U. S. DEPARTMENT OF AGRICULTURE.

REPORT

OF THE

CHIEF OF THE WEATHER BUREAU

FOR

1911.

BY

WILLIS L. MOORE.

[From Annual Reports of the Department of Agriculture.]

WASHINGTON:
WEATHER BUREAU.
1911.

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

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REPORT OF THE CHIEF OF THE WEATHER BUREAU.

UNITED STATES DEPARTMENT OF AGRICULTURE,
CENTRAL OFFICE OF THE WEATHER BUREAU,
Washington, D. C., October 1, 1911.

SIR: I have the honor to submit a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1911.

WILLIS L. MOORE,
Chief of Weather Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

MOUNT WEATHER RESEARCH OBSERVATORY.

The work of the observatory has been carried on along practically the same lines as for the previous year; at this time it is chiefly concerned with the investigation of the upper air over the United States. The work under this head may be divided into three separate branches, as follows:

(1) Soundings of the upper air over Mount Weather, Va., by means of kites and captive balloons.

(2) Soundings of the air at great altitudes by means of free balloons carrying meteorological instruments. While all preliminary testing and the later computing in this branch of the work are carried on at Mount Weather, the actual ascensions are made in the West, since the proximity of Mount Weather to the Atlantic Ocean on the east makes it inadvisable to send up free balloons from that point. The immediate supervision of all of the work enumerated under headings 1 and 2 is assigned to Research Director Wm. R. Blair.

(3) Study of the temperature and pressure changes in the lower layers of the air by means of summit and base stations in the mountains of Colorado.

PROGRESS IN AERIAL INVESTIGATIONS.

Considering first the aerial work at Mount Weather, it may be remarked that four years of nearly continuous kite or balloon records have been secured and published. During the fiscal year just ended, 299 soundings were made by kites, and 69 by captive balloons. The average altitude attained by the kites was 2,929 meters (9,609 feet); by captive balloons, 2,150 meters (7,054 feet) above sea level. Mount Weather itself is 525 meters (1,725 feet) above sea level. The number of kite flights in which an altitude of a mile above the mountain top (2,134 meters above sea level) was reached during the year was 250; two miles, 85. In but 10 flights was an altitude of three miles

reached or exceeded. The mechanical equipment used in kite flying has been brought to a high state of perfection as evidenced by the few "breakaways" of the kites during the year, but a kite meteorograph satisfactory in all respects remains to be constructed.

The classification and compilation of the Mount Weather kite and balloon data necessary in order to study the information secured under different weather conditions have been a part of the office work during the year, and a summary of the mean results for three years has been prepared and is now in the hands of the printer. It will appear as Part 2, Vol. IV, of the Mount Weather Bulletin.

A most important piece of work was accomplished by the Mount Weather Observatory during the year in the completion of two sounding balloon campaigns, the first at Huron, S. Dak., and the second at Fort Omaha, Nebr. Some account of the earlier work in this direction was made in my last annual report. In order to present the subject intelligently, I shall repeat some of the facts given in previous reports.

The use of small free balloons to carry meteorological instruments into the upper regions of the atmosphere dates from 1893, nearly twenty years ago, when Messrs. Hermite and Besançon in France sent up varnished paper balloons carrying registering instruments which brought back a record of the meteorological conditions encountered in the ascension. To Assman of Germany, however, is due the substitution of small rubber balloons in these ascents. The expansion of the confined gas at great altitudes bursts the balloon, the landing of the instrument being effected by means of a light parachute with which the balloon is covered.

The first series of sounding balloon ascents in the United States was made at St. Louis, Mo., in the years 1904 to 1907, inclusive, under the direction of Prof. A. Lawrence Rotch, of Blue Hill Observatory. Professor Rotch conducted 77 ascensions, the instruments being recovered in all but five cases. Thirty-seven of the ascensions reached an altitude of 10,000 meters (6 miles) or greater. In the series by Professor Rotch heights exceeding ten miles (16 kilometers) were attained five times. The Mount Weather Observatory has sent up 91 sounding balloons, of which number 81 were recovered. Heights exceeding ten miles were attained in 37 cases, the greatest height attained being 18.9 miles at Huron, S. Dak., on September 1, 1910.

The exploration of the atmosphere by means of sounding balloons has become an international work, and is carried on through an international commission of which Prof. H. Hergesell, of Strassburg, is president. Through this commission are collected and published the results of aerial observations made quite generally at appointed times by all meteorological services in the northern hemisphere. The most important single result that has come from the observations is the discovery of a region in the atmosphere, about seven miles above the earth's surface, where the fall in temperature with increasing altitude ceases. On the contrary, there may be a slight rise in temperature on entrance to this region. Although various names have been assigned to this region, none fully describes its characteristics. In this report it will be referred to as the "upper inversion." Inversions of temperature are frequently found in the atmosphere next to the earth, but they are generally small in amount and fleeting in character. The upper inversion, however, appears to be a world-wide phenomenon. It was discovered in Northern Europe, and its presence has since been

established in the United States, within the Arctic Circle, north of Europe, over tropical Africa and the Indian Ocean, and in Java.

The matter which follows is largely taken from a preliminary report on the data secured by sounding balloon ascensions in the United States. The full report will be published in the Mount Weather Bulletin, Vol. IV, probably in part 3, which will be sent to press in August, 1911. The statements refer to the most obvious facts ascertained by the balloon ascensions.

The original plan of sounding balloon ascensions in this country contemplated simultaneous ascents from two points on an east and west line. Notwithstanding the great area of the United States, regions adapted to the work are remarkably few, outside of the Western Plains and the Central Mississippi Valley. Fort Omaha, Nebr., was selected as the western station largely because of the presence there of a detachment of the United States Signal Corps which maintains a hydrogen gas plant. The thanks of the Bureau are due to Gen. James Allen, Chief Signal Officer, and the local officials at Fort Omaha, for many courtesies shown while operations were conducted at that point. Indianapolis, Ind., was selected as the eastern station. The board of public parks of that city kindly placed at our disposal ground in the park system on which to conduct the ascensions. For various reasons the number of ascensions at this place was less than at Fort Omaha, but all of the balloon meteorographs sent up were eventually found and returned to Mount Weather.

The second and fourth series of ascensions were made at Fort Omaha, Nebr. In the second Omaha series the balloons used had been on hand about six months, and the rubber had so deteriorated during that time that heights much above 6,000 meters (3.7 miles) were not attained.

The third series was made at Huron, S. Dak. The advantages of the latter station lie in its geographic position being farther north and thus more directly in the path of cyclonic and anticyclonic areas. A successful series of ascensions was made from the State Fair Grounds at Huron, 24 of the 26 instruments sent up being recovered.

During the fourth and last series of ascensions, at Fort Omaha, from February 8 to March 4, 1911, inclusive, 25 meteorographs were sent up, of which 22 were found and returned. This was also an excellent series, but unfortunately no well marked cyclonic areas passed over Fort Omaha during the three weeks the party was there.

Naturally the first thought in connection with the upper inversion is its relation to terrestrial weather conditions. Thus far ideas on the subject are quite hazy, but certain facts have been established, as follows: The lowest temperatures of the upper inversion are found in equatorial regions and the highest in the middle latitudes. In other words, temperature increases with increase of latitude, contrary to the rule which prevails on the earth's surface. In tropical Africa, Berson of the German Expedition found a temperature of −83.9° C. (−119° F.) at an altitude of 19 kilometers (11.8 miles).* At the same elevation in the United States the temperatures range between −55° and −60° C. (−67° to −76° F.). The discovery of the low temperatures aloft over the equator serves to increase, rather than diminish, the complexities involved in the accepted theories of the general cir-

*Later ascensions made at Java, Batavia, confirm the existence of low temperatures over equatorial regions. See van Bemmelin in Met. Zeit., May, 1911.

culation of the atmosphere. Another fact of great interest in connection with the upper inversion is that its temperature, while practically constant from season to season, varies greatly from place to place and from day to day. In the United States the mean of fifty ascensions made under the direction of the Mount Weather Observatory, all of which entered the region, gives for the lower limit of the upper inversion a temperature of −52.1° C. (−61.8° F.) regardless of season. The mean temperature of the lower limit of the upper inversion as deduced from the ascensions made under the direction of Professor Rotch at St. Louis, Mo., for all seasons, is −56.0° C. (−68.8° F.). The lower temperatures registered over St. Louis may be due in part to the latitude effect. The mean temperature of the upper inversion in Europe is not far from −55° C. (−67° F.).

It is said that in Europe the beginning of the upper inversion is found at a less altitude over cyclonic than over anticyclonic areas; also that it is higher in summer than in winter. In this country the lower limit of the upper inversion does not appear to be at a less altitude in cyclonic than in anticyclonic areas, although the evidence is not absolutely conclusive either way. In the Huron series the upper inversion was reached at an altitude as low as 9,328 meters (5.8 miles) on the front of an anticyclone. It was also reached at the low elevation of 9,712 meters (6 miles) in the transition region between a cyclone and an anticyclone, and at an altitude of 9,372 meters (5.8 miles) in a cyclone, while on other occasions in cyclones it has been reached at altitudes ranging from 10,000 to 14,000 meters (6.0 to 8.7 miles). The greatest altitude at which it was encountered, 14,983 meters (9.3 miles) on September 28, 1909, was not in an anticyclone, but in the transition region between a northern cyclone and a southern anticyclone.

In the United States the seasonal distribution of the ascensions has not been so good as might be wished. If the year be divided into two portions, the warmer half, or from April to October, inclusive, and the colder half, from November to March, inclusive, the following results are obtained for the average height of the lower limit of the upper inversion:

	Meters.
Rotch, warmer half, 19 ascensions	11,986
Weather Bureau, warmer half, 29 ascensions	11,808
Rotch, colder half, 5 ascensions	11,192
Weather Bureau, colder half, 21 ascensions	11,082

Thus it is seen that the lower limit of the upper inversion in the United States is found at a slightly less altitude in winter than in summer, agreeing in the main with European observations. The winter series of 21 ascensions was made from February 8 to March 4, inclusive. The summer series was made mostly in September and October.

By reason of the clear skies and relatively dry air of South Dakota and other western States, it was possible to make observations on the motions of the balloons after they had got well into the region of the upper inversion, and thus to obtain some interesting facts concerning the movement of the atmosphere in that region. It is apparent at the outset that the lower limit of the upper inversion is not sharply defined, but that the air motion in the explored part of that region, at

least, partakes of, and probably is controlled by, that of the lower levels of the atmosphere on which it rests. The observations of the wind velocity in the region of the upper inversion were not conclusive in any respect, other than that the movement was at times considerable, and again of rather low value, as on September 7, 1910, when, at Huron, S. Dak., winds at 3 to 11 kilometers altitude (1.9 to 6.9 miles) averaged about 16 meters per second (36 miles per hour). At the base of the upper inversion a wind of 18 meters per second (40 miles per hour) was encountered; at 1,000 meters (3,280 feet) higher, the wind had increased to 32.5 m. p. s. (73 miles per hour). It continued at a high velocity up to 17,227 meters (10.7 miles) and then suddenly fell off to 6.8 m. p. s. (15 miles per hour). On another occasion, September 4, 1910, the enormous velocity of 42.2 meters per second (95 miles per hour) was found at the base of the upper inversion, and a still higher velocity of 48.5 meters per second (108 miles per hour) was encountered somewhat higher. Above this, however, the speed of the wind diminished to zero. The ascension of the 4th was in a cyclonic area, while that of the 7th was on the front of a strong anticyclone moving toward Huron from the British Northwest.

Another interesting conclusion that may be drawn from the sounding balloon ascensions, and also from observations on high mountain stations, is that the gyratory motion of the air characteristic of cyclones at the surface and for some distance above, does not extend far upward*. The movement of the upper layers, say above 10,000 meters (about 6 miles), as indicated from the drift of balloons that ascended to that altitude, appears to be in three main directions, viz.: from west to east under normal conditions; from north to south, or northwest to southeast, when anticyclones dominate the weather; and from south to north, or southwest to northeast, when cyclones control the weather. Perhaps a better way of expressing the idea would be to say that the air currents are from some northerly direction on the east side of anticyclones, and from some southerly direction on the west side, and that under practically all other conditions the drift of the air in the very high levels is from west to east.

One of the interesting facts brought out in connection with ascensions in anticyclonic conditions is that the prevailing west winds of the middle latitudes, formerly believed to extend in an unbroken stratum from an altitude of about 5 kilometers (3.1 miles) to at least 16 kilometers (10 miles), are at times wholly suspended up to an altitude of 12 kilometers (7.5 miles). This fact is confirmed by observations made on Pike's Peak, Colo., as will be referred to later.

In 39 ascensions made under the direction of Professor Rotch, in which the altitude reached was six miles or over, eleven balloons landed almost due east of their starting point, twenty-two landed south-southeast of their starting point, and six landed north-northeast of their starting point. It is not always, nor in the majority of cases, possible to tell from surface conditions the direction the balloon will take. Sometimes, however, there is fair agreement between surface pressures and upper wind drift. In general there is a northerly component in the winds in front and on the east side of an anticyclone, although numerous exceptions to this rule have been noted. One of the most marked exceptions was on November 25, 1904, when a bal-

*Bigelow reached the same conclusion from a study of cloud observations. See report Chief of Weather Bureau, 1898–1899, p. 484.

loon launched at St. Louis, Mo., traveled almost due east to near Louisville, Ky., although the pressure distribution at the surface clearly indicated northerly winds, and winds from that direction actually prevailed at the ground. This balloon, which reached an altitude of 11,500 meters (7.1 miles), and the one sent up the following day, moved with the enormous average velocity of one hundred miles per hour. The second balloon, instead of moving toward the east, as did the one launched on the previous day, moved in a south-southeast direction and landed in western Tennessee. From this change in direction of the air currents it is evident that some temporary disturbance occurred in the atmosphere sufficient to modify greatly the eastward flow. What the disturbance was is not apparent from surface conditions. On the day that the balloon moved eastward there was a marked barometric depression over southern New England which had been stationary for about twenty-four hours. It may have been that the pressure in the higher levels over New England was falling on the day in question, and that the high eastward velocities encountered by the balloon were due to a pressure gradient that existed in the upper regions only. Hann showed more than twenty years ago that atmospheric pressure on mountain tops continues to fall for some time after the turn to rising pressure has set in over surrounding low levels.

The cause of the changes in the direction of the wind aloft is not always apparent from surface distribution of temperature and pressure. Primarily, the direction of the wind on the earth's surface is dependent on the temperature and pressure, the winds blowing from regions of low to regions of high temperature, and from regions of high to regions of low pressure. In the United States the strong winds of winter have regions of higher temperature on their right and in slightly higher latitudes. Unfortunately we are not able to study the temperature changes in the atmosphere as a whole, but only in a thin stratum next to the earth's surface. The upper winds in the United States are uniformly from the west, as has been fully demonstrated in the past. That these prevailing westerly winds are subject to important modifications is shown by the motion of the upper clouds and by the travel of sounding balloons.

Sounding balloon ascensions have added very much to our knowledge of the temperature of the atmosphere up to heights of 15,000 meters (9.3 miles) and even higher, but the number of ascensions to heights above 9.3 miles is as yet small.

The vertical distribution of temperature in different sections of the same anticyclone is well shown by the simultaneous ascensions at Omaha, Nebr., and Indianapolis, Ind., on October 5, 1909. The two stations were, roughly speaking, within the influence of a great anticyclone, Indianapolis being nearest the center and under the higher pressure. The pressure at Indianapolis being higher than that at Omaha, we should expect lower surface temperature, as was actually found. But the low temperature of the air column over Indianapolis extended up to 2 kilometers (1.2 miles) only, at which level the air-column temperatures at the two places were reversed, the western station becoming the colder at that level, and steadily remaining so up to 14 kilometers (8.7 miles). During an earlier ascension at the two stations, on September 30, 1909, the surface weather conditions were quite different from those of October 5, the two stations being separated by a shallow anticyclone, with Indianapolis on the eastern

edge and Omaha on the western edge. As in the first-named case, the eastern station was the colder up to about 3 kilometers (1.9 miles), but from that altitude up to about 12 kilometers (7.5 miles) the Omaha air column was the colder, the difference at the 12-kilometer level amounting to 16° C. (28.8° F.). Marked variations of the temperature at similar great altitudes have been recorded elsewhere, especially in England, where the temperature of the lower limit of the upper inversion has been found to differ on the same day as much as 20° C. (36° F.) at stations not more than 150 miles apart. The lowest temperature recorded in any of the Weather Bureau series of ascensions was −68.9° C. (−92° F.) at Huron, S. Dak., in September, 1910.

A study of observations at mountain stations in Colorado has shown that variations of temperature at the summit and at the base stations are nearly coincident in point of time, and are generally similarly directed, but that there are occasions when a fall in temperature sets in on the plains while the temperature on the mountain tops is still rising. In rare cases, also, the weather conditions on the mountain summits are controlled by causes that are not operative on the plains to the eastward. These studies have increased our knowledge of the effect of local topography in the warming and cooling of the air that is trapped between the mountain ranges. The important fact, revealed in connection with sounding balloon ascensions, that the prevailing eastward drift of the atmosphere is wholly suspended during the prevalence of strong anticyclones is confirmed by a study of the records of wind movement over the high stations of eastern Colorado, at Corona and Pike's Peak. There can be no doubt that the local circulation in strong anticyclones up to the level of Pike's Peak is controlled by the anticyclone, though this is seemingly controverted by observations on the movement of high clouds in other parts of the United States.

The cirrus level in the United States is about 15 kilometers (9.3 miles) above sea level. Clouds in this level have been observed to move directly across the central areas of anticyclones, from west to east, which movement would not be possible did an easterly current prevail at that level. The wind movement over Pike's Peak, Colo., 4,301 meters (14,111 feet) above sea level is from the northeast when an anticyclone occupies the Great Basin to the westward, thus indicating the local control of the wind circulation by anticyclones at the level of Pike's Peak.

At Mount Weather, Va., the kite flights thus far made show that practically all easterly winds, except under special conditions, are shallow winds; that is, they are generally less than a mile in vertical extent.

SOLAR RADIATION.

Between July 16 and October 10, 1910, Professor Kimball was engaged in a pyrheliometric survey of the region west of the Great Lakes and the Mississippi River, preliminary to the establishment of permanent observing stations. One of these, Madison, Wis., has been in operation since July 22, 1910, and others will be equipped as soon as apparatus already ordered is received. Pyrheliometric observations have been maintained throughout the year at Washington, D. C., and were resumed at Mount Weather in May.

The observations at the western stations showed radiation intensities in excess of the five-year averages for Washington, the excess ranging from 4 per cent in August, at Lincoln, Nebr., to 22 per cent in September, at Flagstaff, Ariz.

The most striking features of the year have been the high value of the radiation in February and March on the front of marked high barometric areas, and the low value during the protracted hot wave in May. At Madison, on February 23, and again on March 4, the radiation intensity with the sun shining through an air mass 1.5 (zenith distance of the sun 48 degrees) was 1.67 calories per square centimeter per minute, which is as high as any measurement obtained by the Smithsonian Institution on Mount Wilson during the summers of 1905 and 1906. At Washington the corresponding maximum intensity during this period was 1.47 calories, or 12 per cent less than at Madison.

During the hot wave of May, 1911, the maximum intensity of solar radiation measured at Mount Weather, with the sun at zenith distance of 48 degrees, was 1.20 calories per square centimeter per minute, and the average was little over 1.00 calory.

Measurements of the polarization of sky light, as well as other considerations, indicate that during protracted hot periods a very considerable percentage of the heat reaching the lower layers of the atmosphere is received diffusely from the sky. A Callendar recording pyrheliometer, capable of measuring the heat thus received, has been in continuous operation at Washington throughout the year; but quantitative results can not be given until this instrument has been carefully compared with a Marvin pyrheliometer, which will be done as soon as a new Callendar instrument provided with an improved form of recorder is received.

In response to the request of certain European investigators, a series of special observations on the positions of the neutral points of Arago and Babinet was made by Professor Kimball while on field duty. These are now being continued at Mount Weather in connection with the measurements of the percentage of polarization of skylight, made as in previous years.

The five-year averages of solar radiation intensities for Washington were published in the Bulletin of the Mount Weather Observatory, Vol. 3, part 2. In response to a special request, a resumé of that part of the above paper which treats of sky polarization, together with a summary of the polarization observations obtained while on field duty, was prepared by Professor Kimball for publication in the Journal of the Franklin Institute for April, 1911.

The constants to equation 20, Bulletin of the Mount Weather Observatory, Vol. 1, part 4, are being recomputed from data recently furnished by the Smithsonian Institution. Professor Humphrey's recent computation of the distribution of aqueous vapor in the atmosphere when the sky is cloudless will also be utilized. New tables for facilitating solar constant computations will be prepared from this revised equation. A copy of these tables has already been requested by the Argentina Meteorological Office.

It is believed that accurate determination of the intensity of direct solar radiation, of the quantity of heat received diffusely from the whole sky, and of the rate at which heat is lost at night, will not only be of value to climatologists generally, but will also be utilized by the weather forecaster. Especially urgent is the demand from biologists for accurate data relative to the quantity of heat received from the

whole sky. The University of Wisconsin is now furnishing data of this character for use in connection with certain biological studies.

MOUNT WEATHER BULLETIN.

A full discussion of the upper-air observations made at Mount Weather and elsewhere, as well as of the progress made in other special lines of scientific work, will be found in the successive issues of the Bulletin of the Mount Weather Observatory, which, it may be remembered, is devoted to the results obtained from aerial investigations as well as from other special researches into obscure laws of atmospheric phenomena bearing on the physics and mechanics of the whole atmosphere. Although this publication is mostly filled by the results contributed by the staff of the observatory, yet, when space allows it, contributions of fundamental importance presented by other meteorologists are included in the Bulletin.

The completed Volume II, with its index, was issued in July, 1910, and the completed Volume III, with its index, in July, 1911. The second part of Volume IV was sent to the printer in June of the present year.

FORECASTS AND WARNINGS.

The work of forecasting daily weather and temperature changes, storms, cold and warm waves, and frosts—the primary duty of the Weather Bureau—received the careful attention of the corps of forecasters throughout the year. No important meteorological change occurred without notice having been given well in advance.

Storm warnings to Lake, seacoast, and West Indian stations, and frost warnings for the sugar, trucking, tobacco, fruit, and cranberry regions were issued whenever conditions justified These warnings were successful. Particular attention was given to the hurricanes of September and October, 1910, and a number of testimonials commending the work of the Bureau in connection therewith were received. The warnings of the approach of cold waves resulted in a saving of growing crops and prevented injury to many shipments of perishable goods and to farm stock. Daily forecasts of probable wind and weather conditions off the Atlantic coast, eastward to the Grand Banks, were issued for the guidance of transatlantic steamships.

HURRICANES OF THE YEAR.

West Indian Hurricane of September, 1910.—This storm was first detected near San Juan, P. R., on September 6. It moved in a west-northwest direction, and by the morning of September 14 had reached the Texas coast near the mouth of the Rio Grande. Warnings were issued regularly until the storm disappeared. No loss of life and no wrecks occurred, nor was much damage done except on the north coast east of San Juan. The following editorial from the New Orleans Daily Picayune of September 15, 1910, has reference to this storm:

> Notwithstanding the threatening weather which prevailed over southern Louisiana Tuesday, no damage was experienced, as the storm passed southward some distance out in the Gulf. However, sugar and rice planters were greatly

alarmed. A severe wind storm at this season of the year would lodge the cane and would result in great injury to the rice crop, because few of the rice planters are prepared to flood their rice fields to such an extent as would prevent great damage from high winds. The excellent advices issued from day to day by the United States Weather Bureau in connection with this storm from the date of the inception has been in keeping with its past record. Tuesday morning, long before the storm was being felt at any coast station, shipping, commercial, and agricultural interests along the Gulf coast were advised that the storm was some distance out in the Gulf, southeast of the Texas coast, and was moving in a northwesterly direction toward the mouth of the Rio Grande River. Yesterday morning the storm was moving inland, with its center near the mouth of the Rio Grande and high winds and high tides had occurred along the Texas coast, as though conditions had been made to fit the Weather Bureau's warnings. The value of a service which can foretell where such storms will strike the coast, as was done in this case, cannot be estimated.

West Indian Hurricane of October, 1910.—Attempts made in former years to get reports by wireless from vessels plying in the Gulf of Mexico and the Caribbean Sea met with small success, owing to the small range of the transmitting vessels. This past year, however, a concerted effort was again made to secure these reports, this time with gratifying results. A number of valuable reports were received from vessels in the region of tropical storms, that from the United Fruit Company's steamship *Abangarez*, latitude 14° 20′ N., and longitude 81° 51′ W., received on the evening of October 12, being particularly helpful in locating the most notable hurricane of the season, which struck Key West, Fla., on the afternoon of the 17th. Although the pressure had been below normal for several days previously, this wireless report was the first definite information the Weather Bureau had of the severe storm in the Caribbean. In conjunction with the reports from the land stations, it enabled the forecaster to locate the center of the disturbance with a degree of accuracy which could not have been done through the use of observations made at land stations alone. By the morning of the 13th, the hurricane center was about 200 miles south-southwest of Havana, Cuba, apparently moving northwestward. The storm passed to the westward of Havana on the afternoon of the 14th and over Key West on the afternoon of the 17th. It then moved in a northerly direction to southern Georgia, where it took a course more to the east, and passed off the Atlantic coast near Cape Hatteras on the 20th. During the progress of this storm, timely advices regarding its location, intensity, and probable direction of movement were disseminated by every available means, including wireless, to interests liable to be affected by winds and tides. The following are among the testimonials received as to the value of the service rendered by the Bureau in its advance notices of this storm:

From C. W. Jungen, Manager of the Atlantic Steamship Lines of the Southern Pacific Company:

> I beg to express to you the appreciation of the management of this company for the valuable service rendered by the Weather Bureau during the tropical storm in the Gulf of Mexico and the Atlantic Ocean on or about the 18th to 19th instant, which overtook several of the company's ships in that vicinity. These bulletins were of great assistance to the masters of our ships in preserving the company's property and preventing the loss of life at sea.

From Senator Duncan U. Fletcher, of Florida:

> Permit me to say that I have always appreciated the value of the Weather Bureau to the country, and the service rendered before and during the recent hurricane has further emphasized its indispensability to Florida. * * * * *

From J. R. Brown, President of the Florida East Coast Railway, to the official in charge of the local Weather Bureau Office at Jacksonville, Fla.:

I am pleased to express our appreciation of the excellent service rendered by the Weather Bureau through your office during the past season, and the frequent advisory warnings sent down the line during the approach of the recent hurricane. The information thus furnished, I am advised, enabled us to get practically all our large fleet of floating equipment into hurricane harbors, thus making our loss in this respect comparatively light. We were also enabled to get our scattered forces of about 1,500 men into safe locations, so that there was no loss of life. By use of hurricane flags, rockets, and signal whistles we were enabled to warn the inhabitants of the keys, the fishing fleet in the locality of our work, as also two steamships anchored at Knights Key Harbor. Had we depended on the barometer we would not have been able to secure one-half of our floating plant before the storm was upon us.

From an editorial in the Tampa (Fla.) Morning News of October 20:

That there was no loss of life during the storm is largely due to the efficiency of the Weather Bureau in warning mariners.

From an editorial in the Vicksburg (Miss.) Herald of October 19:

There can be no question that a grave calamity has befallen Cuba and the Florida Peninsula as well. The one gratifying circumstance in it is the proof furnished of the infinite value of the Weather Bureau warnings, which gave ample time for all shipping to seek shelter in safe anchorage.

WEEKLY FORECASTS.

Forecasts of a general character for a week in advance, based on the atmospheric conditions exhibited by the daily chart of the Northern Hemisphere, have been issued on each Sunday throughout the year, except during the last two weeks of June, 1911, and special forecasts announcing important weather and temperature changes were made when occasion called for them. These forecasts have in the main proved reasonably successful, and the demand for them on the part of the press and others has steadily increased.

The weekly forecast issued on August 21, 1910, attracted special attention. In this forecast it was announced that a cool wave would pass over the country the latter part of the ensuing week. This cool wave gave the lowest temperatures of record for August in the Northern Rocky Mountain Region and the Plains States, and snow fell in Wyoming. It caused frosts in Idaho, Montana, Wyoming, Colorado, Nebraska, North Dakota, Minnesota, and Wisconsin, and light frosts at exposed places in New England and New York. The following favorable comments on the part of the press, subsequent to the issue of the forecast, indicate the widespread interest taken in its successful fulfillment:

Oklahoma (Okla.) Oklahoman:

The day was a great triumph for the weather man. The prophesy was on long time, as weather forecasts go. It was made last Sunday. It was accurate to the hour, and to distance, direction, and temperature; geographically correct—absolutely correct. The Sunday forecast said that the wave would start in the Northwestern States and sweep east across the country. For Oklahoma and vicinity Thursday was the day set for the cold spell, and the cold spell came. No one but the doubter was disappointed.

Louisville (Ky.) Courier-Journal:

The present remarkably cool weather for this season of the year was accurately forecast by the United States Weather Bureau one week in advance.

Springfield (Mo.) Republican:

The Weather Bureau at Washington predicted last Sunday that a cool wave would strike this vicinity about the middle of the week, didn't it? And it said that the cool wave would be preceded by very hot weather. * * * The long-distance forecasting department of the Washington Weather Bureau scored one of the biggest tallies in its history Thursday morning, when the cold wave came along.

Boston (Mass.) Transcript:

The official forecaster's reputation as a successful long-range forecaster is better than ever in this vicinity. His cool wave for the East, predicted a week ago, arrived last night on scheduled time, and the temperature consequently was "in the dumps" over night. There were no frosts, to be sure, but the drop in temperature was sufficient to justify the "cool wave" forecast.

Charlotte (N. C.) Observer:

The Observer on last Monday morning published a weather prediction issued from Washington, D. C., stating that chilly blasts would sweep across the country during the week. * * * This forecast was read by many, but most people straightway dismissed it from their minds. During the week, however, there followed such a remarkably accurate verification of the prediction made days before the cold started that the public sat up and took notice. * * * It only affords another striking illustration of the remarkable progress being made in the development of the weather science, and shows also what an excellent and highly valuable service is being given by the Government in this department. * * * The wave advanced true to form and reached the Atlantic by Saturday morning. It pays to listen to the weather man.

INTERNATIONAL WEATHER CHART.

A chart of the Northern Hemisphere is prepared each morning in the forecast map room of the Weather Bureau at Washington, based on reports from a number of stations selected to show, in a general way, the fluctuations of barometric pressure in the great centers of action. The most northerly stations from which reports are received are Nome, Tanana, and Eagle, in Alaska, at about latitude 65° N., while the most southerly is Manila, in the Philippine Archipelago, at approximately latitude 14° N.

Somewhat meager data from five Alaskan stations give a fair indication of barometric changes in that region, but when it is considered that the forecasts for a week in advance are based chiefly on the Alaskan reports, it would appear that a greater number of stations, not so widely separated, should be available to give a more complete survey of the atmospheric changes taking place in that area. Action has been taken looking to the establishment in the near future of a station on the Aleutian Islands at Dutch Harbor. Reports from this station will give valuable information concerning storms that pass from the eastern coast of Asia northeastward and finally reach the United States. At present, storms of this type cross the Pacific Ocean south of latitude 58° N. and strike the North American continent without warning or indication of their approach. With a station in operation at Dutch Harbor, few, if any, storms should reach the continent without their coming first being indicated by some of the Alaskan reports.

During the latter part of the past year reports were received regularly from Nemuro, Japan, and from Shanghai, China. These reports have proved of much value in accounting for the development of disturbances in our Northwest.

Summarized in a general way, a study of the international weather map furnishes indications of weather conditions in the United States several days in advance, somewhat as follows:

(1) Barometer rising and above normal over the Asiatic high area; barometer falling and below normal in the Bering Sea low area, and rising over the Azores and falling over Iceland, indicates a period of mild weather over the northern and eastern districts of the United States.

(2) Barometer falling and below normal over Bering Sea, and falling over the Azores and rising over Iceland, indicates a period of cool weather generally east of the Rocky Mountains.

(3) When the great continental high pressure area extends over west-central Europe and the British Isles it checks the movement of North Atlantic storms, and finally affects the rate of progression of high and low pressure areas over the United States. The usual rate of progression of high and low pressure areas over the United States is resumed five or six days after a return to normal conditions has set in over west-central Europe.

(4) In its normal distribution, atmospheric pressure is high over the eastern, and relatively low over the northern and northwestern portions of Europe. Under these conditions the progression of storms over the United States is normal. When, however, this arrangement of pressure is reversed or disturbed, abnormal storm movements or features will be observed.

(5) At times when the air masses up over western Asia and continental Europe the advance of the Atlantic storms is checked, low pressure prevails for several days over the British Isles, high pressure builds up over the Atlantic Ocean, and the eastward progress of high and low pressure areas over the United States is retarded. This retardation of highs and lows over the United States is not interrupted until about five or six days after normal pressure conditions are resumed over western Europe.

(6) A slight shifting to the westward of the summer North Atlantic high pressure area gives temperatures above the normal and generally dry weather over eastern portions of the United States. If the center of this high pressure area shifts to the westward, south of its usual position as regards latitude, the heat is general from the Gulf of Mexico to Canada. If, however, the center occupies a more northerly latitude in its westward position, the heat area is confined to the more northerly districts of the United States, while the South Atlantic districts receive the benefits of the easterly winds from the Ocean.

(7) When the Atlantic high pressure area occupies a position east of its normal location over the Atlantic Ocean, or exhibits pressure below normal, cool weather for the season, or at least variable temperature, is experienced over the eastern portions of the United States.

(8) As a general proposition, the North Atlantic high pressure area controls to a great degree not only the summer weather of the greater part of the United States, but also the course and character of the West Indian hurricanes.

FROST PROTECTION WORK.

Special attention was given during the year to warnings for the benefit of shippers and growers of perishable products. Forecasts were sent out daily from a number of our larger stations, giving the

probable temperatures likely to be encountered by perishable goods shipped in any direction.

Substations were established in the cranberry marshes of Massachusetts, in the citrus fruit districts of Florida, and in some of the orchard districts of Washington, Oregon, Idaho, Utah, Colorado, and California. During the frost season special reports are sent from these substations to the forecast center, where they are used in the preparation of a special forecast in the afternoon or early evening, supplementing the regular morning forecast. By this means, the growers are enabled to take such precautionary measures as are available to protect their crops. In Washington, Oregon, Idaho, Utah, Florida, and California, the fruit growers smudge and fire when necessary, while in the cranberry regions the cranberry growers flood their bogs to prevent injury. In this line of work it has been the policy to furnish the individual with information particularly applicable to his orchard, rather than to have him depend upon a general forecast that would apply to a large section, but could not accurately cover the section in detail. Effort has also been made to encourage the growers to organize and employ protective measures in saving their crops from frosts and freezes. Thus far, the work has been successful beyond expectation. One example of the fruits of this work is instanced by a letter from Mr. Thomas F. Mahoney, Secretary of the Chamber of Commerce of Grand Junction, which was published in the Denver News of May 18, 1911. In this letter it is claimed that the prompt action taken by the orchardists of Colorado's western slope on the receipt of the warnings of a severe freeze last spring resulted in the saving of two and one-half million dollars.

The following is from a letter written by the secretary of the Yakima Commercial Club, North Yakima, Wash., regarding the work of the past year in that section:

> The timely warnings of danger given did much in the way of prevention of loss from frost, and it is the general belief that, with better preparation on the part of the fruit growers another season, still greater benefits may be derived from the frost service of the Bureau.

The president of the Provo Commercial Club, Provo, Utah, also testifies to the work of the Bureau in that vicinity during the frost season of 1911, as follows:

> Now that the frost period for this season is over and while the matter is still fresh in our minds, we wish to express to you our appreciation of your efforts in our behalf. There is no doubt but what your Weather Bureau has been of service to the fruit grower this season, and, taken together with the keen personal interest you yourself have shown in the all-important question of "Saving the Fruit," we are convinced that with the further aid of the Agricultural Department this question will be solved.

RIVER AND FLOOD DIVISION.

RIVER AND FLOOD SERVICE.

Two new river districts were created during the year, with headquarters at Indianapolis, Ind., and Iola, Kans., making a total of 56 river districts in operation at the end of the year. The new districts were established for the purpose of securing increased efficiency of service, and are maintained with little increased cost of operation, as both previously formed portions of other districts. The Indianapolis

district comprises the watershed of the Wabash River above the mouth of and including the White River, formerly a portion of the Cairo district. The Iola district comprises that portion of the watershed of the Neosho River from the headwaters to Neosho Rapids, Kans., formerly a portion of the Fort Smith district.

Nine new river stations were established during the year, and nine were discontinued, excluding those at Dayton, Ohio, and Fort Wayne, Ind., where regular Weather Bureau stations were opened, with the river work as a portion of their duties. Four rainfall stations were also discontinued.

At the end of the year river observations taken at regular Weather Bureau, paid, and cooperative stations made a total of 601 stations from which reports are available for the benefit of those interested in the rivers of the country.

No automatic river gages were installed during the year, but substantial inclined concrete gages were installed at Portsmouth, Ohio, and Mount Vernon, Ind.

Owing to a large deficiency in the precipitation of the year over a considerable portion of the country, there was an absence of great floods, except in California, where, during February and March, heavy winter snows and rains combined to cause floods, with resultant damage, estimated at $1,750,000. In July and again in October the smaller tributaries of the Ohio River were in flood as a result of heavy local rains. The damage to crops and other interests amounted to about $5,500,000.

By informal agreement with the Forest Service of the Department of Agriculture and the United States Reclamation Service of the Interior Department, the Weather Bureau was designated to ascertain and publish in the Monthly Weather Review the losses by floods in the United States. A summary of this character indicates that the losses during the year were about $7,700,000, of which more than three-fourths fell upon the farmers. The value of property saved through the warnings of the Weather Bureau was estimated at $1,047,000.

The warnings issued for the floods were of value. The great disproportion between the losses and the value of property saved is due to the fact that three-fourths of the former were on crops that warnings could not have saved.

From present indications the new work contemplated during the coming year will not be extensive. On July 1, 1911, river service will be extended over the Neuse River of North Carolina, and river stations opened at Neuse and Smithfield, N. C. The station at Edisto, S. C., will be reopened, and a new station established at a suitable location on the Combahee River for the benefit of the rice planters. A few additional stations will probably be needed along the lower Arkansas River and its larger tributaries. In the extreme West it is proposed to divide the district of California, establishing a new district for the San Joaquin River, with headquarters at Fresno, Cal. This river is now under the supervision of the local office at Sacramento, and the change will result in more prompt service in time of flood. It is also proposed to establish, if possible, a new district at Los Angeles, Cal., for the purpose of issuing flood warnings for the smaller streams of that section.

Steady progress has been made in the preparation of forecast schemes for the Ohio River and its larger tributaries. Schemes have been completed for the Cumberland and Tennessee Rivers, and one for the

Wabash River is well under way. This will complete the scheme for the entire Ohio River watershed, except that portion of the main stream between Mount Vernon, Ind., and the mouth, which it is hoped also to finish within a few months. Considerable work has also been done on schemes for the Savannah and Santee River systems.

MOUNTAIN SNOWFALL WORK.

During the last two years the Weather Bureau has made systematic measurements of the amount of snowfall in the mountain regions of the West for the purpose of determining as accurately as possible the amount of water available for agricultural and commercial interests during the coming spring and summer seasons. It is hardly necessary to comment on the importance of this work, which thus far has been largely experimental on account of uncertainties as to the instrumental equipment required and the proper method of determining the water equivalent of the snowfall. The snow bins and snow platforms installed some time ago have not proved entirely satisfactory. Professor Marvin, of the Instrument Division, has been engaged in the work of devising improvements, and it is hoped that the snowfall stations can be supplied with better apparatus within a year or two. In the meantime no new stations will be opened. During the year 61 stations were closed, experience having demonstrated that they were no longer of importance. At the end of the year there were 281 mountain snowfall stations in operation.

In connection with the study of snowfall and its consequent runoff, a systematic snow survey was begun in the watershed of Maple Creek, near Springville, Utah. While the work was of an experimental nature, it has an immediate effect on the owners of 227 tracts of land that are irrigated by the melted snow waters from the Maple Creek watershed, and it is expected that the experience obtained will be valuable in connection with the future study of the general problem. Thus far the comparatively small outlay in experimental work has been well expended. A report of the work carried on during the spring of 1911 was prepared by Messrs. A. H. Thiessen and J. C. Alter of the Local Office of the Weather Bureau at Salt Lake City, Utah, and published in the Monthly Weather Review for April, 1911. About 2,000 soundings and 277 measurements of the depth and density of the snow were made with the density apparatus devised by Professor Marvin. The final results showed an average snow depth of 36 inches, with an average water equivalent of 11.5 inches, or 32 per cent, making 3,833 acre-feet of water, or enough to spread a layer of water 14 inches in depth over all the land irrigated by the stream. This is the first attempt at a definite measure of the water equivalent of accumulated snowfall, the great value of which to irrigation farmers and those interested in water-power is apparent. It is thought that with two years' more work in the Maple Creek watershed, sufficient observations will have been obtained to permit of accurate forecasts of water supply from the winter snowfall. The system can also be extended to other and larger projects, and the work will be limited only by the amount of funds available for the purpose. The report on the preliminary campaign in the Maple Creek watershed has brought many expressions of commendation from farmers and hydraulic engineers.

EFFECTS OF FORESTS ON CLIMATE AND STREAMFLOW.

As stated in my last report, the Weather Bureau and the Forest Service, with the permission of the Secretary of Agriculture, are cooperating in an exhaustive study of the entire question of forest effects upon climate and streamflow. It is believed that the data to be secured will be of such a character as to shed valuable light upon the subject. The Experiment Station at Wagon Wheel Gap, Colo., established for the purpose of this investigation, is now on a firm basis, and a complete series of observations has been made during the last eight months. Cooperative meteorological stations are also maintained in the Coconino National Forest in Arizona, and in the Fremont National Forest in Colorado, data from which will be available for study and comparison in connection with the records at Wagon Wheel Gap. However, it should be well understood that no results obtained in this semi-arid region would be of any value as a criterion for determining problems in connection with run-off that obtain in the humid regions of the East. It is hoped that in course of time an experimental area may be secured and the necessary plant installed in both the Allegheny and White Mountain regions.

DIVISION OF OBSERVATIONS AND REPORTS.

The new "Division of Observations and Reports," formed during the year, has supervision of the collection and distribution of telegraphic meteorological reports, the distribution of forecasts and warnings, the issue of station maps and bulletins, and the marine work of the Bureau.

At the close of the year there were in operation 197 regular observing stations. The station at Jupiter, Fla., was discontinued during the year and one established at Miami, Fla., in its place. New stations were also established at Fort Wayne, Ind., and Dayton, Ohio. Of these regular stations 164 take two observations daily, at 8 a. m. and 8 p. m.; 25 take one observation daily at 8 a. m., and 8 take one observation daily at 8 p. m., 75th meridian time. These observations are telegraphed to Washington and over circuits to other stations for use in making the daily maps for forecast purposes and the daily weather maps and commercial maps for issue to the public.

The United States is divided into six forecast districts, with centers at Washington, D. C., Chicago, Denver, Portland, Oreg., San Francisco, and New Orleans, at which places the forecasts are made and telegraphed to distributing centers. From these points they are furnished to the public by telegraph, telephone, and postal card.

SPECIAL METEOROLOGICAL STATIONS.

There are 50 special meteorological stations in operation. Of these, 19 are for use in the general forecast work of the service and in making special frost predictions for the orchards of Oregon, Washington, Utah, Idaho, and Colorado; 8 for use in frost predictions for the cranberry interests of Massachusetts, Wisconsin, and New Jersey; 9 for use in the special predictions for the vineyard and citrus fruit interests of California and Florida; 8 in the West Indies rendering reports from

July 1 to November 15 for use in the special hurricane forecasts, and 6 in Alaska for use in the general forecast work of the service.

Under the Portland, Oreg., center, four important fruit districts have been grouped; at Lewiston, Idaho, Boise, Idaho, North Yakima, Wash., and in the Rogue River Valley of Oregon. In the Lewiston district the observing stations are located in the Lewiston orchard district and across the Snake River at Clarkston, Wash., each station being the center of its respective district of orchard bench land. The Boise district has an observer at Meridian, who cooperates with the Boise station. In addition to the special observer at North Yakima, a regular trained observer was put in charge for the fruit season, and arrangements were made to receive reports from cooperating stations at Wapato, Zillah, Sunnyside, Moxee, and Natchez. In the Rogue River Valley a special station was established at Medford under the charge of a trained fruit and orchard superintendent; and, in addition to the old observing stations at Siskiyou and Marshfield, cooperating stations were located at Grants Pass, Ashland, and Jacksonville.

The Salt Lake City office is in charge of the frost-warning service around Provo, Utah, while the fruit region of the Grand River Valley of Colorado receives warnings from Grand Junction. In the citrus fruit region around Los Angeles the observer at that station is in charge of the frost warnings, with special observers at Pasadena, Redlands, Riverside, San Bernardino, and Santa Barbara. San Francisco sends warnings to the fruit interests of Northern California, with an observer reporting from Paso Robles.

In Florida, Jacksonville issues warnings for the fruit and vegetable industries, with special observers stationed at Bartow, Eustis, Titusville, and Gainesville. Arrangements are being made to investigate the fruit conditions of North Carolina.

Frost warnings are issued for the cranberry districts of Massachusetts, New Jersey, and Wisconsin, the most important cranberry-producing section being around Cape Cod, Mass. Arrangements were made during the season for more complete reports in that section by changing the station at New Wareham to the State bog at East Wareham, making the latter place the observation center. The instruments at South Carver were moved to a better location, and new stations were established at Halifax and Marstons Mills. Observations have been continued with good results in New Jersey. In Wisconsin the old station at Berlin was reestablished and conditions improved for observation.

FORECAST DISTRIBUTION.

The appropriation for this branch of the service was inadequate to meet the many demands for daily forecasts and special warnings during the past year. While the decrease in the number of places receiving the warnings at Government expense was 60, there was an increase of more than 500,000 in the number of telephone subscribers to whom the forecast was delivered by free telephone distribution owing to the very favorable arrangements entered into between the Bureau and the various telephone and telegraph companies. By an arrangement between the Southern Bell Telephone and Telegraph Company and the Weather Bureau, which goes into effect on July 1, 1911, this distribution by free telephone will be materially increased during the next fiscal year.

At the close of the year the number of places receiving forecasts at Government expense was 2,120, while by free telephone distribution the forecasts were available to 4,251,347 addresses.

The following table shows in detail the distribution of daily forecasts and special warnings in the several States by the various means employed:

Distribution of daily forecasts and special warnings.

State.	At Government expense.			Without expense to Government by—				
	Forecasts and Special warnings.	Special warnings only.	Emergency warnings.	Mail.	Rural delivery.	Telephone.	Railroad train service.	Railroad telegraph.
Alabama	30	2	136	1,496	690	13,961	0	66
Arizona	5	2	0	191	0	7,399	0	0
Arkansas	21	10	102	932	979	25,233	0	14
California	99	47	0	1,037	2,680	98,212	0	0
Colorado	8	62	38	1,044	718	45,713	0	0
Connecticut	10	0	48	2,333	50	88,026	138	5
Delaware	8	1	16	152	296	4,865	0	27
District of Columbia	0	0	0	843	0	20,000	0	1
Florida	35	114	52	1,392	230	8,198	0	58
Georgia	33	32	293	1,839	1,002	34,318	0	149
Idaho	15	1	0	871	200	13,975	0	0
Illinois	114	6	408	3,547	2,498	372,779	0	17
Indiana	110	1	201	2,808	1,454	188,315	0	71
Iowa	144	7	335	2,727	4,472	121,770	25	0
Kansas	88	2	175	727	2,080	239,392	0	51
Kentucky	45	31	96	2,528	788	54,516	0	1
Louisiana	79	20	49	940	30	18,226	0	18
Maine	14	1	40	1,074	951	44,140	0	0
Maryland	18	4	46	1,984	571	28,950	0	76
Massachusetts	16	10	58	3,270	170	204,047	77	258
Michigan	68	4	316	5,419	600	225,433	206	387
Minnesota	74	3	171	1,944	3,885	159,599	0	13
Mississippi	47	10	59	1,552	1,041	26,166	0	6
Missouri	32	3	236	4,686	2,025	211,985	0	52
Montana	13	20	13	425	0	14,441	0	0
Nebraska	72	4	205	1,999	408	175,262	0	0
Nevada	6	0	0	84	0	646	0	0
New Hampshire	15	1	32	922	1,446	29,622	15	14
New Jersey	24	16	109	1,808	100	27,695	0	176
New Mexico	11	1	0	78	0	4,925	0	8
New York	118	49	346	7,491	1,794	258,826	197	176
North Carolina	74	15	163	1,624	2,096	27,819	0	0
North Dakota	24	0	93	292	1,659	20,919	0	0
Ohio	82	172	237	7,227	321	469,682	24	34
Oklahoma	32	2	16	637	591	6,624	0	130
Oregon	10	5	0	508	175	16,178	0	0
Pennsylvania	83	10	315	5,312	1,718	482,584	1	452
Rhode Island	2	0	11	759	0	1,400	13	18
South Carolina	29	9	105	1,040	576	10,679	0	38
South Dakota	56	9	70	840	115	52,235	0	0
Tennessee	48	5	284	1,850	1,055	37,909	0	3
Texas	78	54	227	1,663	1,188	168,406	0	63
Utah	6	24	0	324	661	12,025	0	0
Vermont	12	1	45	821	467	27,720	12	5
Virginia	53	8	84	1,578	1,393	39,314	101	72
Washington	20	3	0	1,072	1,091	3,560	0	0
West Virginia	26	8	53	968	0	38,320	0	17
Wisconsin	106	7	281	2,085	2,072	61,818	0	0
Wyoming	7	1	8	105	0	6,930	0	0
Total	2,120	797	5,512	86,948	46,336	4,251,347	809	2,376

STORM-WARNING DISPLAY STATIONS.

Fifteen storm-warning display stations were established at points on the sea and Lake coasts during the year, and six were discontinued. Arrangements have been made to begin the display of storm warnings at Seddon Island—Tampa, Fla., Section—as soon as a tower can be erected. As is usual, the display of warnings on the Lakes was dis-

continued for the winter on December 6, and resumed April 10. Inspection trips were made to 124 storm-warning stations.

The following statement gives the number of stations, arranged under district centers, receiving storm warnings:

District centers.	Paid Stations.	Cooperative Stations.	Weather Bureau Stations.	Naval Wireless Stations.
Alpena, Mich.	6	0	1	0
Atlantic City, N. J.	0	4	1	0
Baltimore, Md.	3	1	0	0
Block Island, R. I.	1	0	1	0
Boston, Mass.	24	7	2	4
Buffalo, N. Y.	12	1	1	0
Cape May, N. J.	1	0	0	0
Charleston, S. C.	5	1	1	0
Chicago, Ill.	25	2	1	1
Cleveland, Ohio.	10	0	1	0
Corpus Christi, Tex.	2	0	1	0
Detroit, Mich.	0	1	1	0
Duluth, Minn.	7	0	1	0
Eastport, Me.	0	1	1	0
Erie, Pa.	1	0	1	0
Escanaba, Mich.	2	0	1	0
Eureka, Cal.	0	1	1	1
Galveston, Tex.	4	4	1	0
Grand Haven, Mich. (a)	0	0	1	0
Grand Rapids, Mich. (a)	0	0	1	0
Green Bay, Wis. (a)	0	0	1	0
Houghton, Mich.	2	2	1	0
Jacksonville, Fla.	8	12	1	0
Key West, Fla.	0	2	2	1
Los Angeles, Cal.	1	3	0	0
Marquette, Mich.	1	0	1	0
Milwaukee, Wis.	9	0	1	0
Mobile, Ala.	4	4	1	0
Nantucket, Mass. (a)	0	0	1	0
New Haven, Conn.	2	0	1	0
New Orleans, La.	2	1	2	0
New York, N. Y.	5	4	1	2
Norfolk, Va.	6	4	4	1
Oswego, N. Y. (a)	0	0	1	0
Pensacola, Fla.	3	0	1	0
Philadelphia, Pa.	3	0	1	0
Port Huron, Mich.	3	1	1	0
Portland, Me.	3	2	1	0
Portland, Oreg.	9	3	7	0
Providence, R. I.	1	0	1	0
Rochester, N. Y. (a)	0	0	1	0
San Diego, Cal.	0	2	1	1
Sandusky, Ohio (a)	0	0	1	0
San Francisco, Cal.	2	6	4	3
San Juan, P. R.	0	0	0	2
Sault Ste. Marie, Mich.	5	0	1	0
Savannah, Ga.	4	1	1	0
Tampa, Fla.	3	8	1	0
Toledo, Ohio (a)	0	0	1	0
Wilmington, N. C.	3	2	1	0
Total.	182	80	61	16

(a) Not centers.

STATION MAPS AND BULLETINS.

The policy of discontinuing the station weather maps wherever the newspapers would publish the commercial maps, adopted in 1910, was continued during the past year, and has resulted in the maps being published at 74 places in 132 newspapers, having a total daily circulation of 2,898,000. At first there was some opposition to the commercial map, but this gradually subsided as the vast enlargement of the service thus rendered through the newspapers came to be recognized. A few comparisons of the distribution obtained through the press with that possible through the maps issued at the stations are sufficiently convincing on this point. New York issues daily 1,013 weather maps as compared to 191,000 commercial maps; Chicago, daily weather maps

1,171, commercial maps 507,449; Philadelphia, daily weather maps 375, commercial maps 140,000. While the publication of the commercial maps has been substituted at 54 stations, the daily weather maps are still printed at 58 stations, the total daily issue being 15,000.

Daily weather bulletins (Forms No. 1038) were published at nine stations, the daily issue being 467.

Glass weather maps are changed daily at 42 stations, having a total number of 53 maps. These maps are displayed at Boards of Trade, Cotton Exchanges, Maritime Exchanges, at the stations proper, in the Washington Terminal Railroad station, and in the Senate and the House of Representatives, in Washington, D. C.

MARINE WORK.

The field covered by this section of the Bureau's activities includes the meteorological work of the principal oceans of the world and of the Great Lakes of the United States, the supervision of the wireless telegraph weather service, and the work of the vessel-reporting service.

METEOROLOGICAL CHARTS.

The meteorological work consists in the collection, compilation, and study of ocean and Lake meteorological data, and the publication and distribution of the data thus obtained, by means of the marine meteorological charts of the Weather Bureau, which are distributed to mariners, maritime exchanges, and meteorological institutions throughout the world. The meteorological information collected in this manner is also furnished to the Hydrographic Office of the Navy Department, and forms the essential features of the pilot charts published and distributed by that office.

The publication of a series of monthly charts for the Indian Ocean and the Great Lakes will be completed with the issue for December, 1911, and with the others will constitute the first complete set of meteorological charts covering the principal oceans of the world and the Great Lakes of the United States.

The charts for the North Atlantic, North Pacific, and Indian oceans, and for the Great Lakes, are published monthly, and those for the South Atlantic and South Pacific oceans quarterly. They are mailed forty days in advance of the month or quarter for which the chart is an issue.

The North Atlantic charts contain on their face the normals of pressure and temperature; tables for reducing barometer observations for comparison with data on the charts; wind roses, with percentages of gales and calms for each 5-degree square of latitude and longitude; storm tracks of recent years; fog areas and percentages of days with fog; trade wind limits; sailing routes; magnetic variation lines; location of wireless telegraph stations; tables of equator crossings; a statement of the average conditions of wind and weather; storm-warning signals of the United States, Canada, Mexico, Great Britain, Ireland, Germany, Holland, France, and Portugal; and the United States submarine distinguishing and warning flags. On the reverse side appear as regular features articles on the temperatures of the air and the water surface, and charts of the currents of the North Atlantic and

North Pacific oceans. Special articles have been printed on West Indian Hurricanes, Waterspouts, Cyclones and Anticyclones, Weather Lore of the Sea, Fog and Fog Signals, and Ocean Currents.

The South Atlantic charts contain much the same general information as that appearing on the charts for the North Atlantic Ocean, slight modifications, such as the omission of fog areas and the addition of storm-warning signals for ports on the Indian coast, being the chief differing features. The same general similarity and minor differences are found in the charts for the North Pacific, South Pacific, and Indian oceans.

The fog areas and the percentage of days with fog, as now shown on the charts for the North Pacific and Indian oceans and the Great Lakes, have been pronounced particularly valuable features by those using the charts. Mr. H. C. Thompson, engineer in charge of the survey for a short line railway and steamship route to Europe, states that the fog data for the North Atlantic chart as revised by the Bureau have been an invaluable aid to his project. He has interested himself in an endeavor to secure fog data from Canadian lighthouses for incorporation in an article to be published on fog of the North Atlantic Ocean. The English Meteorological Office, on its chart of the North Atlantic, continues to make use of the fog data and shading published by the Weather Bureau.

A chart has been prepared, and will be published at an early date, showing the average direction and rate of movement of storm centers in each two and one-half degree square of latitude and longitude in West Indian and Gulf waters.

The charts for the Great Lakes were begun with the January number of this year. They contain on their face normals of pressure and temperature; barometer reduction tables; wind roses; storm tracks; fog areas and percentages of days with fog; arrows showing direction of lake currents; magnetic variation lines; location of wireless telegraph stations; a statement of the average conditions of wind and weather; percentages of days with rain, snow, fog, gales, and calms at lake stations; dates of opening and closing of ports on account of ice; wind barometer indications for the Great Lakes; Storm-warning signals of the United States, Great Britain, Ireland, and Canada; a table of verifying wind velocities at Weather Bureau stations; and the United States submarine distinguishing and warning flags. The reverse side presents monthly tables of wind velocities; seasonal tables of snow and ice; lists of lake wireless telegraph stations, with call letters for each; and lists of submarine signal-bell stations, with code.

As evidence of the general appreciation in which the charts are held, the following are quoted from letters received during the year:

From the American consul at Dundee, Scotland:

> I take this opportunity to say that recently the captain of one of the Clan liners, then in this port, called at this office on receiving a letter sending him a supply of these weather report forms and ocean charts, when he expressed his thanks to the American Government for the courtesy in supplying these charts, and desired to say how much they were appreciated by British shipmasters; at the same time speaking in terms of the highest commendation of the system adopted for collecting materials for keeping the charts fully up to date, to which he would give his cordial cooperation.

From Capt. T. W. Pickard, of the British S. S. *Ningpo:*

> I am of the opinion that your publications are of extreme value to seafarers generally, and I think that we should all cooperate with you in the good work.

MISCELLANEOUS PUBLICATIONS.

Additions have been made to the useful information contained in the calendars for the Atlantic and Pacific Oceans, and these have been distributed to all cooperating officials. The large chart, formerly issued, showing the Classification of Clouds, has been put in book form, making it more convenient for use and increasing its durability. It contains full descriptive matter and illustrative plates, with a view to aiding observers in the identification of the several cloud forms according to the International System of Classification. A new and enlarged edition of the Instructions to Marine Meteorological Observers, with a complete index, was issued during the year. The form used in reporting observations has been remodeled into a more light, compact, and convenient form. Its reduction in bulk will also effect a saving in postage.

COLLECTION OF METEOROLOGICAL DATA.

The weather reports from vessels are mailed to the Washington office by the observers, or are forwarded through the local offices of the Weather Bureau. In foreign ports they are usually forwarded through the American consular offices. The American consuls at 154 of the principal foreign ports have assisted the Bureau in the collection of marine meteorological data from vessels, and in the distribution of meteorological forms, charts, and pamphlets. During the year 2,416 cooperating observers forwarded 10,669 books of weather reports.

The Weather Bureau maintains marine centers at its principal seacoast and lake stations, and an official at the center visits vessels in the harbor for the purpose of comparing barometers, securing observers, and collecting marine meteorological observations. Officers and observers of cooperating vessels visit the offices of marine centers for information, comparison of instruments, and supplies of meteorological charts and forms. These offices are equipped with standard instruments, marine instrument shelters, text-books, and other accessories to this work. Assistants are assigned to special duty at New York, Boston, Philadelphia, and Seattle, in connection with this work. The official at Seattle has supervision of the meteorological work of all vessels entering Puget Sound.

The Bureau is indebted to the Weather Bureau of the Philippine Islands, and to the Hong Kong Observatory, for storm tracks of the western portion of the North Pacific Ocean; and to Professor Froc, of the Zi-ka-wei Observatory (Père H. Gauthier, compiler), for approximate tracks of storms of the middle and high latitudes of that ocean. Other valuable data have been contributed by the Indian Meteorological Department, the Australian Meteorological Service, the Meteorological Office, London, England, the Meteorological Service of Canada, and the Deutsche Seewarte, Germany.

WIRELESS TELEGRAPH SERVICE.

San Francisco received 206, and Portland, Oreg., 244 wireless reports of observations during the year. These messages are sent and received without expense to the Bureau through the courtesy of the vessel captains, the United Wireless Telegraph Company, and the Naval Wireless stations. Many of these reports are received at Katalla or

Cordova, Alaska, and forwarded by the Signal Corps cable free of cost.

It is expected that the number of observations reported by wireless telegraph will be increased during the coming year as a result of the regulations, effective July 1, 1911, requiring all vessels of a certain class to be equipped with sufficient apparatus for radio-communication.

VESSEL REPORTING STATIONS.

The Weather Bureau stations at Block Island, Cape Henry, Sand Key, Southeast Farallon Island, Point Reyes Light, North Head, Port Crescent, and Tatoosh Island, in addition to their meteorological work, are required to report all passing vessels, wrecks, marine disasters, and casualties, and to transmit communications between masters, owners, underwriters, and others interested. A total of 28,098 vessels were reported and notice of 47 casualties was given during the year.

The stations at Cape Henry, Sand Key, Southeast Farallon Island, Point Reyes Light, North Head, and Tatoosh Island are equipped for day signalling by International Code, and are prepared to transmit messages by telegraph. Cape Henry and Sand Key are also equipped for night communications by flashlight (Morse Code). An acetylene plant for this purpose was installed at Cape Henry during the year.

The station at Jupiter was closed as a vessel-reporting station on April 20, 1911.

Cape Henry uses the telephone and telegraph in reporting to Norfolk and Newport News. A list of vessels passing that station is sent daily to the Norfolk press and the New York Maritime Exchange. All naval vessels are reported to Norfolk, and in some cases to the Navy Department at Washington. The Maryland and Virginia Pilot Associations cooperate with this station, and such vessels as do not burn night signals, or can not be seen on account of fog, are reported each morning by the pilot boats. A time flag is dropped daily at noon for the benefit of the pilot boats and other vessels in the offing.

When the wireless telegraph regulations become effective, an effort will be made to have the captains and operators on all approaching steamers report the fact by wireless telegraph to the naval wireless station at Tatoosh Island, and, in case of fog, to use this means to report their passage to and from the strait.

The service rendered by the seacoast telegraph and vessel-reporting stations of the Bureau has been of great benefit to shipping in times of disaster during the last year. At about 11 p. m., September 1, 1910, the steamer *Watson*, bound from Puget Sound to San Francisco, with passengers and general cargo, ran ashore at Waddah Island, Wash. It was floated at 1 a. m., September 3, by the aid of the Life-Saving tug *Snohomish*, which was wired for at Port Angeles by our observer at Port Crescent immediately after the wreck. On December 10, 1910, following the wreck of the schooner *William H. Davidson*, our repairman at Manteo, N. C., established a temporary telegraph station on the coast about 30 miles north of Manteo, at the scene of the disaster, and rendered great assistance to the master and crew. Twelve wrecks occurred between Cape Henry and Hatteras during the year, all of which were reported by the Life-Saving stations to the officials at the Weather Bureau telegraph offices at Cape Henry, Hatteras, and Manteo, who in turn promptly telegraphed the information to the various agents, owners, revenue cutters, wrecking companies, and maritime

exchanges. It is estimated that fully $328,250 were saved through the assistance rendered the vessels in distress as a result of these timely reports. Reports of 18 casualties on Lake Huron, in which property valued at $350,000 was endangered, were also given out from the Alpena, Mich., station, as a result of information received by our observer at that point over the Weather Bureau land and cable lines running between the mainland and Middle Island and Thunder Bay Island.

CLIMATOLOGICAL DIVISION.

The Annual Report of the Chief of the Weather Bureau, 1909–1910, was printed and ready for distribution early in the present calendar year. The transfer of the composition and printing of the Monthly Weather Review from the Central Office of the Weather Bureau to the Government Printing Office has occasioned some delay in the issue of that publication, but it is probable that arrangements can be made whereby its issue at a slightly earlier date may be possible.

The issue of the National Weather Bulletin, weekly during the crop-growing season and monthly thereafter, continued as in the past. Its increased circulation as a result of numerous requests indicate that its value is rapidly becoming more widely known and appreciated.

The weekly and monthly summaries of the weather conditions in Porto Rico and Hawaii were issued as in the past, as well as those for Iowa, in cooperation with the Weather Service of that State.

Weekly summaries of the snow and ice conditions, with special reference to the districts east of the Rocky Mountains, were issued as usual during the winter, as well as the monthly summaries of snowfall conditions, for the benefit of irrigation and other interests in the mountain portions of the West. The latter contain more data than formerly, and the information they present as to the amount and distribution of the snow in the mountains, and its condition as regards prospects for early or late melting, has proved of much value to engineers and those dealing with the storage of water for power purposes and its distribution for irrigation.

The daily bulletins of weather conditions over the great corn, wheat, cotton, sugar, and rice-growing States have been issued regularly from about 40 selected points in those districts, the total issue amounting to more than 2,000 copies daily. The demands for the extension of these services have been numerous and persistent, especially for the establishment of additional telegraphic reporting stations in the cotton-growing sections of Texas and Oklahoma, and the wheat-growing districts of Montana and the Dakotas. These demands have been partially met by the establishment of about 20 additional telegraphic reporting stations, mostly in the western portion of Texas and in the Dakotas. The necessity of more stations of this character is still being urged by the many beneficiaries of these services.

The published annual summaries of climatological data for 1910, for the several States, have served as valuable additions to the series, which has been continued since 1896.

The preparation and printing of the 106 Summaries of Climatological Data, covering the entire United States, have been completed. These summaries have proved almost invaluable in answering the thousands of requests for information regarding the climatic features

of the different portions of the country, and the public demand has been so great that reprints of several of the earlier issues have already become necessary.

During the year there was prepared and issued as "Bulletin V, Frost Data of the United States," a set of charts showing the average dates of first killing frost in autumn; average dates of last killing frost in spring; earliest dates of killing frost in autumn; latest dates of killing frost in spring, and the length, in days, of the crop-growing season for all portions of the United States. These charts were prepared from the records of about one thousand cooperative observing stations having the greatest length of record. As the observations selected were made largely in the open country, and therefore removed from the artificial conditions that prevail in the cities, where most of our regular stations are located, they show the conditions that are liable to prevail in the fields, orchards, and gardens more accurately than ever before attempted.

The Weather Bureau derives much of its important climatological data from the records of its cooperative observers, of whom there are at present about 4,000, reporting from points well distributed throughout the entire United States, including Alaska, Porto Rico, and the Hawaiian Islands. Changes in this feature of the work included the opening of 258 new cooperative stations, and the discontinuance of 150 formerly in operation.

The great extension of the agricultural interests, especially those of trucking and fruit raising, necessitates more exact knowledge regarding the details of the climate of the country as an aid in determining the crops and fruits best suited to the various portions. At the present time this need can only be met by the data furnished by the cooperative observers of the Bureau.

The demands for the extension of these reporting stations have been much greater than it was possible to meet. As a rule, new stations have been established only in the more recently settled districts of the western portion of the country, where the necessity for reliable climatological data is most urgent.

The routine work of the Division, comprising the furnishing of climatic data to several thousand applicants, the preparation of certified data showing weather conditions for use in courts, and the tabulation of data into the permanent record books, have been carried forward as usual.

During the year a large number of the original records, including all the river reports, and the summaries of climatological data from 1906 to 1910, inclusive, have been collected, arranged, and properly bound. In September, 1910, the work of examining the original meteorological records from stations was transferred to this Division, due to the discontinuance of the Distributing Division.

The large accumulation of original records is rapidly exhausting the available storage room in the vault, which will soon have to be enlarged if these valuable records are to be kept free from danger of destruction by fire.

INSTRUMENT DIVISION.

The work and duties of the Instrument Division have remained essentially the same during the past year as heretofore. The equipment of instruments at about 200 telegraphic stations and about

4,000 cooperative stations has been maintained in the best condition possible.

Improvements have been made in the equipment of the storm-warning display stations at Delaware Breakwater, Del., Cape Henry, Va., and Sand Key, Fla., through the substitution of acetylene gas for oil in the lanterns, and more particularly through the introduction of separate lanterns, operated by a special signalling key for use in flashing messages from the stations to passing vessels. Credit is due to Mr. J. F. Newsom, in charge of the station at Cape Henry, for the development of this and other useful apparatus for signalling passing vessels.

Kiosks were installed during the year at Indianapolis, Ind., Salt Lake City, Utah, and Memphis, Tenn. These structures, which are now to be found at 29 stations, have met with universal commendations from commercial bodies and the general public, and requests for others are on file, awaiting consideration at such time as funds may become available for their erection. The kiosk has proved of special value in placing meteorological and climatological data of general interest before the public, as well as in affording a display of the instruments used for indicating and recording temperature, humidity, rainfall, and atmospheric pressure. During the year an improved arrangement of counters was devised by Mr. Maring, of the Instrument Division, for showing the accumulated rainfall since January 1, side by side with the normal fall for the same period, so that the data could be compared at a glance and the excess or deficiency for the current year noted.

Special forms of apparatus promising to give satisfactory results in the accurate measurement of snowfall in the mountain regions are described and illustrated in an Instrument Division Circular issued during the year under the title, "Measurement of Precipitation." A limited number of sample gages were installed late in the season at a few selected stations, but the records obtained are not as yet sufficiently numerous to bring out any definite results.

Work upon the apparatus for the absolute measurement of solar radiation has been carried forward, and a number of comparisons have been made with different types of receivers, bridges, etc. Orders were placed in the latter part of the year for an improved form of recording Wheatstone's bridge for the continuous registration of sunshine.

The seismographs at Washington have been maintained in operation throughout the year, but no work of a seismological character has been done at any of the other stations, notwithstanding the general call from a number of sources that the Weather Bureau engage in this important work. It is hoped ample means and authority will be granted the Weather Bureau to add seismological work to its present duties.

LIBRARY.

During the year just ended, 1,064 books and separate pamphlets were added to the Library, which now numbers approximately 31,000 volumes. All additions were fully catalogued under author and subject.

As heretofore, all the scientific periodicals received in the Library, including annuals, were regularly searched for articles of meteoro-

logical interest. These periodicals include all the important journals of general science, and most journals devoted to physics, geophysics, geography, and other subjects germane to meteorology, in many languages. The proceedings and transactions of learned societies are well represented. All articles of permanent meteorological interest were catalogued under author and subject; and in many cases brief notes were added on the catalogue-cards to amplify the information conveyed by the titles.

The periodical literature is, as a rule, more highly specialized than that published in book form, and is therefore indispensable to the special student. The work of cataloguing such literature under appropriate topical headings, about a thousand of which are now used in the Library, requires on the part of the cataloguers a wide knowledge of meteorology and of the principal foreign languages, besides familiarity with library science in general. Hence the Weather Bureau needs to maintain a strong library staff, specially trained in handling the cosmopolitan literature of meteorology, and in sympathetic relations with the scientific staff of the Bureau, to whom it is essential that this literature shall be made readily accessible.

Only by virtue of its direct exchange relations with scientific institutions throughout the world is the Bureau able to secure promptly all the current publications on meteorology. Much of this literature, especially that of an official character, could not be obtained by purchase, even if the funds were available. The periodical publications of the Bureau, especially the Monthly Weather Review and the Bulletin of the Mount Weather Observatory, are an indispensable means of securing valuable literature through exchange.

Select lists of new meteorological publications have been published regularly in the Monthly Weather Review, as in former years. A revised edition of the librarian's "Brief List of Meteorological Textbooks and Reference Books" was issued during the year.

The Library continues to make all translations from foreign languages required in the Bureau; to supervise the small libraries maintained at about two hundred stations; and to perform the work at the Central Office in connection with promotion examinations. All these classes of work have grown steadily during the past year.

Several station libraries have been strengthened by the addition of important works in German and French, dealing with branches of meteorology that are not adequately treated in English. This applies especially to the literature of atmospheric electricity, atmospheric optics, and climatography.

In recording the growth of the Library it appears proper to mention specifically a few of the more important meteorological works published in the course of the year, copies of which have been received.

Doubtless the greatest interest in this connection attaches to the completion of J. Hann's "Handbuch der Klimatologie," 3d edition, of which the third and final volume has recently appeared. This work, in it successive editions, is the only extensive treatise on the climates of the world published during the past twenty years.

W. Trabert's "Lehrbuch der kosmischen Physik" (Leipzig, 1911), is the most noteworthy recent publication belonging to the class of general textbooks of meteorology. A long-awaited new edition of the International Cloud Atlas has appeared. It introduces few changes in the existing classification of clouds, officially adopted in all countries.

Aerology and aeronautical meteorology engage the attention of a rapidly increasing number of writers. Dr. Franz Linke's "Aeronautische Meteorologie," the first volume of which was recently published, is the prototype of a class of books likely to become common. It is a practical handbook dealing with the branches of meteorology of special interest to aeronauts. A third edition of Moedebeck's "Taschenbuch für Flugtechniker und Luftschiffer" is, like the earlier editions, strong in the meteorological branches of the subject. Messrs. A. L. Rotch and A. H. Palmer have issued a novel series of "Charts of the Atmosphere for Aeronauts and Aviators." The British Government has published a noteworthy "Report of the Advisory Committee for Aeronautics, 1909–1910," containing several papers by the Director of the Meteorological Office.

The Carnegie Institution has published the first volume of a work on "Dynamic Meteorology and Hydrography," by Prof. V. Bjerknes and others. Its object is to present the fundamental facts and principles of the subject in a form suitable for treatment by the mathematical physicist, in part according to methods not heretofore applied.

Dr. B. Walter has described an ingenious method of photographing lightning-flashes with two cameras, one moving and the other stationary. ("Ueber Doppelaufnahmen von Blitzen," Hamburg, 1910). Dr. Süring has contributed an important treatise on meteorological photography to K. W. Wolf-Czapek's "Angewandte Photographie in Wissenschaft und Technik," vol. 1 (Berlin, 1911).

Important works on the circulation of the atmosphere included "The Trade Winds of the Atlantic Ocean," published by the British Meteorological Office; W. J. S. Lockyer's "Southern Hemisphere Surface-air Circulation," published by the British Solar Physics Committee; and a fourth installment of H. H. Hildebrandsson's "Quelques recherches sur les centres d'action de l'atmosphère." (Upsala, etc., 1910).

The Bureau of Soils of this Department published a bulletin by E. E. Free, "The Movement of Soil Material by the Wind," which deals very fully with the subject of atmospheric dust, and is accompanied by a well-nigh exhaustive bibliography of this subject. Secular changes of climate during the post-glacial period form the subject of a large volume of reports by numerous collaborators, issued under the direction of the 11th International Geological Congress. ("Die Veränderung des Klimas seit dem Maximum der letzten Eiszeit," Stockholm, 1910).

Climatography was represented by the second and final volume of J. Maurer's "Das Klima der Schweiz" (Frauenfeld, 1910); Tetens and Linke's "Das Klima von Samoa" (Berlin, 1910); O. L. Fassig's "Climate of Porto Rico" (extracted from "Register of Porto Rico, 1910," San Juan, 1911); a second part of G. Hellmann's "Das Klima von Berlin" (Berlin, 1910); F. Eredia's "La temperatura in Italia" (Rome, 1911); and fully a score of other valuable publications. The third volume of Hann's "Klimatologie," mentioned above, was, however, the all-important climatographic publication of the year. It deals with the climates of the temperate and polar zones.

General works on meteorology have recently been published in Russian, Spanish, Dutch, and modern Greek, by Vocikov, Oliver, Gulik, and Eginitis, respectively.

EXAMINATIONS FOR PROMOTION.

The total number of examination papers received and rated during the year was 295, as compared with 258 during the preceding year. Following is the record in detail:

Subject.	1910.		1911.		Total.	Passed.	Failed.
	August.	November.	February.	May.			
English grammar	7	12	9	8	36	20	16
Arithmetic	6	14	10	8	38	26	7
Elementary meteorology	6	12	9	3	30	23	7
Essay writing	7	13	11	18	49	34	15
Algebra	6	13	10	11	40	30	10
Physics	4	9	5	11	29	21	8
Trignometry	3	6	4	5	18	15	3
Astronomy	8	1	3	7	19	19	0
Plant physiology	8	3	4	7	22	21	1
Advanced meteorology	7	1	3	8	19	17	2
Total	62	84	68	81	295	226	69

TELEGRAPH DIVISION.

The various telegraph and telephone lines owned and operated by the Weather Bureau have been maintained in good condition at a total outlay of less than five hundred dollars for minor repairs.

The Block Island-Narragansett section, which extends from the Island to Narragansett Pier, has worked excellently and with little interruption during the entire year.

The Norfolk-Hatteras line was down for twenty-nine days, but Hatteras weather reports failed to get through on time on only fifteen days, the Life-Saving telephone being used at other times of interrupted service. The loop between Cape Henry and Virginia Beach was changed from Western Union telegraph poles to Government poles during the year. The entire section was inspected by the Chief Operator in May. Proper recommendations were made and approved by the Central Office, including the purchase at a cost of $1,182.72 of one and three-fourths miles of new cable to replace an old and defective cable at New Inlet, N. C. General work necessary to put the section in excellent condition will shortly be made. The Life-Saving crews from Cape Henry to Hatteras have rendered valuable assistance in making all minor repairs.

The submarine cable from Key West to Sand Key, Fla., was interrupted for two days during the month of February, due to temporary trouble in the terminal trench at Key West end.

The Alpena-Thunder Bay and Middle Island, Mich., section has worked well, with but thirty-six hours of interrupted service during the year.

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

The Glen Haven-South and North Manitou Islands, Mich., section was thoroughly overhauled during September and October, 1910, and placed in first-class condition by a lineman detailed from the Life-Saving Service. In March, 1911, a landslide at South Manitou Island carried away a portion of the shore end of the cable, burying it in the sand to such a depth that 1,700 feet had to be abandoned. Extra

cable was shipped from Charlevoix, Mich., and, through the cooperation of the Life-Saving Service, the necessary repairs were made and cable service restored on May 31. Repairs were made at the time to the cable box on North Manitou Island, restoring service between that Island and South Manitou; also to the telephones at Glen Haven and Sleeping Bear Life-Saving Station. The line, cable, and instruments between Glen Haven, South Manitou, and North Manitou Islands are now in good working order.

The line from San Francisco to Point Reyes has been placed in good condition at a small expense.

Communication between Port Crescent and Tatoosh was interrupted during the year for a total of fourteen days. Communication between Port Crescent and Seattle, on the Western Union line, was also interrupted for thirty-nine days, and on the Postal wire for fifty-five days.

The Government receipts from all lines for commercial messages handled during the year amounted to $2,018.48.

PUBLICATIONS DIVISION.

The Publications Division has continued to issue the regular publications of the Bureau, consisting of the Monthly Weather Review, the Bulletin of the Mount Weather Observatory, the National Weather Bulletin, the Snow and Ice Bulletin, the Marine Meteorological Charts, the Weather Maps, and the forecast cards. It has also supplied the stations with blank forms, for their meteorological and other station work, and blank maps and cards for disseminating weather forecasts.

On January 1, 1911, most of the printing material, including power and job presses, monotype machines, and type, was transferred to the Government Printing Office, where the actual printing work of the Bureau has since been done, with the exception of the daily weather maps, and cards for the local forecasts, and such small supplies as have been needed for immediate use at the Central Office. Lithographic operations remain unchanged.

As a result of this change in the printing work of the Bureau the services of sixteen employees in its printing office were dispensed with at the close of the year, nine being transferred to the Government Printing Office. Seven rooms on the second floor of the quarters previously occupied have also been vacated, and all printing work is now confined to the first floor.

DIVISION OF SUPPLIES.

The reclassification of property recommended by the Board of Survey went into effect on June 1, 1911. This classification eliminates the group formerly designated "Y" property, which, after becoming unserviceable from use, could be dropped from the returns without special authority. Under the new system only such articles can be dropped as are actually consumed by use or that are of slight value and soon worn out in service.

The equipment of 55 stations with chalk plate and stereotyping outfits for use in casting plates for commercial maps was completed during February, 1911. At a few of these stations the publication of the maps in the daily papers has since been discontinued, but the spare equipment has all been utilized in supplying other map-making offices.

New glass weather maps for public display were contracted for and installed as follows: Two in the U. S. Capitol, and one each at Fort Smith, Ark.; Boston, Mass.; Indianapolis, Ind.; Richmond, Va.; Cincinnati, Ohio; Wichita, Kans.; Vicksburg, Miss., and Peoria, Ill.

All regular stations and all substations issuing daily forecast cards were supplied with improved logotype outfits during the year. Besides a much enlarged vocabulary of weather terms, with standard captions and dates, each new outfit for regular stations includes a hand-printing press that produces excellent impressions in much smaller and neater type than that formerly used on forecast cards. Substations were supplied with new hand-stamping outfits, consisting of a modified vocabulary, and type-holders of new and improved pattern. These new outfits are superior in every respect to the old stamping devices, and are the result of considerable experimental work conducted in this division with a variety of apparatus submitted by manufacturers.

OBSERVATORY BUILDINGS.

No new observatory buildings were authorized during the year, except the reconstruction of the building at Sand Key, Florida, to replace the one that was destroyed by the hurricane of October 11, 1909. This building is now in course of construction, but the work has been unusually difficult because the key was practically washed away by the hurricane of October 17, 1910. The building site is now completely under water, which fact has materially retarded the work. However, the key is gradually reforming and it is expected that in a year or two it will have assumed its previous size. It is probable that the building will be finished and ready for occupancy by or before October 1, 1911. During the building operations the Weather Bureau employees are occupying a room in the lighthouse, and the work of the Bureau is being conducted without interruption.

The same hurricane that washed away Sand Key damaged the observatory building at Key West so badly that it is necessary to replace it. Congress has appropriated $15,000 for the purpose, and it is expected that the building will be completed by March 1, 1912.

The following table shows where the buildings owned by the Weather Bureau are located, the fiscal years in which they were erected, and the cost of the buildings and grounds:

Buildings owned by the Weather Bureau.

Location.	Erected.	Cost of ground.	Cost of buildings.	Total cost.
Abilene, Tex	1909	$2,000.00	$12,841.81	$14,841.81
Amarillo, Tex	1903	1,255.00	6,503.00	7,758.00
Anniston, Ala	1907	1,799.75	12,920.69	14,720.44
Atlantic City, N. J	1902	(*a*)	5,991.00	5,991.00
Bentonville, Ark	1906	500.00	5,119.90	5,619.90
Birmingham, Ala	1907	*b* 61.50	15,630.36	15,691.86
Bismarck, N. Dak	*b* 1899	(*a*)	10,085.99	10,085.99
Block Island, R. I	1904	1,034.50	7,668.25	8,702.75
Burlington, Vt	1906	*g* 20.00	10,043.50	10,063.50
Canton, N. Y	1909	*g* 1.35	14,135.20	14,136.55
Cape Henry, Va	1902	(*a*)	9,222.45	9,222.45
Charles City, Iowa	1907	3,036.75	9,338.47	12,375.22
Columbia, S. C	1905	3,799.00	9,165.00	12,964.00
Devils Lake, N. Dak	1904	2,209.05	7,431.50	9,640.55
Dodge City, Kans	1909	2,050.00	10,837.62	12,887.62
Duluth, Minn	1904	2,041.70	7,430.68	9,472.38
East Lansing, Mich	1909	*g* 11.35	12,781.04	12,792.39
Hateras, N. C	1902	*ak* 217.00	4,889.75	5,106.75
Havre, Mont	1904	1,795.00	5,087.08	6,882.08

a Government reservation.
b Remodeled.
g Donated; figures represent cost of title transfer.
k Additional ground purchased.

Buildings owned by the Weather Bureau.—Continued.

Location.	Erected.	Cost of ground.	Cost of buildings.	Total cost.
Iola, Kans.	1907	2,241.25	9,730.94	11,972.19
Jupiter, Fla.	1902	(a)	6,346.90	6,346.90
Key West, Fla.	1903	2,020.00	7,994.75	10,014.75
Kittyhawk, N. C.	*b* 1902	(a)	1,616.00	1,616.00
La Crosse, Wis.	1907	8,523.50	12,276.24	15,799.74
Modena, Utah.	1903	(a)	4,346.00	4,346.00
Mount Weather, Va.:				
Administration Building.	1909	1863.15	48,035.26	49,898.41
Machine shop and balloon shed.	1904	650.00	8,167.00	8,817.00
Central heating and power plant.	1909	(a)	11,964.74	11,964.74
Absolute building.	*c* 1906	(a)	7,000.00	7,000.00
Variation building.	*c* 1906	(a)	8,904.55	8,904.55
Stable.	1903	(a)	1,900.00	1,900.00
Barn.	1905	(a)	900.00	900.00
Cottage for workmen.	*b* 1905	(a)	1,300.00	1,300.00
Physical laboratory.	*d* 1909	(a)	37,521.51	37,521.51
Cottage and office.	*e* 1909	(a)	11,246.34	11,246.34
Nantucket, Mass.	1905	(*f*)	4,728.53	4,728.53
Narragansett Pier, R. I.	1904	4,151.75	8,036.50	12,188.25
Northfield, Vt.	1909	*g* 101.00	12,795.64	12,896.64
North Head, Wash.	1902	(a)	3,820.13	3,820.13
North Platte, Nebr.	1906	(*f*)	3,818.50	3,818.50
Oklahoma, Okla.	1906	*g* 38.90	10,520.25	10,559.15
Peoria, Ill.	1905	*g* 54.00	7,875.50	7,929.50
Point Reyes Light, Cal.	1902	(a)	2,875.00	2,875.00
Port Cresent, Wash.	1902	102.00	730.94	832.94
Richmond, Va.	1909	*g* 8.75	15,489.01	15,497.76
St. Joseph, Mo.	1909	5,040.95	16,882.80	21,923.75
Sand Key, Fla.	1903	(a)	*h* 14,800.00	*h* 14,800.00
Sault Ste. Marie, Mich.	1899	(a)	2,994.12	2,994.12
Sheridan, Wyo.	1907	2,021.75	12,089.30	14,111.05
Southeast Farallon, Cal.	1903	(a)	5,211.22	5,211.22
Springfield, Ill.	1906	(a)	10,236.50	10,236.50
Tatoosh Island, Wash.	1902	(a)	5,000.00	5,000.00
Washington, D. C.	.....	(*f*)	174,950.76	174,950.79
Yellowstone Park, Wyo.	1904	(a)	11,156.00	11,156.00
Yuma, Ariz.	*b* 1903	(a)	1,500.00	1,500.00
Total	.....	43,648.95	681,884.25	725,533.20

a Government reservation.
b Remodeled.
c Begun in 1905.
d Begun in 1903.
e Begun in 1907.
f Building and ground purchased as a whole.
g Donated; figures represent cost of title transfer.
h Estimated cost of new building now in course of construction.
k Additional ground purchased.

Buildings rented by the Weather Bureau for living and observatory purposes.

Station.	Annual rent.	Other items included.
Alpena, Mich.	$650	Heat, light, water.
Cape May, N. J.	660	
Clallam Bay, Wash.	120	Water.
Del Rio, Tex.	444	Heat, light, water.
Durango, Colo.	318	Water.
Flagstaff, Ariz.	420	
Helena, Mont.	624	Steam-heating plant, water.
Honolulu, Hawaii.	1,020	Six rooms; heat, cleaner, light, janitor and porter service, electric current for fan, storage.
Independence, Cal.	456	Water for domestic and irrigation purposes, and the trimming and care of all trees on the premises.
Kalispell, Mont.	360	
Lewistown, Idaho.	540	
Manteo, N. C.	144	
Moorhead, Minn.	600	Heat, light, water.
Mount Tamalpais, Cal.	420	Heat, light, water, and the free transportation of Government employees and supplies.
Pysht, Wash.	144	Water.
Roseburg, Oreg.	550	Heat, light, water.
Roswell, N. Mex.	720	Heat, cleaner, light.
San Juan, P. R.	600	Ten rooms.
Thomasville, Ga.	420	
Tonopah, Nev.	840	
Twin, Wash.	108	Water.
Winnemucca, Nev.	480	Heat, light, water.
Total	10,628	

PERSONNEL OF THE BUREAU.

The numerical strength of the Weather Bureau at the close of the year was 9,483, as compared with 6,895 at the end of the preceding twelve months. This unusual increase is apparent rather than real, however, since the total owes its enlargement almost entirely to the inclusion of 2,416 marine meteorological observers who have hitherto not been considered in the enumeration. Of the total number, 7,390, or nearly 80 per cent, are cooperative observers, rendering service without compensation other than that received through the free distribution of Government publications.

The total number of commissioned employees at the end of the year, 776, was 16 less than at the close of the preceding year. This decrease has been brought about largely through a lessening of the Central Office force by 25, owing to the discontinuance of a large portion of the printing work. The actual number of commissioned employees at stations, however, was 9 greater at the close of the year than at the time of the last report.

The formation of the new Division of Observations and Reports practically absorbed the Central Office clerical force formerly engaged in the duties performed by the Marine, Forecast, River and Flood, and Distributing Divisions. The force in the remaining divisions has been increased slightly in some instances, with the exception of the marked reduction in the Publications Division, already mentioned.

The enlargement of the commissioned force in the field by 9 was necessitated through the establishment of new stations at Dayton, Ohio, Fort Wayne, Ind., and Miami, Fla. At the stations already in existence the working force was lessened by one at 7 points, in order to meet the demands for additional help at other stations where the service rendered the public had become greatly expanded. The rearrangements thus effected, both at the Central Office and in the field, have had for their sole object the performance of a maximum amount of work with a minimum number of employees.

The number of permanent appointments in the classified service during the year, including those effected by transfer and reinstatement, was 37 less than in the preceding year. The temporary appointments were 22 less. During the same period the promotions, amounting to 172, were also less by 29. All promotions were to the next higher grade, with but one exception, that of an official assigned to a newly established station where the responsibilities of his position were much greater than at the station formerly held.

The number of voluntary resignations in the classified service during the year was 70, or 17 more than in the previous year. Of this number 31 were in the grade of messenger and messenger boy, and 15 were recently appointed assistant observers. The loss in the messenger service is naturally to be looked for as the boys advance toward manhood. The inability to hold all of the new assistant observers is doubtless due to the small salary paid them during the first year or two of their service. At the present rate of wages young men of their attainments are able to command, the temptation to engage in employment giving more lucrative immediate returns than those offered in the lower grades of the Government service has often proved irresistible.

Of the 69 probationary appointments made, only two failed to complete successfully the six months' probationary period. There were

nine forced resignations from the classified service, for various causes, during the year, while the removal for reasons reflecting upon the character of the employees were 3. Of the 14 reductions during the year, 6 were brought about through causes reflecting in no manner upon those reduced, while 8 suffered a decrease in salary for failure to measure up to the standards of efficiency and conduct required by the Bureau.

In the unclassified service there were 5 permanent and 2 temporary appointments, as compared with 5 permanent and no temporary appointments in the preceding year.

The absence record for the service, as a whole, showed a fraction of a day more sick leave and a fraction of a day less annual leave, for each employee, than in the preceding year.

There were 4 deaths in the commissioned force during the year, as compared with 8 for the year before. Among these was Mr. Jesse H. Robinson, Chief of the Telegraph Division at the Central Office of the Weather Bureau, in whose death, on May 1, 1911, the Bureau sustained the loss of a valued official. Mr. Robinson entered the service on March 6, 1872, and was appointed Chief Operator in 1891, and Chief of the Telegraph Division in 1902.

CHANGES IN THE FORCE OF THE BUREAU.

CLASSIFIED SERVICE.

Appointments:

Probationary—

Compositor, at $1,250	1
Skilled mechanics, at $1,200	2
Clerk, at $1,000	1
Clerk, at $900	1
Copyists, at $840	2
Assistant observer, at $840	1
Copyist, at $720	1
Assistant observers, at $720	18
Skilled mechanic, at $720	1
Repairman, at $720	1
Messenger, at $480	1
Messenger boys, at $450	7
Messenger boys, at $360	32
	69

Transfer—

Assistant observer, at $1,000	1

Reinstatement—

Section director, at $1,800	1
Assistant observer, at $1,000	1
Printer, at $1,000	1
Assistant observer, at $840	1
Assistant observer, at $720	1
Messenger, at $600	1
	6

Temporary—

Compositor, at $1,250	1
Skilled mechanic, at $1,200	1
Skilled mechanic, at $1,000	1
Repairman, at $720	1
Folders and feeders, at $680	2
Messenger, at $480	1
Messenger boys, at $360	20
	27

Promotions (all promotions except 1 were to the next higher grade or by certification for advancement from subclerical positions) 172

Reductions:
- Causes—
  - To grant assignment to preferred station 1
  - To grant assignment to preferred work 2
  - As an offset to the Bureau for allowance of quarters, fuel, and light .. 2
  - Necessitated by change of duties 1
  - Unsatisfactory administrative work 1
  - Unsatisfactory services 4
  - Neglect of duty 1
  - Unsatisfactory conduct and neglect of duty 2

  14

Resignations:
- Voluntary 70
- Required because of—
  - Unsatisfactory services 3
  - Unsatisfactory conduct 1
  - Unsatisfactory service and conduct 1
  - Absence without authority 1
  - Non-payment of debts 1
  - Physical unsuitability for Weather Bureau work 1
  - Refusal of tendered assignment 1

  79

Transferred to the Division of Publications, Department of Agriculture 2

Removals:
- Causes—
  - Transfer of certain printing work from the Weather Bureau to the Government Printing Office 7
  - Continued illness 1
  - Neglect of duty and unsatisfactory services 1
  - Intoxication and neglect of duty 1
  - Intemperance and absence without authority 1
  - Legally adjudged insane 1

  12

Dropped from the rolls at termination of probationary period because of unsatisfactory services 2

Deaths 4

UNCLASSIFIED SERVICE.

Appointments:
- Permanent—
  - Unclassified laborers, at $480 3
  - Student assistants, at $300 2

  5

- Temporary—
  - Student assistant, at $300 1
  - Charwoman, at $240 1

  2

Promotions (to the next higher grade) 2

Resignations:
- Voluntary 5

ABSENCE.

Average number of days per employee during calendar year 1910.

	Sickness.	Annual leave.
Station (99 per cent males)	1.5	6.8
Washington, D. C.:		
Males	4.6	23.4
Females	10.2	27.3
Entire service	2.4	11.2

STATISTICS OF THE SERVICE.

The following tables show the numerical strength of the Bureau, and the highest, lowest, and average salaries paid in the commissioned grades:

Numerical strength of the Weather Bureau, June 30, 1911.

At Washington, D. C.:		
Classified	174	
Unclassified	11	
		185
Outside of Washington, D. C.:		
Classified	579	
Unclassified	12	591
Total commissioned employees		776
Additional employees outside of Washington, D. C.:		
Storm-warning displaymen	183	
River observers	383	
Cotton-region observers	125	
Corn and wheat region observers	134	
Rainfall observers	110	
Sugar and rice region observers	7	
Special meteorological observers	82	
Special cranberry-marsh observers	8	
Special snow and ice observers	4	
Mountain snowfall observers	281	
Total noncommissioned employees		1,317
Total paid employees		[a]2,093
Persons serving without compensation (except through the distribution of government publications):		
Cooperative observers and correspondents (omitting 412 paid observers enumerated elsewhere)	4,847	
Cooperative storm-warning displaymen	96	
Cooperative river observers	22	
Cooperative rainfall observers	9	
Marine meteorological observers	2,416	
Total cooperatives		7,390
Total numerical strength		9,483

Distribution of the commissioned force, June 30, 1911.

In Washington, D. C.:	
Accounts Division	[b]14
Climatological Division	17
Executive branch	19

[a] This total embraces all paid persons connected with the Bureau on June 30, 1911, except 14 commissioned employees absent on that date and who had been granted leaves of absence or furloughs without pay for one month or more.

[b] One employee devotes a portion of his time at one of the map stations at the United States Capitol.

In Washington, D. C.—Continued.	
Forecasting	2
Instrument Division	11
Library	5
Observations and Reports, Division of	26
Observatory	1
Publications Division	24
Supplies Division	[a] 11
Telegraph Division	11
Verification Section	2
Drafting Room (under direction of the chief clerk)	4
Heat, light and power plant (under the direction of the chief clerk)	5
Miscellaneous mechanical work (under the direction of the chief clerk)	6
Watch force (under direction of the chief clerk)	6
General messenger and laborer service (under direction of the chief clerk)	21
Total	185
Outside of Washington, D. C.:	
53 stations with 1 commissioned employee	53
45 stations with 2 commissioned employees	90
50 stations with 3 commissioned employees	150
18 stations with 4 commissioned employees	72
14 stations with 5 commissioned employees	70
7 stations with 6 commissioned employees	42
5 stations with 7 commissioned employees	35
2 stations with 8 commissioned employees	16
3 stations with 9 commissioned employees	27
1 station with 10 commissioned employees	10
1 station with 12 commissioned employees	12
1 station with 23 commissioned employees	23
200 stations	[b] 600

In addition to the foregoing there are eight special observing (one man) stations in the West Indies, mainly in operation during the hurricane season, and a special repair station in Washington operated from October to April, inclusive.

The following salary table omits persons on duty at special observing and substations where the salaries are $25 a month or less, and where, as a rule, the tour of duty covers but a small fraction of the day and only certain seasons of the year:

Salaries paid in the commissioned grades.

Grades.	June 30, 1911.	
	Stations.	Washington, D. C.
Classified grades:		
Highest salary	$3,500	$6,000
Lowest salary	360	450
Average salary	1,046	1,173
Unclassified grades:		
Highest salary	720	720
Lowest salary	300	240
Average salary	405	513

Average salary of all (station and Washington) is $1,057.

[a] One employee devotes a portion of his time at one of the map stations at the United States Capitol.

[b] This represents the normal station force. On June 30, 1911, there were actually on duty 591 employees.