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REPORT OF THE CHIEF OF THE WEATHER BUREAU.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., September 22, 1915.

SIR: I have the honor to submit a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1915.

Respectfully,

C. F. MARVIN,
Chief of Bureau.

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

The daily work of the Weather Bureau is an important public service, and every branch of commerce, industry, and business activity is continually finding new ways in which the information obtainable from Weather Bureau sources can aid in the more efficient conduct of those affairs. The 200 principal stations of the Bureau, well distributed throughout the country, form intimate points of contact between the central organization and those it aims and desires to serve. These stations not only collect and report telegraphically the local meteorological condition, but also serve simultaneously the equally important purpose of a local center for the dissemination of every species of weather news. Forecasts, storm, frost, flood, and other warnings and weather bulletins to be of real value must be immediately disseminated. The Weather Bureau is well organized to accomplish this result, and its work and efforts are impaired on some occasions only by the failure or complete interruption of the customary means of communication—that is, principally, the telegraph and telephone service.

Almost the first effect of great floods and destructive storms is to cut off communication by the customary wire service. Wireless methods of communication are subject to but little, if any, interruption by destructive weather conditions, and on such occasions are often the only means of communication that remain. A powerful argument is found in these considerations for the establishment of wireless stations in many regions of the country, especially those that have repeatedly suffered from disastrous floods and storms and the serious loss of communication with the outside world.

The funds appropriated by Congress for the work of the Bureau have remained practically the same for several years, in fact, have suffered slight reductions. The service has, however, been extended in many directions by increasing the distribution of frost warnings, extending the river and flood service, the introduction of fire-wind forecasts for the better prevention of forest fires, the enlargement and publication in better form of weather and crop bulletins, and the

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

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monthly reports of climatological data. These improvements have been accomplished without additional expenditures by economies of administration and efficiency of organization.

The Bureau is in receipt of applications from many sections of the country for extensions of its service. These include requests for river and flood warnings, frost, and cold-wave information; fruit, tobacco, trucking, and vineyard protective work, and water resources information in the sparsely occupied region of the West, where the whole region is as yet but poorly covered with reporting stations. Extensions of the grain, cotton, sugar, rice, and other crop region services are also necessary.

The increases needed represent a normal and legitimate response to the natural growth, development, and extensions of the several industries and activities of the country and are necessary to meet a natural increase in the use that is being made of the Weather Bureau service. The commercial as well as the naval and military interests of the country fully justify the improvement and extension of the work of the Bureau in the Panama Canal and the region of the Caribbean Sea. The changing conditions in Alaska likewise claim attention. In a few words, all the foregoing means increased service. That means more reports, more warnings, more telegraphing, more equipment and general supplies, and additional men.

The details of the work of the Bureau during the past year are briefly discussed under separate topics, as follows:

STATIONS AND OBSERVATIONS.

No increase has been made in the number of principal or fully equipped stations, which is now 197. A substation previously maintained at Wausau, Wis., for the special purpose of a flood-warning service in this section, has been manned by a commissioned employee of the Weather Bureau, as no other satisfactory arrangement could be made to continue the station, and funds are needed for its full equipment.

OBSERVATORY BUILDINGS AND STATION OFFICES.

Two new Weather Bureau Observatory buildings, authorized prior to July 1, 1914, were completed and accepted; that at Sandy Hook, N. J., on August 29, 1914, and the one at Cincinnati, Ohio, on February 22, 1915. The latter is practically the first suburban meteorological observatory established by the Weather Bureau and happens to have been most appropriately placed at Cincinnati, where our present meteorological service may be said to have started in 1869 and 1870, under the initiative of Prof. Cleveland Abbe. Advantageously located on elevated ground in the north part of the city, in Clifton suburbs, it should prove of exceptional value for meteorological work and a permanent place at which such work may go on under favorable conditions for many generations to come. The present down-town station in the Federal Building, in or near which the Weather Bureau station was situated for nearly 45 years, is also to be maintained as a printing and business office.

Contract has been let for the new cottage building and telegraph office authorized by Congress at the Neah Bay (Wash.) station on the Weather Bureau seacoast telegraph line, near Tatoosh Island. Construction work will be taken up promptly.

Necessary repairs and improvements have been carried to completion on Weather Bureau buildings and grounds at Atlantic City, N. J.; Bismarck, N. Dak.; Modena, Utah; North Platte, Nebr.; Sault Ste. Marie, Mich.; San Juan, P. R.; and Sheridan, Wyo. The building belonging to the Bureau but occupying leased ground at Kitty Hawk, N. C.—a discontinued station—was disposed of at public sale.

A farm of about 40 acres, with buildings complete, was leased at Drexel, Nebr., for a new aerological station at which to maintain and continue the kite and balloon work, transferred thereto from Mount Weather.

The building in which the Weather Bureau occupied rented quarters at Jacksonville, Fla., was partially destroyed by fire January 3, 1915, involving a financial loss to the Government for station equipment of about $2,500.

To secure suitable conditions for obtaining accurate observations of weather conditions at its outlying stations, offices are located in Federal buildings wherever suitable quarters may thus be had. Where these are not available nor suitable, rented offices are utilized or, in a number of cases, the Weather Bureau has erected observatory buildings of its own. At the end of the fiscal year there were 45 of these latter, in addition to the central office building in Washington. The accumulated investment for these permanent structures outside of Washington amounts to about $1,000,000 for grounds and property as a whole.

The following statement gives the status and number of Weather Bureau station offices in operation on June 30, 1915:

Free quarters and accommodations:	
In Federal buildings	64
In State or other public buildings	7
In Weather Bureau observatory buildings	45
Total free of rental	116
In rented quarters owned by individuals or corporations	98
Total for entire service	214

SUBSTATIONS.

A few extensions have been made in the work conducted in the interests of the grain, cotton, sugar and rice, cattle, and such industries, notably in the frost-fruit work in the Salt River Valley of Arizona, the Rogue River Valley of Oregon, in the vicinity of Walla Walla, Wash., in southern California, and in the large fruit districts of Ohio.

Two new special meteorological stations were established in Alaska in cooperation with the naval radio service.

The large corps of cooperative observers, now more than 4,500, was further increased during the year by the opening of more than 100 new stations at points from which meteorological data will be useful in determining the climate of the country. The large amount of data collected by these observers, on the whole, was presented in excellent form, and shows a conscientious desire on their part to render the best service possible.

The proper exposure and care of instruments, as well as the correct interpretation of their indications by observers at substations and

the prompt rendition of reports, are fully appreciated, and effor has been made to attain the highest possible degree of accuracy in these respects. To best accomplish this, however, it is imperative that a more frequent inspection of these stations be provided for. A personal visit to the observer enables the section director to acquaint himself with the general environment of the station, to remedy defects in the exposure of instruments, where such exist, or in the manner of recording the observations, and also encourages the observer to renewed efforts if he has become discouraged at an apparent lack of interest in the work. It is also believed that in the establishment of new cooperative stations the equipment should be installed and the observer instructed whenever possible under the personal supervision of a trained Weather Bureau official.

SNOWFALL AT HIGH ALTITUDES IN WESTERN STATES.

The Weather Bureau for some years past has sought to determine in the spring of each year the probable amount of water contained in the snow cover of the higher levels that may later be available for irrigation and other purposes.

The project is a difficult one because of the fact that, as a rule, the higher altitudes are either not inhabited, or, in many cases, only during the summer months; hence, with the exception of the low passes occupied by the continental trunk lines of railroad and a few isolated points where mining camps are located, comparatively little is known of the total amount of the winter snowfall. The total number of high-altitude snowfall stations is gradually becoming less and less, due to the abandonment of mining camps and other enterprises that have been hitherto maintained throughout the year at high altitudes. The present method of obtaining observations of the winter's snowfall through persons who may reside on the higher altitudes throughout the year has reached the limit of its development. On the other hand, the plan of intensive surveys in small watersheds, as developed originally by Thiessen, promises relatively valuable results, but of extremely local application. Three such surveys were made during the current year, as follows: One in City Creek watershed, near Salt Lake City, Utah, at elevations ranging from 8,500 to 9,500 feet above mean sea level; a second in the watershed of Cottonwood Creek, a tributary of Boise River, that joins the main river a short distance above Arrowrock Dam; and the third by the Rock Creek Conservation Co., in cooperation with the Weather Bureau, in the watershed of Sand Lake, Carbon County, Wyo., at altitudes of between 10,000 and 10,500 feet above mean sea level.

All of these surveys were conducted in fairly accessible regions, the plan being to pack supplies, implements, and tent equipage to some convenient base, go into camp at that point, and make daily journeys thence into the snow fields. The greatest objection to this plan is the time consumed daily in going to and returning from the snow fields. Where it is possible to transport supplies and material into the heart of the snow fields, as was done in the City Creek project, much advantage is secured.

The survey in the watershed of City Creek, in 1915, whence Salt Lake City draws its water supply, showed 30 per cent less water in the snow cover than in the previous year, and also that the snow was in a condition favorable to early melting.

The survey in Cottonwood Creek was conducted under very favorable conditions. In the first place, the entire watershed of but 26 square miles had been previously surveyed by the United States Geological Survey, and in the second place, it was possible to measure accurately the run-off from the watershed during the snow-melting season. The results are not yet at hand, but in this connection it may be remarked that a snow survey in this watershed during the previous year brought out the fact that the run-off from snow was remarkably small. This result, it may be remembered, agrees with the conclusions reached at Wagon Wheel Gap, Colo., at the experiment station being conducted jointly by the Forest Service and the Weather Bureau.

An extension of the snowfall work to the watershed of Salt River in Arizona is of sufficient importance to merit separate mention.

SNOWFALL IN SALT RIVER WATERSHED.

The demand for information as to the probable amount of snow water available for irrigation purposes on the watershed of the Salt River of Arizona, above the Roosevelt Reservoir, made itself felt several years ago.

Considering that one of the most important reclamation projects under the supervision of the Federal Government centers in the Salt River Valley of Arizona, it was deemed advisable to spare no effort toward acquiring the information sought. At that time it was known in a general way that the most representative snowfall tract in the watershed of the Salt River above the Roosevelt Reservoir was in the Apache Indian Reservation, north of Fort Apache, in the mountain district of the North Fork of White River, a tributary of the Salt. That country was, however, almost an absolute terra incognita as far as topographic maps are concerned. The first endeavors were therefore in the nature of a reconnoissance survey in an effort to construct a rough topographic map of the watershed. A first survey was made in November, 1913, from Roosevelt, Ariz., as a base, the objective being a four days journey by wagon from that point. A few snow-stakes were set up on that journey, but while the original plan was not carried out by reason of severe snowstorms in the latter part of the month, a substantial contribution was made toward mapping the region. In this preliminary survey valuable aid was extended by officials of the United States Reclamation Service, the United States Forest Service, and by officials and agents of the United States Indian Service.

Such stakes as were installed on the first expedition were visited by a second expedition, also in the nature of a reconnoissance survey, in April, 1914. On this expedition the altitude of the snow line was noted and a considerable amount of general information was secured that will be useful for comparative purposes in future years. It was also concluded as a result of the second expedition that the region about Paradise Creek, a tributary of the North Fork of the White River, was the most accessible locality for making permanent measurements of the depth and density of the snowfields in the vicinity of Fort Apache.

The work of 1915 consisted in two attempts to reach Paradise Creek. The last one, made in the latter part of March, 1915, was successful only by completing the last 8 miles of the journey on snow skis after having left the horses and camp outfit on the way. The

expedition naturally was unable to accomplish all that it had set out to do by reason of failure in transportation arrangements. It, however, determined the fact that the snowfall of the winter of 1914–15 in the mountains of eastern Arizona was extraordinarily heavy.

Fortunately for agricultural and other interests in Arizona that depend upon the water supply, the precipitation of rain, as well as snow, during the winter, was abundant. On April 14, 1915, water began to run over the spillway of the Roosevelt Dam, storage capacity in the reservoir being reached in that month, a fact easily foreshadowed by the reliable reports of heavy snow in the mountains that were made at the close of January, 1915.

Much work remains to be done in the mountain regions of extreme eastern Arizona. Indeed, the work thus far accomplished can only be considered as preliminary to a more general campaign.

EVAPORATION.

Data on evaporation constitute a term in the climatological factors of any given region that is of very great practical value. However, the amount of evaporation from the free surface of a body of water of greater or less extent, as a reservoir, an irrigating ditch, a lake, or the like, and the evaporation from the surface of soils of various compositions and conditions of vegetal covering, or the absence thereof, also the evaporation from such objects as forests, fields of growing grain, etc., are so different under the same general meteorological or climatological conditions that thus far no satisfactory means of measuring evaporation under the several conditions mentioned have been found. These conditions, perhaps more than any other, have been a barrier to the serious undertaking of definite and long-continued series of observations of evaporation according to some one particular method of measurement, which at the best would probably not entirely meet the requirements of any one of the lines of study in agriculture, engineering, forestry, and the like.

Notwithstanding the foregoing, the Weather Bureau has adopted a standard type of apparatus and inaugurated measurements of evaporation thereby. Moreover, the results of various determinations of evaporation that have been made from time to time, either in the Weather Bureau or in cooperation with other Federal services, or that might possibly be available from independent measurements, are now being collated and prepared for publication in appropriate form. The several types of data thus available, however, are not strictly comparable, principally because there has been lack of uniformity in the methods and apparatus used. In many cases no attempt was made to separate rainfall from evaporation, so that the records are for the most part fragmentary, discontinuous, and more or less unsatisfactory.

While numerous attempts have been made to correlate evaporation with the meteorological conditions prevailing while it occurs, yet no dependable formula is known. Temperature of the water surface is an important factor, and this datum is generally wanting in many of the older records. It thus appears that the direct determination of the rate of evaporation in various portions of the country by actual measurements under standard conditions at stations well distributed is certain to ultimately yield data of very great value.

A model Weather Bureau evaporation station is now maintained at Massachusetts and Nebraska Avenues, Washington, D. C., in co-

operation with the American University. Daily measurements have been maintained since early in April, the total evaporation measured in inches being: April, 6.48; May, 6; June, 6.58; July, 7.05. Another station of the same general character is being established at the Roosevelt Reservoir in cooperation with the Reclamation Service, and arrangements are being made for establishing a number of others.

Detailed instructions for the operation and conduct of stations of this character will be published by the Weather Bureau in the near future.

TELEGRAPH SERVICE.

The services performed by the several telegraph and telephone companies in collecting and disseminating weather reports, forecasts, warnings, etc., are fundamental and essential to the work of this Bureau, and, on the whole, have been very satisfactory.

Except for temporary interruptions, the several sections of the coast lines owned by the Weather Bureau were in continuous operation during the year.

The Block Island–Narragansett section has worked with little interruption during the year. A sleet storm on February 3 caused the prostration of a mile of telegraph line on the island. Communication was restored February 7.

Cape Henry–Hatteras section.—Communication was interrupted on this line for a total of 43 days. During these interruptions weather reports from Hatteras were missed but a few times, as they were handled with slight delay by telephone and wireless through the cooperation of the Coast Guard Service and the commercial and Navy wireless stations.

Early in September repairs to the Manteo cable were necessary in order to straighten the cable and close a break caused by the steamer *Trenton* backing into the cable and cutting it in two. The water of the sound in this region is very shallow. November 23, 1914, the Manteo cable was again repaired by Lineman Smith, of the Coast Guard Service, putting in 100 yards of spare cable in place of a portion found defective. The cable, however, continues to work heavy through the south conductor, and in order to work the line through to Hatteras, Manteo at times must be cut off by means of a switch located in the Coast Guard station at Nags Head. This arrangement is not satisfactory, and action to repair or replace the cable must be taken in the near future. General repairs conducted with the aid and cooperation of the Coast Guard lineman were completed in April, 1915. Later two severe storms broke off a number of old poles and left the line in impaired condition. Repairs were again made, however, but new poles and some new wire are still needed.

The transfer office of the line was removed from Norfolk to Cape Henry during July, 1914, and all commercial business in connection with the radio station at Buxton, N. C., and the Western Union and Postal telegraph companies in Norfolk is handled through the Cape Henry office. All city messages for Norfolk are handled direct from Cape Henry by telephone or are telegraphed to the Western Union or Postal offices, where delivery is made without charge to the Government. The arrangement has worked well and all business has been handled promptly and satisfactorily, not a single complaint of any kind having come to the attention of the chief operator.

VESSEL REPORTING.—Cape Henry is one of the most important vessel-reporting stations of the service, 19,706 vessels having been reported during the year. Also, 12 wrecks were reported from various Coast Guard and Weather Bureau stations to Cape Henry, from which point the information was given out and assistance dispatched to the scene of the wrecks.

KEY WEST–SAND KEY SECTION.—The submarine telephone cable connecting Key West with Sand Key, Fla., was broken October 5, 1914, and repaired October 16, at a cost of $172.50. The damage was done, apparently, by the tank steamer *Sioux*, which, during a strong wind squall, dragged her anchors and fouled and broke the cable.

ALPENA–THUNDER BAY AND MIDDLE ISLAND (MICH.) SECTION.—During the year past the total time of interruptions to the telephone line was 4 days and 19 hours on the Middle Island line, and 1 day and 4 hours on the Thunder Bay Island line. The interruptions were almost entirely due to damage by lightning in the city telephone system with which our lines are connected. While the condition of these lines belonging to the Weather Bureau is fair, it has been 21 years since they were constructed and the question of gradual or complete reconstruction will of necessity arise in the near future. Vesselmen use the lines constantly and the revenues thus derived are turned into the Treasury as miscellaneous receipts.

The Beaver Island section from Charlevoix to St. James, Mich., was uninterrupted during the year and was maintained without expense.

Glen Haven–South and North Manitou Island section has worked uninterruptedly throughout the year without expense.

POINT REYES—SAN FRANCISCO SECTION.—This line is in a fairly satisfactory condition, and if the station at Point Reyes is to be maintained action will be taken to put the whole line in good repair.

PORT CRESCENT—TATOOSH ISLAND SECTION.—Communication between Port Crescent and Tatoosh Island was interrupted for a total of 22 days during the past year. This was about 4 days more interruption than last year. The interruptions were the result of logging operations and wagon-road and railroad building, rather than the result of stormy weather. During the same period communication between Port Crescent and Seattle via the Western Union wires was interrupted for a total of 45 days and 9 hours, and by the Postal Telegraph the total interruption was 56 days and 23 hours. It will be noted that, notwithstanding the rough country through which the Government maintains and operates this line, it is kept in more efficient condition than the commercial lines. The line has been of great benefit to shipping, fishing, and other commercial interests during the year, and the telegraph business must necessarily increase as the country is settled and new industries open.

FORECASTS AND WARNINGS.

For a number of years the issue of forecasts and warnings has been most satisfactorily accomplished by subdividing the territory of the United States into several large districts and placing each district in charge of a specially trained and competent forecaster. District

headquarters are now located at Washington, Chicago, New Orleans, Denver, Portland, and San Francisco. The Washington office until recently made all the forecasts on the evening observations, except for the Pacific coast districts. Provision, however, was made near the close of the year so that the night as well as the morning forecasts should be issued from Chicago and Denver for their respective districts. Two advantages result from these changes. The Washington forecaster has a smaller territory at nighttime for which predictions are required, and more time and study can therefore be given to the region covered, while, on the other hand, the preparation of two daily forecasts keeps the district forecaster in closer touch with the current changes in weather conditions than is likely to be the case when he is responsible for only one forecast. Advantages in local distribution are also realized. The Washington forecasters prepare all storm warnings for the Great Lakes and the Atlantic and Gulf coasts, and exercise a general supervision over all the forecasting activities of the Bureau.

Periodical inspections of the principal stations of the service are made by the Washington and other district forecasters.

During the year the Weather Bureau issued daily its usual 36 and 48 hour forecasts of weather, temperature, and winds, and prepared and issued special warnings of frosts, cold waves, storms, and heavy snows.

Weekly Weather Forecasts.—The weekly forecast issued prior to August, 1914, was then suspended because of the interruption of reports from foreign meteorological services brought about by the European war. The issue of a weekly forecast was resumed, however, in a modified form in April, 1915. This forecast is prepared and issued Tuesday forenoon for the week beginning on Wednesdays and is immediately sent to the press associations, and selected portions are telegraphed to certain distributing centers, where they are printed on cards and distributed by mail to such rural newspapers and individuals as can utilize the information or aid in its dissemination.

The most severe and disastrous storm of the year was that of December 7–9, 1914. This disturbance passed up the Atlantic coast, causing high winds and tides along the Atlantic seaboard and considerable property damage along the Delaware and New Jersey coasts. Warnings were issued well in advance.

The Atlantic coast storm of April 2–5, 1915, including Easter Sunday, was quite a severe one in many respects. From a point off the southwest Florida coast on the morning of the 2d it passed northward up the Atlantic coast with increased intensity to a position over the Grand Banks by the morning of the 5th. Storm warnings were ordered for the entire Atlantic coast, and gales occurred, with some damage to shipping. Heavy falls of snow occurred over portions of eastern Pennsylvania, southern New York, New Jersey, Delaware, and New England. A fall of 19 inches was reported from Philadelphia, Pa.

One of the most pronounced cold waves of the winter occurred during the latter part of January, 1915. On the evening of the 26th a very cold high-pressure area was central over the Canadian Northwest. Low temperatures had prevailed for several days over the

Northwestern States and no further warning was necessary, but warnings were ordered for eastern Colorado, western and southern Wyoming, eastern and southern Iowa, and the interior of northern Illinois, and during the 27th were extended generally over the Lake Region, the Central Valleys, New England, and the Middle Atlantic States. This cold wave proved to be the most pronounced of the winter of 1914–15, temperatures as low as zero occurring almost to the Ohio River.

During the month of November, 1914, a succession of storms of marked character crossed the Great Lakes, causing winds of storm force. The rapidity with which one storm followed another was most marked, and necessitated many warning advices.

The heavy and continued rains of May and June, 1915, in Kansas, Nebraska, and adjoining sections, while not producing marked floods in the rivers, nevertheless wrought immense damage to standing crops, not only from overflow and total destruction of the crop in bottom lands along the rivers and small streams, but also by reason of the saturated condition of the soil, it being impracticable to gather the crop until the ground dried out.

An estimate of the damage to crops and farm lands in Kansas places the amount at $6,000,000, with an additional $1,500,000 along the Missouri east of Kansas City.

WEATHER FORECASTS DISTRIBUTED BY WIRELESS.

Amateur wireless operators at Illiopolis, in Illinois, were permitted to aid in the distribution of weather forecasts by a scheme put in operation in June, 1915, as follows:

The sending station receives the forecasts usually by mail or by telephone, and broadcasts them between 12.45 and 1 p. m., in a message sent out at a slow rate—about 10 or 12 words a minute—to accommodate inexperienced operators. The receiving operator copies the message on an approved card and posts it for the benefit of his neighbors. Three places in Illinois—Illiopolis, Rock Island, and Springfield—send the forecasts in this manner, and 16 places in the State receive them. The total number of cards posted daily, except Sunday, is 38.

The distribution of forecasts by wireless was also begun in January, 1914, at University, N. Dak., from which source nine places in the State are supplied.

STORM-WARNING SIGNALS.

At the earnest solicitation of marine interests, especially those on the Great Lakes, a decided improvement in the former system of night storm-warning displays has been worked out so as to convey more definite information by means of the lantern displays. By this arrangement the direction of the expected wind can be shown to the nearest four quadrants instead of to only two directions, as heretofore.

The new night storm-warning signal consists of three lights in a vertical line. Special experiments conducted by the Instrument Division showed that in order to be seen separately by the naked eye as two bright objects the lights must be approximately 4 feet apart for each mile the observer is distant. To secure great brilliancy a standard electric lamp of the gas-filled tungsten type is being tried out, and necessary modifications in the standard lantern are being made. The

new system of night storm-warning displays will be put into operation first on the Great Lakes, and at the earliest practicable date.

Mention may be made of one or more of the new problems the forecasters have under investigation and which will probably be completed during the coming year:

(1) A discussion of the probability of precipitation from the different recognized types of low-pressure areas or storms over the various sections of the United States (H. C. Frankenfield and F. W. Krichelt). This discussion will observe the classification and arrangement adopted in the study of types of storms and storm movements in the United States (Edward H. Bowie and R. Hanson Weightman), issued as Supplement No. 1, Monthly Weather Review, 1914.

(2) A study of types of high-pressure areas of the United States and their movements (Edward H. Bowie and R. Hanson Weightman).

(3) The seriously disturbing influences of heavy local thunderstorms on electrical transmission lines, and the important consequence of these effects to a great part of the population of large cities, necessitate and justify a more intimate and careful study of these local atmospheric phenomena than has been given to them heretofore. It is hoped the Weather Bureau will be able to give increased attention to this interesting problem also.

RIVER AND FLOOD SERVICE.

General and destructive floods were absent during the year, although local torrential rains in southwest-central Texas in the latter part of April, 1915, caused severe floods in the smaller streams that were responsible for a loss of 40 lives and a very large money loss in crops and farms damaged that has been estimated at a little more than $3,000,000.

INSTRUMENTAL EQUIPMENT.—The experience of many years with respect to river gauges may be stated thus:

(1) Vertical staff gauges are to be preferred when local conditions admit of their use.

(2) Sloping gauges of concrete construction, while expensive, are necessary in large streams like the Ohio and Mississippi, in the absence of bridges or docks.

(3) Chain and weight gauges, where they can be used, afford a simple and fairly accurate means of determining the level of the water. They should be frequently checked in order to secure accurate results.

During the year a supply of a form of short-gauge box in conjunction with an enameled scale has been secured. These are superior to an older form suitable under similar conditions, and the new form will replace the old as the latter becomes unserviceable.

INSPECTION OF STATIONS.—A large number of special river stations have been inspected during the year, but it does not seem possible, except in rare cases, to have the zeros of the gauges and other measurements accurately checked by precise leveling.

A first step in the accurate checking of the zeros of river gauges has been taken in the appointment of an engineer to the service, with headquarters at St. Louis, Mo. It is estimated that at least two other engineers should be brought into the service, so that eventually one each would be available for the Pacific Coast, the Mississippi Valley, and the Atlantic Coast States.

COOPERATION WITH FOREST SERVICE.—The experiment station jointly maintained by the Forest Service and the Weather Bureau at Wagon Wheel Gap, Colo., has been maintained throughout the year. The main effort has been centered in securing climatological and hydrological measurements in the lower watersheds.

The Weather Bureau keeps a detail of its skilled observing force at the Wagon Wheel Gap Station, but there are other projects in Western States where it simply furnishes the instrumental equipment.

EMPIRICAL RULES FOR FLOOD FORECASTING.

The construction of a set of empirical rules for the forecasting of floods on the principal rivers of the United States was begun some years ago and has been carried on continuously ever since. During the current year rules for the rivers of South Carolina have been completed and sent to the flood-forecasting center of that State for trial and such modification as may be found necessary by practical experience. The object in reducing the flood-forecasting rules to writing is twofold: First, to preserve the experience gained by the different officials who have been connected with the work, and, second, to minimize the labor that an official on being assigned to any district that is new to him will have to perform in order to become fully acquainted with the regimen of the rivers in the district.

Forecasting rules have thus far been prepared for the majority of the principal rivers of the interior valleys.

METEOROLOGICAL RECORDS AND PUBLICATIONS.

The Annual Report of the Chief of the Weather Bureau, containing climatological data for the calendar year 1913, was printed and distributed as in former years. The customary serial and statistical reports of the Bureau were also issued without interruption. The constantly growing demand for these seemingly dry and uninteresting documents indicates the increasing extent to which the public is learning to make use of the valuable information they contain.

The biennial report on daily river stages, containing the daily gauge readings for 526 stations, has been put through the press and is now available for distribution.

The National Weather and Crop Bulletin was prepared along the lines adopted at the beginning of July, 1914, except that during the present season the date of issue was changed from noon Tuesday to noon Wednesday of each week and provision made for the printing of weekly weather forecasts and a more extensive discussion of the effects of the week's weather upon the principal growing crops, both of which changes appear to have met popular approval. The change in date of issue from Tuesday to Wednesday was a most welcome one to the station officials, as it offered much relief from the usual congestion of work on Mondays and afforded a better mail service in collecting data from their various correspondents.

Telegrams containing summaries of the more important features of the weather and crop conditions over the great corn, wheat, and cotton districts have been furnished the principal Weather Bureau centers in those districts promptly each week for distribution to the public. Likewise the section directors have been authorized to give to the press and others interested, at 12 noon on the date of the issue

of the National Weather and Crop Bulletin, copies of the weekly summaries telegraphed to the central office for use in the bulletin, expanded as necessary. This service has recently been extended so that these summaries are furnished to each Weather Bureau station in the respective States, to be given to the public at the appointed hour.

Snow and ice bulletins were issued weekly during the past winter, as usual, and the snow bulletins for the western Mountain States, issued monthly, were, as a rule, considerably enlarged over those issued for previous years, and contained much additional information regarding the amount and condition of the snow stored in the higher mountains.

The monthly and annual publications of the climatological service of the several States have been published regularly, furnishing prompt means for distributing the information they contain to the interested public. The collection of these summaries for the respective States into single volumes each month, containing a report for each State, has been accomplished as promptly as possible. The number of complete sets now assembled and distributed has increased to nearly 450, and requests to be listed for this publication are still being received.

The daily bulletins for the corn and wheat, cotton, sugar and rice, cattle, and other interests have all been issued regularly with a continued increase in the circulation.

During the year the abridged set of climatic charts was brought down to date, where necessary, and reprinted, and several important additions were made to the set, notably four charts of average relative humidity at 8 a. m. and 8 p. m., January and July, and two of the average temperature for the same months. On account of the numerous demands for Bulletin V, Frost Data of the United States, the supply became exhausted and a reprint necessary, which was accomplished during the year.

Calls for climatological and other data continued as in previous years, the total number of such requests handled at Washington being about 5,000.

The numerous calls for the data contained in the summaries of climatological data by sections, Bulletin W, exhausted some of the separate parts, and new editions of several of the individual sections have become necessary. Some of these have been printed already and others are now ready to go to the printer.

During the year a large amount of work has been accomplished in compiling climatological data for a proposed atlas of agricultural meteorology in cooperation with other bureaus of the department, the largest individual piece of work being the reduction of the precipitation data for the 20-year period 1895 to 1914, inclusive, to a uniform basis. This has necessitated the compilation of the reports from about 3,000 different points throughout the United States, the computation of means, and the establishment of the ratios of the short records to the full 20-year period. Much assistance has been given in this work by the station officials, who have cheerfully responded to every call made upon them. The work is now well advanced, and the material gathered will be of much value to the Bureau in addition to serving the purpose for which originally gathered.

The Monthly Weather Review has continued to appear monthly, presenting numerous important scientific papers bearing on all branches of meteorology and climatology. By authority of Congress the Weather Bureau has been authorized to include seismological investigations in its work, and on December 1, 1914, a section including seismological reports was added to the Review and regularly published thereafter. The Review contains, in addition, statistical tables presenting the results of meteorological observations at all the regular stations of the Bureau.

A committee on scientific papers was appointed during the year to examine and pass upon the merits of scientific papers submitted by Weather Bureau employees, not only to determine their appropriateness for publication, but to give proper credit to their authors for application and abilities thus represented. Twenty papers have been examined and four have been published in the Monthly Weather Review.

A monograph by Messrs. Bowie and Weightman, presenting an extensive study of the movements of storms across the United States, was published at the end of November as Supplement No. 1 to the Monthly Weather Review. A unique collection of meteorological and phenological observations by one man at the same place for over 30 years was offered to the Bureau by Cooperative Observer Thomas Mikesell, of Wauseon, Ohio. This collection compiled and edited by J. Warren Smith will be published as Supplement No. 2.

The assistant editor translated Dr. Besson's pamphlet, "Different Forms of Halos and Their Observation," for publication in the Review. This very useful guide was also issued separately in octavo pamphlet form and distributed to the Weather Bureau observers as an aid to them in improving our records of halo phenomena in the United States. It is a satisfaction to be able to report that some improvement in our observations is already noticeable.

Beginning in May, 1915, the Monthly Weather Review was put on a regular monthly schedule by the Government Printing Office, thereby insuring its publication on the last day of each month, instead of on widely different dates as in the past.

PRINTING DIVISION.

A printing office is maintained at the central office of the Weather Bureau in Washington, for the purpose of promptly printing and distributing weather maps, bulletins, charts, etc., relating to current meteorological conditions. It is indispensable that this printing office be maintained under the supervision of the Chief of the Weather Bureau, for the reason that the maps, bulletins, charts, etc., must be printed and issued as promptly as possible after the information conveyed therein becomes available, as any material delay in their issue and dissemination would render them of little value.

The printing office in Washington also supervises similar but much smaller printing equipments maintained at the principal stations of the Bureau throughout the country and which likewise print and distribute local weather maps, bulletins, and important meteorological information. Incidentally the printing office supervises other work of a printing nature that does not require to be immediately issued

and that, therefore, can be and is printed at the Government Printing Office.

Since the rush work of printing weather maps, bulletins, and the like does not occupy the force and facilities of the printing division for the entire eight hours of each working day, the remaining time is filled in with items of miscellaneous printing for either the central office or the field stations. In this way the plant and equipment are used in the most economical manner possible. The following summary will indicate approximately the work done during the past year:

OUTPUT OF PRINTING PLANT.

LITHOGRAPHIC.

	Copies.
*Charts for Monthly Weather Review	198,450
*Charts for Review Supplement No. 1	105,200
*Charts for Climatological Data	3,222,240
*Climatic Charts in sets of 11 each	5,500
*Charts for Bulletin V	10,500
*Washington weather maps	467,950
*National Weather and Crop Bulletins	132,000
*Snow and Ice Bulletins	26,000

PRINTING.

Station map bases	3,942,000
*Daily forecast cards	472,750
*Monthly meteorological summaries	2,640
Franking forecast cards for stations	21,675,000
Rural free delivery slips	1,368,000
Covers for publications	18,520
Blank forms	1,952,830
*Climatological data (Maryland, Delaware, and Virginia)	11,100
Letterheads	301,850
Addressing envelopes and telegram blanks	50,600
Memorandum slips	413,100
Skeleton letters	19,970
Leaflets	45,200
Cards	193,590
Instructions	19,350
Circulars	20,145
Miscellaneous	80,055

PASTING, STITCHING, AND BINDING.

	Sets.
*Maps, forms, memorandum slips, and climatological data	9,400

PERIODICAL PUBLICATIONS.

The daily, weekly, or monthly issue of our periodical publications at the end of the fiscal year was as follows:

	Copies.
Monthly Weather Review (printed at Government Printing Office)	1,375
*Monthly climatological data (printed at 46 section centers)	444
*Washington weather map, first edition (daily except Sundays and holidays)	1,015
*Washington weather map, second edition (daily except Sundays and holidays)	415
*Washington weather map, Sundays and holidays	530
*National Weather and Crop Bulletin (weekly April to September, monthly October to March)	3,325
*Snow and Ice Bulletin (weekly during winter)	1,320
*Forecast card (daily except Sundays and holidays)	1,550
*Weekly forecast card	200
*Monthly Meteorological Summary for Washington	225

* Work must be done at Weather Bureau.

The foreign distribution of all publications was suspended by departmental order dated August 10, 1914, on account of the European War. This service, however, was resumed in part during October, 1914, and full service by mail, or through the International Exchange Service where possible, was authorized on February 1, 1915. Back numbers of publications for countries that can not yet be reached by the exchange are being held for future shipment.

The distribution of the various periodical publications to foreign addresses is as follows:

	Addresses.
Daily weather map	87
Monthly Weather Review	370
Monthly Climatological Data	75
National Weather and Crop Bulletin	27
Snow and Ice Bulletin	10

Subscriptions filled by this division and covered by remittances made to the Superintendent of Documents were as follows at the close of the year:

	Subscribers.
National Weather and Crop Bulletin	360
Washington weather map	51
Snow and Ice Bulletin	33
Monthly Climatological Data	5

The aggregate receipts from the above sales exceed $400 annually.

Subscriptions for the Monthly Weather Review are filled by the Superintendent of Documents, who is supplied with 75 copies per month for that purpose.

PRINTING PRESSES AT STATIONS.

Owing to the quantity and character of the printing done at our New York and New Orleans offices, a small cylinder press was provided for each of these stations, which, together with the platen presses already in use, has greatly expedited the issue of their publications.

Small platen presses for printing commercial weather maps, with complete outfits of printing materials, were shipped during the year to the stations at Spokane, Wash.; Lansing, Mich.; Springfield, Mo.; Birmingham, Ala.; and Sioux City, Iowa.

The process of standardizing the type and logotypes at all stations was continued during the year as occasion demanded, i. e., whenever it could be done without waste of still serviceable old-style type.

At the present writing there are 46 stations equipped with presses of sufficient size for printing maps DD, 32 stations with small presses for printing maps CM, and 9 stations with 5 by 8 inch Pearl presses for printing forecast cards and other small matter.

LIBRARY.

During the year 935 books and pamphlets were added to the library, as compared with 1,167 additions last year, bringing the strength of the collection up to about 35,000. The apparent decrease in the number of volumes added during the year is due to the fact that many unbound annual publications formerly accessioned separately and included in the count of volumes added to the library are now treated as periodicals and not counted as separate accessions.

Special work carried out by the library during the year includes the preparation, at the request of Mr. Melvil Dewey, of a scheme of classification for meteorology to be used in connection with his decimal classification; also the compilation of a brief bibliography on weather forecasting for use in the forthcoming forecasting manual.

The number of promotion-examination papers rated during the fiscal year was 80, of which 64, or 80 per cent, attained passing grades.

SEISMOLOGY.

It is generally recognized that the systematic collection and arrangement for convenient reference of earthquake data serve several useful purposes. As the data are accumulated and earthquake regions more minutely mapped the engineer is correspondingly able to distinguish with greater certainty between safe and dangerous localities for bridges, dams, aqueducts, or any other important structures. A knowledge of the magnitude, rapidity, and other peculiarities of earth movements is of especial value in the designing of structures of whatever kind to be erected in earthquake regions. Finally, detailed data concerning earthquake motions serve a very valuable purpose in the science of geophysics.

To further these important studies as much as possible, the Weather Bureau began on December 1, 1914, to collect noninstrumental reports of earthquakes from all its regular stations, nearly 200 in number, and also from nearly all its 4,500 cooperative observers. These data are published month by month in the Weather Review.

In addition, the Bureau operates two seismographs—a Marvin vertical pendulum seismograph, giving both horizontal components, at Washington, D. C., and a two-pendulum Bosch-Omori instrument at Northfield, Vt. The Washington records were resumed in October, 1914, and those of Northfield, Vt., began in December, 1914.

Beginning with January 1, 1915, the Bureau has also collected and published as far as possible instrumental records of earthquakes obtained at—

Sitka, Alaska, United States Coast and Geodetic Survey.
Tucson, Ariz., United States Coast and Geodetic Survey.
Honolulu, Hawaii, United States Coast and Geodetic Survey.
Cheltenham, Md., United States Coast and Geodetic Survey.
Porto Rico, United States Coast and Geodetic Survey.
Point Loma, Cal., Raja Yoga Academy.
Denver, Colo., Sacred Heart College.
Georgetown, D. C., Georgetown University.
Lawrence, Kans., University of Kansas.
Cambridge, Mass., Harvard University.
St. Louis, Mo., St. Louis University.
Buffalo, N. Y., Canisius College.
Fordham, N. Y., Fordham University.
Balboa Heights, Panama Canal Zone.
Ottawa, Canada, Dominion Observatory.
Toronto, Canada, Dominion Meteorological Service.
Victoria, British Columbia, Dominion Meteorological Service.

AEROLOGICAL INVESTIGATIONS.

Observations of the diurnal convective system have heretofore been made by means of kites and have necessarily been limited to heights of 3 to 3.5 kilometers. It seemed desirable to have a 24-hour

series of observations to greater altitudes. This was accomplished by means of sounding balloons on July 17 and 18, 1914, at Fort Omaha, Nebr. The observations are not yet completely reduced or published.

Pyrheliometric observations at great altitudes were made in cooperation with the Smithsonian Institution during July, 1914, at Fort Omaha. Three automatically recording pyrheliometers, devised and calibrated by the Astrophysical Observatory of the Smithsonian Institution, were carried up by means of free air balloons. Balloon meteorographs were sent up within an hour or two of the time of the pyrheliometers' ascent. An excellent pyrheliometric record was obtained at a height of 25 kilometers. The complete data are not yet published, but a preliminary statement may be found in a recent report on Field Work of the Smithsonian Institution.

Kite flying from the deck of the United States Coast Guard cutter *Seneca* was undertaken during her May and June cruises into the ice fields of the North Atlantic; 12 observations by means of the kites were made during the May cruise and 16 during the June cruise. In addition to these observations, recording meteorological instruments were exposed on the deck of the *Seneca*, and sea-water temperatures were obtained. These observations will be reduced and published in the Monthly Weather Review.

In the transfer of the aerological work to the Middle West and to the central office at Washington, D. C., considerable progress has been made. It is expected that observations will begin during the fall of 1915.

METEORS.—Meteors often become luminous in the very highest regions of the earth's atmosphere of which we have any knowledge, and the careful and systematic study of meteoric appearances seems to be at the present time the only means we have of gaining information of this region of the atmosphere, which is almost beyond the reach of any other means of investigation. It is hoped that with the development of the aerological work, this line of study may also receive its appropriate attention.

SOLAR RADIATION INVESTIGATIONS.

The standardization of Callendar pyrheliometers effected at Mount Weather in 1913–14 has made possible the reduction to heat units of records obtained at Washington by means of one of these instruments between July, 1909, and April, 1912. These data have been utilized to determine for Washington the diurnal and the annual variations in the hourly and daily amounts of solar and sky radiation. The results are published in the Monthly Weather Review for March, 1915, and the daily totals and departures from the normal have since been published monthly in the Review.

At the end of September, 1914, observations of the intensity of solar and sky radiation were discontinued at Mount Weather, Va. Before the end of the following month most of the radiation apparatus had been transferred to Washington and installed in the College of History building, American University, which affords excellent exposures for both the Callendar and the Marvin pyrheliometers.

The pyrheliometric measurements now obtained at the American University are considered a continuation of similar measurements made at the central office of the Weather Bureau previous to May, 1912. At the university the elevation of the pyrheliometers above sea level is about 100 meters greater and the pollution of the atmosphere due to city conditions is considerably less than at the Weather Bureau. It may be partly on this account that radiation intensities in excess of any heretofore observed at Washington have been measured at the university during the past year. On December 26, 1914, with the sun at zenith distance 62.5°, an intensity of 1.48 calories per minute per square centimeter of normal surface was measured, while on February 28, 1915, with the sun at zenith distance 57.5°, the intensity was 1.50 calories.

During March and April, 1915, the stations at Madison, Wis., Lincoln, Nebr., and Santa Fe, N. Mex., were visited by the official in charge of solar-radiation investigations, and the Marvin pyrheliometers in use were recompared with a Smithsonian silver disk pyrheliometer. The radiation measurements obtained at these stations have since been tabulated in form for publication. Those for Santa Fe, which is 7,000 feet above sea level and in an arid region, show radiation intensities a few per cent in excess of the measurements obtained at other stations. On November 20, 1914, a maximum of 1.64 calories per minute per square centimeter of normal surface was measured with the sun at zenith distance 55°. On the same day with the sun at zenith distance 60° the intensity was 1.60 calories. These exceed any previous measurements obtained at Santa Fe. Likewise, at Madison, Wis., the monthly maxima from November, 1914, to March, 1915, exceed the maxima for corresponding months since the fall and winter of 1911–12, and the midday intensity of 1.50 calories obtained at Mount Weather on September 28, 1914, was the highest ever measured at that station. We are therefore led to the conclusion that unusually clear skies were experienced in the United States during the fall and winter of 1914–15, although in some districts the cloudiness was above normal.

The official in charge of solar radiation investigations and an assistant spent most of the month of May, 1915, among the mountains of southwestern North Carolina, where special temperature investigations in the interest of horticulture are in progress. Measurements were made of the rate at which heat is radiated to the atmosphere from a blackened surface when located in a valley at the foot of a mountain slope, when on a mountain slope, and also when on a mountain peak. The results of these observations, when fully discussed, will be published in the Monthly Weather Review or elsewhere.

At the end of June, 1915, the Marvin pyrheliometer in use at Lincoln, Nebr., was moved from the Weather Bureau office, in the business section of the city, to the experiment station building on the State University farm, just outside the city limits. A Callendar pyrheliometer was also installed on the roof of the same building, at an elevation of 56 feet above ground and 1,340 feet above sea level. The radiation records will be utilized by the Nebraska experiment station in its investigations, as well as by the Weather Bureau in its climatological studies.

The Weather Bureau is now obtaining continuous records of the amount of solar and sky radiation received on a horizontal surface at Washington, D. C., Madison, Wis., and Lincoln, Nebr. At each of these stations, and also at Santa Fe, N. Mex., the intensity of direct solar radiation on a surface normal to the incident solar rays is measured at frequent intervals on clear days.

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