REPORT OF THE CHIEF OF THE WEATHER BUREAU
United States Department of Agriculture
Washington

November 24, 1925.

Hon. W. M. Jardine,

Secretary of Agriculture.

Sir:

I have the honor to submit herewith a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1925.

Respectfully,

C. F. Marvin

Chief of Bureau.

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In previous years it has been the practice to discuss in this report our progress during the year in the several lines of activity comprising the work of the Bureau. Since this no doubt led to repetition of unimportant details, it is now proposed, in the interest of economy, to limit these remarks to two topics which have at the time some marked public interest. Those chosen for this report are:

1. Meteorological service in aid of aeronautics.

2. Solar radiation and weather forecasting.

(1) METEOROLOGICAL SERVICE IN AID OF AERONAUTICS.

Many happenings during the past fiscal year in the field of aviation have emphasized the frailty of all types of aircraft with reference to the buffetting of storms and other adverse weather conditions. Fifty years ago the destruction of shipping on the Great Lakes and in marine navigation was the primary cause which led to the creation of the Weather Bureau "for giving notice on the Northern Lakes and on the seacoast, by magnetic telegraph and marine signals, of the approach and force of storms." To-day the necessity of an intensified service of this character, for the purpose of warning pilots of aircraft, is paramount and outstanding, and the great organization of the Weather Bureau, with its widespread network of stations embracing reports literally from the entire Northern Hemisphere, is obviously a prerequisite to the furnishing of meteorological advices for aeronautics.

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

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Very early in the stages of the World War the Bureau initiated action to impress upon the military departments of the Government the importance of meteorology in war operations, and voluntarily offered its services and cooperation. At a later stage meteorological units in the departments, especially the War Department, were very largely organized from Weather Bureau men, including such names as Major Bowie, Major Blair, Captain Reed, Captain Thiessen, Lieutenant Weightman, and Lieutenant Sherry, and a considerable number of others. Some of these officers still remain with the military branches of the Government.

Subsequent to the war, on occasions, for example, of the trans-Atlantic flight of seaplanes by the Navy Department and a long list of subsequent flights by both Army and Navy organizations, the Weather Bureau has never failed in the slightest degree to give the fullest possible service and cooperation at its command in the form of special reports collected, distributed, and made available; also very important forecast information and advices from our ablest experts in this field.

Some have supposed that aviation interests should maintain their own meteorological services. This is undoubtedly true in times of war and to a limited extent in time of peace for purposes of training and as a nucleus on which to build in time of war. It seems, however, that a very little consideration will show the existing meteorological organization in the Weather Bureau should be completely competent to furnish all branches of the Government, civil and military alike, during peace times, with all species of meteorological services and advices. Separate agencies would necessarily require full reports from the entire network of stations. Upper-air reports alone are not sufficient. If the Weather Bureau does not serve aviation, some other agency must duplicate its system of reports to do so, and this means great waste of time, effort, and money.

The Weather Bureau is now performing a very considerable service in aid of aviation, and the cooperation with the military and other branches of the Government is extensive and cordial. The service that the Bureau can perform is naturally limited considerably by lack of specific appropriations. In fact, only a small appropriation has been granted by Congress for the extension of this activity. This increase was made during the war, and by means of it six stations were established over the country for measuring upper air conditions by means of kites and pilot balloons. In addition a small number of other stations were established mostly at existing Weather Bureau stations, and at little additional cost, for making observations with pilot balloons only. The Army and Navy also have pilot balloon stations, whose reports are telegraphed to the Weather Bureau each day. It is thought that any one can see that six major stations and 15 or 20 pilot balloon stations are very inadequate to give the forecasters a very comprehensive picture of conditions in the free air over a country of the expanse of the continental United States.

It seems to be altogether self-evident, if not, indeed, axiomatic, that the expansion of the existing meteorological organization of the Weather Bureau to fully meet the needs of both civil and military aviation

in the United States can be secured at a small fraction of the cost that would be required to organize and maintain separate agencies of any kind for meeting all the various meteorological needs of the Nation, especially on a peace-time basis of activity.

This introduces the question of a meteorological organization for the Nation on a war-time basis, especially with a state of warfare on our own soil. This important question has been analyzed and examined in the most thorough fashion on the part of the Weather Bureau and the following states the case briefly:

The Army and Navy now have limited meteorological units for use at flying fields, naval bases, ordnance proving grounds, etc. These are necessary not only for peace-time service but as a nucleus for a trained personnel and the development of programs for application in time of war. But it is quite evident that these men, only a few of whom are technical men and meteorologists from the scientific standpoint, would be a mere handful in comparison with the large number that would be required during hostilities. Trained meteorologists are scarce at any time, and the complications and difficulties that arise in time of war in the most advantageous utilization of man power would aggravate the situation. Perhaps 90 per cent of the trained and dependable meteorologists of the country are in or associated with the Weather Bureau.

Therefore, it would seem to be the part of wisdom to in some way arrange that in time of war the Weather Bureau, or such parts of it as might be necessary, should automatically become a part of the military organization, and that such plans be worked out in advance, so that there would be a smoothly operating and efficient meteorological service immediately available. Any one familiar with the difficulties experienced by our military people during the Great War in independently obtaining and training men for meteorological work will appreciate at once the great need for better preparedness along this line. Possibly the best way to accomplish the purpose would be by placing the Weather Bureau in a status similar to that of the Coast Guard and Coast and Geodetic Survey, more particularly the latter, whereby officials of the Weather Bureau in sufficient number would have the status and rank of reserve officers and the work so organized that an immediate transfer could be affected. These precedents seem to abundantly justify the provisions herein suggested for a war-time organization.

Returning to the Weather Bureau service at the present time, the Bureau is keenly alive to the existing needs for more service and its responsibility to supply the same. It has repeatedly outlined programs and proposals for the enlargement and improvement of its aerological service, but, as previously stated, additional appropriations permitting of such extensions have not as yet been granted.

One of the more recent statements of this character was drawn up in answer to a request for information from a committee appointed by the Secretary of Commerce on the recommendation of the American Engineering Council. It was shown in that statement how to utilize not only

the fully equipped first-order stations of the Bureau but to secure special reports from cooperative stations at very slight cost. The program would, of course, include first the collection of advices and information as to existing meteorological conditions and the dissemination of this to all agencies, whether civil or military, in need thereof. The cost of extension of this existing organization would, of course, depend very largely upon the number of aircraft and airways in operation at any particular time. On the present basis it is estimated that an additional appropriation of about $75,000 per annum would be adequate to meet the needs for each 1,000 miles of airway.

Not only have these plans for the betterment and extension of the existing meteorological service of the Weather Bureau been maturely considered and worked out but its officers have cordially and wholeheartedly entered into conferences, through an interdepartmental committee created by the coordinator, with representatives from the branches of the departments interested. The objects are to more completely and fully coordinate the needs, activities and interests of the Weather Bureau and the military branches of the Government and to work out the best solution for certain serious existing difficulties. Mr. E. B. Calvert, Chief of the Forecast Division of the Weather Bureau, is chairman of the interdepartmental committee, and while the work of the committee and related subjects is still in progress, some of the major objectives may be mentioned here:

An outstanding deficiency in existing service is the fact that the twice-daily observations telegraphed from the regular field stations on which weather forecasts and warnings are based are taken at hours which do not best meet the needs of aviation, especially in the eastern and central sections of the country where a very large part of flying is done. The observations are taken nominally at 8 o'clock a.m. and p.m. eastern standard time. It is necessary for forecasting purposes that they be taken synchronously. Although the observations are collected at forecasting and distributing centers by an intricate but highly efficient system of telegraph circuits in about one hour after they are taken they can not be made available before much of the early morning flying operations begin. The observation hours were established years ago, long before navigation of the air was other than a dream, and for sound and justifying reasons which it is not necessary or important to explain at this time. However, why the observations are not now taken earlier is a pertinent question. To those not familiar with the situation it would seem to be a simple thing to do, but is not. Difficult and perplexing problems are involved, some of which will be briefly referred to later. It is believed that all are solvable, but the essential solvent is money.

There is urgent need for more observations in the upper air. The number of telegraph reports of observations taken at the surface (about 200 in continental United States, 12 in Alaska, 48 in Canada and in the West Indies and contiguous areas, and considerable numbers from ships at sea), while not altogether sufficient, need not be immediately increased to any material extent. Contrasted with this is the fact that in all the United States upper air observations are available from 26 places. It must

be known what is going on in the air above us, as well as on the surface, in order that better and more detailed forecasts and advices may be given aviators. It is evident that data of this sort now available are far too scant. Here again it is a question of money.

Another and emphatic need is specially organized services along the principal airways whereby aviators, whether they be military or civilian, can secure quickly and at any time detailed information of weather conditions existing over the line of flight before they take the air, and also advices as to weather changes that are likely to occur during the flight. Such an organization should consist of fully equipped first-order stations, spaced not more than 250 miles apart (regular Weather Bureau stations now in operation would meet this requirement in most instances), at which complete observations would be taken at short fixed intervals and oftener when necessary, and include upper winds, visibility, cloud heights, fog, etc. These stations should be connected by leased wire and act as distributing centers by direct contact with aviation fields. In addition, substations should be located between the principal stations and to either side of the airways not more than 75 miles apart, from which supplemental eye observations of visibility, low clouds, fog, thunderstorms, squalls, rains, snow, etc., can be obtained by telephone at fixed times, or as often as required. The importance and value of airway organizations of this kind cannot be too strongly emphasized. None now exist. It is confidently believed that the cost of such airway units would be more than offset by savings due to more economical operations than otherwise would be possible, and the prevention of losses of planes and property, as well as in the saving of lives.

Previous reference has been made to the taking of observations at an earlier hour, to arrangement of facilities for making the observations available promptly to flying fields, and to the need for more observations taken in the upper air. These are the principal subjects that thus far have received attention by the committee.

The time at which observations are taken at field stations will be advanced by two hours as soon as certain complicated problems have been solved and means are provided for putting the change into effect. When accomplished the established hours of observation will be 6 o'clock a.m. and p.m., eastern standard time, corresponding to 5 o'clock, 4 o'clock and 3 o'clock, respectively, in the central, Rocky Mountain, and Pacific coast time-zone areas. The change will result in some disadvantages from a scientific standpoint, and cause much personal hardship, especially in the western areas, to employees who already have long and exacting hours of service every day in the year, Sundays and holidays included, by requiring that they begin their work before daylight; but these are merely disadvantages and knotty problems affecting the mechanical and administrative questions involved in the change. The greatest concern relates to factors which do not come within the independent decision of Government officials but must be worked out with the consent and cooperation of other agencies. One of the most difficult adjustments to be made is the system of telegraph circuits by means of which the weather observations are collected. These

circuits are not composed of leased wires. They are commercial wires controlled and manned by the Western Union Telegraph Co. and set up promptly at 8 o'clock, morning and night. However, they are used exclusively for the transmission of weather reports during the period of the set-up (about one and one-half hours) and then reverted to commercial use. A great many of the observation points connected by the circuits are located in small cities and towns of relatively small commercial importance. The providing of telegraph operators in these places and the rearranging of operating conditions so much earlier than business hours is a complicated matter, the details of which will require considerable time to work out. Undoubtedly a considerable increase in operating cost will be involved. The Western Union Telegraph Co. is now at work on the details of the problem.

Another feature involved in the proposed change is the fact that there is close cooperation between the United States Weather Bureau and the meteorological services of neighboring nations, especially Canada. The latter's system of operation conforms with ours. Its observations are taken at the same time, the character of the observations is the same, our code is used, and exchanges are made by direct contact with our circuits. In fact, from a meteorological standpoint, no boundry lines exist. Canadian weather reports are indispensable to us and correspondingly that service could not function successfully without reports from our territory. On the other hand, the need of the Canadian service for earlier reports is not as pressing as ours, and in some respects the difficulties confronting it in changing observation hours are comparable to ours with the added fact that it will involve an inescapable and material increase in the expense budget of that service. A conference has been held with the director of the Canadian meteorological service and we feel assured of his alignment with our program.

The committee has made a study of all the aviation fields of the country -- Army, Navy, State and municipal -- with relation to their present and prospective needs for the weather reports, and the best methods for promptly providing them with the regular morning and evening observations. A tentative plan has been worked out which it is believed will be effective. Radio will be used. It is the purpose to select the necessary number of Weather Bureau offices located in cities where high-power Government radio stations are available and favorably situated geographically with relation to the aviation fields to be served; to connect these Weather Bureau offices and radio stations by direct wires attached to the transmission apparatus; to assign expert radio operators in the Weather Bureau offices; and to broadcast as complete a system of weather reports as may be necessary, as fast as the reports are received and checked. In this way current weather information can be made available to fliers in a very short time after the observations are taken. Final selection of all the broadcasting points has been made, but Washington will be one of them and the naval radio station at Arlington will probably be used. It is a pleasure to state that the officers of the Navy Department have cordially cooperated with the committee, concurred in the practicability of the plan and given assurance that facilities will be provided for making it effective.

Army & Navy.

Some recent newspaper comments may have left an impression in the public mind that the Weather Bureau is doing little or nothing for the

benefit of aviation. This, as has been shown, is far from being true. It would require too much time to enumerate the numerous instances of special service that have been rendered during the past several years, including practically every important flying event, or to describe in detail the extensive program of daily service rendered in the aid of aviation. However, the latter may be summarized as follows:

Flying weather forecasts are made and issued twice daily for practically all sections of the United States. For this purpose the country has been divided into 14 zones.

Elaborate bulletins containing surface and upper air reports and flying weather zone forecasts are broadcasted twice daily from the naval radio stations at Arlington, Va., and San Francisco, Calif.

Flying weather forecasts for central zones are broadcast twice daily by radio stations in Chicago and from the naval radio station at Great Lakes, Ill.

Special route forecasts are furnished daily to the Air Service of the Army for flying operations about Chicago and for the routes between Belleville, Ill., and ~~Clemson~~ Selfridge Field (near Detroit, Mich.).

Special forecasts are issued twice daily for the naval flying operations about San Francisco and San Diego.

Special and detailed forecasts are issued each morning and evening at Washington for several flying routes, including the model airway, to supplement the zone forecasts distributed by radio. These forecasts are made available by telegraph or telephone directly to Army and Navy flying fields and those issued in the p.m. are published regularly in some morning papers.

Accommodations in the forecast room of the Weather Bureau at Washington are provided representatives of the Army and Navy for copying on charts current weather reports as fast as they are received from all parts of the United States and Canada, and these representatives telephone the route forecasts directly to their offices before leaving the Weather Bureau office. The charts are taken by automobile or motorcycle to the Bureau of Aeronautics and Bolling Field and posted for the benefit of aviators.

The full system of a.m. and p.m. weather reports received by telegraph at Washington, together with regular and special flying weather forecasts, are sent by messenger to the office of communications, Navy Department, from which they are immediately telegraphed over Navy leased wires to Lakehurst, N. J., for use of the meteorological officer at that place.

The Weather Bureau has five district forecast centers located at Washington, Chicago, New Orleans, Denver, and San Francisco, and weather information, forecasts and warnings for the group of states comprised within a district are issued from these centers. These district forecasters are in close touch with the aviation interests within their districts and give

direct service as conditions and facilities warrant. Moreover, local service is rendered by the officials at all Weather Bureau field stations.

When the air mail service introduced night flying across the continent in the early summer of 1924, arrangements were made at the request of the Second Assistant Postmaster General to provide special forecasts therefor. They are issued by the district forecaster at Chicago for two sections of the route, one from Bryan, Ohio, to Omaha, Nebr., and the other from Omaha to Rock Springs, Wyo. The forecasts and weather information are made available to both east and west bound fliers at Omaha.

Special service has been given in a number of cases in connection with flying activities, but there is very little organized flying of this sort at the present time. However, a complete service was arranged in connection with the first commercial reliability tour for the Ford trophy.

Aviators are always privileged to confer directly with the forecasters of the Weather Bureau, and calls by telephone for this purpose are numerous.

(2) SOLAR RADIATION AND WEATHER FORECASTING.

That solar radiation is the primary cause of all features of terrestrial weather has always been recognized by the Weather Bureau. Early in its history, when Prof. S. P. Langley was conducting at the Allegheny Observatory his pioneer researches on solar heat, Prof. Cleveland Abbe brought them to the attention of the Chief Signal Officer of the Army, with the result that in a short time provision was made for a complete expedition which enabled Prof. Langley to transport his party and delicate instruments to the top of Mt. Whitney, Calif. There, in the last days of August and early September, 1881, upon this summit, about 14,500 feet above the sea, as near the outer limits of the earth's atmosphere as it was practicable to carry instruments at that time, Langley made his classical measurements of the solar constant.

These early investigations upon the intensity of solar radiation made under the auspices of the Signal Corps had for their primary object the further solution of the fundamental problems of meteorology, and the results were submitted for publication in December, 1883, as Professional Papers of the Signal Service, No. XV, entitled "Researches of Solar Heat." From that day to the present the Weather Bureau has been interested in all studies of solar radiation, and the observations of the Astrophysical Observatory of the Smithsonian Institution and those of foreign workers in the field have been a subject of constant study.

What is the present consensus of interpretation of all such observations?

Some investigators, but not many, claim that observations show important changes of solar intensity from day to day, frequently amounting to 5%, and sometimes as great as 10%, at intervals of ten or more days. The Weather Bureau, basing its conclusion upon an exhaustive study of all the

observations available, finds itself compelled to join the much larger group of those who doubt that real changes in the intensity of solar radiation occur. The Bureau of course believes that it is physically possible for variations to occur. But the critical question is this: If there are variations, are they big enough to stand out above the variations which inevitably follow from changes in the transparency of the atmosphere and from the errors to which even the most highly refined instrumental determinations are subject, No one can go entirely beyond the earth's atmosphere and actually measure there the intensity of solar radiation. All that can be done is to measure it after it has penetrated to a greater or less depth the ocean of air in which we live. Even if observations are made on high mountain tops, we must still make the best estimate we can of how much the incoming radiation was depleted before reaching our measuring instrument. Briefly, such observations show us two things: First, inferior observations show relatively large irregular fluctuations of the derived value of the solar constant. These observations may be inferior because the instruments and methods are faulty, or the atmospheric depletion of incoming radiation may be large and irregular, indicating that the station is badly located, or both adverse conditions may exist. When observations are made with the best possible equipment at the best possible localities, we find that the fluctuations are only about a third or a fourth as great as those at inferior stations. This in itself shows that the large variations at the inferior stations are quite wholly errors of derivation of the solar constant and not real changes in solar intensity outside the earth's atmosphere.

Second, when we subject the several thousand observations of the solar constant that have been accumulated during the past 20 years to critical analysis by the methods which mathematicians employ to evaluate errors of observations and disclose the true facts, we find that the total fluctuation in the derived value of the solar constant from the best stations is so small that it is entirely plausible that all of it may be nothing but possible errors of derivation. Instrumental observations which are 100% perfect, that is, without error, are known to be humanly impossible. If, therefore, there is any real change from day to day in solar radiation, it appears to be so small as to be submerged in the unavoidable variations of our measurements.

Efforts to get sufficiently accurate simultaneous observations at two or more independent stations have been imperfectly successful. Our conclusions at the present time rest almost entirely upon the testimony of a single witness, that is to say, upon observations made almost always at a single station that is not always the same one. What we greatly need are observations of the same sun from several entirely independent stations. Efforts are now being earnestly directed toward securing such observations in the future. The question of solar variability can be settled only when this objective is attained.

The reality of solar variations from day to day, therefore, has not been proved, and at best the effect of such changes, if any, are so vanishingly small when compared with those which we know to be due to the atmosphere, as to be negligible from the point of view of our daily weather changes.

While the foregoing conclusions relate to short interval changes of a few days, the studies by Dr. Kimball and Mr. Clough indicate that even the changes over periods of months, seasons and years must still be regarded as taking place with extreme slowness, if indeed they exist at all.

These considerations lead us to the question, what meteorological effects may be expected from such small variations as the best statistical analyses of data show may still be possible?

Following Sir Napier Shaw, whom we hold to be the world's leading meteorologist, we may most appropriately measure the flood of heat energy which the sun pours upon the earth in terms of electrical units. It amounts to 135,000 watts per square decameter. All are familiar with the rating of our household electric lights as 25, 50, 100 watt lamps, etc., because they consume electrical energy at the rates indicated by the numbers. Accordingly, the electrical unit, watt, is quite generally understood. In the United States, however, a square decameter is nearly an unknown thing. It is the metric measure of a surface having an area of a little more than 1000 square feet. This is less than the area of a small ballroom floor. It is just about the area of ground occupied by a small detached 8-room cottage. Consequently, if a beam of sunshine having a cross section of one square decameter could be transmitted without losses in its journey through the atmosphere to the little 8-room cottage and there converted into electrical energy, the amount would maintain about 2700, 50-watt lamps at full brilliancy. This would mean about 300 lamps to the room, with 300 to spare for the attic and cellar! Now, the best interpretation of the observations of the solar constant seems to allow us to admit that the average day-to-day variation of the sun may possibly be as much as one quarter of one percent. This means that to equal the effect of average high solar radiation we should have to add 7 lamps to the 2700 already alight in our little cottage, and on some other occasions to turn off 7 Such slight changes in the flood of illumination would plainly be quite inconsequential and the results could be ascertained only by the most refined measurements. This imperfect analogy will help the non-technical reader to grasp the quantitative insignificance of the alleged day-to-day fluctuations in solar intensity and the probable success of weather forecasting resting upon such a basis.

Let us see how these thoughts work out when we consider sunshine and the atmosphere as a whole.

Suppose for a moment the whole surface of the earth were a perfect reflector and that the atmosphere were peffectly transparent. All the phenomena which we call weather and now ascribe to the effects of solar radiation would disappear, because the solar energy would simply be totally reflected back into space with no terrestrial effects whatever. Of course such conditions never prevail. As a fact, no matter how transparent the atmosphere may seem to be, some of the incoming radiation is always scattered and intercepted, while on cloudy days greatly varying amounts are caught up. Thus, all the phenomena of weather are caused by the solar heat that is

entrapped in the atmosphere either on its way to the earth's surface as incoming radiation, or on its way from that surface as heat transmitted by conduction and convection, or intercepted from outgoing earth radiation or reflection. Obviously, weather can and does vary enormously even if we assume the incoming radiation to be absolutely constant day after day indefinitely. But, it is perfectly plain also, that if the incoming radiation independently changes its intensity there is a new and added cause of weather fluctuation. If, however, these solar changes, not yet proved to occur at all, cannot exceed on the average more than one quarter of one percent, how highly fallacious must it be to regard such small fluctuations as a major cause of weather effects which are actually controlled by the far greater fluctuations in the atmospheric transformation of solar energy. Using again the analogy of our little cottage, we should, in order to imitate the atmospheric effects, have very frequently to turn off as many as 1000 to 1500 or more lamps. If, in the meantime, some one should play us the trick of turning off (or on) even 10 more lamps, in representation of the independent possible changes in solar intensity, the effects would be so inconsequential as to be inseparable from the effects due to atmospheric transformation.

It is hoped that the foregoing explanations, couched in non-technical language, will help the reader to visualize the nature of what is really a very difficult and complex scientific problem. Widespread public interest and expectations have been needlessly aroused in the United States by premature and unfounded representations that new and better methods of forecasting the weather for both short and long times in advance have been discovered, based upon the alleged fluctuations of the solar radiation. One advocate of solar variability states, "There are a vast number of straws all of which point in this direction and combined make up a very stiff bundle of evidence." These straws and all other evidence have been thoroughly examined by the experts of the Weather Bureau, with the conclusion already stated. It is our conviction that a bundle of straws however stiff it may be, constitutes evidence which can only be regarded as circumstantial and therefore not as a fit foundation upon which to build up a system of weather forecasting.

The Bureau highly prizes the unmistakable evidence of general public confidence accorded its extensive system of forecasts of storms, floods, etc., and will in the future, as in the past, insist upon direct scientific evidence as the only legitimate basis for going before the public with a new system of forecasts, especially for months, seasons and years ahead. It is one thing to fabricate what to the public appears to be a highly plausible new scheme of forecasting; it is quite another to be responsible to the public for the failure that is certain ultimately to attend any scheme that is not founded upon an absolutely sound scientific basis.

The causes and laws of the sequence of weather conditions are subjects of constant study by experts of the Bureau, and many valuable articles have been published. The public, eagerly awaiting the advent of scientific long range forecasts, may rest assured that the Bureau is diligently searching for a sound basis for such forecasts. Our library contains not only

the latest and best but practically all of the world's literature on meteorology, and our leaders note and utilize every real advance wherever made in the science. The Weather Bureau is prepared to engage in public long range forecasting just as soon as an assured scientific basis for such forecasts has been formulated.

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