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REPORT OF THE CHIEF OF THE WEATHER BUREAU, 1936

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., August 31, 1936.

Hon. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I submit herewith a report of the work of the Weather Bureau during the fiscal year ended June 30, 1936.

Sincerely yours,

WILLIS RAY GREGG, *Chief.*

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INTRODUCTION

Genuine progress was made during the year in reorganizing the work of the Weather Bureau in harmony with recommendations by the Science Advisory Board. (See Annual Report, 1934.) The purpose of this reorganization is to place the Bureau in a position of leadership and bring it up to a standard of excellence that will enable it to contribute its full share in the development of the economic and social life of the Nation. To do this it has been necessary to abandon or greatly modify some of the methods and practices formerly employed; to adopt and use the results of researches that have proved their worth, either in this country or in others; and, in particular, to develop a vigorous program of research in the Bureau itself, a feature of the service that, for one reason or another, had been sadly neglected for some years.

These changes in policy and outlook are being made gradually, and at the same time all regular features of the service are being continued. Many of them are already benefiting from those changes, but, generally speaking, the program of reorganization will require several years for completely working out. The progress thus far has been accomplished largely through adjustment and change within the Bureau itself. Happily, however, a modest increase

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

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in funds during the past year considerably accelerated this progress. It will be necessary that similar increases in funds be provided for the next several years; otherwise it will be impossible for the Bureau to meet the rapidly increasing demands for service from all types of activities.

Up to a few years ago a skeletonized form of service was accepted as reasonably satisfactory or, at any rate, as the best that could be had. No one thought very much about a more detailed service. The advent of aeronautics completely changed the picture. For that activity it was found necessary that weather conditions be reported with great accuracy, not only along the airways but also for considerable distances on either side in order that the development of unfavorable weather could be predicted well in advance of its arrival on flying routes. Moreover, the general daily forecasts were found to be wholly inadequate. It was necessary to develop a new type, very definite and covering a period of about the same length as that of the flight itself.

Now, the question naturally arises, if this intensive type of service is good for aeronautics, why not for other activities also? The answer to the question is that we are tending in that direction right now. In every branch of the Bureau's service—for example, protection of fruits from frosts, protection of forests from fires caused by weather, protection of many sections throughout the country from damage and loss of life by hurricanes, floods, cold waves, heavy snows, etc., these and many others—the demands for more and more detailed data and greater definiteness in the forecasts have increased enormously. Then there are the requirements incident to soil conservation and other phases of our national resources program. The vast engineering projects having as their objective the prevention or control of floods, the storage of water, and the creation of power, are dependent on longer and more complete records of rainfall and other weather conditions than are available if these projects are to be intelligently planned and carried out.

We cannot correct the faults and failures of the past, but we can profit from them in planning for the future. The outlook, with only moderate increases in funds, is extremely bright. Aside from the increasing interest in weather service and the insistent demand for more of it, already referred to, we have now the further encouragement that through the rapid extension of the frontiers of meteorology—in the horizontal by the use of radio; in the vertical through ever-improving technique, again including radio—we have and shall have in increasing measure the necessary working tools for analyzing the structure of the atmosphere in a detail and with a definiteness heretofore impossible. Some of the ways in which the Bureau is endeavoring to extend these frontiers and to take full advantage of what is found there are outlined briefly in the following paragraphs.

ORGANIZATION OF A METEOROLOGICAL RESEARCH DIVISION

During the year the Meteorological Research Division was organized through the consolidation of the previously independent technical units of Meteorological Physics (including the air-mass analysis group), Editorial Office of the Monthly Weather Review, and Solar Radiation Investigations; the position of meteorological consultant was added; and W. J. Humphreys, who was retired from active service as meteorological physicist, was appointed collaborator in the Division.

The usual editorial activities, information and consulting services, and various meteorological studies were continued during the year; observations of solar radiation were made, reduced, and published as in past years, with improvements effected in the instrumental equipment at some of the stations.

PROGRESS IN AIR-MASS ANALYSIS

Substantial progress was made in developing the program of air-mass analysis investigations and their application in forecasting, and in extending the benefits of this work to the field, although progress has been handicapped by lack of funds and facilities. To develop an adequate and effective working procedure in air-mass analysis, to articulate it with the other work of the Bureau, and to amalgamate it with the accumulated knowledge and experience gained in the past, require a prolonged period of preliminary study and trial. The work now being carried on at the Central Office in Washington is designed to evolve, as rapidly as possible, a satisfactory and workable technique of procedure, and to gain the necessary experience. The routine part of the work is gradually being

expedited, to make the results more promptly available and of greater assistance to the official forecasters who are utilizing it to a constantly increasing extent. The preparation of from two to four analyzed maps daily, and the construction of daily vertical cross sections through the atmosphere over the United States so far as available data permit, have been continued, and daily conferences on these charts have been carried on.

Widespread interest has been manifested in this work, both on the part of the personnel of the Bureau and on that of many interests which it serves. It has not been possible to increase further the number of highly trained air-mass personnel beyond the three mentioned in the preceding annual report, or to meet all desires and requests for service in connection with the work. However, a limited number of selected Weather Bureau men have been detailed for brief periods of intensive training at the Central Office, through both formal instruction and actual practice in assisting in the regular work.

LECTURES BY DR. PETTERSSEN

During January 1936 Sverre Petterssen, of the Norwegian Meteorological Service, conducted a series of lectures and conferences at the Central Office on the physical analysis of weather maps by frontal and kinematic principles, and on weather forecasting. These discussions afforded striking evidence of the extent to which it has become practicable during recent years for the former empirical methods of forecasting to be supplemented by procedures based on an understanding of the physical processes that are operating; great benefit to the work of the Bureau resulted from this personal contact with Dr. Petterssen.

In addition, a limited amount of research work on several problems involved in air-mass analysis and its practical applications has been carried out—particularly a preliminary study of the physical phenomena leading to the development of the severe cold waves which often enter the United States from Canada.

RESEARCH IN LONG-RANGE WEATHER FORECASTING

Articles in the press as well as inquiries from numerous individuals indicate that the need for pursuing investigational work looking toward the making of long-range weather predictions is as urgent as, perhaps more urgent than, ever before. The Secretary's active encouragement of research along these lines has been an inspiration not only in this Bureau but in other branches of the Department. Under the Bankhead-Jones Act, work has been taken up in the Bureau of Agricultural Economics to examine the different methods of long-range forecasting in use and to appraise their relative possibilities. Publication of the results of this survey should promote and encourage research work along these lines in institutions of learning, and in commercial, industrial, and agricultural fields. Already cooperation has been secured from at least one of our leading universities.

In addition, the Weather Bureau, under an allotment from the Works Progress Administration, has continued its investigations begun under the Civilian Works Administration. This work consists in establishing relationships between conditions in the United States and precedent conditions in foreign countries. So far there has been completed a preliminary survey of relationships between temperatures by quarter years in 12 districts of the United States with pressure conditions at 60 foreign stations distributed throughout the world, both in the Northern and Southern Hemispheres. The time intervals employed were 3 months, 6 months, and 9 months. The survey of rainfall conditions in the United States as compared with precedent pressure conditions at the 60 foreign stations is rapidly nearing completion. It is planned next to take up relationships between foreign temperatures and rainfall and subsequent temperature and rainfall conditions in the United States. When these preliminary surveys have been completed, combinations will be made by means of multiple correlation coefficients and the necessary regression equations, of the significant relationships found in the preliminary surveys looking to the making of seasonal forecasts. It seems likely from what has been developed up to the present time that it should be possible, when the formulas indicate well-marked departures from normal weather, to make seasonal outlooks having a probability of success of 7 out of 10 and possibly 8 out of 10 cases. The situation is being carefully canvassed to ascertain whether secular trend, that is, tendencies to higher or lower values extending

over periods of 25 to 40 years, may not be utilized to improve the chances of success mentioned above. A suggestion of conservatism may not be out of place in emphasizing that expectations indicated above should be anticipated only when abnormalities indicated by the formula are large and this, of course, would only occur in about one-third of the years.

Steady and worth-while progress is being made on the problem of seasonal forecasts that will no doubt be of great benefit in the not too distant future.

IMPROVEMENTS IN EQUIPMENT

RADIO METEOROGRAPH

In cooperation with the National Bureau of Standards the Weather Bureau has worked toward the perfection of a practical system for radiometeorography, whereby knowledge of meteorological conditions aloft can be made instantly available for forecasting and other purposes. The Instrument Division has designed and constructed a model telemeteorograph for transmitting temperatures and pressure indications by means of radio to be used in connection with this system. It is hoped that this instrument, which is simplified in electrical and mechanical design, will meet service requirements in trustworthiness and relatively low cost of manufacture. A further contribution by the Weather Bureau is the substitution of a timing device driven by air escaping from a small rubber balloon for the spring-driven clockwork hitherto employed.

CEILING LIGHT PROJECTOR

Investigations to develop a more intense beam of light for illuminating a spot on a cloud layer at night as a means of determining height of cloud layer are being carried on in cooperation with the National Bureau of Standards.

ANATHERMOSCOPE

It is known that in some regions, notably on the Pacific coast, an abnormally warm layer of air at a height of several thousand feet precedes by several hours the formation of fog. Knowledge of this formation and height of these low clouds or fog will facilitate the dispatching of airplanes in this district. Some inexpensive device is needed to indicate the existence of such a layer. Accordingly there has been developed in the Instrument Division a device that responds almost instantly to a sudden change in temperature. It is arranged to show some sort of signal, either a light at night or a parachute released in daytime, if, when carried aloft by a small balloon, such a layer of abnormally warm air is penetrated. It is in the experimental stage.

DICTIONARY OF METEOROLOGICAL TERMS

Among the important services rendered by the Weather Bureau Library was the continuation of work on a dictionary of meteorological terms. The technical vocabulary of meteorology and its rapid growth during recent times have for many years been the subject of able investigations and record by the late C. F. Talman, who was in charge of the Library until his death in July 1936. The results of his labors are now embodied in a unique and invaluable card dictonary, of an encyclopedic character, of meteorological terminology, nomenclature, and usage.

PROGRESS IN MARINE METEOROLOGY

During the year the Bureau undertook the work of reviewing and preparing meteorological information for publication in the Sailing Directions of the Hydrographic Office. Hereafter, as it becomes necessary from time to time to revise the volumes in this series, the Bureau will cooperate by preparing meteorological summaries and tables from original weather observations taken on shipboard and at coastal stations. Work done as a part of this program during the past year included finished manuscripts for Sailing Directions for West Indian waters, the Indian Ocean along the coast of East Africa and East Indian waters. Similar work was begun in connection with Hydrographic Office publications in the aid of air navigation.

COMPILATION AND SUMMARIZATION OF BACK DATA, UNDER WORKS PROGRESS ADMINISTRATION

As a special project under the Works Progress Administration at New Orleans, La., the task of compiling and summarizing marine weather observations in the files of the Weather Bureau was resumed in March 1936. The original observations used in the project were taken on ships at sea during the years 1880 to 1933, inclusive, on voyages in all parts of the oceans where merchant ships have navigated. In that period of years more than 5,000,000 such observations have accumulated. In order that the information contained in these observations may be made available to the mariner and others in the form of wind roses, wind and weather summaries, and other charts and compilations, they must be sorted by ocean squares, usually 5° of latitude and longitude, after which they are tabulated and summarized. This task has involved more work than could be accomplished by the regular Bureau staff, hence the observations have accumulated without more than a relatively small amount of important information being extracted.

Much valuable preliminary work in this line was accomplished during the winter of 1933–34 by a project under the Civil Works Administration. More than 2,000,000 machine card records of ocean weather observations for the period 1912 to 1931, inclusive, were produced at that time. These machine cards, together with more than 3,000,000 additional observations in original form, are the basis of the work at New Orleans which was still in operation at the close of the year.

In preparation for the project, the supervisors were given preliminary training in the Weather Bureau. The workers have varied in number from about 180 to 240. On July 1, 1936, 2,350,000 observations had been recorded on tally sheets; 260,000 had been transcribed from the original list sheets to individual slips for sorting and tally; and 650,000 machine cards had been tallied.

On completion, this project will provide exceedingly valuable information in convenient form for the needs of navigation of the oceans and the air over the oceans, and will lay the groundwork for studies of world weather in relation to the problems of agriculture, flood control, and other important activities.

IMPROVEMENT OF MARINE METEOROLOGICAL EQUIPMENT

Excellent progress was made in attaining a higher standard of barometers on shipboard. The type commonly used is the aneroid, a considerable proportion of which are defective. The most frequent defect is a lack of compensation for temperature changes. Barometers that are not properly compensated show a complex reaction to both temperature and pressure of the air which is difficult to evaluate. The Bureau does not have funds for a program of furnishing standard instruments and does not pay the mariner for taking weather observations. It is therefore necessary to present the facts to the mariner by correspondence or personal visit to the ship when a barometer is suspected of having serious defects, and to endeavor to have the defects remedied or the instrument replaced. In this effort the Bureau receives the most hearty cooperation of the mariner.

During the year ended June 30, 1936, defective barometers on 81 additional merchant ships were replaced at the suggestion of the Bureau. This action has important results for the reason that barometric pressure is one of the most significant elements in weather forecasting, making accuracy in barometer readings essential.

RESEARCH PROJECTS

A special study of atmospheric refraction and mirage at sea was completed during the year. The study was based on data compiled from marine observers' weather reports. In the course of the study, it was found that refraction phenomena occur not only in local regions where the atmosphere is disturbed, but over larger areas along the boundary lines of oceanic cyclones and anticyclones both progressive and semipermanent. In addition, it was found that atmospheric conditions producing fog might also produce mirage. The investigation is of special interest to mariners because excessive refraction sometimes involves a menace to navigation. The results of the study have been put in manuscript form for publication on the Pilot Charts of the Hydrographic Office as a contribution from the Weather Bureau.

Investigations in temperatures of the sea surface were continued. The University of Oklahoma entered into active cooperation with the Bureau in these studies by initiating action to purchase a sea-water thermograph for installation on a merchant ship, bringing the total number of such installations under supervision of the Bureau to 14.

IMPROVEMENT IN FLOOD-FORECASTING ORGANIZATION

The outstanding floods in the year that ended June 30, 1936, occurred in the upper Ohio Valley and in the Atlantic Coast States north of North Carolina. They were caused primarily by a storm which moved in a generally south-to-north direction over the Atlantic Coast States, but their intensity was greatly augmented by the deeply frozen ground and heavy snow blanket, resulting from the unusual rigors of the winter. Their unprecedented severity clearly established the urgent necessity for an early consummation of a plan that had been developed, and was being put into effect gradually, for strengthening the river and flood service to meet, or keep step with, the increasing attention being given water conservation and use, the development of natural streams, the protection against floods, and the steady growth of industry and agriculture in river valleys.

From year to year increasing demands for weather information are being made on Bureau stations, and it is difficult to keep pace with them. Calls for daily river stage forecasts and general river news are increasing at a corresponding rate, and when floods threaten the officials in charge of stations on rivers are submerged with demands for information. As an example of the great interest in flood information, one office in a recent flood had 8,611 telephone calls in 20 consecutive hours; this rate would have continued through a longer period except for the abrupt ending of the telephone service by flooding.

HYDROLOGIC SPECIALISTS REQUIRED IN RIVER FORECAST WORK

It has for some time been realized that the officials in charge of the numerous and varied duties making up a day's work on a Bureau station no longer are able to study river problems in the deliberate way necessary in attaining the desired ends, and in the emergency of a flood they find themselves overwhelmed. It was, therefore, obvious that, in justice to the public, hydrologic specialists should be available to relieve these officials of the task of revising and developing new flood-forecasting formulas based on improved hydrologic data constantly becoming available, to prepare and keep current systems for the prompt collection of rainfall and river-stage data, to study the requirements in overflow valleys for flood forecasts and to perfect and keep up to date plans for satisfying these requirements, and to coordinate the flood work of the Bureau with the work of other agencies engaged in collateral activities.

The program that has been set up, to accomplish the foregoing, and toward which the Bureau is working, provides for hydrologists in each important river basin of the country to handle the details just outlined and, in general, to be charged with the direct responsibility of giving an efficient and smooth-working river and flood service in their respective districts. The start that has been made seems almost too small to be worthy of mention; only two basins have been provided for—the Missouri and the upper Mississippi—but the advantages of and the necessity for carrying the plan to completion are so obvious it is felt the necessary funds will be provided in a comparatively short time.

SERVICE IN AID OF AIR NAVIGATION

The meteorological service for airways was expanded somewhat during the year to provide limited service on 11 new airways, totaling approximately 4,000 miles. Under this expansion, 79 stations were established and equipped with meteorological instruments to report one weather observation for each airplane clearance. Such service is maintained on approximately half of the 32,000 miles of airways in the United States, Alaska, and Hawaii, while on the other half weather reports by teletype and radio are provided on an hourly basis.

There are now 52 first-order Bureau airport stations where weather maps, hourly weather reports, pilot-balloon observations, and meteorological advice or forecasts are available. In addition, there are 186 stations rendering hourly weather observations, 324 airway stations rendering weather observations on

call, and 66 off-airway stations rendering reports every 6 hours in the airway weather network, or a total of 628 stations. Additional reports from stations in Canada, ships at sea, and city offices of the Weather Bureau are received. Selected reports from the above groups are relayed to all airway teletype and radio circuits every 6 hours for the preparation of 6-hour weather maps. Ten airport stations, located at Newark, N. J.; Cleveland, Ohio; Chicago, Ill.; Atlanta, Ga.; Kansas City, Mo.; Dallas, Tex.; Salt Lake City, Utah; Portland, Oreg.; and Oakland and Burbank, Calif., supervise the service in their respective districts and issue regular and special airway weather forecasts every 6 hours for the periods 4 a. m. to noon, 10 a. m. to 6 p. m., 4 p. m. to midnight, and 10 p. m. to 6 a. m., eastern standard time.

The extreme weather conditions, such as cold waves, heavy snows, floods, and drought which occurred during the year, not only brought heavy demands upon the Bureau airport stations from the aviation industry but brought an increasing volume of telephone calls from outside interests. The calls became so numerous and time-consuming that the service for airways was jeopardized. To correct this situation, telephone numbers at busy airport stations were unlisted to divert outside telephone calls to city offices of the Bureau, where properly they should be received.

CONSOLIDATION WITH BUREAU OF AIR COMMERCE

The consolidation of meteorological and communication activities at 35 airports, effected near the end of the previous fiscal year through cooperation of the Bureau of Air Commerce and the Weather Bureau, was continued throughout this fiscal year, with the exception of three stations, namely, Murfreesboro, Tenn.; Pendleton, Oreg.; and Wichita, Kans. The necessity for point-to-point radiotelegraph communication or the junction of teletype circuits prevented the continuance of the plan at the latter stations. However, additional consolidations were made at Charlotte, N. C., and Jacksonville and Miami, Fla., during the year. The plan of utilizing both Bureau of Air Commerce and Weather Bureau personnel in carrying out the work of each Bureau has proved to be a most efficient and economical arrangement. It has, in large part, eliminated dual responsibility of the employees, permitted certain economies to be effected, and has provided more time for maintenance of radio and teletype aids by the Bureau of Air Commerce. The advantage of the maintenance program at consolidated stations is reflected by a marked drop in the number of reports to that Bureau of inoperative facilities at such stations.

AIRPLANE OBSERVATIONS

During the fiscal year there were in operation in the United States and the Hawaiian Islands 23 airplane weather stations, whereat an instrument called an aerometeorograph is taken aloft by an airplane to make an autographic record of the barometric pressure, temperature, and relative humidity of the free air, and the pilot makes visual observations of such phenomena as clouds, precipitation, icing conditions, turbulence, etc., encountered during the flight. These included the following:

Weather Bureau stations; flights made by a private flying concern under contract:

1. Billings, Mont.
2. Cheyenne, Wyo.
3. El Paso, Tex.
4. Fargo, N. Dak.
5. Murfreesboro, Tenn.
6. Oklahoma City, Okla.
7. Omaha, Nebr.
8. Spokane, Wash.

Army stations; flights made by the Army Air Corps, carrying an aerometeorograph, the records of which are evaluated by personnel of the Weather Bureau, which organization owns the instruments:

1. Barksdale Field, Shreveport, La.
2. Boston, Mass.
3. Kelly Field, San Antonio, Tex.
4. Maxwell Field, Montgomery, Ala.
5. Mitchel Field, Hempstead, N. Y.
6. Selfridge Field, Mount Clemens, Mich.
7. Scott Field, Belleville, Ill.
8. Wright Field, Dayton, Ohio.

Navy stations; flights made by Navy Department, using Navy equipment and personnel, while the data are furnished to the Weather Bureau:

1. Lakehurst, N. J.
2. Norfolk, Va.
3. Pearl Harbor, Hawaii.
4. Pensacola, Fla.
5. San Diego, Calif.
6. Seattle, Wash.
7. Washington, D. C.

In the first category of stations the Bureau had one more than during the preceding year. This was established at El Paso, Tex., in July 1935. It has proved to be very strategically located, as evidenced by its great worth for the analysis of air masses passing into the central part of the country from the Gulf of Mexico and the Pacific Ocean, and has aided in the determination of the normal trajectory of these air masses during different times of the year, a matter which hitherto was troublesomely uncertain.

During the fiscal year the station at Spokane, Wash., where prior to July 1935 weather flights were made by pilots of the Washington State National Guard, was changed from the second to the first category.

An Army station was opened in August 1935 at Boston, Mass., where formerly airplane weather observations were made by the Army Air Corps in cooperation with the Massachusetts Institute of Technology during the school term. The value of observations from this place has been enhanced as a result of their being extended throughout the entire year.

The Army station which was opened at Barksdale Field, Shreveport, La., in June 1935, having been transferred from Galveston, Tex., has shown itself to be important by giving a better representation of air masses in the vicinity of the Gulf of Mexico, whence comes so much of the warm, moist air necessary for precipitation in the central and eastern parts of the country.

The Navy station formerly located at Sunnyvale, Calif., was closed in October 1935.

From the beginning of the fiscal year observations of vertical and oblique visibility at elevations of 5,000, 10,000 feet above sea level, and the maximum altitude reached were required of all pilots engaged in making these flights.

On October 15, 1935, all airplane weather stations began to render reports of the specific humidity and equivalent potential temperature prevailing at the various significant levels for which data were transmitted. These reports have demonstrated their great value in the daily analysis of air masses, fronts, and concurrent weather phenomena. The use of vertical cross sections of the atmosphere to portray meteorological conditions in the third dimension was thereby facilitated and was extended, in general, during the fiscal year. Summaries of these additional data are being compiled at the Central Office of the Bureau for future application.

An investigation made to determine certain physical aspects of polar continental air, which gives rise to cold waves, indicated the urgent need for one or more airplane weather stations in the regions over which these air masses acquire their intense coldness. Under the stimulus of this work an allotment of funds under the Bankhead-Jones Act was sought and secured to establish an airplane weather station at Fairbanks, Alaska, during the winter season 1936–37. Some of the equipment for this purpose was procured and plans were formulated for establishing the station during the succeeding fiscal year.

PILOT-BALLOON OBSERVATIONS

Pilot-balloon observations were inaugurated at one additional station located at Missoula, Mont., during the fiscal year. The number of observations per day were increased from two to three at one station, from two to four at another and from three to four at nine stations. At the close of the year a total of 244 pilot-balloon observations were being made daily at 77 stations, including three in Alaska and one at San Juan, P. R. Assistance was given by the Bureau to a commercial steamship line operating between San Francisco and Honolulu in making daily pilot-balloon observations from two of their ships for service to the trans-Pacific airline operations. A special summary of upper air winds in the upper troposphere and lower stratosphere correlated with temperature, pressure, and humidity was made for the benefit of aeronautical interests engaged in studying the problem of high-altitude flying. This summary will soon be ready for publication. Action was taken to gain more information regarding the air movements in the stratosphere.

OPERATION OF THE TELETYPE SYSTEM FOR HURRICANE-WARNING SERVICE

During the year eight tropical storms were charted in the Gulf of Mexico, Caribbean Sea, and southern North Atlantic Ocean. The collection of weather observations from ships at sea, and from island and coastal stations, in connection with the issue of advices and warnings of these storms, afforded an excellent test of the new teletype system for hurricane-warning service which was inaugurated on July 1, 1935.

Operated exclusively for that service, the teletype system connects forecast centers at New Orleans and Jacksonville directly with 10 other Bureau stations on the coast. Instant communication of important observations to the forecast centers and immediate dispatch of advices and warnings are made possible. During periods when tropical storms approach the coast the ordinary commercial facilities for communication are severely taxed by the large volume of inquiries from persons who are anxious about the protection of life and property in the threatened areas. The control of a clear channel to important Bureau distributing stations has proved to be highly valuable in such emergencies.

Experience in connection with the eight tropical storms of the past year shows that a larger collection of observations can be secured with greater speed and at more frequent intervals than was possible heretofore. With this additional information at hand, advices and warnings are issued at shorter intervals and in greater detail. The infrequency and brevity of public releases regarding tropical storms was the subject of criticism under the former plan, but ordinary commercial facilities shared with the public could not be satisfactorily adapted to the drastic service requirements of storm emergencies.

With the teletype system in operation, each of the Bureau's coastal stations in the system is promptly supplied with all of the significant weather reports collected by radio, cable, and telegraph for immediate dissemination of vital information to the general public by radio broadcast, in the daily newspapers, by posted bulletins, and to individuals by telephone, telegraph, messenger, and by personal contact. The teletype system during its first season of operation was an unqualified success.

ABNORMAL WEATHER OF RECENT YEARS

Several noteworthy climatic features in recent years have attracted widespread attention, especially the succession of three severe and widespread droughts—1930, 1934, and 1936—each of tremendous national significance. Other abnormalities include the severe winter of 1935–36, unprecedented floods in the Eastern States, bad dust storms in the Midwest, and destructive tornadoes in the Southeast, all occurring during the spring of 1936.

COLD WINTER OF 1935–36

For a number of years the winters, in general, had been mild, especially the five up to and including 1934–35. In contrast to these the winter of 1935–36 was one of the severest ever experienced in many districts, being the coldest of record in some northwestern sections of the United States, with a 3-month temperature average of from 6° to as many as 12° F. below normal; in the northern Plains, for example, the winter was from 15° to nearly 20° colder than the average for the preceding five winters. However, a considerable area in the far Southwest had a somewhat warmer than normal winter.

The coldest weather occurred during a period of about 30 days ended around February 20, during which the temperatures were persistently low. At Devils Lake, N. Dak., typical of conditions in the central-northern part of the country, there was established a winter-temperature record that probably has no parallel in the climatic history of this country for a first-order Weather Bureau station. At this place the temperature went below freezing on November 27 and did not thereafter rise to the freezing point until March 1, a period of 96 days. For 37 days, January 14 to February 19, there was only 1 day on which the thermometer registered as high as zero, while the week ended February 17 had an average temperature of —28°; the average for 2 months—January and February—was —13°.

EASTERN FLOODS, MARCH 1936

In addition to the severe cold, the snowfall was the heaviest in many years in the country north of the Potomac, Ohio, and Missouri Rivers, and late in February and early in March mild, rainy weather caused rises and ice gorges in the rivers of New England and the Middle Atlantic States. In Virginia and Maryland some damage resulted from ice movement, but the combined run-off from the rain and melted snow was insufficient to give injurious floods. New England, New York, and Pennsylvania were not so fortunate, and there was considerable damage from both the crushing effects of ice and from flood waters.

By March 16 the streams in Virginia and Maryland had fallen considerably and a fall had begun north of Maryland. Conditions were approaching normal, but on March 17 a storm that originated on March 15 in Texas had moved to south-central North Carolina, bringing general rains over the Middle Atlantic

seaboard and the upper Ohio Basin. These rains were phenomenally heavy in the country to the west of the coastal plains and along the divide between the eastern rivers and the upper Ohio Basin. Precipitation of nearly 5 inches occurred in 12 hours or less over a large area in the mountainous sections of Virginia, Maryland, and western Pennsylvania, and more than 6 inches fell at some stations in a period of 48 hours or less. The storm moved slowly in a northeasterly direction and the rains were heavy over all of the North Atlantic seaboard. To the northeastward the amounts were not so heavy, but from a flood-producing viewpoint the results were about the same, because the rivers in the southern part of the area under consideration were much lower at the beginning of the rain than they were in Pennsylvania, New York, and New England.

The rains fell on well-saturated and semifrozen soil, and the percentage of run-off was unusually high. This, coupled with the fact that the northern rivers were at or above flood stage, and those in Maryland and Virginia, while not in flood, were higher than normal, gave the most disastrous floods of record in the James, Potomac, Susquehanna, Connecticut, and Merrimack Rivers, in some of the tributaries of the Ohio River in Pennsylvania and in the Ohio from Pittsburgh, Pa., to below Wheeling, W. Va.

The Ohio River flood gave a record crest stage of 46.0 feet at Pittsburgh on March 18. The previous high-water record was 38.7 feet on March 15, 1907.

Flood losses in the Northeastern States in March were undoubtedly the greatest of record. Several hundred thousand people were made homeless by the flood waters and many homes were completely destroyed. The actual number of drownings may never be known, but unofficial figures place it at more than 170. Business was partially or completely paralyzed in many of the large industrial sections, and losses to wage earners and retailers amounted to large sums.

MIDWEST DUST STORMS

The great drought of 1934 terminated in most sections of the country in September of that year, but the weather continued outstandingly dry in a southwestern area, centering in southeastern Colorado, western Kansas, western Oklahoma, northwestern Texas, and northeastern New Mexico, the area becoming popularly known as the "Dust Bowl." For the 18 months from September 1934 to February 1936, while most other sections had near normal precipitation, this area received from less than half normal to only about 60 percent of normal. As a result of the continued dryness, there were bad dust storms in the southwestern area during the months of March and April, with some dust occasionally carried by the wind far to the eastward, even to New England; May had heavy rainfall, which effectively ended the bad dusty condition.

SOUTHEASTERN TORNADOES

During the first week of April 1936 two series of disastrous tornadoes occurred in several Southeastern States, the first on April 1–2 and the second on April 5–6. In the first series tornadic storms were reported from 7 cities or towns in Georgia and the Carolinas; in the second the storms were of greater geographic extent, occurring at 17 different places scattered through 6 States, including Arkansas, Tennessee, Mississippi, Alabama, Georgia, and South Carolina.

For the first series the most destructive storms occurred at Cordele, Ga., at 7:30 a. m., April 2, and Greensboro, N. C., about 7 p. m. of the same day. At Cordele 23 persons were killed and nearly 500 injured. In addition to the heavy loss of life, the property destruction was appalling, 287 buildings being demolished, of which 100 were among the best residential homes in the city. Many of the finest houses were torn to splinters, as if blown up by great charges of dynamite. The property damage amounted to some $3,000,000.

In the wake of the Greensboro storm the casualties counted included 13 persons killed, 144 injured, and 289 buildings demolished, 56 of which were totally wrecked; property damage was estimated at $2,000,000. This was the most destructive tornado of record for North Carolina.

In the second series a very disastrous storm occurred at Tupelo, Miss., at 8:55 p. m., April 5, causing appalling loss of life and between $3,000,000 and $4,000,000 of property destruction; 216 people were killed, and 700 injured at Tupelo and in its vicinity.

The most destructive of all the tornadoes occurred at Gainesville, Ga., about 8:30 a. m., April 6. The storm was attended by winds of most violent force, which utterly demolished about 750 houses and badly damaged more than 200 others, almost completely destroying the business district of the city. The loss of life reached the appalling total of 203, while 934 others were injured. Evidence indicates that the Gainesville destruction was probably the work of three distinct tornadoes occurring almost at the same time.

The tornadoes comprised in these two series, considering the number of people killed and injured and the property damage, probably rank third in destructiveness in the tornadic history of the United States. In the first series of April 1–2 about 41 persons were killed and 540 injured; in the second, April 5–6, some 452 persons lost their lives and 1,775 were injured.

THE 1936 DROUGHT

The weather of 1936 has been decidedly unfavorable for agriculture over the greater portion of the United States, making the third year since 1929 with such prevailing conditions. Precipitation of the winter and early spring was very scanty in the Southwest, where the soil became extremely dry, and severe dust storms caused much damage by drifting and by blowing out winter wheat. However, in May there was a reaction to abnormally heavy rains, materially improving conditions; they were especially helpful to winter wheat over large areas, particularly in Kansas.

While the May rainfall improved the outlook materially in the Southwest, other parts of the country were less fortunate, and serious conditions slowly, but surely, developed over large areas. Dry weather in May and June brought widespread damage to early truck, hay, and pastures, the latter becoming very poor in nearly all sections between the Appalachian and Rocky Mountains.

The spring was the driest of record in many southeastern localities, and great harm resulted to early crops in considerable areas, especially from North Carolina southward and southwestward to central Alabama. The winter wheat crop was not seriously affected by the drought, principally because of May rains in the western portion of the Wheat Belt, and comparatively cool weather in the eastern part, though it became decidedly dry and some deterioration resulted, especially in northern districts.

The heat and drought seared what little pasture was left, and dried up available stock water. With neither food nor water to be had over large areas, the livestock situation became desperate, with heavy shipments necessary to prevent death of thousands from starvation and thirst. The spring wheat crop and other small grains in the Northwest were severely damaged, but conditions continued favorable in the North Pacific area.

July was extremely dry throughout the interior of the country, with considerable areas having less than 10 percent of normal rainfall. On a State-average basis, there was less than half of normal (usually much less) in the western Ohio Valley, the Lake region, the upper Mississippi Valley, and throughout the Plains from Oklahoma northward to North Dakota and Montana. Kentucky and Ohio, with 90 and 79 percent of normal, respectively, were the only States between the Appalachian and Rocky Mountains north of the Cotton Belt having as much as half of the normal rainfall. The States from Oklahoma northward to North Dakota had only from 20 to 36 percent of normal; Minnesota had about 20 percent, and Iowa less than 15 percent. July 1936 was drier than July 1934 in every State from Kentucky, Missouri, and Oklahoma northward to the Canadian border.

The month was also extremely hot; the hottest July of record in Indiana, Illinois, Minnesota, Nebraska, the Dakotas, and Montana. The average temperature for the month was higher by far than the previous high record in a large central-northern area. In North Dakota the monthly mean exceeded the previous high July record by 6° and the previous maxima in South Dakota and Montana were exceeded by more than 4°.

The months of June and July combined had an average of only about one-third of normal rainfall in the Plains States and around 40 percent of normal in the western Ohio and middle Mississippi Valleys. In the interior States the 2-month period was much drier than the same 2 months during the great drought of 1934. In that year, for these 2 months, Missouri had about 30 percent more rainfall; Ohio, Kansas, Nebraska, and Montana about 50 percent more; Indiana, Illinois, Wisconsin, and North Dakota about twice as much; Minnesota and

Iowa considerably more than twice as much, and South Dakota nearly three times as much rain as fell this year.

The 4 months of the growing season to the 1st of August were the driest of record in the Dakotas, Minnesota, Wisconsin, Iowa, Missouri, Illinois, and Indiana, and the second driest in Ohio, Kentucky, Oklahoma, Kansas, and Montana. Of the Central and Northern States between the Appalachian and Rocky Mountains only Michigan, Kansas, and Nebraska were drier in 1934 than this year for these 4 months.

Of the major crops, corn suffered the greatest loss from the drought and heat of July. Up to the beginning of this month this crop had not been seriously harmed over wide areas, but in July the extremely high temperatures and lack of rainfall caused heavy losses, especially from the Mississippi Valley westward. The prospective crop was reduced during the month from 2,244,834 to 1,439,135 bushels, as reported by the Department of Agriculture.

August weather was characterized for the most part by a persistence of abnormal warmth and scanty moisture in the interior valleys and central and southern Great Plains. Maximum temperatures ranged up to well above 100° F. almost daily over a large area. Rainfall was of a decidedly local character, though scattered showers were rather frequent in the Northern States of the interior of the country. During August the drought extended southward to include most of Texas and Louisiana, Arkansas, Mississippi, and Tennessee, but in northern sections, from New England westward to the Plains, conditions improved materially. The weather continued favorable in most of the southeast and much of the Atlantic area and also rather generally from the Rocky Mountains westward, though the Pacific Northest became too dry.

The summer (June–August) was the driest of record in Illinois, Missouri, Oklahoma, Kansas, Nebraska, and the Dakotas. In addition, while previous dry records were not broken, Indiana, Wisconsin, Minnesota, Iowa, and Arkansas had less rain in the summer of 1936 than during the same season in the drought of 1934. Previous high temperature records were exceeded in many sections.

EARLY SEPTEMBER RAINS

During the first 10 days of September widespread drought-relieving rains occurred over much of the interior of the country, especially in the Lake region and the Mississippi and Ohio Valley States. The early September moisture brought only partial relief in the Plains States, except in Kansas, extreme western Oklahoma, and northwestern Texas, where good rains occurred. While the rain came too late to materially improve the corn crop, it was timely and of great value in conditioning the soil for plowing, for fall seeding, and for late forage crops to be used for pasturage.

DROUGHTS IN THE UNITED STATES

Droughts in the United States may be divided into two general classes. In one class are those of a transitory nature, affecting usually a relatively small area and of comparatively short duration, frequently lasting only a single year; in the other those general drought conditions that have a tendency to persist for comparatively long periods of time. Smoothed weather records show long-time trends in precipitation, covering a good many years, alternately above and below normal. The short-period droughts are not usually definitely related to these more general long-time trends. When a minimum phase of precipitation obtains, such as is now being experienced, there occur at short intervals what may be called families of droughts, in contradistinction to the transitory, or short-period ones, that fall in the first-named group.

DROUGHT PERIOD OF 1886 TO 1895

Prior to the minimum phase of precipitation responsible for the present family of droughts, so to speak, the last general condition of this kind occurred in the latter part of the eighties and the early nineties of the last century. At that time, following a series of years of rather abundant rainfall, widespread scanty moisture began in 1886; and while interrupted in 1892 by fairly abundant moisture, there was a marked tendency generally for subnormal rainfall from 1886 up to 1895, culminating in severe droughts in 1894 and 1895, the driest

years of that minimum phase. The year 1896 had fairly good precipitation, but 1897 was deficient in moisture between the Mississippi River and the Rocky Mountains.

Following this general long-time drought there were several belonging to the transitory class, being short-lived, and often seriously affecting only comparatively small areas. Among these may be mentioned that of 1901 in the interior valleys and the Southwest. The following year, 1902, had plenty of moisture in most States. Another occurred in 1910, principally in the Central and Northern States and the South, but this again was largely a 1-year affair. Another one in 1917 affected principally the Southeast and northern Plains, and still another, in 1925, was severe in the South and Southeast. Thus for some 60 years up to 1930 there were a number of short-period droughts but only one persistent and markedly dry phase of United States climate, that of 1886–95, lasting, in general, about 10 years, but some years, of course, being better than others.

DROUGHT PERIOD OF 1930 TO 1936

The present dry phase began in 1930 and has continued, with a few interspersions of fairly good years, such as 1935, up to the present time. There have been in this period 3 extremely dry years—1930, 1934, and 1936. Table 1 shows the percentage of normal rainfall, by States or sections, for each year from 1930 to 1935, inclusive, and by months from January to August 1936.

TABLE 1.—*Percentage of normal precipitation by States*

State or region	1930	1931	1932	1933	1934	1935	1936							
							Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.[1]
Alabama	87	81	121	91	104	93	253	139	61	159	48	44	133	128
Arizona	114	144	100	86	78	112	69	150	102	27	42	64	110	103
Arkansas	96	97	105	101	88	117	24	51	45	54	49	31	130	11
California	78	103	66	86	76	94	104	226	51	96	64	254	272	120
Colorado	105	85	86	92	66	96	100	157	76	44	91	101	97	137
Florida	114	83	100	106	101	99	187	219	106	77	101	120	89	96
Georgia	93	74	114	84	96	90	224	134	89	219	35	68	88	122
Idaho	95	83	111	100	89	72	180	171	83	73	57	170	91	130
Illinois	75	102	98	94	88	112	61	87	56	72	50	40	37	79
Indiana	75	97	108	103	75	100	48	108	73	91	50	38	47	91
Iowa	82	112	102	79	85	105	157	123	59	40	71	61	13	98
Kansas	100	97	89	83	74	106	108	23	10	45	129	31	26	34
Kentucky	61	92	97	111	81	126	69	57	103	121	37	20	90	59
Louisiana	95	94	112	98	106	102	107	90	43	93	111	11	104	88
Maryland-Delaware	58	94	115	120	112	116	186	124	169	80	62	81	99	91
Michigan	74	97	108	99	83	93	98	105	50	79	66	64	38	130
Minnesota	89	89	86	83	80	102	101	193	125	63	79	46	22	91
Mississippi	89	98	127	94	100	96	124	98	50	98	60	32	119	57
Missouri	78	100	94	90	85	118	45	75	40	63	52	29	40	21
Montana	81	66	106	103	73	71	116	194	75	72	49	71	49	89
Nebraska	109	83	89	85	61	97	167	112	52	65	90	53	17	57
Nevada	109	89	92	75	79	96	119	242	61	38	51	162	223	102
New England	82	99	105	107	103	93	183	83	241	120	85	88	73	108
New Jersey	77	81	103	109	99	93	178	86	140	90	74	133	51	81
New Mexico	101	126	112	88	70	102	154	99	43	35	155	76	81	80
New York	82	97	108	96	90	97	122	81	184	116	77	69	54	111
North Carolina	76	88	105	79	108	97	213	117	147	159	21	89	117	85
North Dakota	86	87	99	77	55	105	119	152	107	27	34	39	28	66
Ohio	71	99	97	99	70	104	55	99	108	94	48	46	79	105
Oklahoma	94	96	104	93	84	112	27	31	23	29	94	51	24	7
Oregon	87	94	102	108	99	78	178	117	72	77	120	155	12	39
Pennsylvania	68	88	92	107	92	95	130	78	199	88	54	91	67	118
South Carolina	84	78	113	75	95	89	216	114	137	272	13	77	87	85
South Dakota	90	73	96	76	66	85	118	121	70	59	53	37	24	69
Tennessee	80	86	119	102	95	100	106	71	125	98	31	24	153	54
Texas	96	95	110	84	87	121	39	39	49	55	176	51	158	63
Utah	118	79	105	83	74	85	132	236	95	55	44	120	209	95
Virginia	60	91	107	95	110	112	203	125	157	104	35	82	93	83
Washington	78	121	127	136	110	84	145	120	100	47	36	211	131	70
West Virginia	59	99	102	113	87	119	111	84	159	104	49	55	111	94
Wisconsin	82	98	83	89	100	100	110	135	89	50	75	57	28	163
Wyoming	104	82	95	87	78	87	156	203	100	71	24	114	119	115

[1] Preliminary figures.

EARLIER DROUGHTS

The few available precipitation records, covering 100 years or more, indicate that a general dry phase, somewhat comparable to that of 1886–95, and the more recent one of 1930 to date, obtained in the thirties of the last century, or approximately 100 years ago.

Some tree-ring records of the far Northwest indicate that there probably was a major minimum precipitation phase, at least in that area, soon after the middle of the eighteenth century, within the period 1755–80, with a succeeding maximum phase culminating about the beginning of the nineteenth century.

WET PHASE OF 1865–85

The outstanding wet phase of the United States climate in the last century was from about 1865 to 1885, with a secondary maximum during the first two decades of the present century, though several transitory droughts were interspersed. All of the foregoing statements refer specifically to the interior of the country east of the Rocky Mountains.

While study of long weather records has not as yet disclosed a law sufficient to justify a forecast of future droughts, such study does give an historical background, which warns us that droughts in future may be expected, just as severe as those of the past. For example, the records show that in the early nineties, or some 40 years ago, there was a drought in the Dust Bowl just as severe as that recently experienced. Doubtless, when the present drought definitely comes to an end there will be a period of years with comparatively heavy rainfall, just as before, and little will be heard about dust-storms and the like. But in the planning of a permanent farm program for such areas the basic considerations should include the practical certainty that dry climatic phases, at least as severe as in the past, will recur in the future.

RATIFICATION OF INTERNATIONAL CONVENTION FOR PROMOTING SAFETY OF LIFE AT SEA AND ITS SIGNIFICANCE TO METEOROLOGICAL SERVICE

Ratification of the International Convention for Promoting Safety of Life at Sea (signed at London on May 31, 1929) was consented to by the United States Senate on June 19, 1936, and ratified by the President on July 7, 1936. Although the convention consists principally of rules and regulations pertaining to the construction, equipment, and navigation of ships, it includes provisions of high importance to meteorology. It was the second conference of its kind. The first was held in London in 1914, but in it meteorology had no serious part. References therein to weather service to mariners consisted principally of codes, tabulations, and generalities which were of no value and, in fact, were obsolete by the time the convention articles were published.

Meteorology had a far different status in the 1929 convention. An official of the Weather Bureau was included in the United States delegation. Two other nations had meteorologists in their delegations. Articles pertaining to meteorology are included in two parts, one (Act 34) being compulsory in character, and the other (Act 35) involving moral responsibility and cooperation

The master of any ship under United States registry which meets with "a dangerous tropical storm" is bound by the provisions of article 34 to utilize all means of communication at his disposal in informing other ships in the vicinity and also in conveying the information by radio to competent Government authorities. Such reports by ship masters will result in service of incalculable value to ships as well as to coastal areas in providing information to national meteorological organizations on which to base warnings of tropical storms.

The second portion, article 35, of the meteorological provisions is of hardly less importance. It provides that the contracting governments shall encourage the collection of meteorological data from ships at sea. It also specifies that the governments party to the convention shall "cooperate in carrying out as far as possible the following meteorological arrangements":

(*a*) To warn ships of gales, storms, and tropical storms * * *.
(*b*) To issue daily, by radio, weather bulletins suitable for shipping * * *.
(*c*) To arrange for certain selected ships to take meteorological observations at specified hours, and to transmit such observations by wireless telegraphy for the benefit of other ships and of the various official meteorological services, * * *.

Other stipulations concern priority in the transmission by radio of weather observations from ships to national meteorological services; giving of service on the oceans by national organizations in best position to serve various zones and areas; and uniformity in procedures in carrying out the meteorological provisions of the convention. In the matter of uniform procedures the last paragraph of article 35 is of special interest. It reads as follows:

> Every endeavor will be made to obtain a uniform procedure in regard to the international meteorological services specified in this article, and, as far as is practicable, to conform to the recommendations made by the International Meteorological Organization, to which organization the contracting governments may refer for study and advice any meteorological questions which may arise in carrying out the present convention.

The importance and significance of the London (1929) International Conference for Promoting Safety of Life at Sea will instantly appeal to meteorologists. For the first time meteorological science and service have been given definite standing in an international agreement; also, for the first time, official recognition has, in a similar way, been given by governments to the International Meteorological Organization. Ratification of the convention by the United States Senate has advanced the influence of that organization to a position which will make it a potent factor for stabilizing working arrangements among the national meteorological services of the world.

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