MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 59, No. 1
W. B. No. 1036

JANUARY, 1931

CLOSED MARCH 3, 1931
ISSUED MARCH 31, 1931

THE EVOLUTION OF METEOROLOGICAL INSTITUTIONS IN THE UNITED STATES

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The object of this paper is to outline the stages in the growth of the organizations that have dealt with climate and weather in the United States of America and to present a chronological bibliography.

It should be noted that there has been mutual reaction of the growing institutions and the growing science of meteorology. The invention of the electric telegraph, after institutions and science were well founded, acted as a powerful catalyst, enabling the science to be effectively applied to the forecasting of storms and weather.

The settlement of the continent, gradually pushing the frontier westward, widened the field of observation. The Civil War marks an important turning point, from financial stringency to post-war inflation, which accounts for the diffusion of meteorological work among many institutions where it was scantily supported by eking out small sums from budgets intended for other purposes, before the war, and then afterward the quick development of a single relatively lavishly supplied institution.

Sir Napier Shaw (**68**, p. 1) argues that the change from horseback and stage coach to railways and from sailing vessels to steamers, as well as improvements in dwellings and clothing, caused people to lose interest in weather and to relegate it to institutions. On the other hand, is it not true that the size of atmospheric phenomena bars them from the scope of individuals, and even of institutions, like universities, that lack country-wide extent?

1753: In colonial times the only country-wide organization was the Post Office. Benjamin Franklin, appointed Postmaster-General of the Colonies, 1753, used his contacts with postmasters and shipmasters for research on progression of cyclones, and ocean currents (**47**, pp. 488–490), but his manner of publication nearly cost him all credit (**58**).

On April 2, 1814, amidst the war of 1812, James Tilton (1745–1822), revolutionary patriot, member of the Continental Congress, then Physician and Surgeon-General of the Army, directed hospital surgeons to record the weather (**49j**), (**1**). This was forgotten in the larger development of meteorological work that followed reorganization of the Army, April 14, 1818, by Secretary of War Calhoun, for whom the credit was claimed (**27**). The several chiefs of the Army Medical Department, who directed its meteorological service, were (**57**):

1813–1815. James Tilton, M. D. Physician and Surgeon-General.

1818–1836. Joseph Lovell, M. D., Surgeon-General.

1836–1861. Col. Thomas Lawson, M. D., Surgeon-General.

1861–1862. Col. C. A. Finley, M. D., Surgeon-General.

1862–1864. Brig. Gen. W. A. Hammond, M. D., Surgeon-General.

1864–1882. Brig. Gen. J. K. Barnes, M. D., Surgeon-General.

The Army Medical observations are especially valuable because they are the earliest available in the West. Long series of records were kept at a few fixed stations, but many posts were occupied for only a few years until the advance of the frontier carried them westward again. The meteorological organization terminated June 19, 1874, after which post surgeons sent their meteorological reports direct to the Signal Service and Weather Bureau. The results were published in four volumes (**2**), (**8**), (**21**), (**22**), and these were the basis of the climatologies of Forry (**12**) and Blodget (**25**).

The Surgeon-General's office cooperated with Espy's service, with the Smithsonian even to changing instruments and hours of observation (**16**, 1849, p. 14), with Paine in starting the meteorological work of the Signal Service (**32**), and with Myer in organizing that work (**33**, 1870).

1817: Josiah Meigs (1757–1822), Commissioner of the General Land Office, Interior Department (previously lawyer in Bermuda defending American vessels captured by privateers, professor of natural philosophy at Yale, acting president University of Georgia), asked money from Congress to equip land offices with barometers, etc. (**46**), (**49g**). Denied this aid, his bureau undertook a modest program of observations. The results, deposited with Meigs' papers in the American Institute of New York City, were placed in the New York Public Library, October, 1928.

1817: Heinrich Wilhelm Brandes (1777–1834), German meteorologist and mathematician, drew weather maps, invented isobars (1820), (isotherms had already been invented by Humboldt (**68**, pp. 260–261, 298)), discovered cyclonic wind circulation, rediscovered progression of cyclones, and proposed a meteorological service for the study of storms (**59** pp. 45–51), (**68**, p. 299), thus antedating many later claimants for these honors.

1825: Simeon DeWitt (1756–1834), Vice Chancellor of the University of the State of New York, previously Chief Topographic Engineer on Staff of General Washington in Revolution, also Surveyor General of New York, procured a grant from the state legislature, and organized meteorological observations at the Academies operated throughout the state by the Regents. Results were published in two volumes (**23**), (**36**), design and exposure of instruments studied. Joseph Henry (**39**), (**52c**) and James H. Coffin (**52a**) were trained in the New York service. Cooperated with Smithsonian from 1849 (**16**, 1849, p. 14). Appropriations ceased, 1863, and service mostly discontinued, on account of the Civil War.

1828: Heinrich Wilhelm Dove (1803–1879) and William C. Redfield (1789–1857) started debate on theory of tropical cyclones that afterward involved Espy and Loomis and led to important advances (**44**), (**68**, p. 296).

1834: James Pollard Espy (1785–1860), (**52b**), chairman of a joint committee of the American Philosophical Society and the Franklin Institute, of Philadelphia, established a net of observation stations to study storms. Four reports (**3**), (**31**) and numerous climatic tables were published. A weather map of the storm of June 19, 1836, in third report, based on observations at 18 stations scattered from Massachusetts to Ohio, shows the storm by wind directions only. The storm of March 16, 17, 18, 1838, in the fourth report, represented by a weather map based on observations at 50 stations covering the states east of the Mississippi, is shown by wind arrows, weather, and barometer readings, entered at each station, and by circles drawn around the centers of lowest pressure, at 12-hour intervals.

The committee obtained an appropriation of $4,000 from the Pennsylvania legislature (Laws of Pennsylvania, 1837, p. 73) to equip an observer in each county with barometer, thermometers, and rain gage. This quota of one observer per county, set up in 1837 as a goal to be attained, now stands as a limit that it is prohibited to exceed, act of August 30, 1890 (26 Stat. 371, 398.)

April 20, 1838; The first appearance of meteorology in the records of Congress is a memorial from the Pennsylvania Lyceum, instigated by Espy's committee, asking a national weather service (**4**).

December 18, 1838, Espy himself asked the Senate to offer awards in proportion to the result for rainmaking by burning woodlands (**5**).

December 20, 1839, the American Philosophical Society transmitted the request of the Royal Society, London, for cooperation with James Clark Ross's Antarctic Expedition by establishing five meteorological and magnetic observatories (**6**). John Quincy Adams (37, v. 10, pp. 211, 306), to whose committee this was referred, tried to attach these observatories to the survey of the northeastern boundary, but was voted down (**7**). Philadelphians supplied one observatory, at Girard College, with aid from the Topographical Engineers, United States Army (**17**).

1840: Elias Loomis (1811–1889), professor of mathematics and natural philosophy, Western Reserve College, Hudson, Ohio, published an important paper on storms (**9**) in which progressive movement was shown by mapping the trough line on successive days, a method afterward adhered to by Espy (**16** 1859, pp. 108–111). A second paper (**13**) shows the storm by isobars and isotherms, essentially as in present-day weather maps. Inasmuch as Brandes described but did not publish his isobaric maps of 1820, Loomis is entitled to great credit (**45**), (**59**), (**68**).

1840: Espy visited England and France to present memoirs to the British Association for the Advancement of Science and the French Academy of Sciences (**10**), where Arago, in his speech of introduction, bracketed Espy with Ampere and Newton.

1841: Espy's Philosophy of Storms (**11**) published, bringing convection and thermodynamics of moist air into meteorological science with their proper weight.

January 6, 1842: Espy appeared in Washington, determined to make a place for himself as national meteorologist. J. A. Adams, chairman of the Congressional committee on the Smithson bequest, records the interview in which Espy sought to have that bequest devoted to a national weather service with Espy as chief (**37**, v. 10, p. 65, v. 11, p. 52). Espy approached other influential politicians and secured a place as Professor of Mathematics, Depot of Charts, Navy Department (the germ of the present Naval Observatory and Hydrographic Office) which he held from May 7, 1842 to July 5, 1845, and another as clerk at $2,000 per annum in the Surgeon General's office beginning August 26, 1842. The item of $3,000 for meteorological work inserted by Senator Preston, of South Carolina, in the Army Bill (Act of August 23, 1842) had not created a position, hence Espy was soon attacked by watchdogs of the Treasury (**56**), pp. 507–511, but Espy enlisted powerful friends, including John Q. Adams, Jefferson Davis, Alexander H. Stephens (**40**), (**61**, p. 45), (**33**, 1883, pp. 586–588), whose tactics of inserting a rider in one appropriation bill after another, Army, Civil and Diplomatic, Naval, Legislative, Executive and Judicial, sufficed to afford him a salary of $2,000 every year until June 30, 1859 (**56**, p. 608), although Senator Pearce, of Maryland, was obliged to threaten a filibuster in the closing hours of the session to get it through on one occasion, and it was forgotten and the fiscal year 1847–48 not covered until 1852. Espy also applied his knowledge of air currents to the invention of a ventilator, which the Twenty-ninth Congress had him install on the chambers of both houses at not to exceed $250 each, and a relief bill to pay him $10,000 for the use of his ventilators on naval vessels appeared session after session.

Espy expanded the observing net that he had organized at Philadelphia in 1834 to a corps of 110 in 1842 and 1843, 50 having barometers. Increase A. Lapham became Espy's observer at Milwaukee, and his papers show daily observations tabulated on printed forms, mailed at the end of each month. These were addressed to the Surgeon General's office until August, 1849, afterward to the Navy Department. The printed forms of the Smithsonian were used beginning 1853. Espy and assistant, paid from his $2,000, extracted data, plotted them on daily weather maps, and returned the reports to the observers. Selected maps, graphs of the march of the barometer, and generalizations of the laws of storms, afforded material for four reports (**14**), (**20**), (**26**), the last of which had the distinction of being submitted to Congress as a Presidential message.

Espy and Henry had been fellow members of the American Philosophical Society at Philadelphia and came into close relations after Henry came to Washington as Secretary of the Smithsonian Institution in 1846. Espy and Loomis wrote letters in support of the meteorological part of Henry's program for the Institution (**18**); Espy signed with Henry a joint circular soliciting observers (**16**, 1851, p. 68); Espy enjoyed laboratory facilities at the Smithsonian (**26**). On the other hand, Henry procured an order from the Secretary of the Navy directing Espy to cooperate with the Smithsonian (**16**, 1848, p. 29) and claims that Espy was directed to apply to him for instructions (**16**, 1849, p. 14), and he was much interested in Espy's appropriation (**16**, 1849, p. 14), (**56**). However, the tenor of Espy's reports and of Bache's eulogy on Espy (**16**, 1859, p. 108–111) indicate that Espy attached little importance to such restrictions. The claim of Assistant Secretary Goode that "the memoirs of Professor James P. Espy on meteorology * * * were all prepared as part of the Smithsonian meteorological work" (**54**, p. 496) is discounted by the reports themselves. The first report was published and the material of the second and third, was gathered before the Smithsonian was organized. Espy's generalizations supplied one of the arguments for the memorial of Lapham (**32**) that finally resulted in the establishment of a national weather service 10 years after Espy's death.

July 1, 1842, Matthew Fontaine Maury (1806–1873) was assigned to charge of the Depot of Charts (Depot of Charts, 1830–1844; Naval or National Observatory,

1844–1854; Naval Observatory and Hydrographic Office, 1854–1866; Hydrographic Office separated, 1866) (**49b**), and began to collect and summarize ship's log-books, "Wind and Current Charts," published beginning 1846; organized International Marine Meteorological Conference, Brussels, 1853; published "Physical Geography of the Sea," first edition, 1854, fifteenth, 1874; proposed to collect weather observations from farmers as he had from sailors, and Senator Harlan introduced a bill to enable him to do so, 1856½ (**24**). Maury's wind and current charts enabled merchant sailing vessels to shorten voyages and were highly appreciated by merchants and underwriters. Those of New York City presented him a $5,000 silver service, 1853, and foreign potentates showered upon him medals and orders of nobility. He was elected to 45 learned societies, 20 foreign. He was not appreciated by his superior officials, who sought to retire him. He resigned, 1861, to throw in his lot with the Confederacy (**43**), (**69**), (**70**), (**71**).

1844. Morse and Vail demonstrated electric telegraph (**52e**), Washington-Baltimore, and established first commercial line, 1845.

1846. Redfield suggested telegraph for storm warnings, (**15**).

1847. First storm warnings, Barbadoes, Carlisle Bay from barometer at Bridgetown (**68**, p. 297).

1846: Smithsonian Institution (**49h**, **54**, **56**) organized under executive direction of Joseph Henry (1799–1878) (**39**), pioneer physicist, whose name is now borne by the unit of magnetic induction. He had been in contact with the meteorological work in New York and at Philadelphia (**56**, pp. 212, 257–263). His program for the new Smithsonian Institution (**16**, 1847, pp. 6, 13) contemplated climatological observations and telegraphic reports for prediction of weather and storms, but was greatly hampered by meager funds. The Regents appropriated $1,000 for meteorological work at the end of 1848, and a corps of 150 observers was organized and began reporting 1849. Their number increased, and they were augmented as Henry procured the cooperation of the Surgeon General's hospital surgeons, Espy's observers in the Navy Department, the New York Academy observers, and of observers at grammar schools and light houses in Canada. Henry stimulated the beginning of state weather services in Massachusetts (1849), Maine, Illinois (1855), Texas (1858). The number of observers rose to 616 just before the Civil War, and reached 599 again in 1869. Suspension of payments by the First National Bank of Washington, in the panic of 1873, tied up the working funds of the Smithsonian and compelled Henry to ask the Signal Service to take over the Smithsonian observers, and this was done February 2, 1874 (**33**, 1874, pp. 88–89, 286–287).

Henry cooperated with the Commissioner of Patents, then in charge of government work in agriculture, prepared reports on the relations of meteorology to agriculture in exchange for the franking of observers' reports and the publication of observations at Government expense (**16**, 1855 pp. 26–28), (**30**). The title of the latter publication is misleading in suggesting that observations were made under the direction of the Patent Office. This cooperation suddenly ceased at the death of Patent Commissioner Mason, 1860, (**16**, 1850, p. 34), but on creation of the office of Commissioner of Agriculture, 1862, similar relations were established (**16**, 1863, p. 32). Results were published (**30**), (**35**). Lorin Blodget, climatologist, was employed to prepare the first (**16**, 1854, p. 25), but "set up such claims to a personal right of property in it" (**16**, 1855 p. 19) that it was taken away and given to Prof. J. H. Coffin, of La Fayette College (**52a**), who, followed by his son, performed many valuable services for the Smithsonian and for meteorology. The later volumes were prepared by C. A. Schott, of the Coast and Geodetic Survey.

1848: Jones & Co. (John D. Jones, agent, later vice president, and president to 1895, Atlantic Mutual Insurance Co., marine underwriters), Merchants Exchange, New York City, advertised "daily and hourly telegraphic meteorological reports" (**19**). Compare Francis Galton's Weather Map Company (**68**, pp. 306–308).

June 14, 1849: James Glaisher started first telegraphic weather reports for London Daily News (**68**, p. 302).

August 8, to October 11, 1851: Telegraphic weather maps lithographed and sold at a penny each, at the Crystal Palace Exhibition, London (**59**, p. 64), (**68**, p. 302).

November 14, 1854: Storm in Black Sea, during Crimean War, enabled Leverrier, discoverer of the planet Neptune, to procure Emperor Napoleon's consent for first national telegraphic weather service, beginning February 17, 1855, in France; extended over Europe, 1857; published daily bulletin, 1858; issued storm warnings, 1860 (preceded by Buys Ballot in Holland by a few months); published daily isobaric weather maps from 1863 (**59**), (**68**).

1857: Smithsonian telegraphic weather observations, arranged with presidents of telegraph companies in 1849 (**16**, 1850, p. 14), begun along lines New York to New Orleans and Washington to Cincinnati (**16**, 1857, pp. 26, 27). Weather reports published in "Evening Star" and exhibited to visitors to Smithsonian by hanging pieces of colored card on iron pins fixed in a map (**16**, 1858, p. 32); later these cards were cut into disks bearing arrows to show wind direction also, and were oriented by hanging from one of eight holes (**16**, 1869, p. 50). Compare this device with maps of Brandes, 1820, and Loomis, 1843.

Henry predicted weather for his own use in planning lectures and reported results to a scientific society (**28**), (**55**). These observations were crowded off the wires by war business in 1861, temporarily resumed 1862 (**16**, 1862), and contemplated again 1867 (**16**, 1867, p. 28.) Arrival of the French maps and beginning of weather services throughout Europe and in Turkey and India inspired Henry to urge in his annual reports (**16**, 1865, pp. 56–59) the establishment of an American national weather service. In spite of the presence of three senators and three representatives on the Board of Regents of the Smithsonian Institution, no action was taken to place Henry's recommendations before Congress (**56**).

The contributions of the Smithsonian to meteorology were listed by Henry (**16**, 1871, pp. 43, 57) as follows: Inaugurating the climatological observations which have been in operation upward of 20 years, introduction of improved instruments, publication of extensive series of meteorological tables, reducing and publishing material from all records since the first establishment of the country, showing the practicability of telegraphic weather signals, publishing Arctic observations, publishing special records, memoirs on meteorological subjects, diffusion of knowledge of meteorology through correspondence, urging upon Congress the establishment of a meteorological department.

1857: Capt. George Gordon Meade, Superintendent of the Survey of the North and Northwest Lakes, Corps of Topographical Engineers, United States Army, commander in chief of the Union army at the battle of Gettysburg, began meteorological observations at 25 stations on the Great Lakes. Results were published at Detroit and in reports of the Chief of Engineers (**29**), and manuscript

records forwarded to the Smithsonian. This service ceased 1872–1876 as the Signal Service extended over the same area.

September 1, 1869: Cleveland Abbe (1838–1916), director of the Cincinnati Astronomical Observatory, organized daily telegraphic reports from cities in the Middle West, and published a weather map with the support of the Cincinnati Chamber of Commerce for three months (**34**), afterward at Abbe's own expense for six months. Meantime, in February, 1870, Manager Armstrong of the Cincinnati office of the Western Union Telegraph Co., through whose hands Abbe's reports were received, started a similar publication, with which Abbe merged his efforts in May, 1870. This later publication, copies of which survive (**67**, p. 25) and in Lapham papers in Wisconsin Historical Society, exhibit the weather by discrete symbols and figures for weather, wind direction, and temperature, but no barometer readings, isobars, isotherms, nor weather predictions. Compare maps of Brandes, 1820, Loomis, 1843, and Paris Observatory, 1863. On July 20, 1869, Abbe and his friends organized a meteorological society, the Western Meteorological Association.

1869: Daniel Draper (1841–) organized the municipal meteorological observatory in Central Park, New York City, now operated by the United States Weather Bureau. Draper devised many automatic instruments for the observatory, which have also found use in industry.

1869, December 8: Increase A. Lapham (1811–1875), Quaker, philanthropist, naturalist, meteorological observer for Espy, Smithsonian Institution, Lake Survey, and Abbe, sent a memorial, "Disasters on the Lakes", (**32**), to Gen. Halbert E. Paine, Member of Congress from Lapham's home district at Milwaukee. This memorial enumerated the losses of sailors and ships on the Great Lakes in the storms of 1868 and 1869, cited Espy's laws of American storms, and Leverrier's successes in giving warning of European storms. This scientific, humanitarian, and economic appeal, the solidarity of Congress, then filled with Union officers accustomed to work together, contributed to Paine's success in procuring the passage of the Act of Congress, February 9, 1870 (16 Stat. 369), directing the Secretary of War to take meteorological observations and give warning of the approach of storms. On February 28, 1870, the Secretary of War assigned this duty to the Chief Signal Officer (**33**, 1870, p. 16), an office that originated June 27, 1860, when Asst. Surg. Albert J. Myer was appointed Major and Signal Officer to develop a system of military communication that he had invented (**51**). Although he had not held that office continuously, Myer was Chief Signal Officer in 1870 when the meteorological work was authorized by Congress, and Paine states (Lapham Papers) that Myer secured its assignment to his administration, where it was designated the "Division of telegrams and reports for the benefit of commerce." Sketches of the Signal Service (**41**), (**46**), (**52***a*) and of the Weather Bureau (**66**) are available, so that only a few points will be given here.

The initial appropriations for meteorological work by the Signal Service were: Year ending June 30, 1870, $15,000; 1871, $50,000; 1872, $102,451; 1873, $250,000. These figures do not include pay or allowances of officers and enlisted men. The total appropriation exceeded a million dollars in 1884 and 1885, and was mostly expended on meteorological work.

Observations commenced November 1, 1870. The first forecaster was Increase A. Lapham, "assistant to the Chief Signal Officer," stationed at Chicago, with supervision over the signal service on the Lakes until the close of navigation, 1870, who issued the first storm warning at noon, November 8, 1870. Lapham drew isobaric maps such as forecasters use to day (**33**, 1871. pp. 7, 167–172, and 15 charts).

In order to enlist state aid in distributing agricultural warnings and to collect agricultural and climatological observations, State Weather Services (**49 d, e, 50**) were organized from 1883 onward by Lieut. H. H. C. Dunwoody, who had suggested them in 1881 (**41**). In October 1895 control of these services passed from the states to the United States Weather Bureau, and with the "voluntary observers" of the Smithsonian net were then merged in the Climate and Crop (now Climatological) Service of the Weather Bureau.

Beginning about 1884, agitation for conversion of the meteorological service into a civilian bureau brought a series of bills before Congress. The Act of October 1, 1890 (26 Stat. 653), introduced by Senator William B. Bate, of Tennessee, effected the transfer to the Department of Agriculture. The magnitude of the change is best seen by comparing the expenditures of the Signal Corps before and after the change on June 30, 1891: 1891, $753,284.70; 1892, $31,697.62. The chiefs of the meteorological service, with dates of appointment have been:

July 28, 1866: Brig. Gen. Albert J. Myer (1828–1880).
December 15, 1880: Brig. Gen. William B. Hazen (1830–1887).
March 3, 1887: Brig. Gen. Adolphus W. Greely (1844–).
July 1, 1891: Mark W. Harrington (1848–1926).
July 4, 1895: Willis L. Moore (1856–1927).
August 4, 1913: Charles F. Marvin (1858–).

Published results are considerably too numerous to mention, but summaries of summaries will be found in Bulletins Q and W of the Weather Bureau and in the Atlas of American Agriculture. The publications of the Signal Service and of the Weather Bureau have been listed (**48**), (**63**).

1884–1896: The New England Meteorological Society, W. M. Davis, secretary, was organized to operate the state weather service as a unit for New England (**42**), (**53**). It also functioned as a scientific society, holding meetings, and by cooperative investigation of sea breeze, thunderstorms, etc. Meetings and papers were reported in the American Meteorological Journal, results in Publications of Harvard College Observatory.

1884: Abbott Lawrence Rotch (1861–1921) founded Blue Hill Meteorological Observatory, primarily for research on clouds, instruments, and upper air observations with kites and balloons, the latter extended, 1905, to the trade-wind region of the Atlantic in cooperation with Teisserenc de Bort. Rotch was active in support of the New England Meteorological Society and the American Meteorological Journal. Since 1912 the observatory, bequeathed to Harvard University has been directed by Alexander McAdie, former official of the United States Weather Bureau. Among Blue Hill meteorologists are H. H. Clayton, S. P. Fergusson, C. F. Brooks, A. H. Palmer (**62, 73**). Results published in Annals of Harvard College Observatory and Publications of Blue Hill Observatory.

1917: The World War brought into existence the Meteorological Section, Signal Corps, United States Army (**64**), and the Aerographic Section, United States Navy (**65**).

1919: The American Meteorological Society, C. F. Brooks, secretary, open to meteorologists throughout North and South America, was organized (**72**).

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1860	1079	1	253
1861	1118	1	95
1862–63	1184		201, 491
1866	1285	1	414
1867	1325	1	
1868	1368	1	
1869	1413	1	

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SOIL TEMPERATURES IN THE UNITED STATES [1]

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By writing to all the agricultural experiment stations and examining the available literature on the subject, soil temperatures for 32 stations in the United States have been obtained. Only the very cordial cooperation of the agricultural experiment stations, the library of the United States Weather Bureau, and certain individuals has made possible the collection of the data. The stations, though few in number, are fairly representative of the country as a whole.

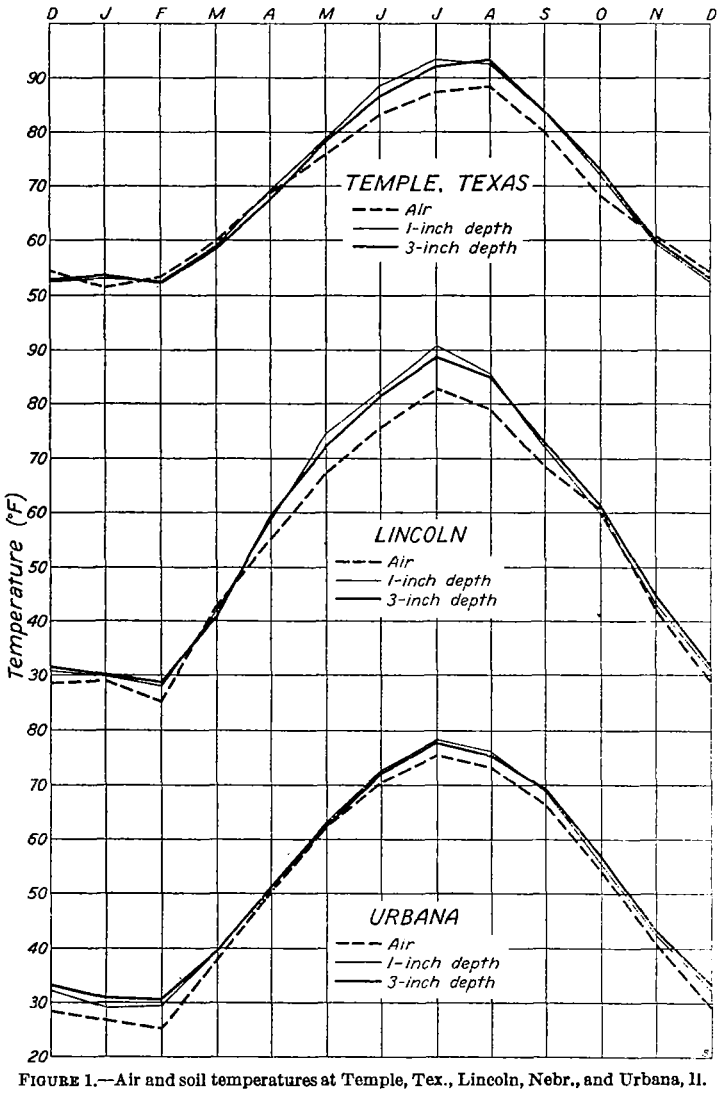

FIGURE 1.—Air and soil temperatures at Temple, Tex., Lincoln, Nebr., and Urbana, Ill.

Many variations in the conditions under which the soil temperatures were taken occur. In general, the experiment stations obtained soil temperatures not because of interest primarily in the temperatures themselves, but to determine the extent to which the temperatures were favorable or unfavorable for an important local crop or for bacteria harmful or helpful to that crop. Thus the thermometers were often placed at the depth at which the seed would be planted, so the depths for the different stations vary considerably. Also, because the interest was chiefly in connection with crops, records were often taken only during the growing season instead of throughout the year. Soils such as clay, loam, sand, peat, etc., are indicated; soil covers are various—bare, cultivated, sod, orchard, tobacco, cotton, mulches, etc.; exposures noted at different stations indicate variations between hillsides and bottom lands, dry soil and wet soil, shade and sun, etc. The accompanying table of soil temperatures indicates these variations where possible; it will be noted that some stations make no specification whatever as to the soil, soil cover, or exposure at the place where the soil thermometers were placed. In cases where temperatures of several kinds of soil or soil cover or exposure were recorded at one station, all of the data are included in the table for purposes of comparison at the station itself.

The material was sent to the authors in many different forms—some of it had already been published; some was in the form of graphs from which the desired temperatures could be read; in many instances the original thermograph records were sent and readings and tabulations were made from them; often a letter from an official of the station indicated all the soil temperatures that the station had available. Where possible, the temperatures in the tables were obtained by averaging the mean daily maximum and mean daily minimum temperatures for each month.

It is very apparent that the soil temperatures obtained for the 32 stations are by no means uniform—variations occur in the years, months, or days of record, the method

[1] Based on a paper presented before the Association of American Geographers at Worcester, Mass., December 29, 1930, by Edith M. Fitton.