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REPORT OF THE CHIEF OF THE WEATHER BUREAU, 1934

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D.C., September 11, 1934.

SIR: I submit herewith a report of the work of the Weather Bureau during the fiscal year ended June 30, 1934.

Respectfully,

W. R. GREGG, *Chief.*

Hon. HENRY A. WALLACE,
Secretary of Agriculture.

The Weather Bureau is authorized by its organic act to serve a wide variety of interests, including agriculture, commerce, and marine and aerial navigation. This service is provided in part through cooperation with other departments, both civil and military, and with various bureaus of the Department of Agriculture. For example, its forecast work in the protection of forests from fires is carried out in cooperation with the Forest Service, its marine work with the Hydrographic Office, Navy Department, and its service in aid of flying activities with the Bureau of Air Commerce, Department of Commerce. Weather is so intimately related to the welfare and happiness of all classes of people that the most effective service can be attained only by working closely with all other agencies, both governmental and nongovernmental, with which cooperation is possible. During the past year a definite beginning has been made in the development of this policy.

ADOPTION OF PROGRAM RECOMMENDED BY THE SCIENCE ADVISORY BOARD

It has been recognized for some time that there was need of a broader, more open-minded viewpoint regarding the utilization of results of the more recent studies and investigations in forecasting. This feeling found expression during the past year in a report submitted by a committee of the Science Advisory Board, the latter having been created by the President on July 31, 1933, for the purpose of cooperating with the Federal Government in the handling of all problems in which science is involved.

The membership of the special committee on the Weather Bureau was as follows: Robert A. Millikan, director, Norman Bridge Laboratory of Physics, and chairman of the executive council, California Institute of Technology, Pasadena, Calif., chairman, Isaiah Bowman, chairman, National Research Council, director, American Geographical Society, New York City, Karl T. Compton, president, Massachusetts Institute of Technology, Cambridge, Mass., and Charles D. Reed, senior meteorologist in charge, Weather Bureau section center, Des Moines, Iowa.

The committee's report was published in December 1933, was approved in January 1934, and action to carry out its recommendations has been proceeding since that time.

The most important recommendation is that relating to the development of forecasting on the basis of what is known as "air-mass analysis." Briefly stated, air-mass analysis consists of a detailed study of masses of air of decidedly different structure as to temperature, moisture, and wind that meet along an

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

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irregular line variously referred to as a "discontinuity line", "polar front", "wind shift", etc. These masses of air, cold and dry from polar regions, warm and humid from equatorial, do not readily mix but tend to preserve their individual identities, the warm, moist air being forced to rise above and flow over the denser cold air, with resulting condensation and precipitation and other attendant phenomena which give us most of the stormy weather characteristic of temperate latitudes.

The chief requisites for the application of air-mass analysis to forecasting are (1) personnel qualified by training and experience in this school of thought; (2) daily reports of temperature, humidity, and other conditions up to 3 or 4 miles above the earth's surface at a large number of places well distributed over the country; and (3) more frequent and more detailed reports of surface conditions, including observations at sea.

In carrying out the first objective a special nonassembled civil-service examination has been announced for the purpose of bringing into the Bureau several well-qualified men who have specialized in forecasting based on air-mass analysis. The introduction of this method will require probably from 3 to 5 years, during which period the personnel of the Bureau, already experienced in forecasting, will be given additional training along the newer lines.

The second part of the program, namely, securing upper-air observations of temperature, humidity, etc., has been put into effect to the extent that this is possible at the present time. This has been accomplished through cooperation with the War and Navy Departments. In all, 20 airplane stations are now in operation, 7 operated by each of these Departments and 6 by the Weather Bureau. They are quite well distributed over the country. Daily flights are made to heights of about 17,000 feet, and the data are at once transmitted by the teletype system of the Bureau of Air Commerce. The organization of this network of upper-air stations constitutes the most important step in the development of the air-mass analysis program. The data will be of great value in theoretical studies as well as in the more practical work of forecasting.

Under existing conditions not much can be done in putting into effect the third objective, namely, securing more frequent and more detailed observations of surface conditions, both on land and at sea. However, a definite program has been worked out for adoption as soon as practicable. It provides for 4 daily weather maps instead of 2 and for more precise information regarding cloud types, character of precipitation, pressure changes, and other elements. The data will be reported in accordance with a system of codes and units that has been adopted for international use, thus assuring comparable reports from all countries.

Generally speaking there has been comparatively little progress in forecasting for many years. It is confidently believed that, through the greater employment of modern working tools such as radio and the airplane which will give essential data in the vertical as well as in the horizontal, we now stand on the threshold of an era of real progress, providing forecasts more accurate and more specific and covering somewhat greater periods in advance than have been possible up to the present time.

COMPILATION OF METEOROLOGICAL DATA

An important accomplishment during the year just ended was the compilation of meteorological data under the Civil Works Administration program. For many years data have accumulated but, owing to lack of personnel, have been summarized only in part. This important work has now been brought more nearly up to date, with the result that a great body of statistical data is now available which is of great value in such studies as those designed to establish cycles or correlations that may possibly be used as bases for longer period forecasts than are now justified. In addition, the data are very useful in furnishing information concerning conditions that prevailed at various times in different parts of this country and its possessions, in the upper air and at sea. Included in this project are the data secured during the International Polar Year. These data, together with those from all other countries that participated in the program, are being entered on Northern Hemisphere maps, which will thus show on a larger scale than has heretofore been possible the progressive changes that occur in weather conditions from day to day and from month to month. Important conclusions are expected from studies of these charts.

The data that have been compiled and classified from ocean weather observations provide information for certain areas where hitherto little has been known concerning climatic conditions, particularly those regions in which hurricanes and other tropical storms have their genesis. The relation of weather to sea-surface temperatures is also receiving attention as a result of this activity.

AEROLOGY

Airplane weather observations were made under contract with commercial operators at four stations during the year. Heights of 17,000 feet were reached in practically all cases, and flights were made nearly every day at all stations. Considerable progress has been made in increasing the accuracy of the data by improving the recording instruments (aerometeorographs) and the method of calibration. The data have been found to be of increasing value in the forecasting work of the Bureau and in providing a better understanding of the mechanics of the atmosphere.

A total of 46 sounding balloons was released from the Weather Bureau airport station, Omaha, Nebr., during January, the international month for 1934. Forty-four (96 percent) of the attached meteorographs have been found and returned. These records are being computed and will be published by the International Commission for the Exploration of the Upper Air.

Measurement of upper-air wind currents by means of pilot balloons was maintained at 75 stations, including 3 in Alaska and 1 in San Juan, P. R. Two to four observations were made daily, weather permitting, at each station to an average altitude of 12,000 to 15,000 feet. These observations provide valuable information for current use by forecasters and air-transport companies and also for studies of the general circulation of the atmosphere.

Good progress was made in the preparation of a summary of average upper-air wind conditions over the United States, based on the records of pilot-balloon stations having a record of 3 years or more. One section of the summary covering the eastern section of the country has been published.

SERVICE IN AID OF AIR NAVIGATION

On account of a reduction in appropriations available for the fiscal year, it was necessary to carry on the weather service over the civil airways on an amount approximately $250,000 less than that for the previous year. Consequently, no extensions of service were possible, but service was continued on approximately 25,000 miles of existing airways without material curtailment. This was accomplished by reducing personnel and other expenses and by utilizing the services of Department of Commerce radio operators for the taking of surface observations wherever possible. The latter arrangement was made possible through a cooperative agreement with the Department of Commerce and the fact that a system of remote control of the radio stations from the airports had been developed and placed in use at many points. The supervision of all weather service performed by the Department of Commerce employees rests with the Weather Bureau.

Material progress in the stabilizing of the service along administrative, forecasting, and observational lines has been made, and further work in this direction is now going forward.

RIVER AND FLOOD SERVICE

At the opening of the year strenuous efforts were being made to reduce the cost of the service and bring it within the limit of available funds. Although the river and flood work had been undergoing a process of paring for several years, and some important features had been discontinued to meet the necessities, further and rather drastic reductions were made in July 1933. However, through the aid of an analysis of the organization made just prior to the last retrenchment, suspensions of service were confined to the parts that might be called the least essential. Because of the extremely dry weather that has prevailed for a year or more there have been no floods of a general nature, and the decrease in the number of stations has not been felt in a serious way, except that the loss of records is bound to be felt by those who use Weather Bureau data in studies on the relation of stream flow to precipitation.

On June 30, 1934, reports from 709 river gages were available to the Weather Bureau. Of this number 626 were read by the Bureau, and 83 were read for the Bureau by other agencies, principally the Engineer Corps of the Army. Many of the reports (98) are available only in times of threatened or actual floods; 482 are available daily throughout the year, and 129 are available daily in the months that may be said to constitute the flood season.

Despite the dry weather there were some local floods, and some of them were quite severe. The total damage has been estimated at $20,000,000, and the value of property saved by warnings issued by the Weather Bureau has been estimated to amount to $4,000,000.

The Weather Bureau has always worked under disadvantages in its river and flood service; outstanding among these handicaps was the unstable nature of the river gages, which in most instances were of a temporary type, difficult to hold in adjustment. In September 1933 the Public Works Administration gave the Bureau an allotment of $150,000 for replacing river gages with structures of a substantial and modern type. Work under this allotment has progressed actively, and by June 30, 1934, the following river gages had been erected:

Type of gage:	*Number erected*
Staff	76
Weighted chain	9
Weighted wire	97
Recording	47
Total	229

The work is 80 percent complete, and will be brought to a close in December 1934.

The new network of gages will enable the Weather Bureau to improve its stage and flood forecasts, largely through the adoption of the rating-curve method made possible by the erection of recording gages, but another highly important advantage that will be gained through the erection of recording gages will be the opportunity to collect data from which the relation between stream flow and precipitation can be determined. A knowledge of this relation is necessary in planning for power dams, irrigation projects, flood protection and prevention, and farm and city water supplies. However, reliable statistics regarding the relation are too scanty to be of great value, and the dry weather that has prevailed over most of the country has shown engineers in a most positive way that sound plans for water conservation, so necessary to agriculture and the general economic life of the country, cannot be made without a definite knowledge of the volume of water that streams may be expected to deliver in long periods of insufficient rain.

In large parts of those States comprising the Rocky Mountain country the water required for agriculture, for mining, and for towns and cities comes from mountain snowfall. The Weather Bureau maintains as a part of the river and flood work a service devoted to the collection of information of the amount and consistency of snow in the mountain snow fields—snow that is depended upon to give the major part of stream flow until some time in the summer. This service has been valuable throughout its existence of about 25 years, but the increased development of water conservation, which will result in a decrease of waste in times of flood and a greater possible use later in the season, makes it imperative that this service be coordinated to a greater extent with the needs and activities of water users, and a study of the necessities, and the action that is practicable, is now being made.

THE 1934 DROUGHT

Widespread severe drought during the crop-growing season of 1934 adversely affected the principal grazing and grain-producing areas of the country to an unprecedented extent. However, there is nothing to indicate that the 1934 drought in the Midwestern States constitutes a permanent change to desertlike conditions. There have been great climatic changes in geologic times. That is, large areas of the United States have moisture conditions at present very unlike those prevailing a great many centuries ago, but certainly no marked permanent change in climate has taken place within the last few years. On the contrary, the longest available rainfall records indicate that the 1934 drought in these areas is but what may naturally be expected to occur at comparatively

long intervals of 30 to 40 years, notwithstanding the present drought is more severe and covers larger areas than any other of which there is a record.

The 1934 drought differed from that of 1930 in several respects. It began in the early spring, while in 1930 critical conditions did not develop in most affected sections until about midsummer. Also it was first severely felt in the Northwest, from which it spread rapidly to many other areas, while in 1930 the spread was westward from the Central Eastern States. In addition the areas affected in 1934 were much more extensive than in 1930.

It is characteristic of precipitation records, in the long run, to vary in wave-like progression. When short-period fluctuations in the records are smoothed there appear successive up-and-down trends, merging, more or less regularly, one into the other and covering comparatively long periods. In general, the difference in the rainfall for the periods of comparatively heavy and those of lighter amounts is marked, and the trends are rather uniform in progress from maximum to minimum and vice versa. However, the time phase, or number of years from maximum to minimum and return to maximum, appears decidedly irregular and without apparent conformity to any law of succession.

Precipitation records for the States east of the Rocky Mountains show a well-marked tendency during the past quarter of a century to decreasing amounts, or lighter rainfall, in much of the North, especially the Northwest, and, until recently, to heavier rains in the South. In most cases in the South and East the trends have changed to downward in recent years.

In the northwestern area the last maximum appears for the 10 years up to about 1908, or around 25 years ago. Since then, there has been a rather regular decrease, as shown by a 10-year moving average, to the present time. In Minnesota, for example, the average precipitation for the 10 years ended with 1908 was approximately 29.5 inches, and for the decade ended with 1933 just a little more than 23 inches. In other words, the former 10-year period had nearly 30 percent more rainfall than the latter. A falling off in precipitation of such magnitude is especially important in a region like this, where the amount normally is rather small. This long-time northwestern decline in precipitation has centered in Minnesota, but covers the northern Plains to the west, especially the Dakotas, and extends to the western Lake region on the east.

About midway between these long-interval depressions in rainfall curves appear series of successive years with comparatively abundant rains, and there is nothing at this time to indicate that history, in this respect, will not repeat itself with a return to another temporary period, not now predictable, when much heavier rains will again be the order of the day. A long record at St. Paul, Minn., covering about 100 years, shows two previous depressions, rather similar to the present, at 30- to 40-year intervals.

The first covered the 10 years ended with 1848 and the second the decade ended with 1894. After each of these there was a marked recovery, with the peaks of the curves appearing in 1874 and 1908, respectively. The amplitude of these swings, or the difference between the averages for the periods of heavier and lighter rainfall, on a 10-year average-rainfall basis, is from about 24 inches minimum to 32 inches maximum. That is, on an average, the wet periods have about one-third more rain than the dry periods.

Long records for other sections of the country show similar trends, but they are not in agreement, one with the other, in regard to the time phases of the trends. For example, the Washington, D. C., record, beginning with 1817, shows a minimum for the 10 years ended with 1831 of 32.2 inches. Thereafter, there was a somewhat irregular, but very definite, rise to 48.2 inches for the decade ended in 1891. Since then the trend has been downward, but not uniformly, to 39.8 inches for the decade ended with 1933. Here we have a difference in the 10-year average of rainfall up to 1831 and the 10-year average ended with 1891 of 16 inches, or about 40 percent. The decrease since the maximum in 1891, or during the last 42 years, has been 8.4 inches.

The Washington record differs from that at St. Paul, Minn., representing northwestern conditions, in that, for the past century, only 1 maximum is shown in the Washington record and 2 in the St. Paul record. Also in the Washington record there is a 60-year interval between the minimum in 1831 and the maximum in 1891, which is much longer than any single trend at St. Paul. Still further, the Washington maximum in 1891 coincides, approximately, with the St. Paul minimum in 1894. In other words the trends for different areas are frequently in opposition instead of agreement. A compari-

son of records at other long-record stations shows a similar lack of agreement in this respect.

While the trend in precipitation in the Northwest has been downward for a good many years, the present deficiencies in the central valley States, in general, began with June 1933. Table 1 shows the total rainfall by States from June 1933 to July 1934, inclusive, and the percentage of normal, for this 14-month period.

TABLE 1.—*Average State rainfall and percentage of normal for the 14-month period June 1933–July 1934*

State	Total rainfall	Percentage of normal	State	Total rainfall	Percentage of normal
	Inches	*Percent*		*Inches*	*Percent*
Alabama	56.49	90	Nevada	6.34	66
Arizona	11.85	81	New England	50.52	104
Arkansas	48.77	87	New Jersey	52.84	98
California	16.54	69	New Mexico	15.31	83
Colorado	15.49	76	New York	41.76	90
Florida	74.06	111	North Carolina	52.56	88
Georgia	53.38	89	North Dakota	13.13	57
Idaho	17.50	90	Ohio	32.52	71
Illinois	28.82	64	Oklahoma	31.14	78
Indiana	31.58	68	Oregon	24.79	93
Iowa	26.81	67	Pennsylvania	45.48	89
Kansas	24.21	71	South Carolina	48.97	84
Kentucky	46.14	86	South Dakota	16.10	61
Louisiana	63.85	96	Tennessee	53.38	91
Maryland and Delaware	51.99	106	Texas	31.33	85
Michigan	28.42	78	Utah	8.84	61
Minnesota	22.54	69	Virginia	45.93	91
Mississippi	52.65	84	Washington	46.64	126
Missouri	30.97	63	West Virginia	46.34	89
Montana	16.85	87	Wisconsin	28.00	74
Nebraska	19.44	63	Wyoming	11.94	69

As previously mentioned, the 1934 drought became established to such an extent as seriously to affect agriculture first in the Northwest, early in the spring, centering in eastern Montana, the Dakotas, and Minnesota. From this area there was a rapid spread southeastward, southward, and southwestward, so that by the end of May it had become the most extensive drought in the climatological history of the United States. In general, by that date the drought was severe throughout the Ohio and central and upper Mississippi Valleys, the central and northern plains, most Rocky Mountain sections, and the Great Basin of the West, covering approximately three-fourths of the country.

The 1934 spring season, March to May, inclusive, was the driest of record in both the Dakotas, Minnesota, Nebraska, Iowa, and Illinois; and the second driest of record in Ohio, Indiana, Wisconsin, Missouri, and Kansas. In Illinois, for example, the total rainfall for the 3 months was only 4.21 inches; the previous low record, 6.06 inches, was more than 40 percent greater than this. In Minnesota the previous low spring record, 3.39 inches, was more than 20 percent greater than the 2.79 inches that fell in the spring of 1934. North Dakota had only 1.27 inches of rain during the 3 months; the previous low record, 2.15 inches in 1901, was nearly 70 percent greater.

Extremely high temperatures during May in the interior valleys and the Northwest intensified the effects of the scanty rainfall; over considerable sections it was the warmest May ever known. For example, at Des Moines, Iowa, the average May temperature of 71° F. was not only the highest of record, but equaled the June normal. In the northern plains the averages for most stations were higher than the normal for June. Huron, S. Dak., had a May average of 70°, which was 4° higher than the June normal, while the Rapid City mean of 67° was 3° higher than the normal for June. Throughout this northwestern section it was not uncommon for maximum temperatures to range from 100° to 104° for several days in succession. Dust storms were numerous and damaging.

At the end of May small grains, hay, pastures, and other feed crops had suffered severely and were deteriorating at a rapid rate. However, June

brought material relief over large areas, as much more rain occurred than theretofore over most of the severely droughty sections. Precipitation in June was only slightly below normal in the Ohio Valley, ranging from about three-fourths of normal in Illinois to somewhat above normal in Kentucky, while much of the central-northern area had from 90 to 98 percent of normal. However, in the Southwest there was a corresponding diminution in rainfall, with June hot and dry in many sections. The dryness centered in Texas, which had less than one-fourth of its normal rainfall, while both New Mexico and Arizona had less than half of normal. At the same time, an area in the central-north, centering in eastern Montana, had no relief, and parts of the Northeast, especially northern and western New York, needed rain badly.

With the advent of July, conditions became rapidly worse in many Central, Southwestern, and Western States, where the effect of the scanty rainfall was aggravated by the persistence of extremely high, often record-breaking, temperatures.

In the Ohio Valley and parts of the upper Mississippi Valley earlier rains had supplied soil moisture sufficient to enable vegetation to withstand the excessive temperatures rather well, and in a few areas the growth of cultivated crops continued excellent. In places the dividing line between favorable and unfavorable conditions was very sharply drawn. An outstanding case is that of Iowa. Conditions in the northern part of the State were generally favorable, with pastures improving rapidly, minor crops doing well, and corn in good to excellent condition, while in the southern portion the situation became serious, with hope for winter feed nearly gone, water supplies exhausted, and no prospect of corn for grain.

At the close of July, conditions in southern Iowa were typical of those in most other sections between the Mississippi River and Rocky Mountains where all crops, except cotton in the southern portion, showed extremely rapid deterioration, with pastures practically gone, the water situation serious, and even trees dying in sections of the Great Plains.

In the Southeastern States, extending from central Virginia to Alabama, and including much of Kentucky and Tennessee, generally good growing conditions continued through July, but considerable portions of the Northeast and Middle Atlantic area, including New England, much of New York, Maryland, and northern and western Virginia, became decidedly dry.

The first half of August brought very helpful showers to most of the Ohio Valley area, and the last half of the month the weather was much cooler, with substantial to heavy rains, in much of the Southwest, especially Oklahoma and Missouri. In addition, during the first few days of September widespread generous rains effectively relieved droughty conditions, at least temporarily, over a large midwestern and southwestern area extending from southern Minnesota and Nebraska southward over the western winter Wheat Belt. The rains were especially timely in conditioning the soil for seeding winter wheat over the most important sections of the belt.

The summer of 1934 was by far the hottest of record over a large midwest area, the excess above normal temperature in many places being nearly twice as great as that for the previous warmest summer of record. At Columbia, Mo., the average maximum temperature for July was 100° F.; at Oklahoma City, Okla., 100°; Topeka, Kans., 102°; and Fort Smith, Ark., 102°. For the summer months (June–August) Des Moines, Iowa, had 22 days with maximum temperatures 100° or higher; Columbia, Mo., 34 days; Topeka, Kans., 47; Oklahoma City, Okla., 45; and Fort Smith, Ark., 53. Nothing remotely approaching this for sustained heat has been experienced in any State east of the Rocky Mountains since weather records began.

In addition to the serious drought situation over the great western grazing areas and the central grain sections, the scarcity of snow in the western mountains during the preceding winter created a serious situation in the matter of water supply for spring and summer irrigation in many western sections where irrigation is practiced. For example, the seasonal snowfall up to the end of March in California was less than half the normal; in Wyoming there was but little more than a third as much as in the preceding year; Colorado had about half of normal, and in New Mexico, at the close of March, only drifts remained in the northern slopes at the higher elevations, in the northern part of the State.

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