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U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

REPORT

ON THE

CHIEF OF THE WEATHER BUREAU

FOR

1897.

BY

WILLIS L. MOORE.

[From the Report of the Secretary of Agriculture.]

WASHINGTON:
WEATHER BUREAU.
1897.

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.

SIR: I have the honor to submit a report of the operations of the Weather Bureau of the Department of Agriculture during the fiscal year that ended June 30, 1897.

Very respectfully,

WILLIS L. MOORE,
Chief.

Hon. JAMES WILSON,
Secretary of Agriculture.

By way of introduction to my detailed report for the year 1896–97, I desire to submit the following comparison of the expenses and efficiency of the service during the past fiscal year as compared with those for 1883–84, when the appropriation for the weather service was the largest ever made, and to give some facts showing the necessity for a much larger appropriation in the future.

In 1883–84 the weather service cost $993,520. The extension of its scope and the increase in its usefulness since that time are matters of history. Attention is invited to a few of the important changes that have been made in recent years, particularly those showing an increase in the efficiency of the Service. The appropriation for the current year is $883,772, which is $109,748 less than in 1883, while it is safe to say that the volume of work performed and the benefits derived by the public are much greater than they were in 1883.

In 1883 weather maps were not issued, except at the Central Office in Washington, D. C. During the last fiscal year 4,315,000 maps were issued at 81 stations outside of Washington, D. C., and there has been an increase of 1,166,105 copies within the last two years, to meet the constantly increasing demands of the public.

In 1883 forecasts and warnings were sent to 8,094 places by mail, no other methods of distribution, except through the daily press and a railroad train service, being then in use. During the last fiscal year daily forecasts and warnings were sent to 51,694 places by mail, telegraph, telephone, etc., and there has been an increase in the number of places receiving forecasts in the last two years of nearly 30,000.

In 1883 no information was collected respecting the weather as influencing crops; now climate and crop conditions are reported from about 8,000 places, and the results are summarized in the

Weekly Climate and Crop Bulletins which are issued at each State center and published by practically the entire press of the country, both rural and urban. In 1883 there were less than 300 voluntary observers in cooperation with the Bureau and no systematic publication of their reports was made; now there are about 3,000 voluntary observers making daily readings of standard Government thermometers and rain gauges, the daily observations being collated and neatly printed in tabular form at 42 State centers. These printed State reports are very useful in the development of the natural resources of the country. It is now possible for agriculturists, merchants, manufacturers, civil engineers, and health seekers to compare the salient climatic features of almost any county in one State with the conditions that may exist in another State.

In 1883 there were 41 stations on our sea coasts and the Great Lakes where storm signals were displayed for the benefit of mariners; now there are 253 stations where these signals are displayed, at each of which, in addition to displaying the signals, telegraphic bulletins, giving the location, intensity, and the probable movement of the storm are distributed to vessel masters within one hour after the information is dictated by the forecast official at headquarters.

The appropriation for the current fiscal year is $883,772; it is inadequate to meet the demands made by the people, either directly to this Bureau or through their representatives in Congress, for a material extension of the benefits of the weather service. A conservative estimate of the money needed to meet the legitimate requests of the agricultural, marine, commercial, and manufacturing interests of the country is $1,044,050, being an increase of $160,348. This sum provides for the establishment and equipment of new stations at important centers of population, $75,000 being estimated for that specific purpose. The amount now appropriated is barely sufficient for the requirements of the actual working force at the meteorological stations, leaving no opportunity for the extension of the present system or the establishment of new stations; in fact, it is only with the utmost care and by requiring from nine to twelve hours work every day in the year, including Sundays and holidays, of the majority of station employees that the important duties of the Service can be performed. Every mail brings urgent requests from Representatives in Congress, farmers, mariners, merchants, and professional people for extensions which it is impossible to grant. In the efforts to meet this public demand all workers have been taxed to the limit of physical and mental endurance.

The increase asked for also contemplates the establishing of several stations in the southwestern part of the country where an extensive area is not now included in the domain covered by meteorological observations. This unprotected region includes large portions of

Nevada, Utah, Arizona, New Mexico, and southeastern California. This region should have four or five additional stations employing one observer each. The weather conditions which cause frost in the orange and raisin sections of California drift in a southerly direction from the north and northeast. The making of the most accurate frost warnings for the extensive fruit interests of southern California requires the additional stations above referred to. Additional evidence that these stations are essential to a better service may be had in the fact that many storms which cause rain in New Mexico, Colorado, Texas, Kansas, Nebraska, and farther east, have their origin in the open and unprotected territory which it is now proposed to cover by observation stations.

Additional stations are also needed to meet the demands of many cities which, although not being so geographically situated as to furnish the Bureau useful observations for its storm warnings service, are still so important in their manufacturing, marine, and other industries as to render it advisable to establish complete meteorological stations in their midst for the purpose of preserving a record of the prevailing atmospheric conditions. Such a record will be exceedingly useful in the development of their industries, and it will also be possible to effect a more prompt and systematic distribution of storm warnings and forecasts than obtains at present. There are to-day over 50 cities of more than 50,000 population having no Weather Bureau station. To be sure, some of these are contiguous to cities having Weather Bureau observatories, and do not, therefore, require a completely equipped station.

The new estimates include an item of $20,000 for the purpose of purchasing standard signal lamps for all stations displaying storm signals. A few of these lamps are now in operation at several of the more important stations. Signals at these stations may be seen at a greater distance than heretofore, thus giving a greatly improved service to shipping. Conservative estimates made by those interested in shipping indicate that one hurricane sweeping the Atlantic seaboard might cause damage to floating craft of over three millions of dollars. During the past three years, ten or more of these destructive storms have visited our coast line. In every case the danger warnings have been displayed long in advance of the storm, and there have been no marine disasters of importance. There are 253 ports displaying danger signals. A recent inspection of the stations discloses the fact that the present equipment is composed of a heterogeneous assortment of lights and lanterns. The importance of a proper equipment is so great that it would be wise economy to provide each station with such a light as was, after many experiments, recently adopted as a standard by the Weather Bureau. The storm-warning service long ago outgrew the experimental stage. It has demonstrated its usefulness to such an extent that only the most efficient and permanent appliances should be used for conveying its valuable warnings to mariners.

The estimates include an item of $10,000 over and above the amount allotted for the present fiscal year, for the purpose of purchasing instrument shelters for issue to voluntary observers of the Weather Bureau, who number about 3,000 at the present time. These shelters will enable the Bureau to obtain more accurate climatic observations, since the thermometers will be exposed so as to have free circulation of air, and yet will be protected from sunshine, rainfall, and radiation from surrounding structures. Many employees are now engaged in collating and publishing these reports, for the purpose of establishing the climatic features of every portion of each State in the Union. It is an unwise economy that does not provide for the taking of accurate observations upon which so much subsequent time and labor are expended.

An item is included of $5,000 for the purpose of erecting a small brick and stone building on the Government reservation between the two canals at Sault Ste. Marie, Mich. The average number of vessels passing through these canals in the season of navigation is 80 per day. The Weather Bureau office at that point is maintained chiefly in the interests of shipping, and its location should be on this Government reservation, where it can be of the greatest service to vessel masters.

It is of great importance that offices be located with a view of securing several advantageous conditions. Nearness to the press, the telegraph office, and, if at a lake port, proximity to the harbor, are important conditions in securing prompt and effective distribution of storm warnings and weather information. Beside providing for these, the proper exposure of meteorological instruments must not be overlooked. A flat roof, with no buildings of greater elevation in close proximity, is the best practicable city exposure. At marine ports a prominent tower visible from all parts of the harbor is necessary for the display of danger signals. Wind velocity increases and temperature decreases very rapidly with the first thousand feet of ascent from the surface of the earth; hence in securing an exposure above surrounding structures great care should be exercised not to locate meteorological instruments so high that their readings are not comparable with the results obtained from the stations of other cities; or so high as to show too wide a departure from readings taken within a few feet of the earth.

It is apparent that economy in expenditure should not induce the Government to locate its meteorological observatories in other than the most advantageous surroundings. Under no circumstances should the accuracy of the meteorological readings be subordinated to the desire to secure quarters rent free.

OPERATIONS OF THE YEAR ENDED JUNE 30, 1897.

The work of the Bureau during the last fiscal year was conducted on lines tested and approved by the experience of former years. There was no relaxation in the efforts to improve the methods of administration, and to make the Service of the greatest good to the largest number of people.

Forecasts.—The usual forecasts of temperature, wind, and weather were issued twice daily, as were also special warnings of cold waves, frosts, severe storms, and hurricanes, as occasion demanded.

One storm, of a very destructive nature, passed across the eastern border of the United States since the date of last report. This storm, the coming of which was foretold on the evening of September 27, 1896, struck the coast of Florida in the vicinity of Cedar Keys on the morning of September 29, and passed rapidly northward to the region of the lower Lakes by the morning of the 30th.

The force of the wind was so great in many localities that human foresight could not avail in preventing loss of life and property. The remarkable feature of the storm was the violence manifested throughout the Middle Atlantic States. Sixteen lives were lost in Virginia, District of Columbia, Maryland, and Pennsylvania; 98 in Florida, Georgia, and South Carolina. The loss of property was estimated at $7,000,000.

The passage of a West India hurricane through the center of the populous districts of the Middle States is not wholly new in the annals of meteorology, yet it is seldom that one of such violence takes a course so far inland. The lesson of it all, especially for architects and structural engineers, is that violent winds during the hurricane season must be included within the category of weather probabilities as far inland as the eighty-fifth meridian.

The hurricane signal was hoisted on six other occasions during the year for storms of less violence. There were no violent storms of which timely notice was not given.

The greatest field of usefulness of the Service lies, as has been observed in previous reports, in forecasting the severe storms that at times visit our shores and the marked cold waves that occasionally sweep from the Rocky Mountains eastward, rather than the ordinary changes in temperature, wind, and weather.

The official in charge of the New York office, in reporting upon the severe storm of December 15–16, 1896, says:

> After the issue of the hurricane warning not a vessel was reported to have left port, except the steamship *St. Louis*, of the American Line, and it is believed she came to anchor off Sandy Hook bar. The storm was very severe in this section and was attended by all the most dangerous features of such storms; the wind blew a gale (54 miles per hour) on shore from the northeast, with fine sleet, heavy driving snow, and temperature below freezing; it is

seldom that the mariner encounters such a combination of dangers. All vessels prepared for the storm and, in view of the timely warning, there was a chance for all to seek a harbor of safety. It is marvelous that not a vessel of any class was lost or even disabled in this section.

The official in charge at Boston reports concerning the hurricane warning of October 10, 1896 :

This was the most marked success of the year. The information of the approach of one of the most destructive and protracted storms of recent years was very timely. Vessels of all classes were tied up and shipping was practically suspended from October 10 to 16, inclusive. The saving of property in this instance was enormous, exceeding many times the cost of the maintenance of the entire Weather Bureau for years. The press of this city commended the Bureau in the highest terms for its good work and placed the value of shipping saved by the warning at millions of dollars, which was of little importance compared with the saving of human life.

The above comments, it may be urged, necessarily partake more or less of the nature of *ex parte* testimony; granting this, there is still an abundance of testimony from the standpoint of the people in general, as witness the following from the editorial columns of the Jacksonville (Fla.) Daily Times-Union of September 6, 1897 :

THE SEASON OF HURRICANES.

Shipmasters at this, the season of West India hurricanes, should watch with more than usual care the forecasts of the Weather Bureau, and should take no chances when low or cyclonic areas are reported in the Gulf. For five successive years Florida has not escaped from having one or two hurricanes, with a wind velocity of from 45 to 80 miles an hour. In preceding years they pursued a course either to the eastward or the westward of the State, but in all instances doing great damage to shipping. In fact the men who go down to the sea in ships have found the latter part of August, the whole of September, and the first part of October to be the most perilous period of the year, but the increased efficiency of the Weather Bureau, due to more numerous stations, better appliances for observation, quick means of communication, and particularly careful study of this enemy of shipping, has lessened these perils in a great degree, so that a shipmaster of intelligence and caution should now, in coastwise voyages, know in a general way just about the weather he will encounter from port to port.

Flood warnings.—The warnings issued by the Bureau, in connection with the disastrous floods that occurred in the lower Mississippi Valley in the spring of 1897, were most timely and effective. The daily forecasts issued by the officials in charge of the river centers gave timely notice of the gradual rise of rivers to the danger line, and as soon as it was seen that floods were imminent, warnings to that effect were sent from the Central Office in Washington, D. C. Thus, on March 15, two weeks before the first serious break in the levees, it was announced in a special bulletin that—

The reports indicate a continued rise in the lower Mississippi River during the next ten days or two weeks, and from the water now in sight, and rainfall likely to occur within the next few days, it is probable that the impending flood will prove very destructive in Arkansas and northern Louisiana. The most destructive overflow is likely to occur between the mouth of the Arkansas and the mouth of the Red river, and the observers of the Weather Bureau in that region have been directed to warn the public generally of approaching danger.

Again, on March 19, it was announced that—

The floods in the lower Mississippi during the next ten days or two weeks will, in many places, equal or exceed in magnitude and destructiveness those of any previous years, and additional warning is given to residents of the threatened districts in Arkansas, Louisiana, and western Mississippi to remove from the region of danger.

As the flood approached its height these warnings were repeated and emphasized, notably so on March 28, April 3, 15, and 17. The local officials, under instructions from the Central Office, gave the widest possible distribution to these warnings, by mail and telegraph, throughout the threatened regions; a daily bulletin was also given to the press, thus keeping the public thoroughly informed of the present and prospective extent of the flood. Through the courtesy of Mr. John Hyde, Statistician of the Department of Agriculture, I am able to submit a rough estimate of the values of live stock and farm products on hand in the flooded districts of the Mississippi River immediately preceding the flood, which are as follows:

January 1, 1897, horses, cattle, sheep, and other live stock	$10,037,540
March 1, 1897, corn, oats, cotton and other movable farm products of last years crop	4,664,900
Total	14,702,440

It would be impossible to estimate the value of live stock and moveable property saved by these warnings, but certainly the saving amounted to many millions.

At a time when the Mississippi River at New Orleans was at the highest stage ever known, warnings were sent to that city that within five days the gauge reading would show a further increase in the height of the water of over one foot; that it was imperative that the height of the levees be still further increased.

The water reached the height predicted exactly on the date specified in the warnings, but the levees had been strengthened and raised to meet the impending danger.

At Cairo the river rose to danger line on February 26, and remained above it for fifty-nine days. Danger line was reached at Memphis on March 10; at Vicksburg on March 16; at New Orleans on March 18. The duration of the flood at these points was as follows: At Memphis, fifty-three days; at Vicksburg, eighty days; at New Orleans, eighty-eight days. The highest water ever known was experienced at Memphis and points below.

On April 5 the Secretary of Agriculture directed the Bureau to prepare a map, showing the area then under water, at the earliest possible moment. By a free use of the telegraph, such a map was completed at 3:30 p. m. of the following day, and was of fair accuracy, as shown by subsequent detailed reports. A full report of this flood, together with a review of previous floods, and a discussion of normal rainfall and drainage in the Mississippi basin, is in preparation for early issue.

Hydrography.—There have been maintained during the year 113 river and 42 rainfall stations, making daily observations and full monthly reports, together with such telegraphic reports as have seemed advisable for the purpose of river forecasting. In addition special reports are received at times of heavy rainfall and high water from 33 other stations. Voluntary river observations are also made by and reports received from a considerable number of unpaid observers.

The system of river and rainfall stations was revised at the end of the past year, such changes as were made going into effect on July 1, 1897. It was sought in this revision to secure a greater number of continuous records throughout the year. Such a course was necessary, as without continuous records the regimen of the streams could not be correctly determined. To do this without much increase of expense, some of the less important stations were closed.

Beginning with the issue of the Monthly Weather Review for November, 1896, there has been included in that publication a monthly report on the condition of the rivers of the United States, accompanied by a table of average and extreme gauge readings and range in the river stages at the various river stations. Since April 1, 1897, this has been supplemented by a hydrographic chart for selected stations on seven of the more important rivers. This feature of the Weather Review furnishes the only means in the country of obtaining current river data from all sections.

Part V of the series of Daily River Stages, published by the Weather Bureau, was issued near the end of the year. This volume embraces daily stages at all stations for the years 1893, 1894, and 1895. A companion volume of daily rainfalls for the same years is in press.

The river service is composed of 22 sections, each with a central office receiving reports from a definite area and each making local forecasts for the river district under its supervision. In the case of impending great disaster, the Central Office at Washington dictates the important warnings for distribution by the section centers.

As yet the rules of flood forecasting are largely empirical. The official in charge of a river center is familiar with the main river and its tributaries; the area and topography of the catchment basin; the frequency and intensity of the rainfall, especially the intensity; the average time of passage of flood crest between one station and another, and the history of past floods. The knowledge of low-water conditions, especially where bars and shoals exist, is perhaps of equally as great importance as the knowledge of high water. The people living in regions contiguous to navigable streams are materially affected in their industries by the conditions of navigation, and the Weather Bureau in giving fairly accurate predictions of variations in low-water stages, as well as in giving warning of destructive floods, renders a signal benefit to river shipping. The official in charge of a river center makes timely dissemination of warnings when floods threaten.

During recent years a very thorough reorganization and systematization of the river and flood service has been effected. From the local observers who measure the rainfall or gauge the river heights to the trained meteorologists who are in charge of the river centers; from the latter officials to the forecast officers at the Central Office; and from these to the Chief of Bureau, the organization has been slowly strengthened, until it is believed the Bureau is able to efficiently serve the public during an emergency.

Cold-wave and frost warnings.—The year was somewhat remarkable for the absence of severe cold waves and destructive frosts, but such as occurred were, as a rule, accurately forecast in good season. A system of reporting the advance of cold waves from station to station (reports being sent by the stations affected to those nearest and in the probable path of the cold wave) was put in operation during the year over the eastern Rocky Mountain slope from Nebraska to Texas, on the recommendation of Lieut. Col. H. H. C. Dunwoody, U. S. A., who is assigned to duty with the Weather Bureau as Supervising Forecast Official. In this, as in many other instances, Colonel Dunwoody has shown his fitness as an able assistant to the Chief of Bureau.

Gratifying success attended the warnings issued for the benefit of the fruit industry of Florida, the sugar interests of Louisiana and Texas, and the truck-growing districts of the eastern seaboard.

The rain warnings issued from the San Francisco office for the benefit of the raisin industry during the drying season, and on the accuracy of which that industry is greatly dependent for success, were, in every instance, justified. The official in charge of the San Francisco office states, in reference to the work of the Bureau in this particular, that during the last three years not a single rain occurred in the raisin-drying region without warning, and in only one instance was an unnecessary warning issued.

Distribution of forecasts and warnings.—The distribution of forecasts and warnings has been continued on practically the same lines as in former years, particular attention having been given to the development of the system of mail distribution by logotype cards in the large cities.

The number of forecasts and special warnings distributed in each State and Territory, not including those contained in the daily press reports and weather maps, is shown in the table below:

States and Territories.	By telegraph or telephone at Government expense.			Without expense to the United States, by—				Totals.
	Daily forecasts.	Cold wave and frost.	Emergency.	Mail.	Telegraph or telephone.	Railroad telegraph.	Railroad train service	
Alabama	22	....	63	569	6	26	12	698
Arizona	8	....	....	....	3	....	....	11
Arkansas	40	4	58	289	26	7	....	424
California	108	7	8	1,219	98	349	....	1,779
Colorado	11	10	47	396	....	6	7	477
Connecticut	18	6	32	525	49	16	151	792
Delaware	5	....	6	33	....	21	....	65
District of Columbia	....	....	....	830	18	....	....	848
Florida	44	42	82	377	2	68	....	585
Georgia	51	40	82	571	2	99	41	886
Idaho	9	....	....	174	1	....	....	184
Illinois	67	25	883	2,108	5	308	459	3,855
Indiana	91	2	98	1,134	1	194	287	1,807
Indian Territory	7	1	....	103	1	....	....	112
Iowa	107	5	183	1,089	38	11	....	1,433
Kansas	40	3	142	434	20	37	8	684
Kentucky	44	66	76	564	116	25	....	891
Louisiana	25	22	6	412	19	1	....	485
Maine	25	1	13	861	8	17	17	942
Maryland	24	2	17	821	88	100	....	497
Massachusetts	22	16	32	1,818	22	....	331	2,241
Michigan	81	19	167	2,648	25	309	457	3,706
Minnesota	48	11	87	1,068	54	7	....	1,270
Mississippi	44	14	62	200	55	9	....	384
Missouri	87	6	191	3,150	90	107	60	3,691
Montana	15	....	16	22	4	....	....	57
Nebraska	65	4	147	775	2	11	....	1,004
Nevada	8	....	....	49	8	....	....	55
New Hampshire	11	1	18	275	....	9	81	340
New Jersey	31	24	70	785	17	160	....	1,087
New Mexico	6	....	....	28	8	4	....	36
New York	112	22	201	3,606	282	256	61	4,540
North Carolina	58	15	114	587	17	1	16	808
North Dakota	19	9	96	....	45	....	....	169
Ohio	118	111	107	3,393	88	78	17	3,997
Oklahoma	4	1	8	45	10	....	....	68
Oregon	22	....	....	610	9	....	104	745
Pennsylvania	64	18	105	1,557	712	705	7	3,163
Rhode Island	2	....	5	21	....	....	27	55
South Carolina	58	4	65	497	62	42	10	783
South Dakota	42	81	76	855	12	....	....	516
Tennessee	84	4	98	838	64	31	2	1,061
Texas	51	31	181	499	140	64	....	969
Utah	18	....	....	184	....	....	....	147
Vermont	11	1	16	464	18	11	13	529
Virginia	39	11	91	750	105	75	95	1,166
Washington	25	2	....	359	24	....	29	489
West Virginia	17	9	44	249	6	32	....	359
Wisconsin	55	13	184	1,182	37	....	16	1,387
Wyoming	8	5	6	5	8	....	....	22
Total June 30, 1897	1,886	613	3,481	37,913	2,347	3,196	2,258	51,694
June 30, 1896	1,581	598	3,481	22,642	1,712	3,550	1,939	35,501
Increase	305	15	00	15,271	635	....	319	16,193
Decrease	....	....	....	....	....	354	....	....

Distribution of weather statistics by maps.—Detailed information of the actual weather conditions existing over considerable areas is graphically shown by the daily weather maps, the circulation of which increased more than three-fourths of a million copies during the year, the total issue being 4,625,250 copies. Business houses, public offices, and schools are the principal recipients of the maps. The extension of the improved system of printing adopted last year has made this large increase possible. There are at present 81 map-printing stations, at 27 of which an improved printing process is in use. In addition to these there are 21 stations where meteorological bulletins, containing weather data in tabular form, are issued.

CLIMATIC WORK.

Aside from the issuance of daily forecasts and special warnings the Weather Bureau is charged by law with the reporting of temperature and rainfall conditions in the cotton, corn, and wheat regions; the gauging and reporting of rivers, and other matters.

The cotton region service covers the Southern States from the Carolinas, Georgia, and Florida westward to Texas. Observations of the temperature and rainfall are made at 129 stations throughout this region.

The corn and wheat region service extends from Michigan, Ohio, and Kentucky westward to and including the Dakotas, Nebraska, and Kansas, in which territory 132 daily reports are made at as many stations.

The climatic statistics collected from cotton, corn, and wheat region stations are conveyed to the general public, for whose information they are obtained, chiefly through the medium of the daily press and by telegraphic reports that are bulletined in the principal grain and produce exchanges of the country.

PUBLICATIONS.

The text, charts, and statistical matter required in the presentment of the various phases of climate and weather are prepared and printed at the Central Office. The work involved in this connection is varied, and, in some cases, of exceptional character. No material change has been made in the organization of the various divisions having charge of the collection and discussion of climatological data, or in the character of the publications issued, a list of which appears below:

Title.	When issued.	Edition.
1. Daily Weather Map	Daily	850
2. Weekly Climate and Crop Bulletin	Tuesdays, April to October	5,000
3. Weekly Snow and Ice Chart	Mondays, during cold season	800
4. Monthly Climate and Crop Bulletin	October to March	5,000
5. Monthly Weather Review	15th of each month	3,800

Monthly Weather Review.—The scope of the Monthly Weather Review has been enlarged and its usefulness increased through the untiring efforts of its editor, Prof. Cleveland Abbe. It should be noted that Professor Abbe was one of the most active of those who, thirty years ago, advocated a Government weather service. In 1869, with the aid of the Cincinnati Chamber of Commerce and the Western Union Telegraph Company, he collected observations by telegraph and issued daily forecasts. In 1870, when Congress authorized the War Department to establish a tentative weather service, he was engaged to assist Gen. A. J. Myer, in laying the foundation of that which has grown to be the present extensive weather service of the Agricultural Department. Possessing a profound knowledge of the mathematics, the physics, and the literature of meteorology, he has been a modest, loyal, and valuable assistant to the several executive heads of the Service. He was the first and is still the senior professor of meteorology. I regret to report that to-day the Government, in whose service he has spent twenty-seven years of his earnest life, now pays him but two-thirds of the salary he received on entering its service. At an early day I hope to see his salary restored to, say, $4,000 per annum. He has edited the Monthly Weather Review in such manner as to command the admiration of both American and European scientists. Quotations from it are to be found daily in the popular scientific journals of this country and of the world.

Although the majority of the articles in the Review are of an elementary and popular character such as are suited to the needs of teachers and students of all grades, except in the higher colleges, yet a large number of its readers on the other hand would appreciate strictly technical articles, and it is proposed to hereafter consider the needs of these readers.

It is now some years since charts of normal pressure at sea level and normal surface isotherms were published in the Review. The subsequent accumulation of data has been reduced in the Records Division and it is proposed to publish greatly improved charts of normals and extremes in the Review during the coming year.

The prediction of the weather is, to a considerable extent, conditioned upon the extent of the area from which telegraphic reports are received. This may also be found to be true when we consider the possibility of making long range, seasonal predictions. A forecast of the general character of the weather for the whole of any month must take into consideration the meteorological conditions over a very large part of the globe. The atmosphere must be studied as a unit, and to this effect, on the one hand, the principles of mechanics that apply to it must be set forth in terse formulæ, while, on the other hand, the meteorological statistics must be presented for the whole globe in a similar manner, such that the complex, mechanical interactions may, as far as possible, be worked out graphically. It is proposed to publish in the Monthly Weather Review, during the next two years, a number of contributions to this general study of the whole atmosphere. Several purely mathematical papers are available, beginning with one by Mr. Joseph Cottier. This will be followed in due season by charts of the sea-level and upper-level isobars, isotherms, and winds, and by the results of the study of cloud heights and motions, upon which latter work Prof. F. H. Bigelow is now engaged.

The prompt publication of these results will greatly stimulate progress in knowledge.

The new work in contemplation will, probably, add four charts on the average to each Monthly Weather Review and will increase the letter press by two pages of text and two of tabular matter.

ORIGINAL INVESTIGATIONS AND REPORTS.

Climatology.—The general character of the investigations conducted during the fiscal year under the subhead climatology embodied researches along the following lines:

1. The study of such statistics as were accessible and available in connection with the climatic and seasonal distribution of the meteorological conditions prevalent at the inception, increase, and abatement of sickness and mortality, the purpose of such study being to determine whether there is such a persistent association of certain climatic or meteorological conditions with any of the phases of sickness and mortality, as to afford reasonable ground for the belief that the relation is in any manner one of cause and effect.

2. Such investigation as it might appear practicable to make relative to the demands made by meteorological conditions upon the heat-producing powers of the animal body.

3. Such investigations as it might appear practicable to make relative to the influence of meteorological conditions upon the vital activity of pathogenic bacteria.

Some progress has been made along all three of the above indicated lines of research.

Along the first line, statistical studies have been conducted with reference to the influence of climate, season, and weather upon sunstroke and pneumonia. Along the second line, considerable attention has been given to devising some special apparatus which should approximate, as nearly as practicable, the thermic conditions of the human body, and with which it might be feasible to obtain an instrumental approximation of the demands made by the general weather conditions upon the heat-producing powers of the human body; also, some experiments have been made to obtain a more or less concrete idea of the relation of the general meteorological conditions to the protective efficiency of clothing, as judged by the temperature between the different layers of clothing. While along the third line of study much thought has been given to planning some feasible methods of experimentation. Considerable more time will be required before it will be possible to give more definite details regarding the greater part of the matters that have so far been investigated.

The subjects of sunstroke and the influence of the general weather conditions upon the efficiency of clothing have formed topics of preliminary papers contributed to the Monthly Weather Review (November and December, 1896, and May, 1897) by Dr. W. F. R. Phillips, in charge of the section on climatology. It is hoped that more complete reports can be made upon these two subjects.

The study made by Dr. Phillips of the meteorological conditions associated with the occurrence of sunstroke, particularly those which obtained during August, 1896, has apparently given some information that may be of importance concerning this class of morbid phenomena.

From trustworthy information received in response to a circular sent out August 20, 1896, it appeared that 2,038 deaths occurred during that month which were directly attributed to sunstroke, as the term is ordinarily used and accepted. Although this number of deaths was unusually large there was reason to suppose that the actual number of fatalities from the intense heat was much larger; and accepting the usually stated ratio of cases and deaths the number of persons that must have suffered in greater or less degree was something enormous. In 841 cases of sunstroke, the clinical histories of which were obtained with more or less exactness, the fatality was 16.6 per cent, and were this rate assumed as the index of fatality that obtained in general during August, 1896, the 2,038 deaths would have represented the occurrence of 12,277 cases of sunstroke of varying severity.

From a comparative study of the sunstrokes and the weather prevalent during their occurrence the following conclusions regarding the relation and influence of the meteorological conditions were reached:

(*a*) That the number of sunstrokes followed more closely the excess of the temperature above the normal than it did that of any other meteorological condition.

(*b*) That the number of sunstrokes did not appear to sustain any specific relation to the relative humidity.

(*c*) That although the absolute humidity was greatest during the maximum of sunstrokes, yet it did not appear that its variation influenced the number of cases.

(*d*) That the other recorded meteorological conditions, i. e., the atmospheric pressure, wind, rain, and state of weather, did not show any features that could be regarded as of etiological significance.

Inasmuch as there appeared to be a closer association between the course of the sunstroke and the course of the atmospheric temperature than between any other meteorological element or condition, an attempt was made to ascertain, if possible, what degree of temperature was necessary or most likely to excite sunstroke. An examination of the different statistics appeared to show that there was empirical evidence for assuming that each locality had for its acclimated inhabitants a particular sunstroke temperature or range of temperature, and for adopting as a provisional index of the sunstroke temperature the normal daily maximum temperature of each climate. This provisional standard applied to the cases of sunstroke as reported in the cities of New York, Boston, Philadelphia, and Washington, from which places the statistics were most numerous, gave the following results:

In New York City 96 per cent of the cases occurred with daily mean atmospheric temperatures equal to or slightly above the normal maximum temperature for August (the period in question). In Boston and Philadelphia 91 per cent and in Washington 77 per cent of the cases occurred under like conditions of temperature.

In the light of these results the following working hypothesis was proposed: Sunstroke becomes imminent during the summer months when the mean temperature of any one day or of several successive days becomes equal or nearly equal to the normal maximum temperature for the period.

Also, an attempt was made to determine, by using such statistics as were accessible for other years, how far the hypothesis above stated could be depended upon as a criterion of impending danger from sunstroke, with the result that it appeared to be a fairly good index for the eastern and central portions of the United States. No statistics were accessible for the States of the western plateaus. But, with respect to the above hypothesis, this caution is to be kept in mind: That although the hypothesis embodies certain plausible climatological conditions, it was evolved simply as an empiricism based upon quite a large number of facts, and that it does not rest upon a satisfactory knowledge of all the factors involved, and that even before it can be said to represent accurately an empirical relation it must be corroborated by a larger mass of statistics than are at present accessible.

The rainfall of the United States.—The results of a study of the rainfall registers of the United States by Mr. Alfred J. Henry, with especial reference to the period 1871–1896, will shortly appear as Bulletin D of the Weather Bureau, from which the following facts and conclusions are drawn:

Observations of the rainfall in this country have been made at irregular intervals since 1738. In recent years the number of rain stations has been greatly increased, chiefly through the efforts of voluntary observers and private individuals interested in climatic research. While the material at hand is much greater than ever before, the lack of continuity in the registers of private persons is a most serious defect. Probably less than 2 per cent of the available registers extend over twenty consecutive years, too short a period to determine the true normal precipitation.

The amount of rain that falls in any region, on the average, depends largely upon its geographic position with reference to (*a*) the ocean or other large body of water and (*b*) to the average path of atmospheric disturbances.

The annual fluctuations of the rainfall of the United States during the ten years 1887–1896 are shown by the numerical value of Table I. The figures in the table represent the difference between the actual and the normal rainfall of each geographic district, plus (+) indicating the excess, in inches and tenths, and minus (—) the deficit. The figures "+2.4" for New England, 1887, were obtained by computing separately the departure from the normal of the rainfall at each of the 9 stations comprised within that district. The separate departures were added algebraically and the sum divided by the number of stations in the district, in the case of New England, 9. This operation gave the average departure for the district, viz, + 2.4 inches.

Departures from the normal precipitation by geographic districts (1887–1896).

Districts.	No. of stations.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.
New England	9	+ 2.4	+10.1	+ 5.2	+ 5.8	+ 0.8	− 4.8	− 0.8	− 7.5	− 2.8	− 5.0
Middle Atlantic States	11	− 1.0	+ 4.7	+12.5	+ 5.4	+ 4.5	− 2.8	+ 2.9	− 2.5	− 7.6	− 7.2
South Atlantic States.	11	− 1.5	+ 0.2	+ 2.0	− 5.0	− 1.7	− 7.4	+ 1.5	− 2.0	− 1.5	−10.7
East Gulf States	5	− 6.0	+ 7.2	− 6.7	− 5.0	− 0.2	− 7.0	− 1.2	− 6.9	− 6.4	− 9.0
West Gulf States......	8	− 6.1	+ 8.8	− 2.2	+ 2.1	− 9.0	− 8.8	− 9.8	− 4.6	− 8.6	−12.5
Ohio Val. and Tenn ...	11	− 4.2	+ 1.9	− 4.8	+ 9.2	+ 0.8	− 1.9	− 2.6	− 8.9	−11.6	− 4.6
Lower Lake Region...	8	− 3.9	− 4.8	− 2.4	+ 5.2	− 3.6	+ 3.8	− 0.8	− 3.8	− 5.5	+ 0.1
Upper Lake Region ...	10	− 3.1	− 5.0	− 3.6	− 0.1	− 2.4	− 0.8	+ 0.7	− 2.8	− 5.4	− 4.6
Extreme Northwest ..	4	− 1.0	− 2.9	− 6.8	− 0.4	+ 3.9	− 1.0	− 0.9	− 0.4	− 1.1	+ 2.9
Upper Mississippi Val.	18	− 4.9	− 0.6	− 6.1	+ 0.1	− 5.1	+ 4.7	− 3.4	− 8.7	− 9.2	+ 0.5
Missouri Valley	10	− 2.2	− 2.8	− 4.1	− 4.1	+ 0.9	+ 2.0	− 2.1	− 8.0	− 0.6	+ 0.2
Northern Slope	6	+ 1.1	0.0	− 2.4	− 2.7	+ 4.5	+ 1.8	− 1.8	− 1.2	− 1.0	+ 0.9
Middle Slope	7	− 4.2	− 4.5	− 0.8	− 4.2	+ 6.0	+ 1.8	− 5.4	− 5.1	+ 0.6	− 1.8
Southern Slope........	4	+ 1.8	+ 8.7	− 2.4	+ 1.8	− 0.8	+ 2.2	− 5.2	− 3.4	+ 4.0	+ 1.0
Southern Plateau	9	+ 0.9	+ 0.2	− 1.4	+ 1.0	− 2.1	− 4.7	− 1.7	− 2.7	+ 0.2	+ 1.1
Middle Plateau	5	− 3.9	− 1.7	+ 1.9	− 0.4	+ 2.0	− 0.6	+ 0.4	+ 0.7	− 2.8	+ 2.4
Northern Plateau.....	4	− 2.1	− 4.5	− 4.1	− 4.1	− 0.8	0.0	+ 6.2	+ 3.2	− 3.0	+ 1.1
North Pacific Coast...	8	− 6.2	− 6.6	−10.6	− 9.0	+ 8.4	− 3.0	+13.3	+11.8	+ 5.8	+10.1
California	12	− 5.6	− 1.8	+11.4	+ 1.9	− 3.4	+ 4.4	+ 1.0	+ 0.6	− 1.1	+ 1.0
Above the mean...	....	4	8	5	9	9	7	7	4	4	11
Below the mean...	....	15	10	14	10	10	11	12	15	15	8

A cursory examination of the table shows that there has been a very general deficiency of rain in the majority of years and in almost all of the districts. Moreover, there does not seem to be any law of compensation by which a deficit in one district is balanced by a surplus in another. The South Atlantic and Gulf States, in particular, show a marked deficit throughout almost the entire period. This fact naturally suggested an inquiry into the rainfall of the preceding ten years. The following statement shows the average precipitation at the principal Weather Bureau stations in the region just mentioned for twenty consecutive years, in periods of ten years each:

Average annual precipitation in periods of ten consecutive years, 1877–86 *and* 1887–96.

Stations.	1877–96.	1877–86.	1887–96.	Difference.
Lenoir, N. C	50.09	51.40	48.78	− 2.62
Hatteras, N. C	65.58	73.41	57.76	−15.65
Wilmington, N. C	53.06	58.83	47.30	−11.53
Charleston, S. C	54.59	56.82	52.37	− 4.45
Augusta, Ga	46.99	46.53	47.44	+ 0.91
Savannah, Ga	59.83	50.91	48.75	− 2.16
Jacksonville, Fla	53.40	57.69	49.12	− 8.57
Mobile, Ala	62.67	66.61	58.73	− 7.88
Montgomery, Ala	50.97	52.04	49.90	− 2.14
Vicksburg, Miss	54.37	62.04	46.69	−15.35
Memphis, Tenn	52.77	56.76	48.78	− 7.98
New Orleans, La	58.81	61.34	54.28	− 7.06
Shreveport, La	47.34	54.26	40.42	−13.44
Galveston, Tex	46.18	52.40	39.96	−12.44

The facts presented above may be viewed from either of two standpoints, viz: (1) Either the rainfall of the first period was abnormally high and the apparent decrease in the second period is merely a return to normal conditions, or (2) there has been a permanent decrease in the rainfall. The first proposition seems to be the more rational one. The heavy rainfall on the Texas coast, where there is a marked deficiency, is largely due to the advent of cyclonic storms from the Gulf, which often have a very slow movement and give torrential rainfall for several days in succession. Thus, 8.70 inches fell on September 16–17, 1877; 8.40 inches on October 24, 1877; 8.24 inches on September 3–4, 1885; 16.53 inches on September 15–20, 1885. In the last-named case the rainfall at points less than 100 miles inland was not a fifth of the fall at Galveston on the coast. The movement of these storms, after passing several hundred miles northward, is much accelerated, and less rain is precipitated than on and near the coast.

The seaward margin of the South Atlantic States is in the region of West India hurricanes, and naturally receives a greater amount of rainfall in years when these storms are prevalent. While these facts may partially explain the marked variation in the rainfall of individual years, they by no means fully account for the phenomenon.

The variation between the rainfall of the 10-year periods, as shown by the above table, was not so marked elsewhere in the United States, although the fall of the second period was generally below that of the first.

It was not possible to extend the comparison to earlier periods except for portions of the older States, as New England, the Ohio Valley, and the middle Mississippi Valley. Here no positive evidence of a periodicity was obtained, although some sixty years of continuous observations were examined.

Rainfall of the crop season.—The exact amount of rainfall required for the successful cultivation of crops has not been fixed nor can be in terms of rainfall alone. On the Pacific Coast, and over comparatively small areas in the arid regions, wheat and other cereals are grown with a seasonal rainfall considerably less than 15 inches; but it should be remembered that the climatic conditions, as regards temperature and humidity, are somewhat different from those which obtain in the wheat region of the Northwest. The character of the soil, especially as regards its ability to retain moisture, is a very important consideration. It is said, in explanation of the fact that wheat is grown in eastern Washington, where the *yearly* fall is generally under 18 inches, that the rainfall of winter and early spring is conserved in the soil, and is supplied to the plant by capillary action during the early part of the growing season.

The average rainfall of Spokane, in the wheat region of eastern Washington, during April, May, and June, is but 4.5 inches, or about as much as falls in a single month in the wheat regions of the Mississippi Valley. It is quite obvious that the growth of the plant is not due to the rainfall of the spring and early summer months alone.

A comparison of the seasonal precipitation chart (not here reproduced) with the returns of the Eleventh Census confirms the view above expressed, viz, that the area adapted to the cultivation of cereals can be broadly defined by the line of 15 inches, or nearly that amount of rain per season, although no hard and fast rule can be laid down. The valley of the Red River of the North, in Minnesota and North Dakota, is widely known as a famous wheat-producing region, yet the seasonal rainfall is a little under 15 inches from St. Vincent northward.

The area included within the line of 15 inches and over of rain per crop season is practically coextensive with the territory east of the one hundredth meridian. The lower Missouri, middle and upper Mississippi, and the Ohio valleys, the Middle States, and New England, however, receive on the average 20 inches and over of rain during the crop season.

The least amount of rain that ever falls during the growing season, April to September, varies from about 22 inches in central Florida to 10 inches on the Lower Lakes, and from about 15 inches at the mouth of the Mississippi to about 8 inches in northern Minnesota.

The years of minimum rainfall or drought, from 1871 to 1896, fall in groups separated by irregular time intervals. The first group centers about 1871; the second, 1881; the third, 1887; and the last, 1894–95. The drought of 1887 was severe in some months, but not consistently so throughout the entire season. The droughts of 1881 and 1894 were widespread and severe. The former was confined principally to the States east of the Alleghanies, while the latter was felt from Nebraska eastward to Massachusetts and southward to Alabama. Prior to 1870 the few records available indicate a severe drought in Kansas and western Missouri in 1860, more severe than has since been experienced. Widespread drought in the central valleys and Lake Region was noted in 1863. The periods of extensive drought in chronological order are, therefore, 1860, 1863, 1870–71, 1881, 1887, and 1894–95. There have been, of course, severe local droughts in various portions of the United States during the intervening years, as there must always be in a territory of such vast extent.

The table below was prepared to illustrate the fact that generally the least rainfall may be expected to occur within a period of twenty-five years. The second column of the table shows the least rainfall of the crop season during the twenty-six years 1871–1896 and the third column the least ever recorded in previous years.

In nine of the sixteen cases the year of least rainfall occurred prior to 1870, but the differences in individual cases are not great and disappear altogether in the general average of both periods.

Least rainfall April to September, inclusive, at the stations named.

Stations.	1871-1896.	Previous years.	Remarks.
New Bedford, Mass	13.2 in 1891	11.6 in 1849	Continuous record from 1814.
Boston, Mass	13.9 in 1887	11.3 in 1836	Continuous record from 1818.
Providence, R. I.	16.3 in 1894	11.3 in 1836	Continuous record from 1832.
Amherst, Mass.	13.9 in 1887	11.8 in 1836	Continuous record from 1836.
New York, N. Y.	12.7 in 1881	12.5 in 1849	Continuous record from 1836.
Newark, N. J.	12.1 in 1881	16.4 in 1845	Continuous record from 1844.
Philadelphia, Pa	10.3 in 1881	14.5 in 1825	Continuous record from 1825.
Washington, D. C.	14.3 in 1894	16.7 in 1869	Continuous record from 1856.
Savannah, Ga	19.0 in 1881	20.8 in 1857[1]	Continuous record from 1837.
Portsmouth, Ohio	12.8 in 1878	9.7 in 1834[2]	Continuous record from 1830.
Cincinnati, Ohio	12.6 in 1895	11.9 in 1870	Continuous record from 1835.
Louisville, Ky	14.0 in 1881	15.4 in 1850[3]	Continuous record from 1842.
St. Louis, Mo	10.7 in 1871	15.8 in 1870	Continuous record from 1837.
Miami, Mo	13.3 in 1871	8.1 in 1860	Continuous record from 1847.
Monticello, Iowa	10.2 in 1871	12.4 in 1868	Continuous record from 1855.
Fort Riley, Kans	11.1 in 1875	9.7 in 1860	Continuous record from 1854.
Average	13.2	13.2	

[1] 1839, 1859-1868, inclusive, and 1870 missing. [2] 1856, 1857, and 1858 missing. [3] 1860 missing.

Some climatic features of the arid regions.—At the request of the Secretary of the National Irrigation Congress, the fifth annual session of which was held at Phœnix, Ariz., December 15–17, 1896, a report was prepared upon some of the climatic features of the arid and subarid regions of the great Southwest.

Opportunity was taken to present the salient features of the temperature of evaporation, popularly known as the sensible temperature, of this vast region. As has been elsewhere stated, the sensation of heat, which is usually referred to atmospheric conditions, depends not only on the temperature of the air, but also upon its dryness, the velocity of the wind, and other circumstances. It was shown in the report that the high temperatures of the Southwest were mitigated in no small degree by the prevailing dryness of the atmosphere and the clearness of the sky, the latter tending to promote terrestrial radiation—an effective means of lowering the temperature of the nighttime.

The southwestern part of the United States possesses a climate intermediate between that of the tropics and the temperate zones. The sequence of weather is more uniform than in higher latitudes; the changes in temperature from day to day are less; rainfall is deficient; the sky is generally clear; insolation and radiation are both strong; the range of temperature from day to night is large, from from 25° to 35°; the winds are generally light and evaporation is high.

The concluding part of the report deals with the strength of the surface winds over the arid region and the time such winds are available for driving windmills. It is shown that on the plains east of the Rocky Mountains effective winds (6 to 20 miles per hour) prevail about 50 per cent of the time; that on the eastern foothills of the Rocky Mountains and in sheltered valleys effective winds could not be depended upon more than 30 per cent of the time when irrigation is most needed.

In the Great Basin, Arizona, and New Mexico, effective winds prevail from 30 to 50 per cent of the time, depending somewhat upon the nature of the land surface and the immediate environment of the wind motor.

Storms, storm tracks, and weather forecasting.—There was prepared and issued during the year, Bulletin No. 20, Storms, Storm Tracks, and Weather Forecasting, by Prof. Frank H. Bigelow. The purpose of the bulletin was to create a more intelligent interest in the daily weather map, and to spread among the people at large some of the guiding principles of weather forecasting. It is very generally admitted that the forecasts and warnings of the Bureau find their fullest application to the varied interests of agriculture, commerce, and navigation among persons who have given the matter some study and who possess a rudimentary idea, at least, of the general principles of forecasting. The bulletin contains results that have been acquired by years of practical experience. Professor Bigelow treats the subject by months beginning with August when the atmospheric circulation is rather feeble and the eastward drift slow, passing gradually through the months of transition from hot to cold, finally reaching the winter months whose characteristics are a boisterous circulation of the atmosphere, rapid eastward movement, and great alternations of temperature, pressure, etc.

The origin of storms in latitude and longitude, their progressive motion and general characteristics are tersely set forth in this work.

Aerial work.—The results obtained with kites have been discussed in detail in a series of articles published in the Monthly Weather Review, Vol. XXIV.

In the work of the preceding year special attention was given to producing a kite that would fly at the highest possible angle of elevation consistent with a large angle of incidence; that is to say, if the bridle of any kite is so set that its angle of incidence is, say 20°, then, if the action of this kite were absolutely perfect, upon a short string, it should fly at an angular elevation of 70°. Owing to the weight of the kite, the pressure of the wind upon the framework, and other causes, no actual kite could fly at so great an angle under such circumstances, but it was found possible, by means of certain improvements, to secure an approximation to the perfect kite in this respect, represented by a numerical efficiency of from 90 to 95 per cent. This efficiency has been calculated upon a mechanical basis similar to that employed in other branches of applied mechanics.

In the work of the current year, while still retaining the improvements brought out in the preceding year, attention was directed to securing an increased pulling power for a given kite, other things remaining the same. What may be regarded as a final solution of this element of the problem has not, as yet, been reached, but important improvements and discoveries have been made. Full details of these will be reserved for more extended presentation in a subsequent report. It will suffice for the present to say that an elevation of 7,500 feet has been reached by a single kite carrying over 2 pounds in instruments, and the entire supporting action was secured from 41 square feet of sustaining surface, yielding from 50 to 80 pounds pull on the line.

Complete safety and immunity from breaking the main line is one of the most important factors in kite flying. This is the more difficult to secure in proportion as the elevations aimed at are greater, for the reason that in such cases the strain upon the line must be increased until the margin of safety is comparatively small.

Two important improvements have been effected, both contributing to increase the safety of the operation of flying a kite.

The first of these consists of an improved method of bridling a kite, so that by securing a peculiar relation of the forces in action the pull upon the line tends to remain more nearly constant when great variations take place in the force of the wind. Only recently has it been possible to fully develop the mechanics of the action of the forces in this particular case, and it is now believed that by the aid of this knowledge we shall in the near future be able to secure a still more perfect automatic regulation of the pull than has thus far been realized in the kites now in use.

The second improvement, tending to increase the safety in kite flying, consists in what has been called the "safety line." This is a small piece of steel wire of the finest possible quality, inserted immediately between the end of the main line and the kite. If, for example, it is desired to protect the main line so that it shall not be strained to more than 90 pounds by the kite, then a "safety line" of such a size that it will be broken by a strain of 90 pounds is selected. This line is inserted in such a way that it carries all the pull of the kite, and if, by any circumstances, the strain exceeds 90 pounds the "safety line" will break. The kite, however, does not escape, but is immediately held in restraint by means of a supplementary bridle that was previously a little slack, and which is fixed to the kite at such a point that when the kite is flying from the supplementary bridle the pull, other things being the same, will be much smaller than obtains with the normal bridle. In actual work it has been found that the pull falls from about 90 pounds to about 50 pounds when the safety line breaks. The kite, therefore, continues to fly in a very satisfactory manner, and it is sometimes difficult to say certainly whether or not a safety line has broken until the kite is landed.

The general success attained in the experiments made prior to July 1, 1897, has justified a considerable extension of the work during the ensuing year, the preparations for which are now well under way.

Object of kite flying.—The object of perfecting an apparatus for more successfully flying kites is to secure meteorological observations at great altitudes above the surface of the earth. From a knowledge personally gained by many years' service as an official forecaster, I do not hesitate to express the opinion that we have reached the highest degree of accuracy in the making of forecasts and storm warnings possible to be obtained with surface readings only. It is patent that we are extremely ignorant of the mechanics of storms; of the operations of those vast yet subtle forces in free air which give inception to atmospheric disturbances, and which supply the energies necessary to continue the same. It has, therefore, been the policy of the Bureau, during the past two years, to systematically attack the problem of upper air exploration, with the hope of ultimately being able to construct a daily synoptic weather chart from simultaneous readings taken in free air at an altitude of not less than one mile above the earth.

It is believed that the method adopted by European investigators of sending up observers in balloons, or of liberating free balloons with automatic instruments attached, will be of very limited use in acquiring a more perfect knowledge of the forces that work about a storm center. The plan previously proposed by the Bureau of making daily balloon ascensions from a given station would give results of slight benefit to the weather forecaster. The plan on which I have been working the past two years is to secure a simultaneous view, by means of automatic instrument displayed at the same moment of time from many stations and elevated to a height of at least one mile. It is believed that simultaneous observations at a high level, from many given stations (if the kites can be perfected to such a degree as to render it possible to secure daily observations), will ultimately result in a better understanding of the mechanics of storms.

If the kite stations can be established and successfully operated day by day, we shall then construct a chart from the high-level readings obtained at many stations, and study the same in connection with the surface chart made at the same moment. Being thus able to map out the vertical gradients of temperature and pressure, as well as the horizontal distribution of these forces, on two levels, it is hoped to better understand the development of storms and cold waves, and eventually to improve the forecast of their coming, extent, and rate of movement. To be sure, the success of this investigation depends on perfecting the appliances for carrying the instruments to great elevations. Effort will be made to successfully establish about twenty kite stations during the present fiscal year. If these can be successfully operated, and if results are obtained which are useful to the forecaster, it is desired to continue them as a part of the Weather Bureau system; otherwise, they can be discontinued as soon as negative results are shown.

Cloud work.—The international simultaneous cloud observations referred to in my last report were concluded on June 30, 1897. About 7,000 observations for cloud heights, and probably 2,000 pairs of observations for direction and velocity were obtained at the primary station in this city.

The plan for a system of simultaneous observations over the whole world on the height, direction of motion, and velocity of movement of clouds was set in operation May 1, 1896, in accordance with the suggestions of the International Committee having charge of this work. The United States Weather Bureau has undertaken to contribute its share to this study of the circulation of the upper strata of the atmosphere over the Northern Hemisphere, and accordingly established a primary station at Washington, D. C., and fourteen secondary stations in various parts of the United States, to carry out these observations. The cooperation of the authorities of the War Department in maintaining a base line station on the War, State, and Navy Building, for the theodolite work required in these operations has been of invaluable assistance, because that site was the most favorable for the observations in connection with the telephone service.

At the nephoscope stations a very large number of readings for the relative motion of clouds have been made. Much of this latter work was done by volunteers, in the interests of this investigation, who realized the necessity of exploring our storm phenomena more thoroughly than heretofore. The Bureau has also collected on its charts, during the past twenty-five years, a series of cloud observations which are now to be drawn upon to provide fundamental data for this discussion. The "cloud year" ended for us on June 30, 1897, but some of the European observations will be continued longer, as there was delay in beginning the work at the time originally fixed.

The three classes of data mentioned, from the theodolites, the nephoscopes, and the Weather Bureau charts, now afford an opportunity, for the first time, to study our North American circulation carefully. The observations are being reduced as rapidly as possible, and the necessary theoretical studies are intrusted to Prof. Frank H. Bigelow, who is endeavoring to reach definite conclusions, based upon sound data, as to the true theory of hemispherical circulation and other matters related to the origin and propagation of our storms. Much labor is required to handle the material but it is expected to have the report ready during the year 1898.