

which mandated a phase-in of double hulls on oil-carrying vessels, beginning in 1995.¹²

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¹² For a full review, see Commission on Engineering and Technical Systems of the National Academy of Sciences (1998).

WEATHER

Myron P. Gutmann and Ben Tausig

Weather Research and Climatological Data

The data in Tables Cf286–569 represent a microscopic portion of the vast amount of data collected and preserved in the service of understanding and predicting the weather of the United States. The quantity and quality of the data have grown and improved over the past two centuries, thereby advancing knowledge of weather processes achieved by American and other scientists. The double goal of meteorologists and climatologists has been to understand current weather and climate, and to predict future weather and climate, for general scientific purposes and to contribute to the

overall social, economic, and political good of the United States. The mass of data that have accumulated are the consequence in large part of an institutional commitment by the U.S. government to support weather forecasting and science to ensure the quality of life of many Americans, including parents planning school day clothing for their children; farmers planning planting, irrigation, and harvest; and NASA planning its operations in space.¹

The early history of climatological recording in the United States was marked largely by guesswork and nonstandardized analytical techniques, although several trends in the nineteenth century helped to transform observation from casual study into the highly useful and practical science of meteorology. During those years, American settlers moving west in search of fertile farming territory relied increasingly on information about the weather in making decisions about where to settle. Although such information remained hit-or-miss for many decades, this process established a link between accurate weather data and successful farms.

In the United States, 1814 was the first watershed year in weather observation, as the U.S. Army Medical Department, in coordination with a small group of academics, began recording data at military posts. Previously such activity had been restricted to hobbyists and expeditioners such as Lewis and Clark. Thanks to increased interest from scientific communities and the government, by the middle of the century every state in the Great Plains and Western United States had at least one weather observation site.

In 1847, the Smithsonian Institution began a meteorological project that extended a network of observation across North America. This project, whose existence was catalyzed by leading meteorologists such as Elias Loomis and James Pollard Espy as well as Smithsonian director Joseph Henry, had long been a dream of scientists who surmised that weather observation could move drastically forward only through the work of a geographically broad and well-organized association of data recorders. With hundreds of observers, the Smithsonian network represented just such an organization, and indeed dominated weather data collection for nearly twenty years. Unfortunately, the Civil War and a building fire eventually ravaged the network irreparably. To the dismay of many scientists, in 1873 the U.S. Army Signal Office assumed control of the work the Smithsonian had previously done.

Despite increased scholarly and governmental attention to monitoring weather and understanding climatological issues, farmers and settlers remained generally uninformed. Folklore persistently acted as a crucial means of predicting and reacting to weather. The climatic volatility of the central and western United States further complicated this problem. Storms, floods, and freezing temperatures alternated with extended periods of drought and heat. Some scholars have even asserted that the mid-nineteenth century was a "little ice age," during which typically dry regions experienced increased precipitation and cooler temperatures. While more rain aided travelers along the Oregon Trail, it also contributed to widespread confusion about the nature of climate in the Western states. The inadequate work of the Signal Office led to misinformation and inaccurate forecasts. The scientific community criticized

¹ This review of the early history of American meteorology draws upon Whitnah (1961), Hughes (1970), and Fleming (1990).

the office for their poor research methods, and farmers had little reason to trust a poorly run government agency as opposed to a localized volunteer network.

Consequently, the government and meteorologists shifted to a state-level, farm-oriented approach to observing weather. The growth of western settlement and the need for farms gave meteorology a new importance. Which regions could be settled, and with what crops? How large and diverse should farms be? These questions hinged on accurate, regionally specific weather data and thus necessitated increasingly scientific methods.

Two major events of the 1890s altered the course of weather research in the United States. The first was the transfer of responsibility for government weather monitoring from the Signal Corps (formerly Signal Office) to the U.S. Department of Agriculture. This move signaled a strengthening of the ties between farming and meteorology. The second was the extended period of drought in the Great Plains, which forced a revision of certain inaccurate folk theories, such as the idea that cultivation and precipitation enjoyed a causal relationship.

In this period and immediately after, not only were measurements further standardized and instrumentation greatly advanced, but the functioning of the entire network of weather observation was also encouraged by the needs of industry. In the early twentieth century, commercial interests and local government worked together to avoid disasters such as crop failure or fire resulting from the lack of warning regarding weather phenomena. For example, the Weather Bureau aided farmers in the 1910s when it created reports on water availability and gave advance forecasts of fire hazards. Later, the growth of aviation provided a strong stimulus to the active development of meteorological reporting and forecasting, spurred by economic needs and by the opportunities for observation made possible by increased access to higher altitudes with balloons and aircraft.

At the turn of the twentieth century weather data were still backward by later standards, despite new levels of government intervention and the abandonment of archaic theories. The Progressive-era notion of dry farming, for instance, thought to be a means of combating drought, was ineffective despite its pretension toward a scientific basis. Such theories relied on pseudoscientific conclusions, suggesting that meteorology at the beginning of the century still retained many of its old problems. As the first half of the twentieth century progressed, however, scientific advances in meteorological science and in weather mapping and forecasting gradually brought improvements in the quality of forecasts and the strength of the underlying science.

Meteorology truly became an effective and practical tool after the Dust Bowl of the 1930s, when effective forecasting began and people began to realize the potential for human environmental impact. One of the weaknesses of the period between the two World Wars was the growing difficulty in dealing with the very large quantity of data that had begun to accumulate from regular daily (and sometimes hourly) observations at hundreds of weather stations throughout the United States. Only when data processing methods (initially punched cards) began to be widely used were scientists able to make use of more of the data that had been collected for so long. At first, these methods were extensions of earlier analog traditions of mapping weather and its progress across space and through time, but eventually digital processes were invented. (See Nebeker 1995, 1996; Cressman 1996; Kutzbach 1996; and Monmonier 1999.)

Numerical methods for studying weather phenomena had begun to be explored in the first decades of the twentieth century, but despite successes in identifying the role of mathematics in the study of weather processes, only slow progress was made until the advent of electronic computers in the 1940s. Then, led by innovators who saw the possibility of using computers to understand weather, and the possibility of using weather data and forecasting to advance the development of computers, matters changed rapidly in the late 1940s and early 1950s. Nearly all meteorology has become computational in the five decades since.

High-speed computing has given value to the large volume of numerical weather data that have been collected for the United States since the 1890s. Not only are they used to understand the past and to predict the near future, but they are also increasingly important in the effort to understand the risk of climatic change that most scientists believe exists today. In response to the need for continuous series of historical climatological data, the National Climatic Data Center has created the U.S. Historical Climatological Network as a digital record of the best and most representative data for the United States in the past century. Most of the climate data in this chapter are drawn from the USHCN publications. The products of USHCN and others have made possible the creation of data sets – such as VEMAP (Vegetation/Ecosystem Modeling and Analysis Project) – that allow the testing of competing models of climate change in the past and future. (See Karl, Williams, et al. 1990; Kittel, Rosenbloom, et al. 1995; and Kittel, Royle, et al. 1997.)

The temperature and precipitation measures that are included here represent a small portion of the information that is available and useful for the analysis and prediction of weather and climate. They are important because they allow those who study historical events, patterns, and trends to see local phenomena across the United States in great detail in the twenty-first century; in earlier times this was also possible but with lower resolution.

History of American Weather

A comprehensive history of American weather has not yet been written. One reason for this omission may be that the weather is not intrinsically a “national” phenomenon. The famous “year without a summer” in 1816 was attributable to the eruption of Mount Tambora in eastern Java, half a world away. The effect was felt in Western Europe and China as well as in the eastern United States, and is now thought to have interacted with a cooling cycle already underway for several years (Harington 1992). In our tables, the effect is observable only in the temperature and rainfall series for New Haven, Connecticut (series Cf556–557). Much more recently, the stormy seasons associated with the term “El Niño” are traceable to a warming of ocean waters off the coast of Chile (Changnon 2000). These effects are readily observable in the more abundant data available for modern times. See, for example, the extraordinary precipitation recorded for San Francisco in 1998 (series Cf563).

Furthermore, weather conditions and fluctuations within the United States are by no means uniform. On the basis of weather proxies such as tree rings, types of vegetation, amounts of snowfall as recorded in ice cores, and so forth, researchers have documented significant regional climate fluctuations over the centuries. The western part of the country went through a long hot spell

known as the Altithermal from about 7,000 years ago to about 4,500 years ago, after which temperature and rainfall settled into patterns similar to what they are today (Laskin 1996, p. 26). In recent times, the experience of global warming has been highly uneven. The Southeast is one of the handful of places in the world that have actually experienced cooling across the twentieth century, perhaps because of the increased presence of sulfate aerosols, changes in atmospheric circulation regimens, or changes in cloud cover (National Assessment Synthesis Team 2001, p. 29). In light of these divergences, any aggregation of rainfall and temperature figures into national averages is distinctly artificial.

But weather fluctuations in particular times and places have certainly played an important role in American history. The first general migration from New England to the Middle West occurred in 1817, immediately following the year without a summer. Evidently, this pattern persisted throughout the nineteenth century. Historians have documented an association between out-migration from Maine and unusually cold, wet summers (Smith, Born, et al. 1981, pp. 451–56).

Perhaps the most famous weather-based episode in American history is the migration of farmers onto the western Great Plains during the 1880s, on the basis of several years of unusually high rainfall. Developers promoted the theory that rainfall patterns could be favorably influenced by human settlement, summarized in the slogan “Rain follows the plow.” Although much of this was mere unscrupulous propaganda, Libecap and Hansen (2002) show that farmers at that time lacked reliable data on which to base their decisions. Instead, they learned the hard way from experience that western Kansas is normally too dry to support agriculture on a nonirrigated basis.

Some historians maintain, however, that the impacts of the weather on American life and activities have been greatly exaggerated. William B. Meyer argues that “The opposite is closer to the truth.” Meyer’s (2000, p. vii) complaint is that changes in the weather (the “less visible and less important sources of change”) have received far more attention than the social changes (changes “in plain sight”) transforming relationships between weather and society. For example, the shift from canals and rivers to railroads reduced the vulnerability of the country’s transportation to frost and snow. Improvements in transportation and distribution facilities have greatly diminished the impact of weather fluctuations on food and fuel supplies. Technological improvements, most notably air conditioning but also long-distance trade in water, have encouraged migration and development in areas previously considered inhospitable for human settlement. When the full history of American weather is written, in other words, it will have to acknowledge that interactions between activity and the weather have historically operated in both directions.

Nonetheless, the temptation is irresistible to use these abundant data to ask whether there have been long-term changes in American weather, most notably whether the country has in fact shared in the worldwide experience of global warming. Because systematically recorded temperature data are available only for modern times, however, students of long-term temperature trends are forced to compare proxy records with instrumental evidence. Such comparisons do show rising temperatures beginning in the late nineteenth century, roughly coincident with the rising volume of fossil fuel emissions. The same methods show that the pattern has been essentially similar for the United States, albeit with regional variations and even one regional exception in the Southeast (National

Assessment Synthesis Team 2001, pp. 21–31). Over most areas of the country, warming of more than 1 degree Fahrenheit has occurred, consistent with global averages. Warming has been greatest in the Northeast, the Southwest, and the upper Midwest, reaching as much as 3 degrees Fahrenheit in the northern Great Plains. Correspondingly, the number of days on which the temperature falls below freezing has dropped by about two days per year. Over the same period, precipitation in the coterminous United States has increased by 5 to 10 percent, which is broadly consistent with global changes in the midlatitudes.

Because these conclusions are derived from sophisticated statistical procedures, often requiring supplemental data to adjust for subtle geographic and climatological effects, no attempt is made to replicate them here. The scientific community has not yet reached full consensus on the causes of these warming trends; other possibilities include changes in solar radiation, a decline in the impact of volcanic eruptions, or a change in the linkage between the atmosphere and oceans. The most recent comprehensive assessment rejects these alternative possibilities and supports the conclusion that the primary causal factor has been the increasing concentrations of greenhouse gases and aerosols (National Assessment Synthesis Team 2001, p. 24). The weather information presented in the tables here will be useful for historians, but specialized scientific researchers will undoubtedly want to utilize more detailed sources of technical data.

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