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REPORT OF THE CHIEF OF THE WEATHER BUREAU

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., September 29, 1939.

Hon. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I submit herewith a report of the work of the Weather Bureau for the fiscal year ended June 30, 1939.

Sincerely yours,

F. W. REICHELDERFER, *Chief.*

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INTRODUCTION

In his introductions to recent annual reports, the late W. R. Gregg,[1] as Chief of the Weather Bureau, stressed the importance of weather service in modern business and professional activities. He pointed out the need for expansion of the Bureau, and for certain changes to enable it to put "first things first" in weather service. Some of the necessary changes have been accomplished.

The process of adapting the weather service to its changing environment is obviously a more or less continuous one. Like other applied sciences, the science of weather forecasting is profoundly affected by developments in kindred fields as well as in meteorology. Aeronautics and radio communication have opened to the meteorologist new possibilities and new responsibilities. Agricultural planning, forest-, soil-, and water-conservation programs, and flood-

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[1] Dr. Gregg's untimely death on September 15, 1938, left vacant the office of Chief of the Weather Bureau. C. C. Clark, Assistant Chief, served as Acting Chief until December 15, 1938, when the present Chief was appointed.

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

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control projects all make new demands upon meteorology, and these demands must be met if the programs are to be successful. Faced with increasing requirements, it is necessary for the Bureau to reexamine the entire weather service and appraise the relative importance of each activity. Newer and more pressing activities may have to replace those which have decreased in importance through developments in recent years. Attention has been directed during the past year to reorganization which will accomplish these changes in an orderly and progressive manner. Continuation of this process is one of the most important tasks for the coming fiscal year.

Climatology, long an important branch of the Bureau's work, has become more important in its application to present-day social and economic conditions. Comparatively minor variations in climate have changed the occupations and curtailed the means of livelihood of thousands of citizens. It is necessary to know as much as possible about the character of climatic changes now in progress and future trends therein. The study of microclimatology has assumed great practical importance in some occupations and professions, notably in agricultural economics, hydrologic engineering, and soil conservation. The Weather Bureau is extending its network of climatological stations as rapidly as possible to meet these modern requirements.

Plans for the current year call also for extension of the Bureau's river and flood warning service; and for amplification of forecasts of weather conditions which relate to forest fires. The fire-weather forecasts greatly assist the Forest Service and other agencies in taking preventative measures. In order to provide more specific weather forecasts for the general public, new forecast districts are being organized from portions of some of the larger districts. The smaller districts enable the forecasters to give more attention to local variations in weather. Further steps are being taken in cooperation with vessel weather observers to develop the ocean weather-reporting system, a program important in the service of storm and hurricane warnings for our coasts.

Ocean weather reports have taken on new importance with the establishment of regular schedules of transocean aircraft. During the last decade or two much progress has been made in international cooperation in meteorology. The science receives further impetus from extension of the various national weather reporting systems to cover additional significant areas of the globe in the interest of air transport. Meteorology is an international science; our weather is determined by air-mass characteristics which originate over other continents or distant oceans. Daily exchange of weather reports among the nations is essential to forecasting of weather and is the basis for research directed towards more complete understanding of storm development and behavior. If international exchange of weather reports is to serve its purpose, the meteorological procedure and practice among nations must be standardized and coordinated, and all observations and reports must be comparable and prompt. Each country, therefore, needs a national weather organization with a comprehensive and unified system of observing and reporting stations to furnish synoptic reports and disseminate its weather information in conformity with standard and uniform times and methods.

Improvements which will facilitate essential exchange of observations have recently been adopted in the weather code used by the Bureau.

In the current appropriation, provision is made for a large increase in aerological observations. These should result in further progress in physical methods of weather analysis and forecasting. Recent technique in air-mass analysis has been introduced at certain of the district centers and is being extended throughout the service as rapidly as possible. The current appropriation also provides for the first unit of a new central office building to house the Bureau's administrative activities in Washington. Administrative offices are now scattered among four widely separated buildings. The present main central office structure, erected as a residence more than 50 years ago, was not designed for office use and is poorly adapted therefor. The new building, authorized after many unsuccessful attempts to obtain funds in past years, will greatly facilitate administrative work.

Much attention has been given during the past year to research and in-service training. These two are closely related and must proceed together. The training program deserves emphasis. Recent advances in meteorology have made it necessary to provide refresher courses for many in the profession. Moreover, since the growing requirements of agriculture, aviation, business, commerce, and other occupational and professional pursuits have increased the volume of work beyond the capacity of present staffs at our city offices and airport stations, a shortage of trained personnel exists. Provision has therefore been made for widespread in-service training and for encouragement of meteorological education and research in universities in various parts of the country.

Some of the advances in the science of meteorology during the past year are briefly reviewed in one of the following sections. Progress in meteorological research has often appeared relatively slow and the results have sometimes been disappointing. In the atmosphere we have to deal with vast and complex physical processes which are difficult to analyze. The development of greater precision in weather forecasting and extension of forecasts to cover a longer time-range are possible only through research. More thorough understanding is necessary with reference to atmospheric circulation and the interaction of air masses underlying various weather conditions. If we recall the success attained in other scientific fields in which research efforts have been persistent and competent, we have reason to expect that similar research efforts in meteorology will yield great benefits. There are few human activities which can boast complete indifference to weather, present or future.

AEROLOGICAL OBSERVATIONS

RADIOSONDE[2] OBSERVATIONS

The steady improvement in the development of radiosondes has resulted in the establishment by the Weather Bureau of six stations where scheduled observations were made daily during the fiscal year.

[2] A radiosonde is a radiometeorograph, an instrument which is sent aloft by a small balloon and which transmits a radio signal indicating pressures, temperatures, and humidities in the upper air.

In addition, the Bureau continued in operation six airplane observation stations. Arrangements were made for the purchase of radiosonde equipment for use on two Coast Guard cutters engaged in international ice-patrol duty off the Grand Banks of Newfoundland. These observations were made daily from March through June 1939. Through cooperative arrangements between the Weather Bureau, Harvard University, and Massachusetts Institute of Technology, daily radiosonde observations were made from March through June at Cambridge, Mass., and St. Georges, Bermuda. These reports and those of the Coast Guard vessels referred to above were transmitted promptly by radio to the Weather Bureau, where they were used in its regular forecast work. These records, together with radiosonde records from the Azores, Iceland, and the French S. S. *Carimare*, stationed in the Atlantic, will provide valuable data for research problems to be undertaken in meteorological conditions over the Atlantic, where upper-air data have been so meager.

Special sounding-balloon observations were made during the period August to November 1938 at seven southern Weather Bureau stations during the passage of tropical storms. A study and analysis of these records will be made.

During April, the international month for 1939, special sounding-balloon observations were made at Omaha. These data will be furnished the International Aerological Commission and published by that organization together with similar data from other countries for studies of world-wide meteorological problems.

Arrangements were made with the Pan American Airways, Inc., to carry an aerometeorograph on their trans-Atlantic and trans-Pacific planes to obtain records of temperature, humidity, and pressure at the flying levels, together with eye observations of significant conditions encountered. In this connection the aerometeorographs formerly used in airplane observations are to be fitted with strip charts that provide for a 24-hour record.

PILOT-BALLOON OBSERVATIONS

Pilot-balloon observations, by which upper-air winds are measured, were inaugurated at 23 additional stations, including Anchorage, Alaska, bringing the total number of pilot-balloon stations to 102. The use of larger (100-gram) pilot balloons, capable of ascending to heights of 20 kilometers or more, was adopted at 23 additional stations. Nine of these stations are located in the Southeast, where a knowledge of the wind data at high altitudes has been found to be of great assistance in forecasting the movement of hurricanes. Helium was substituted for hydrogen in the inflation of observational balloons at about one-third of the stations making such observations. Because the use of helium for this purpose completely eliminates the explosion hazard associated with hydrogen, arrangements were made to extend the use of helium to nearly all balloon stations during the fiscal year 1940. Special balloon theodolites were purchased for "tail-method" observations. Such observations involve the angular measurements of tails attached to the balloons used in wind-aloft measurements and indicate variations in the assumed ascensional rate of such balloons caused by vertical currents in the

atmosphere. Such variations in the assumed ascensional rates result in erroneous values of wind direction and velocity, unless they are actually measured by some method such as this. With the assistance of the Works Progress Administration, all upper-air wind records, involving about 1 million observations, were reduced to punch cards, and arrangements made whereby all future observations of this nature would be so recorded by the Weather Bureau.

SERVICE IN AID OF AIR NAVIGATION

New airport stations rendering 24-hour service and taking 4 pilot-balloon observations a day were established at 20 air terminals, providing a better network of such stations over the country and permitting pilots and others to consult more frequently with qualified Weather Bureau personnel concerning meteorological conditions while en route over the civil airways.

Several new off-airway stations reporting each 6 hours were established to fill in gaps in the previous network of such reports.

About 60 airway hourly reporting stations were equipped with mercurial barometers for the more accurate rendering of barometric pressures and particularly of altimeter settings for the use of airmen in determining their heights above the ground. Similarly, work was continued on the modernization of instrumental equipment at all types of stations, large numbers of these being supplied with new concentrated-beam ceiling projectors, open-scale barographs, eight-point wind indicators, improved temperature- and dewpoint-measuring equipment, etc.

A considerable number of reporting stations were established on new airways during the year.

A new edition (fourth) of Circular N, Instructions for Airway Meteorological Service, was prepared and issued. This publication contains complete instructions regarding the taking and transmission of airway weather reports, transmission of pilot-balloon and radiosonde reports, preparation of forms and forecasts, instructions for inspectional work, installation and care of instruments, etc. To facilitate future revisions that may become necessary, the circular has been issued to Weather Bureau stations and others closely connected with airway meteorological work in loose-leaf form.

There are 720 points in the continental United States at which observations are made for or utilized in the airway meteorological service. The principal classifications of these stations according to personnel, facilities and service rendered are given below. It will be noted that the total number of stations in the classifications is greater than the total number of reporting points given above. This is because many stations fall into several clasifications. For example, all stations in paragraphs (1) and (2) are also teletype stations and are included in paragraph (3); likewise, many stations in paragraphs (1), (2), and (3) are also included in paragraph (4).

(1) There are 88 stations located at airports manned completely by a staff of civil-service Weather Bureau employees, rendering 24 hours of service daily, where hourly or more frequent weather reports are received and transmitted by teletype, weather maps are prepared

every 6 hours, and all information, including airway forecasts and upper-air pilot-balloon and radiosonde reports, are posted for the information of pilots and other aviation interests concerned. Trained personnel are available at all times to discuss with and advise pilots and others of present and probable future weather conditions along the airways.

(2) Thirty stations are manned by one civil-service Weather Bureau employee and three noncivil-service airway observers. These stations are in a position to render service similar to that of stations described in paragraph (1) except that only one (in some cases two) weather map is prepared daily and the trained civil-service employee is available for consultation and advice only during his tour of duty, which consists of 8 hours a day, 5 days a week.

(3) Three hundred and fifty-three of the stations are equipped with teletype and send and receive hourly or more frequent weather reports.

(4) One hundred and seventy-one stations transmit by teletype every 6 hours (1:30 and 7:30 a. m. and p. m.) data, in addition to that transmitted at other hours, for the preparation of weather maps. These additional data include the 3-hourly pressure change and characteristic, the kind, height, and direction of clouds, the time, character, and amount of precipitation, thunderstorms, 5,000-foot pressures, maximum wind velocity and direction, maximum and minimum temperatures, and snow on ground.

(5) One hundred and sixty-five stations are located on the airways but are not equipped with teletype facilities. They are manned by part-time airway observers, who telegraph reports at definite times, or when called on to do so, to designated centers for the clearance of scheduled airplane flights.

(6) There are 132 stations located off the airways, manned by part-time airway observers, except in a few places where Weather Bureau city offices are located, which telegraph complete 6-hourly reports at 1:30 and 7:30, a. m. and p. m., for map purposes. The reports are telegraphed to designated centers, where they are placed on the Civil Aeronautics Authority teletype circuits for national distribution to all airport and map-making stations.

(7) Twenty-five of the stations mentioned in paragraph (6) are selected to forward reports every 3 hours to enable forecasters to keep track of weather trends and developments between their 6-hour map and forecast periods.

(8) Eleven stations are designated as airway general-supervising stations and forecast centers. These stations, which have general supervision over their respective districts and prepare all forecasts for the airways and terminal landing points within the district, are located at Newark, N. J., Arlington, Va., Atlanta, Ga., Cleveland, Ohio, Chicago, Ill., Kansas City, Mo., Fort Worth, Texas, Salt Lake City, Utah, Seattle, Wash., Oakland, Calif., and Burbank, Calif.

The Weather Bureau airport and general-supervising station formerly at Portland, Oreg., was transferred to Seattle, Wash., thus permitting more efficient use of teletype and radio circuits and the furnishing of more adequate service to the new Seattle-Alaska, the northern transcontinental, and the Pacific-coast airlines, all of which terminate in Seattle.

In addition to the above, the Bureau maintains approximately 100 stations in Alaska and Hawaii, from which reports are obtained and service rendered to the aviation interests in these localities. Numerous reports are also received from Canada and Mexico and from ships in the Atlantic and Pacific Oceans, the Gulf of Mexico, and the Caribbean Sea.

CLIMATE AND CROP WEATHER DIVISION

The Climate and Crop Weather Division continued to render service to widespread and diversified interests. Special reports were issued from time to time on the status of the weather conditions, with special emphasis upon droughts. The demand for certified reports for court use continued to be heavy; approximately 600 such certifications were issued. In addition to this, some 2,000 inquiries relating to the climate of the United States and other countries were answered by mail from the central office alone during the year.

The climatological service with its 5,000 cooperative observers and 45 section centers maintained its regular activities. Records totaling nearly 2 million daily observations were printed and distributed within approximately 1 month after receipt of form reports. In addition to these, Form 1030, or the Monthly Meteorological Summary, was issued at approximately 150 first-order offices to furnish weather data promptly at the close of each month. Station annual summaries for 1938, with comparative data, were issued for 65 stations.

Collection of data by means of Forms 1001 and 1001A continued, marking the completion of the sixty-ninth year of detailed meteorological records for the entire country. Cooperation was maintained with other agencies, particularly the engineers of the War Department, in furnishing past records of precipitation. A very essential need of the Bureau was met by preparing and publishing a set of definitions and descriptions of hydrometeors.

The fruit-frost service was maintained at its usual efficiency. Warnings issued in the field by the fruit-frost personnel were instrumental in saving a large proportion of the citrus crop in California during the serious freeze of November 1938. In some sections of California frost damage was considerable, but in others, through timely warnings, the bulk of the crop was saved. The citrus industry produces an annual crop valued at 35 to 40 million dollars, and the savings from frost damage through timely warnings average more than the total appropriation for the Weather Bureau. In addition to those in California, similar warnings were issued in Florida, Texas, and Arizona, and in the apple- and pear-growing districts of the Pacific Northwest.

The collection and dissemination of data on the weather-crop relationship were continued, with 44 section centers publishing weekly reports for their respective sections on the effect of the prevailing weather on crops and farming operations. These State reports are widely distributed and furnish a comprehensive summary of current information. In a number of States close cooperation is maintained with the Bureau of Agricultural Economics' crop-reporting service, and a joint report is prepared for release. Summaries of these

weather-crop publications are telegraphed to Washington every Tuesday for inclusion in the Weekly Weather and Crop Bulletin, which affords a Nation-wide survey of the effect of weather on crop conditions from week to week and in addition contains current, pertinent information on droughts or other adverse weather conditions.

The corn-and-wheat-region and cotton-region services continued in operation. These furnish daily reports on temperature and rainfall throughout the important grain- and cotton-producing areas of the country. The issuance of these daily reports gives all who are interested an accurate, timely picture of current weather.

RECENT WEATHER TRENDS

Because of the recent successive drought years and a longer time persistence of abnormally high temperatures, many people are asking, "Is our climate changing?" During the present decade there has been a decided tendency to dry weather and for more than two decades to abnormal warmth, notwithstanding an occasional bad flood or a severely cold winter. Considering the country as a whole, the winter seasons, with the exception of those of 1917–18 and 1935–36, have been rather uniformly warmer than normal for the past quarter of a century, and, on an annual basis, every year of the last decade has had above-normal temperature. Also, in the matter of rainfall, there has been an equally marked tendency to droughts in recent years. However, an examination of the longer weather records of the country, going back 100 years or more, indicates that this does not represent a permanent change of climate, but rather a warm, dry phase of our normal climate, to be followed by a cooler, wetter phase; when there will be more rainfall and lower temperatures.

The situation may be described in this way: We have weather and we have climate. Weather refers to conditions for a day, a week, or even a year. We say, for example, that last week was wet or dry, cold or warm, as the case may be. Climate is the average weather (temperature, rainfall, etc.) over a very long period of years, for the purpose of comparison, say, 100 years. We know that weather from day to day and week to week frequently has a more or less cyclic tendency, that is, a few cool or cold days are succeeded by several days of warmer weather, and frequently a few days of rain by fair, sunny weather for a short period. The same thing applies broadly to climate, the difference being that we count the time in periods of years instead of days. It is important to remember that these climatic cycles vary in length, just as do the weather cycles, resulting in some periods of light rainfall, or droughts, lasting longer than others.

Climate presupposes the existence of records of sufficient length to determine the general run of weather, and consequently the value of a record for such purpose increases with the length of time it represents. Therefore, a record covering only a few years, say up to 10, has little value in climatic studies of this character for that particular period may not represent the basic climatic characteristics of the locality. If records for our Midwest were available only for the last 10 years, an appraisal of its climate based on this period would be very misleading.

Of the various aspects of historical climate, the question of long-time tendencies, or trends, is one of the most, if not the most, important. The present warm, dry phase has been typified during the present decade by three Nation-wide, destructive droughts, 1930, 1934, and 1936, and by a general warmth not exceeded for a century.

An examination of past records covering many years, some of them more than a century, discloses certain characteristics and interesting features of these long-time trends in precipitation and temperature. The cycles of precipitation, if we may call them such, usually are shorter and less extensive geographically for a given phase than those of temperature. For a good many years past, and until recently, there has been a marked downward trend in precipitation over the Northwest and much of the West, and to somewhat less extent in central districts, while in much of the South the trend, in general, was upward. These trends in moisture have great economic significance, especially with regard to agriculture. The importance of the shortage in moisture resulting from the markedly subnormal rainfall is well illustrated by stating that for the Dakotas alone the shortage in water, as compared with the normal rainfall, was nearly 3,000 tons per acre of land for the period from 1930 through 1936.

In the case of temperature there has been a much more systematic and extensive upward trend since the turn of the century, not confined to any group of States, nor the United States, but in evidence throughout the world. Examples for widely scattered localities for the last two decades may be cited: Portland, Oreg.—17 of the 20 years warmer than normal; the warmest year of record, 1921; every year since 1922 above normal; Omaha, Nebr.—15 years warmer than normal; warmest of record, 1931; Washington, D. C.—17 years warmer than normal; warmest of record, 1921; every year above normal since 1926; Capetown, South Africa—19 years warmer than normal; warmest of record, 1927. Summaries of monthly records published in the Reseau Mondial for the 23 years 1910–32 for which this publication is available, show that for this period the world as a whole had subnormal temperature in only a year or two, approximately normal for a couple of years, and considerably above normal in all other years. Some long records indicate that an extended period of abnormal warmth prevailed about the beginning of the nineteenth century, but that for an intermediate period, more pronounced from about 1855 to 1877, the general run of temperature in the United States was as much below normal as the last quarter of a century has been above normal. This indicates that the present warm, dry trend may similarly be a temporary phase.

THE WEATHER OF 1939

Following a summer of relatively high temperatures with mostly adequate rainfall, ranging from near normal to decidedly above normal in nearly all sections of the country, the fall months of 1938 continued abnormally warm. Rainfall was heavy in the Rocky Mountain and Great Basin areas and also in most of the more eastern States, but much of the interior was decidedly dry. At the beginning of the winter soil moisture was ample over most of the

eastern half of the country, except for considerable areas in the South.

THE WINTER OF 1938–39

The winter of 1938–39 was characterized by continued abnormally warm weather, a condition markedly in evidence during the winter seasons of the past quarter of a century or more. The lowest temperature reported was −51° F., at Meadowlands, Minn., on February 21. The lowest observed in Alaska was −60°, at Fort Yukon on February 7. Moisture was generally abundant the latter part of the season except in limited areas in the Northwest. In December precipitation was scanty throughout nearly the entire country, being markedly deficient in the Great Plains, where the monthly totals ranged from only about 25 percent of normal in Kansas to a little more than half the normal in North Dakota. However, after January 1 precipitation became more abundant and the winter culminated in one of the wettest Februarys of record. This month broke all previous February records for heavy rainfall in a large part of the Southeast. For the winter as a whole precipitation was above normal in the southern Rocky Mountain States, on the west Gulf Coast, and everywhere east of the Mississippi River, Florida excepted.

THE SPRING OF 1939

The spring (March–May) was warmer than normal throughout the country except in a limited area from the upper Lake Region eastward. March was relatively dry in much of the Midwest, and April decidedly so in the Great Plains, the Rocky Mountain States, and the Pacific Northwest. Because of continued scanty rainfall, severe drought conditions had developed over a large western area by the middle of May. The lack of moisture was intensified by high temperatures, and the need for rain became pronounced from central Kansas and Missouri northward and northwestward to the Canadian border. Another major drought year appeared to be in the offing, but the latter part of May brought generous and extensive rains to most Midwest sections, which effectively relieved droughty conditions and revived vegetation enormously. Some southwestern sections, including most of New Mexico and Arizona, continued unfavorably dry.

The Midwest spring dryness was in marked contrast to the spring of 1938, when rains were heavy over most of the country. There was less rainfall during the spring months than in the spring of 1936, a severe drought year, in Colorado, New Mexico, Texas, Kansas, Nebraska, South Dakota, and Minnesota, but in other Midwest States there was somewhat more moisture than in the spring of 1936. In review, the winter had mostly abundant rainfall, but in early spring the amounts became scanty in the northern Great Plains, and droughty conditions spread from there southward and eastward until by the middle of May nearly the entire interior of the country was needing rain badly.

For the first half of the year (January–June) precipitation was about normal to considerably above normal in all States from the Mississippi Valley eastward. The region from the Ohio Valley southward had the largest excesses. However in the western half

of the country, all States, except Montana, had deficient precipitation, the relatively driest State being California, with only 64 percent of normal precipitation.

THE SUMMER OF 1939

June had abundant rains except in the Southwest, where a considerable area continued dry, including principally Colorado, New Mexico, and Arizona. In an area between the Mississippi River and Rocky Mountains the June rainfall was timely, substantial, and very beneficial to growing crops. The amounts were especially abundant in the northern Great Plains, with Montana receiving nearly one and one-half times the normal. Temperatures continued to range generally above normal.

In July a serious drought developed in the Northeastern States, unfavorably affecting an area from New Jersey and Pennsylvania northeastward. Some sections had the greatest July rainfall deficiency in half a century up to nearly the close of the month, when there were intermittent showers on several days. However, these were decidedly local in character and irregular in amount, in some cases being heavy and in others not enough to be of material benefit. Early in August additional rains occurred over most of the northeastern area. However, an urgent need for rain continued over a large southwestern section and also throughout the Great Plains from North Dakota to the Rio Grande. Most other interior States had sufficient moisture for current crop needs.

The summer (June–August) was characterized by abnormal warmth in all areas and markedly deficient rainfall over large western sections, especially from the western plains westward. Colorado had the greatest deficiency in moisture, with average rainfall for the 3 months only half the normal. However, from the Mississippi Valley eastward the summer totals were uniformly above normal, except in the Northeast from Pennsylvania and New Jersey northward. New York had only about three-fourths of normal rainfall for the season. Alabama, with one and one-half times the normal, was the wettest State.

FIRE-DANGER-RATING FORECASTS

Marked progress has been made in further adaptation of fire-weather-forecasting procedure to the peculiar needs of forest-protection agencies. The newly developed forecast terminology has enabled forestry officials using the forecasts to be certain that they understand the forecaster's exact meaning. A significant forward step was taken in the use of fire-weather forecasts in specifically determining the degree of prevention and suppression effort required to handle fire situations developing out of predicted weather conditions.

As a result of the extensive damage to forests in New England by the destructive winds in the storm of September 1938, the fire-weather service in that region has been considerably strengthened. In addition to this a cooperative program between the Weather Bureau and the Forest Service has been inaugurated which extends the latter agency's fire-danger-rating activities to include predictions of fire-danger levels for 24 or more hours in advance. Fire danger is

rated on a simple numerical scale that is definitely linked with, and translatable into, prevention action and strength of force which must be held in readiness to handle anticipated fire business. Prior to this all such rating practice has been confined to the determination of danger conditions for the current day. However, wind damage to New England forests brought about a marked increase in the likelihood of serious fire outbreaks, and it became evident that actual predictions of fire danger as well as of weather occurrences would be of great assistance under such extraordinary circumstances.

To accomplish this, close cooperation between the Weather Bureau and the Forest Service was necessary, involving coordination of the efforts and facilities of the two agencies in New England. Detailed reports from Forest Service fire-danger stations are sent to the Weather Bureau office in Boston to supplement the meteorological observations regularly used in the fire-weather work. A Forest Service official is assigned to assist the fire-weather forecaster in analyzing this mass of information both from the fire-danger and fire-weather standpoints. After a thorough study has been made, a forecast is issued to cover conditions during the ensuing 24 to 48 hours. Finally, by integrating the predicted values of weather elements and measured fuel-moisture contents, a forecast of tomorrow's class of fire danger is made. Both predictions are given joint distribution throughout New England, together with an analysis of prevailing weather and fire-danger conditions by telephone, telegraph, and scheduled broadcast from numerous radio stations.

RADIO MICROPHONES IN WEATHER BUREAU OFFICES

Radio broadcasting ranks high as a means for disseminating weather forecasts and warnings. At present more than 500 broadcasting stations are cooperating with the Weather Bureau in this work. From each of them local and State forecasts are given out on fixed schedules from one to five times a day, and special broadcasts of warnings of cold waves, storms, frosts, floods, etc., are made whenever such warnings are issued. For the most part forecasts are supplied to broadcasting stations by telegraph and telephone; in some cases other means are employed. Difficulties often arise that result in broadcasting stations not receiving the latest forecasts or in erroneous interpretations of the predictions being announced. Much of this difficulty is being overcome by installing in Weather Bureau offices microphones directly connected by wire with the broadcasting stations. The forecasts and synopses are given by Bureau employees in person, thus controlling responsibility for what is broadcast. Microphones are now in 36 Bureau offices, and this number is steadily increasing. The microphones are furnished and installed by the broadcasting companies as a public service.

Direct radio announcements from Weather Bureau offices will have an important part in the new program of four maps and forecasts a day. Heretofore, it has been impossible to provide in the early morning fresh and detailed forecasts of weather for the remainder of the day because those announced by radio or published in the morning paper were predicated on observations taken 10 or more hours before. The new program will provide for four forecasts

a day in contrast with the present two. The early-morning forecasts now being made available are based on observations taken at 1:30 a. m., eastern standard time. These forecasts will come to business people by radio before they leave home for their offices and may be termed "breakfast-table" forecasts. Thus, people engaged in industries that are affected by weather can plan their work in the light of the latest weather information instead of having to depend on information many hours old or wait several hours for a prediction.

WEATHER OBSERVATIONS FROM COAST GUARD STATIONS

Cooperation between the Weather Bureau and the Coast Guard in the taking of observations was materially extended during 1938 to include the furnishing of complete observational data at 6-hour intervals from selected Coast Guard stations between eastern Long Island and Cape Hatteras.

A complete equipment of meteorological instruments was installed at 11 coastal stations, and instruction was given to personnel at these stations in observational techniques. The observations which are transmitted in numeral code are collected at central points through Coast Guard facilities and made available for use in the airway and general service work of the Bureau. These reports are of especial value in connection with trans-Atlantic flying and the issuing of storm warnings.

RIVER AND FLOOD SERVICE

The reorganization and expansion of the river and flood service, which is responsible for the prediction of flood and navigation stages in the rivers of the United States, has continued to progress in its three-fold program: (1) Refinement and expansion of the observation and reporting system of effective rainfall in upstream basins of major drainage areas; (2) hydrometeorological analysis of rainfall for use by the Army and Department of Agriculture in the design of flood-control works; (3) expansion of the mountain-snowfall service in the West. In addition, a winter-sports bulletin was inaugurated during the winter of 1938–39 for the benefit of the increasing number of skiers and other winter sports enthusiasts who have need for current information on snow conditions and related weather forecasts.

The flood forecasts issued by the Weather Bureau are of proven economic value. In addition to minimizing or preventing the loss of human life by providing opportunity for evacuating threatened areas, the advance flood predictions enable manufacturers and warehousemen to remove perishable goods; such forecasts also provide essential warnings for the safeguarding of navigation and the construction and operation of emergency protective works.

In order to maintain the flood-warning service at the greatest possible efficiency under existing appropriations, the River and Flood Division endeavors to extend its facilities into new areas and to improve forecasting methods through research. Research has progressed along two lines: (1) Hydrometeorological studies conducted in cooperation with the Corps of Engineers of the Army and the conservancy agencies of the Department for the purpose of deter-

mining, by hydrometeorological methods involving air-mass analysis and transposition of storms, the maximum flood-producing characteristics of regions in which there are flood-control projects; (2) rainfall run-off studies conducted at the hydrologic regional centers of the River and Flood Division. These studies systematically attack the problem of determining river stages from rainfall data, which thus become the basis of flood-forecasting procedure in headwater and tributary basins. The older method of forecasting by gage relationships is not adequate for present-day needs, especially in headwater areas, where periods of concentration are short. It is in these headwater areas, however, that flash floods occur, often with destructive effects far out of proportion to the size of the streams involved.

The flood-forecasting service in Pennsylvania has now been consolidated on a cooperative basis with the Commonwealth of Pennsylvania and the United States Geological Survey and is designated as a Federal-State forecasting service. In Pittsburgh, a W. P. A. project has been established for the preparation of river-basin maps on which are shown all rainfall and river stations.

The expansion in winter sports in recent years not only represents an expansion in national recreational facilities but has resulted in their becoming a business of major proportions. To meet this new demand, the Weather Bureau has engaged selected observers in winter-sports areas to send weekly reports on snow conditions to regional centers, where they are consolidated and disseminated by press and radio, together with special winter-sports weather forecasts for the week end. The winter-sports reporting and forecast service was confined last winter to the northeastern United States and the Southwest, but it is planned to extend the program into the other sections of the country in the near future.

PROGRESS IN MARINE METEOROLOGY

REVISION OF THE PILOT CHARTS

For the first time in more than 25 years the weather information on the pilot charts is undergoing a thorough revision. The charts were founded on the researches begun by M. F. Maury, an American naval officer, nearly 100 years ago. Millions of ships' weather observations, which have accumulated in the files of the Weather Bureau, have been compiled and summarized to provide new data for wind roses to 16 compass points, the fog and gale frequencies, and average wind and weather conditions. Publication of the revised material for the North Pacific Ocean began with the issue of January 1939. Similar revisions are planned for other oceans. The meteorological information on the pilot charts is widely used by ships of all nationalities.

NEW CLIMATIC ATLAS OF THE OCEANS

The Atlas of Climatic Charts of the Oceans, based on 5½ million observations from ships at sea, has been printed and distributed. A description of material in this Atlas has been included in previous reports. It is of practical importance especially to maritime navigation, transoceanic aviation, and world climatology.

CHARTING OF SEA SWELLS

In 1938 several nations cooperated in a study of sea swells on the North Atlantic Ocean. The survey was organized and carried out for the period November 14–19. The Weather Bureau took part and was assisted by the Hydrographic Office, the Coast Guard, and the Bureau of Lighthouses. A large number of special observations from ships and coastal stations was obtained in the survey; they were assembled by an International Subcommission for the Study of Sea Swell. Arrangements are being made for an analysis of the data and for the preparation of synoptic charts of swell and related elements. The results are expected to be of importance in forecasting the arrival of sea swells in localities where they are sometimes dangerous to shipping.

TEMPERATURES OF THE OCEAN SURFACE

An investigation dealing with temperatures of the ocean surface was completed, and the results were published. This study covered the western North Atlantic Ocean, including the Caribbean Sea and the Gulf of Mexico. Normal surface temperatures were determined by months for each 1° square from data collected during the 20-year period 1912–31. A summary with 16 charts was published in the Monthly Weather Review, February 1939, and was also distributed as a separate. The charts are intended primarily as an aid in weather forecasting but are also of practical value in air-conditioning of ships' cargoes and for other commercial purposes.

THE "EYE OF THE STORM"

In a special study of the calm center, or "eye," of the tropical cyclone, completed during the year, it was found that although there is considerable uniformity in the meteorological and sea conditions in the center of tropical cyclones, nevertheless there are occasional wide variations, as for instance, in the state of the sea, which, generally described as tumultuous, is occasionally smooth or only slightly confused. The results of the study, which are of special value to maritime interests, have been made available in manuscript form for publication on the Pilot Charts of the Hydrographic Office as a contribution from the Weather Bureau.

WORK IN PROGRESS

A detailed study has been begun of fog in restricted portions of the North Atlantic Ocean where fogs occur an appreciable percentage of the time, with special reference to the great North Atlantic steamer lanes. It is contemplated that this study will give: The normal distribution of fog for each month, on a 1°-square basis; the wind directions most frequently associated with fog for each 5° square; and historical compilations of variations in fogginess for a few representative areas.

Efforts were continued, as in previous years, to improve barometry on shipboard. As one result, during the year, shipmasters and shipowners replaced, at their own expense, defective and erratic barometers on 44 ships. In order to obtain greater accuracy in

barometer readings, a special investigation was made in the reaction of aneroid barometers to temperature and pressure changes, and a system of variable corrections was inaugurated for reporting ships on the Pacific Ocean. As a further aid in enlisting the interest of the mariner in accuracy of barometer readings and in the preparation of weather maps on shipboard, a special article entitled "Technique of Drawing Isobars on Weather Maps" was prepared and published on the Pilot Charts. Improvement in barometry on shipboard is needed for accurate weather forecasting and as an aid to safety of navigation.

CLOUDS

Clouds are of great interest to the layman as well as to the weather forecaster. Publications of the Bureau on cloud forms and codes were revised to conform to the new cloud definitions and descriptions in the International Atlas of Clouds and States of the Sky. Three publications were printed and distributed. The first is a sheet with 20 selected cloud pictures and abridged definitions for the convenience of observers in identifying cloud forms. The second is a booklet of 24 pages containing 32 selected pictures and complete definitions and descriptions. The third deals especially with cloud codes; it is intended primarily for the use of observers, contains 100 pages, including 70 selected pictures, and presents in detail the code specifications for synoptic messages. Cloud publications are quite necessary in securing accurate observations for weather-map analysis and forecasting.

INTERNATIONAL CONFERENCES

Representatives of the Weather Bureau took part in two meteorological conferences in which meteorologists of many countries participated. A conference of Regional Commission III (South America) was held at Montevideo, Uruguay, in February 1939. While membership in this commission is confined to directors of meteorological services in South America, many of the problems discussed were of mutual interest to the services of both North America and South America; consequently the Weather Bureau sent a representative in compliance with the request of the Commission. As a result of the conference, the cooperative relations between the weather services of the two continents were enhanced, and special progress was made in planning for more adequate reporting from ocean areas and for improved meteorological protection for aircraft.

International conferences held in Berlin, Germany, in June 1939, were attended by two representatives from the Weather Bureau. The biennial meeting of the International Meteorological Committee followed sessions of the Commissions on Maritime Meteorology, Aeronautical Meteorology, and Aerology. Subjects for discussion and coordination included meteorological protection for aviation on long-distance flights and ships' weather reporting in connection with transoceanic service. A special conference of representatives of the Weather Bureau, Civil Aeronautics Authority, and European meteorological services, made preliminary plans for an extended system of rapid exchange of meteorological information between Europe

and North American services four times a day, for the protection of aircraft in flights across the North Atlantic. Standard methods of furnishing weather information were outlined in detail in a new reglement prepared in the Commission for Aeronautical Meteorology. Other important accomplishments included the authorization of an increase in the number of selected ships of all nations for meteorological reports and the draft of new statutes for the International Meteorological Organization, which has voted to hold its next important conference in Washington and Toronto in 1941 for adoption of new statutes and for consideration of many other international problems. The Washington meetings will include the Conference of Directors, held at intervals of 6 years, and a joint conference of regional commissions for North America and South America. This is the first time that international meteorological meetings of this character have been scheduled to be held in North America.

INSTRUMENTAL EQUIPMENT

BAROMETERS

In order to compare the Weather Bureau standard of barometry with those of the Canadian Meteorological Service and the National Bureau of Standards, a high-grade mercurial barometer with 0.6-inch-bore tube was procured in June 1939. After comparisons in the Instrument Division, it was carried by automobile to Toronto, then back to the Instrument Division, and then to the National Bureau of Standards. The investigation is not completed, but it can be stated that the three systems are in agreement within the limits of readings of instruments of this type.

In order to provide mercurial barometers considered especially suitable for use by inspectors, a number of Tuch pattern instruments have been rebuilt. These are expected to be issued shortly.

Twelve ½-inch-bore mercurial barometers procured during the year are now under inspection and calibration. They are intended for installation at stations in various parts of the country so located as to be accessible to inspectors. They will serve as means of reference to make sure that no change beyond allowable tolerance occurs in the inspector's barometer. No departure from the long-established practice of determining corrections for mercurial barometers by comparison with the Instrument Division substandard in Washington is contemplated by this arrangement.

The Weather Bureau standard of barometry is the mean value of the readings of a group of high-grade mercurial barometers that were originally compared with those at Kew Observatory in England and have since been safeguarded and intercompared from time to time during half a century.

A set of precision aneroid barometers is being purchased in the hope that it may serve as an auxiliary means for checking airways barometers. If this method is successful the accuracy of mercurial barometers can be checked in a shorter time by the Weather Bureau airway inspectors than at present.

Development of a fixed-cistern mercurial barometer for station use is in progress. This type can be read more quickly than those of the usual Fortin pattern and possesses advantages in determin-

ing instantaneous values when pumping accompanies high-wind velocities.

CEILING-LIGHT PROJECTORS

In cooperation with the National Bureau of Standards, and the Canadian Meterological Service, there is being developed a new method for determining cloud heights in daytime under conditions of precipitation. Under these conditions the ceiling-balloon method is very inaccurate. The new method consists of interrupting or modulating the light beam projected upon a cloud layer. A light-sensitive clinometer is directed to the projected spot, and the height of the cloud determined by triangulation. In the Weather Bureau the light beam is modulated by electrical means; in the Canadian system it is modulated by mechanical means.

RADIOSONDE

In order to make sure that radiosonde indications are accurate, not only were inspections made at the contractor's factory, but subsequent laboratory and field tests were made by the Bureau. Laboratory checks consist in subjecting the radiosonde to changes of temperature and pressure in the same manner that they occur in an actual sounding, and comparing indications with those of standard instruments. Field checks consisted in attaching to the same balloon carrying the radiosonde three types of recording instruments, which on recovery furnish data for comparing soundings. A method was devised for obtaining slow ascensional rates during the first few kilometers of a sounding so that more accurate values of relative humidity might be obtained. Further development work was done on the radiosonde to improve its performance, especially in rainy weather.

TRANSOCEANIC AEROLOGICAL SOUNDINGS

Experiments have been carried out both on the Atlantic seaboard and the Pacific by placing airplane sounding instruments on transocean aircraft. This use of these instruments presents several problems which it is hoped can be solved during the coming year; for example, exposure of the instrument on the airplane in a way to avoid aerodynamic drag and at the same time obtain an accurate determination of the aerological conditions.

LIBRARY

The Weather Bureau library has the largest collection of meteorological literature in the world. It is extensively used by the technical staff of the central office and by the field stations of the Bureau, as well as by other governmental organizations and private institutions. Of late the demands on the library have increased because of the natural growth of the Weather Bureau service and increasing interest in meteorological research. Nearly 200 periodicals are received, about 50 of which are purchased; the remainder come by exchange with the Monthly Weather Review or are gifts. Many of these periodicals deal solely with meteorology; all contain items of interest for meteorologists. The library also receives by exchange official publications from meteorological services and institutes throughout the world.

Almost every Bureau office, including those at airport stations, requires a small collection of technical works for frequent reference. During the past 3 years the number of volumes in these station libraries has been increased by one-third in an attempt to meet the growing needs of the service.

ADOPTION OF A NUMERAL CODE

Arrangements were perfected to put into operation on July 1, 1939, a numeral code for the transmission of weather observations from meteorological stations located on land. This replaces a code composed of words which was utilized by the Weather Bureau for many years but was not adaptable to international uses. The code is an important factor in modern meteorological services because of the necessity for expeditious exchange of weather data between nations. The numeral code is constructed on principles adopted by the International Meteorological Organization and consists of groups of not more than five figures. As a rule the number of figure groups in a message is not less than five nor more than nine.

Expeditious transmissions, economy, brevity, and accuracy in translating the information, regardless of the country from which an observation emanates, are the objectives of the code, rather than secrecy.

METEOROLOGICAL RESEARCH

Progress in research was achieved in a number of problems covering a wide field in meteorology and its practical applications. The results of research carried on by the Weather Bureau are published as completely as possible in the Monthly Weather Review, which, in addition to its function of promptly disseminating climatological and weather data and reports for public use, also provides limited facilities for the publication of contributions to meteorology.

Among the more important research papers of most general interest that appeared in the Monthly Weather Review may be mentioned the following:

New Values for the Infrared Absorption Coefficient of Atmospheric Water Vapor, by Walter M. Elsasser (vol. 66, p. 175), continuing the investigation of this important problem in meteorological physics, begun last year.

The Determination of Evaporation from Land and Water Surfaces, by C. W. Thornthwaite and Benjamin Holzman (vol. 67, p. 4).

Three papers on synoptic meteorology and air-mass analysis: Frontal Movements Contrary to Indicated Gradient Flow Produced by Minor Waves, by A. K. Showalter (vol. 66, p. 165); The Use of Vertical Cross-Sections in Studying Isentropic Flow, by C. H. Pierce (vol. 66, p. 263), supplementing the paper by H. R. Byers on isentropic charts published on pp. 63–68; and a Practical Method of Computing Winds Aloft from Pressure and Temperature Fields, by Edward M. Vernon and Edward V. Ashburn (vol. 66, p. 267).

Two reports on climatic investigations: Precipitation in the Great Plains, by W. A. Mattice (vol. 66, p. 117), timely summary of climatological data to date for this region; and Climatic Research in the Soil Conservation Service, by C. W. Thornthwaite, Benjamin Holzman, and David I. Blumenstock (vol. 66, p. 351).

Reports on the unprecedented flood-producing rain in southern California: Synoptic Analysis of the Southern California Flood of March 2, 1938, by Charles H. Pierce (vol. 66, p. 135); Southern California Rain and Flood, February 27–March 4, 1938, by Lawrence H. Daingerfield (vol. 66, p. 139); and the usual monthly reports on West Indian tropical disturbances.

A number of manuscripts reporting important investigations were awaiting publication at the close of the year, earlier publication having been prevented by lack of printing funds.

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.

An investigation of the formation of cold waves, which was started in the fiscal year 1937, was brought to a logical completion. The results of upper-air soundings at Fairbanks, Alaska, and their interpretation in relation to terrestrial radiation and snow-surface temperature measurements, are the subjects of comprehensive research reports. The results show that the temperatures, even up to heights of several thousand feet, in the cold air masses of high latitudes in winter are affected by delicate thermal adjustments according to the temperature of the snow surface at the ground and its output of long-wave radiation. Attention was directed toward the problem of the release of these cold air masses, once formed, into the "waves" of intense cold that sweep southward into the United States, especially in its relation to other problems of the general circulation of the atmosphere. In cooperation with the Massachusetts Institute of Technology, under a Bankhead-Jones project centered on the problem of summer weather activity, an integration of the work on winter polar-air invasions and the action of the broad circulation systems of lower latitudes was accomplished. At the same time, in a project in cooperation with the California Institute of Technology the same general methods involved in the study of the cooling of the air overlying the snow surface of the frozen North were applied to the development of "cooling curves" showing, from a given distribution of temperature and water vapor, the rates of cooling or heating at various levels and at various places in the atmosphere.

Three of the most important results that appear to have definite application to longer-period forecasting which have come out of the cooperative research projects with the Massachusetts Institute of Technology and the California Institute of Technology are:

1. The discovery of what appear to be the real factors determining the positions of the warm anticyclones which are the centers of action for the air circulation over the Northern Hemisphere at any given time.

2. The determination of the factors that regulate the displacements of these centers, particularly with respect to the intensity of the west-to-east circulation in middle latitudes, easily observed on ordinary weather charts.

3. The development of modern data concerning radiation and convection into systematic tables and curves of cooling and heating, as mentioned above, producing for the first time concrete detailed information concerning the driving forces of the atmospheric circulation.

In any study centered around long-period atmospheric phenomena the atmosphere of the whole Northern Hemisphere must be the laboratory or proving ground. This is reproduced in miniature on the daily charts of the Northern Hemisphere prepared under a cooperative project with the Massachusetts Institute of Technology, started previously by the Bureau of Agricultural Economics, and taken over this year by the Weather Bureau. Not only were the theories tested by putting them into practice in actual long-range experimental forecasts based on the Northern Hemisphere maps, but also several new clues useful in long-range forecasting were discovered from these charts. The Bureau of Agricultural Economics has cooperated in statistical studies in connection with these charts; and indices based on the observed intensities of the west-to-east, or so-called zonal, circulations have shown great promise.

The study during the previous year of the possibilities of a link between solar activity and meteorological phenomena in the lower atmosphere, brought about through the action of ozone present in the upper atmosphere, justified a modest program of investigation. In cooperation with the University of Rochester, self-recording apparatus for measuring variations in ozone is being developed for field use. New York University is cooperating by furnishing for comparison purposes a Dobson ozone-measuring instrument. It is expected that regular observations will begin soon at Whiteface Mountain, N. Y., to investigate the significant relations between atmospheric ozone content and the weather.

AIR-MASS ANALYSIS

Progress in the development of improved methods of analysis and forecasting of day-to-day weather has continued. Practical acomplishments included the integration of the daily map-analysis work with the map and forecasting procedures at the Bureau's largest forecast center, located in Washington, so that virtually complete practical application of air-mass analysis has been effected. Another accomplishment has been the development of speedy computation methods based on special nomographs for constructing isentropic charts for the use of the forecasters in making their daily predictions. Isentropic charts present the atmospheric flow in a very satisfactory and complete two-dimensional picture and have been recognized as the most practical means of direct representation of upper-air data.

As part of the Bureau's investigational work a detailed study of the New England hurricane of September 1938 was completed; and a special micrometeorological study was made of the winds in the Labor Day 1935 hurricane of the Florida Keys, which was used directly by the United States Army Engineers in cost estimates of hurricane-protection dikes. An investigation of stratosphere heights over the United States, making use of the new radiosonde ascents was started; and various aerological investigations, such as the problem of ice formation on aircraft, thunderstorm electricity, etc., were carried on.

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