# REPORT OF THE CHIEF OF THE WEATHER BUREAU.

---

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
OFFICE OF THE CHIEF,
*Washington D. C., October 14, 1916.*

SIR: I have the honor to submit a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1916.

Respectfully,

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

Hon. D. F. HOUSTON,
*Secretary of Agriculture.*

---

The service of the Weather Bureau to the country for the past year has been fully and effectively maintained at practically the same annual expenditure as in the preceding year. Throughout the crop-growing season and over the great agricultural, horticultural, and citrus regions of the country the weather was generally favorable after July of last year. Less favorable conditions marked the first half of the growing season of 1916, and a number of important crops have suffered.

In August and September the Gulf region was visited by two very destructive West Indian hurricanes, causing great property losses, especially in Texas and Louisiana, but the wide dissemination of timely warnings of these storms by the bureau was doubtless the means of saving many lives and safeguarding property interests as well.

Some details of the work of the bureau are outlined under a series of captions, as follows:

## STATIONS AND OBSERVATIONS.

Few changes of consequence have been made in the principal stations of the service, which now number 199. These stations furnish the principal telegraphic reports upon which the weather forecasting is based. Supplementary or substations are also maintained at over 4,500 points where the activities are carried on upon a cooperative basis. New cooperative stations are constantly being established, especially in new and sparsely settled regions from which observations have been previously unobtainable.

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

## ERRATA NOTICE

One or more conditions of the original document may affect the quality of the image, such as:

Discolored pages
Faded or light ink
Binding intrudes into the text

This has been a co-operative project between the NOAA Central Library and the Climate Database Modernization Program, National Climate Data Center (NCDC). To view the original document contact the NOAA Central Library in Silver Spring, MD at (301) 713-2607 x124 or Library.Reference@noaa.gov.

HOV Services
Imaging Contractor
12200 Kiln Court
Beltsville, MD 20704-1387
December 13, 2007

New Federal buildings were occupied during the past year for offices at Denver, Colo.; Pocatello, Idaho; Thomasville, Ga.; Williston, N. Dak., and Wytheville, Va. The Weather Bureau stations at these points were moved to quarters therein from rented offices.

Local conditions and facilities having changed at the station at Port Crescent, Wash., the Weather Bureau station was removed on February 29, 1916, to Port Angeles, Wash., a thriving town about 20 miles to the eastward. The Weather Bureau telegraph line extending from Tatoosh Island, Wash., to Port Crescent, Wash., was thereupon extended to Port Angeles, by the purchase from the Western Union Telegraph Co. of wire and poles already in place and in good condition. This seacoast telegraph line enables the bureau to maintain continuous communication between the important station of Tatoosh Island and the station at Port Angeles, which became the new eastern terminus of the Weather Bureau line on March 1, 1916.

A new telegraph office and cottage building authorized during the previous fiscal year was completed at Neah Bay, Wash., October 1, 1915. This building affords comfortable living quarters for the repairman of the Port Angeles-Tatoosh telegraph line stationed there and office for the telegraph business of the Government handled at that place. Necessary improvements were effected at Tatoosh Island station, where tanks for storage of rain water, required for drinking and culinary purposes were provided. No other source of supply is available on the island.

All Weather Bureau buildings, of which there are now 46, were maintained in good, serviceable condition by repainting and repairing wherever needed for proper upkeep.

An effort was made to ascertain whether the buildings and property of the Weather Bureau at Mount Weather, Va., could be utilized by any other branch of the Government, with the result that the Public Health Service, Treasury Department, after investigation, contemplated using the buildings and property as a sanatorium. House bill 13672, introduced by Mr. Carlin March 24, 1916, provided for the transfer and necesary alteration of the property. It has recently been learned, however, that this project has been abandoned or deferred.

Suit of The United States *v.* The Northern Pacific Railway *Co.* to quiet title to land at Bismarck, N. Dak., formerly used as a military post and occupied as a Weather Bureau station since June 1, 1894, was set for trial at the June, 1916, session of the United States district court of North Dakota. Before the case came to trial, however, a compromise was offered, which was accepted by the Attorney General of the United States. This compromise is in effect as follows:

Northern Pacific Railway Co. quitclaims to Government rights to property north of tracks, railway company to have property south of tracks for yards and sidetracks and reimburse Government for improvements thereon.

A saving of about $600 per annum was effected in the arrangements for rented quarters and roof exposures at 5 of the stations in the West Indies.

### EXAMINATION OF METEOROLOGICAL FORMS.

Careful examination of the important meteorological forms rendered by the regular station force, as well as those from the large corps of cooperative observers and painstaking efforts to make instructions as definite as possible, have resulted in a general lessening of the number of occasional errors detected in the statistical reports of meteorological data.

### COOPERATIVE STATIONS.

The experience of the past year in working up the large amount of data required for the proposed Atlas of American Agriculture has demonstrated the excellent character of the work of the cooperative observers, who perform their simple but important duties without compensation. In fact, the records indicate that the observations made by the men and women who make up the list of cooperative observers are as correct and trustworthy as possible under the circumstances.

### INSPECTING COOPERATIVE STATIONS.

The policy of frequent inspection of cooperative stations has been adhered to during the past year, and many necessary inspections were made by a number of the State section officials. These inspections are especially helpful in bringing to light defects in instrumental equipment or observational work, and afford opportunity for the bureau to indicate its appreciation of the valuable service rendered the public by these faithful observers.

### SNOW BULLETINS.

During the past winter effort was made to increase the amount of information pertaining to the snow conditions in the far Western States, by securing a greater number of reports from the higher mountain districts. These additional reports will furnish an index to the character and amount of the snow in the regions where it remains unmelted until late in the season, and enable estimates to be made of the probable waterflow in the streams used for irrigation and power purposes.

### SERVICE IN ALASKA.

The supervision of the climatological work in Alaska was assigned during the past year to the official in charge of the Washington State service at Seattle, and provision has been made for the publication of an annual summary of climatological data for that Territory for 1915, similar to those issued for the several States.

In view of the rapid development of Alaska, the appropriation act for the fiscal year 1917 provides funds for the establishment of a fully equipped weather bureau station at some central point in the Territory. This will also permit the development of a local weather service and the publication of a monthly bulletin for this region to meet the growing demands for climatic information.

### OCEAN METEOROLOGY.

In general the work of the marine section has progressed along the usual lines. Owing to the effect of the war on ocean shipping the number of vessel reports received during the year has been largely below that of normal times, except from the Pacific Ocean. The examination and charting of reports received from the Atlantic Ocean have continued, and this work has been kept as nearly up to date as feasible.

It is considered highly desirable that reports received from the Pacific Ocean should be charted in the same manner as those of the Atlantic. Owing to the growth of shipping on the Pacific in recent years it has been possible for the bureau largely to increase the number of vessel reports from that ocean, so that the preparation of a synoptic chart is now believed to be warranted. Plans to accomplish this are now being formulated.

The extension of work in the Pacific Ocean has a two fold purpose. Not only is it designed to throw light on coming weather in the United States—weather changes, as is well known, moving from west to east—but it is in line with a concerted and widespread movement in all branches of science to inaugurate a special study of the Pacific, with the object of adding to the world's general knowledge of this vast area.

During the last hurricane season, extending from July to November, many valuable reports were received by wireless from the special service maintained on vessels traversing the West Indian waters and the Gulf of Mexico, enabling the forecasters to determine accurately the position, direction of movement, and rate of progress of the severe storms that reach the mainland of the United States from those regions.

### HYDROLOGIC WORK IN SOUTHERN CALIFORNIA.

Preliminary action has been taken looking toward the establishment of a river district center at Los Angeles, Cal., for the purpose of giving such notice as may be possible of the coming of destructive floods which issue from the mountains of Los Angeles and San Bernardino Counties during the prevalence of heavy and continuous rains. Cooperative rainfall observations at 12 points in the mountains of Los Angeles County were begun in January, 1916.

In connection with this subject and closely related thereto, the bureau has undertaken, in cooperation with the Forest Service, to carry on a series of rainfall measurements in the Los Angeles National Forest. The chief contracting parties to the cooperation are the board of supervisors of Los Angeles County on the one hand and the Forest Service of the Department of Agriculture on the other hand, the latter representing such other branches of the Federal Government as are contributing to the work.

### MEASUREMENT OF PRECIPITATION AT HIGH ALTITUDES.

This work, begun in 1909, in Pacific coast, plateau, and Rocky Mountain States, has been continued during the year at about 180 stations. Intensive measurements of snow depths and densities at the beginning of the melting season have been made in limited regions

on the watershed of Cottonwood Creek, a tributary of the Boise River of Idaho, in the Paradise Creek Valley, on the headwaters of the White River in Arizona, on the watershed of City Creek, near Salt Lake City, Utah, and in the watershed of Lake Tahoe, Nev. In the last named the measurements were made in cooperation with the agricultural experiment station of Nevada, at Reno. From the nature of the case, intensive measurements of snow depth and density can not be made on any considerable portion of the snow fields of high altitudes; in fact, grave difficulties are encountered at altitudes between 8,000 and 10,000 feet. The purpose of the bureau in the matter has been to develop methods and apparatus whereby the measurements can be made quickly, and to demonstrate the practical utility of the work by actual surveys over portions of small watersheds, whence comes the water supply of residents of the lowlands below. A case in point is that of Salt Lake City, Utah, where the water supply is drawn from the Wasatch Mountains to the eastward. In summer, in the absence of sufficient rainfall, the flow of the mountain streams is almost wholly derived from the melting of the winter's snowfall. The usefulness of the method has been so clearly shown to the officials of Salt Lake City for several years past that they have independently conducted a survey over one of the larger watersheds and have aided the bureau on a survey in one of the smaller watersheds which contribute to the water supply of the city. Aside from the importance of these snow surveys from a practical point of view, they also contribute indirectly to our knowledge of the relation which exists between the fundamental phenomena of precipitation and run-off.

### LIGHTSHIP WEATHER STATIONS.

Through the cooperation of the Bureau of Lighthouses, Department of Commerce, there has been introduced an entirely new class of weather stations aboard lightships equipped with wireless apparatus. These stations will report upon weather conditions by wireless twice each day. Each will be equipped for measuring pressure, temperature, and wind velocity. At Frying Pan Shoals both the regular and relief vessels have been equipped, but reports have not yet been received. At Nantucket Shoals one ship has been equipped, but reports have not yet been rendered. Plans are under way for equipping the Heald Bank light vessel in the near future.

### EVAPORATION WORK.

Although the demand for the installation of evaporation stations has increased, the introduction of class A stations has progressed rather slowly, because the funds for purchasing equipment and the facilities for administration are not considered equal to a rapid extension of this work. Eight stations have been equipped and are now rendering monthly reports.

### STORM-WARNING STATIONS.

The storm-warning stations of the bureau on June 30, 1916, were as follows:

Paid stations, 191, a decrease of 2 during the year.

Cooperative stations, 113, a decrease of 4 during the year.

Weather bureau stations displaying storm warnings, 60, the same as last year.

A system consisting of three lights in a vertical line to signal by night the same information concerning storms now furnished by day has been installed on the Great Lakes, only 3 stations remaining to be completed. In connection with this work new electric lamps of increased brightness and a standardized system of wiring in conduit have been installed. Stations on the Great Lakes equipped with oil-burning lanterns have had a third lantern furnished, together with necessary means of display. Other improvements have consisted in the removal of towers to more favorable locations and the erection of new steel towers in a number of cases, with the object of placing the storm-warning equipment on the Great Lakes in first-class condition throughout.

## TELEGRAPH SERVICE.

The commercial telegraph companies have continued their hearty cooperation with the bureau in maintaining service. Complaints of delays have generally received prompt and effective attention, with satisfactory results. Reports over all circuits are often sent and received and the circuits closed by 9 a. m., one hour after taking observations.

The contract for special operators' services employed at various Weather Bureau stations was found to be inconsistent as to the amount charged. A reorganization was effected in this feature of our work and will result in a decrease in cost of nearly $900 per annum.

A further revision of several circuits was undertaken and put into operation May 1, 1916, by which a saving of over $2,000 per annum will be effected, in addition to increasing the number of reports to several stations. Another revision of certain circuits during June will also effect a saving of over $300 per annum and still give much-desired evening reports to certain stations.

### WEATHER BUREAU SEACOAST TELEGRAPH AND CABLE LINES.

In all cases these are lines connecting outlying points of importance from a meteorological point of view with which no other means of communication are available for the transmission of reports. While these lines are maintained and owned by the Weather Bureau distinctly for its meteorological work, they nevertheless have come to carry a considerable amount of commercial business which brings in a small revenue. Lines are maintained in the following sections:

Block Island-Narragansett.
Mount Weather-Bluemont.
Norfolk-Hatteras.
Key West-Sand Key.
Glen Haven-South and North Manitou Island.
Alpena-Middle Island-Thunder Bay Island.
Grand Marais-Whitefish Point.
Beaver Island.
Tatoosh-Port Angeles.
North Head.
San Francisco-Point Reyes.

The increased importance of coastal communication to the operations of the Government is fully recognized, and every effort has been made to maintain the lines in the charge of the Weather Bureau in an efficient condition of repair and operation. As maintenance expenditures on these lines have been maintained at the minimum in former years, rather extensive repairs have been necessary in some instances. Nevertheless, a careful accounting of revenue and repair cost still shows a small balance in receipts over costs of repairs amounting to $287.83 on an income of $5,654.

## FORECASTS AND WARNINGS.

### DISTRIBUTION OF WEATHER FORECASTS.

The distribution of weather forecasts has been continued along the same lines as in former years and by the same methods, i. e., by telegraph, by telephone, by mail, and by wireless. The daily forecasts are available by telephone to more than 5,000,000 subscribers, and by mail to more than 100,000 addresses. Distribution by wireless has been somewhat extended during the year. By this means the forecasts for nine States are distributed from four points. Those for North Dakota, South Dakota, and Minnesota are broadcasted from University (Grand Forks, N. Dak.); for Illinois, from Springfield, Ill.; for Ohio, from Ohio State University, Columbus, Ohio; for Iowa, Kansas, Missouri, and Wisconsin, from the United States Naval Training Station, Great Lakes, Ill. These forecast messages are received at about 270 amateur radio stations. A further extension of the distribution may be expected through the issue of forecast cards by the wireless operators. This feature of the matter has been given consideration, but the results are not yet determined.

### SPECIAL FORECASTS.

Special forecasts for the benefit of the alfalfa crop during the harvesting season were inaugurated, and in order to meet the needs of these interests forecasters were authorized to extend the period covered by the forecasts beyond the regular 36 and 48 hour periods provided for in instructions.

### WEEKLY FORECASTS.

The day of issue of the weekly forecasts was changed from Tuesday to Saturday, so that at present these forecasts cover the ensuing calendar week.

### NIGHT FORECASTS.

The issue of night forecasts was begun at the New Orleans, La., forecast district center. Both night and morning forecasts for the respective districts are now issued at each district center.

### EXTENSION OF THE METEOROLOGICAL SERVICE IN THE WEST INDIES.

Arrangements are being made for the extension of the meteorological service in the West Indies, the Caribbean Sea, and the Panama Canal, in order to make more efficient the issue of storm advices for the southern waters of the United States.

### SEVERE STORMS.

Two tropical storms, originating in the Caribbean Sea in August and September, 1915, and moving northwestward to the Gulf coast, developed unsual intensity and occasioned great loss of life and immense destruction of property. The first of these passed over Galveston and Houston, Tex., August 16 and 17, the barometer falling to 28.20 inches at Houston and the wind reaching a maximum velocity of 93 miles per hour from the east at Galveston. It was estimated that about 280 lives were lost and property amounting to $20,000,000 destroyed. The second struck the coast about the mouth of the Mississippi on September 29 and passed northward over New Orleans, La. The barometer fell to 28.11 inches at New Orleans, the lowest reading on record in the United States, and the wind attained a maximum velocity of 130 miles per hour from the east. The estimated number of lives lost was 275 and the value of property destroyed $13,000,000. Warnings of these storms issued by the Weather Bureau, beginning with the first day of their appearance, were given widespread and effective distribution well in advance, and were without doubt the means of great savings, both in life and property.

## RIVER AND FLOOD SERVICE.

Sixty-two of the principal stations of the bureau participate in the work, and about 600 subordinate river-gaging and rainfall-reporting stations furnish the necessary hydrologic data for the respective watersheds. Flood warnings and all forecasts of river stages are issued by trained section officials specifically authorized to do so, but all this work is rather closely supervised at Washington, in the belief that constant oversight is necessary and helpful in maintaining the service at a high standard of efficiency.

The severe floods of January and February, 1916, in the Mississippi below Cairo, in the rivers of Arkansas and Oklahoma, and, later in the year, in the Mississippi between Dubuque, Iowa, and Louisiana, Mo., afforded a critical test of the efficiency of the organization. As the flood crest on each stream approached, timely and accurate warnings thereof were distributed well in advance. The present system of flood forecasting is the result of about 10 years of well-sustained effort on the part of river forecasters to improve the warnings and to get a better grasp upon the problem.

### LOSS AND DAMAGE BY FLOOD.

A compilation of the loss sustained in the United States during the calendar year 1915, due to flood waters, places the amount at nearly $21,000,000. Of this amount a little more than half fell upon the agricultural interests of the country.

## AGRICULTURAL METEOROLOGY.

From the early days of the service the issue of frost warnings for the special benefit of gardeners and horticulturists, and the citrus, the tobacco, the cranberry, and other industries, has been marked by constant study, improvement, and extension. With the advent of arti-

ficial methods of orchard heating and the more or less successful protection of extensive areas from frost injuries by smudging and other means, a great demand has been created for frost forecasts and warnings. Similarly, for many years the Weather Bureau has maintained during the crop-growing season a special service of weather reports and the prompt issue of bulletins relating to conditions throughout the great grain, cotton, and agricultural and stock regions of the country generally. A number of studies have also been conducted, especially of late years, to discover and formulate the relations between weather and crops and the character and amount of the influence of weather on production.

With economies of administration in all lines of our work and without specific increase of funds it became possible during the past year to reorganize and bring together all this work into a new division, designated "Division of Agricultural Meteorology." While a number of new lines of work will be undertaken in this new division, the bulk of its work at the present time comprises former activities now brought together, coordinated, and improved.

It seems opportune to outline briefly the scope and purposes of agricultural meteorology as now organized in the Weather Bureau.

### DIVISION OF AGRICULTURAL METEOROLOGY.

This new division was organized February 21, 1916, under the supervision of Prof. J. Warren Smith, for the purpose of conducting studies of every character of the relation of weather to crops and the collection of statistical data required in such studies, including the direction and supervision of cooperative relations with the State experiment stations and other contributing organizations. The division is to conduct investigations of the effect of weather and climate upon the growth and yield of crops and will control the distribution of frost warnings and forecasts to special agricultural interests, conduct studies for the protection of crops and orchards from frosts, and, in general, supervise the activities of the Weather Bureau which relate to agriculture and which are comprised in a number of special services briefly mentioned and described in the following:

### CORN AND WHEAT REGION SERVICE.

This service covers the 16 principal grain States, and its organization includes 1 region center and 13 district centers, with 168 special stations from which telegrams are received daily. Daily bulletins showing the temperature and rainfall at these stations are published at 18 different points, with a total daily issue of 2,775 copies. This service was reorganized during the spring of 1916 by the establishment of a region center at Chicago, making the districts conform to State lines so far as possible, the establishment of new district centers in Montana, North Dakota, and South Dakota, and the extension of observational stations into the new grain regions of the Northwest, as well as into some of the uncovered grain districts in the Central States. This was accomplished by the establishment of 14 new corn and wheat stations. Data covering the rainfall at each of the 168 stations and temperature at 5 stations in each State are telegraphed to the region center at Chicago each morning, and, after

being charted and tabulated, a summary covering the weather conditions throughout the corn and wheat regions is telegraphed to 18 different points and there published in the form of daily bulletins, besides being given to the press.

### COTTON REGION SERVICE.

This service covers the 11 principal cotton States, and consists of 1 region center and 15 district centers, and has 166 special stations. Daily records of temperature and rainfall are telegraphed from these special stations in each district to the district center, and at these centers and 11 other points daily bulletins are published, with an issue of 1,736 copies. Weekly bulletins and charts giving the temperature and rainfall over the cotton States are also published at New Orleans. This service was expanded during the spring of 1916 by the extension into the new cotton-growing district in western Texas and other uncovered fields. Preliminary work was started to reorganize this service along State lines, but it was thought best to delay the change until the season of 1917.

### SUGAR AND RICE REGION SERVICE.

This service covers the rice-growing region of Texas and Louisiana, and the sugar district of the Southern States. No material change was made during the year just ended. However, correspondence has been under way looking to the extension of the rice-region service.

### SPECIAL FRUIT REGION SERVICE.

This service consists of several separate branches, consisting of the cranberry service in eastern Massachusetts and southern Wisconsin, investigations into temperature conditions at various elevations in the mountains in western North Carolina and in the Salt River Valley in Arizona, and special forecasts and warnings for the benefit of fruit men who are protecting their orchard crops from spring frosts in Ohio, Colorado, Utah, Idaho, Washington, Oregon, and California. This service has been expanded during the year by the establishment of seven new stations in the grape and peach-growing district of northern Ohio, by the extension of the special cranberry service in the Shell Lake district of southern Wisconsin, and by the detail of trained men for special duty in the fruit district in the Hood River Valley in Oregon and the Gunnison Valley in Colorado. These men studied the local situation and gave expert information to the fruit growers as to the temperature to be expected, and whether it would probably be necessary to prepare for lighting the fires in the orchards. These men proved to be of unusual benefit to the orchard growers in these valleys, and there is already a demand for the extension of this service into other districts where fruit is intensively grown and arrangements are made for protection of the orchards by heating. In Ohio this warning service is given by long-distance telephone from the section center at Columbus with considerable success, by a careful study of the temperature and weather records in each orchard where heating is carried on.

### SPECIAL TOBACCO SERVICE.

This service is now carried on in the States of Connecticut and Wisconsin, with 2 district centers and 13 stations. No material change was made during the year in these States, but arrangements were completed for the establishment of a special tobacco service in the important tobacco districts in western Kentucky. In this State not only will warnings be issued for the tobacco growers at critical periods, but the general effect of the weather conditions upon the development of the tobacco will be studied through cooperation with the officials of the agricultural experiment stations.

### SPECIAL CATTLE-REGION SERVICE.

This service at present has 1 district center at Amarillo, Tex., with 12 special stations, and receives reports from 9 other points in the cattle-range district of the Southwest. Daily bulletins are published giving the rainfall and temperature over the southwestern cattle ranges, with an issue of 625 copies. This service has been expanded somewhat during the year by receiving reports from a wider area. Preliminary steps have been completed for the establishment of a new cattle-region district center at Roswell, N. Mex.

### SPECIAL ALFALFA SERVICE.

This service is maintained in Utah, with three special stations. There has been no change during the year. In addition, however, there has been an expansion of special three or four day forecasts for the benefit of alfalfa harvesters throughout the whole western part of the country during the present season. If fair weather is expected for three or four days, or if a rainy spell is in anticipation, this information is telegraphed from the district centers to the large alfalfa-growing points, where action is taken to disseminate the information for the benefit of the various alfalfa growers. The temperature forecasts will be issued in the same way in connection with the harvesting of alfalfa seed.

### SPECIAL TEMPERATURE AND STORM WARNINGS FOR SHEEPMEN.

In the spring of 1916 special rain and temperature forecasts for the sheepmen in Oregon, Washington, and Idaho were made by the district forecaster at Portland, Oreg., during the shearing and lambing season. It is estimated that there are more than 6,000,000 sheep in these States. As winter feeding is expensive, sheep are usually shorn and put on the ranges as early as possible. Early lambing is encouraged also. Before being shorn, if stormy and cold weather prevails, the sheep may succumb to fatigue and starvation, and after being shorn it is necessary to keep the sheep near natural or artificial protection for a short period if unfavorable conditions prevail. The forecasts enable proper precautions to be taken by anticipating these conditions, and also give information as to favorable weather conditions for several days in advance, so that sheep may be grazed farther away from protection. During the spring of 1916 this information was telegraphed to 26 different points in these three States, and from them distributed by telephone to hundreds of sheepmen. The information has been found to be of very great importance, and the service will be continued and expanded.

### COOPERATION AND INVESTIGATION.

Cooperation is going on between the Weather Bureau and other Government bureaus and departments in several different lines of activities. Among them will be noted the keeping of records of temperature, rainfall, and depth of snow, as well as the distribution of special forecasts and warnings by the officials of several other branches of the Government service. Among the most important are the following: (1) The publication of the monthly crop report at 40 different Weather Bureau stations in the United States for the Bureau of Crop Estimates. These reports cover the crop conditions in every State in the Union. No material change has been made during the year, although plans are in progress for improving these published reports by including a general statement of the weather conditions and a running statement of the crop conditions. (2) Cooperation with the Office of Markets and Rural Organization in the publication of daily market reports. This service was in operation from May 9 to June 12 at Chattanooga, Tenn., in connection with the strawberry crop. Market information was telegraphed to our official at Chattanooga and daily bulletins were prepared and issued at that office.

### SPECIAL FRUIT STUDIES.

Studies are going on as to temperature variations at different altitudes in North Carolina, Oregon, Colorado, and Ohio, and investigations have been continued in connection with temperature and frost forecasts for the benefit of those fruit growers who are heating their orchards, and information has been gathered as to the value of these heaters and the expense of orchard protection. These matters are of very great importance, and it is hoped that funds will be in hand for a considerable extension of this investigation, particularly along the line of frost damage and the best heating methods.

Five sets of maximum and minimum thermometers have been furnished to the Bureau of Entomology for use in fruit orchards at Kanawha Station, Wood County, W. Va., in connection with the study of weather effects on the fruit trees and on the activities of damaging insects. This service was put into operation in May, 1916. Two full sets of instruments were also furnished to Prof. E. P. Felt, for use at Newfane, near Lockport, N. Y., and Kendal, near Albion, N. Y., to study the relation between the weather and the damage done by the codling moth. It is believed that the evening temperatures have an important influence upon the deposit of the eggs of this moth, and this investigation is to determine some facts regarding that matter. Four sets of instruments that had been in use in central Massachusetts by Prof. J. K. Shaw, of the College of Agriculture, at Amherst, Mass., in studying the weather conditions at different elevations and its effect upon the apple crop, were moved in the spring of 1916 to the Berkshire Hills in western Massachusetts, where a study was carried on to determine the connection between inversions in temperature in relation to the development of peach buds.

### COOPERATION WITH EXPERIMENT STATIONS.

Correspondence was begun early in the season with the directors of all the agricultural experiment stations in the United States,

preliminary to cooperation to determine the critical period of crops and the weather that has the greatest effect on crop yields, as well as on the extent of insect and fungous damage. It is expected that a definite and extensive system for keeping regular records of the different weather factors and the development of the most important crops will be instituted at a large number of these stations, and such preliminary work started as may be continued through a series of years, and from which large results may be anticipated.

### WEATHER AND CROP STUDIES.

The chief of this division, before his appointment to this position, had made studies to determine the critical period of growth of corn, potatoes, wheat, hay, fruit, and other crops by mathematical and graphical correlation methods, and the division is now continuing these studies as fast as the routine duties will allow. Some of the results of these investigations are appearing in the National Weather and Crop Bulletin that is prepared by this division and others will appear from time to time in various publications as the subject is developed. It is believed that it has remarkable possibilities for development for the benefit of the agricultural interests of the country.

### NATIONAL WEATHER AND CROP BULLETIN.

The most important routine work of the division is the issue of the Weather and Crop Bulletin, which is published weekly during the summer months and monthly during the winter season. During the past year publication of the weather and crop diagram pages covering the weather and condition of cotton, corn, and wheat, started in 1915, was continued, but a change was made to allow the division of this territory into 12 diagrams instead of 7, thus making the areas smaller and the data more definite. Detailed studies have been printed to show the effect of rainfall and temperature upon crop conditions, and the knowledge gained in these and other similar studies has been applied in discussing the effect of current weather upon the development of crops. The regular publication of the weekly weather forecasts in the bulletin was discontinued in the spring of 1916, and since then any reference made therein to the forecasts has been in connection with the current weather conditions. The issue of this bulletin is 3,750 copies.

## METEOROLOGICAL RECORDS AND PUBLICATIONS.

The several annual, monthly, and other serial publications of the bureau have been issued in regular sequence, and continue to supply the general and technical public with useful information.

On account of the large demands for climatic data from all portions of the country, it has been necessary to reprint several of the separate parts of Bulletin W and Climatological Data of the United States by Sections. Others are now ready for reprinting when opportunity offers. The growing demand for these summaries indicates that the entire set should be brought down to date and reprinted.

### MARINE OBSERVATIONS.

The publication of the monthly summaries of weather conditions over the north Atlantic Ocean in the Weather Review, together with charts showing the averages of pressure and temperature, the prevailing direction of the winds, and the paths of the more important storms, begun during the early part of the year, has continued.

### ATLAS.

Substantial progress was made during the year in the preparation of material for the Weather Bureau portion of the proposed Atlas of American Agriculture. Many of the more important charts have been prepared and are now in the hands of the draftsman for reduction to the final base size to be adopted, and it is expected the work will be very generally completed during the present fiscal year. Much work has been required of station officials in preparing the material for these charts, but this has resulted in the bringing together of a large volume of valuable material not previously summarized at stations.

### ATMOSPHERIC MOISTURE.

Much material has been gathered in preparation of a report on the vapor pressure and relative humidity of the United States which it is hoped can be completed and published in the near future.

### STUDY ON ANTICYCLONES OF THE UNITED STATES.

A study by Mr. E. H. Bowie and Mr. R. H. Weightman on the anticyclones of the United States and their average movements is nearing completion, and the manuscript has been submitted for publication.

### TREATISE ON WEATHER FORECASTING.

A board consisting of Profs. A. J. Henry (chairman), H. J. Cox, and H. C. Frankenfield, and Mr. E. H. Bowie, have been engaged during the last year or so upon the preparation of a treatise or manual on weather forecasting in the United States. This important subject has never received the treatment that its importance deserves. Weather forecasts under governmental auspices have been made continuously for about 45 years, yet only fragmentary and scattered references to the general principles of the art have appeared in print. The manuscript and the illustrations were completed during the year and the matter is now in type, forming a printed volume of 370 royal octavo pages with 199 illustrations.

### SUPPLEMENT.

A collection of phenological and meteorological observations at Wauseon, Ohio, mentioned in the report for last year, was issued as Supplement No. 2 on September 4, 1915.

### PRINTING IN COOPERATION WITH THE BUREAU OF CROP ESTIMATES.

The printing of the monthly crop statistics furnished by the Bureau of Crop Estimates for the several States has continued as in past years, and no effort has been spared by our station officials to place the information in the hands of the public as early as possible.

## PRINTING DIVISION.

The operations of the printing division have continued very much as heretofore, certain advantages having been realized from an extension of the floor space into area formerly utilized for storage purposes.

The following table shows the output of work for this division:

LITHOGRAPHIC.

| | Copies. |
|---|---|
| Charts for Monthly Weather Review | 184,101 |
| Charts for climatological data | 684,770 |
| Hurricane charts | 6,200 |
| Miscellaneous charts and maps | 22,525 |
| Map A | 57,210 |
| Daily Washington Weather Map | 463,125 |
| National Weather and Crop Bulletin | 110,270 |
| Snow and Ice Bulletin | 23,210 |
| Blank forms | 11,800 |

PRINTING.

| | |
|---|---|
| Station map bases (Forms DD, E, and CM) | 7,620,000 |
| Daily forecast cards | 472,220 |
| Weekly forecast | 7,615 |
| Monthly Meteorological Summary | 2,520 |
| Franking forecast cards for stations | 19,608,900 |
| Rural free-delivery slips | 1,707,400 |
| Covers for Climatological data | 4,980 |
| Blank forms | 2,606,190 |
| Climatological data, Maryland, Deleware, and Virginia | 23,210 |
| Letterheads | 216,200 |
| Addressing envelopes | 69,950 |
| Memorandum slips | 142,900 |
| Skeleton letters | 11,300 |
| Cards | 47,492 |
| Instructions | 17,100 |
| Weather Bureau topics and personnel | 2,800 |
| Circulars and circular letters | 19,740 |
| Station regulations and amendments, pages | 53,900 |
| Labels | 19,000 |
| Miscellaneous | 126,753 |
| Binding Monthly Climatological Data, sets | 4,839 |
| Flexotype work (4 months) | 3,330 |

### PERIODICAL PUBLICATIONS.

The daily, weekly, or monthly issues of our periodical publications at the close of the year were as follows:

| | Copies. |
|---|---|
| Monthly Weather Review | 1,425 |
| Monthly Climatological data for the United States | 310 |
| Washington Weather Map, first edition, (daily, except Sundays and holidays) | 990 |
| Washington Weather Map, second edition (daily, except Sundays and holidays) | 440 |
| Washington Weather Maps, Sundays and holidays | 540 |

| | Copies. |
|---|---|
| National Weather and Crop Bulletin (weekly from April to September, monthly from October to March) | 3,750 |
| Snow and Ice Bulletin (weekly during the winter) | 1,110 |
| Forecast cards (daily, except Sundays and holidays) | 1,550 |
| Weekly forecasts | 240 |
| Monthly Meteorological Summary for Washington, D. C | 250 |

The distribution of periodical publications to foreign countries through the international exchange service and by mail was as follows:

| | Addresses. |
|---|---|
| Washington Weather Map | 83 |
| Monthly Weather Review | 376 |
| Monthly Climatological Data | 71 |
| National Weather and Crop Bulletin | 30 |
| Snow and Ice Bulletin | 7 |
| Annual Report of Chief of Bureau | 43 |

The number of paid subscriptions on our mailing lists at the close of the year was as follows:

| | Subscribers. |
|---|---|
| Washington Weather Map | 56 |
| National Weather and Crop Bulletin | 491 |
| Snow and Ice Bulletin | 49 |
| Climatological Data | 7 |

Subscriptions for the Monthly Weather Review are filled by the superintendent of documents from the 75 copies furnished him each month by this division.

Remittances received by the superintendent of documents covering subscriptions for Weather Bureau publications were as follows:

| | |
|---|---|
| Washington Weather Map | $152.15 |
| National Weather and Crop Bulletin | 118.25 |
| Snow and Ice Bulletin | 12.25 |
| Climatological Data | 48.30 |
| Station Weather Maps | 217.61 |
| Total | 548.56 |

## LIBRARY.

During the year 775 books and pamphlets were added to the library, while about 275 were eliminated, by transfer to the Library of Congress or otherwise. The total strength of the collection is now approximately 35,500 volumes. Apart from reference books and files of scientific journals, the books in the library relate almost exclusively to meteorological, climatological, aeronautical, and seismological subjects, including an immense amount of statistical literature, and the collection is quite unique among American libraries. Special efforts were made during the year to bring up arrears of binding. The total of 2,208 volumes sent to the binder was much greater than in any previous year.

## AEROLOGICAL INVESTIGATIONS.

The installation of the Drexel Aerological Station was completed, and free observations by means of kites were begun in October, 1915.

Twenty-eight observations to an average height of 2,850 meters were made in October and November, 1915. The addition of a man to the station force in December, 1915, made it possible to begin at that time daily observations in the free air. In addition to the daily observations, when opportunity offered, series of observations continuing for a period of 30 to 36 hours were made. During a series of observations a kite flight is made every three to three and a half hours. The data obtained enable us to follow atmospheric changes in considerable detail. In connection with the daily observations, a daily telegram, giving atmospheric conditions observed at one or two selected levels, is sent to the forecast offices of the Weather Bureau at Washington, D. C., and Chicago, Ill.

In all, 350 observations to an average height of about 2,800 meters have been made up to June 30, 1916. Of these, 88 were made in 11 different diurnal series, 28 were made before December 1, 1915, and the others were made as daily observations.

Owing to the impossibility of importing meteorographs of the kinds we have been using, or of getting parts for them, the work of rebuilding, repairing, and calibrating these instruments has been especially heavy during the past year. In addition to this, a working model of a self-recording balloon theodolite has been constructed and preliminary work done on a simple form of meteorograph and on a manometer for use in calibrating pressure elements of meteorographs directly in millibars. An additional kite reel was built for us by an outside firm, and delivered in November, 1915. Some necessary calibration on the reel has since been completed by us and the machine made ready for issue to a new aerological station.

It has been impossible for the past year or two to import rubber balloons such as we use in making aerial soundings to great heights. We have therefore gone into the subject of the manufacture of these balloons with interested rubber companies in this country, in an effort to have them produced here. A number of sample balloons have been prepared and tested. Some of these have been of fair quality, but not yet suitable for our work.

## SEISMOLOGICAL INVESTIGATIONS.

The work of collecting and publishing earthquake data, begun December 1, 1914, has been continued during the past year. These data are of two kinds—noninstrumental reports of earthquakes felt, and instrumental records, often of quakes wholly imperceptible to the senses. The noninstrumental reports are rendered by all the regular stations of the bureau, nearly 200 in number, and also by nearly all the bureau's 4,500 cooperative observers. The instrumental records published by the bureau have been obtained in part by instruments owned and operated by the bureau itself, one at Washington, D. C., and another at Northfield, Vt., and partly through the cooperation of 18 additional stations distributed from Panama to Alaska and from the Hawiian Islands to Porto Rico.

During the calendar year 1915, 150 earthquakes were felt within the borders of the United States proper. The great majority of these produced no damage whatever, but some three or four were distinctly severe, though only two occurred in populous regions.

## SOLAR RADIATION INVESTIGATIONS.

Continuous records of the total radiation received on a horizontal surface from the sun and sky are obtained at Washington, D. C., Madison, Wis., and Lincoln, Nebr., and the daily totals are published month by month in the Monthly Weather Review. For the two first-named stations, which now have records covering periods of 5 years and 6 years, respectively, the daily departures of radiation from the normal, and the accumulated excess or deficiency of radiation for the month and since the first of the year, are also published. During the crop-growing season of 1915 the accumulated departures were quite insignificant at Washington, but showed a marked deficiency at Madison. Between May 1 and August 10 this deficiency amounted to 14 per cent of the normal radiation, and between May 1 and September 30 it amounted to 11 per cent. Between May 1 and August 31 the mean daily temperature over the State of Wisconsin averaged 4.5° F. below the normal, and the development of corn and some other crops was greatly retarded. During the first half of 1916 Madison recorded about the normal amount of radiation, but Washington showed a deficiency of about 7 per cent. There is evidence that this deficiency was even greater in New England and the North Atlantic States, where the development of certain crops was markedly retarded. The exact relation between plant development and the amount of the incoming radiation, and whether the relation is a direct one, or is a secondary effect of the resulting lower temperatures, are questions that can not be answered definitely until the radiation measurements have extended over a longer period of time.

Measurements of the intensity of direct solar radiation on a surface normal to the incident solar rays have been continued at Washington, D. C., Madison, Wis., Santa Fe, N. Mex., and Lincoln, Nebr. At each of these stations except the last named the series of readings extends over a sufficient number of years to give reasonably accurate monthly normals. Between July 1, 1915, and June 30, 1916, the monthly means of the intensities measured were generally above the normal at Madison and Santa Fe, and below the normal at Washington. At the two first-named stations the monthly maxima have generally exceeded those of 1914–15, and are the highest that have been measured since the depression in radiation intensities that followed the eruption of Katmai Volcano in Alaska in June, 1912.



WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916