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# REPORT OF THE CHIEF OF THE WEATHER BUREAU.

UNITED STATES DEPARTMENT OF AGRICULTURE,  
WEATHER BUREAU,  
Washington, D. C., October 8, 1920.

SIR: I have the honor to submit herewith a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1920.  
Respectfully,

C. F. MARVIN,  
*Chief of Bureau.*

Hon. E. T. MEREDITH,  
*Secretary of Agriculture.*

It seems appropriate in this report to lay special emphasis upon the limitations which now surround practically all the activities and service the Weather Bureau is charged by law to render. For several years the annual appropriations of the Bureau have remained practically stationary, while costs for services and supplies of all kinds have advanced greatly. To the difficulties these conditions bring in maintaining the service of meteorology applied to the interests of agriculture, commerce, and navigation at its proper standard of completeness and efficiency there are added the necessities of meeting, as far as possible, the new demands created by simply the normal growth of the Nation as well as needs which are now a permanent part of national existence as a result of war experiences and developments. Meteorological service for aeronautics and military operations must be supplied. The Weather Bureau is the logical Federal agency for this purpose and needs the strongest possible support of Congress and the people to enable it to meet all its new obligations.

Every national activity, industry, and interest has become aroused to the immediate practical value of weather advices, warnings, forecasts, and information in the daily sequence of affairs. Aviation and the aerial mail service are protected and assured a greater percentage of safety and success by a foreknowledge of flying conditions. The total number of stations now equipped to render the special free-air data required is only 11, to represent the continental United States. Even supplemented by about an equal number of reports from Army posts and Naval bases, the number of stations is ridiculously inadequate and must be increased to meet the present demands and future growth of aviation.

Limited personnel, whose rate of pay has remained stationary with stationary appropriations, has compelled the Bureau to make numerous curtailments of useful activities. For example, it was formerly the custom for employees of the Bureau to prepare daily the large glass weather maps on the principal exchanges, boards of trade,

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

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chambers of commerce, etc., in the larger cities of the country. Much dissatisfaction prevails whenever it is imperatively necessary, from lack of funds and trained employees, to curtail this service.

The enormous development of motor traffic and trucking has created an urgent demand upon the Bureau for weather reports and statements of road conditions for vicinities surrounding each of its principal stations. This has been met as far as possible, but the Highway Weather Service, as it is called, falls far short of supplying the motoring public with the aid and service to which it is entitled.

A new enterprise in the form of weather and rain insurance imposes other important obligations of preparedness upon the Bureau to supply facts and data this undertaking requires. This is not a burden at the present time, but is doubtless destined to crystallize into an activity which in the aggregate for the country will entail a very material added expenditure of time and effort.

Obviously meteorology can not be limited by either national or even continental boundaries. Its logical field must embrace the entire globe. Every success attained in great storm warnings and forecasts simply increases the confidence of those served and benefited, awakens greater expectations, and imposes added obligations upon the forecasters. The greatest hope in meeting this situation comes through the collection of numerous reports from the vast ocean expanses and international exchange of observations. A circumpolar service of this character, but of small extent, which existed before the war, has not yet been restored, but happily agencies are at work which give promise that the future will ultimately bring about the realization of a daily weather map, first of the Northern Hemisphere and, possibly, later of the world. In the meantime, every effort is now being directed to the restoration of the meteorological reports of the oceans.

In general terms, the Weather Bureau is suffering from the ravages of the war and the consequences of an enormous change in economic conditions. Its work is conducted under strained conditions by a faithful personnel, largely discouraged by the slow and inadequate adjustment of Federal occupations to existing conditions of life. The rehabilitation of the service is now a most urgent need.

Comments are submitted in the following regarding the principal features of the work:

### FORECAST SERVICE.

No material changes have been made in the regular forecast service of the Bureau, which was somewhat fully described in the annual report for last year. The Bureau can not adequately meet the demands for forecasting with the funds at present available. Some of the special service rendered, during the year just closed, illustrates the nature of these demands.

### SPECIAL FORECASTS AND WARNINGS.

**ARMY AND NAVY BALLOON RACE.**—This race was confined to officers of the Army and Navy, three balloons being entered from each of these branches of the service. It was scheduled to start at 6 p m. September 25, 1919, and complete arrangements were made to furnish

not only forecasts of surface and upper-air conditions that would be encountered, but also weather observations taken at the surface and aloft. Temporary headquarters were located at the starting grounds and telegraphic and telephonic communication established directly with the St. Louis office of the Weather Bureau. Each contestant was supplied with the observations, forecasts, and advices without delay. The information furnished was of pronounced value and the forecasts were accurate to a remarkable degree.

**RECRUITING TOUR OF NAVY HYDROPLANE "NC-4."**—The naval flying boat *NC-4* began its recruiting trip from Rockaway Beach, Long Island, the latter part of September, the first part being a return trip to Atlantic City, thence to Portland, Me., from which place the route extended down the coast to the Florida Straits, thence over the Gulf of Mexico to Pensacola and New Orleans, up the Mississippi and Ohio Rivers as far as St. Louis and Cincinnati, back again to the Gulf, and westward to Galveston. During this cruise, which covered several months, the Weather Bureau furnished a. m. and p. m. forecasts of weather and wind directions and velocities, both at the surface and aloft, for the aviation zone in which the boat happened to be at the time.

**NATIONAL BALLOON RACE.**—This race was scheduled to start from St. Louis, Mo., at 6 p. m. October 1, 1919. A special message was sent that morning stating that there would be showers and thunderstorms to the east and north of St. Louis that night and the following day, and that the conditions would not be favorable for free ballooning. A second forecast, based on special observations, was sent at 2 33 p. m. advising that the race be postponed, as the balloons would be carried northward toward the Great Lakes, where squalls and thunderstorms would be experienced. Notwithstanding this advice, the race was started at the appointed time. The contestants, 10 in number, were carried northward as predicted, and squalls, thunderstorms, and generally unfavorable weather occurred. One of the balloons, with its two occupants, was lost in Lake Huron.

**TRANSCONTINENTAL RELIABILITY AEROPLANE RACE.**—This race was confined to aviators of the United States Army. Starting points were San Francisco, Calif., and Mineola, N. Y., the course being a round trip between the two points. It began October 7 and ended October 31, 1919. Special forecasts were prepared for the benefit of the contestants each morning and evening during the entire period. For this purpose the route was divided into seven zones, and a separate prediction of weather that would be encountered was issued for each zone and telegraphed to the control stations. These forecasts were of great assistance to the flyers. The race was won by Lieut. Belvin W. Maynard. In commenting on the race the official news bulletin of the Air Service said:

Lieut. Maynard's wonderful time was due to the fact that he took advantage of the splendid service rendered by the Weather Bureau in sending the weather forecasts to all of the control stops. If he had been informed that the weather would be bad for the next control stop, he would immediately take off and get to this stop before the storm had approached. This enabled him to gain a distinct advantage over the other participants at the very outset of the race.

OPEN-AIR ENTERTAINMENTS AND WEATHER INSURANCE.—For many years the Bureau has been called on to furnish special forecasts covering periods of State and county fairs, round-ups, picnics, and other large assemblages in the open air. This year more applications of this kind were received than ever before. However, a new and important feature has been involved in such service, due to the rapid increase of weather insurance written by companies to cover owners and directors of such enterprises against losses due to bad weather. Extensive and expensive preparations have to be made in advance for such enterprises. The entertainments are extensively advertised to occur at stated times, and large losses are sure to occur if weather of a character to prevent attendance prevails. Insurance companies now underwrite such risks, and settlements are made on stipulated weather occurrences. The insurer and the insured are vitally concerned, especially the latter, in the forecasts that are made for them a day or two in advance of the opening, and daily thereafter if the performances continue for several days. These special forecasts are made available to the public also and are appreciated by those who expect to attend. Moreover, an important and difficult problem has been injected because of questions of settlement based on records of actual weather occurrences that naturally arise. The Bureau has been obliged to decline to install apparatus and make observations on the premises; but it has freely advised as to the kind of apparatus to be used, how the observations should be made, etc. Service to the people is incumbent on the Bureau, but it often becomes a question as to differentiation between public service and individual service. However strict an interpretation may be placed thereupon, it is patent that the rapid increase in weather insurance is bound to place large additional duties upon the Bureau in making weather observations, compiling data, and furnishing special information, all of which will severely tax the Bureau with its present limited appropriations.

#### FLYING-WEATHER FORECASTS.

A new form of forecasts, known as "Flying Weather," was begun in July, 1919, at the request of the War Department, for the especial benefit of the Air Service of the Army. The country was divided into 7 zones, and a separate forecast made for each of them in the a. m., and certain of the eastern zones in the p. m. Later the number of zones was increased to 13. These forecasts are telegraphed directly to the Air Service, which distributes them to the air fields. A typical forecast, which will explain their character, is as follows:

*Zones Nos. 1 and 2: Poor flying weather to-day; local thundershowers probable; moderate to fresh south and southwest surface winds, becoming west and moderately strong above 3,000 feet.*

Similar service has been furnished the Post Office Department as an aid to mail-route aviators ever since the aerial-mail system was inaugurated. It is likely that arrangements will be made for supplying similar information for the coastal zones of the Navy. Increased demands for aerial observations and forecasts are inevitable in other directions as aerial navigation develops and as an essential factor of success. Meteorological information and forecasts are destined to become of as much importance to navigators of the air as to navigators of the seas.

## STORMS.

Although only two or three storms of extraordinary character and violence occurred, cold waves, storms, heavy snows, frosts, etc., which required the issuance of warnings and advices, were in excess of the average. It was a year of weather abnormalities which necessitated extra vigilance on the part of the forecasters. The general excellence of their work is deserving of commendation.

The most notable storm was the hurricane that occurred in September. It was first detected a little west of the island of Antigua on September 2. It passed inland near Corpus Christi, Tex., on the 14th. A detailed description of this storm was published in the *Monthly Weather Review* for September, 1919. It was of exceptional violence. The barometer at the center was nearly the lowest on record, and its path, after passing Key West, was abnormal. From the time it passed Key West until it struck the southern Texas coast its course was entirely over water and was beyond the range of all land observation stations. Owing to the effectiveness of the warnings that were issued few vessels remained in the Gulf of Mexico; therefore wireless reports from vessels were not available, and the forecasters of the Bureau were placed at a disadvantage in determining its course and progress.

The most violent storm that has visited the Great Lakes, measured by low barometric pressure and high-wind velocities, occurred November 29 and 30. Warnings were issued well in its advance. The winds reached hurricane force, velocities of 72 miles per hour at Port Huron, 84 miles at Detroit, and 80 miles at Buffalo and Toledo being recorded. However, so thoroughly had shipping been warned that there was not a single marine casualty—probably an unprecedented occurrence for a storm of such magnitude and intensity.

Another storm of unusual intensity passed up the Atlantic coast between February 2 and 8. Its outstanding characteristics were its slowness of movement, being nearly stationary off the Virginia coast for nearly two days, and the record-breaking tides that occurred. A unique incident of this storm was that the Weather Bureau was able to profit by its own warnings. Its observatory building at Cape Henry, Va., was seriously menaced by the high tide and encroaching waves, but advantage was taken of foreknowledge of conditions and the building was saved by the erection of sand-bag bulkheads, in which work the officers and men of the Army Engineer Corps located at Fort Story, near by, rendered invaluable assistance.

## HIGHWAY WEATHER SERVICE.

No material changes were made in the highway weather service during the year. This was due entirely to the fact that funds were not available, and that station officials were repeatedly informed that no extension of this work could be made if it involved increased expense of any kind. Bulletins giving information of the conditions of roads, the effect of weather thereon, and other information of value to automobilists and those engaged in the transportation of goods by trucks are issued from 62 stations located in 30 States.

There has been so much demand for an extension of this work, so many expressions of its value by automobile associations, road commissioners, and the traveling public that it has been difficult to resist pressure for extensions. It is a work that the Weather Bureau is best fitted to perform; its value is unquestionable, and it is hoped that appropriations may become available whereby the public demands may be met.

WEATHER MAPS.

The demands for the resumption of the weather maps, which were discontinued at more than 50 stations during the war, are numerous and insistent. Weather maps have been issued for more than 40 years. They are the most effective means of distributing weather information, and the educational, scientific, agricultural, commercial, and navigation interests of the country appreciate their value and expect the service in this form. No serious objection was made to their discontinuance during the war and as a war necessity. Now that nearly two years have elapsed since the war terminated, they can not understand why this service should not be resumed. However, the high cost of paper, materials, and service, which made their discontinuance necessary, have not abated. No additional funds have been appropriated, and it is impossible for the Bureau to resume the service with present appropriations. Weather maps should be resumed at a considerable number of the stations that are located in large cities and populous centers.

VERIFICATION OF FORECASTS.

The question of the accuracy of the forecasts and warnings issued by the Weather Bureau is of public interest. The present system of verification has not been changed for five years. The following table shows the percentage of accuracy attained in the forecasts issued for all States and sections of the country from 1915 to 1919, inclusive:

*Verification of a. m. 36-hour weather and temperature forecasts.*

Year.	1915		1916		1917		1918		1919		Average.		
	Weather.	Temperature.	Combined.										
Washington district:													
Northern New England.....	84.3	90.4	83.8	89.9	83.8	90.7	82.6	86.1	84.5	88.4	83.8	89.1	86.5
Southern New England.....	85.9	91.1	85.8	91.5	85.6	92.4	82.9	89.4	84.7	90.0	85.0	90.9	88.0
Eastern New York.....	86.6	91.2	86.2	91.5	88.1	92.2	81.4	86.6	86.4	88.1	85.7	89.9	87.8
Western New York.....	84.6	91.4	84.7	89.0	84.7	89.9	83.2	86.0	84.7	88.1	84.4	88.9	86.7
Eastern Pennsylvania.....	87.2	91.6	84.6	90.4	86.4	92.7	83.1	89.2	85.8	87.7	85.4	90.3	87.9
Western Pennsylvania.....	85.5	92.4	85.7	90.7	83.7	91.8	83.5	87.6	84.3	90.7	84.5	90.6	87.6
New Jersey.....	86.8	92.8	84.8	91.8	85.8	93.9	83.2	90.4	87.4	90.4	85.6	91.9	88.8
District of Columbia, Maryland, and Delaware.....	87.5	94.2	86.2	93.4	85.9	93.9	83.8	90.1	86.3	92.0	85.9	92.7	88.3

Verification of a. m. 36-hour weather and temperature forecasts—Continued.

Year.	1915		1916		1917		1918		1919		Average.			
	Weather.	Temperature.	Combined.											
Washington district:	<i>P. ct.</i>													
Virginia.....	87.0	93.1	85.2	92.9	85.0	91.8	84.2	89.7	86.1	91.7	85.5	91.5	88.7	88.7
West Virginia.....	84.7	92.2	86.3	89.0	84.7	88.7	81.9	86.0	83.5	89.6	84.2	89.3	86.8	86.8
Kentucky.....	85.2	92.8	87.7	89.7	87.5	91.6	83.5	88.4	86.0	91.1	86.0	90.8	88.4	88.4
Ohio.....	84.6	92.2	86.4	89.8	84.6	89.7	83.4	87.0	83.7	89.4	84.5	89.8	87.2	87.2
Indiana.....	86.0	92.3	86.8	89.0	85.2	89.6	81.8	87.7	85.2	88.5	85.0	89.5	87.7	87.7
Lower Michigan.....	82.8	91.2	84.6	89.6	82.0	89.6	81.8	86.3	83.2	89.2	83.1	89.2	86.7	86.7
Upper Michigan.....	82.6	89.7	81.4	88.2	83.7	86.9	79.2	87.3	81.0	87.0	81.6	87.2	84.7	84.7
North Carolina.....	86.8	92.2	87.0	93.3	85.2	92.5	84.7	90.9	85.1	93.6	85.8	92.5	89.2	89.2
South Carolina.....	87.3	93.7	87.4	95.0	87.4	93.5	85.5	92.2	83.6	95.4	86.2	94.0	90.1	90.1
Georgia.....	87.0	94.7	87.5	94.6	86.8	92.1	85.2	92.1	82.2	94.0	85.7	93.5	89.6	89.6
Florida.....	88.6	96.6	86.6	96.3	86.7	95.8	85.6	96.2	83.4	97.3	86.2	96.4	91.3	91.3
Alabama.....	86.7	95.0	86.4	93.6	86.6	91.5	84.2	92.0	82.7	94.7	85.3	93.4	89.4	89.4
Mississippi.....	85.7	94.3	87.5	92.9	85.7	91.1	84.4	92.5	83.2	93.3	85.3	92.8	89.1	89.1
Tennessee.....	85.6	92.6	86.4	89.1	86.3	90.9	83.4	89.4	84.0	91.6	85.1	90.7	87.9	87.9
District average.....	85.9	92.6	85.9	91.5	85.6	91.5	83.3	89.3	84.4	91.0	85.0	91.2	88.1	88.1
Chicago district:														
Illinois.....	84.3	92.0	86.9	90.6	87.2	91.8	83.8	89.4	86.4	90.0	85.7	90.8	88.3	88.3
Missouri.....	84.8	90.6	86.0	89.6	87.1	90.2	84.4	89.0	86.2	89.3	85.7	89.7	87.7	87.7
Kansas.....	84.6	87.6	87.3	87.1	91.0	88.3	86.0	89.0	80.2	91.0	87.6	88.6	88.1	88.1
Nebraska.....	86.2	86.4	85.3	86.0	89.5	86.3	88.2	87.4	87.4	88.5	87.3	86.9	87.1	87.1
Iowa.....	84.1	90.1	85.8	88.4	86.9	87.9	83.3	86.4	84.4	88.5	84.9	88.3	86.6	86.6
Wisconsin.....	83.2	90.3	84.8	88.8	86.1	89.3	83.4	89.3	85.6	90.0	84.6	89.5	87.1	87.1
Minnesota.....	86.3	87.5	83.8	87.5	86.5	87.2	85.3	86.7	85.3	88.1	85.4	87.4	86.4	86.4
North Dakota.....	87.5	83.9	80.2	85.9	88.9	85.3	87.5	83.2	88.1	86.7	87.6	85.0	86.3	86.3
South Dakota.....	87.4	84.8	85.0	84.2	88.5	86.0	84.6	84.6	85.8	86.4	86.7	85.2	86.0	86.0
Wyoming.....	85.8	84.7	85.9	85.9	89.7	85.2	86.5	86.4	88.9	86.8	87.4	85.8	86.6	86.6
Montana.....	83.8	84.6	85.8	85.6	88.1	82.7	87.5	84.1	89.1	85.0	86.9	84.4	85.7	85.7
District average.....	85.3	87.5	85.7	87.2	88.1	87.3	85.7	86.8	86.9	88.2	86.3	87.4	86.9	86.9
New Orleans district:														
Louisiana.....	87.0	94.9	88.9	93.3	88.4	92.9	87.4	93.2	82.6	93.7	86.9	93.6	90.3	90.3
Arkansas.....	85.4	91.4	88.0	90.0	87.6	90.4	86.8	90.4	84.8	89.8	86.5	90.4	88.5	88.5
Oklahoma.....	85.3	90.2	88.3	88.5	89.2	87.7	87.1	87.9	86.9	90.6	87.4	89.0	88.2	88.2
East Texas.....	87.4	92.2	89.6	91.6	90.6	91.4	89.1	90.8	86.9	92.6	88.7	91.7	90.2	90.2
West Texas.....	90.6	90.9	94.5	90.4	94.2	91.1	93.6	90.0	89.5	92.5	92.5	91.0	91.8	91.8
District average.....	87.1	91.9	89.9	90.8	90.0	90.7	88.8	90.5	86.1	91.8	88.4	91.1	89.8	89.8
Denver district:														
Colorado.....	86.7	85.8	86.7	86.1	89.1	86.2	87.1	85.9	87.7	85.3	87.5	85.9	86.7	86.7
New Mexico.....	87.8	90.7	89.0	91.2	91.2	91.1	88.4	89.2	87.4	90.6	88.8	90.6	89.7	89.7
Arizona.....	90.7	90.9	90.6	91.9	91.9	91.3	90.0	90.8	90.1	91.4	90.7	91.3	91.0	91.0
Utah.....	88.8	89.3	89.8	87.3	91.7	89.5	87.6	91.1	80.3	89.8	89.4	89.4	89.4	89.4
District average.....	88.5	89.2	89.0	89.1	91.0	89.5	88.3	89.3	88.6	89.3	89.1	89.3	89.2	89.2
San Francisco district:														
Washington.....	86.2	93.8	87.5	92.4	86.0	92.3	86.3	90.2	84.8	90.3	86.2	91.8	89.0	89.0
Oregon.....	87.1	89.8	89.2	89.7	87.1	89.6	83.0	87.6	84.3	88.5	86.1	89.0	87.6	87.6
Idaho.....	84.2	89.2	87.4	85.4	87.8	86.9	84.6	87.1	84.8	86.6	85.8	87.0	86.4	86.4
Nevada.....	89.4	89.8	89.3	89.0	92.2	90.2	91.9	89.7	90.1	89.0	90.6	89.5	90.1	90.1
Northern California.....	88.4	93.4	90.9	92.4	92.8	92.8	91.5	93.3	91.1	92.8	91.1	92.9	92.0	92.0
Southern California.....	91.4	96.6	93.2	97.0	94.2	95.6	90.3	95.9	93.9	95.6	92.6	96.1	94.4	94.4
District average.....	87.8	92.1	89.6	91.0	90.0	91.2	87.9	90.7	88.3	90.5	88.7	91.1	89.9	89.9
Grand average, all districts.....	86.3	91.0	87.0	90.2	87.6	90.3	85.4	89.0	86.0	90.3	86.5	90.2	88.4	88.4

The forecast centers are located at Washington, D. C.; New Orleans, La.; Chicago, Ill.; Denver, Colo.; and San Francisco, Calif., and comprise States as indicated in the table. The combined accuracy for all the districts for the five-year period is 88.4 per cent. Veri-

fications are made of a. m. forecasts based on observations taken at 8 a. m., seventy-fifth-meridian time. These forecasts are made 36 hours in advance. It has long been recognized that the complete verification of weather forecasts, by which is meant the finding of the exact relation between the conditions forecast and those which actually occur, involves insurmountable difficulties and that approximately accurate results only are possible according to a series of relatively arbitrary rules. As verifications are based on the results of two observations a day (8 a. m. and 8 p. m., seventy-fifth-meridian time), account is taken only of precipitation or its absence during 12-hour periods. For example, the forecast "Rain to-night, fair Wednesday," would be counted a failure in the second period if some rain fell after the morning observation, although the weather was fair for the rest of the day; it would receive a credit of only 50 per cent by the rules of verification, but the public would undoubtedly regard the forecast as a complete success. In the same manner, a rain forecast for both periods would fail if the rain stopped just before the first observation of the second period.

While general rules for the verification of weather forecasts will always fail and succeed, more or less, in individual cases of the kind cited, it is nevertheless generally admitted that in such cases the failures and successes balance each other in the long run, so that after all the general averages under empirical rules fairly represent the true results.

#### RIVER AND FLOOD WARNINGS.

Increased cost of materials and services required in the upkeep of river gages, including demands for increased compensation on the part of some of the gage readers, has made it difficult to maintain the full program of activities in the safeguarding of life and property from destruction by flood.

The problem was met in part by a revision of the observational work whereby the season was shortened, wherever it could be safely done, and the small amount so saved was applied in granting small increases in compensation at the most important points. At the close of the year the revision had been completed and the maximum possible service was being rendered for the minimum expenditure of funds.

The flood-warning service has functioned efficiently throughout the year, notwithstanding the large number of unusual floods in various parts of the country. In October and November, 1919, serious flooding occurred in the region from northeast Texas to the upper Ohio Valley, and in December of that year the most severe flood in 35 years occurred in the streams of southeastern Mississippi, Alabama, and western Georgia. Notwithstanding the fact that full publicity was given to the coming of these floods, there was a small loss of life and a great loss of property, mostly unavoidable.

The floods of 1919 have emphasized the fact that matured crops grown on lands subject to overflow are not safe until removed to places not subject to overflow. This was particularly noticeable in the case of the 1919 corn crop in the lower Ohio Valley and elsewhere, much of which was lost by flood. Scarcity of farm labor may be the

explanation of a large part of the loss, but the fact remains that loss of corn in overflowed regions has been experienced for many years.

#### MOUNTAIN-SNOWFALL MEASUREMENTS.

On account of the great deficiency of snow for the winter of 1919-20 in large parts of the far West, the measurements of snowfall in mountain regions have clearly indicated the necessity of conserving the water supply in the lowlands. In one case the State has taken formal action toward conservation of the water supply. The number of mountain-snowfall stations is slowly diminishing, since it is rarely possible to replace an observer when he abandons his residence in the mountains.

#### COOPERATION.

Much valuable aid in determining the amount of snow in the mountains has been given by the forest rangers in Western States. Special acknowledgment is due the Forest Service of the Department. By a cooperative agreement with that service, an intensive survey of the precipitation in the mountains of Los Angeles and San Bernardino Counties is being made. The data collected are to be used in planning a system of flood protection for the lowlands of those counties.

The Wagon Wheel Gap county experiment station maintained in cooperation with the Forest Service of the Department, has been in operation during the year. The forest cover of watershed B has been removed in accordance with the original agreement and the experiment may be said to have reached and entered upon the second stage. A discussion of the results of meteorological and stream-flow observations during the first stage has been completed.

#### STATIONS AND ACCOUNTS DIVISION.

##### WEATHER BUREAU QUARTERS IN FEDERAL BUILDINGS.

Suspension of work on Federal buildings during the period of the war throughout the United States was so general that no new Federal buildings were completed at places where Weather Bureau stations are located, and no removal thereto from rented quarters was made during the fiscal year ended June 30, 1920. Furthermore, in several instances the urgent demand for quarters in Federal buildings by other branches of the Government necessitated relinquishment of rooms already assigned and used by the Weather Bureau as follows:

At Lewiston, Idaho, Philadelphia, Pa., and Vicksburg, Miss., one room was given up and Weather Bureau furniture and equipment crowded into remaining space. At Baltimore, Md., about one-third of the Weather Bureau space was relinquished for use of the Revenue Service. At Fort Smith, Ark., Cairo, Ill., and Sacramento, Calif., office space was rearranged to better accommodate occupants of the building.

## RENTED QUARTERS FOR WEATHER BUREAU OFFICES.

A general increase in rentals was demanded for office quarters where leases expired by limitation on June 30, 1920. Where removals to less expensive quarters and reduced space could not be effected, it was necessary to renew existing leases, and the total cost to the Bureau by reason of these increases for the next fiscal year, even attended in some cases with reduction of floor space, is \$4,548.10.

*Status of Weather Bureau offices at stations outside of Washington.*

Free quarters and accommodations:	
In observatory buildings (owned and controlled by the Weather Bureau)-----	45
In State university buildings-----	5
In Federal buildings-----	74
Total free of rental-----	124
Rented buildings, etc., owned by individuals or corporations:	
In office buildings-----	81
In buildings with grounds, aerological, and special meteorological stations-----	16
Total number rented buildings partly or wholly occupied-----	97
Total-----	221

The foregoing does not include Weather Bureau buildings at Narragansett Pier, R. I., and Mount Weather, Va., which continue unoccupied, in charge of caretakers.

## TELEGRAPH SERVICE.

No material changes occurred during the year in the operation of the "circuit" system whereby reception by telegraph of about 175 coded weather observations are reported to the central office twice daily. By the same means 140 stations connected directly with these circuits, 21 in number, receive a specified number adequate to their needs. In addition to these circuit reports, daily observations are received from approximately 40 other points by special message and cablegram and about 50 from ships at sea by wireless.

Close cooperation of the Western Union Telegraph Co. has existed since the foundation of the circuit system many years ago and is vitally necessary for the effective maintenance of the work. Steadily increasing use by this company of the "multiplex" machine system, mentioned in report of last year, has continued to militate somewhat against accurate and prompt transmission of reports and general miscellaneous business by special message.

Reception of reports from cable stations has not been as prompt as heretofore except in isolated cases. Several important cables were broken or interrupted at various places during the autumn of 1919. In consequence, the wireless systems of the Navy Department became greatly congested in an effort to carry the business, which included numerous daily weather reports from cable stations and also from ships at sea. Embarrassing delays naturally ensued. This condition continued throughout June, the beginning of the hurricane season, and still obtains at this writing. Vigorous efforts have been made to effect improvement without sensible results.

Refusal of one telephone and telegraph company to renew a contract at former favorable rates necessitated, in the interest of economy, transference of a large part of the service performed by that company to the telegraph companies. This amounted to about \$5,000 annually. Because of late opening of many of these offices, noted in the last report as having resulted from abridgment of the hours of labor of operators, prompt dispatch of the cotton and corn and wheat messages involved could not be accomplished. This latter condition applies equally to many small offices throughout the Middle and far Western States at which observational reports are prepared for transmission to circuit centers at early hours. At some of these points railroad offices are available from which the telegrams may be transmitted, but frequent delays are inevitable where so filed, due to the pressure of other business, especially at train times. Prompt transmission at early hours could be accomplished by the telegraph companies by assignment of special operators for this purpose, cost of which is prohibitive.

The great disparity between the wages paid commercial telegraphers and the salaries possible for the Weather Bureau to pay its operators leads to repeated resignations and vacancies for long periods before places can be filled. The work has suffered severely on this account and serious delays occur in clerical positions, leading to great dissatisfaction and inefficiency.

#### WEATHER BUREAU TELEGRAPH AND TELEPHONE LINES.

Continued extensive use has been made of facilities afforded by these lines during the year by the Navy Department, the War Department, and the Coast Guard Service, the latter having contributed as heretofore in their maintenance.

The land lines are in excellent condition and the cables are still giving regular and satisfactory service, notwithstanding all but the Key West-Sand Key cable were laid 17 or more years ago. The time is not far distant, however, when new cables must be supplied, and provision should be made by adequate appropriations for such contingency.

#### BLOCK ISLAND-MATUNUCK BEACH (R. I.) SECTION.

[Telegraph.]

Until early spring telegraphic transmission over this cable was excellent. On April 27, however, a heavy escape developed, stopping communication. Arrangements were at once begun to effect repair, which was completed on June 16 at a cost of \$829.75. Since then transmitting conditions have been excellent through the three conductors. Two conductors of this cable are rented to a telephone company for telephonic purposes. During the year the line earned \$739.68.

Prompt and satisfactory communication between the mainland and Block Island is impossible because of the inadequate facilities afforded by the Weather Bureau cable. By far the greater part of the business is conducted by telephone. The situation calls for a new cable, with at least 10 conductors, which should be owned and operated by some strong commercial company.

## NORFOLK-HATTERAS (VA.-N. C.) SECTION.

[Telegraph.]

The 172 miles of land line, including several short cables totaling about 4 miles, worked unusually well and is in excellent condition. New insulators were installed from Norfolk to Coast Guard station No. 165, a distance of about 35 miles, materially increasing efficiency. Of the four conductors in the new Manteo-Nags Head cable, one became useless in February from the effects of lightning; since then one of the two reserve conductors has been used in lieu thereof. Repair by the Coast Guard Service is expected in the near future.

Between Cape Henry and Coast Guard station No. 163, a distance of 10 miles, 10 pin cross arms were installed by the War Department in place of 4 pin arms in a first-class manner in order to provide for stringing several extra wires for the use of that department.

Because of the encroachment of the sea at Nags Head, necessitating removal of numerous cottages to a safe distance from the beach, the poles were moved back about 100 yards for a distance of 1 mile.

During April the pole line across Rudy Inlet was changed to the right of way of the Norfolk & Southern Railway Co., thus removing the line from private property.

This Norfolk-Hatteras line is of great value to the various governmental services using it and to the public generally by reason of the large amount and character of information collected and disseminated through this instrumentality.

The Coast Guard Service has cooperated most efficiently in the maintenance and improvement of the line, practically all of the repair work having been accomplished by them.

## KEY WEST-SAND KEY (FLA.) SECTION.

The cable connecting this point is owned by the Navy Department, having been laid by that department in January, 1919. No land line is operated.

## ALPENA-THUNDER BAY-MIDDLE ISLAND (MICH.) SECTION.

[Telephone.]

Land lines, 22 miles; cable, 5½ miles.

The total time of interruption during the year was three days on the Thunder Bay line due to necessity of repairs on the 12 miles of land line.

The lines are in fair condition except that the number of poles breaking off at the ground, due to rot, is increasing. Seventeen poles fell during the year owing to the effect of storms. One thousand dollars should be made available for sawing off and resetting those now in good condition and for replacing about 25 others. This would add approximately 10 years to the life of the line.

The naval communication service contemplates the erection of a radio-compass station on Thunder Bay Island or North Point this fiscal year if possible. The communication between the compass station and the Alpena radio station is to be maintained by two metallic circuits. One of these circuits could be made available to

both the Weather Bureau and the radio service for telephonic communication to and from the island.

This offers an opportunity for cooperation by the radio service in the matter of reconstruction and maintenance of the Thunder Bay Island telephone line.

**WHITEFISH POINT-GRAND MARAIS (MICH.) SECTION.**

[Telephone.]

No interruption of moment occurred on this line. The twice-daily reports received from Whitefish Point during navigation are of decided importance to shipping interests. The reports are addressed "Observer, Sault Ste. Marie," transmitted through to Grand Marais Coast Guard station, including the 10 miles of Weather Bureau line to Vermillion Point, thence by a private telephone line to Seney, where they are transferred to a Western Union Telegraph wire.

The country through which the private telephone wire line runs is sparsely settled. Information has been received that the line is deteriorating and that it is only a question of time when it will be abandoned.

It is understood that the Navy Department is considering placing a radio station at Whitefish Point, which will afford communication with Sault Ste. Marie, provided a 3-mile land line can be built between Detour and Detour Point. If established, this channel can be used for transmission of Weather Bureau reports to and from Whitefish Point.

**NORTH AND SOUTH MANITOU ISLANDS-SLEEPING BEAR POINT (MICH.) SECTION  
AND BEAVER ISLAND-CHARLEVOIX (MICH.) SECTION.**

[Telephone.]

These two worked satisfactorily throughout the year.

**SAN FRANCISCO-POINT REYES-MOUNT TAMALPAIS (CALIF.) SECTION.**

[Telephone.]

Extensive use is made of this line by the Coast Guard Service, which cooperated with the Weather Bureau in the preceding year in a reorganization plan as set forth in the report for June 30, 1919.

About 5 miles of new wire was strung by that service between Point Reyes and Fairfax, replacing faulty wire placed in the course of reconstruction of the line during the previous year.

A plan for the maintenance of the line jointly by the Weather Bureau and the Coast Guard Service was entered into April 1, 1920, which designates certain sections for which the Weather Bureau and Coast Guard will be responsible, separately. This has been of material advantage to the Weather Bureau.

A total of 1,518 messages were transmitted during the year, mostly observational reports and requests for information. No commercial business is handled.

The three test stations installed in May, 1919, and mentioned in the report for last year have further demonstrated their usefulness in locating trouble. The portion of the line between Mount Tamalpais and Mill Valley (4 miles) worked generally well throughout

the year except from July 17 to 25, during which period an interruption of six days occurred. About 1,000 messages were transmitted to and from Mount Tamalpais. The weather reports from this point are of great benefit to the service.

#### NORTH HEAD-PORTLAND (OREG.) SECTION.

[Telegraph.]

No extensive changes or repairs were made during the year, the cost for ordinary repairs being but \$9.

As detailed in the last report the Weather Bureau is permitted by the War Department the use of a conductor in the military cable between Fort Canby and Fort Stevens, the cable formerly owned and operated by the Weather Bureau between these points having been abandoned because of further unserviceability. During June the War Department laid a new section of cable for a part of the distance between Fort Canby and Fort Columbia. Much improvement in transmission has been noted. Use of the military cable is subject to recall at any time. Permanency of continuance of communication by wire between Portland and North Head, vital to Weather Bureau interests in that section, can be secured only by the laying of a new cable either by the Weather Bureau or by another agency which would assure preservation of Weather Bureau interests.

A new cable and necessary land lines would cost approximately \$25,000 to \$30,000 at this time.

#### TATOOSH ISLAND-PORT ANGELES (WASH.) SECTION.

[Telegraph.]

Length, about 90 miles. Extensive logging operations along a considerable portion of this line continued throughout the year as for several years previous, causing numerous interruptions by breaks and groundings. The number was augmented by results of road building, storms, and falling timber. Communication was thus interrupted for a total of 17 days, 88 breaks having occurred.

The span wire between Tatoosh Island and the mainland parted on July 10, resulting in an interruption of three days and four hours. A new span wire will be strung this autumn, because of faulty character of present span due to rust.

Seven hundred and fifty dollars was expended during the year for ordinary and general repairs. Much of this amount was expended for labor, the cost of which has about doubled in the last few years. About 15,000 commercial messages were handled, resulting in Government tolls of about \$2,400. In addition over 3,000 free Government messages were transmitted and about 1,500 long-distance telephone calls passed over the line.

Various alterations were made in the route of the line made necessary by town improvements, by removal from swamps, menaing forest conditions, and changing of county roadbed. Similar changes are contemplated during this year in order to improve general conditions. The line continues to be of substantial benefit to logging companies and the shipping, fishing, and commercial interests.

Regular tri-daily and special vessel reports are a special feature of the work of the stations along the line and are highly regarded by the interests served.

**AEROLOGICAL INVESTIGATIONS.****KITE STATIONS.**

Free-air observations by means of kites have been continued throughout the year at Broken Arrow, Okla.; Drexel, Nebr.; Ellendale, N. Dak.; Groesbeck, Tex.; Leesburg, Ga.; and Royal Center, Ind. These observations include daily kite flights and, whenever possible, continuous series of flights covering periods of 24 to 36 hours. Records of air pressure, temperature, humidity, and wind direction and speed are thus obtained. Brief summaries are telegraphed daily to the central office and other district forecast centers.

**PILOT BALLOON STATIONS.**

Observations by means of pilot balloons were continued at five of the kite stations (all except Drexel, Nebr.), and at Ithaca, N. Y.; Lansing, Mich.; Madison, Wis., and Washington, D. C. Early in the fiscal year this work was organized also at Burlington, Vt., and Denver, Colo. These observations are made twice daily, and the indicated wind conditions at various heights are telegraphed to the central office and other district forecast centers for use in furnishing advices to the military, naval, and postal aviation services. For the most part the balloons are assumed to have a constant rate of ascent and are followed with one theodolite only. In order to check the accuracy of the ascensional rate formula, however, observations are made with two theodolites, whenever opportunity offers, at the five kite stations.

**WEST INDIAN HURRICANE SERVICE.**

In order to add to our knowledge of the origin, direction, and speed of movement of hurricanes, plans were made late in the fiscal year to organize an aerological service in the West Indies for the period July to November, 1920, inclusive. Owing to the limited funds available, observations were undertaken by the Weather Bureau at two new stations only, viz, at Key West, Fla., and San Juan, P. R. These, however, together with similar stations organized by the Navy at Coco Solo, Canal Zone, and Santo Domingo, Dominican Republic, and several already in operation in the Gulf States, form a network of stations which, it is believed, will furnish information of much aid in the study of these destructive storms and in forecasting their direction and rate of movement. It is to be hoped that this service may be greatly extended during the next two or three years.

**COOPERATION.**

Throughout the year cooperation with the Army and Navy meteorological services has not only been maintained but has been rendered considerably more effective than heretofore. In addition to the two balloon stations established by the Navy in the West Indies, already referred to, about a dozen similar stations are operated by these two services in various parts of the United States. These stations are so distributed with respect to those of the Weather Bureau that the country east of the one hundredth meridian is well

covered. Observations are made and telegraphed in the same manner as are those at the Weather Bureau aerological stations.

Special observations were made during the year in connection with the trans-Atlantic flight of the British dirigible *R-34*, the Army and Navy race from St. Louis, and the recruiting trip of the *NC-4*.

#### CENTRAL OFFICE.

All observations made at kite and balloon stations, Weather Bureau, Army, and Navy, are forwarded to the central office of the Weather Bureau for final reduction and study. Data based upon these observations are furnished in answer to numerous inquiries not only from other Government departments but from commercial aviation concerns as well. A summary of aerological investigations at Drexel, Nebr., was published and widely distributed. Similar summaries for the other kite stations are in preparation. Several papers, containing discussions of aerological data and their application, were published, and work was begun on an aerological survey of the United States east of the Rocky Mountains based upon all kite and balloon observations thus far obtained.

#### CLIMATOLOGY.

The work in climatology during the fiscal year just closed was carried forward mainly along the lines pursued in previous years.

The somewhat deranged conditions of the observing force at numerous stations, due to frequent changes, tended to less accurate work and thereby added to the work of the checking and verification. Frequent changes in the clerical force and a lessened efficiency, due to the general lowering of the morale, have hindered progress and added materially to the labors of the more responsible supervising employees.

On the whole, however, the station forms work has been nearer the standard required than might have been expected and much credit is due to officials in charge of the several stations for the diligence shown in securing good work under the frequently continued handicap of untrained assistants.

A considerable increase in work to meet the needs of aviation has been entailed by the call for wind movement and duration from the different direction points, but it is thought the data finally summarized from all sources are believed to be of the high standard usually maintained.

No change has been made in the manner of presenting the climatic statistics gathered by the Bureau, save in the case of Form 1030, Monthly Meteorological Summary, issued at the close of each month from practically all stations. This form has been revised to include much additional material pertaining to the hourly temperature and moisture values, as well as additional comparative data, and is now being issued at practically all stations provided with proper printing facilities. Also the policy of encouraging the press to print in their daily issues more data on moisture, inaugurated last year, has continued, and this is now being accomplished satisfactorily at the majority of stations.

## CLIMATIC DATA.

The various tables, charts, and discussions of weather conditions for the Monthly Weather Review and the Annual Report of the Chief of the Weather Bureau, emanating from the division, were prepared in the usual form. Special effort is being made to secure each year more complete statistics on the occurrence and distribution of hail and the amount of damage from tornadoes and other wind-storms for publication in the section reports as well as in the Annual Report of the Chief of the Weather Bureau. It is also contemplated adding to the last-named publication the summarized data on evaporation now being accumulated.

The monthly and annual climatological reports for the several States were issued as in previous years, although considerable delay has occurred at several sections due to insufficient printing force. In the absence of any criticism it is assumed they present the data in the form desired by the public, and despite continued efforts to economize in their issue on account of the high cost of production the mailing lists continue to grow.

## COOPERATIVE STATIONS.

As in previous years, effort has been directed toward improved character of records made by the several thousand cooperative observers, rather than to extend their number. This has been accomplished in the main, although some departures from the established regulations governing the distribution of these stations have appeared necessary. On the whole, however, the number of stations has not been materially increased, and opportunity has been afforded in several instances to reduce fully equipped stations to the status of rainfall stations only, so that the number of full temperature and rainfall stations probably remains about as in previous years.

Owing to a general spirit of unrest, changes in observers were probably more frequent than in previous years, this being more especially the case where the observations are maintained by corporations, railroad companies, and municipal institutions. Considering all factors affecting the cooperative work, it is really remarkable that, with labor at such a premium, so many people are willing to give the time necessary to perform this work without a thought of remuneration. In fact, a recent attempt on the part of one or two observers to form an organization of cooperative observers to demand a place on the Government pay roll met with almost universal condemnation and refusal to associate for such a purpose.

## INSPECTION OF STATIONS.

The policy adopted several years ago of inspecting the cooperative stations at least once in each three years was carried out as fully as the funds and the general shortage of help at the section centers would permit. The extent of these inspections, however, fell far short of the program outlined and that really necessary to maintain the service at the highest standard of efficiency.

It is becoming more and more apparent that only by frequent contact with the officials of the Bureau and a persistent propaganda of encouragement is it possible to maintain among the less enthusiastic observers that unflagging interest so necessary for a continuity of records that will faithfully portray the climate at the point of observation.

#### STATION PUBLICATIONS.

On account of the frequent changes in the working force at a few of the printing stations and the employment of inexperienced help, the issue of the monthly summaries for several States has been much delayed and the work of assembling, binding, and distributing these combined reports was, as a consequence, greatly hindered. Likewise the annual summaries, 1919, for several States were still unpublished at the close of the fiscal year. These reports serve their best if issued promptly, and it is believed this condition could be improved and at the same time some economies in both labor and funds accomplished by strengthening the printing force at a few stations so that groups of States might be issued from a single point. This, of course, could not be extended to more than three or four States, as some sections would necessarily be always late. It would also afford an opportunity to help out a section where the printer might be sick or where frequent changes had prevented prompt issue.

#### CENTRAL OFFICE PUBLICATIONS.

At the beginning of the winter of 1919-20, the Snow and Ice Bulletin, heretofore issued as a separate publication by this division, was merged with the National Weather and Crop Bulletin and so continued throughout the winter. The preparation of the material for that portion of the bulletin was continued by the division, but, on account of limited space, the tables of statistical data were not as full as formerly, although the charts showing the distribution of the winter's snowfall were made somewhat more comprehensive than in previous years, including generally more data from the high mountain regions of the West.

On account of lack of funds only a few reprints of the exhausted sections of Bulletin W were provided for, and much inconvenience has been experienced in answering requests for weather data from those now exhausted. A number of these have been prepared for reprinting, and it is hoped opportunity will be afforded during the present fiscal year to issue several of the more important sections.

The climatology of Hawaii in much detail, prepared by the official in charge at Honolulu and revised at this office, is now awaiting an opportunity to print, and similar data for Alaska now largely under way should be made available to the public as soon as possible.

A complete revision of all the sections of Bulletin W, bringing the tables down to 1920, and enlarging somewhat on the amount of material presented, particularly in sections where, on account of specialized industries, weather changes and possibilities are factors of the utmost importance, should be provided for as soon as possible.

## WORK ACCOMPLISHED DURING THE YEAR.

Requests for data from all classes of our citizens, from the courts, from corporations, and industrial interests, continued with increasing volume. Publications available for distribution afforded a convenient means of answering many of these requests. In many other cases, however, it was necessary to extract material from the original records. All were answered as fully as possible, and in no instance, as far as official records show, was dissatisfaction expressed at the effort made to meet the wishes of the applicant. On the other hand, hundreds of letters, voicing keen appreciation for the intelligence displayed in interpreting and frequently anticipating the needs of those applying for information, have been received.

## OCEAN METEOROLOGY.

In recognition of the increasing importance of marine meteorology consequent upon the growth of our merchant marine and the developments in transoceanic flight, the marine work of the Bureau was organized as a division of the central office, effective April 1, 1920. Prior to that date the work at Washington was conducted by the marine section, a branch of the climatological division. Outside of Washington marine work is carried on by officials of the Bureau located at the principal ports, in connection with other duties.

During the year the marine work progressed along the usual lines. There was a substantial and satisfactory increase in the number of reports received from ships, sufficient to warrant the expectation that the total number will shortly equal or possibly exceed that of the prewar period. Every effort was made to secure additional reports.

The examination and charting of reports from the North Atlantic Ocean was continued and some tentative work done in connection with the charting of reports from the North Pacific Ocean. Summaries of weather conditions over both these oceans were published in the Monthly Weather Review, and tracks of the more important storms furnished the Hydrographic Office, under departmental arrangement, for publication on the pilot charts. An increased amount of data was supplied for use in Admiralty cases. Officials at Weather Bureau offices located at the principal ports were actively in touch with maritime interests.

The safe and economical operation of ships depends largely upon a fundamental knowledge on the part of their officers of the weather of the oceans. If the United States is to succeed in its efforts to conduct an extensive merchant marine, one of the necessary conditions is that it add to the present-day knowledge of ocean or marine meteorology. The Weather Bureau is the governmental agency charged by law with the duty of furnishing meteorological information in the aid of navigation and has been earnestly endeavoring to meet the demands upon it in this field. War and postwar developments have, however, broadened these demands until the Bureau is unable adequately to meet the needs of the situation with the resources now at its command.

**AGRICULTURAL METEOROLOGY.**

The principal routine work of this division is the collection of temperature and rainfall data and the effect on crops and farm operations and the publication of this information in weekly weather and crop bulletins. These reports are issued at 11 a. m. Wednesday and cover the weather conditions up to 8 a. m. Tuesday. The National Weather and Crop Bulletin is issued at Washington, while local bulletins are published at the section centers in each State. A special Corn and Wheat Region Bulletin is published weekly at Chicago covering the grain-growing States, and a special Cotton Region Bulletin is published at New Orleans covering the cotton belt. There is a growing and insistent demand for these reports, especially for the National Weather and Crop Bulletin.

The weekly issue of the National Weather and Crop Bulletin was continued throughout the winter months and was combined with the Snow and Ice Bulletin, which heretofore had been published as a separate report. This arrangement was found so advantageous that it will be continued in the future, as it seems important to give information each week on the effect of snow cover, or lack of it, on meadows and grain fields, the effect of high or low temperatures on fruit and southern truck crops, and the effect of weather on ranges and stock.

**SPECIAL SERVICES.**

The collection of temperature and rainfall data and the publication of daily bulletins were continued in the principal grain, cotton, sugar, and rice States. This service should be extended to include the grain-growing districts of Wyoming, Virginia, West Virginia, Maryland, and Pennsylvania. The weekly collection of data in the range districts in Texas, New Mexico, Arizona, Utah, and Wyoming was continued. This service should be extended over Montana and other winter-grazing States. The collection of meteorological data from special stations in the tobacco, fruit, truck, and alfalfa-seed districts was continued during the critical periods to aid in issuing warnings and damaging temperatures.

The special weather-warning service for spraying operations was extended to additional counties in western New York and into the central and lower Hudson Valley in the eastern part of the State. Special forecasts appear to be essential in determining the proper time for spray applications in all fruit districts. The special investigations in the citrus and deciduous fruit-growing districts of the Pacific coast were continued and resulted in the publication of Farmers' Bulletin 1096, "Frost and Prevention of Damage by It."

**COOPERATION.**

Cooperation was continued with other bureaus of the Department in maintaining special meteorological stations at various points in different sections of the country, as an aid to research and investigations of the many agricultural problems in which weather is an important factor.

**EFFECT OF WEATHER ON CROPS.**

It has been determined that most crops have a critical period of growth, usually short, when favorable weather will cause a good yield and unfavorable weather a poor yield, regardless, mainly, of earlier or later weather conditions. Studies to determine this critical period are carried on as far as time and opportunity will permit. Some of the studies carried to completion relate to the effect of temperature, rainfall, and snow on winter wheat, cultivation and rainfall in the Great Plains, relation between precipitation and the grazing capacity of ranges, the seasonal distribution of precipitation, and sunshine in the United States.

The greatest need in this direction is the establishment of agricultural meteorological stations at the agricultural experiment stations in the principal crop-growing areas. When established a careful and systematic record can be begun of the temperature, rainfall, sunshine, etc., and at the same time a complete record of the development of the various crops. By maintaining these stations for a period of years, the most critical period of growth and the weather factor most affecting the crop can be determined.

**WEATHER BUREAU PRINTING OFFICE.**

The principal publications issued during the year included the Daily Weather Map, Monthly Weather Review, and Supplements, Daily River Stages at river-gage stations in the United States for 1918, National Weather and Crop and Snow and Ice Bulletins combined, forecast cards, weekly forecast, and Form 1030, Monthly Meteorological Summary for Washington, D. C.

At the end of the year there were 934 paid subscribers on our various mailing lists, exclusive of the Monthly Weather Review, and the total receipts from subscriptions amounted to \$823.97. Subscriptions for the Monthly Weather Review are received and filled by the superintendent of documents, Government Printing Office, who requires 200 copies each month.

The amount allotted the Weather Bureau for printing and binding at the Government Printing Office is inadequate, and, as a consequence, several important publications had to be suspended until the allotment for the present fiscal year became available.

**MONTHLY WEATHER REVIEW.**

The increased size of the Monthly Weather Review, occasioned by the larger number of contributions received during the year following the signing of the armistice, was maintained until January 1, 1920, when a reduction of 30 per cent was rendered necessary by the low state of the printing funds. Although the sections dealing with the weather and earthquakes of the month were condensed somewhat, the major portion of the cut fell on the section devoted to original contributions. During the remainder of the fiscal year this resulted in an appreciable increase in the number of papers awaiting publication and also in a reduction in the supply of new contributions received, for lack of ready publication tends to dampen the enthusiasm of potential contributors. That the Monthly Weather Review is

becoming more and more appreciated, and therefore is playing a useful rôle in the development of meteorology, is shown by the necessity of increasing the edition published from 1,525 for the last number in fiscal year 1919 to 1,750 for the corresponding issue a year later. Even with 1,750 copies published, the supply of the last three issues held for sale has been exhausted. A large part of the increases in demand came through paid subscriptions, which nearly doubled.

In addition to the usual editorial work, the results of investigations undertaken mainly in the interests of improved general and local forecasting, especially of winds at flying levels, were prosecuted and published. Specifically, these were—clouds and their significance; effect of winds and other weather conditions on the flight of airplanes and balloons, sleet and ice storms (glaze), preliminary steps in the making of free-air pressure, and wind charts. Reprints of the articles on weather and aeronautics were distributed to all aviators of the Army and Navy. During four months daily open-air instruction and lectures on clouds and their significance to classes of naval meteorological officers were given.

#### LIBRARY.

During the fiscal year 1,050 books and pamphlets were added to the library, the strength of which is now over 39,000. Political changes brought about by the war have greatly complicated the work of libraries in which, as in the case of the Weather Bureau library, a large part of the collection is classified and shelved according to geographical divisions. Reclassification of many books to take account of recent changes of this character is in progress. The same cause has made necessary an extensive revision of the foreign mailing lists of Weather Bureau publications, and this has been carried out by the librarian. A marked growth of interest in meteorology that has followed the war is indicated by the large number of requests which the library now receives from all parts of the United States and elsewhere for information and the loan of books.

#### INVESTIGATIONS IN SEISMOLOGY.

The important work of collecting and publishing earthquake data, begun December 1, 1914, has been continued during the year.

During the calendar year 1919, 86 separate earthquakes, strong enough to be felt, were reported from different parts of the continental United States. The great majority of these produced no damage whatever, and none produced any important damage. No important earthquakes occurred in our outlying possessions.

#### VOLCANOLOGY.

The work in volcanological observations is conducted at the crater of the volcano Kilauea, Hawaiian Islands, and was taken over by the Weather Bureau on the 15th of February, 1919, under an appropriation by Congress of \$10,000, which has been continued yearly since that time. The funds available have been just adequate to carry on the routine activities of observational work organized a number of years ago under the direction of Dr. James A. Jaggard, jr., origi-

nally of the Massachusetts Institute of Technology and now in charge of the work under the Weather Bureau. On special occasions the observations are extended to include the volcano at Mauna Loa. A visit to some part of Mauna Loa more than once a year is desirable. Experience proves that Mauna Loa erupts more frequently from places along its rift systems outside of the summit crater than at the summit crater itself. There has been no activity at the summit crater during the 1919 outbreaks from the south flank, and in 1920 Mauna Loa is quiet.

Seismometric registration has continued as heretofore, with no unusual events during the period. The Hilo instrument has been operated nearly continuously.

The general results of observations at Kilauea are brought together from month to month in a small bulletin, which is issued regularly. In addition, a summary has been issued to newspapers and printed with fair regularity.

#### INSTRUMENTATION.

The instrumental equipment of the field stations has been maintained in a serviceable condition, but at a number of stations repairs to roof equipment needed could not be made owing to difficulty in getting satisfactory estimates.

#### STORM-WARNING EQUIPMENT.

The three-lantern system was completed during the fall, and is now in effect throughout the country. The storm-warning equipment destroyed in the Corpus Christi district by a hurricane is now being replaced, the larger portion of the expense coming out of funds for 1920. Few additions or improvements have been possible with the limited funds at our disposal.

#### NEPHOSCOPES.

The Bureau now has at the factory ready for distribution 100 nephoscopes of a new pattern.

#### EVAPORATION.

The evaporation stations have not been increased in number, on account of expense and because it was thought best not to add to the duties of stations at this time.

#### INVESTIGATIONS IN SOLAR RADIATION.

Observational work has been maintained at Washington, D. C., Madison, Wis., Lincoln, Nebr., and Santa Fe, N. Mex., as in previous years.

A summary has been prepared of the measurements made previous to July, 1919, and utilized in the determination of average monthly sunshine intensities in the United States east of the Rock Mountains. These have been published in the Monthly Weather Review for November, 1919, in the form of charts, which are the only sunshine intensity charts yet published for any country.

The above summary also has served as the basis for determinations of the intensity of direct solar illumination, and of the illumination from the sun and sky, which latter is commonly called daylight intensity. These results are also published in the Review for November, 1919, in the form of diagrams, by means of which the illumination of surfaces normal to the incident solar rays, of horizontal surfaces, and of vertical surfaces variously oriented, may be determined for different parts of the United States east of the Rocky Mountains, at any hour of any day of the year, under average clear-sky or overcast-sky conditions.

On account of the few points at which solar radiation measurements have been made, the above results must be considered as a first approximation only. With a view to providing for additional observing stations, two new Marvin pyrheliometers were constructed and standardized during the year, and a few pyrheliometric measurements were made at points in California and Oregon during February to April, 1920. Owing to the lack of adequate funds, however, it has been necessary to defer the establishment of stations on the Pacific and Gulf coasts, where they are urgently needed.

The few measurements obtained indicate that during the spring months, at least, solar radiation near sea level in the Pacific Coast States has about the same intensity as in the Plains States.

Measurements of the intensity of the heat radiated from different types of orchard heaters and of the retardation of nocturnal cooling by a smoke cover were made during the winter of 1919-20 in orchards in California and Oregon. The results, which were published in the Review for June, 1920, indicate that to protect orchards from frost the attempt should be made to warm the air by the total combustion of fuel rather than to retard cooling by the production of a smudge through the imperfect combustion of fuel.

A study of the relation between the solar constant values published by the Smithsonian Institution and the weather conditions in the United States was well under way at the end of the year. It promises interesting developments in the subject of temperature control.

