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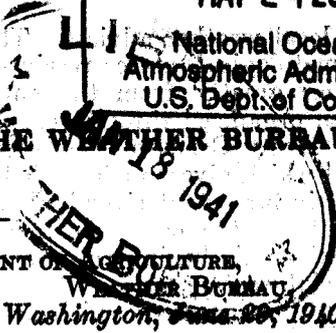
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National Oceanic & Atmospheric Administration
U.S. Dept. of Commerce

U.S. Weather bureau

[Administrative]

REPORT OF THE CHIEF OF THE WEATHER BUREAU,
1940



UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU

Washington, June 30, 1940.

HON. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I present herewith the report of the Weather Bureau for the fiscal year ended June 30, 1939, the last of a long series of annual reports as a unit of the Department of Agriculture.¹

Sincerely yours,

F. W. REICHELDERFER, Chief.

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INTRODUCTION

The fiscal year 1940 saw greater development in many branches of the national weather service than any other similar period for many years. In his annual budget the President had recommended appropriations to permit sound growth of important phases of this service which had long needed modernization, and the Congress, recognizing the growing importance of meteorological information in modern air transport, agriculture, business, commerce, and industry, provided funds to support most of these recommendations. The airways weather branch was amplified by addition of observations in blind spots in the network and by increase in upper-air soundings which are essential for general weather service as well as for air transport. The general forecast and warning service was improved by providing for four weather maps per day in parts of the country and by organizing two new forecast districts which can give greater attention

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¹The Weather Bureau was transferred to the Department of Commerce, effective June 30, 1940 (Public Res. No. 78, 76th Cong.—approved June 4, 1940), in accordance with the President's Reorganization Plan No. IV, submitted to the Congress on April 11, 1940, pursuant to the provisions of the Reorganization Act of 1939 (Public No. 19, 76th Cong.—approved April 8, 1939).

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

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to local weather advices. The agricultural weather service and the climatological service received modest increases, the latter also benefiting greatly from the enlarged hydrologic program which has been organized through cooperation of the flood-control agencies of the Army Corps of Engineers and the Department of Agriculture and which gives much needed reports and planning statistics on rainfall in important river basins. Congress also provided for improvements in the ocean weather service in the Atlantic and Gulf of Mexico. A beginning was made in long-needed extension of the special weather services for warnings of fruit frost conditions and of forest-fire dangers which accompany unusually low humidities and lightning storms.

Extension of these weather services has been in accordance with the general program of the Bureau for developing the national meteorological service and encouraging progress in weather science through research, as stated in our last annual report.

In the following pages the most important projects of the year are briefly presented. No attempt is made to give a comprehensive review of the regular service activities of the Bureau. This information is contained in other publications. The process of shaping the organization to render the best possible weather service was pursued through consolidation and coordination of offices in the field and through changes in the administrative structure of the Central Office in Washington. City offices were combined with airport offices in 16 cities where it was found that more effective 24-hour service to all interests could be provided from the airport station. Such consolidations will be accomplished progressively in localities where the facilities of the Weather Bureau airport offices are adequate to render general weather service without impairing the special service to aviation or curtailing the meteorological aids for agriculture, business, industry, and other interests. In most cases such consolidation results in a better and more comprehensive weather service for the general public.

Among the projects completed during the last year the following are cited because of their interest to the public and their role in providing better weather information for important country-wide activities:

On July 1, 1939, the official observations of the Weather Bureau were transferred wherever practicable to its airport locations for the purpose of providing reports and records more representative of open-air conditions and better suited to the various uses of business and professional interests. Pursuant to the policy of decentralizing the weather forecast and warning services of the Bureau and establishing smaller forecast districts so that forecasters can devote closer attention to local weather conditions, two new forecast districts were established and a third authorized. These are the Kansas City district, comprising Missouri, Kansas, and Oklahoma; the Albuquerque district, comprising Arizona, New Mexico, and western Texas; and the Boston district for New England which is scheduled to begin service prior to January 1, 1941. Plans are now being completed for a special forecast organization for the Los Angeles area. The remaining large forecast districts will be organized into smaller units as rapidly as funds and personnel can be made available. The air-

ways weather work has been greatly expanded to meet the growing needs of air transport and two new districts have been established for the administration of this service. Wherever possible the airways weather-service districts are made to coincide with the general weather forecast districts. The hydrologic program which has been organized in cooperation with the Corps of Engineers, United States Army, is an important contribution toward an adequate climatological network for the entire country. This will remedy the deficiencies in data long felt by agronomists, engineers, and other professions in which more accurate statistics of weather elements such as rainfall and temperature are needed. The number of cooperative climatological stations has been increased in connection with this program to the limit of present facilities. These stations, which cost a negligible sum compared with the value of their reports to agriculture, aviation, and engineering, should be increased in number twofold or threefold to give an adequate coverage for the United States.

A recent country-wide survey of the uses of the Weather Bureau gives some indication of the vital part which weather and meteorological service play in the economic life of the Nation. This survey reveals that the savings attributed by business and industry to weather reports, forecasts, and warnings issued by the Bureau are more than 3 billion dollars annually. Many activities could not operate successfully without the daily weather service. As the science of meteorology advances and the weather service becomes more specialized and reliable, the number of its users and the variety of its uses in business and industry rapidly multiply. In some of the more modern fields, such as flood control, soil conservation, agricultural planning, and light and power utility services, meteorological information is essential to economies in operation. While much of the information needed is within the present scope of the science, the Bureau's facilities cannot meet all requests. In order to meet these needs as effectively as possible, planning conferences have been held with representatives of various interests and a program laid down to coordinate services and, through cooperation with private meteorologists, to extend the benefits of applied meteorology as far as possible to the business and commercial life of the country.

A list of the daily uses of weather reports and forecasts by various occupations and professions of Nation-wide scope runs into hundreds of items. A few of the less known, selected from different fields, are illustrative of the public's deep-rooted interest in meteorology. It is hardly necessary to recall that the air-transport pilot relies on the hourly and special weather reports to show the way around bad storms and point out alternate safe landing fields clear of fog or storm; that the airport planner needs weather statistics and summaries to select a suitable site and to orientate runways and hangars properly with respect to prevailing winds; and that the operator and dispatcher need data of winds aloft to plan their flight schedules. It is not so well known that the large flour mills and the bakeries which specialize in fancy cakes and cookies lose thousands of dollars daily in materials ruined in processing if they do not know in advance of certain extreme humidity conditions and make preparations therefor. Nor is it generally known that the published weather map permits economies amounting to hundreds of thousands of dollars to coal

mines and coal shippers throughout the country by enabling them to distribute carloads where most needed, and to reroute when necessary to meet the demands in an area threatened by a cold wave.

Similarly, the watermelon wholesaler, the ice-cream manufacturer, and the perishable-fruit shipper diverts his shipments from a cool region where there is little demand to a section where hot weather is due and the demand will increase. The great dairies which ship by refrigerator cars increase the amount of refrigerant for a hot spell to avoid serious loss through spoilage. If cool weather is in prospect the amount of refrigerant can be reduced and hundreds saved in operating costs. Hydroelectric systems avoid the cost of starting their steam plants when weather forecasts indicate that the dwindling supply of water will be replenished by heavy rains in a day or two. The street railway gets out its snow plows and the city street department takes on hundreds of employees when a heavy snowstorm is forecast. Thus, the streets and tracks are kept clean and the snow has no chance to accumulate and tie up traffic. The city's business, which is almost inevitably paralyzed when a heavy snowstorm comes unexpectedly, goes on without serious interruption. Warned of a cold wave or a blizzard, the cattleman drives his herds to shelter, the shipper holds his perishables in the warehouses, the orange grower harvests his nearly ripe fruit or lights his orchard heaters, and the savings from loss in stock and fruit run into millions of dollars in a week. The master of a vessel remains in port or changes his course to avoid a damaging hurricane of which he is warned by radio from the Weather Bureau. The merchant, reading of approaching rain and cold, changes his advertised special from straw hats and sportswear to umbrellas and topcoats. The yacht clubs and beaches are warned of a coastal gale and high tides in time to protect small craft and evacuate the people, and thus almost certain loss of life and heavy damage to movable property are largely avoided. These are a few of the scores of ways in which the weather service safeguards the lives and property of the Nation day after day, workday and holiday, throughout the year.

In the national-defense program the Weather Bureau, with other Federal agencies, has been called upon to prepare its service for national emergency. In modern military operations a foreknowledge of meteorological conditions which influence a maneuver or a campaign is often the key to successful planning. In 1917-18 the shortage of expert meteorologists was keenly felt by all military branches. To prepare for possible needs, an extensive schedule of training for additional meteorologists is being put into effect through cooperation between the Weather Bureau, the Civil Aeronautics Administration, and civilian universities. It is expected that two or three hundred more meteorologists will eventually be trained in this program.

On the last day of the fiscal year covered by this report the Weather Bureau became an administrative part of the Department of Commerce, under provisions of the President's Reorganization Plan No. IV. The purpose of this plan is to bring the Weather Bureau into closer coordination with the Civil Aeronautics Administration and with the aeronautical interests of the country which find

meteorological service indispensable. The transfer from the Department of Agriculture, where the Weather Bureau was organized almost 50 years ago, does not involve any curtailment of its work for agriculture and other general business and commercial activities. In his message of transmittal the President states:

The importance of the Weather Bureau's functions to the Nation's commerce has also led to the decision to transfer this Bureau to the Department of Commerce. The development of the aviation industry has imposed upon the Weather Bureau a major responsibility in the field of air transportation. The transfer to the Department of Commerce, as provided in this plan, will permit better coordination of Government activities relating to aviation and to commerce generally, without in any way lessening the Bureau's contribution to agriculture.

This view gives promise of further development in meteorology and increase in its usefulness to the Nation. It is expected that the program previously referred to will continue along sound and economical lines to develop the work of the Bureau in meteorology and climatology and their service applications. Two phases of development which are very important and to which only brief reference is made in this report are (1) research and (2) education, or in-service training. There can be little progress in a science or a service based upon applied science without research which reveals new scientific possibilities and training which keeps the personnel of the organization abreast of scientific developments and modern technique. With rapid progress in meteorology, it is all the more important to provide a continuous training process in order that meteorologists in the Government service may maintain their professional qualifications. During the past year, noteworthy progress has been made in this task. A résumé is contained under the appropriate paragraph in following pages.

REORGANIZATION OF THE CENTRAL OFFICE

Prior to June 1940 the administrative headquarters of the Weather Bureau in Washington, usually called the Central Office, had functioned through divisions based upon projects or types of service. These divisions as distinct meteorological services were to some extent complete and self-sufficient units. As their work was extended throughout the country the possibility of overlapping and duplication of activities arose. Moreover, as local Weather Bureau services gradually were consolidated at airports the distinction between the duties of the divisions tended to disappear. It was advantageous to reorganize the technical service divisions of the Central Office in order to base their duties logically upon the fundamental functions of the Bureau. The organization now operates under three broad headings: (1) the technical service group which includes the divisions of station operations, synoptic reports and forecasts, climatology, and instruments; (2) the scientific services group which includes research, education (in-service training subject matter and coordination of work with universities), library, and professional publications; (3) the staff services group which comprises budget, business administration, personnel management, and supply. This organization provides for functional operations which can be expanded as necessary without overlapping of basic duties among divisions.

WEATHER SERVICE FOR CIVIL AIRWAYS

New airways forecast and general supervising stations were established at Albuquerque, N. Mex., and Billings, Mont., during the year to provide service in areas not adequately covered by existing networks. The Albuquerque station also issues regular State and general forecasts in addition to airway forecasts. An additional qualified forecaster was added to each of the other 11 airway-forecast centers to ameliorate acute shortage in staffs.

New airport stations, which render 24-hour service each day, take 4 pilot-balloon observations and prepare 4 weather maps, were established at 30 major air terminals.

Instruments were provided for stations on 10 new airways. Thirteen new off-airway stations reporting each 6 hours were established. In addition, 13 existing off-airway stations were equipped to provide reports at 3-hour instead of 6-hour intervals, as formerly.

The service in Alaska was improved by the establishment of a first-order station at Anchorage with pilot-balloon observations, and the organization of forecast centers at the existing stations at Fairbanks and Juneau. The Nome station was also strengthened by two more employees. Sixteen new second-order stations to report each 6 hours were established in the Territory during the year.

Ship reports from the Atlantic Ocean west of the 35th Meridian were increased from 2 to 4 times a day from each ship. The number of reporting ships was increased. All ships in the Atlantic now report fully in international code. This service was organized not only for the benefit of marine navigation but also to provide meteorological protection for flights to and from the United States and Europe over the Atlantic Ocean. The Newark, N. J., airway general supervising and forecast center was transferred from Newark to La Guardia Field, Long Island, N. Y., and the staff increased to provide forecasts for ocean flights. The number of airway general supervising and forecast centers is now 14 (including Juneau, Alaska). At the end of the fiscal year, 92 first-order airport stations which prepare weather maps, make hourly weather reports, pilot-balloon observations at 6-hour intervals, and provide meteorological advices 24 hours daily were in operation.

Since February 1940, two Coast Guard cutters have been stationed between New York and the Azores for the purpose of making daily weather observations and to replace to some extent the daily reports from merchant vessels which have been greatly curtailed since the outbreak of war in Europe. Surface observations each 6 hours, twice-daily pilot-balloon, and one daily radiosonde observations are made. The Weather Bureau furnished the meteorological equipment and has assigned three men to each vessel. The vessels are relieved alternately after a 3-week period at their ocean stations. The reports from these vessels are transmitted by radio to the Weather Bureau for use in transocean weather advices.

The Weather Bureau assigned two meteorologists to the United States Antarctic Expedition and also furnished meteorological equipment for surface, pilot-balloon, and radiosonde observations. Reports from the Expedition state that both surface and upper-air observations are being made regularly.

UPPER-AIR OBSERVATIONS (RADIOSONDE AND PILOT BALLOON)

Twenty-eight radiosonde stations were operated during the year, including one each at San Juan, P. R., and Swan Island, West Indies. The latter two were in operation only during the hurricane season, July–November. Radiosondes entirely replaced airplane observations during the year. Pilot-balloon observations were established at 30 additional stations. Helium replaced hydrogen at all pilot-balloon and radiosonde stations of the Bureau. The use of 100-gram balloons was inaugurated at 17 stations, these being in addition to the 24 stations using these large balloons last year. The larger balloons are much more satisfactory than 30-gram balloons for obtaining upper-air wind observations, especially when strong winds prevail.

FORECAST AND WARNING SERVICES**IMPROVED FORECAST DISTRIBUTION**

A major improvement in distribution of forecasts was the inauguration of early morning broadcasts in Washington, D. C., and at a large number of Weather Bureau offices throughout the country. These broadcasts contain local forecasts based on observations taken several hours before and are designed to be of value to industry, agriculture, and the general public in planning the day's activities. They are frequently referred to as "breakfast broadcasts" because they are as a rule scheduled between 7:00 and 7:30 a. m., at a time when most people are at the breakfast table. In addition to forecasts, the broadcasts usually contain a synopsis of weather conditions over the country and also local data of interest. Reception of the broadcasts, which in many cases are made direct by Weather Bureau officials over microphones installed in their offices, has been highly favorable, and this feature has been extended as rapidly as facilities were made available by broadcasting companies. The early weather broadcasts are supplemented by others, on regular schedules during the remainder of the day and evening. The recently inaugurated weather maps at 6-hour intervals have contributed greatly to the success of this service.

AUTOMATIC TELEPHONE WEATHER SERVICE

The more frequent reports and forecasts have contributed also to the successful operation of the automatic telephone weather forecasts which have been started in Washington, New York, Newark, Baltimore, Detroit, and Chicago. This service which was inaugurated by the Weather Bureau through the cooperation of local telephone companies makes the latest forecasts available by the regular public dial telephone. Teletype connections between the Weather Bureau office and the recording room at the telephone exchange facilitate the rapid and accurate transmission of the latest forecasts. That this service is filling a genuine need for weather information is evidenced by the large number of calls received each day. At New York the average number of calls per day is 30,000, but when unusual weather conditions arise, and on special occasions, the calls in a 24-hour period frequently exceed 50,000. The number has been as high as 79,000 in a day. It is significant that a large number of the calls come from the business district.

IMPROVED DISTRIBUTION OF REPORTS

Improvements in forecast distribution through the breakfast broadcasts and by automatic telephone have been made possible by modernization of the communications system of the Bureau by which reports are distributed to forecast centers and field stations. During the year all city offices of the Weather Bureau situated on civil airways were provided with airways teletype drops which give these offices a continuous flow of weather observations and forecasts from all parts of the country. Other Weather Bureau offices, about 30 in number, not favorably situated for connection with the airways teletype system, have been provided with a comprehensive collection of reports by timed wire service.

HURRICANE WARNING SERVICE

An important development in this field was the further coordination between the Coast Guard and the Weather Bureau whereby arrangements have been made for the rapid dissemination of hurricane warnings, evacuation of persons in areas threatened by inundation, and other precautionary measures for the protection of life in emergencies caused by severe tropical storms. This cooperative program has been brought to high efficiency and usefulness in the coastal sections of the Gulf of Mexico by the use of Coast Guard trucks which proceed to areas menaced by the storm and insure appropriate safety measures. Movement of the trucks is directed by radio on advices from the Weather Bureau. In addition to their life-saving activities, the trucks report to the Weather Bureau meteorological observations at frequent intervals during the progress of the storm. These reports are of great value, especially in critical situations when the civil population is endangered. The hurricane-warning service is also closely coordinated with the work of state highway patrols, the American Red Cross, railroads and trucking companies, and other agencies organized to act quickly to safeguard life and property and to render prompt relief to storm sufferers.

In other areas subject to occasional tropical storms, particularly those on the Atlantic coast north of Florida, the storm and hurricane-warning service has been further strengthened by improved communication facilities which provide prompt collection of frequent weather reports and transmission of forecasts and warnings.

MARINE WEATHER INFORMATION BY RADIO

Receipt of reports at 6-hour intervals from ships at sea has made it possible to improve the radio weather bulletins for marine interests. The four broadcasts daily giving complete Major Weather Bulletins over Naval Radio Station NAA/NSS, Washington, D. C., were begun in September 1939. These radio bulletins give the meteorological observations from approximately 200 selected land stations and from a large number of ships at sea. The warnings and forecasts contained in these bulletins, and in other bulletins broadcast from coastal points, are copied by almost every commercial ship along the coasts of the United States. Similar expansion in weather broadcasts over Station

NPG, San Francisco, and NMN, Honolulu, is now in progress. These contribute greatly to safety of life at sea and to conduct of naval operations.

PROGRESS IN MARINE METEOROLOGY

Revised weather information for pilot charts, including wind-rose data to 16 compass points, fog and gale frequencies, and average wind and weather conditions, has been under preparation. Data for the North Atlantic Ocean and the Mediterranean Sea were completed during the year, and publication will begin with the issue of January 1941. Recent meteorological data, with text, tables, and charts, were furnished to the Hydrographic Office for publication in several sailing direction volumes during the year. Further revisions of sailing directions and upper-air pilots are nearing completion or are being outlined for the coming year. Studies of the relationship between wind direction and dense fog on the North Atlantic Ocean have been continued, and the area covered has been increased. A critical examination is being made of data which apparently indicate strong upward trends in air and water temperatures since 1885.

Improvement of barometry on shipboard has received much attention. As a result, shipmasters and shipowners replaced, at their own expense, defective barometers on 56 ships during the year. Ships' barometers have been tested for accuracy and improved testing equipment is being provided as rapidly as possible. A much-needed increase in the accuracy of ships' reports, so important in weather forecasting and safety of navigation, has resulted.

Because of war conditions, ship weather reports, especially by radio, have been sharply curtailed in the Atlantic except along the American seaboard. In an effort to keep the vessel weather service as effective as possible, the Weather Bureau is maintaining an emergency schedule of visits to ships in Atlantic and Gulf ports to encourage the cooperation of officers on all vessels that cross areas from which radio weather reports are desired.

RIVER AND FLOOD SERVICE

The river and flood service is responsible for the prediction of flood and navigation stages in the rivers of the United States. Development has proceeded in three general fields: (1) Refinement and amplification of observations and reports of rainfall and river stages in the upstream areas of the major drainage basins and improvement of forecasting methods; (2) hydrometeorological analysis of rainfall and snow melt for use by the Corps of Engineers and the Department of Agriculture in the design of flood-control works; and (3) expansion of the mountain snowfall service in the West and addition of the Great Lakes region to the winter sports bulletin.

Total damage due to floods during the year ending June 30, 1940, has been estimated at \$17,535,000, and savings due to forecasts and warnings issued by the Weather Bureau have been reported to the amount of \$3,530,000.

The systems for collection of basic data and procedures for making forecasts from these data are gradually being refined and extended.

This work is carried on for 73 river districts through the 10 established hydrologic regions. Under the hydrologic program, in cooperation with the Departments of War and Agriculture, approximately 850 recording precipitation gages and 325 nonrecording gages were installed in various sections of the country. These installations supplement the existing network of Weather Bureau climatological stations and provide data necessary for the flood-control programs of the Departments of War and Agriculture. A network of reporting rainfall stations was established in the Ohio River Basin in cooperation with the Corps of Engineers for their use in operation of flood-control works. Under the Works Project Administration project at Pittsburgh the preparation of river-basin maps on which are shown river and rainfall stations was completed. The mountain-snowfall service in the West was augmented through the installation of 9 additional stations, while about 30 new evaporation stations were established throughout the country.

CLIMATE AND CROP SERVICE

In its regular service to widespread and diversified interests, the Division of Climate and Crop Weather collected and published monthly and annual climatological data for more than 5,000 stations, comprising some 2,000,000 observations during the year. Preliminary summaries were published for approximately 150 first-order offices immediately after the close of each month, and annual climatic summaries were issued for 65 stations.

A field unit was set up for checking all climatological forms at Elkins, W. Va., and another for the checking of aerological forms at Chattanooga, Tenn. Various climatic tables are also prepared at the Elkins, W. Va., checking station.

The fruit-frost-warning service operates principally in the Pacific Coast States and Florida. As a direct result of the service rendered during the severe freeze in Florida, much damage to citrus fruit and groves was prevented. The freeze culminated on January 28-29, 1940, after a long, cold period during which damaging frosts extended southward over the Peninsula, even to the Florida keys. Advance warnings by the Weather Bureau enabled growers to pick and store in warehouses many hundreds of cars of fruit that otherwise would have been a total loss. The garden-truck season was at its height during the freeze with harvest in full progress. Large savings were effected through rush harvesting after the Bureau's timely warnings of the impending freeze. Subsequently, detailed reports were received of the savings resulting directly from the Weather Bureau service. An aggregate saving of more than 6 million dollars at retail value was reported by the citrus industry and an additional several million dollars by truck growers and the general public. The annual cost of the Bureau's frost-warning service in Florida is \$43,000, financed jointly by the Federal Government and the State of Florida.

The collection and dissemination of weather information in relation to crops continued as a regular service with 44 regional centers publishing weekly reports for their respective States, in addition to the Weekly Weather and Crop Bulletin issued in Washington. During the year arrangements were completed in several States for the

joint issue of the Weekly Weather and Crop Bulletin by the Agricultural Marketing Service, the Extension Service, and the Weather Bureau. This cooperation is now effective in Arizona, Colorado, Kansas, Michigan, Montana, Nebraska, Oklahoma, Pennsylvania, Utah, Virginia, and Wyoming. Weekly collection of weather reports from cooperative observers was arranged in several States for use of the Agricultural Marketing Service.

A major project of the Division during the year was the compilation of data and the preparation of climatic charts for the 1941 Yearbook of the Department of Agriculture, entitled "Climate and Man." This included: (1) Summarization of records for about 4,800 stations covering a uniform period of 40 years from 1899 through 1939; (2) preparation of text matter, maps, and tabular material dealing with the climate of the world; (3) preparation of text matter and maps on the climate of the United States; (4) arranging text discussion, maps, and tabular matter for 42 climatic sections (usually States); and (5) compiling detailed frost reports for each climatic section, together with data for Hawaii, the West Indies, and Alaska. To accomplish the tremendous amount of work involved in this project a Federal W. P. A. grant was provided with an allotment of \$60,000. The project began August 16, 1939, and continued through June 1940, with an average employment of 77 persons.

THE NEW ORLEANS W. P. A. PROJECT

Most of the material included in the Marine Atlas, entitled "Climatic Charts of the Oceans," published by the Weather Bureau in 1938, was prepared under this project. Since the latter part of 1938 the work has been primarily the summarizing of the vast quantity of airway observations and pilot balloon data collected by the Weather Bureau since the passage of the Air Commerce Act in 1926. A large number of final summaries and charts has been completed during the year. These include:

A summary of upper-air winds for all levels by velocity groups, by months and by seasons, including all pilot-balloon observations made prior to 1939, at 120 Weather Bureau stations.

A summary of resultant wind direction and velocity by months and by seasons, as computed from pilot-balloon observations, for the same full period of record for all Weather Bureau stations. All levels up to 10,000 meters above sea level were included.

A file of punch cards prepared by coding all regular hourly surface airway observations made at Weather Bureau Airport stations during the period 1934-38. These 6 million punch cards now contain every hourly observation made at 260 airport stations during the 5-year period.

An hourly analysis of surface airway observations by months showing the occurrence of (1) cloud ceilings at various altitudes, (2) visibilities, (3) fog and certain other states of weather, and (4) calms and winds from the various directions by velocity groups. This hourly analysis has been condensed into monthly, seasonal, and annual summaries to show the percentage occurrences without regard to hours of the day. The work has been completed for 150 Weather Bureau stations and will be extended during the next project year to include 110 additional stations.

Charts showing certain summarized data of airways surface observations and pilot-balloon soundings. These charts with descriptive text and tables are to be published during the next year in the form of an Airway Atlas. Inquiries already received indicate great demand for these valuable charts.

Analysis of visibility conditions showing causes of low visibility and the associated wind direction and velocity. This study was made for the Civil Aeronautics Administration for use in planning installations of blind-flying equipment. It represents conditions at 260 airports. The Administration has taken these data and reduced them to descriptive chart forms now published under the title, "Low Visibility Airport Wind Rose Summary."

Precipitation deficiency indices for a selected group of Weather Bureau cooperative climatological stations. This work was done for the Soil Conservation Service, Department of Agriculture, and is being used in studies of irrigation needs in certain areas.

In addition to the foregoing major studies, the project furnished data in response to approximately 100 requests by the Army, Navy, Civil Aeronautics Administration, other Government agencies, and outside interests. These requests in general called for special tabulations for selected localities.

REVISION OF BULLETIN W

The next revision of Bulletin W, which is a large three-volume work comprising the climatology of the United States, will be made after records are received for the current calendar year to bring all data contained in this publication up through 1940. All previously published records are being checked thoroughly, as well as those for the 1930 decade which are to be added. Arrangements have been made for the operation of 15 W. P. A. projects at various section centers for the checking and summarization work, and it is hoped that similar projects at other centers can be provided. It is intended, as far as possible, that all values comprising the 1940 edition shall be based directly on copy obtained from original records. Also, data will be revised to meet the requirements, as far as possible, of hydrologists and to conform to recommendations of the Special Advisory Committee to the Water Resources Committee of the National Resources Committee as outlined in a report dated November 6, 1935.

THE WEATHER OF 1940

During the summer of 1939 there were rather favorable moisture conditions east of the Mississippi River and a marked deficiency in rainfall over the Great Plains. The fall was characterized by widespread abnormal warmth and deficient moisture. While precipitation was scanty in all sections of the country, except a few far southwestern States and locally in the middle Atlantic area, drought was especially severe in the Great Plains, with deficiencies in precipitation greatest in the western Winter Wheat Belt. Nebraska had only 25 percent of normal rainfall. December 1939 continued relatively dry, except in the far Northwest, but early in January generous rains or snows improved the outlook materially.

THE WINTER OF 1939-40

During much of the winter, temperatures were mild for the season, except that in January very cold weather occurred over the eastern half of the country. It was the coldest January of record throughout the Southern States as far north as Missouri and Kansas with the temperatures averaging from 2° to 4° F. lower than any previous January since State-wide records have been tabulated by the Weather Bureau. The outstanding feature was the long persistence of extremely low temperatures. The lowest reported for the Southern States were as follows: Virginia -20°; North Carolina -18°; South Carolina -13°; Georgia -17°; Alabama -16°; Mississippi -14°; Louisiana -8°; Texas -8°; Arkansas -14°; and Florida 8° above zero. The South had lower temperatures than some areas much farther north; for example, the lowest for the month at Washington, D. C., was 7°, while the lowest for Mississippi was -14°. The western half of the United States had an abnormally warm winter. Precipitation was far above normal nearly everywhere from the Rocky Mountains westward, but was moderately below normal quite generally over the eastern half of the country.

THE SPRING OF 1940

The regional distribution of temperature for the spring (March-May) was quite similar to that for the preceding winter. Over the eastern half of the United States the averages ranged from 1° to 5° F. below normal, while the western half had an abnormally warm spring. The warmest weather relatively was experienced in the Pacific Northwest where the temperature averaged as much as 4° or 5° above normal. The spring was generally wet from Kentucky and Indiana eastward and northeastward, also over a considerable northwestern area, including North Dakota, Montana, Idaho, and the North Pacific States. In other sections there were moderate deficiencies in precipitation.

INSTRUMENTAL EQUIPMENT

BAROMETERS

The comparison of the Weather Bureau standard of barometry with those of the Canadian Meteorological Service and the National Bureau of Standards initiated last year has been completed. The three systems were found to be in agreement within limits of readings of the instruments.

Rebuilt Tsch-pattern barometers have been issued for use by inspectors and ½-inch-bore mercurial barometers have been installed at stations in various parts of the country where they are accessible to the inspectors for use as subsidiary standards. A set of precision aneroid barometers has been received and they are being observed to determine whether they are accurate enough to be used as subsidiary standards. Specifications have been prepared for fixed cistern mercurial barometers for station use. An initial quantity will be purchased shortly

CEILING LIGHT PROJECTORS

The development of the modulated-beam ceiling-light projector has proceeded in cooperation with the National Bureau of Standards and specifications have been prepared for both the projector and detector units. The experimental installation has measured ceilings in the daytime up to 8,000 feet under overcast conditions and up to 4,000 feet with broken clouds. A small quantity of projector and detector units is to be purchased for service tests.

RADIOSONDES

Sample chronometric radiosondes have been tested and specifications have been prepared for this type of instrument. It is expected that a quantity of chronometric radiosondes will be purchased within the next fiscal year. A radiosonde laboratory has been established and partially equipped. For this laboratory a quick reading manometer was designed and built in the instrument shop. A Jones conductivity bridge was purchased for use in calibrating thermal elements of modulated audio frequency radiosondes. Standard facsimile recorders are being rebuilt in the instrument shop for use as chronometric radiosonde recorders.

SOLAR RADIATION MEASUREMENTS

Two types of potentiometer recorders, suitable for solar radiation measurement, were investigated. These recorders are also suitable for use with modulated audio frequency radiosondes.

UPPER-AIR SOUNDINGS AT SEA

During the year the Weather Bureau has established eight stations on Coast Guard cutters for the purpose of making meteorological observations at sea. This has involved modification of standard meteorological instruments to adapt them to marine use. Work has been done on marine theodolites and on the technique of making pilot-balloon and radiosonde observations at sea.

METEOROLOGICAL RESEARCH AND EDUCATION

Research, the indispensable guide to progress in any science, is especially necessary in modern meteorology. The field here is not the laboratory or the isolated specimen but the entire atmosphere which surrounds the globe and is always in motion relative to the earth's surface. Its movements have until recently been subject to comparatively limited study because of lack of upper-air data. There is evidence now of real progress toward a more complete understanding of the laws which govern the movements and characteristics of the atmosphere, an understanding which will logically lead to better knowledge of weather and its changes—past, present, and future.

Progress has been made during the year by the cooperators in the research project to develop better methods for making 5-day weather forecasts. It has been possible also to increase somewhat the facilities and staff for research in solar radiation and ozone distribution, both of which may have more influence upon weather than has yet

been discovered. Among applied research activities may be mentioned the project to develop better methods of forecasting of conditions conducive to forest-fire weather, arranged in cooperation with the Forest Service. Demands upon the Bureau's research personnel for assistance in coping with pressing activities in the service and training programs have prevented them from giving full attention to research matters, circumstances which are expected to be relieved by the current large program for training more meteorologists. Some progress has been made in the research projects which were discussed in the last Annual Report. For further information the reader is referred to recent technical papers on meteorology, particularly those published or referenced in the Monthly Weather Review and the Bulletin of the American Meteorological Society. Space does not permit inclusion of a bibliography of important meteorological papers published during the year, but because of its popular interest attention is invited to one issue of the Monthly Weather Review (Supplement No. 39) on Reports on Critical Studies of Methods of Long-Range Weather Forecasting. Inquiries directed to the Weather Bureau Library indicate continued increase in public interest in the science. The Library now has 58,000 volumes and receives 200 periodicals monthly, many dealing solely with meteorology.

The field of research is broad and needs the attention of many more scientists than the Government alone can provide. Moreover, the stimulus which comes from new viewpoints and educational associations is needed to keep research active and productive. It is the policy of the Weather Bureau therefore to encourage research in meteorology through cooperative projects at universities which are staffed and equipped to carry on such work. Results indicate that this method is the most economical and fruitful form for general research in meteorology at Government expense, providing the individual projects are carefully selected and assigned as well as properly supervised and coordinated.

Reference was made in the introduction to the great importance of educating and training professional personnel in a science in which the views and technique are changing as rapidly as they now are in meteorology. The Office of Research and Education of the Weather Bureau keeps closely in touch with academic institutions which offer courses in meteorology and climatology. It encourages the development of these courses within reasonable limits and is able in many cases to assist those interested in meteorology in arranging to take accredited courses. During 1940 ten Weather Bureau employees attended advanced courses in meteorology under the provisions of the Civil Aeronautics Act. About that many more availed themselves of opportunities to attend meteorological courses under the status of leave without pay. A much larger number attended part-time courses at various universities. In-service training of Weather Bureau personnel was pursued through the Regional Technical Conferences at Washington and Chicago. These conferences included a 12-week review of air mass concepts and weather-map-analysis technique. Approximately 100 Weather Bureau officials and assistants attended these Regional Technical Confer-

ences during the year. The correspondence course in basic principles of applied meteorology which is designed to reach employees who do not have access to other forms of training in this science is being completed for use next year. At the present time extensive plans are being formulated to train a much larger number of professional meteorologists in order to meet the requirements of the national defense program.

INVESTIGATIONS UNDER THE BANKHEAD-JONES ACT

As a part of the general weather- and crop-forecasting program of the Department of Agriculture, the Weather Bureau continued to conduct, in cooperation with the Bureau of Agricultural Economics and several universities, investigations directed toward a more complete understanding of processes affecting weather changes and the persistence of weather abnormalities, with a view to increasing the range of weather forecasts. The following projects were conducted under this program during the year 1940. A résumé of results will be presented in other publications of the Bureau:

- Investigation of Warm and Cold Anticyclones and the Role of Ozone as a Link Between Solar Activity and Atmospheric Changes
- Investigation of Radiation Absorption and Fluid Mechanics as Applied to Weather Forecasting
- Experiments in Five-to-Ten-Day Weather Forecasts Based on Northern Hemisphere Charts and Statistical Studies
- Development of Instruments and Observational Technique for the Determination of Atmospheric Ozone Content
- Development of the Olland Type Radiosonde Apparatus