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U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

REPORT

OF THE

CHIEF OF THE WEATHER BUREAU

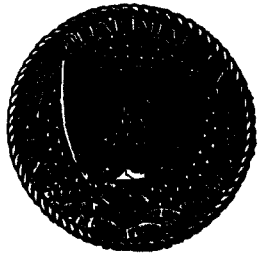
FOR

1898.

BY

WILLIS L. MOORE.

[From the Report of the Secretary of Agriculture.]



WASHINGTON:
WEATHER BUREAU.
1898.

National Oceanic and Atmospheric Administration
Report of the Chief of the Weather Bureau

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REPORT OF THE CHIEF OF THE WEATHER BUREAU.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., September 19, 1898.

SIR: I have the honor to submit a report of the operations of the Weather Bureau during the fiscal year that ended June 30, 1898.

Respectfully,

WILLIS L. MOORE,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

NEW WORK AND SPECIAL INVESTIGATIONS.

Extension of West Indian hurricane service.—During the latter part of the fiscal year it became apparent that the methods of gathering information of the approach of West Indian hurricanes, which served so admirably when warnings for the Gulf and Atlantic coasts only were issued, were wholly inadequate for a service that should cover the waters of the West Indies, in which upward of 200 naval and transport vessels of the United States were operating. The presence of this large fleet in the hurricane region made it imperative that precautionary measures, looking to its safety in time of severe atmospheric disturbances, be adopted at once. Accordingly a bill was drafted and submitted to Congress on June 16, 1898, authorizing the Bureau to establish and operate observing stations throughout the West Indies and along the shores of the Caribbean Sea. The provisions of the measure were incorporated in the general deficiency bill, which it will be remembered, did not become law until after the close of the fiscal year that ended June 30, 1898.

At that time, however, arrangements had been made to establish stations for making meteorological observations and displaying hurricane signals at the following points: Kingston, Santiago de Cuba, Santo Domingo, St. Thomas, Barbados, Port of Spain, Curaçoa, and Barranquilla. At the above-named places observations will be made twice daily and cabled to Kingston and the Central Office in Washington. It is expected that twice-daily observations will also be cabled from Martinique through the cooperation of the French meteorological service of that island.

The Weather Bureau will receive, when the West Indian service is fully established, twice-daily telegraph reports, not only from the stations above named, but also from Habana, Nassau, Vera Cruz, Tampico, Coatzacoalcos and Merida through international comity, and the voluntary cooperation of private persons. For daily reports from Habana our heartiest acknowledgements are due to Prof. Louis G. Carbonell, Superintendent Naval Service of the Antilles; from Nassau, to His Excellency Sir Ambrose Shea, Governor of the Bahamas; from Vera Cruz, Tampico, and Coatzacoalcos, to the Mexican Telegraph Company; from Merida, to a private observer, Señor Felix Gomez Mendicuti, C. E. The action of Professor Carbonell in forwarding daily weather reports from Habana during the period of hostilities between Spain and the United States is exceptionally gratifying to the officials of the Bureau as it must also be to scientists the world over.

A thorough inspection of the three stations of the Mexican Telegraph Company was recently made by an official of the Weather Bureau. As a result the service was much improved and the system of observation brought into much closer harmony with our own.

Thus it will be seen that ample provision has been made to extend the network of existing stations to the southward so as to include all of the dangerous waters of the West Indies, the Caribbean Sea, and the Gulf of Mexico.

Although the protection of our naval forces was the primary object in the extension of the storm-warning system to the West Indies, other considerations of scarcely less importance made the step a wise and beneficent one. First and foremost of these was the very material strengthening of the storm-warning system of the Gulf and South Atlantic coasts that would result from an extension of observing stations to the northern coast of South America; second, the improvement in the existing service that would follow the substitution of skilled observers for special agents in the West Indies; and, finally, the need of an efficient storm warning service for the benefit of commercial interests throughout the West Indies and on the shores of the Caribbean Sea.

If, as now seems probable, the exigencies of war permit the removal of the greater part of the fleet from West Indian waters, the meteorological service will still serve a useful purpose in the protection it will afford to the growing commerce of that very extensive region.

Meteorological Service of the Republic of Mexico.—I am informed by Señor Mariano Bárcena, Director of the Central Meteorological and Magnetic Observatory of Mexico, that steps have been taken to thoroughly equip about 30 stations in the Mexican Republic with meteorological instruments of the most approved pattern, and to establish a meteorological service similar to our own, at the earliest

practicable date. An exchange of reports between the two services that will be mutually advantageous, especially as regards the approach of West Indian hurricanes and "northers" in the Gulf of Mexico, will doubtless be effected.

Establishment of additional Observation Stations in the arid and subarid regions of the West.—The places of observation in the arid and subarid regions of our country have been so widely separated hitherto that it has not been possible to secure a perfect survey of the distribution of temperature and pressure, the conditions so essential to the making of accurate forecasts, not only for those regions, but for the extensive area farther to the eastward. On the recommendation of the Honorable Secretary of Agriculture, an appropriation was made by the last Congress for an increase in the number of stations in the above-named regions. Provisions have already been made for the installation and equipment of stations at Kalispell, Mont.; Boise City, Idaho; Mount Tamalpais, Cal.; Flagstaff, Ariz.; and Fort Worth, Tex. Arrangements have also been made for the establishment of additional stations in the South and Central Valleys, as follows: Meridian, Miss.; Macon, Ga.; Lexington, Ky.; Elkins, W. Va.; Evansville, Ind., and Escanaba, Mich. The additional stations thus provided for will not only assist in the development of agricultural and industrial interests in the respective States in which they are located, but will also be of material benefit in improving the warnings and forecasts, especially for the regions west of the Rocky Mountains.

International cloud observations.—The series of observations undertaken in cooperation with the International Cloud Committee, extending over one complete year, was concluded on June 30, 1897. It embraced observations on the height, azimuth, and velocity of motion of clouds at Washington as a primary station, and at 14 secondary stations in the States east of the Rocky Mountains, except a half year at Baker City, Oreg. The computation and the discussion of the observations have been going on during the past year, and are so far advanced that it has been possible to prepare several chapters of the final report. It is hoped that this portion of the work may be completed by the end of the year 1898.

Among the results obtained in connection with these observations may be mentioned the construction of a fundamental set of constants and formulæ in the barometry and thermodynamics of the atmosphere; the application to the reduction of the pressures on the Rocky Mountain Plateau of some new data; the delineation of the great atmospheric currents in several levels above areas of high and low pressure, respectively; the construction of the purely cyclonic and anticyclonic components which indicate quite clearly the structure of storms; the distribution of the eight types of clouds in height and

the velocity of their movement in high and low areas, respectively; a careful discussion of the vertical gradients of temperature, humidity, and pressure, besides many minor points of scientific interest and value.

Aerial work.—The work of producing a thoroughly satisfactory kite was begun in the latter part of 1895. The early experimental work naturally took a wide range. Various forms of kites were devised and thoroughly tested, and many valuable laws relating to the strength and efficiency of kites were developed. At the date of last report a fairly satisfactory kite had been developed, but much still remained to be done in order to make the appliances and devices improvised during the experimental work suitable for permanent use in the hands of observers of only average skill and experience. The kite finally adopted for practical work was an improved form of the Hargrave cellular type, both theory and practice having indicated the general superiority of this type over all others where power, efficiency, structural strength for a given weight, and durability are to be considered. A popular idea prevails that any one possessed of a few materials and a little ingenuity can construct a thoroughgoing kite. This is not true as regards the present Weather Bureau kite. The size and construction of every detail have been worked out with reference to the several strains at the different points, securing thereby the maximum strength with the minimum weight. Another desideratum of not less importance is a device that will enable the kite to automatically adjust itself in all winds so as to pull a moderate amount only. This result, it is believed, has been secured to a greater degree in the Weather Bureau kite than in any other form yet described. There is still need of improvement in the present design, but it is doubtful if such can be secured until we understand more completely than at present the precise nature of the sheltering effect the forward cell exerts upon the rear cell. This and other important details still remain obscure and undeveloped. Little or nothing was done during the past year to remove these obscurities, since the whole time was occupied in preparing for practical work. Briefly stated, the latter consisted in perfecting a complete working outfit of aerial apparatus based on the results of previous experimental work. Little difficulty was experienced in constructing a satisfactory reeling apparatus with its dynamometer, measuring dial, and graduated arc. Likewise the improved nephoscope devised by Professor Marvin in 1896, answered satisfactorily as an alt-azimuth instrument. A suitable form of automatic register for recording temperature, pressure, humidity, and velocity of the wind was not, however, to be had of the manufacturers of meteorological instruments. A form of instrument had previously been devised, but it was not satisfactory in all respects. Under these circumstances a wholly new form of kite meteorograph, recording four

elements, viz: wind velocity, temperature, pressure, and humidity, was devised by Professor Marvin. The instrument complete weighs 2.1 pounds. A special construction was adopted for the thermometers securing an unusually high degree of sensitiveness. The thermometers are, in fact, nearly or quite as sensitive as our standard mercurial thermometers. This quality is especially necessary in a kite meteorograph, since the elevation of the kite is almost constantly changing, often considerably, and a sluggish thermograph will not show the temperature at a given spot correctly.

Another important feature in the improved meteorograph consists in the exposure of the thermometer bulb and hygrometer. These are placed inside a long tube, 2¼ inches in diameter, open at both ends, and so arranged upon the kite that the wind blows with full speed directly through the tube, thereby affording not only the most perfect ventilation of the instruments contained, but screening them at the same time from radiation. The tube is wholly inclosed within the case of the instrument, from which it is insulated, in the heat sense, by plates of ivory and rubber. Arrangements of this character have repeatedly been shown to be necessary in order to secure accurate results in the free air.

At the date of last report it was hoped to establish at least 20 stations during the coming fiscal year. We have been able, however, to completely equip but 16, as follows: Cairo, Ill.; Cincinnati, Ohio; Cleveland, Ohio; Dodge City, Kans.; Dubuque, Iowa; Duluth, Minn.; Fort Smith, Ark.; Knoxville, Tenn.; Lansing, Mich.; Memphis, Tenn.; North Platte, Nebr.; Omaha, Nebr.; Pierre, S. Dak.; Sault Ste. Marie, Mich.; Springfield, Ill.; and Topeka, Kans. Washington, D. C., was already equipped at the beginning of the year.

The observers chosen for the work were, with three exceptions, drawn from the list of eligibles on the register of the Civil Service Commission; the three additional men being drawn from the force at stations. All these men were called to Washington and given a practical course of instruction in the art of flying and managing kites. The whole period of instruction extended from the 17th of March to the 18th of April, but the same observers were not in attendance for the whole period.

The contractor for furnishing the meteorographs was seriously delinquent, and caused great delay in beginning the observations; many stations made ascensions without meteorographs for two or three weeks, and all stations were not fully equipped until the first week in June.

If each station had made an ascension daily during June, 510 ascensions could have been made; whereas, 278 actual ascensions were made, in each of which the elevation attained exceeded 1,000 feet.

Considering the great natural obstacles in this work, and the fact that June is one of the least windy months of the year, we are disposed to regard the number of ascensions made as, on the whole, a satisfactory percentage (54) of those possible. It is regretted that similar data as to the percentage of ascensions that can be made during windy seasons of the year are not also available at this time.

The standard kite employed contains about 68 square feet of supporting surface, and only one of these kites is required at a time. The practice adopted by some investigators of flying several small kites in tandem in order to gain power enough to sustain instruments proved to be much less satisfactory, on the whole, than our own practice of using one large kite. The latter is far easier to manage in critical situations, and also under unfavorable conditions of flight; it is, moreover, more efficient. Originally, each station was supplied with two of the large kites. Subsequently, additional kites were sent out in a few cases to replace those wrecked and rendered completely unserviceable by accidents. As yet, too short a time has elapsed to furnish data for a satisfactory estimate of the average life of a kite; this may prove to be something like six months, while we are not yet able to determine the probable losses of wire and meteorographs. The practice adopted of suspending the meteorograph within the kite structure completely shields it from injury in ordinary work with the kite. Notwithstanding numerous small, and a few serious accidents to the kite itself, the meteorographs have, thus far, completely escaped injury, often in a seemingly remarkable manner. In one case, with 12,000 feet of wire out, the kite was struck by lightning, fusing the wire and setting the kite adrift. Both the kite and the meteorograph were discovered the second day afterwards 20 miles away. The kite was but little injured, and the meteorograph was still running. In another case the kite broke away at great elevation and soon disappeared from sight. The most careful search failed to discover a trace of its whereabouts, and it was given up as lost, either in the waters of adjacent lakes or the somewhat more distant Canadian forest. About three weeks later the meteorograph was found, and returned to the Weather Bureau having suffered only such injury as resulted from long exposure to the weather.

As a result of the year's work 16 stations have been completely equipped, and the observers have already had the experience necessary to fit them for the more onerous work of the fall and winter months. We are now in a position, so far as means and appliances are concerned, to obtain a complete series of observations. It is yet too early to express an opinion as to the value of the observations already secured in the practical work of the Bureau. The observations contain much information that is new and of practical importance, aside from their value in making weather forecasts.

The problem of connecting barometric observations made on the Rocky Mountain plateau with those of low levels on either side will, in all probability, receive substantial aid from kite observations. The chief difficulty in this problem, heretofore, has been a lack of exact information respecting the temperature and moisture of the air column that would exist between the plateau station and sea level if the plateau were removed. It happens not infrequently that the temperatures a mile or more above sea level are not much less than on the plains in the same latitude near sea level. Applying a correction to these temperatures based on the present accepted rate of decrease of temperature with altitude gives a result generally too high to correspond with temperature on each side in the same latitude at sea level. It is expected that the kite observations will add largely to our knowledge of the temperature gradients aloft, and thus contribute to the solution of the problem of reducing barometer readings on the plateau to sea level. Anything that will remove the uncertainty that at times exists in our present reductions to sea level will be a distinct gain in the forecast service.

The kite work of the present year, as in the past, has been conducted under the personal supervision of Prof. C. F. Marvin, to whose skill and inventive genius much of the success that has attended our efforts is due.

FORECASTS AND WARNINGS.

Districts and Personnel.—The forecast districts remain the same as last year, viz: Oregon and Washington, Local Forecast Official, B. S. Pague, Portland, Oreg., in charge; California, Nevada, and Arizona, Forecast Official W. H. Hammon, San Francisco, Cal., in charge; Montana, Wyoming, Colorado, Kansas, Nebraska, North and South Dakota, Minnesota, Wisconsin, Iowa, Missouri, Illinois, Indiana, and Michigan, comprising the Chicago Forecast District, Prof. E. B. Garriott, in charge, with Forecast Official H. J. Cox, as first assistant. Forecasts for the remainder of the country were made at the Central Office in this city. Lieut. Col. H. H. C. Dunnwoody, Supervising Forecast Official, was in charge of the Forecast Division of the Central Office until May 31, 1898, on which date he returned to duty in the Signal Corps of the Army, after twenty-six years of useful service in the Weather Bureau, and its predecessor, the Signal Service. On Colonel Dunwoody's relief, the charge of the Forecast Division was intrusted to Prof. Park Morrill. Professor Morrill entered upon his new duties with great zeal and energy. He was especially active in attending to the details of the storm warning service then being established in the West Indies. In the midst of his labors he was stricken with fever, but remained on duty until compelled to take to his bed. His illness terminated fatally on August 7, 1898, at a time when a career of increased usefulness and activity was within his grasp.

Prof. E. B. Garriott, who was in charge of the Chicago forecast district at the time of Professor Morrill's illness, was called to the Central Office to take charge of the Forecast Division.

In the death of Professor Morrill the Bureau lost an intelligent and zealous official. He combined, in a marked degree, the qualities of the scientist and the executive.

Efficiency of Bureau.—The true measure of the efficiency of the Weather Bureau is found in the promptness and accuracy with which notice of the approach and force of severe atmospheric disturbances is given. The efficiency of the Bureau during the year just ended, judging from this criterion, was fully equal to the high standard of the previous year. While we were unable to discover new laws or principles, the application of which would tend to improve the accuracy of forecasts of minor disturbances, it was possible by the exercise of constant vigilance to issue warnings of all severe storms that occurred.

Prof. E. B. Garriott, in charge of the Forecast Division, has prepared a brief account of the chief storms of the year and the work of the Bureau in announcing them. Professor Garriott's full report is herewith, as appendix A, from which the following has been summarized.

Four hurricanes, all of which were duly announced, visited the Atlantic and Gulf coasts during the fall of the year. The most severe of the four was that of October 23–26, which moved slowly from off the Florida coast to the vicinity of Hatteras, where it increased greatly in intensity, causing violent northeast gales along the coast as far northward as New England.

The duration of the storm in the vicinity of Hatteras enabled the Bureau to make a definite prediction with regard to the tide at Norfolk, Va., where, owing to the low level of the city, much valuable property is liable to damage by inundation. In the case in question cotton and other property valued at approximately $850,000, were removed to places of safety. It was also reported to the Weather Bureau that between 800 and 900 vessels remained in port along the north Atlantic coast as a result of the warnings issued for this storm.

Three severe storms passed from the interior to the eastern seaboard during November, 1897. In one of these the ill-fated steamer *Idaho* with 19 of her crew of 21 was lost on Lake Erie. This vessel, it will be remembered, left Buffalo on the afternoon of the 5th in the face of storm signals which had been flying since daybreak. The Chicago Chronicle of November 12, 1897, commented on the wreck of the Idaho as follows:

> The wreck of the steamer *Idaho*, with the loss of 19 lives, off Long Point, last week, points a moral and adorns a tale for lake mariners. The disaster was the result of carelessness and temerity. The *Idaho* was thirty-five years old,

and, though not exactly unseaworthy, should not have been exposed to a severe storm. The storm signals were flying when the boat put out of the port of Buffalo to make its way up Lake Erie. Captain Gillies trusted to his own judgment instead of to the warnings of science. He also trusted in the stoutness of an old craft, not fitted for the severe tempests of the season. Small as it is, Lake Erie sees the worst storms that sweep across the Lake basin.

We are accustomed to jeer at the Weather Bureau when unheralded storms carry devastation in their tracks across land and sea. Sometimes, perhaps often, forecasts of storms are not fulfilled; but this is only in the case of minor changes from calm to disturbance not seriously affecting navigation nor the pursuits of trade and labor on land and sea. Serious warnings are seldom without cause.

A remarkably violent storm of wind and snow swept over eastern New York and New England on January 31–February 1, 1898. The greatest violence of the storm was manifested on the New England coast on which nearly two score of mariners lost their lives and as many vessels were wrecked. At Boston heavy damp snow, driven by a 50-mile gale from the northeast, completely prostrated overhead wires of all sorts and paralyzed transportation lines, both steam and electric, for several days. Warnings of this storm were given the widest possible distribution on the morning of the 31st.

Forcasts of freezing weather in Florida on January 2–4, 1898, also on February 2–4 were made in time to enable residents of that State to take such precautions as were possible to preserve early vegetables and fruit trees from destruction. Likewise in California during December, 1897, January and March, 1898, warnings well in advance of the unusually low temperatures that occurred in those months were issued. Frost occurred in the fruit region of California quite frequently during March, 1898. In spite of the efforts made to protect fruit, then in blossom, much damage was done owing to the severity of the frost.

In the middle and northern districts of the country the winter was one of the mildest on record; cold waves were neither widespread nor severe.

Forecasts of floods.—A brief description of the important floods of the year, of which there were five, will be found in Appendix A. But for the timely warnings issued by the Weather Bureau the losses from these floods would have been far more severe than they were. The flood in the Ohio in January was anticipated and the dates on which the danger line would be passed at important points were accurately indicated.

Warnings relative to the March flood in the Ohio were sent to Cincinnati on the 22d, and as the flood continued to increase in volume a warning was sent to Cairo on the 23d that the river would exceed the danger line considerably. This warning was supplemented each day, until the wave crest had passed, by others sent to all points between St. Louis and New Orleans.

At Cairo a stage of 48 feet was forecast for March 31, and on that

date the gauge registered 47.6 feet; the rise continued and culminated on April 6, with a reading of 49.8 feet.

These timely warnings saved thousands of dollars to steamboat men, lumber dealers, and farmers living in the riparian districts. Levees were strengthened at the weaker places, and the levee authorities stationed men with material and implements for strengthening and building up as occasion might require.

Warnings regarding the flood in the Arkansas were issued and widely disseminated by telegraph, telephone, and through the mails and press. The Little Rock Board of Trade, appreciating the value of the warning and realizing the great damage that would result from the high stage indicated, chartered the steamer *Irma* and sent her 70 miles down the river, with instructions to stop at every landing and settlement, to blow her whistle and distribute the flood warnings, and to give every person who came to the landing full information in order that every precaution to save life and property might be taken.

In addition to flood forecasts, warnings of low water were issued as the occasion required, and forecasts of this character were fully appreciated, as at certain low stages traffic is wholly or partially suspended, and at times it is absolutely essential that boatmen should know the low water stage expected in order to intelligently prosecute their work.

Weather and temperature forecasts.—Turning now to the forecasts of weather and temperature—the minor atmospheric disturbances—we may note that no substantial increase in accuracy has been attained. In the present state of knowledge respecting minor atmospheric changes, it is not possible to forecast them with as great accuracy as might be desired. Experiments have been made with kites, and instruments have been sent aloft to secure observations of pressure, temperature, and humidity, but as yet the observations are too few in number to determine their real value in weather forecasting. The upper air currents of summer, the only period during which observations have been secured, are feeble. Frequently, too, it has not been possible to make an ascension by reason of lack of movement in the surface currents. Observations are now being made as rapidly as circumstances will permit at 17 stations. The reduction of these observations is attended with some little uncertainty, but we hope to improve present methods and to eventually secure satisfactory data.

The discussion of the cloud observations, made in concert with foreign meteorological services during 1896–97, is in the hands of Prof. F. H. Bigelow. Professor Bigelow hopes to complete his work during the coming year. Fortunately, the kite observations now being made can be used to supplement the cloud observations. The former, also promise practical results along a line of work hitherto

unsuspected, viz : that of reducing barometric observations on the Rocky Mountain Plateau to lower levels on either side, thus contributing to the better understanding of the actual pressure changes which occur in the Plateau Region.

DISTRIBUTION OF FORECASTS.

Forecasts and warnings were distributed with the utmost dispatch and in accordance with methods tried and proven by the experience of previous years. The daily press has contributed very greatly to the success that has attended our efforts to make a thorough distribution of the forecasts. Valuable aid has also been extended in disseminating special warnings of cold waves, storm winds, frosts, etc. The telephone appears to be a valuable medium of communication between the local observer and the public, and one that bids fair to eventually become of still greater usefulness in disseminating the warnings of the Bureau. The valuable cooperation of numerous telephone companies is here acknowledged.

The total number of forecasts distributed during the year, exclusive of those published in the daily papers, was, approximately, 23,531,500, as shown by the table below. Sixty-four per cent of the yearly distribution was by logotype cards sent through the mails or carried by messengers; 23 per cent by maps and bulletins; 10 per cent through the cooperation of railroad, telegraph, and telephone lines, while the remaining 3 per cent were distributed by telegraph and telephone at the expense of the Bureau.

The State receiving the largest number of forecasts was Ohio, 2,157,300; the next largest, New York, 2,033,400, followed by Michigan, Illinois, Missouri, and Pennsylvania, in the order named.

Distribution of forecasts, warnings, maps, and bulletins during the fiscal year 1897–98.

States.	At Government expense.			Without expense to the United States, by—				By maps and bulletins.		Grand total.
	Forecasts and special warnings.	Special warnings only.*	Emergency warnings.*	Mail.	Telegraph or telephone	Railroad bulletin.	Railroad train service.	Maps.	Bulletins.	
Alabama	8,400	0	63	163,500	5,100	8,700	6,300	122,100	0	314,100
Arizona	600	1	0	0	2,400	0	0	0	6,000	9,000
Arkansas	9,300	4	58	122,400	10,800	1,800	0	50,100	9,600	204,000
California	25,200	22	3	609,600	33,300	104,700	0	200,400	5,400	978,600
Colorado	3,900	13	47	166,800	0	1,800	2,100	95,400	0	270,000
Connecticut	3,600	6	32	220,800	14,700	3,600	45,300	0	0	288,000
Delaware	1,500	0	6	9,600	0	6,600	0	0	0	17,700
District of Columbia	0	0	0	314,100	3,900	0	0	282,000	0	600,000
Florida	15,300	44	32	129,600	600	20,100	0	47,400	5,400	218,400
Georgia	17,700	40	82	249,900	600	31,800	12,300	94,200	0	406,500
Idaho	2,400	0	0	75,000	600	0	0	0	0	78,000
Illinois	22,200	24	383	831,000	7,500	82,200	137,700	405,300	0	1,485,900
Indiana	29,700	1	98	613,800	2,700	53,100	86,100	111,000	0	896,400
Indian Territory	2,400	1	0	27,000	300	0	0	0	0	29,700
Iowa	34,800	5	183	473,700	11,100	3,300	0	161,400	15,000	699,300
Kansas	12,300	3	142	155,400	6,000	38,400	4,500	3,300	18,300	238,200
Kentucky	13,509	53	76	192,900	35,700	10,200	0	96,300	0	348,600
Louisiana	8,700	24	6	136,500	3,300	900	0	144,900	0	294,300
Maine	7,800	1	13	296,400	2,400	6,900	23,100	32,700	0	369,300
Maryland	7,800	2	17	323,100	9,900	29,400	0	129,300	0	499,500
Massachusetts	6,600	16	32	570,900	6,600	0	120,300	288,600	0	993,000
Michigan	32,100	13	167	1,029,000	20,400	114,600	137,100	197,100	0	1,530,300
Minnesota	14,400	11	87	373,800	1,500	2,400	0	145,800	0	537,900
Mississippi	15,900	12	62	117,900	16,200	4,800	0	145,800	0	306,600
Missouri	26,700	6	191	945,900	30,900	32,100	18,000	339,000	0	1,392,600
Montana	4,800	0	16	125,100	4,800	0	0	0	17,400	152,100
Nebraska	18,600	4	147	279,300	600	3,300	0	77,100	8,100	387,000
Nevada	1,200	0	0	21,600	900	0	0	0	0	23,700
New Hampshire	3,300	0	13	98,100	0	3,000	9,300	0	0	113,700
New Jersey	10,200	24	90	324,300	17,100	52,200	0	0	0	403,800
New Mexico	2,700	0	0	9,000	900	1,200	0	0	0	13,800
New York	35,100	22	201	1,182,900	87,000	78,000	50,400	600,000	0	2,033,400
North Carolina	18,300	14	114	211,500	5,700	2,100	4,800	85,800	0	328,200
North Dakota	6,000	10	96	1,500	4,200	0	0	300	0	12,000
Ohio	48,300	106	197	1,631,100	76,200	24,600	5,100	372,000	0	2,157,300
Oklahoma	1,200	1	8	13,500	3,000	0	0	0	0	17,700
Oregon	7,200	0	0	183,600	2,700	0	31,200	129,300	600	354,600
Pennsylvania	19,200	12	105	606,000	182,700	207,000	0	204,300	0	1,219,300
Rhode Island	900	0	5	6,600	0	0	8,100	0	0	15,600
South Carolina	15,600	5	65	174,600	18,600	12,300	3,000	65,400	0	389,500
South Dakota	12,000	24	76	149,400	3,600	0	0	34,500	12,900	212,400
Tennessee	10,500	4	93	335,100	19,200	11,700	600	143,700	0	520,800
Texas	16,200	28	184	267,600	54,100	19,200	0	74,700	5,400	437,200
Utah	4,200	0	0	130,200	0	0	0	0	4,500	138,000
Vermont	3,300	1	16	152,400	17,100	3,000	3,900	0	0	179,700
Virginia	27,300	11	91	277,500	22,800	20,400	28,800	123,600	0	500,400
Washington	7,200	2	0	135,600	1,200	0	8,700	48,900	0	201,600
West Virginia	5,100	7	44	161,400	21,900	8,100	0	16,800	0	213,300
Wisconsin	26,100	14	134	378,900	11,100	300	4,800	164,400	0	585,600
Wyoming	2,100	1	6	4,200	1,500	5,400	0	6,900	0	20,100
	629,400	592	3,481	15,009,600	783,400	1,009,200	751,500	5,239,800	108,600	23,531,500

* Issued as occasion requires.

DISTRIBUTION OF WEATHER STATISTICS BY MAPS AND BULLETINS.

Five million two hundred and thirty-nine thousand eight hundred weather maps of all classes, and 108,600 bulletins were distributed during the year, an increase of about 600,000. Each map or bulletin contains a daily forecast and statistics showing the weather conditions over some part of the United States. In the larger cities, as New York, Chicago, and Philadelphia, the map contains a large number of reports; it is almost as complete in fact as the one issued at the Central Office. The maps are used largely by boards of trade, business houses, and public offices; there is also a very considerable number issued to the schools and colleges of the country for purely educational purposes.

CLIMATIC WORK.

Cotton, Corn, and Wheat Service.—The special service maintained in the cotton, corn, and wheat regions consists in reporting the daily temperature and rainfall at 129 stations in the cotton region, and 131 in the corn and wheat region. No changes have been made in either of these services during the past year. The information collected is promptly telegraphed to important commercial centers and displayed by bulletin or otherwise in public places.

The Climate and Crop Services of the various States and Territories were efficiently conducted during the year. Improved appliances for printing the monthly climate and crop reports in neat and uniform style have been installed in all but seven sections, viz, Idaho, Kansas, South Carolina, South Dakota, Utah, West Virginia, and Wyoming. The weekly bulletins of all of the sections except Nevada and Utah are printed in attractive form.

Establishment of Climate and Crop Service in Alaska.—The establishment of an agricultural experiment station in Alaska in April, 1898, led to the detail of an official of the Weather Bureau for duty in organizing a climate and crop service in that Territory. Meteorological observations have been made at but few places in Alaska since the withdrawal of Signal Service observers in 1887, and while the climate of the coast is fairly well determined, comparatively little is known of interior Alaskan climate, especially in summer.

The central station of the new service is located at Sitka, at which point continuous registers of wind velocity, sunshine, temperature, and pressure will be made. Check observations of standard instruments at 8 a. m. and 8 p. m., local mean time, will also be made.

Snowfall at high levels in Wyoming.—The section director of the Climate and Crop Service of Wyoming, in cooperation with a special agent of the Office of the Experiment Stations of the Department of Agriculture, has been directed to make a careful study of the precipitation at voluntary stations in mountain regions, with a view of

determining the amount of snowfall at high levels. He has been directed to secure as many additional voluntary observers as possible, and, wherever the reports are especially desirable, to arrange for paid observers. It is desired to know if a uniform ratio exists between precipitation at moderate levels and precipitation on high mountain ranges. It is true that the amount of snowfall determines in a great measure the volume of water available for the purpose of irrigation during the growing season of crops. If the ratio between mountain snowfall and the precipitation at lower levels be always the same, it will, of course, be possible to determine the amount of snow by the precipitation measured at our many stations on low levels, but if the ratio be not constant, it is apparent that accurate measurements of precipitation should be made within the elevated zone that supplies the streams of summer. From this and similar investigations it may be possible to make a fairly accurate estimate of the volume of water to be expected during each growing season. The subject is one that requires careful investigation, so that faulty conclusions be not reached.

PUBLICATIONS.

The business of the Publications Division differed materially from the corresponding period that closed with June, 1897, only in the quantity of work done. The excess of impressions, by letter presses, was 38 per cent; of completed copies, 86 per cent; while the increased product of the lithograph presses exceeded 16 per cent.

The regular publications include the morning Weather Map, 850 copies; the Monthly Weather Review, 4,000 copies; the Climate and Crop Bulletins, weekly during the crop season, April to September, inclusive, and monthly during the rest of the year, 4,000 copies; the Meteorological Chart of the Great Lakes, monthly except December, January, and February, 3,000 copies; the Snow and Ice Chart, weekly during the winter season, 1,600 copies, and the River Bulletin, monthly since January, 1898, 650 copies.

MONTHLY WEATHER REVIEW.

The Monthly Weather Review has been edited by Prof. Cleveland Abbe and published regularly, the date of issue being six or seven weeks after the close of the month to which it refers. Each number now contains sections contributed by the Forecast, Climate and Crop, and Records Divisions, besides those by the Librarian and the Editor. In addition to these regular sections the Bureau is indebted to numerous friends throughout the world for "special contributions" that are oftentimes of great interest to meteorologists and especially to members of the service. The statistical matter in the Review forms a very comprehensive record of the climate of the several States and Territories. For reference and future investigation such a record is invaluable. The Review has also been enriched by regular

monthly contributions of climatological data from Hawaii, Mexico, Jamaica, Haiti, Nicaragua, and Canada.

In size it has not exceeded the prescribed limit of fifty pages of text and ten charts, but a larger percentage of the text has been printed in smaller type than was formerly used. There are usually twenty pages of tabular matter, eight regular and several extra charts in each number.

The Annual Summary, together with the table of contents and index, completes each volume which, in accordance with past precedents, is known as the "Monthly Weather Review and Annual Summary" for the respective years.

RAINFALL AND OUTFLOW OF THE GREAT LAKES.

In answer to a request from Mr. C. H. Keep, Secretary of the Lake Carrier's Association, a report on the rainfall and outflow of the Great Lakes was made by Prof. C. Abbe and published in the Monthly Weather Review for April, 1898. The important result therein demonstrated is one that has, in fact, been long suspected, namely, that we know too little about the evaporation and the drainage from the watershed of the lake region to justify any minute conclusions. The "drainage or run-off" is a matter that should be determined by hydraulic engineers. In order that the Weather Bureau may respond satisfactorily to the public demands for information on evaporation, it will be necessary to establish a large number of evaporometers in the Lake region in such positions as to give the evaporation from the *water surface of the lake* as distinguished from the measurements in *thermometer shelters* usually made by meteorologists.

MINUTE OSCILLATIONS ON THE GREAT LAKES.

Mr. F. H. Dennison, of the Canadian Meteorological Service, having established a continuous record, on a large scale, of the oscillations on Lake Ontario, has shown that minute temporary waves have such a connection with atmospheric conditions that they may, perhaps, be used to predict distant thunderstorms. These oscillations are of much interest from several points of view and observations should be maintained at Weather Bureau stations in connection with the evaporometers before mentioned, and in addition to any similar stations that may be maintained by the Chief of Engineers, United States Army, or by the Director of the United States Geological Survey.

METEOROLOGICAL CHART OF GREAT LAKES.

During a personal inspection of Weather Bureau stations on the Great Lakes in the summer of 1897, I became convinced that the usefulness of the Bureau in that region could be greatly increased. One of the measures adopted with that end in view was the issue of a monthly chart to vessel masters, the first issue of which was mailed

on September 27, 1897. The chart shows, among other things, the lake ports at which storm warnings are displayed, the localities in port where information respecting the weather can be obtained, the regions of fog, the prevailing winds, and other statistical information respecting the winds and weather on the lakes.

The collection and publication of data relating to fog frequency have been productive of interesting results. It has been shown that fog prevails in mid lake more frequently than on shore, and that some parts of the lakes are more liable to fog than others. Eventually it will be possible to map the areas of greatest fog frequency on the lakes for the guidance of lake captains. Whether it will be possible to predict the occurrence of fog on the lakes is a question the Bureau is not yet ready to answer.

WEATHER BUREAU TELEGRAPH LINES.

At one time the Federal Government owned and operated about 5,000 miles of sea coast and frontier telegraph lines. In 1891, 633 miles of these lines, mainly on the sea coast, were turned over to the Weather Bureau as appropriate to a purely meteorological service. These lines traverse thinly settled regions or connect islands with the mainland by submarine cable at points where there is not enough commercial business to warrant the construction of a private line. The total revenue from Weather Bureau lines on account of commercial dispatches, during the year, was $4,220.19, which sum was covered into the United States Treasury, as required by law.

These lines serve a double purpose; first, they enable the Bureau to receive early information of changes in the weather at exposed points on our coast, and second, they permit of the display of storm warnings near several of the great highways of vessels entering or leaving our ports; they also contribute largely to the safety of vessels navigating our shores, as evidenced by the specific cases quoted below.

(1) The British Bark *Culdoon*, Captain Richter, Cape of Good Hope to Boston, went ashore March 23, 1898, on the south side of Nantucket Island. Wrecking companies were at once notified of the disaster and by speedy action the vessel and cargo, valued at $100,000, were saved.

(2) The steamer *Tuscarora* and cargo, valued at $700,000, went ashore on Middle Island, Lake Huron, during a dense fog, October 24, 1897. By means of the Weather Bureau system of cables and telegraph lines connecting Thunder Bay and Middle Island with the observer's office in Alpena, assistance was summoned and the steamer was saved after lightering 800 tons of merchandise.

INSTRUCTION IN METEOROLOGY.

The instruction given in meteorology in the United States varies in

its character according as this subject is considered as a part of a course in climatology and geology, or as a course in mathematics and physics. The former method of treatment is appropriate to high schools and to the needs of those who contemplate becoming observers in the Weather Bureau; the latter method of treatment is appropriate to universities and should fit one for the prosecution of important work in dynamic meteorology.

The importance of the subject has been kept in mind, especially in the assignment of observers to duty at points where there are colleges or universities not already provided with instructors in meteorology. Prof. Cleveland Abbe, Editor of the Monthly Weather Review, has been requested to prepare a report on the general condition of the subject in the United States. His report will doubtless stimulate interest in the matter and lead to a better conception of the standard of technical knowledge required for admission to the Weather Bureau service.

It is encouraging to be able to report that during the past year the courses in meteorology have been strengthened in a large number of high schools and academies.

The well known course of Prof. Wm. M. Davis, in Harvard University, now devolves upon Mr. R. DeC. Ward, who has published an "Outline of Requirements in Meteorology," intended to serve as an aid to teachers in preparing students for examination in elementary meteorology, presented for admission to Harvard College and the Lawrence Scientific School."

A meteorological observatory has been erected at Columbia University, New York City, under the direction of Prof. William Hallock of the Department of Physics, and a complete course of instruction in this subject will undoubtedly follow.

A course of lectures on hydrodynamics in its application to the motions of the atmosphere, has, during the past year, been offered by Prof. James McMahon of Cornell University.

Mr. O. L. Fassig, of the Weather Bureau, on duty at Baltimore, was assigned to the duty of instructor in climatology at the Johns Hopkins University, in addition to his other duties. The course of lectures given by Mr. Fassig has undoubtedly stimulated interest in climatic research at the University and throughout the State. Already plans have been made for the study of two special climatic problems of considerable economic importance.

IMPROVEMENT IN INSTRUMENTAL EQUIPMENT.

Early in the year a systematic plan for the betterment of the instrumental equipment of Weather Bureau stations was formulated, due regard being paid to the various local, educational, and other interests subserved at the several stations. This method secured a

judicious distribution of the supplies that became available during the year, and, as a result, the equipment of all the stations is now in a more uniformly excellent condition than ever before.

The Weather Bureau stations at all important points are regularly visited by students and classes of local educational institutions. Advantage has been taken of the valuable opportunity thus afforded to instruct large numbers of pupils in the use of meteorological instruments as well as the methods of observation and general work of the Weather Bureau.

There are now in use at regular stations of the Bureau, not including either the stations of the West Indies or the Marine Service on the Great Lakes, 90 registers (double and triple) recording velocity and direction of the wind, and, with few exceptions, sunshine and rainfall; 113 thermographs, recording the air temperature, and 105 barographs, recording air pressure. No other similar territory in the world is covered with such a complete equipment of instruments, recording climatic and meteorologic phenomena.

LOSS OF FARM PROPERTY BY LIGHTNING.

A number of inquiries have been received during the last few years relative to the frequency of thunderstorms. Several correspondents of the Bureau hold to the view that there has been a perceptible increase in the number of storms and fatalities by lightning stroke within a comparatively short period. This view is also held by insurance companies which include lightning risks in their business, and statistics have been adduced in support of this contention. Thus, to quote a single illustration: The Farmers' Mutual Fire Insurance Company, of Readington, N. J., a company that insures isolated farm property, mainly in central and northern New Jersey, paid in losses by lightning during the six years, 1882–1887, $24,388; during the six years, 1892–1897, $62,153.

The following illustrates the variation from one year to the next: The Mutual Fire Insurance Companies of Michigan sustained a loss of $37,563.64 in 1895, due to lightning stroke, of which there were 316. In the following year a loss of $143,841.26, on account of 1,509 cases of lightning stroke, was sustained.[1] Such a variation from year to year is perplexing alike to the insurer and the insured. The statistics of thunderstorms for Michigan, collected by the Weather Bureau, show that there were 14 per cent more storms in 1896 than in 1895, while the number of lightning strokes, as shown by reports received by the Commissioner of Insurance for Michigan, increased 377 per cent.

In order to determine the frequency of lightning stroke and the amount of property that is destroyed annually by that phenomenon, the Weather Bureau has undertaken to collect, through the coopera-

[1] Michigan Insurance Reports, 1896–1897.

tion of agents and adjusters of Farmers' Mutual Insurance Associations and many private persons, statistics of loss to farm property, including livestock in the fields. The data so collected will, in the course of time, afford means of determining an equitable rate on lightning risks.

NEED OF ASSISTANT CHIEF OF BUREAU.

I regret to have to report that almost my entire time has been consumed in executive work, leaving little or no time for personal study and investigations. The executive work is constantly growing; in addition to the work involved here in the city of Washington, there are 165 outlying completely equipped meteorological stations, at the majority of which conditions continually arise that require careful executive consideration. While I have no desire to shift the responsibility for a portion of the work to another official, I feel that for the best interests of the service an assistant to the Chief of Bureau should be available in times of emergency and when the Chief is absent from the city on official business.

APPENDIX A.

STORMS, COLD WAVES, AND FLOODS OF THE YEAR.

By Prof. E. B. GARRIOTT.

Four hurricanes visited the Atlantic and Gulf coasts. One of these was severe on the Texas coast September 13, 1897, where, owing to high winds and tides, 13 lives were lost, and the property loss was $150,000. The second hurricane skirted the south Atlantic coast September 21, 1897, and disappeared south of New England September 24. Reports of incoming vessels showed that this storm was quite severe off Hatteras September 22. In advance of both of these storms all shipping and ports in the Gulf of Mexico and along the Atlantic coast received, respectively, ample warning of high winds.

In October, 1897, two hurricanes moved northeastward along the Atlantic seaboard; the first from the 19th to the 21st, and the other from the 23d to the 26th. Reports received indicated that the benefits derived from hurricane warnings, issued in connection with these storms, were very great, more particularly in the case of the storm of 23d to 26th, which, from New York south to Hatteras, was the most violent and destructive that had occurred for years. Danger warnings and special telegraphic bulletins were displayed at all ports from twelve to twenty-four hours in advance of the hurricane, and the information was widely disseminated by means of the telephone, telegraph, and signal rockets at night, and, as a result, few disasters to shipping occurred. Between eight and nine hundred vessels were reported to have remained in port at harbors on the Atlantic coast as a result of the signals and warnings. At Norfolk, Va., it was estimated that the warnings saved $850,000 worth of cotton and other merchandise from damage by high tides.

Three severe storms occurred in November, 1897. The first of these advanced from Kansas to the Gulf of St. Lawrence from the 3d to 6th, causing high easterly to northerly winds on the upper Lakes and violent southerly to westerly gales on the lower Lakes. This was the storm in which the ill-fated *Idaho* was lost on Lake Erie. This vessel left Buffalo harbor the afternoon of the 5th in the face of the storm signals, which had been flying since daybreak. The second storm appeared in Kansas on the 7th, crossed the lower Lake region on the 9th, and moved eastward off the New England coast on the 10th, its passage being attended by gales, for which signals were ordered well in advance of the storm's arrival. The third storm of November advanced from the region north of Montana to New England from the 9th to 12th, attended by gales over the Great Lakes and along the New England coast. The daily press at the various lake cities published many commendatory notes regarding the value of the warnings issued in connection with these storms and the estimation in which they were held by the interests served.

The Chicago Chronicle of November 12, 1897, stated, editorially:

"The wreck of the steamer *Idaho*, with the loss of nineteen lives, off Long Point, last week, points a moral and adorns a tale for lake mariners. The disaster was the result of carelessness and temerity. The *Idaho* was thirty-five years old, and though not exactly unseaworthy, should not have been exposed to a severe storm. The storm signals were flying when the boat put out of the port of Buffalo to make its way up Lake Erie. Captain Gillies trusted to his own judgment

instead of to the warnings of science. He also trusted in the stoutness of an old craft, not fitted for the severe tempests of the season. Small as it is, Lake Erie sees the worst storms that sweep across the lake basin.

"We are accustomed to jeer at the Weather Bureau when unheralded storms carry devastation in their tracks across land and sea. Sometimes, perhaps often, forecasts of storms are not fulfilled; but this is only in case of minor changes from calm to disturbance not seriously affecting navigation nor the pursuits of trade and labor on land. Serious warnings are seldom without cause."

The Buffalo Times, November 14, 1897, contained the following:

"During the past week the local Weather Bureau has done navigation interests invaluable service. It has given warnings of the storms which have prevailed during the week, and undoubtedly has in this way saved two or three million dollars worth of property, and nobody knows how many lives. Yesterday morning 50 vessels left port after waiting for the storm to blow over. Certainly the navigation interests of the Queen City of the Lakes could ill afford to do without the services of the Weather Bureau."

Detroit papers commented as follows:

Detroit Tribune, November 12, 1897.—"The Weather Bureau at this point issued warnings of the approaching storm last Wednesday and at once ordered up storm signals at points along the entire chain of lakes. The orders were repeated yesterday morning. That much attention was paid to the signals is shown by the fact that the vessel passages at Detroit yesterday were among the lightest in number on record."

Detroit Free Press, November 12, 1897.—"It is a fact deserving of praise that every storm this month was seen in the distance and predicted long before it reached the lakes. For a period of twenty-four to thirty-six hours ahead the inhabitants of the Lake region have been told of the coming of each; and as it came closer, and immediate conditions could be gauged, the public have been given exact details, including direction and velocity of wind. Some men say this is a matter of luck. There is some excuse for this remark in view of the utter failure of predictions in times past. But there is another side to it. The Bureau has, without doubt, been brought to a high state of efficiency. The Chief and his assistants have profited by past experience just as every man of sense takes warning of what has gone before, and endeavors to improve on his record. The science of studying the origin and tracks of storms has been refined, and the process of refinement has by no means been completed. New instruments have had much to do with this, but study and application and reasonable deductions have had more.

"The natural result is the greater respect paid to the Bureau, its bulletins, and charts than ever before. The November chart, containing diagrams of the courses of past storms for that month, has jumped into popular favor. Requests are made for it every day by lake masters, owners, and others. More heed is taken of storm warnings, for the lake sailor has come to look on them as worthy of trust. The one great exception was the starting of the steamer *Idaho* from Buffalo last Friday. The prediction of that storm and its attendant conditions had been made many hours before."

Four storms of marked severity developed in the southwest in January, 1898, and, following nearly the same path, moved northeastward across the central valleys, the lower Lake region, and the New England coast, accompanied by heavy snow in the northern portion of the regions traversed, and by high winds, causing considerable damage to various interests and interrupting traffic in northern Illinois, Wisconsin, and Lower Michigan. The first storm, that of the 21st–23d, caused unusually high tides on the Massachusetts coast, which resulted in considerable damage to seaport cities and towns in that region. Warnings were thoroughly distributed well in advance of these storms and were of undoubted value. The warnings of heavy snow for the states named were ample and very accurate.

A wind and snow storm of unusual violence passed over eastern New York and New England January 31, and February 1, 1898. High wind, in connection with heavy snow, caused great distruction to shipping on the New England coast, and great damage to railroads, telegraph and telephone lines throughout

eastern New York and New England. The warnings issued the morning of the 31st were given the widest possible distribution throughout the threatened regions, and, as shown by reports received, were of great benefit. Conservative and reliable estimates place the loss by the storm to electric and steam railroads, telegraph and telephone companies in the city of Boston and neighboring cities and towns, and to corporations and individuals generally at about $1,500,000. The damage to shipping is estimated at from $150,000 to $200,000.

Severe storms also occurred on the New England coast February 15 and 16, and from February 18 to 22, 1898, a heavy snow and wind storm moved from Texas northeastward to New England. The warnings issued in connection with these storms were opportune, and the warnings of heavy snow and high north to northeast winds for the States of the upper Mississippi Valley and the upper Lake region, made mainly in the interest of transportation companies, were fully verified, the snowfall in the upper Lake region exceeding 18 inches.

From March 2 to 5, 1898, a storm moved from the eastern part of the Gulf of Mexico to the New England coast. All shipping was well warned and no serious losses were reported.

The severe storms of April, 1898, occurred over the Lake region on the 13–15th, and 18–20th, and along the Atlantic coast on the 26–29th. The coast storm was attended by unusually severe gales and high tides on the middle Atlantic coast, but owing to warnings disseminated very little damage resulted.

COLD WAVES AND FROSTS.

The Florida freeze of January 2–4, 1898, was very destructive to early vegetables, and caused considerable damage to citrus trees and pineapples. From the 2d to the 4th the following minimum temperatures were reported from Jacksonville, Tampa, and Jupiter, respectively: January 2, 25°, 28°, 30°; January 3, 26°, 26°, 30°; January 4, 38°, 38°, 34°. Warnings of these injurious conditions were sent from Washington, and, although both of the days on which the messages were sent were holidays, making effective dissemination difficult, the warnings were, through the efforts of the Weather Bureau observers, by means of the mail, telegraph, and telephone services, and the cooperation of the railroad officials, very widely distributed throughout the threatened districts, and enabled the adoption of effective measures for the protection of crops.

Severe cold weather prevailed in Florida February 2–4, 1898, with the following minimum temperatures at Jacksonville, Tampa, and Jupiter, respectively: February 2, 26°, 31°, 40°; February 3, 32°, 38°, 50°; February 4, 34°, 34°, 52°. The amount reported saved by warnings in Florida by fruit and vegetable growers alone reached $68,000, and these figures represent only a part of the total, there being hundreds of growers who were benefited, directly or indirectly, from whom no information could be obtained.

The Florida press complimented the Weather Bureau very highly upon the timely and accurate warnings given and agreed in placing the estimate of fruit trees and vegetables saved thereby at thousands of dollars.

Heavy frosts occurred the mornings of April 6 to 9, 1898, in the south Atlantic and Gulf States, with light frost on the 8th as far south as Jacksonville, Fla. Warnings of these frosts were issued from the Central Office the mornings of the 5th, 6th, and 7th, and extensively distributed throughout the regions named. The warnings were received in North Carolina fourteen hours, on the average, in advance of the frost, a period amply sufficient to employ methods for protecting crops. The saving to the berry crops was placed at thousands of dollars. Mr. H. T. Bauman, shipping master of the Fruit Growers' Association, estimates the saving in the State at $100,000, and the approximate value of the crops protected, principally strawberries, at $600,000 to $700,000.

In December, 1897, and January, 1898, frost and freezing weather occurred in the citrus fruit districts of California. On December 2 and 3, the temperature fell below freezing as far south as Los Angeles and Riverside counties, but the injury to the fruit interests was probably small. Warnings of these frosts were, in every instance, issued on the morning of the day preceding their occurrence. In March, 1898, frosts, in some instances quite destructive, occurred in the fruit regions of California nearly every night from the 12th to the 27th, inclusive, and on the 9th and 10th a severe "norther," with gales on the coast, prevailed in California. Warnings of frost were distributed throughout the districts visited in advance of and during the period of frosts, and many efforts at protecting the fruit then in blossom were made, which were not generally successful, owing to the extreme severity of the frost. In some instances even grain was severely injured.

The cold waves of the middle and northern districts of the country were neither severe nor widespread, the most notable visitations of this class occurring over the west and northwest States March 22 to 23, and 24 to 28, 1898. All interests in the States lying between the Lake region and the Rocky Mountains were warned of the approach of these cold waves, and an immense saving to property and stock on the cattle ranges of the north and northwest was effected

FLOODS.

During the past fiscal year there were two floods of note in the Ohio River and its tributaries, the Tennessee and Cumberland; two in the lower Mississippi River; and one in the Arkansas River.

Floods in the Ohio.—The first flood in the Ohio culminated at Cincinnati January 26, with a gauge reading of 52.2 feet; in the Cumberland at Nashville on January 22, with a reading of 38.6 feet; and in the Tennessee at Johnsonville January 29, with a reading of 29.1 feet; the danger line at these points being 45, 40, and 21 feet, respectively.

The tremendous outpour of the streams that empty into the Ohio within a few miles of the gauge at Cincinnati was chiefly responsible for the several successive rises that were recorded. The Ohio had reached 38 feet on the 14th, when river interests in the bottoms began to prepare for prompt action in case of emergency. The danger line (36 feet) was passed at Point Pleasant on the 17th. The rise had only reached 44.6 feet at Cincinnati by midnight of the 17th when, the local freshets having run out, a fall began. Steady and heavy rains on the 19th over the territory drained by the local streams, caused a sudden rise in the Ohio at this point of 6 inches per hour, the danger line being passed on the 19th at midnight. This rise was a purely local one attributed mainly to the Little Miami River. But for the concentration of several heavy rains, piling up a tremendous mass of water in front of Cincinnati the storms of the month would hardly have swollen the river above the danger line.

Although the rise of 52.2 feet was unusual, submerging the valleys and lowlands, and causing inconvenience and expense in Cincinnati by necessitating the removal of goods, and from a temporary cessation of business, river interests did not suffer materially from this flood.

A second and more disastrous flood occurred in the Ohio River in March, the rise, beginning on the 15th, coming largely from the northern tributaries of the river. The rise was continuous, and on the 29th at Cincinnati, reached a maximum height of 61.4 feet, the highest stage in March since the record began in 1858.

The conditions which prevailed in the Allegheny Valley and along the Monongahela, earlier in the month, due to the influence of fair and warmer weather, were followed by unusually heavy rains over the headwater tributaries of the

Ohio, resulting in three freshets within the space of ten days, the first and last of which stopped a trifle short of the flood line, while the second, largely out of the Allegheny, reached a stage of 31 feet above low water on the 24th at Pittsburg, the highest record since February, 1891.

The heavy snowfall on the 1st and 2d of March is shown by the record of 5 inches at Cincinnati. This was followed by the fair weather already referred to which caused the freshets in northern tributaries of the Ohio. Then came the heavy rains of the 17th, the river rising sharply by the morning of the 18th, between Parkersburg and Louisville, and continuing to rise in consequence of the heavy and general rains, especially over its northern watershed. Four or five days later, about the time that the danger line (45 feet) was reached at Cincinnati, extraordinary rains occurred which inundated a large portion of the States of Ohio and Indiana, flooding the valleys of the Muskingum, Scioto, and Miami. At noon on the 24th the 50-foot mark was reached at Cincinnati, and on the morning of the 25th a further rise of 2 feet was recorded, the water now encroaching upon the lower levels of the city. The Grand Central Railway depot was abandoned at midnight.

On the 26th and 27th the Great Miami and Indiana streams were again employed in carrying a great volume of water into the lower Ohio, the rains of the last date causing an increased and prolonged rise in the vicinity of Cincinnati, the river coming to a stand at 61.4 feet at 3 a. m. on the 29th, remaining stationary until 7 a. m., when it began to recede slowly.

By this flood many interests suffered incalculable damage other than the business interests immediately affected along the river; labor suffered severely through enforced idleness; eight or nine railroads were, for the time being, abandoned. At Zanesville, on the Muskingum River, the damage to property was paralyzing, a loss of $2,000,000 being estimated, while 4,000 people were driven from their homes.

Floods in the Mississippi.—The first flood in the Mississippi culminated at Cairo, Ill., on January 31, with a gauge reading of 44.4 feet. The second and more serious rise followed that which culminated in the Ohio at Cincinnati, March 29, with a gauge reading of 61.4 feet, the gauge indicating 49.8 feet at Cairo, April 6, on which date the highest point was reached.

The January flood was precipitated by the sudden rise from Cairo to Helena coming out of the Ohio and Cumberland rivers January 10 to 13, due to heavy rains over the entire watershed contiguous to these streams. At first the rise was only moderate, but the freshets in the small streams emptying into the main tributaries caused an increase at the rate of 2 to 3 feet daily. During eleven days, ending January 22, the amount added to the Memphis stage was 22.5 feet, while at Cairo and Helena the increase was over 27 feet. At Memphis the entire rise for the month amounted to 27.9 feet, the highest stage being 32.2 feet, reached on the 31st. In the lower Mississippi the January rise was the most rapid in recent years, Vicksburg's rise at the close of the month being 30 feet, and New Orleans about 9 feet.

The flood of the first week of April, while largely consequent upon the Ohio flood of the last days of March, was affected somewhat by the breaking up of ice, but more especially by heavy rainfalls, which commenced about the 10th of the month and continued to the end, resulting in a total precipitation of more than twice the usual quantity for the month, filling and overflowing main tributaries. As an example, at Hannibal the total rainfall on the 27th was 3.42 inches, which caused an unprecedented overflow of the waters of Bear Creek, flooding 100 residences, washing out railroad bridges, and damaging roadbeds, with other destruction.

On April 1 the Mississippi River was above danger line from Cairo to Mem-

phis, and a week later the Helena gauge indicated a like condition. The rise at Memphis averaged one-half foot per day until the 11th when it stood at a 37.3-foot stage, remaining stationary two days before the fall set in. The total height of the flood wave was 27 feet, and this was reached at Memphis in twenty-seven days from the time of its first appearance at that place. The water was above danger line at Memphis twenty-two days. At New Orleans the danger line was reached on the 18th, and the forecasts of the Weather Bureau were to the effect that a nearly 50-foot stage would be reached at Vicksburg, and not to exceed 17 feet at New Orleans. Planters and others along the river were fully prepared, therefore, and while the water reached the exact stage anticipated, there were no serious overflows.

Flood in the Arkansas.—The flood in the Arkansas that occurred during May was the greatest known in years. On the 7th the river at Fort Smith, Ark., attained the unprecedented height of 35 feet. The crest of this rise reached Little Rock on the 11th, with a maximum stage of 27.5 feet, which was attained at 1:30 p. m. of that date. The danger line was passed on the 6th, and was exceeded during ten consecutive days thereafter. In consequence of the continued rapid rise in the upper Arkansas and its tributaries flood warnings were issued on the 5th forecasting a stage of 27.5 feet at Little Rock, or just 0.4 foot lower than the highest stage reached in 1892, when the lowlands along the Arkansas from Little Rock to the mouth were overflowed and devastated. The damage done along the Arkansas west of Little Rock was greater than from any previous flood. In the immediate neighborhood of Fort Smith the loss was from $2,000 to $2,500. Notwithstanding the precautions taken and the extra work done, levees were broken, resulting in immense overflows by which thousands of acres of growing crops were destroyed. The immediate cause of the flood was the general and heavy precipitation during the first few days of the month in the valleys drained by the Arkansas and its tributaries.

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