UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
Washington, D.C.
September 15, 1930.

Sir: I submit herewith a report of the work of the Weather Bureau during the fiscal year ended June 30, 1930.

Respectfully,

C. F. Marvin

Chief of Bureau.

Hon. Arthur M. Hyde,

Secretary of Agriculture.

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

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The topics chosen for particular discussion in this report are the drought of 1930 and expansions of service in aid of aviation.

THE UNPRECEDENTED DROUGHT OF THE SUMMER OF 1930

Basing the statement on weather reports up to August 31 we may say that the drought and heat wave are over, but reports for the remainder of the year will be required before a full history can be written.

The central and eastern portions of the country have now passed through the most severe drought in the climatological history of the United States. By the first of September the drought had continued for nine months in the middle Atlantic area, six months over the Ohio and middle Mississippi Valleys, and for shorter periods in nearly all other sections east of the Rocky Mountains. The middle Atlantic area was dry during the winter season. In March the drought extended westward over the Ohio and middle Mississippi Valleys, and thence in other directions as the season progressed.

For the spring months, March to May, West Virginia, Kentucky, Indiana, Illinois, and Missouri had the least precipitation of record, with the average for the group only 57 per cent of normal, while the middle Atlantic area had only slightly more than 60 per cent. In June, the Ohio and lower Mississippi Valleys suffered most, while by July deficiencies in precipitation extended to all States east of the Rocky Mountains, except New England and Georgia. In this month 18 States had only 20 to 50 per cent of normal rainfall, with an average of 39 per cent. In August the drought continued in nearly all sections and was greatly intensified in some Northern and Southeastern States not theretofore seriously effected.

For the summer, June to August, a belt of States extending from Maryland and Virginia southwestward to the lower Mississippi Valley established new railfall records for the season, while in a group of 16 States, including Pennsylvania, Maryland, Virginia, West Virginia, Tennessee, Kentucky, Ohio, Michigan, Indiana, Illinois, Missouri, Oklahoma, Arkansas, Texas, Louisiana, and Mississippi, the average precipitation was only 54 per cent of normal. Not a single State east of the Rocky Mountains had as much as normal precipitation for this period of the three principal growing mohths, and some half dozen States had less than half the normal. The summer season was generally warm, with the period from about the middle of July to middle of August having abnormally high temperatures, with the previous maximum records equalled or exceeded in many places These unusually high temperatures greatly intensified the effect of the deficient moisture.

July and August combined brought the driest weather of record to Pennsylvania, Maryland, Virginia, West Virginia, Kentucky, Missouri, and Arkansas, with an average for these seven States of only 41 per cent of normal. The growing season, as a whole, March to August, was the driest of record over a large area, comprising the Middle Atlantic States and the Ohio and middle Mississippi Valleys.

Table 1 contains a summary of drought data by months. The deficiencies in rainfall, the percentages of normal, are shown for each State, for all successive months when the amounts were continuously below normal, the heavy type indicating the greatest deficiencies of record for the respective months. This tabulation shows graphically the spread of the drought as the season progressed. For example, in January, only three States that continued dry thereafter had deficient precipitation, while for March the number had increased to 9; May to 10; June to 19; and July to 30. It will be noted that South Dakota and Nebraska had more than normal rainfall in August, hence there were only two consecutive months with deficiencies.

Considering the New England States as a unit, and also Maryland and Delaware, there are 32 units and units and States east of the Rocky Mountains. Of these, 27 had deficient rainfall in March, with an average deficiency of 40 per cent; 27 in April, with an average deficiency of 38 per cent; 20 in May, with an average deficiency of 29 per cent; 24 in June, with an average deficiency of 34 per cent; 30 in July, with an average deficiency of 52 per cent; and 30 in August, with an average deficiency of 45 per cent.

Table 1. Deficiencies in precipitation, in percentages of normal, for the drought of 1930, by States and months, for the period continuously below normal.

	Dec.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Number of Months	Average monthly deficiency
Maryland and Delaware	27	18	30	42	26	38	15	64	76	9	37
Virginia	34	18	52	44	33	36	26	62	65	9	41
West Virginia	26	49	17	16	45	46	36	59	45	9	38
Missouri			19	53	47	28	22	76	44	7	41
Kentucky				53	68	30	55	70	39	6	52
Ohio				18	34	53	42	62	28	6	40
Indiana				54	26	55	32	47	36	6	42
Illinois				53	21	55	13	70	41	6	42
North Dakota				89	14	19	11	58	33	6	37
Alabama					65	5	53	26	22	5	34
Montana						41	43	35	7	4	32
Arkansas							79	80	32	3	64
Tennessee							68	46	38	3	51
Mississippi							87	50	27	3	55
Louisiana							88	39	14	3	47
Texas							36	58	43	3	46
Oklahoma							3	68	40	3	37
Kansas							5	41	10	3	19
Minnesota							5	29	67	3	34
Iowa								61	29	2	45
Wisconsin								30	67	2	48
Michigan								54	73	2	64
Pennsylvania								50	66	2	58
New Jersey								13	29	2	21
New York								23	36	2	30
North Carolina								38	49	2	44
South Carolina								18	61	2	40
Florida								40	39	2	40
Georgia									63	1	--
Nebraska *							16	56	47	2	--
South Dakota *							26	63	31	2	--

*August above normal.

UNDERSCORE INDICATES GREATEST DEFICIENCY OF RECORD

The drought has established the following low precipitation records for the periods named:

Maryland and Delaware: December to August; March to August summer (June to August); July; August; July and August combined.

Virginia: December to August; March to August; summer (June to August); July; August; July and August combined.

West Virginia: December to August; March to August; spring (March to May); summer (June to August); June; July; July and August combined.

Kentucky: March to August; spring (March to May); summer (June to August); June; July; July and August combined.

Ohio: March to August; July.

Indiana: March to August; spring (March to May).

Illinois: March to August; spring (March to May); July.

Missouri: March to August; spring (March to May); July. July and August combined.

Arkansas: Summer (June to August); June; July; July and August combined.

Tennessee: Summer (June to August); June.

Mississippi: Summer (June to August); June.

Louisiana: June.

Minnesota: August

Pennsylvania: March to August; July and August combined.

OTHER NOTED DROUGHTS.

Previous outstanding droughts in the United States are of record for the years 1881, 1894, 1901, 1911, 1916, and 1924.

Table 2 contains data comparing these with the drought of 1930. It shows the percentage of normal precipitation for each of the droughts for the spring months March to May combined and for June, July, and August separately. A comparison of the figures shows that the 1930 drought, when considered in all its details, easily takes first place in the climatological drought history of the country.

Table 2. --Percentage of normal percipitation for March to May, June, July, and August in 27 States, 1930, 1881, 1894, 1901, 1911, 1916, and 1924

State	1930				1881				1894				1901				1911				1916				1924			
	March to May	June	July	August	March to May	June	July	August	March to May	June	July	August	March to May	June	July	August	March to May	June	July	August	March to May	June	July	August	March to May	June	July	August
Maryland	64	85	36	24	79	182	54	26	---	---	---	---	128	79	123	135	64	105	61	230	98	151	125	51	153	136	57	95
Virginia	61	74	38	35	68	74	74	27	72	46	89	76	138	108	104	198	80	83	68	136	79	135	121	73	137	107	77	98
W.Virginia	64	64	41	55	89	131	90	30	84	73	48	52	144	126	70	127	80	98	61	167	102	120	76	120	140	104	98	115
Kentucky	51	45	30	61	73	123	49	33	77	68	49	81	80	100	41	138	95	102	56	108	79	122	102	113	98	110	88	81
Ohio	64	58	38	72	78	147	95	34	82	65	41	52	96	110	69	100	81	97	62	164	104	122	49	94	99	160	72	64
Indiana	54	68	53	64	85	134	38	33	90	68	41	55	64	116	38	94	87	100	50	97	84	174	71	97	96	163	56	112
Illinois	57	87	30	59	83	123	88	62	84	59	45	53	66	85	73	53	82	72	70	124	77	141	36	120	78	174	100	150
Missouri	59	78	24	56	80	114	38	44	88	80	62	42	70	43	50	50	73	37	100	110	98	143	30	105	82	151	135	108
Arkansas	94	21	20	68	92	105	37	22	133	33	105	124	79	33	66	81	90	58	126	222	62	121	55	70	88	84	63	65
Tennessee	86	32	54	62	89	100	36	44	81	55	93	93	91	70	45	239	96	86	109	110	79	127	166	119	97	77	86	59
Alabama	77	47	74	78	111	79	33	147	76	51	93	153	118	65	63	189	92	91	106	111	74	79	310	80	93	125	67	64
Mississippi	96	13	50	73	83	54	38	80	84	55	116	134	80	52	80	159	94	102	128	145	92	93	204	82	91	80	34	41
Louisiana	79	12	61	86	71	23	56	43	100	38	98	125	80	63	114	106	95	96	151	154	95	81	129	87	92	62	24	44
Texas	99	64	42	57	102	9	81	73	107	79	81	200	76	39	96	62	102	27	142	81	87	67	104	104	100	54	35	50
Oklahoma	95	97	32	60	98	21	181	33	101	42	55	50	96	53	61	53	59	29	171	124	73	174	26	40	95	90	94	80
Kansas	94	95	59	90	114	73	85	63	69	120	48	23	86	57	53	84	61	15	118	116	86	147	24	68	86	54	109	132
Nebraska	130	84	44	147	159	134	85	54	54	84	41	25	86	118	47	79	75	47	88	125	76	90	53	125	61	113	112	79
Iowa	78	129	39	59	84	164	130	79	74	60	16	47	72	82	60	38	83	40	60	97	97	82	47	76	61	180	98	159
S. Dakota	90	74	37	131	121	86	93	127	102	83	33	55	69	183	67	114	63	51	78	155	113	103	89	150	56	140	63	109
N. Dakota	81	89	42	67	77	109	38	104	125	97	23	48	46	174	166	78	92	89	69	156	106	112	123	122	79	120	77	70
Montana	84	57	65	93	--	--	--	--	--	--	--	--	114	112	67	42	104	112	67	150	95	154	47	100	65	107	74	84
Minnesota	88	95	71	33	81	88	49	154	148	64	20	40	74	142	95	67	93	93	103	131	133	120	80	113	87	106	80	149
Wisconsin	83	136	70	33	101	103	157	91	133	83	25	25	72	108	117	52	92	88	103	116	108	157	44	94	116	108	98	222
Michigan	84	106	46	27	90	155	97	75	133	90	46	18	83	81	140	91	92	100	94	97	122	155	40	90	95	78	117	129
Pennsylvania	80	102	50	34	81	171	50	40	130	64	53	43	139	86	89	162	77	115	64	181	100	149	100	62	117	137	78	91
New Jersey	68	114	87	71	97	153	42	24	113	63	37	55	148	44	129	196	80	146	79	178	92	114	118	26	129	114	57	88
New York	97	116	77	64	86	97	62	40	105	93	67	43	145	93	122	135	72	110	72	122	114	128	85	58	108	76	88	95

In 1881, June was very dry in the Southwest, and July and August in the central valleys and in the East.

In 1894, severely droughty conditions were confined to the central valleys and the Northwest.

In 1901, the central valleys, especially the western Corn Belt, suffered most.

In 1911, the greatest deficiencies in precipitation occurred rather early in the season.

In 1916, and 1924, the droughts covered comparatively small areas.

The drought seriously affected all growing crops, and the scarcity of water for livestock, and in some sections for domestic use, became a serious problem, especially in Kentucky and some other parts of the interior valleys. Winter wheat was not affected by the drought; in fact, the weather was favorable for ripening which gave a good quality of grain and better yields than expected in many places. Early spring wheat also largely escaped, but heat and drought damaged the late crop considerably, especially in the shriveling of grain. In general, oats were less harmed than spring wheat, though the late crop was badly damaged in the North Central States, notably in the upper Mississippi Valley, and late flax was materially reduced in yield. Potatoes also suffered serious harm in the interior valleys, but continued fairly good in many heavy producing sections. Late truck crops and gardens, pastures and hay, and corn were the hardest hit, and the damage to these, together with the shortage of water for livestock and other uses in many places, constituted the most serious aspects of the drought.

A prospective corn crop of 2,802,000,000 bushels on July 1 was reduced by September 1 to 1,983,000,000 or a loss of more than 800,000,000 bushels. The condition of pastures in many central and eastern parts of the country was, by far, the lowest of record.

In addition to its economic effects, mention may be made briefly that river stages show the extent and severity of the drought. In the Missouri Basin above Pierre, S. Dak., and in that part of the upper Mississippi Basin above the Iowa-Minnesota Line low river stages are not unusual for July and August, but in the remainder of the drainage area of the Mississippi River system, and on the Atlantic slope of Pennsylvania, Maryland, Virginia, and North Carolina the dry weather is plainly reflected in the low water stages. Many of the small streams in the Missouri Basin are dry, and in the remainder of the drought area all streams are either as low as they have ever been in August, or are very close to the low record. In North Carolina and in the territory drained by the southern tributaries of the Ohio, low states in 1925 appear to have been slightly lower than those prevailing in the present summer.

Wells are failing, water for stock is scarce where comparatively large streams are not available, and the matter of sewage disposal in a few places is becoming acute. The hydro-electric plants on the large streams are not suffering, but on the smaller streams they have either shut down or are drawing rather heavily on their reserves. Navigation on the controlled rivers is not interrupted, but on the Mississippi, especially north of Cairo, the low water has made it necessary to materially decrease the length of tows, which is a very serious interruption.

CAUSES OF DROUGHTS, HEAT WAVES, Etc.

Foremost in the minds of all during a summer like 1930 is the question, what causes such abnormal conditions? No conclusive and comprehensive answer can be given. Moreover, the answer will need to be varied and adapted more or less to particular cases. Directing our answer particularly to the extensive drought of 1930, all we can say is that these unusual conditions are best explained as a prolonged stagnation of the air over nearly the whole continental extent of the United States. In ordinary years this great blanket of atmosphere overlying the continent is in more or less active circulation. Cool air from the polar regions moves southward from time to time. This feature of circulation has been especially absent this summer. Warm air from the tropical latitudes moves northward at intervals. Air from the oceans and Gulf moves inland, and there is a more or less active and continuous interchange of these different air masses, causing the agreeable and favorable conditions that prevail in ordinary years. This circulation and interchange has been conspicuously absent for a long time during the present great drought.

During this stagnation the occasional showers and thunderstorms here and there over the drought-stricken region served only to dry out the overlying air masses. Only a part, at best, of this water is evaporated back into the free air, and with little or no moisture borne in by winds from the oceans, each successive inland shower, coupled with the stagnation and absence of general rain-causing processes, tends to further deplete the moisture supply and intensify the drought condition. It may be pointed out, also, that over most of the United States the summer heat is normally at its maximum about the last week of July. Therefore, summertime stagnation and lack of active circulation within the continental air blanket causes the absence of precipitation and permits the culmination of excessive temperatures, but the experts are unable to assign a specific cause for the prolonged stagnation.

CYCLES AND SEASONAL WEATHER FORECASTS

The occurrence of any notable weather event, such as the drought of the summer of 1930, is always made the occasion for discussion of the possibility of predicting such happenings sufficiently far in advance to permit of steps being taken, if indeed any such are possible, to lessen the economic loss which is bound to result to long as they arrive unheralded

Another even more futile imagination is that these untoward happenings can be caused or suppressed by man himself. For example, many letters are received urging that by the use of explosives and aerial bombardment, we can cause plentiful rain. Curiously enough, another group of writers urge us to employ aerial explosives and bombardment to destroy hurricanes, tornadoes, etc. Here we have the absurd representation that by the use of exactly the same means we can supply rainfall to drought-stricken regions, or we can suppress tornadoes, hurricanes, etc., which are frequently accompanied by even torrential rainfalls.

With reference to these and the possibility of future forecasting, the Weather Bureau continues to hold an entirely open mind and to seek for promising lines of attack on the problem of such forecasts, but we can not be led away from a sane and rational conservatism in these matters, either by the occurrence of great natural disasters or the confident assertions of advocates of this, that, or the other fanciful idea. In so far as a sound physical basis for seasonal forecasts is involved, the subject can be said to be still in the speculative stage. Some practical advances have been made by means of correlations, but the sum total of results attained by this method is relatively small.

The complexity of the problem is well illustrated by the weather extremes of the past year in different agricultural areas. While a great part of the United States was suffering for want of rain, western Europe was experiencing an extraordinarily wet harvest season, and in the great corn-growing region of Argentina the weather was so continuously wet as to delay the conditioning of corn for shipment overseas. It will be readily understood that until the different kinds of weather which occur simultaneously throughout the world have been satisfactorily correlated among themselves, forecasts therefor from a single factor, such as periodicity in sunspots or variations in solar radiation, can have no hope of success.

One line of attack on the problem of seasonal weather forecasts that is thought by meteorologists to offer some promise of success is that afforded by changes in the temperature of the surface waters of the oceans. It is well known that the oceans exert a pronounced influence on the climate of adjacent land areas. The character, amount, and extent of the influence depend on various circumstances, as latitude, direction of the prevailing winds, topography, and distance from the coast. Inadequacy of observations and other difficulties have hitherto operated to prevent any considerable investigations in this field by the Weather Bureau, although some preliminary work has been done in recent years. However, as a result of the development of commerce with Latin America and the opening of the Panama Canal observations from ships have been increasing from the strategic water areas embracing portions of the Atlantic equatorial currents and the Gulf Streams.

Much has been said by many people that weather phenomena recur in cycles. Naturally this whole subject is a very complicated one, and we all recognize the ups and downs, and the frequent extremes of heat and cold, wet and dry weather phenomena. A critical study of these phenomena has failed to disclose any such orderly system of recurrences as the word "cycle" connotes in the minds of most people. Forecasts on any such basis as this will fail quite as many times as they might succeed, and even at the best the intervals between recurrences are subject to such wide changes in length of interval, and the magnitude of the extremes, although sometimes large, are frequently entirely insignificant, so that the reality of cycles is very problematical, and forecasting by means of them is as yet unsuccessful.

The subject of correlations and periodicities of weather phenomena are under continuous investigation by one or more of the experts of the bureau, in the hope of discovering useful information.

WEATHER SERVICE FOR AIRWAYS

In previous annual reports, particularly those issued in 1927, 1928, and 1929, the bureau's service for flying activities was discussed at some length, principally from the point of view of organization and the legislation authorizing it. It seems proper at this time to indicate the general character of this service, as now organized, and to point out needs for expansion as the network of airways is still further extended.

As is well known, the Weather Bureau is charged with the duty of furnishing service for all interests - agriculture, commerce and navigation, which last now includes the air as well as the sea. In doing this the bureau has organized a network of some 210 first-order stations, well distributed over the entire country. These stations regularly exchange reports twice daily and also keep continuous records of weather conditions for statistical and research purposes. The twice-daily reports are used in issuing summarized statements and forecasts which are given wide dissemination by telegraph, telephone, radio, and the press. This may be called the bureau's general or primary service.

In addition, several more detailed and intensive services have been organized to meet special needs, including the protection of fruit and other crops from frost, warnings of conditions favorable for floods, forest fires, hurricanes, and other violent storms. For these services numerous second-order stations - several hundred of them - have been established at points from which experience shows that the information is needed. The reports are made by noncommissioned personnel, in accordance with prearranged schedules or on call.

The most recently organized of these intensive services is that for flying activities on commercial airways. The bureau's authority for this service is defined in section 5 (e) of the air commerce act of 1926. In organizing the service, close cooperation is maintained with the Department of Commerce which is charged with providing communication, lighting, and landing facilities for the airways. As a rule, detailed

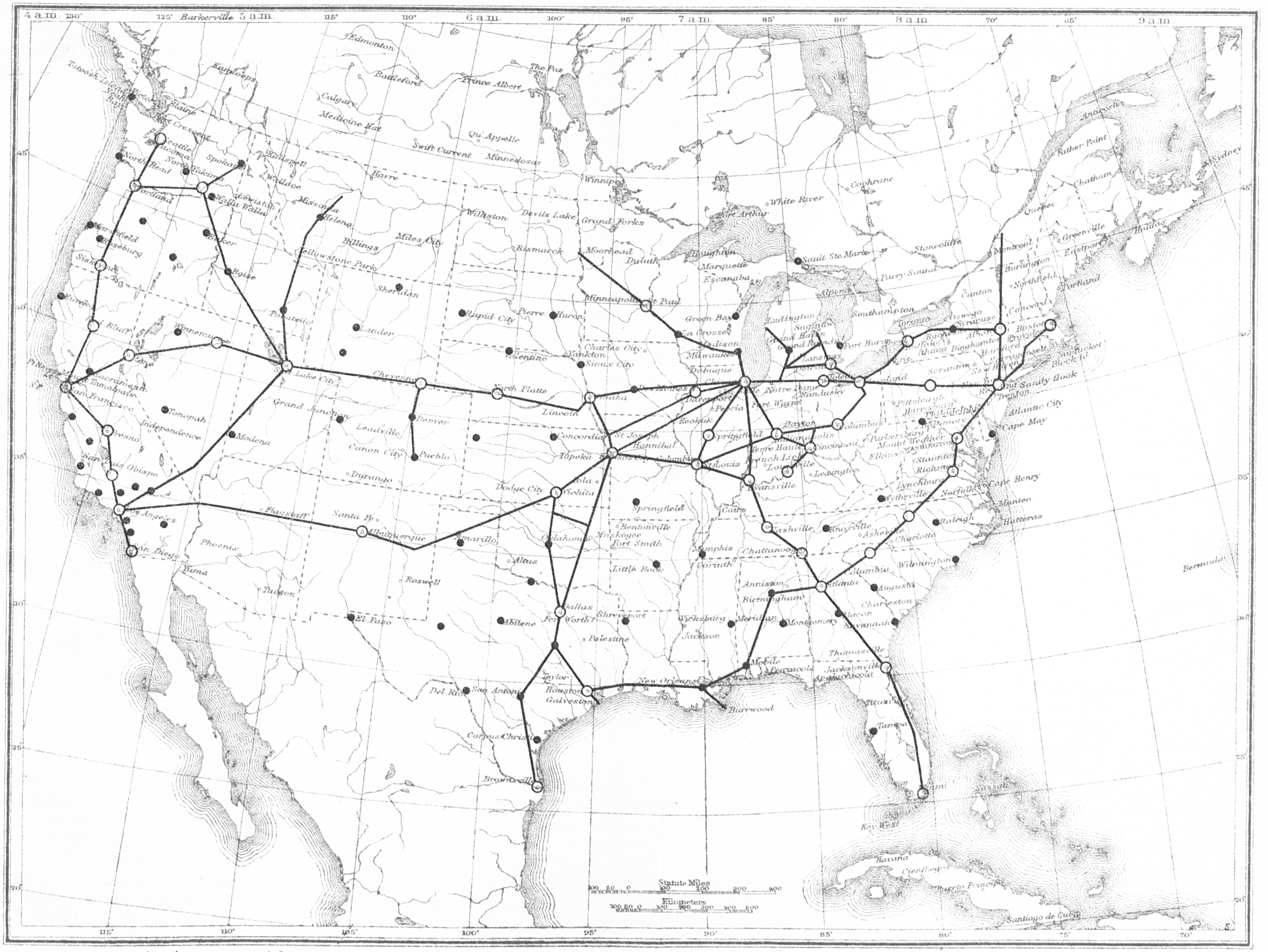

Chart showing commercial airways for which intensive weather service has been organized. Open circles are Weather Bureau airport stations, with continuous 24-hour service. Dots are additional stations off the airways that furnish three-hourly reports to designated centers.

surveys of proposed airways are made jointly by representatives of both departments. In the course of these surveys a study is made of past records in order to determine the general character of the weather conditions that are likely to be encountered. Pilots and officials of the air-transport companies and others who are familiar with the section are consulted with a view to determining what the needs are and how to meet them. Finally, a program of service is formulated and organized. Naturally, it is necessary to keep this program within the limit of funds appropriated for the purpose and also to distribute those funds equitably and impartially to all sections of the airways system.

The basic features of the service are timely reports of current conditions and short period forecasts. In other words, the aim is to give the pilot the weather of the "now" and the "soon-to-be". To do this, special observing stations are established along and near the airways. The distance between these stations varies from 5 or 10 to 100 miles, depending on the topographic and meteorological characteristics of the section. The time interval between reports also varies, this depending largely on the volume of traffic. Where flying is more or less continuous, both day and night, reports are received from all observing stations on the airways once each hour, and in some cases intermediate half-hourly reports are received from the more important terminal stations. On airways having as yet but little traffic - one regular daily flight each way, for example - the reports are timed to fit the schedules. This latter type of service as a rule characterizes only the earlier stages of an airway's history. As flying increases and off-schedule flights become common, experience shows that the needs for service can be met adequately only by frequent and regular reports.

Attention is invited to the accompanying chart which shows the airways for which service is now furnished. At about 50 of the more important terminal airports on these airways the bureau has established continuous 24-hour service with full instrumental equipment and personnel of four to seven technically trained men. At some 250 intermediate stations the observations are made by properly instructed, though not technically trained, personnel who report the conditions as observed by eye or with comparatively simple instrumental equipment. Reports from these special stations are transmitted to the bureau's more important centers on the airways.

Naturally the prompt collection of these reports (and unless they are prompt, all the effort is wasted) requires a highly efficient communication system, whose organization is a function of the airways division of the Department of Commerce. It was early found that, for this particular purpose, dependence can not be placed on the ordinary commercial facilities. During the time of peak loads, that is in the middle of the day, absolute promptness could not be guaranteed. All types of business are entitled to equal service. It was evident, therefore, that a system of communications under absolute control is necessary. This has been

accomplished on some of the main airways through the installation of a printing telegraph, or teletype, circuit. The circuits consist of leased telephone lines 500 to 800 miles in length between terminal airports with drops at the intermediate weather-reporting stations, each one of which has an automatic typewriter, or teletype machine. The messages are typed on these machines in sequence, the various stations following one another in rapid succession; and each message is received on tape by all other stations in the circuit. This system of communications is prompt and is rapidly increasing in efficiency and reliability. The Department of Commerce plans to extend it eventually to all interstate-trade air routes.

All reports, whether sent by teletype, telephone, telegraph, or radio, include information concerning the following elements: General condition of sky and weather; ceiling; visibility; surface wind direction and velocity; temperature; barometric pressure; and miscellaneous conditions, such as thunderstorms, squalls, and state of landing field as affected by rain, snow, etc.

In many cases dew point is also reported, and some of the airport stations (about 45 at present) give detailed data of wind direction and velocity at various heights.

For the general condition of sky and weather no instruments are required, but certain definite terms have become standard for expressing it, such as "clear", "broken clouds", "overcast", "fog", "heavy rain", "sleet", etc. This first word in the report tells the pilot at once whether conditions are satisfactory, impossible, or simply uncertain and therefore subject to further study.

The next two items, ceiling and visibility, usually answer this question of uncertainty. For observations of ceiling at night when clouds are present the so-called "ceiling light" is in general use. A beam of light is shot upward, in some cases vertically, in others at a 45° angle, and in still others at some intermediate angle. The use of this instrument has not as yet wholly passed the experimental stage, but the concensus of opinion is that a vertically projected beam gives the best results. There is still some uncertainty also as to the most satisfactory intensity. At present 250-watt bulbs are in general use, although a higher intensity is favored by some, especially for stations in mountainous country, where high ceilings are essential for safety. In all cases the beam makes a spot of light where it strikes a cloud. This spot is more or less definite and well marked, depending on the density of the cloud mass. The height of the spot, and therefore of the ceiling, is determined by means of an alidade, or clinometer. The angular reading of this instrument, together with the known distance of the light source from the point of observation, provides the necessary data. In many cases the alidade is graduated in heights instead of degrees and thus eliminates the need of computation or the use of tables or graphs.

For observations of ceiling in the daytime, so-called "ceiling balloons" are used. These are about the size of ordinary toy balloons, although of a somewhat better quality. They are filled with hydrogen until just capable of sustaining a 40-gram weight. When released, they rise at a known and fairly constant rate. It is then only necessary to note accurately the exact time of their disappearance in the cloud. As in the case of ceiling lights, when the cloud mass is of a light and tenuous nature, there is some slight uncertainty as to the exact moment of disappearance, and it is general practice to report the height at which the balloon begins to be indistinct. Ceilings are usually given only to the nearest hundred feet. Greater precision is not warranted in view of the fact that the cloud base itself varies as much or more within relatively short distances.

Observations of visibility are noninstrumental. It is customary to give the greatest distance at which conspicuous objects can be clearly seen. Whenever practicable, lights are used at night. This method is approximate only, but fortunately it is most nearly accurate at times when the information is of most importance, that is, when visibility is low. It should be stated that observations of visibility show conditions in the horizontal, not in the vertical. No attempt is made to measure vertical visibility except when clouds are low, in which case it is defined by the height of the ceiling.

These two elements - ceiling and visibility - have been dwelt on at some length for the reason that all pilots ask first for information regarding them. Many ask for nothing else if these are favorable. Whereas they were never thought of in meteorology before the days of flying, now they are among the most important working elements of the meteorologist whose duty it is to tell pilots what the weather is or is going to be.

Wind direction and velocity at the surface, temperature, dew point, and barometric pressure are all so well known, as also the instruments used in observing them, that only a passing reference is necessary. Information concerning surface wind is useful principally in connection with taking off and landing. Temperature and dew point together determine the likelihood of fog and of ice formation on the planes. Reports of pressure enable the pilots to correct their altimeters, in addition to furnishing the meteorologist with basic data for synoptic charts or weather maps.

Miscellaneous phenomena are observed directly without instruments. They include thunderstorms, line squalls, exceptionally heavy rain or snow, ice formation as reported by incoming pilots, and any other conditions a knowledge of which is useful and at times vital in determining whether or not flights should be made. Special attention is always given to this part of the reports.

For measurements of upper wind direction and velocity, so-called "pilot balloons" are in general use at airports. These balloons are about 6 inches in diameter and are made of pure rubber. Different

colors are employed to give the best possible visibility against varying backgrounds of sky and cloud. The balloons, when filled with hydrogen, are about 28 to 30 inches in diameter and ascend at a nearly uniform rate of 600 feet a minute. Their ascent is watched with a theodolite, and angular readings are made each minute. By means of slide rule, portable telephone, and plotting board, computations are made while the observation is in progress, with the result that the wind conditions at various levels are known in detail within two or three minutes after the balloon disappears. For observations at night a small lantern is suspended a few feet below the balloon. Reports containing these data are received as a rule at the Weather Bureau's airport stations, where they are made available in various ways. In almost all cases the reports are posted on a bulletin board. If conditions are generally good, the pilots are usually satisfied with a reading of the bulletin; but, if conditions are uncertain in spots, individual copies are sometimes made for the pilots to take along on their flights.

Along with this organization by the Weather Bureau, the Department of Commerce has established a network of radio stations which broadcast the reports for certain airways once each hour. There are now about 40 such broadcasting stations. Some of the air transport companies have equipped their planes with receiving sets and others are doing so as rapidly as practicable. Thus, in addition to the information given at the airport stations of the bureau, the pilots receive supplementary reports while making their flights.

The broadcasts include not only reports of current conditions but also of expected changes for the next few hours. Short-range forecasts have already proved to be a great aid, and it seems certain that, with the increased accuracy that is bound to come, they will ultimately constitute the most valuable feature of the weather service. There is some question as to most suitable period of time to include in the forecasts. Naturally the shorter the period, the more precise the forecasts; but, on the other hand, their value is limited unless they cover at least a reasonable period. As a basis for compromise, the maximum length of the great majority of flights has been chosen, that is three to four hours.

As earlier stated, the basic material for all forecasting is the country-wide, twice-daily collection of reports which are used in constructing the well-known weather maps. The forecasts for 12 to 24 hours, based on these reports, are quite dependable but are necessarily given in general terms. What is needed is their amplification and localization. For this purpose supplementary reports from relatively small areas are required, small at any rate as compared with the country-wide, twice-daily system.

As an experiment the period of three hours has been selected, the observations being made at 2, 5, 8, and 11 a.m. and p.m., 75th meridian time. About 110 stations are at present in this system. They transmit their reports to airways-forecast centers at Atlanta, Ga., Cleveland, Ohio, Dallas, Texx, Fort Crook (near Omaha) Nebr., Oakland, Calif.,

Portland, Oreg., and Salt Lake City, Utah. The data are entered in detail on base maps, and lines of equal pressure are drawn. The maps for 8 a.m. and p.m., seventy-fifth meridian time, being based on the bureau's primary system of reports, are of course much more complete than are the six others. The latter are used as auxiliary to the former and serve to show the changes taking place in the areas for which the short-range forecasts are issued.

Although designed primarily for flying activities over established airways, the 3 hour system of reports and forecasts in large part also solves the problem of so-called "off-airways" flights. Before the organization of this system there was no provision for obtaining special reports from places not on regular routes, except by special call and at the expense of the pilots desiring them. Now, however, information is fairly complete for large areas, and any one desiring reports for cross-country flights in those areas has only to listen in at the proper times, since these summaries are regularly broadcast, as well as the hourly reports of conditions along the established airways themselves.

Thus far the need and value of short-range forecasts have been stressed. They are relatively precise and cover approximately the duration of nearly all flights. But they will never do away with the necessity of the longer-period forecasts, to which rather are they supplementary. The 12 to 24 hour forecasts will become increasingly important. While the individual pilot is interested in the weather for a few hours, the operations manager of an air-transport line needs to make his plans as far in advance as possible. Particularly is this true if passenger service is included.

Thus, the three main features of weather service for aeronautics are each essential to the proper functioning of the others. (1), The frequent, individual reports tell of the weather now; (2), The short-range forecasts cover the individual flights or announce the weather that is soon to be; and (3) the basic general forecasts indicate the likelihood of successful flying to-morrow. Considered in reverse order, the general forecasts form the groundwork of the entire service; they are supplemented by the more intensive shorter-period forecasts; and both of these are still further supplemented by timely reports of current conditions, which check the forecasts previously made and provide data for slight modification in them, if necessary.

Again referring to the chart, the system of airways there shown is only a beginning. Already surveys are being made by the Department of Commerce for many additional lines, and eventually the entire country will be covered. As rapidly as these airways are established the Weather Bureau, to the extent that additional appropriations permit, will organize service for them, along the lines of the present service, with such modifications in details as experience may show to be desirable. Fortunately the cost of these extensions will be considerably less per airway mile than that of the service thus far organized, since much of the latter will give information that will meet in part the needs of the new lines.