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REPORT OF THE CHIEF OF THE WEATHER BUREAU.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, September 10, 1923.

HON. HENRY C. WALLACE,
Secretary of Agriculture.

SIR: I have the honor to submit herewith a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1923.

Respectfully,

C. F. MARVIN,
Chief of Bureau.

A new significance is attached nowadays to the weather factor in all human conduct and operations. For centuries a topic often convenient to fill lulls in conversation and for other purposes, the present and prospective weather for a continent, almost for the whole world, is now spread before the public twice a day in all the newspapers, weather maps, and a multitude of bulletins and advices. The United States leads the world in the utility, practicability, and extent of this public service, and even the smallest progressive nation recognizes that an organized public weather service is now quite as much a necessity as, say, a postal service or a police force. This is a growth and development of the past 50 years. In the United States the general public takes the work of its Weather Bureau more or less as a matter of course. In early years its forecasts and prognostications were not taken very seriously, and its popular sobriquet of "Old Probabilities" was suggestive of the humorous estimate in which its work was generally held. That was when the bureau was a very young institution, literally in its childhood. A historian telling the life story of the bureau can easily discern its progress into sober youth and manhood. With this came a period when the public viewed its pretensions and accomplishments (or failures) with some seriousness. However, with small sympathy for the bureau's forecasters, and less understanding of the difficulties of their tasks, storms of complaints for failures prevailed throughout the land. These are written in the columns of the public press throughout the closing years of the last century.

Recognizing its limitations, undismayed by the onslaught of its critics, confident of the wonderful possibilities of its useful public service and its ability to make it worth while to the Nation—to make its work pay back to the Nation in economic benefit many hundreds of dollars for one expended on the maintenance of the work—the bureau, through its technical staff of loyal and patriotic public serv-

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

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ants, struggled on, bettering and extending the service little by little and in many ways. What does the historian who studies the press and weather bulletins of the present day find with respect to this work? Every paper carries the message of present and prospective weather, and for those who need fuller details special bulletins convey everything known and ascertainable. The shippers of perishable foods and products are told of the hot and cold waves their shipments will encounter en route to any destination. To the great centers of population this foreknowledge permits the saving of many thousands of dollars annually in losses either of products or by damage claims, or both. Severe cold waves, heavy snows, and general storms overspread extended regions of the country time and again each year. The newspapers carry well in advance timely details of these occurrences, and livestock is sheltered, provisions made for maintaining traffic, snows removed without embarrassing blockades, and every precaution taken to minimize the ill effects which would overtake every community visited unawares by these atmospheric phenomena. Orchards are protected from frosts, and fruits and agricultural crops are saved and matured under the prompt and helpful advices of the meteorologist. In the flooded areas of the great waterways advices are given many hours, often days, and sometimes weeks in advance of the crest stages, generally to the fraction of a foot, which the flood will attain. Such floods, in changing intensities, are annual features of the river channels, and the service is performed when the need arises, year after year. Only the merchants, the engineers in control of river operations, and the agriculturists whose acres are subject to possible inundation are able to speak from personal experience of the accuracy and value of the flood warnings of the bureau. These serve to minimize the losses and destruction which, without forewarnings, would become a calamity. Meteorology and radio communication have literally transformed the navigation of the sea from a great peril to a state of relative safety, especially in coastal waters and on the high seas in reach of the daily broadcast of weather reports from coastal stations. Cargo and even passenger ships now shape their movements on weather reports. During the hurricane season of the southern seas we may safely say a captain would not leave port without the latest weather advices, if conditions were menacing, any more than he would leave without his compass or some other essential of navigation. On the Great Lakes vessels are often compelled to make shelter or tie up at dock during stormy conditions. It has been stated that any delay of this character entails an economic loss of from \$50 to \$100 per hour per vessel. Ignorance of the status and progress of such storms on the part of the navigators leads to an embarrassing dilemma. To leave shelter too soon is to incur hazard of storm damage. To delay unnecessarily is to suffer excess of per hour loss. The local official of the Weather Bureau steps in at this point and with his command of the weather situation he is able to broadcast advices to shipping which literally save many hours of ships' time with practically no losses in safety and security. Here, again, only those actually profiting by this useful service of the bureau are aware of its great economic benefits.

With the advent of the practical navigation of the air a whole new service is now demanded, a service of flying-weather forecasts

and weather advices to aviators. This compels the bureau to extend its observations and measurements above the surface into the free air, which is being done in a very limited way at the present time by means of kites and little so-called pilot balloons.

The historian following the growth of the bureau to its present 50 years of maturity may find in the public press and like sources these and many more detailed accounts of the useful work being done.

The confidence of the public at the present time in the forecasts, warnings, and advices of the bureau has been expressed over and over again in print and statement. Evidence of it is found, moreover, in the urgent appeals from many interests and many localities for extensions and new features of service.

It need not be said that all such activities require expenditure of public funds. Instruments must be purchased and maintained in operation, offices rented, and many expenses incurred which to-day are much in excess of the same costs before the war. If we place the population of the United States, including all outlying possessions except the Philippines, at only 100 millions, 2 cents per annum from each man, woman, and child would more than pay the entire costs of maintaining the Weather Bureau work. The time has come when, with the prevailing high costs, the bureau is unable to fully maintain its work, much less meet increasing demands for service with its present facilities. Practically every one of its more than 200 field stations is operating under the minimum number of personnel, often in crowded offices, and with no flexibility to meet temporary losses from sickness, absence on leave, and unfilled vacancies. What happens is overtime hours of work and loss of vacations, with corresponding fatigue, discouragement, dissatisfaction, and inefficiency. In these post-war times of insistent effort at curtailment of public expenditures and the securing of the maximum of efficiency and economy in Government administration, the Weather Bureau feels it can invite the closest investigation of its status. If anyone supposes the maximum return is not being given him, let him visit any one of the principal stations and ascertain for himself its program of work and service, and the low salary scale which has prevailed for years because of rigid statutory limitations and peculiar conditions of compensation established in this bureau years before the war and which still continue. Increases are necessary to maintain and extend this useful service.

The annual program and routine of the public service of the Weather Bureau is not a heritage handed down to us from the distant past or even from the last generation. It is conspicuously a creation and development of the leaders and seniors in its present personnel, including the great contributions from a small number of faithful men and brilliant meteorologists who have passed beyond. We are the generation which is passing on to our successors a highly organized and developed service. Our task, our responsibility, is to recruit and train those who are to carry on and perfect this work in the future. This will not be possible unless the salary scales and readjustments which already have been worked out by the reclassification agencies are granted. Until that is done few college-bred men and students of science, equipped intellectually to meet the requirements, will be attracted from other lines of endeavor.

When that pay scale does become operative we may hope to secure applicants for our vacancies, among whom will be those qualified for the most difficult tasks of professional weather forecasting. We must not overlook the inexorable principle that the more successful and accurate the service of professional forecasting becomes the more exacting and expectant become the public demands.

At the present day professional meteorology furnishes a fascinating and alluring career for any student interested. The sequence of weather conditions and the investigation and formulation of its laws are not to be excelled in any scientific pursuit for infinite variety of aspect, perplexing difficulties, and alluring interest.

Meteorologists are on the threshold of new discoveries in the domain of forecasting. The public receive with respect and confidence the forecasts of storms and weather for a few days in advance, but they are not satisfied that we stop at that point. Letter after letter is received from all sides asking the bureau for forecasts for seasons, for months, and even years ahead. The only answer in all such cases is that the bureau knows of no sound physical laws by which such forecasts can be made with any promise of success. It will not jeopardize the confidence it has won from the public by undertaking to do a thing it can not do well and upon a scientific basis.

There are a few perhaps more deeply versed in some other science than meteorology, such as astrophysics, sociology, geology, economics, etc., who have essayed to claim discoveries upon which a species of long-range forecasting is possible. The professional meteorologist and forecaster, however, is inclined to view such enthusiasts as irresponsible for the successful verification of such forecasts, as over-optimistic, or as bold and daring pioneers who possibly may blaze a way through the wilderness only to leave to others the difficult task of establishing sure and safe communication.

Conservatively, however, this much may be said of long-range forecasting: No scientist has or can demonstrate, I believe, that the making of weather predictions of a general character for a considerable period of time in advance transcends any basic laws of nature or is inherently impossible. That which is not *impossible* must be *possible*, and let this be the justification of those who seek to advance the science and art of meteorology in this difficult field.

FORECAST SERVICE.

Each year now adds new demands for special forecasts and service in connection with outdoor exercises, entertainments, fairs, aviation meets, airplane flights, etc., as the confidence of the general public grows in the service the Weather Bureau is able to give. All of these demands were met and many expressions of appreciation of service rendered were received from the beneficiaries. The forecasts issued twice daily for all sections of the country and warnings of frosts, cold waves, storms, and heavy snows, whenever conditions warrant, all of which are widely and effectively distributed through newspapers, by telephone, telegraph, radio, maps, bulletins, cards and other means, meet general requirements; but the rapidly increasing utilization of weather information by

Many business industries is resulting in requests for more special forecasts and direct service. The calls for such information by telephone and telegrams heavily tax the ability and facilities of the bureau. Many field offices respond to a hundred or more telephone calls a day under normal weather conditions and several times as many when unusual or destructive conditions are indicated. A considerable portion of these calls require special consideration and attention. There are nearly 200 field offices to which the public has personal and telephonic access, and the volume of special service that is given by this means alone is enormous. These calls come for the most part from business men whose interests are affected in one way or another by the weather.

One incident will illustrate the extent to which the telephone is used in serving the people by direct contact. Announcement had been made by the Weather Bureau of a hurricane in the Gulf of Mexico which was approaching the Texas coast. The manager of the telephone company in one of the coast cities reported that during the 24 hours succeeding the warning slightly more than 200,000 telephone connections were made through his office, of which number more than 100,000 were for weather information. It was necessary to assign seven operators in addition to the regular force to handle the calls.

FRUIT SPRAY AND HARVEST WEATHER FORECASTS.

This trial forecast service, which has been conducted in New York State in the aid of spraying operations in the apple-growing districts and special forecasts in connection with harvesting, was continued during the past year with the cooperation of the local agriculturists. It was necessary to confine the work to practically the same limited areas as last year because of lack of funds, although State organizations arranged to distribute the forecasts in some additional counties without further cost to the Weather Bureau. As heretofore stated, it will not be possible to extend these services to other areas and States and to place the project on as effective basis as its great importance justifies until such time as adequate funds are provided therefor.

HAWAIIAN FORECAST SERVICE.

Since 1918 forecasts have been issued at Honolulu for the benefit of shipping in waters contiguous to the Hawaiian Islands. This service, although handicapped because of paucity of ship reports on which the forecasts largely were based, was very successful and met with commendation from marine interests. In the spring of 1923 the service was greatly improved through the cooperation of the Navy Department in transmitting to Honolulu daily radio messages containing additional ship reports and current observations from 16 stations along the Pacific coast from Alaska to southern California. These additional reports, together with those from Midway Island, have enabled the Honolulu forecaster to chart general barometric-pressure distributions and weather conditions in the Pacific Ocean east of the one hundred and seventieth meridian and have greatly facilitated the issuing of more accurate forecasts for the Hawaiian Island district.

ALASKAN SERVICE.

An organized unit of the Weather Bureau has been in operation in Alaska since 1916, with headquarters in Juneau. A large part of the activities have been devoted to the securing of records from all accessible portions of the Territory for climatological purposes and the maintenance of stations for the taking and telegraphing of observations for forecasting requirements in the States. Twice-daily observations are obtained from 11 stations with a gratifying degree of regularity by means of radio, telegraph, and cable (in most cases a combination of the three). The active and cordial cooperation of the Signal Corps of the Army and the Office of Communications of the Navy was essential to the success of this service. These reports are of inestimable value in the general forecast work of the bureau, especially in the issuing of storm warnings for the Pacific coast and cold-wave warnings for the Middle and Western States.

It is estimated that the value of perishable products saved as the result of cold-wave warnings issued last winter for the Chicago district alone exceeded \$10,000,000, although the winter was not an unusually severe one. The district forecaster, in commenting on these estimates, stated that it would have been impossible to issue these warnings so timely and accurately if no reports from Alaska had been available. The estimates were for the Chicago district alone. Many other commercial districts in which the Alaskan observations were an equal factor in issuing cold-wave warnings therefor were similarly benefited. This is cited to indicate the tremendous economic value that the service maintained by the Weather Bureau in Alaska is to the commercial and marine interests of the United States.

During the past years daily forecasts have been made only for the Juneau district of southeast Alaska. The Government railroad from Seward, on the Pacific coast, to Fairbanks, in the Yukon Valley, a distance of 470 miles, was completed during the past year. This railroad furnishes easy travel and accessibility to the most extensive and richest agricultural region in the Territory, and its completion created a demand for a forecast service. Such service was begun on January 2, 1923. The forecasts, made in the early forenoon each day, Sundays excepted, are cabled from Juneau to Seward, and are distributed by telegraph along the railroad. They are also further distributed by telephone and by publication in newspapers published at Anchorage and Fairbanks. The forecasts cover a period of 36 hours in advance and are for the Matanuska-Susitna and Tanana Valleys and contiguous coasts and the regions traversed by the Government railroad. Officials of the railroad stated that the forecasts during the winter months were of much assistance in keeping the road open and in the making of preparations for removing snowdrifts from deep cuts.

An incidental part of this forecast service was the establishing of reporting meteorological stations at Fairbanks, Anchorage, and McKinley Park, and the transferring to Cordova of the station formerly located at Valdez. One of these stations, McKinley Park, is located in the Mount McKinley National Park, the eastern border of which extends for 30 miles along the railroad. The park contains the highest mountain peak in North America, abounds in magnificent scenery, and is likely to be one of the great attractions to tourists

from the United States. The forecast service is designed to be of benefit to these visitors.

RADIO DISTRIBUTION OF WEATHER FORECASTS AND INFORMATION.

The distribution of forecasts, warnings, and weather information by radio was covered in some detail in the previous annual report. This work continued during the past year along the same lines, but more effective and widespread distribution was accomplished. Beginning September 1, 1922, arrangements were made with the United Fruit Co. for broadcasting and disseminating twice daily special weather bulletins from its radio station on Swan Island for the benefit of shipping in the Caribbean Sea. These bulletins consist of wind and weather forecasts for western Gulf of Mexico (west of longitude 90°), eastern Gulf of Mexico (east of longitude 90°), and for the Windward Passage. Whenever conditions warrant, the forecasts are preceded by advices and warnings regarding any storm or hurricane that may be in progress and of "northers" during the winter months. During the hurricane seasons these are added to the morning bulletins of weather observations taken at 8 a. m., seventy-fifth meridian time, at 10 stations located in Cuba, the West Indies, and on the eastern coast of Central America.

An added feature of the service from Swan Island is that signals consisting of a red pennant by day and a red light by night are displayed from the radio tower to indicate that information concerning a hurricane, a storm, or a "norther" is in possession of the radio operator, which can be obtained by boat call ashore. This service is for the special benefit of ships not equipped with wireless, although any ship so equipped may obtain the information by radio call.

Although the number of commercial and private broadcasting stations that cooperate with the Weather Bureau in disseminating forecasts, warnings, weather and crop information, etc., remains about the same, there has been a material increase in the effectiveness of the service. Cooperation with a number of small stations with limited range was discontinued and several large and more powerful stations added. To meet popular demands the information sent out by radiophone from several stations has been amplified, and now includes river forecasts and stages, conditions of highways as affected by the weather, effect of weather on crops, weather reports from the principal crop areas, special forecasts for the guidance of farmers in harvesting, etc. In many cases forecasts for several States are now broadcast from a single station. The gradual discontinuance of the smaller and less powerful stations has left the bureau with a chain of well-distributed and reliable stations, from which hearty and continued cooperation may be expected. They are so located that practically all sections of the country are assured of opportunity to obtain the forecasts satisfactorily and directly. It is impossible to approximately estimate the number of people being served in this way. In addition to the hundreds of thousands of receiving-set owners who receive the forecasts by radiophone, large numbers of whom can obtain them in no other way, many repeat them to their neighbors by telephone. This latter form of service has become so potential that arrangements are in hand for a definite form of organization which will replace the telegraphing of forecast messages now

sent to centers for distribution. It is expected that more effective service will be accomplished thereby and that considerable economy will result.

Broadcasting by radiophone from the Arlington naval radio station (NAA) of weather forecasts and warnings for each of the States comprised in the Washington forecast district was inaugurated February 15, 1923. Broadcasts are made three times daily—at 10.05 a. m., 3.45 p. m., and 10.05 p. m., respectively, on a wave length of 435 meters. A general forecast covering the entire district and such storm and flood warnings as are issued for any portion thereof are included. On Saturdays there is included in the 3.45 p. m. broadcast the weather outlook for the ensuing week, Monday to Saturday, inclusive, for the North and Middle Atlantic States, the South Atlantic and East Gulf States, the Ohio Valley and Tennessee, and the region of Great Lakes. On Wednesdays, March 15 to November 30, inclusive, a summary giving the effect of the weather on crops during the preceding seven days ending at 8 a. m. Tuesday is given in the 10.05 a. m. and 7.45 p. m. broadcasts. A feature of the service from Arlington, which provides for dissemination of the weather forecasts immediately after they are issued, is that the announcements are made directly from the Weather Bureau office in Washington, which is connected by telephone with the radiophone transmitting apparatus at Arlington, Va.

STORM-WARNING SERVICE FOR THE NORTH ATLANTIC OCEAN.

The need for a storm-warning service for the North Atlantic Ocean was quite conclusively demonstrated during the past winter. Not for many years were the cyclones in that region so intense and so frequent. They caused delayed voyages, much damage to ships and cargoes, and distress to passengers. The experiences of vessels caught in these storms occupied much space in the public press. The following is quoted from an editorial in the Philadelphia Public Ledger of January 8, 1923, in reference to storms in the North Atlantic:

One naturally may ask: What are we going to do about the cyclones in order to lessen the danger to navigation and to increase the comfort of the passengers? It will, for obvious reasons, be impossible to divert the storms to other courses or to diminish their severity. The only possible thing to do is to give warning of their presence, their intensity, and their direction of travel that vessels may steer clear of regions of violent winds. This can be done, as has been demonstrated by meteorological work on board the French steamship *Jacques Cartier*, which during its last several trips on the Atlantic has acted as a floating meteorological forecast and distributing center.

The Weather Bureau has followed with much interest the pioneer work of the French steamship *Jacques Cartier*, referred to in the editorial. This ship is engaged in general freight carrying and is commonly in service between European and American ports. Its distinctive feature is that it is also used as a school for the training of officers for the merchant ships of its owning company, about 50 cadets being continually under instruction. The training course includes all phases of navigation, commercial and international marine law, astronomy, and a thorough course in theoretical and applied meteorology. A weather-forecast and storm-warning service is conducted as an incidental part of the instruction in meteorology. The

latter project has the cooperation and support of the French Meteorological Service. The ship makes about three voyages a year, mostly to southern ports. Consequently it renders only intermittent service and is only occasionally on northern routes, for which there is the greatest demand and need for weather forecasts and information. The forecasts issued from the *Jacques Cartier* are based upon United States Weather Bureau bulletins containing observations from stations in the United States and Canada, upon similar European reports broadcast from the Eiffel Tower in Paris, and upon reports collected from ships at sea. The forecasts and warnings are distributed by radio twice daily for the benefit of ships of all nations that are within range.

The Weather Bureau received an invitation to have a representative take passage on the *Jacques Cartier* for the purpose of observing and reporting on the meteorological work conducted thereon. It was accepted, and last spring the supervising forecaster of the Weather Bureau made a trip on the ship from the United States to France and return. He reported that the work was an unqualified success, that its accomplishments demonstrated quite conclusively that a forecast service for the ocean is feasible, of great economic value, and that there is much need therefor, especially on the North Atlantic.

Continuous service of this character would require the utilization of at least three vessels and would involve no interference with their regular voyages and traffic. Continuous service is necessary to keep vessel masters informed at all times as to the wind and weather conditions along the routes they are traveling; advise them as to the location, intensity, and direction of movement of storms which might cause damage to ships and cargoes or at least retard progress; enable them to avoid such storms as far as possible; enable them to lay out ship work en voyage and to take advantage of fair weather and smooth seas for painting and other outside work; give them information of wind and weather conditions to be expected at ports of destination, thereby preventing unnecessary delays, and in other ways provide useful and advantageous information.

The plans for such service have been worked out and submitted to the United States Shipping Board. They have met with approval of that organization, which has offered cooperation in the way of providing facilities on the necessary number of Shipping Board vessels running regularly on the northern routes between the United States and Europe. The bureau is alert to the inauguration of some service of this character at the first opportune occasion.

The total reported flood losses during the year were \$36,591,362, while the value of portable property saved by flood warnings was given in admittedly incomplete returns as \$4,240,465.

ADMINISTRATIVE FEATURES.

Changes in organization and administration during the year were few and not of great consequence. Several stations of observation were discontinued and others established with decreased cost of operation.

While the river service east of the Missouri is virtually sufficient for present needs, the reverse is the fact for the great territory to the

westward. The natural and steady expansion of the great agricultural and commercial interests, together with the attendant increase in population, reasonably requires a proportionately increased service if the legitimate requirements of the people are to be fulfilled. We need hundreds, yes thousands, of additional river stations. The cost of a rainfall station is about \$12, with practically no maintenance cost except depreciation on equipment. The original cost of a river station will average about \$100, with an annual maintenance cost of about \$175. Owing to present program of economy no increases of consequence are contemplated at this time.

For several years the mountain snowfall service has been in need of a complete reorganization. This service is maintained in the mountain regions of the far West in order to provide farmers and others reliable information as to the amount of water that may be relied upon each year for irrigation and hydroelectric purposes, and the constantly increasing demands for more accurate and comprehensive service have exceeded our ability to supply under present conditions. Intensive work of the most approved character is highly necessary but must await the appropriation of the requisite funds.

RESEARCH WORK.

During the year schemes for forecasting river stages and floods have been completed for the Willamette River system of Oregon, the Connecticut River, and the Brazos River of Texas. Other schemes will be undertaken as time will permit, mainly for the smaller rivers, as those for the larger rivers and their tributaries are virtually complete, although some need revision from time to time.

RIVERS AND FLOODS.

The outstanding floods of the year were those in the Arkansas River from eastern Kansas to the mouth, the Neosho River of Kansas and Oklahoma, and the Cimarron and North Canadian Rivers of Oklahoma. Four weeks of almost continuous and frequently excessive rains brought about these floods, and the crest stages were, as a rule, higher than any previously recorded. Coming as they did at a season of matured wheat and growing corn and other crops, and covering in southeastern Kansas and northeastern Oklahoma alone nearly 300,000 acres of highly productive lands, the floods caused loss and damage, very incompletely reported, to the value of \$27,884,200, of which by far the greater portion was in crops, matured and prospective. During the great Mississippi Valley floods of 1922 the total losses as reported were \$17,087,790, nearly \$11,000,000 less than in the Arkansas and Canadian Valley floods, but the former flood came before the planting season had well set in, and, furthermore, the lands were protected by high levees.

No flood warnings, however accurate and timely, can prevent loss of crops and damage to fixed property, but movable property, especially livestock, can be secured, and it is a pleasure to say that during this Arkansas Valley flood livestock and other property to the value of \$1,350,000 were reported as having been saved by the flood warnings of the Weather Bureau.

A demand for the extension of the cattle-region service over important western grazing districts continued. Extension of service should also be made to some important grain States in the corn and wheat region, but increases in funds are needed for these extensions.

FRUIT FROST WORK.

This service is of great value to the citrus growers of southern California, who are strongly organized to combat frost conditions and accomplish the saving of much fruit during periods of critical weather conditions. The minimum temperature forecasts and special frost warnings during the current year were remarkably accurate. The various fruit growers' exchanges cooperated extensively with the bureau during the past year in giving financial and other assistance.

After the close of the frost season in southern California, the special bureau representatives rendered excellent service in the San Joaquin Valley (Fresno-Lindsay district), the Santa Clara Valley (San Jose district), the Napa Valley (Winters district), the Rogue River Valley (Medford district), and in the fruit sections of eastern Washington.

Other fruit frost activities were conducted during the year as follows:

NEW MEXICO, ROSWELL.—Much interest was shown in the work, and nearly all orchards are equipped with frost-fighting devices.

ARIZONA, YUMA.—A temperature survey was continued, primarily in the interest of the citrus industry in this vicinity, which is a growing one.

COLORADO.—Fruit frost work continued in the Gunnison and Uncompahgre Valleys in the vicinity of Delta and Montrose, Colo. (Denver district), the Colorado River Valley in the vicinity of Grand Junction, and in the Canyon City fruit district (under Pueblo). The work was conducted in a satisfactory manner, and the minimum temperature forecasts and special frost warnings were satisfactorily verified.

NEW JERSEY, NEW LISBON.—The work in this district was maintained by the official in charge at Philadelphia, Pa., but no special representative was assigned to New Lisbon.

KANSAS, WICHITA.—The three stations recently established in this district were maintained during the year.

FLORIDA.—Fruit frost work was continued at the same centers where it was in operation last year, namely, Jacksonville, Pensacola, and Tampa, the work being conducted by the maintenance of special stations along practically the same lines as previously.

ILLINOIS, PEORIA.—Service in the vicinity of this station was maintained as during the previous year, four special cooperative fruit stations being operated.

MISSOURI.—Fruit frost centers were maintained at St. Joseph and Springfield, Mo., and special warnings furnished to fruit growers.

COOPERATION.

A number of committees, consisting of representatives of the various bureaus of the department, were appointed by the Assistant Sec-

retary of Agriculture during the year to cooperate with State colleges of agriculture and extension services in agricultural activities, the chief or assistant chief of the division of agricultural meteorology being designated a member of each. These committees were appointed and worked chiefly during the latter part of the year, and their activities were progressing at its close. They were as follows:

RANGE COMMITTEE.—Data bearing on the range problem relating to the work of the Weather Bureau were prepared and submitted to the general committee.

RANGE EXTENSION TEACHING COMMITTEE.—A range handbook is under preparation. Weather Bureau data for inclusion in this have been submitted.

SPRING-WHEAT REGION COMMITTEE.—The assistant chief of division attended a conference of the Spring Wheat Regional Council at St. Paul, Minn., in January, 1923, at which it was decided to prepare a bulletin showing the physical characteristics of the spring-wheat region, about one-third of which should be devoted to climate; at the close of the year the preparation of the climatic section was well advanced.

OZARK COMMITTEE.—Weather Bureau material has been submitted for use of this committee.

COTTON COUNCIL.—Two subcommittees of the Cotton Council are working, namely, Forms and Functions of Local Associations and Statistical Investigations. This division is represented in both of these committees.

EXTENSION COMMITTEE.—This committee has made a final report to the Assistant Secretary, which includes a recommendation that each major bureau of the department detail an employee to give his entire time to extension problems, to be financed by the Extension Service.

Some preliminary arrangements were made for cooperation with the extension agents of the department in educational work in meteorology, i. e., informing the farmer and the business man what the Weather Bureau has available that would be of assistance to them and how it may be obtained. A trip was made by the official in charge through the Southeast and in some of the States east of the Mississippi River to acquaint the extension agents and others with the nature of our products, and to formulate plans whereby the information could be distributed in the most expeditious and widest manner possible.

PUBLICATIONS.

The following papers, prepared either by employees of the division, or by station officials cooperating, were published during the year:

- Influence of Weather on the Yield of Crops. J. Warren Smith. Monthly Weather Review, November, 1922.
- Frost Fighting in the Pecos Valley. C. Hallenbeck. Monthly Weather Review, January, 1923.
- Predicting Minimum Temperatures. W. J. Bennett. Monthly Weather Review. February, 1923.
- Precipitation of Africa. Research Series No. 13, American Geographical Society. (Included with Vegetation and Soils, by H. L. Shantz and C. F. Marbut.) By J. B. Kincer.

The Climate of the Great Plains as a Factor in Their Utilization. Read by J. B. Kincer at the annual meeting of the American Geographers, Ann Arbor, Mich., December, 1922, and published in the annals of that association.

AGRICULTURAL METEOROLOGY.

The regular weekly summaries of weather conditions and their effect on the advance of vegetation and farm operations were published, as during the preceding year, through the medium of the department bulletin entitled "Weather, Crops, and Markets." During the crop-growing season the weekly corn and wheat region bulletin was continued at Chicago, and a similar bulletin issued at New Orleans covered conditions in the Cotton Belt. The various section centers also issued weekly State summaries as usual, in most cases throughout the year.

At the more than 200 principal stations of the Weather Bureau the uniform policy is to secure station offices and quarters in Government-owned buildings free of rent wherever practicable. However, owing to conditions that fail to furnish satisfactory exposure for instruments, or otherwise provide suitable quarters for the bureau, it is necessary to rent offices in many cases. The following tabulation indicates conditions as of July 1:

STATIONS AND ACCOUNTS DIVISION.

Status of Weather Bureau offices at stations outside of Washington.

Free quarters and accommodations:	
Observatory buildings (owned and controlled by the Weather Bureau).....	46
State university buildings.....	5
Federal buildings.....	78
Total free of rental.....	129
Rented buildings, etc., owned by individuals or corporations:	
Office buildings.....	90
Buildings with kite-flying fields, aerological.....	6
Total number rented buildings partly or wholly occupied.....	96
Total.....	¹ 225

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

Special meteorological station at Valdez, Alaska, was discontinued March 31, 1923, and removed to Cordova, Alaska, where free office quarters were obtained. Telegraph-line repair station at Twin, Wash., was discontinued June 30, 1923.

LEASED QUARTERS.

Existing leases for office quarters and accommodations at 24 field stations of the bureau expired by limitation June 30, 1923. These involved a total annual rental, as heretofore paid, of \$19,371.36. In taking up the matter with lessors in each case it was found that at 13 of the stations new leases could be had at the same price as hereto-

¹ Three stations have quarters in two buildings, viz, Cape Henry, Va., two Weather Bureau; Cincinnati, Ohio, and Oklahoma, Okla., Weather Bureau and Federal.

fore, while at some of the remaining 11 stations exorbitant rentals were demanded, in one instance as much as 150 per cent increase, bringing the total to \$25,082.64, an increase of \$5,711.28. After extended negotiations office space was reduced and compromises effected whereby new leases were executed for these 24 stations at a total cost of \$22,794 for next fiscal year, an increase of \$3,422.64, a clear saving to the bureau of \$2,288.64 over and above rentals as originally demanded and keeping within the limits of the appropriation. Enforced removals were made at Tacoma, Wash., and Dayton, Ohio, due to building operations, and rental of roof of an adjoining high building for exposures of instruments at Dubuque, Iowa (\$100 per annum), is included in the above total.

FEDERAL BUILDINGS IN RELATION TO ADJACENT HIGHER COMMERCIAL BUILDINGS.

Federal buildings at places where the Weather Bureau has field stations generally are not more than three or four stories, and it is rare that suitable exposures for Weather Bureau instruments are available thereon. In recent years, and especially during 1923, the erection of higher commercial buildings in the vicinity of Federal buildings thus occupied has seriously interfered with the exposures of recording instruments. Funds for moving from free quarters to a rented building are in depleted condition, and in order to obtain proper exposures of instruments for meteorological observations which are of paramount importance it has been necessary in some instances to place the instruments on higher adjoining buildings, with electrical connections to registers in the office of the Government building, thereby avoiding payment of high rentals for office quarters.

REPAIRS AND UPKEEP OF WEATHER BUREAU BUILDINGS.

Only a few repairs were made to the buildings and grounds owned by the Weather Bureau during the year owing to limited funds. Repairs and repainting have necessarily been postponed from year to year and must now be taken up to insure proper preservation of this property.

Among the more important repairs and improvements effected during the year were those at Tatoosh Island, Wash., where a combined water-supply and electric-light equipment was installed, cistern water being the only available supply at this isolated place. This is collected from the roof of the observatory building and pumped into an elevated tank. Electric light (110-volt direct current) is furnished for the buildings and will also be utilized for storm-warning displays, all greatly improving the usefulness and efficiency of this important station located at the Pacific Ocean entrance to the Strait of Juan de Fuca.

At Sandy Hook, N. J., the two-story brick building erected August, 1914, has never been satisfactory as an observatory and residence for the official in charge due to porosity of exterior walls causing interior dampness. Applications of fluorspar compounds having failed to make the structure waterproof, the entire surface of the building was given two coats of magnesite stucco. Work was completed December, 1922, with effective results since.

Needed storage buildings were erected on the reservations at Cape Henry, Va., Burlington, Vt., and Abilene, Tex.

Conditions at Cape Henry, Va., were also greatly improved during the year by connections with the Norfolk Southern Railroad power line, thus securing better electric-light service for Weather Bureau buildings and storm-warning night displays made at that place.

SURPLUS BUILDINGS AND PROPERTY.

Weather Bureau buildings and grounds at Narragansett Pier, R. I., and Mount Weather, Va., remain surplus and unoccupied, in charge of caretakers. The sale, disposition, or rental of this valuable Government property has not been authorized as yet. Cost of only the most urgent repairs and upkeep amounted to about \$2,500 per annum, which expense is necessary in order to keep the property from being rendered wholly worthless. In the interests of economy and good business management something should be done in the matter without further delay.

TELEGRAPH DIVISION.

Telegraphic transmission conditions throughout the country during the year were what may be considered as normal, although general use of the multiplex system for message business by the principal telegraph company, instead of "hand" sending which prevailed previous to the war, reduced efficiency in some sections. This latter method, however, is still used for forwarding "circuit" reports, and the system was maintained at a uniformly high standard, despite varying weather conditions of adverse character.

Local service was performed during the first half of the year with difficulty, owing to shortage of operators due to resignations of trained men because of inadequate compensation and to harassing delays in securing successors. This situation resulted largely by reason of the low salaries paid by the Weather Bureau as compared with the more attractive ones which commercial establishments are enabled to offer for the services of first-class telegraphers. Equalization and adequate pay will doubtless ensue when reclassification becomes effective; meanwhile, further losses may be expected and are imminent.

Performance of the audit work of the division suffered somewhat until the disturbing conditions above referred to were remedied. Earnest and continuous efforts by the division force during the winter, however, brought this work up to date in the late spring. No opportunity occurred for revision and improvement of division records and other nonessential activities of a desirable character referred to in the last report which have lain dormant since the immediate post-war period because of frequent and long-continued losses in personnel.

Contracts were renewed on favorable terms with the various telegraph, telephone, wireless, and cable companies, with the exception of one telegraph company, with which there has been no formal agreement for several years, although the rates for service named in the last executed contract are continued indefinitely by informal agreement.

An important element of the communication service during the hurricane season is the prompt reception of cable messages from the

West Indies and the coasts contiguous to the Gulf of Mexico and the Caribbean Sea and of wireless messages from ships in these and Atlantic waters. The cable service was fairly good, but, as heretofore, inordinate delays in receipt of ship messages were experienced, largely due to static electricity which prevails during the summer months. It is not likely much improvement will occur until this handicap to prompt transmission is eliminated.

WEATHER BUREAU TELEGRAPH AND TELEPHONE LINES.

On the whole, these lines served satisfactorily the purposes for which they were constructed, namely, transmission to and from isolated stations on the Atlantic and Pacific coasts and in Lake Michigan, of meteorological reports, storm warnings, vessel and wreck reports, and miscellaneous Government and commercial messages.

The conductor used for many years for telegraphing in the submarine cable connecting Block Island, R. I., with the mainland, however, developed trouble for a while in the fall of 1922 and became permanently disabled on March 26 last. The Coast Guard immediately offered to attempt repair, but because of unforeseen troubles appearing in the machinery of the cable ship, repair was necessarily deferred for several months. In the meantime all telegrams had to be telephoned to and from the island. The conductor was repaired on July 1 and is now giving good service. It is liable, however, to break down at any time because of progressive electrolysis. In order that the large amount of telegraph and telephone business offered, especially in the summer, may be adequately taken care of, a new cable of greatly increased capacity should be laid by a commercial company immediately. This situation was presented several years ago to the presidents of the commercial companies directly interested without result. Two of the three conductors in this cable are leased to the New England Telephone & Telegraph Co. for telephone purposes, and it is only a question of time when the Weather Bureau will be compelled to terminate the lease and to assume entire control and operation and to build or lease land lines on the island and mainland in order to connect with a telegraph office.

Three other cables owned and operated by the bureau as telephone lines, viz, those connecting Beaver Island and North and South Manitou Islands, Lake Michigan, with the mainland, worked without interruption during the entire year. The line from Point Reyes to San Anselmo, Calif., connecting at the latter point with San Francisco via the Pacific Telephone & Telegraph Co., is also operated telephonically. General conditions were improved by a rerouting of 13 miles of the line and by substituting copper wire for the old galvanized-iron wire formerly in use. The 10-mile telephone line between Whitefish Point and Vermilion Point, Mich., was turned over to the Coast Guard March 1, which has supplied and now owns practically all the present material.

Two remaining lines are operated telegraphically, that between North Head and Fort Canby, Wash., 2½ miles, connecting with Portland, Oreg., by way of a War Department cable across the Columbia River, thence by Western Union wire from Fort Stephens, and the line from Tatoosh Island to Port Angeles, about 90 miles in length. These are not only vitally important to the Weather Bureau and other

Government interests, but also carry a large volume of commercial business.

Under changed operating conditions across the Columbia river, displacing the cooperative arrangement with the Western Union Telegraph Co. effective for many years, the Weather Bureau now pays for all business transacted beyond Fort Canby, the tolls amounting to about \$500 per annum. No revenue accrues to this line, except \$90 per annum for its use by the telegraph company for commercial business.

Frequent reconstruction and repair work has always been necessary on the Tatoosh-Port Angeles line because of its location in rough woodland territory. Devastation by heavy storms which occur during the winter and spring and damage resulting from logging operations constitute the chief causes of trouble. The usual amount of this work was accomplished during the past year. The winter repair station at Sekiou, midway between Clallam Bay and Neah Bay, and that at Twin were closed June 30. The repair work of the sections will be done by employees at the stations on each side, thus enlarging the areas of the several sections concerned and reducing to some extent operating costs. Rerouting and improving the county roads is still in progress, and as this work is completed in a section relocation along these roads of the telegraph line follows.

The Government receipts from all lines for commercial messages handled during the year amounted approximately to \$4,853. Expenses of labor and material for repair, reconstruction, and relocations amounted approximately to \$4,000.

NORFOLK-CAPE HENRY-HATTERAS (VA.-N. C.) SECTION (TELEGRAPH).

Owing to imperfect wire conditions south of Coast Guard station No. 179 during the first half of the year, considerable trouble was experienced in transmitting the large volume of business transacted over this line. During the latter half of the year 19 miles of new wire was strung, many poles reset, and new insulators installed over portions of this section, resulting in further improved operating conditions. The line is now in almost perfect working order, and when additional new insulators and poles are installed, which it is expected will be done in the near future, the line should be in excellent condition throughout its length of approximately 170 miles.

A new pole line was constructed and new copper wire strung for a distance of 1½ miles across New Inlet, which has completely filled up. This installation takes the place of a cable heretofore used for transmission across the inlet. The cable will be allowed to remain in place to be used in emergency cases.

Some short but necessary changes were made in the route of the line through the lighthouse reservation at Cape Henry and through the schoolhouse grounds at Hatteras.

Six hundred yards of line were blown down about 200 miles south of Cape Henry in April. Temporary repairs were made at once, but permanent reconstruction work will be deferred until the coming autumn. Three hundred poles and accessories were purchased during the year, the greater part of them having already been used in the reconstruction work above noted.

The line has been brought to its present satisfactory condition through the fine cooperation of the Coast Guard, which is largely interested in the upkeep of the pole line, as a metallic telephone circuit is maintained thereon, connecting near the Hatteras station with the Coast Guard line to Morehead City, N. C.

WHITEFISH POINT-VERMILION POINT (MICH.) SECTION (TELEPHONE).

For a number of years past replacement of poles and wire have been made by the Coast Guard and at its expense as the old materials became unserviceable. As practically none of the original line remained, jurisdiction and control of the present line was turned over to the Coast Guard on March 1, 1923.

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

These lines, consisting of both cable and land lines, although constructed 18 and 20 years ago, respectively, worked satisfactorily throughout the year. The Manitou lines are operated by Coast Guard officials, who perform the necessary occasional work of repair and upkeep, the materials for which are supplied by the Weather Bureau.

POINT REYES-SAN ANSELMO (CALIF.) SECTION (TELEPHONE).

This line connects through the San Anselmo exchange of the Pacific Telephone & Telegraph Co. with the Weather Bureau office in San Francisco, and is used for transmission of meteorological observations, vessel and wreck reports, forecasts, and storm warnings. The Lighthouse and Coast Guard Services also have large need for its facilities, and the latter contributes extensively to its maintenance. No commercial messages are handled. In February a section of 13 miles of wire was transferred from poles of the Western Union Telegraph Co. to those of the Pacific Telephone & Telegraph Co., thus affording improved auditory and maintenance conditions, copper wire having been substituted for galvanized-iron wire. Number of messages handled by the Weather Bureau, 1,481; cost of Weather Bureau of upkeep, \$8.64.

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

But little interruption occurred on either of these lines, except during a portion of the winter and in June. This was caused by a defective connection in the Alpena local exchange.

During the year some repairs were made costing \$97, but the extensive reconstruction contemplated as referred to in the last report has been deferred, with the expectation of accomplishing it during the coming autumn.

By means of the two lines of $27\frac{1}{2}$ miles in length, including $5\frac{1}{2}$ miles of submarine cable, marine interests are greatly benefited, as they not only enable the bureau to display storm warnings, but also to obtain accurate information regarding weather conditions from each point for dissemination.

NORTH HEAD-FORT CANBY (WASH.) SECTION (TELEGRAPH).

Since January 1 of this year the reciprocal arrangement between the Weather Bureau and the Western Union Telegraph Co. for service between Portland and North Head became inoperative because of the decision of the War Department to assess the latter company a definite annual sum for use of its cable across the Columbia River for transmission of commercial business. Previously the telegraph company had free use of cable facilities, first of the Weather Bureau cable and later of the War Department cable, in return for free use by the Weather Bureau of wire facilities between Fort Stevens and Portland. This change has not affected transmission of Weather Bureau business, which continues to be transacted directly between the Weather Bureau offices at North Head and Portland, but greater cost is entailed.

The Weather Bureau land-line facilities between Fort Canby and North Head are utilized by the telegraph company for a nominal consideration. Interruption between North Head and Portland totaled 175 hours, nearly all of which occurred on the Washington side of the Columbia River.

Commercial business increased greatly during the last three months of the year, owing to better facilities for communication with Alaska and with ships having been provided in the rebuilding of the naval radio station at North Head, with which the Weather Bureau wire connects.

It seems unnecessary to give detailed accounts of the several lines operated by the bureau, as these have been given in previous reports, and conditions are not materially different at the present time. A list of the lines, however, is given below.

Block Island and Matunuck Beach, R. I.—Telegraph line, two-wire, leased to commercial company for telephone communication.

Norfolk-Cape Henry, Va., and Hatteras, N. C.—Telegraph line.

Whitefish Point and Vermilion Point, Mich.—Telephone line.

Beaver Island and Charlevoix, Mich.—Telephone.

North and South Manitow and Sleeping Bear Point, Mich.—Telephone.

Alpena, Middle Island, and Thunder Bay Island, Mich.—Telephone.

Point Reyes and San Anselmo, Calif.—Telephone.

North Head and Fort Canby, Wash.—Telegraph.

Tatoosh Island and Port Angeles, Wash.—Telegraph.

AEROLOGICAL INVESTIGATIONS.

Free-air observations by means of kites and balloons were continued throughout the year. This work has become an important integral part of the Weather Bureau's program.

KITE STATIONS.—Observations with kites were made regularly at Broken Arrow, Okla.; Drexel, Nebr.; Due West, S. C.; Ellendale, N. Dak.; Groesbeck, Tex.; and Royal Center, Ind. Kite flights are made daily, whenever possible, and in addition, when conditions are favorable, continuous series of flights are made for periods of 24 to 36 hours. Records of air pressure, temperature, humidity, and wind are thus obtained.

PILOT-BALLOON STATIONS.—Observations by means of pilot balloons were made at the six kite stations, above listed, and at Burlington, Vt.; Denver, Colo.; Ithaca, N. Y.; Key West, Fla.; Lansing,

Mich.; Madison, Wis.; San Francisco, Calif.; San Juan, P. R.; and Washington, D. C. The observations are made twice daily at the six kite stations and at Key West, Fla., and Washington, D. C., and once each day at the remaining stations, and the computed wind conditions at various heights are telegraphed to district forecast centers at Washington, D. C.; Chicago, Ill.; and San Francisco, Calif.; where they form the basis for "flying weather" forecasts issued to the military, naval, and postal aviation services.

Special observations have been made, when requested, for use in connection with long-distance flights, free-balloon races, etc.

Observations with two theodolites have been continued, whenever opportunity afforded, in order to check the accuracy of the formula for rate of ascent of balloons and the behavior of the balloons themselves at high altitudes. These observations have shown that the revised rate of ascent formula gives extremely reliable results, except when there are pronounced vertical movements in the atmosphere. Even then the error is appreciable only in the lower layers.

COOPERATION.—Effective cooperation with the Army and Navy meteorological services has been continued throughout the year. Each of these services maintains a number of pilot-balloon stations, whose primary purpose is to furnish data of immediate local interest to aviators at flying fields. These observations are also telegraphed to district forecast centers of the Weather Bureau for use in issuing "flying weather" forecasts. They thus supplement, in a very helpful way, the observations made at Weather Bureau aerological stations. In addition to the stations in the United States proper the Navy maintains one at Santo Domingo, Dominican Republic, and one at Coco Solo, Canal Zone, which, together with those of the Weather Bureau at San Juan, P. R., and Key West, Fla., furnish information of value in connection with the development and movement of hurricanes. A much larger number of stations is necessary, however, to make this service as effective as it should be.

In cooperation with representatives of the United States Air Service, the air-mail flight records for one year were analyzed and studied in connection with the Weather Bureau's kite and balloon data, and the results of this investigation were published under the title "The Wind Factor in Flight: An Analysis of One Year's Record of the Air Mail."

The official in charge of aerological investigation is the Weather Bureau representative on a sectional committee that is preparing an aeronautical safety code. The committee is composed of representatives of the Departments of War, Navy, Commerce, and Post Office, the Society of Automotive Engineers, the National Aeronautical Association, and aircraft manufacturers. The code, when completed, will provide regulations for the design and manufacture of aircraft, qualifications of pilots, establishment of airdromes and airways, and dissemination of meteorological forecasts and warnings, etc.

CENTRAL OFFICE.—All observations made at kite and balloon stations by the Army and Navy, as well as by the Weather Bureau, are forwarded to the central office of the Weather Bureau for final reduction and study. Data based upon these observations are furnished in answer to numerous inquiries, not only from other Gov-

ernment departments but from commercial aviation concerns as well. In many cases reprints of special discussions and summaries were issued in answer to these requests.

Work has been continued on the preparation of a summary entitled "An Aerological Survey of the United States." When completed, this will contain the results of all free-air observations made in this country.

The publication of monthly summaries of free-air conditions in current issues of the Monthly Weather Review was begun in January, 1922, and has been continued.

During the year there was brought to completion an exhaustive study of the relations existing between surface winds and temperatures on the one hand, and free-air pressures on the other, the purpose being to make possible the construction of pressure maps for upper levels for use in forecasting. This has been published as Supplement No. 21, entitled "The Preparation and Significance of Free-Air Pressure Maps for the Central and Eastern United States." A preliminary application has yielded encouraging results, and it is believed that with further extension of the study important and valuable aids to forecasters will be provided.

CLIMATOLOGICAL DIVISION.

METEOROLOGICAL REPORTS.

The work of checking receipt of and the examination of meteorological forms from all classes of stations, the preparation of letters correcting errors discovered in these reports, their filing, and final assemblage and binding for preservation have gone forward promptly, and the several processes of accomplishing these are as near up to date as feasible.

PUBLICATIONS.

The Annual Report of the Chief of Bureau, 1921-22, was prepared and printed as usual, and special effort was made to make the chapters on windstorms, hail, etc., as complete as possible.

The summaries of climatological data from the various States were published without material change from the style last adopted. A useful feature of the climatological data for the California section was provided for in the form of an annual summary showing by months and for the season the precipitation for that section during the rainfall season 1921-22—that is, from July 1 to June 30—instead of for the calendar year. This summary is issued as promptly as possible after July 1, and gives to those interested in the seasonal distribution of precipitation in that State the earliest possible facts. The publication has been well received by the water interests of the State and may be extended, if found desirable, into other Pacific States where precipitation conditions are similar to those of California.

A special effort was made at the close of 1922 to have printed for each of the regular stations an annual summary of station weather data for that year, together with tables of monthly and annual means of temperature and monthly and annual totals of precipitation, for the entire period of observations at the respective stations, as these data, particularly those of the monthly and annual temperatures,

heretofore had not appeared in convenient form for distribution and study. This work was accomplished largely by the hearty cooperation of the office forces at the various stations provided with printing facilities, and much credit is due station officials for the spirit of cooperation exhibited, particular attention being invited to the Fort Worth, Tex., office, where more than 20 such reports were printed. These reports serve many needs at the stations and are greatly in demand for answering questions concerning local weather conditions.

COOPERATIVE WORK.

The gathering of weather data by our large army of cooperative observers progressed as usual, though no great effort was made to extend this work, save in a few localities where the absence of a permanent population interferes with the collection of continuous data.

As indicating the increasing demands for weather information in connection with business interests, attention is invited to the numerous requests for the opening of new observing stations and the willingness of individuals, companies, and other organizations to furnish, without cost to the Government, the necessary outfit of instruments, provided the bureau will advise as to the selection of the necessary apparatus, supervise its exposure, and have general control of the observations in order to assure the collection of reliable data. The country is mainly so well covered with reporting stations that no material extensions are required, and such new stations as are being opened, particularly those recording temperature, are mainly at the expense of those requiring the service.

Cordial cooperation continues with many departments and bureaus of the Government in securing observations from localities which otherwise would be unrepresented on account of scarcity of population. This is particularly the case with the Forest and Indian Services, whose employees cover areas having no stable population.

INSPECTION OF COOPERATIVE STATIONS.

On account of lack of sufficient funds for several years, the inspection of cooperative stations has been badly handicapped, and a crying need for wholesale inspections is now apparent. As stated in previous reports, such inspections are necessary to establish that personal connection between the bureau and the cooperative observer which seems so necessary to permanent cooperation. In fact, the lack of this contact is believed to be the weakest point now existing in our system of cooperation in collecting weather data.

WEATHER INSURANCE.

The demands of the public for protection on account of changes in the weather, in every conceivable manner, have necessitated on the part of insuring companies the collection and careful study of precipitation statistics, and many calls have been made on this division, as well as the various stations, for data on the distribution of precipitation during the various parts of the day and otherwise, in order to arrive at rates reasonable to those seeking protection and safe to the insuring companies. The general matter of rain insurance has necessarily entered into the field of our cooperative

observers, who receive many requests for statements concerning the precipitation for certain specified periods. These requests will doubtless greatly increase as this form of protection grows, and it promises serious complications in the way of payment for service, possible errors of record due to attempts to secure data for other than the regular hours of observation, etc.

SPECIAL WORK ACCOMPLISHED DURING THE YEAR.

The preparation of the daily normals of maximum, minimum, and mean temperatures was continued during the year, the reduction of the short-record stations to the full 46-year period being a task of great magnitude, and only slow progress has been possible owing to press of current work.

The reprinting of the sections of Bulletin W, which had made good progress during the preceding year, made little advance during the fiscal year just closed, on account of lack of funds. The printing of 25 additional of these sections was authorized near the close of the year, but they still remain unprinted.

The program outlined some years ago for collecting, tabulating, and printing of weather statistics from foreign countries was taken up during the fiscal year just closed by the assignment to the division of an assistant versed in such matters. Considerable progress has been made in assembling the data for the Central and South American States, and one section, that on Central American States and adjacent areas, has been published in the *Weather Review* and separates obtained for distribution as required. Other sections for the principal South American countries are mainly ready for publication, but are being held for additional data that may be forthcoming from other sources than our library affords.

A proposed section covering the islands of the Pacific is also well on the road to completion.

THE MONTHLY WEATHER REVIEW AND PRINTING.

The *Monthly Weather Review*, now in its fifty-first year of publication, continues to serve as an important medium in the diffusion of information concerning the results of research in meteorology in all parts of the civilized world. It also enables the United States to meet its international obligations to furnish other nations and Governments with a statistical résumé of the meteorology and climatology of an important part of the North American Continent.

The number of copies of the above-named publication that shall be printed for free distribution has been limited. As the demand for it increases it becomes embarrassing to distinguish between those who should receive it gratis and those who should be required to subscribe for it through the Superintendent of Documents. The experience of the bureau leads to the belief that the time is fast approaching when free distribution to individuals as such must be restricted to those who can qualify under certain broad requirements, such, for example, as being a collaborator or cooperator with the bureau, an educational institution offering a course in meteorology, libraries, and workers in agricultural colleges and experiment stations.

On account of the special courses being given by educational institutions throughout the country in meteorology and kindred sub-

jects, the demand for all publications has increased considerably. It has been the policy to comply with these requests in such numbers as the existing regulations will permit. Applications for publications from individuals receive prompt and careful attention. In case the publications are exhausted or can not be supplied the applicant is so advised.

During the year several new publications were printed, including a chart of Description of Cloud Forms and two Monthly Weather Review Supplements, entitled "The Spring Floods of 1922" and "Thermal Belts and Fruit Growing in North Carolina." These supplements contain valuable meteorological data for which there has been a considerable number of requests from institutions, engineers, and specialists in this particular work.

Paid subscriptions for the daily weather map have increased. Insurance companies, specializing in rain insurance, have found the daily weather map and climatological statistics an important factor in their work. The increase in subscriptions for the Monthly Weather Review through the Superintendent of Documents has made it necessary to furnish additional copies to meet the public demand. The present subscription price of the Monthly Weather Review is \$1.50 per year, payable in advance to the Superintendent of Documents, Government Printing Office, Washington, D. C. The Monthly Weather Review Supplements are available for purchase through that office at a price furnished upon application, provided the edition is not exhausted. They are not included in the subscription for the Monthly Weather Review. The mailing lists of the Weather Bureau have been revised and brought up to date, resulting in the discontinuance of a number of subscriptions.

Under the regulations prescribed by the congressional Joint Committee on Printing, quarterly printing-plant reports and annual inventory reports from 97 field stations and the printing office, Washington, D. C., were rendered to the chief, Division of Publications, Department of Agriculture, for transmittal to the committee. The data furnished on each of these quarterly reports include number of jobs, total number of copies, number of type pages per copy, number of illustrations, total cost of printing and binding, editorial cost, and the proportionate salary for the quarter, and number of employees engaged on the work. Samples of all work performed during the quarter are attached to these reports. The inventory report rendered annually includes the printing and material and equipment on each of the field stations and the printing office, Washington, D. C., with the cost of each item of machinery or equipment, and the estimated value at the present time. These reports also show whether the plant is housed in a Government-owned building or rented property. Contract-printing and printing-machinery reports are also rendered quarterly.

INVESTIGATIONS IN SEISMOLOGY AND VOLCANOLOGY.

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

Instrumental records have been obtained by instruments owned and operated by the Weather Bureau at Washington, D. C.; North-

field, Vt.; and Chicago, Ill. Similar data have been secured for publication from various seismic observatories distributed from Panama to Canada and from the Hawaiian Islands to Porto Rico.

The noninstrumental reports rendered by the regular and cooperative observers of the Weather Bureau recorded 84 separate earthquakes strong enough to be felt by the unaided senses in continental United States during the calendar year 1922. Although some of these were felt over wide areas, none resulted in appreciable damage. No important earthquakes occurred in our outlying possessions.

Special investigations and observations of volcanic phenomena have been steadily conducted at Kilauea. In the main, activities at this place have been mild, and at the time of this report the volcano is practically dormant.

LIBRARY.

During the fiscal year 968 books and pamphlets were added to the library, bringing the total strength of the collection up to about 42,000 volumes.

In addition to these books, which are kept at the central office in Washington, though available for loan to stations, there have been issued to stations for permanent use during the past 25 years more than 11,000 books, generically described as "station textbooks." Allowing for books withdrawn, discarded, lost, etc., the number of such books now permanently deposited at Weather Bureau stations is estimated at more than 8,000, not including files of Weather Bureau publications and various miscellaneous books of which no record is kept at the central office. An especially strong collection of meteorological literature has been assembled at the Chicago station. This collection contains many rare works, including files of the leading meteorological journals and foreign official reports, and has been gathered to serve as a reserve library, from which books could be transferred to the main library in Washington in case of loss of the latter by fire. Station libraries are used to some extent by the public as well as by the personnel of the stations. Inquiries for meteorological information addressed to the central office are in many cases answered by referring the inquirers to books accessible at Weather Bureau stations.

OCEAN METEOROLOGY.

This work is sustained by the cordial cooperation of many shipmasters making daily observations at Greenwich noon. The number of reports rendered was adequately maintained, in so far as the regions traversed by the principal trade routes were concerned, and the matter furnished for periodical publication on the Pilot Charts and elsewhere was prepared in the usual manner, and the Hydrographic Office was assisted in the revision of texts relating to cyclonic storms for its publications.

An important feature of work accomplished during the year was the preparation of a comprehensive article on the tropical storms of the eastern North Pacific Ocean, off the west coast of Mexico and Central America. This work was undertaken in the interest of the

shipping in those waters, which has greatly increased in volume since the opening of the Panama Canal.

Requests have recently been renewed for the Weather Bureau to increase its contributions of data relating to world meteorology. Further participation in this work, however, must await increase of force.

INSTRUMENT DIVISION.

THE INSTRUMENT INDUSTRY.—Conditions during and immediately following the war which made it difficult to obtain instruments from Europe have been followed by the stimulating effect created by demands from the Army, Navy, Air Service, and Shipping Board, and from industrial concerns, for meteorological instruments. American manufacturers have hence been justified in undertaking the manufacture of instruments heretofore largely imported, so that practically all the instruments used by the Weather Bureau are now obtainable in this country. However, clocks for the recording cylinders of thermographs and barographs await further development, and there is considerable promise along these lines also. The present tariff schedule requires the various branches of the Government to pay from their appropriations the same import duties as are paid by anyone else; hence there is no financial advantage to a bureau in purchasing instruments abroad, and such conditions are favorable to the upbuilding of a stable and dependable meteorological instrument industry in this country.

The storm-warning display equipment, which was thoroughly overhauled several years ago, has required little repair, except on the Gulf coast, where changes in organization and the rapid deterioration of ironwork have required a considerable number of replacements. The three-lantern system of display, now in satisfactory operation throughout the bureau, has not been found unduly expensive to maintain.

Exposures of instruments at a number of first-order stations are becoming impaired by the rapidly increasing erection of high office buildings. The problem is not solved by moving the instruments to the higher building. While the wind instruments are given a better exposure by such a removal, the rain-gauge exposure is seriously impaired. Meteorological stations in parks or suburban observatories offer the best solution of the problem of securing sound meteorological data in the large cities.

The evaporation program inaugurated in 1916 has been continued, with about 50 stations rendering regular reports, which are published in the State section reports. Many requests for additional stations have had to be refused because funds were not available for extensions. The data being accumulated are of much value, particularly at this time of increased interest in water resources. A careful digest of accumulated evaporation records is much needed.

Measurements of rainfall for short periods at places where outdoor events are insured against rainfall are in increasing demand. The conditions set forth in insurance policies require exactness, particularly as to time, while the large amounts sometimes named in the policies justify unusual precautions against unauthorized interference. Three of the weighing-recording gauges described in Circular

E, Instrument Division, have been issued for this purpose, and, in an effort to secure a less expensive gauge that would assist observers, an 8-inch gauge has been fitted with an attachment that automatically shifts the flow to the measuring tube at the beginning of the insurance period and out of the tube at the end of the period.

The investigations in anemometry by Messrs. Fergusson and Covert, begun in 1922, are nearly completed. Final corrections for the present standard and many other patterns have been determined throughout the range of the natural wind for the first time in the history of anemometry, and from a group of instruments of an improved pattern it is expected that there will be selected a new standard whose indications will be more nearly constant than those of the present standard. This work has been made possible by the kind cooperation of the Bureau of Standards.

The advice of the Weather Bureau is being sought with increasing frequency regarding ways and means for protection against lightning, which inquiries are largely due to the extensive circulation of Farmers' Bulletin No. 842, "Modern Methods of Protection Against Lightning."

During the past year and a half Roy N. Covert has represented the Weather Bureau on a sectional committee of the American Engineering Standards Committee, which is developing a standard for the protection of buildings and other property against lightning. The American Institute of Electrical Engineers and Bureau of Standards are acting as sponsors for this standard, which should be available for public use during 1924. As stated in the introduction to the standard, its purpose is to promote the prevention of fire and other loss from lightning by directing attention to the best available means of protection. Practically all organizations interested in protection against lightning are represented on the sectional committee.

The exhibit work of the Weather Bureau is now merged with the general exhibit work of the department, exhibits being made largely by subjects rather than by bureaus. Under the present plan a committee is created for each major exhibit, with a representative from each bureau of the department, to bring before the general committee the facts that his bureau can contribute. The chief of the Instrument Division is the Weather Bureau representative on committees now preparing the 1923-24 exhibits.

SOLAR RADIATION INVESTIGATIONS.

As in past years, the intensity of solar radiation at normal incidence has been measured on days when the sky was free from clouds at Washington, D. C.; Madison, Wis.; and Lincoln, Nebr. The total radiation received on a horizontal surface directly from the sun and diffusely from the sky has also been continuously recorded by automatic instruments. The results have been published each month in the *Monthly Weather Review*.

A thermoelectric pyrliometer has been devised and constructed in the Weather Bureau machine shop for use in connection with a recording voltmeter to obtain continuous records, not only of the total radiation received on a horizontal surface but also of the in-

tensity of solar radiation at normal incidence. Pyrheliometers of this type are now in use at Washington; one has been furnished to the Chemical Warfare Service for experimental work at its arsenal, Edgewood, Md., and two others are about ready to be installed at the Weather Bureau observatories at the University of Chicago, Chicago, Ill., and in Central Park, New York. A description of this pyrheliometer has been published in the *Monthly Weather Review* for May, 1923, and in the *Journal of the Optical Society of America*, and *Review of Scientific Instruments* for September, 1923.

A convenient method has been devised for the determination of the intensity of daylight that may be expected at window openings in the country, on city streets, or on open or closed courts. Briefly stated, the method utilizes the measurements of sky brightness and daylight illumination made by the Weather Bureau in recent years and determinations by the Weather Bureau and others of the coefficient of diffuse reflection of different materials to determine the brightness of the various surfaces that are visible from a window, such as sky surface, lawn or street surface, the walls of buildings, etc. A complete demonstration of this method has been prepared for publication in an early number of the *Journal of the Illuminating Engineering Society*.

The Weather Bureau received 1 of the 12 Owens dust counters which were distributed to observatories in 12 different countries by the Bureau of Section (C), Meteorology, of the International Union of Geodesy and Geophysics and is taking part in an international investigation of the dust content of the atmosphere. Since December 7, 1922, a determination of the number of dust particles per cubic centimeter has been made on each working day and the character of the particles noted. Most of the determinations have been made in a suburb of Washington, but on some days measurements have also been made on the street near the center of the city and also at the top of the Washington Monument, 500 feet above the street level. Through the cooperation of the Army Air Service a few examinations of atmospheric dust have been made during airplane flights up to a height of 12,000 feet above sea level, and arrangements have been made for more observations of this character. For this purpose a modification of the Owens dust counter has been designed and constructed in the Weather Bureau machine shop.

Besides city smoke and particles taken up from the surface of the earth by the wind, occasionally particles are found that appear to be of volcanic origin or even from some source other than the earth.

The investigation has special reference to atmospheric pollution in cities, and also to atmospheric transparency, which is of prime importance to aviators.

In cooperation with the Chemical Warfare Service experiments were conducted at the Edgewood Arsenal, Md., to determine the efficiency of a smoke barrage, such as is employed by the Army to cover the movements of troops, in protecting orchards and other forms of vegetation from damage by frost. The results, which have been prepared for publication, confirm our previous conclusions that the most practical and economical method of combating frost is to heat the surface layer of air by the combustion of some form of cheap fuel.