr. Of the Signal Service Weather Reports', HR 48A-H2.2, Committee on Agriculture, RG 233, National Archives I; *Journal of Proceedings: Twentieth Session of the National Grange of the Patrons of Husbandry, 1886* (Philadelphia: J. A. Wagenseller, 1886), 133.

23. *For the Relief of Farmers of the United States by Extending to them the Benefits of the Signal Service*, HR 2318, 49th Cong., 1st sess.; *For Extending the Benefits of the Signal Service to Farmers of the United States*, HR 2506, 49th Cong., 1st sess.; House Committee on Agriculture, *Extending the Benefits of the Signal Service to the Farmers of the United States: Hearings on H.R. 2318 and H.R. 2506*, 49th Cong., 1st sess., May 5, 1886, 30.

24. Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, MA: Harvard University Press, 1987), 239.

25. Charles Postel, *The Populist Vision* (New York: Oxford University Press, 2007), 138.

26. Erik D. Craft, 'The Value of Weather Information Services for Nineteenth-Century Great Lakes Shipping', *American Economic Review* **88**, (5, 1998): 1059—76.

so-called 'distant parts of the country', a problem that despite a multiplicity of overlapping communications technologies – telegraph, newspapers, Farmers' Bulletins, daily weather maps, flag warning systems, visual signals affixed to railroad cars, and locomotive whistles to signal approaching storms – was not solved until the permanent establishment of rural free delivery in 1902 and the widespread use of telephone weather forecasts in the first few years of the twentieth century.[27] Often the accuracy and value of weather forecasts in the countryside was judged harshly in the qualitative court of public opinion.[28] As Iowa writer and persistent Weather Bureau detractor Emerson Hough complained in 1909, 'Now what does the farmer *get* when he gets a forecast?'[29] What farmers might one day get, Bureau Chief Willis Moore had predicted at the turn of the century, was accurate weekly and monthly predictions that would create a utopia of agricultural productivity and efficiency in which farmers would know when to expect rain in the corn and wheat regions or ideal planting weather in the cotton belt. Such foreknowledge, Moore speculated, would yield 'a wonderful conservation of human energy' and efficiency on a national scale with 'effort … withheld in one part of the country, and prodigious energy exerted in another'. But, Moore cautioned, such a scenario was but a distant dream since legitimate long-range forecasts had a scope of only two to three days in summer and one to two days in winter. Explicitly acknowledging the limitations of forecasting, Moore noted that the 'Weather Bureau … does not claim to be able to do more than it is possible to accomplish'.[30]

27. US Department of War, *Annual Report of the Secretary of War* (Washington, DC: Government Printing Office, 1876), 110; E. B. Calvert, 'How the Weather Bureau Disseminates Forecasts and Warnings', in *Report of the Chief of the Weather Bureau, 1895–96* (Washington, DC: Government Printing Office, 1896), xxii-xxiii; E. J. Prindle, 'Weather Forecasts: The Manner of Making Them and Their Practical Value,' *Popular Science Monthly* 53 (1898): 309. Quotation in US Department of War, *Annual Report of the Secretary of War*, 1876. On the history of rural weather telegraphy in the late nineteenth century, see Jamie L. Pietruska, 'Propheteering: A Cultural History of Prediction in the Gilded Age' (PhD diss. Massachusetts Institute of Technology, 2009), chap. 3.

28. The forecast verification process by which the Bureau calculated its accuracy percentages was complex and inspired controversy both within the Bureau and among its detractors. The turn of the century found the Bureau dealing with various problems of verification, including the differences in standards of verification between the Bureau's central office and its Chicago district, the climatological diversity within the geographic boundaries of a single forecasting district, the difficulty of translating a general forecast into a local context, the disjuncture between the Bureau's quantitative verification and the public's qualitative assessments, and the rigid rules and language of Bureau forecasting that sometimes yielded forecasts that were technically accurate according to Bureau standards but misleading enough to pose an economic risk to farmers. US Weather Bureau, *Proceedings of the Second Convention of Weather Bureau Officials, Held at Milwaukee, Wis., August 27, 28, 29, 1901* (Washington, DC: Government Printing Office, 1902); Emerson Hough, 'Does the Weather Bureau Make Good?' *Everybody's Magazine*, May 1909, 609–21.

29. Hough, 'Does the Weather Bureau Make Good?' 613.

30. Willis L. Moore, 'Weather Forecasting', *Forum* **25** (1898): 351—52.

What the national weather service could and could not accomplish was a recurring topic in the pages of government reports and print media throughout the late nineteenth century and beyond. The weather service had its supporters and detractors in every era, but in the 1880s and 1890s it drew sustained federal scrutiny of its management and public scepticism regarding the accuracy and relevance of its forecasts. Such negative publicity began in 1881 with a widely reported embezzlement scandal, after which Congress reduced the Signal Service's annual appropriations, two major federal investigations of the Weather Bureau exposed numerous operational inefficiencies, and the Chicago Board of Trade, among many other organisations, voiced persistent criticism and called for a more efficient service. In 1881 Secretary of War Robert Lincoln concluded that meteorology and the military had 'no natural connection' and the Allison Commission's inquiry of 1884–86 ultimately recommended ending the military oversight of the weather service. At the close of the 1880s, the *Boston Herald* doubted that the Signal Service would ever be able to make sense of the 'immense mass of data' it had collected throughout the decade, and the *Chicago Journal* warned that 'the signal-service weather predictions are as faulty as ever. It is safer to bet on the election than to bet on the signal-service.'[31] Management controversy persisted after the weather service was transferred to the US Department of Agriculture and reconstituted as the Weather Bureau in 1891, and Chief Mark Harrington and Secretary of Agriculture Sterling Morton waged a public battle over control of the organisation in 1893.[32]

'SHOWING THAT WEATHER FORECASTING IS A MATTER OF SCIENCE AND NOT OF RELIGION'

Government weather bureaucrats in the 1890s, wary of public criticism and reluctant to issue potentially unsuccessful long-range forecasts, cultivated a culture of certainty to which all forecasters were expected to conform. In December 1891, Chief Mark Harrington, upon learning of a San Francisco Bureau official's publicly stated intention to make monthly forecasts, warned in

31. Quoted in H. Helm Clayton, *The Transfer of the United States Weather Service to a Civil Bureau* (Boston: Alfred Mudge, 1889), 11–29.

32. Donald Whitnah, *A History of the United States Weather Bureau* (Urbana: University of Illinois Press, 1965), 46–60; quotation in James Rodger Fleming, 'Storms, Strikes, and Surveillance: The US Army Signal Office, 1861–1891', *Historical Studies in the Physical and Biological Sciences* **30** (2, 2000): 328. For details of the Allison Commission's work, see A. Hunter Dupree, *Science in the Federal Government* (Cambridge, MA: Harvard University Press, 1957), 188–92. On the history of the weather service, see Charles C. Bates and John F. Fuller, *America's Weather Warriors, 1814–1985* (College Station: Texas A&M University Press, 1986); Patrick Hughes, *A Century of Weather Service: A History of the Birth and Growth of the National Weather Service, 1870–1970* (New York: Gordon and Breach, 1970); James Rodger Fleming, *Meteorology in America, 1800–1870* (Baltimore: Johns Hopkins University Press, 1990); Monmonier, *Air Apparent*.

early December that 'the idea is a good one but the heading is not wise – such advertisement should not be made.'[33] In 1893 Secretary of Agriculture Morton shut down what he called the 'wholly theoretical' work of Weather Bureau Professor F. H. Bigelow, a well-known proponent of solar radiation theories of long-range forecasting who envisioned monthly and perhaps yearly forecasts in the Bureau's future. Such forecasts would, Morton exclaimed to Harrington in June 1893, 'degenerate, so far as precision and certainty is concerned, into the style of the ancient almanacs, wherein we read "about this time expect rain", running down the column and covering several days, and even weeks'. '[T]he real object of the Weather Bureau work', Morton went on, 'is to state with more certainty what the weather will be tomorrow, or the next day.'[34]

Less than six months later, Harrington travelled to Boston to preside over the public trial of New England district forecaster Henry Helm Clayton, a Blue Hills Observatory meteorologist well-known for his vigorous campaigning in the late 1880s for the transfer of the military weather service to a civilian agency. Clayton would subsequently achieve local fame and international recognition for the uncommonly accurate weekly forecasts he published based on theories of weather cycles and solar radiation. But the Weather Bureau put Clayton under scrutiny not for his experimental work in seven-day weather periods and local long-range forecasting but rather for fifteen inaccuracies in his daily maps between June and September 1893, errors that included mislabelled or missing isotherms and isobars, missing temperature lines or missing degree marks.[35] Although there is no evidence that Clayton's mislabelled maps had any serious consequences for readers, none of whom wandered unprepared into a storm or ventured out on dangerous waters as the result of unmarked isobars or isotherms, Clayton's maps circulated widely throughout New England and thus became a threat to the Bureau's public image, a symbol of inaccuracy in an institution that defined itself by the very opposite. As the *Boston Globe* reported, the Bureau

33. Mark Harrington to R. E. Kerkane, 4 Dec. 1891, Letters Sent by the Chief of the Bureau, Meteorological Correspondence of the Signal Office, 1870-93, vol. 1, RG 27, National Archives II.

34. Sterling Morton to Mark Harrington, 29 June 1893, Letters Sent by the Chief of the Bureau, Meteorological Correspondence of the Signal Office, 1870-93, vol. 3, Records of the Weather Bureau, RG 27, National Archives II, College Park, MD; 'Weather Bureau Reforms', *NYT*, 13 Jul. 1893. In the face of a severe economic downturn, Morton instituted a series of budget-cutting measures that included a reduction in the number of telegraphed forecasts as well as a curtailing of meteorological research in favour of a strict focus on forecasting. Whitnah, *A History of the United States Weather Bureau*, 65–66; Hall, 'Our Crippled Weather Service, *Science* **22**: 44.

35. Clayton, *The Transfer of the United States Weather Service to a Civil Bureau*; H. Helm Clayton to Willis Moore, 10 Dec. 1904, box 5, folder 18, Henry Helm Clayton Papers, 1877–1949 and undated, Smithsonian Institution Archives, Washington, DC; 'Forecasting the Weather', *Washington Post*, 20 Jul. 1894; Sterling P. Fergusson and Charles F. Brooks, 'Henry Helm Clayton: 1861–1946', *Science* **105** (n.s. no. 2723, 7 March 1947): 247—48; 'Carelessness Alleged', *Boston Daily Globe*, 7 Nov. 1893.

'did not want the impression to be in circulation that the weather department was making mistakes every day'.[36]

The Bureau's inquiry found Clayton guilty of forecasting inaccuracy (and perhaps not sufficiently penitent), whereupon he resigned his position as district forecaster. The trial swiftly resolved what Clayton's superiors understood as a personnel problem but at the same time revealed a more formidable epistemological problem. During the proceedings, one professor argued that inaccuracy was an inevitable feature of weather forecasting, announcing to the crowded room that 'it is impossible to conduct the work of a bureau of this kind without errors; it is no use to expect it'.[37] But expect it the Weather Bureau did.

Clayton's public hearing essentially put the federal government's weather bureaucracy and its standards on trial as well. Weather Bureau procedure in the 1890s carefully monitored the Bureau's public image, requiring all newspaper clippings mentioning the Bureau to be submitted to Washington headquarters attached to a standardised form, and many officials cited an unprecedented degree of public accountability by the end of the century.[38] The first convention of Weather Bureau officials, a professional conference devoted to the presentation and discussion of papers on various theoretical and administrative topics, focused squarely on the challenge of public relations. A speaker on the topic of 'Relation Between the Weather Bureau and the Public', G. N. Salisbury of Seattle, argued that the Bureau's increased visibility had resulted in a more knowledgeable public with more stringent demands. Such a public, Salisbury argued, had unreasonably high expectations for more specific two-day forecasts or forecasts of the next week's weather. Salisbury advocated a conservative approach to long-range forecasting that acknowledged the uncertainty of such an endeavour:

> If we do not know, with considerable certainty, what the weather will be two or more days in advance its prediction should not be attempted. It savors of charlatanism; it begets lack of confidence in us; our information becomes unreliable, and whom can we blame save ourselves, if we offer the odium or oblivion assigned to all false prophets?[39]

36. 'Chief Harrington is Coming', *Boston Daily Globe*, 14 Dec. 1893.
37. 'Mr. Clayton Returns', *Boston Daily Globe*, 2 Dec. 1893; 'To Question Clayton', *Boston Daily Globe*, 15 Dec. 1893; Mark Harrington to Sterling Morton, 23 Dec. 1893, Letters Sent by the Chief of the Bureau, 1891-95, 1897–1911, vol. 4, RG 27, National Archives II; Harrington to Clayton, 21 Dec. 1893, Letters Sent by the Chief of the Bureau, 1891–95, 1897–1911, vol. 4, RG 27, National Archives II; quotation in 'Friends Rallied', *Boston Daily Globe*, December 17, 1893.
38. 'To Question Clayton', *Boston Daily Globe*, 15 Dec. 1893; Weather Bureau, 'Clippings, Suggestions, etc.' 23 December 1893, box 883, Forecast Division Series (1893), Weather Bureau Correspondence, RG 27, National Archives II.
39. US Weather Bureau, *Proceedings of the Convention of Weather Bureau Officials, Held at Omaha, Nebr., October 13–14, 1898* (Washington, DC: Weather Bureau, 1899), 15–16.

Salisbury feared the potential damage of inaccurate long-range forecasts to the Bureau's public image, declaring that,

> each correct statement and each accurate prediction adds to the grandeur and beauty of its temple of reputation; while every misstatement, and every gross failure, is a stone taken from its foundation, lessening the stability and threatening the overthrow of the structure.[40]

Even more damaging to the Bureau's 'temple of reputation' than its own potential long-range inaccuracies was the accuracy of private weather prophets, according to convention speaker E. A. Beals of Cleveland. Beals observed that unseasonable weather invariably brought newspaper reporters to the local Bureau office in search of historical weather data, and that only local Bureau officials with well-maintained records would be able to furnish the desired information. Should a local office fail to provide comparative meteorological data, Beals warned, journalists would turn to the authority of the 'oldest inhabitants', thereby ensuring that 'the public mind receives further confirmation as to the changeableness of climate, the certainty of equinoctial gales, the infallibility of the goose bone and the ground hog in foretelling all sorts of calamities'.[41]

Beals's scenario – the well-organised bureaucracy and scientific authority of the professional weather office competing with the vernacular knowledge of weather lore and the decentralised authority of local history – embodied the Bureau's turn-of-the century efforts to redefine weather forecasting as a modern scientific practice and to relegate weather prophecy to the realm of pre-modern quackery. In the discussion following Beals's paper, Bureau official J. Warren Smith praised the epistemological labours of Chief Willis Moore, who 'went out among the people … [and] showed them that he was an expert and not a prophet'.[42] And a subsequent comment by a Mr. Sims exhorted the expert, not the prophet, to 'lead the people out of the darkness of ignorance into the light of intelligent meteorology'.[43] Sims's invocation of the truth of Enlightenment science vanquishing the darkness of weather prophecy further underscored the epistemological incompatibility of these two ways of knowing the future. Sims's conversion imperative – the need to convert the unlearned from adherence to irrational belief to acceptance of meteorological truth – clearly resonated with Moore, who thereafter set out on a proselytising mission in the popular press. By 1902 Moore's attempts to educate the public about the stark difference between authoritative scientific forecasting and illegitimate long-range prophecy had earned him the *Washington Post*'s distinction as the government scientist who had done the most 'to combat superstition and ignorance' in the broader

40. Ibid.
41. Ibid. 71.
42. Ibid. 73.
43. Ibid. 74.

ideological project of 'civilizing the masses and bringing them in touch with modern science'.[44]

Nearly thirty years before receiving the *Post*'s acclaim, the seventeen-year-old Moore began working in the newspaper industry as a printer and reporter for New York's Binghamton *Republican*, and then as a printer for the *Hawk-Eye* in Burlington, Iowa, where he landed after his gold-seeking expedition in the Black Hills went bust. As Moore later recalled, his housemate at a Burlington boarding house had just set up a local weather signal station and the young Moore decided that he too would be well suited for 'the weather business'. At the urging of his boss Frank Hatton, subsequently Garfield's Postmaster General and editor of the *Washington Post*, Moore ventured to Washington in 1876 to take the entrance exam for the Signal Service's meteorological training school at Ft. Myer, Virginia. Moore then moved up the ranks as Milwaukee district forecaster in 1891, Chicago forecast official in 1894, and then Chief of the Weather Bureau from 1895 to 1913. As Bureau Chief, the erstwhile printer and newspaperman sought to improve the production of weather maps and to popularise the work of government meteorological science in print media.[45] And at the centre of Moore's public relations campaign was his attack on weather prophecy.

Moore's escalating opposition to long-range weather prophecy intensified in 1904, the same year that debate over weather forecasting reached the floor of Congress. In March 1904, Republican Senator Thomas Bard of California proposed a bill designed for 'the promotion of further discovery and research in meteorology'. The centrepiece of Bard's bill was a forecasting contest that would award two prizes totalling $150,000 to those most successful in making thirty-day temperature and rainfall forecasts over a six-month period.[46] Contestants would be required not only to make accurate long-range forecasts, but also to articulate the scientific principles underlying their methods to a jury of university experts in meteorological sciences. The goal of Bard's proposed competition was to uncover 'the physical basis of meteorology' and thereby mitigate the uncertainty

44. 'Scientist as Prophet', *Washington Post*, 3 Aug. 1902. For a general discussion of Moore's efforts to convey the nature and significance of the Bureau's work to the public, see Bernard Mergen, *Weather Matters: An American Cultural History since 1900* (Lawrence: University Press of Kansas, 2008), 13.

45. 'Scientist as Prophet', *Washington Post*, 3 Aug. 1902; James B. Morrow, 'The Man Who Chases Cyclones', *Boston Daily Globe*, 5 Sep. 1909; quotation in James B. Morrow, 'Blame Moore for Hot Wave', *Los Angeles Times*, 5 Sep. 1909; Mark Monmonier, 'Telegraphy, Iconography, and the Weather Map: Cartographic Weather Reports by the United States Weather Bureau, 1870–1935', *Imago Mundi* **40** (1988): 19—23.

46. Contestants would be required to forecast the temperature for any three states from a predetermined list: Massachusetts, New York, Pennsylvania, District of Columbia, Georgia, Ohio, Minnesota, Missouri, Kansas, Texas, and California. 'The Promotion of Meteorology', *Monthly Weather Review* **32** (no. 5, May 1904): 220—21. For newspaper coverage of Bard's bill, see 'Big Prizes Offered Weather Prophets', *Los Angeles Times*, 27 Mar. 1904; 'To Promote Research in Meteorology', *Washington Post*, 27 Mar. 1904; 'Good Work of Senator Bard', *Los Angeles Times*, 8 May 1904; 'Forecasting the Weather', *Los Angeles Times*, 10 Aug. 1904.

of weather forecasting, which the *Los Angeles Times* acknowledged when it reported that 'the government weather experts do not know [the physical basis for meteorology]. Nobody knows what causes weather till after it has happened, at any rate, and then the knowledge is worthless.' The *Times* did allow that the Weather Bureau's twenty-four hour forecasts were relatively accurate thanks to the swift telegraphic transmission of surface weather conditions from west to east, but it concluded that the Bureau was unable 'to analyze the weather and say what is going to happen next with certainty'.[47]

The Weather Bureau publicly and Moore privately opposed Senator Bard's contest on the grounds that it would perpetuate the very meteorological uncertainty it set out to eliminate. Moore warned Bard that the bill's support of long-range prophecy would weaken the reputation of government science and ultimately be detrimental to the public. Moore acknowledged the existence of an honest class of long-range forecasters – the well-intentioned but unlearned in physics or astronomy – but vilified the majority as savvy quacks exploiting the limitations of Weather Bureau forecasting as well as the trust of the public. Moore pointed to the prophets' exploitation of uncertainty as the key to their stature, arguing that their imprecise predictions of where and when storms would strike allowed them a greater chance of accuracy and fame. Moore decried these forecasters for their disaster-mongering, declaring that 'most long-range weather forecasters are of that pernicious class of people that predict swarms of locusts, wars, famines, and other scourges'. As Moore explained to Bard, Atlantic City hotel managers had asked him in 1902 to debunk a prophet's forewarning of a disastrous hurricane, a prognostication that compelled frightened guests and hotel workers to flee the area. But Moore's reassuring public statement did little to quell the panic, and the exodus continued.[48]

Long-range weather prophets like the one who emptied Atlantic City represented a threat to Moore not only because of their direct competition with government science and the economic consequences of their influence on public behaviour, but also because of their disruption of the boundary between the scientific and the supernatural. As Moore wrote to Senator Bard, 'It is wrong for them to tell the public that there is something occult and mysterious in science. They claim to possess wonderful powers, but when put to the test … can never show any principle back of their systems.' Furthermore, Moore alleged, Bard's contest would bestow official government recognition on the long-range weather prophets and thereby garner more public attention for their private forecasts.[49] Moore's worst fears were never realised, as Bard's bill never made it out of

47. 'An Innovation in Barometric Observation,' *New York Daily Tribune*, 30 Apr. 1903, quoted in Garriott, *Weather Folk-Lore and Local Weather Signs*, 47; 'Big Prizes Offered Weather Prophets,' *Los Angeles Times*, 27 Mar. 1904.

48. Willis Moore to Thomas Bard, 29 Feb. 1904, box 5, folder 18, Clayton Papers; US Weather Bureau, *Proceedings of the Third Convention of Weather Bureau Officials Held at Peoria, Ill., September 20, 21, 22, 1904* (Washington, DC: Government Printing Office, 1904), 45.

49. Willis Moore to Thomas Bard, 29 Feb. 1904, Clayton Papers.

committee. But the long-range forecasters' claims for 'something occult and mysterious in science' fuelled Moore's crusade against weather prophecy in the early twentieth century and inspired his vigilant policing of a rigid boundary between science and superstition, forecasting and prophecy.

At the Weather Bureau's convention in Peoria, Illinois in September 1904, Moore exhorted his colleagues to denounce more aggressively the quackery of long-range forecasting. Responding to chief forecaster E. B. Garriott's paper on the potential value of solar radiation analysis to such an endeavour, Moore urged the Bureau to 'attack' the work of the long-range forecasters who had recently begun 'to spring up like a mushroom growth, prosper, and grow rich and fat on the proceeds of their work'. And Moore's comments echoed far beyond Peoria: his 'scathing rebuke' of Garriott was reported by the Associated Press as well as local newspapers.[50]

The American public needed protection, Moore believed, from the economic risk embedded in the uncertainty of long-range weather forecasting. Publicly and privately, he warned of the financial loss incurred by farmers, manufacturers, shippers, merchants, and businessmen who orchestrated their activities according to inaccurate long-term predictions – and cited extensive correspondence from those who did. And in general, the Signal Service and then the Weather Bureau regularly collected testimonials from individuals and institutions that had an economic stake in weather forecasting and then cited them in government reports and published circulars in order to legitimise their profession, to justify their operating expenses, and appeal for increased Congressional appropriations.

Public weather testimonials revealed that the federal government's weather data had both predictive and retrospective value. Commercial shipping firms and railroad corporations consulted short-term forecasts and storm warnings to adjust their deployment of ships, boats and freight trains in anticipation of fog or snow storms, and canal shippers used the 'Probabilities' and river reports to steer clear of ice in river junctions. Before the introduction of refrigerated railroad cars, shippers of perishable beef, fruit and vegetables relied on forecasts of extreme temperature changes when scheduling their shipments and the merchants awaiting these shipments used the forecasts to anticipate delays in delivery. The economic value of short-term forecasts and storm warnings was cited by agricultural producers including, for example, fruit growers in California and farmers in the corn and wheat belts who heeded frost warnings from district forecasting centres, cattle ranchers on the Rocky Mountain plateau who sheltered their livestock after receiving cold wave warnings from the Denver office, and southern sugar cane growers who received frost warnings from the New Orleans office. As the secretary of the Sacramento Valley Development Association wrote to Willis Moore in 1909, 'the good that has resulted from

50. US Weather Bureau, *Proceedings of Peoria Convention*, 43; Associated Press, 'Called Charlatans', *Los Angeles Times*, 22 Sep. 1904; 'Weather Fakirs', *Grand Forks (ND) Daily Herald*, 24 Sep. 1904.

this efficient handling of storm, flood and frost notices can hardly be measured in dollars and cents'.[51]

The Bureau's long-term climatological data – retrospective tabulations of monthly weather observations – also functioned as a predictive mechanism. Real estate brokers, potential buyers and prospective homesteaders used the meteorological history of a place to project the future value and appeal of land in a distant part of the country. Manufacturers such as agricultural machinery firms and fertiliser companies, along with retailers and travelling salesmen, estimated product demand based on the Bureau's climatological publications. Engineers building bridges, sewers and irrigation systems frequently consulted the rainfall data for watershed areas in order to determine the capacity of water flow required in their projects. Climatological records also proved indispensable to railroad agents, insurance companies and lawyers who sought historical data to assess claims of weather-related financial loss and personal injury. Railroad companies settling rebate claims for perishable goods spoiled in the heat or damaged by freezing temperatures checked the Bureau's climatological reports to verify the allegedly hot or cold weather on a particular day in the previous month or year and, similarly, courts often heard the testimony of Bureau officials regarding icy sidewalks, limited visibility, damaging winds, and lightning strikes that were crucial to resolving legal claims for personal injury or damages.[52]

Thus the Bureau's short-term warnings and long-term climatological data proved economically valuable to the agricultural producers who received them, to railroad and commercial shipping companies, banks and real estate brokers, chambers of commerce, boards of trade and commodity exchanges, civil engineers and utility companies, among others, all of whom relied on knowledge of the weather of the immediate future or the distant past to inform their business decisions. But those who 'keep pace with modern progress', Moore argued, did not put their faith in long-range forecasts.[53] And according to Moore's logic of 'modern progress', the uncertainty of long-range forecasts had no place in the modern capitalist marketplace – itself as unpredictable as weather.

Of all those who might consult long-range weather prophets before making business decisions, farmers had the most to lose, according to the Weather

51. 'Scientist as Prophet', *Washington Post*, 3 Aug. 1902; 'Chief in Reading Weather', *Washington Post*, 27 Aug. 1905; quotation in O. H. Miller to Willis Moore, 5 Feb. 1909, box 2, Reports on Value of Climatological Publications, Administrative and Fiscal Records, RG 27, National Archives II.

52. T. B. Jennings to Willis Moore, 18 June 1908; G. Howland to Willis Moore, 17 June 1908; A. J. Mitchell to Willis Moore, 5 June 1908; Levi A. Judkins to Willis Moore, 5 June 1908, box 1, Reports on Value of Climatological Publications, Administrative and Fiscal Records, RG 27, National Archives II; Henry J. Cox, 'Use of Weather Bureau Records in Court', in *Yearbook of the United States Department of Agriculture, 1903* (Washington, DC: Government Printing Office, 1904), 303–9.

53. 'How 'Fake' Weather-Forecasters Fool Farmers', *NYT*, 11 Dec. 1904; US Weather Bureau, *Report of the Chief of the Weather Bureau, 1903–1904* (Washington, DC: Government Printing Office, 1904), xiii–xvii.

Bureau and the popular press. E. B. Garriott, head of the forecasting division, issued a circular in 1904 that impressed upon Bureau personnel their obligation to protect ostensibly naïve agrarian populations from the fraud of weather prophets, who, Moore alleged, had insinuated themselves into the rural press. Garriott instructed Bureau section directors to encourage their local newspapers to 'print articles that will teach people the truth about forecasts and storm warnings, instead of misleading their readers by publishing the predictions of fakirs'.[54] The *Washington Post* lauded Moore's efforts to disabuse rural populations of their faith in weather wisdom:

> …by making science bear directly on the most prevalent superstitions, by showing that weather forecasting is a matter of science and not of religion, by convincing the rural population that when the bureau predicts rain for the day following, the fact that all the roosters in the country are perching upon the top fence rail will not change it, Prof. Moore has done more for the advancement of intelligence than any other scientist in Washington.[55]

The *Post's* account outlined the epistemological agenda of Moore's attack on weather prophecy: the Bureau sought first to redefine forecasting as a modern, rational, scientific practice in opposition to prophecy as a pre-modern belief system predicated on folk wisdom; and second, to teach farmers to transform their faith in natural signs into trust in a federal government bureaucracy. In 1903 the Bureau aimed to secularise weather forecasting through the publication of a bulletin by E. B. Garriott entitled *Weather Folk-lore and Local Weather Signs*, which denounced long-range forecasting based on a variety of methods: past trends and seasonal averages in local weather conditions, planetary meteorology (including planetary motion, lunar phases, and 'stellar influences'), and natural observation of plants and animals. A review in the *San Jose Mercury News* mentioned the 'mutual hatred' of Garriott's bulletin and a traditional almanac, and the *Farming* magazine called the Bureau's bulletin 'iconoclastic', declaring that 'this all means that the traditional ground hog, goose bone, changes of the moon, and other time-honored weather indicators as a matter of fact have nothing to do with the weather, and therefore must be eliminated from the calculations of the farmer who wants to be up-to-date'.[56]

To demonstrate that accurate weather prediction was a modern, rational, scientific practice, Moore conducted public verifications of the weather prophets he sought to expose as unscientific (but calculating) frauds. Moore illustrated both forecasting systems in a series of comparative charts published in the Weather Bureau's 1903–1904 annual report and in the *New York Times* in a December

54. 'Not Official Sharps', *Washington Post*, 12 Jul. 1904.

55. 'Scientist as Prophet', *Washington Post*, 3 Aug. 1902.

56. Garriott, *Weather Folk-Lore and Local Weather Signs*; 'Modern Weather Man Discusses Wise Saws', *San Jose Mercury News*, 20 Mar. 1904; 'Good-by to the Ground Hog', *Washington Post*, 4 Nov. 1906.

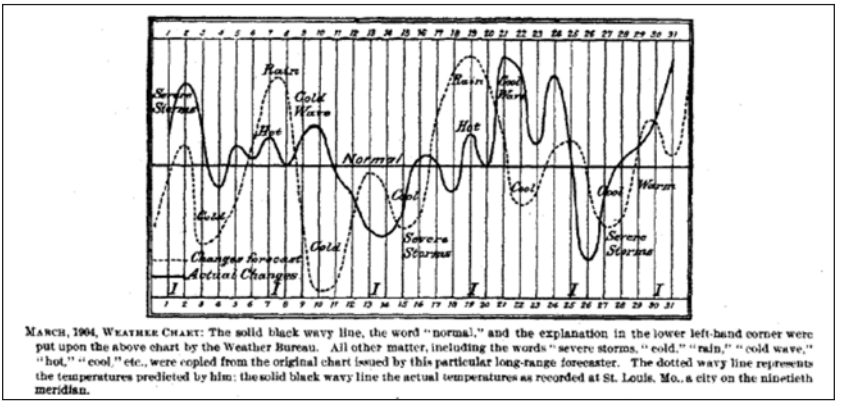
FIGURE 1. 'How "Fake" Weather-Forecasters Fool Farmers', *New York Times*, December 11, 1904.

The montage beneath the headline positions Willis Moore between an interior photograph of the well-equipped forecaster's office and the imposing edifice of the Weather Bureau headquarters. Weather prophets, almanac readers, and bird watchers – all discredited by Moore and the Bureau – are depicted, literally and figuratively, on the margins of professional meteorological science.

1904 article that featured his crusade against the self-taught weather prophets who operated outside the boundaries of professional scientific meteorology. (See figure 1.) Moore's charts, which the *Times* billed as the 'Humbug Exposed in Diagrams', compared predictive weather data to retrospective, superimposing the Bureau's recorded temperature variations for a given month on long-range weather predictions.[57]

The Bureau's annual report reproduced a weather chart sold by a popular long-range forecaster and superimposed the actual recorded temperatures for March 1904. (See figure 2.) Moore found much to fault in the weather prophet's work: a vertical axis without labelled temperature increments, a 'normal' horizontal axis originally printed as three separate lines (which Moore called 'another

57. 'How 'Fake' Weather-Forecasters Fool Farmers', *NYT*, 11 Dec. 1904. Moore was not the first to publish weather verification charts. In 1864, the British Board of Trade requested verification charts of former *H.M.S. Beagle* captain Robert FitzRoy's weather forecasts. Anderson, *Predicting the Weather*, 151.



MARCH, 1904, WEATHER CHART: The solid black wavy line, the word "normal," and the explanation in the lower left-hand corner were put upon the above chart by the Weather Bureau. All other matter, including the words "severe storms," "cold," "rain," "cold wave," "hot," "cool," etc., were copied from the original chart issued by this particular long-range forecaster. The dotted wavy line represents the temperatures predicted by him; the solid black wavy line the actual temperatures as recorded at St. Louis, Mo., a city on the ninetieth meridian.

FIGURE 2. Reprinted from Weather Bureau, *Report of the Chief of the Weather Bureau, 1903–04* (Washington: Government Printing Office, 1905), xv.

artifice of the long-range forecaster to avoid being specific'), and warnings of storms and high winds that never materialised. Moore based his charges on E. B. Garriott's extensive analysis of long-range forecasting that critiqued the prophets' 'storm periods', two- or three-day intervals in which they forecast storms in some locality. As Garriott observed, with a net cast so wide, both geographically and temporally, a storm was bound to occur somewhere and thus verify the forecast. This vague but invariably accurate system of 'storm periods', Garriott complained, 'admits no failures'.[58] Moore's charts depicted not only the failures but also the distinct boundary between short- and long-term forecasting, implicitly legitimising the former by explicitly discrediting the latter. Thus Moore's charts represented in visual terms the Bureau's self-fashioning as the institutional embodiment of professional scientific meteorology.

Not everyone within the Bureau agreed that its war on the long-range weather prophets was best waged in the press. At the 1904 Peoria convention, Bureau official J. Warren Smith argued that the Bureau's 'campaign of education' in the popular press and scientific journals was less effective than his method: visiting a local newspaper office with weather maps and long-range forecasts in hand to illustrate the greater accuracy and value of short-term forecasts and to persuade the managing editor to discontinue the long-range predictions. When Smith conducted his verifications, he did more than expose the ostensible quackery of long-range forecasting; he followed literally the Bureau's admonition that its officials 'will best service the public interest when they teach the communities

58. U.S Weather Bureau, *Report of the Chief of the Weather Bureau, 1903–1904*, xv–xvi; Garriott, *Long-Range Weather Forecasts*, 9.

they serve the limitations of weather forecasting'. The Bureau's conservative logic of forecasting persisted from the 1890s into the early years of the twentieth century: emphasising the accuracy of short-term forecasts while refusing to speculate about less certain long-term weather conditions. Still, despite Smith's and the Bureau's attempts to re-educate the public accordingly, demand for long-range forecasts remained high. As Smith recounted, a common response from the newspaper editors he tried to convert was that 'the public wants something of this kind; the Bureau does not furnish it and these long-range fellows do'.[59]

THE SCIENTIFIC BASIS OF LONG-RANGE WEATHER FORECASTING

On March 27, 1906, Willis Moore announced to the crowd at the Maritime Association dinner at the Waldorf-Astoria that the Weather Bureau was about to begin forecasting the weather a month ahead of time. Moore, who had just delivered an address on the history of the weather service, was ridiculed by a man at his table who mocked the Bureau's accuracy record. Moore stood up and retorted with this statement: 'The Weather Bureau believes that for the first time in the history of meteorological science it has within its grasp the scientific basis of long-range weather forecasting – that is forecasting of the character of the month to come'. The forecasting system was still months from operational, Moore allowed, but the Bureau had committed itself to an experimental program of monthly forecasts based on new sources of meteorological data: upper-air kite and balloon observations, isobaric charts spanning the northern hemisphere (based on telegraphed reports from an extensive network of stations), and possibly solar radiation studies. Observations of temperature, moisture, pressure, and wind direction and velocity at an altitude of one mile were telegraphed from the Mt. Weather meteorological research complex in Virginia to Washington daily beginning in June 1907.[60] Thus began the Bureau's shift from ground to air, away from its empirical focus on tracking and projecting observable surface conditions and toward exploration of the heavens for the secret to long-range forecasting.

Moore's announcement surprised the Waldorf-Astoria crowd in 1906 and immediately drew a storm of public scepticism, but behind the bluster of the Bureau's anti-prophecy campaign was a history of quiet experimentation with the theory and practice of long-range forecasting dating back to the last years of

59. US Weather Bureau, *Proceedings of Peoria Convention*, 43, 249; US Weather Bureau, *Report of the Chief of the Weather Bureau, 1903–1904*, xiii; US Weather Bureau, *Proceedings of Peoria Convention*, 248.

60. 'Forecasts for a Month', *NYT*, 28 Mar. 1906; 'Long-Range Weather Forecast', *Macon (GA) Daily Telegraph*, 30 Mar. 1906; 'Rival of Hicks', *Aberdeen (SD) Daily News*, 5 Apr. 1906; US Weather Bureau, *Report of the Chief of the Weather Bureau, 1907–1908* (Washington, DC: Government Printing Office, 1909), xiv–xv. Quotation in 'Forecasts for a Month'.

the nineteenth century.[61] At the 1898 Omaha convention, Bureau official Patrick Connor of Kansas City, Missouri, a neighbour of renowned long-range prophets W.T. Foster and Rev. Israel Hicks, explained his occasional success in long-range forecasting based on a theory of solar magnetism put forth by F. H. Bigelow, whose theoretical work had been curtailed by Secretary of Agriculture Morton in 1893. His colleague B. S. Pague of Portland, Oregon was more successful, having spent the last two years regularly making three- to seven-day forecasts that were used by farmers, fruit growers, boatmen, and shippers. Pague attributed his success to the northwest geography that yielded clearly delineated movements of high and low pressure areas across his region. Later in the convention, A. B. Crane of Pensacola, Florida echoed the Bureau's scepticism regarding the feasibility of long-range forecasts but allowed that local periodicities – repetitions in weather patterns over time for a particular region – occasionally made long-range predictions possible. But such a method was hit or miss, Crane stressed, and according to his deterministic vision of science, meteorology was not yet sufficiently developed to enable reliable long-range forecasts: 'Science is defined as consisting simply of the systematic arrangement of facts, and more facts are needed before the artist, however energetic or skilful, can unfold that intricate study, long-range weather predictions.'[62]

The science and art of long-range forecasting were combined in the most popular theory of long-range forecasting at the turn of the century, solar radiation, which drew upon traditional understandings of planetary meteorology as well as modern scientific study of astrophysics. The logic behind all sun spot and solar radiation theories was one of correlation: if terrestrial conditions and solar conditions were interrelated, then analysing periodicity in sun-spot cycles would enable long-range forecasting of a variety of terrestrial phenomena. The discovery of sun-spot periodicity drew great enthusiasm from scientific and popular publications, and some envisioned a kind of meteorological utopia in which sun-spot cycles would enable forecasting of far more than temperature and precipitation: 'magnetic and electrical conditions (including the aurora borealis), … barometric pressure, humidity, the winds, cloudiness … depth and quantity of discharge of rivers, retreat and advance of glaciers, number of shipwrecks, bank failures and commercial crises, the crops, prices of grain, famines, wars, and even flights of butterflies'.[63]

61. In response to Moore's Waldorf announcement, the *New York World* noted, 'Prof. Moore has the proud distinction of having missed the weather more often than any man of his inches. His guesses have kept the entire nation guessing.' 'Foster's Weather Bulletin', *Los Angeles Times*, 16 Apr. 1906. For criticism of the Bureau's long-range forecasting project, see 'Long-Range Weather Forecast', *Macon (GA) Daily Telegraph*, 30 Mar. 1906; Frank Waldo, 'Long-Range Prediction Impossible', *Boston Daily Globe*, 26 May 1907; 'Next Year's Weather', *Chicago Daily Tribune*, 27 Jan. 1907.

62. US Weather Bureau, *Proceedings of Omaha Convention*, 43–48, 157–60.

63. C. G. Abbot, 'The Relation of the Sun-Spot Cycle to Meteorology', *Monthly Weather Review* **30** (no. 4, 1902): 178–81, quoted in Garriott, *Long-Range Weather Forecasts*, 45.

The Weather Bureau's initial vision of long-range forecasting was far more modest, and, considering its vociferous critique of weather prophets in the first years of the twentieth century, its entry into the long-range forecasting business was surprisingly quiet. The Bureau first published general weekly, not monthly, forecasts on an experimental basis in April, May, and June 1908 and then made them a regular feature beginning in late March 1910, after the success of special forecasts like the one for Sunday, February 13, 1910:

> During the present week a general storm, followed by a cold wave, will cross the United States. The center of this storm will appear over the Pacific States within the next two days, cross the Rockies, Plains States, and central valleys during the middle days of the week, and reach the Atlantic seaboard by Friday. The cold wave promises to be rather severe. It will overspread the North Pacific States by Tuesday morning, the middle and northern Plains States and Central Valleys by Thursday, and reach the Atlantic seaboard by Friday or Friday night.[64]

The Bureau's forecast before this blizzard met a far more favourable public reception than Chief Signal Officer Greely's had in March 1888. One Oklahoma newspaper celebrated 'the remarkable accuracy' of the Bureau's long-range forecast and deemed it 'the story of a prediction and its fulfillment'.[65]

But despite such accolades, the Bureau's predictions for the week ahead were not substantively different from the long-range prophecies Moore and his colleagues had so fervently denounced six years earlier. As a subsequent assessment of long-range weather forecasting observed, the Bureau's weekly 'weather outlook' was not an actual forecast but rather 'a broad generalized statement'. A sample outlook for the North and Middle Atlantic states predicted, 'Period of snows over North and rains and snows over South portion about middle of week; temperatures near or below normal'.[66] The Bureau's weekly outlook was characterised by the same temporal and geographic uncertainty the Bureau had formerly condemned in the imprecise 'storm periods' of long-range weather prophets.[67]

Willis Moore did not earn nearly the same accolades as the weekly outlooks, and his tenure as Bureau Chief ended in political disgrace. He faced Congressional allegations (unproven) of improper spending in the Mt Weather, Virginia research complex, widespread and public critiques of his management style from numerous subordinates, an investigation by the House Committee on Expenditures in the Department of Agriculture in 1912 and the Secretary

64. US Weather Bureau, *Report of the Chief of the Weather Bureau, 1907–1908*, xiv; Hughes, *A Century of Weather Service*, 39-41; quotation in US Weather Bureau, *Report of the Chief of the Weather Bureau, 1909–1910* (Washington, DC: Government Printing Office, 1911), 16.

65. Quoted in US Weather Bureau, *Report of the Chief of the Weather Bureau, 1909–1910*, 16.

66. Robert DeC. Ward, 'The Present Status of Long-Range Weather Forecasting', *Proceedings of the American Philosophical Society* **65**, (no. 1,1926): 6.

67. Garriott, *Long-Range Weather Forecasts*, 8.

of Agriculture's rejection of his requests for increased appropriations the same year. Moore's ultimate undoing, however, came as a result of his overt political manoeuvring for the office of Secretary of Agriculture under the incoming Wilson administration. Moore nemesis Theron Akin of New York authored a House resolution that called for Moore to 'at the proper time receive the toe-end of Woodrow Wilson's copper-toed boot and be relegated to the political scrap heap'.[68] Akin's wish came true when President Wilson dismissed Moore on 16 April 1913, well before Moore's resignation was scheduled to go into effect on 31 July.[69]

Under Willis Moore's successor, Charles F. Marvin, the Bureau once again publicly denounced long-range weather forecasting as false and unscientific. The Bureau's investigations into the application of solar radiation and sun-spot periodicity to long-range forecasts, buttressed by leading opinions within the international meteorological community, found no definitive causal link between solar conditions and terrestrial climate and thereby relegated the sun to the unscientific realm of planetary meteorology and astrology. The moon, the planets, and now sun-spots and solar radiation were merely 'picturesque frameworks upon which to display weather forecasts for sale', the Bureau declared in a well-publicised bulletin in 1916.[70]

Although solar radiation theories passed in and out of vogue and debates over fraudulent long-range forecasting waxed and waned in the first third of the twentieth century, the scope of the Bureau's weekly forecast remained essentially unchanged until 1940, when the Bureau introduced a five-day forecast that was more specific than the previous weekly outlook. In 1950 the Bureau published thirty-day outlooks for the first time. The Bureau's monthly long-range forecasting hinged on three major advances in mid-twentieth-century meteorology: the emergence of Jacob Bjerknes's front theory in 1937, intensified long-range forecasting research during World War II, and innovations in mathematical atmospheric modelling in the mid-1960s.[71] But these developments notwithstanding, the problem of the long-range forecast – called a 'will-o'-the-wisp' in the late nineteenth century and an 'academic problem' in the early twentieth century – persisted, and Moore's war on the weather prophets echoed throughout the

68. *Resolution calling upon employees of the Weather Bureau to give evidence as to certain alleged irregular conditions existing therein and so forth*, HR 858, 62d Cong., 3d sess., 21 Feb. 1913, 5.

69. Whitnah, *A History of the United States Weather Bureau*, 117–28.

70. 'Forecasting of Weather is "Faked"', *Idaho Daily Statesman*, 30 Mar. 1916; 'Warning Against Forecasters', *Aberdeen (SD) Daily News*, 30 Mar. 1916; 'Denies Credit to Prophets', *Los Angeles Times*, 9 Apr. 1916; 'Fake Weather Prophets and Long Prognostications Taboo', *Columbus (GA) Ledger*, 19 Apr. 1916; 'Long-Range Weather Forecasts', *Scientific Monthly* **2** (no. 5, 1916): 519—20. Quotation in 'Forecasting of Weather is "Faked"'.

71. Hughes, *A Century of Weather Service*, 39–41, 69, 71, 138.

twentieth century, as government, academic and private long-range forecasters squared off time and again in debates over accuracy and authenticity.[72]

In 1904, at the height of Moore's anti-prophecy campaign, Professor C. M. Woodward concluded his refutation of weather prophet John H. Tice's forecasting theory of planetary equinoxes by declaring that his aim was to 'help clear the way for the coming of the true science of meteorology which the future certainly has in store for us'.[73] In his turn-of-the-century attack on long-range weather prophecy, Willis Moore did exactly that – 'clear the way" for modern meteorology. The Weather Bureau's entry into long-range forecasting acknowledged that its 'true science of meteorology', based on data from the upper atmosphere and the northern hemisphere, accommodated more uncertainty than did the empiricism of late-nineteenth-century meteorology, which based its short-term predictions on geographical projections of observable surface conditions.

Acknowledgment of the uncertainty of long-range forecasting was not confined to the Weather Bureau. The increased demand for weather insurance in the second and third decades of the twentieth century signalled a broader public awareness of the limitations of weather predictions. In 1892 a writer for the *Harrisburg Patriot* joked about the lucrative possibility of 'a weather insurance bureau' to aid planners of summer and winter recreational excursions.[74] By 1916 weather insurance was no longer a joke but a proposal by the US Office of Farm Management, which advocated a comprehensive insurance mechanism to effectively redistribute the economic risks that inclement weather posed to farmers.[75] The press reported widespread interest among the non-farming population as well, especially regarding rain insurance. In 1921 three companies sold rain insurance but, by 1925, the number had risen tenfold.[76]

In 1921 the Rogers Peet Company published an advertisement for a raincoat that also heralded the new legitimacy of weather insurance. The advertisement

72. 'Forecasting the Weather', *Omaha World Herald*, 25 Sep. 1892; Charles Fitzhugh Talman, 'Weather Forecasters Take On New Duties', *NYT*, 21 Nov. 1926.

73. C. M. Woodward, 'The Planetary Equinoxes – An Examination of Mr. Tice's Theory', in Garriott, *Long-Range Weather Forecasts*, 31.

74. 'Some Enterprising Individual', *NYT*, 7 Aug. 1892.

75. Weather insurance was common in Britain before it became well established in the United States. Tornado and hail insurance had been available in the United States since 1861 and 1880, respectively, but did not gain significant momentum until the second decade of the twentieth century. Frost insurance became available in the US in 1920 after an insurance industry survey revealed significant demand among citrus growers in Florida, California, and Louisiana. G. Wright Hoffman, 'Weather Forms of Insurance', *Annals of the American Academy of Political and Social Science* **130** (March 1927): 121—30.

76. William Gardner Reed, 'Weather Insurance', *Monthly Weather Review* **44** (no. 10, 1916): 575—80; 'Why Not Insure Crops Against Bad Weather?' *NYT*, 25 Mar. 1917; 'Wide Interest Felt in Rain Insurance', *NYT*, 27 May 1920; 'Topics of the Times', *NYT*, 28 May 1920; 'You Can Now Insure Your July 4 Outing', *NYT*, 27 Jun. 1920; 'Rain Insurance Grows Popular', *Los Angeles Times*, 10 Aug. 1921; 'Weather Insurance Takes Strong Hold', *NYT*, 14 Aug. 1921; 'New Insurance Covers Weather', *Atlanta Constitution*, 18 Aug. 1921; 'Let it Rain; What of It! I'm Insured, You Know', *Boston Daily Globe*, 11 Sep. 1921.

quoted the *Journal of Commerce's* estimation of such insurance as 'formerly regarded as a rather frivolous form of enterprise, [but] is now taking its place among the older and recognized forms of insurance'.[77] As the president of the Henry W. Ives Insurance Company observed in 1920, rain insurance – covering society garden parties, baseball games, horse races, boating companies, and Coney Island candy stands – represented 'an entirely new class of risk'.[78] To mitigate this new class of environmental risk, the Ives Insurance Company sold, beginning in the 1910s, 'Pluvius policies' to protect farmers, builders, sports fans, and outdoor recreation companies from getting financially soaked by an unforeseen rainstorm. The 'Pluvius policies' were not based on the Weather Bureau's short-term forecasts, however: clients had to buy policies at least a week before the event they wanted to insure since, as historian Kristine Harper reminds us, '[n]o one could predict the weather a week in advance'.[79] Companies selling rainfall insurance were essentially betting on the uncertainty of long-range forecasts, confident in their own ability to predict that no weather prophet – federal government forecaster or private citizen – would accurately predict the next week's weather.[80]

Just as the early twentieth-century insurance industry recognised that weekly weather forecasts belonged to a world of chance and not certainty, so too had the US Weather Bureau reimagined long-range forecasting as an inherently uncertain endeavour. The Bureau's culture of certainty in the 1890s – a climate in which Henry Helm Clayton was found guilty of mapping inaccuracies in a public trial and pronounced unfit to forecast – gave way in the early twentieth century to a culture of probability. Although the federal government introduced the 'Probabilities' of short-term twenty-four hour forecasts into daily life in 1870, the Weather Bureau did not acknowledge that predicting the weather was indeed a

77. 'What Better Policy than a Fair-Weather Overcoat of Rainproofed Scotch Mist!' *NYT*, 25 Jan. 1921.

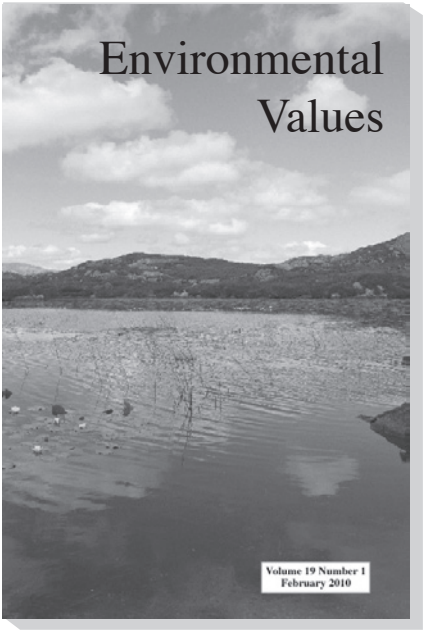
78. 'You Can Now Insure Your July 4 Outing', *NYT*, 17 Jun. 1920.

79. Kristine C. Harper, *Weather by the Numbers: The Genesis of Modern Meteorology* (Cambridge, MA: MIT Press, 2008), 19. As Harper reports, insurance companies used the Weather Bureau's long-term climatological data to calculate their own risk in issuing rainfall policies a week in advance (19–20).

80. The war years also saw a flurry of experimentation in crop insurance at the same time that demand for rainfall, tornado, and hail insurance steadily increased. By 1915 farmers were generally well-insured against fire, with almost two thousand farmers' mutual fire insurance companies carrying policies that totalled over five billion dollars, more than 40 per cent of the nation's farm property value that year. Hail insurance, available from two mutual insurance company providers in the early 1880s and 28 mutual insurance companies and five joint-stock companies by 1910, became much more prevalent in the 1910s, during the 'golden age' of American agriculture, until its coverage in 1919 totalled an unprecedented half a billion dollars. And in 1917 a few insurance companies introduced blanket coverage for farmers that was not tied to a particular kind of natural hazard but rather sought to mitigate the risk of unpredictable market prices. G. Wright Hoffman, 'Crop Insurance – Its Recent Accomplishments and Its Possibilities', *Annals of the American Academy of Political and Social Science* **117** (January 1925): 95, 111, 99–102.

probabilistic endeavour until the advent of its own long-range weekly forecasts in 1908. Such a reimagination of the nature of weather forecasting could not have occurred without the turn-of-the-century epistemological labour of the US Weather Bureau, and in particular Chief Willis Moore, to publicly discredit long-range weather prophets in order to construct its own institutional reputation and professional scientific authority. Ultimately the Weather Bureau's forecasting work came to accept the very indeterminacy it had formerly denounced as the failure of long-range weather prophecy, thereby rationalising uncertainty into its weekly outlooks and into its vision of modern meteorology.

Environmental Values



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ISSN: 0963-2719 (print) 1752-7015 (online), four issues per year.
Vol.20, 2011, approx. 144 pages per issue. **Includes ELECTRONIC ACCESS**.
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