# REPORT OF THE CHIEF OF THE WEATHER BUREAU.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
*Washington, D. C., October 11, 1921.*

SIR: I have the honor to submit herewith a report of the operations of the Weather Bureau during the fiscal year ended June 30, 1921.

Respectfully,

C. F. MARVIN,
*Chief of Bureau.*

Hon. HENRY C. WALLACE,
*Secretary of Agriculture.*

No material change has occurred in the customary annual program of the work of the Bureau except that some additional curtailments and omissions of service have been entailed from the continued high costs and charges which must be met from appropriations remaining the same as in pre-war times.

The serious difficulties encountered in maintaining and recruiting the personnel of the service have somewhat abated. At the close of the year the number of temporary and untrained employees carried on the rolls without civil-service status, pending the certification of eligibles, had been reduced to 72. However, comparatively few young men in the country with the qualifications and abilities required for the grade of assistant observer seem attracted by the low entrance salaries ($1,080 with bonus of $240) and the poor opportunities of progress and advancement still characterizing Government position in the Weather Bureau. The registers of eligibles secured as a result of the several civil-service examinations which have been held have been rapidly exhausted in effecting replacements of temporary appointees by probationers willing to accept the positions and assignments tendered.

The success of the Weather Bureau and the economic benefits flowing from its service and warnings depend in a peculiar and extreme degree upon its man power—upon the technical experience and ability of its personnel. Professional meteorologists and forecasters can not be secured from the universities or from the outside. The Bureau itself is the only possible training school for the future leaders in the service.

The long-promised and long-delayed reclassification of Government salaries is nowhere more greatly needed or justified than in the Weather Bureau. The imaginary economies in withholding urgently-needed increases for properly strengthening and recruiting the personnel is not economy, but sap and injure the vitality of the organi-

zation and is certain to be reflected in future inferiority and inefficiency. Another legislative year should not go by without some concrete congressional enactment making the promised reclassification effective.

The new demands upon the Bureau for its services and advices in aid of aviation; for data and the certification of facts with reference to storm, weather, and rain insurance; for reports on the influence of weather upon the public highways; for extensions of its various services in reporting frosts, cold waves, hurricanes, etc.—all continue to be pressed urgently by the diverse interests involved. Even under the present national exigencies compelling the utmost economies in Government appropriations, it is intended to urge upon Congress, through the Director of the Budget, certain very necessary increases to enable the Bureau to meet its reasonable obligations and responsibilities to the public with reference to the most urgent needs. It is easy to show that Weather Bureau service and advices carry with them, in a very great degree, an immediate and direct economic benefit in the saving of the lives, properties, and foodstuffs of the Nation. Many shocking accidents in aeronautics have resulted very directly from lack of sufficient foreknowledge of flying-weather conditions along the customary airways. The Weather Bureau is the agency charged by law to perform this new service, and a skeleton organization is now in operation. However, the funds available suffice to provide only a fraction of the stations, reports, and advices needed to represent conditions over such a great extent of territory as the United States.

Hurricanes and violent storms of the tropical oceans bring losses and disasters to shipping of the Gulf, and alarm and consternation to the residents of the whole Gulf coast. At such times the Weather Bureau at Washington, and its field stations in the menaced region, are literally overwhelmed with direct and indirect applications for information. Its warnings and advices allay the fears of some, quiet needless alarm of others, and guide many to make timely escapes from almost certain death in threatened localities, or to take precautions to minimize the destructive effects of a storm which can not be escaped.

Vessels while still at sea now receive, often days beforehand, warnings which are broadcast daily by wireless, and thus are easily able to shun the danger zone and probably escape injury or wreck.

Warnings of frosts, cold waves, blizzards, and weather conditions damaging to perishable foodstuffs in shipment are other important services of the Bureau showing an immediate beneficial or monetary return and saving. These are all services which can not be curtailed or abridged without great public detriment and even loss of life and property.

Even under the present program of economy a reasonable support of this work is justified and will be rewarded.

## FORECAST SERVICE.

Only three tropical storms occurred within this fiscal year, two in the closing six months of 1920 and one striking the Texas coast on June 22, 1921. Fortunately, none of these was notably severe or accompanied by marked losses of life and property.

It is important to recognize, however, that because of the very meager reports available, little idea of the severity and destructiveness of these great storms can be formed while they are far at sea. These characteristics are disclosed only after the storm passes inland. On the other hand, the broadcasting of warnings and advices merely reporting the existence of such a storm at once awakens the fears and apprehension of the public which are fully allayed only after the final report of the dissipation of the storm or its passage beyond our territories.

It seems quite pertinent to this question to make a few quotations from newspaper editorials commenting on the beneficial service of the Weather Bureau with special reference to the hurricane of September 21, 1920.

AHEAD OF THE HURRICANE.

The storm now beating against our southern coast did not come as a surprise. Two days ago the Weather Bureau gave public warning of the hurricane's approach and was able, within fairly narrow limits, to tell where and when it would strike and what force would be back of the blow. Probably the shipping saved in this one tornado is greater in value than the cost of the Weather Bureau for years, and one does not like to fix a money value on the great saving of life.—*Chicago Evening Journal*, September 22, 1920.

VALUE OF WEATHER BUREAU ATTESTED.

The importance and value of the United States Weather Bureau service was unmistakably and impressively attested in connection with the terrific storm which on Tuesday night swept up from the Gulf of Mexico and struck the coast of the United States, particularly across Louisiana. Hours before the hurricane had reached the mainland the weather official knew it was coming. Warnings were hurriedly sent out, not only to the shipping in the Gulf but to the cities, towns, and farms over the section that was threatened. As a result of the warnings, ships and especially the smaller craft out in the open scurried to shelter. Boats that were ready to sail remained in port. On land as well preparations were made to meet the storm. Shelters were constructed, insecure movables were fastened down, trains were given added protection—in short, every possible precaution was taken to withstand the rage of the elements when it should break.

As a result of these preparations it is estimated that many lives were saved and much property loss prevented. The storm came in its fury and much damage was done; for it is not within the ability of man to shield completely the open fields and their crops, his homes, and other possessions from torrential storm and hurricane. But when the violence had abated and a survey of the damage brought realization of what might have been suffered had the storm come unannounced there could not but be universal gratitude and appreciation of the ability of the weather service to forecast the future and send out its beneficial warning.—*Salt Lake Desert News*, September 23, 1920.

A MILD HURRICANE.

The hurricane of this year did not prove as severe as many of its predecessors and the damage was comparatively small. This is partly due to the fact that residents along the coast have been fully educated to the danger of the hurricane and now adopt the sensible plan of getting out of the danger zone as much as possible and protecting their property as well as they can. There is small profit and little sense in the effort by a human being to fight a hurricane. Because of the precautions taken and through the additional fact that the storm was not as severe as has been known in other years, the country escaped with a minimum amount of damage and loss of life.

It must be said for the Weather Bureau in connection with the work of forecasting this storm that it performed most admirable and valuable service. To predict when and where a West Indian hurricane will arrive at a given point and estimate with any degree of accuracy the condition in which it will arrive

is no easy task. Indeed, there are times when the undertaking is simply impossible. There are no observation stations in the middle of the Gulf of Mexico and, lacking these, the Weather Bureau is sorely handicapped by the lack of necessary information.

On this storm, however, the Bureau made a most excellent record. It reported its appearance in the western Caribbean Sea and estimated the time of its approach as closely as could possibly be done.—*San Antonio Daily Light*, September 23, 1920.

DETECTION OF THE STORM.

That the tropical storm (Sept. 22, 1920) that was detected by the United States Weather Bureau 500 or more miles out at sea spent its fury before coming inland is not the important point. Detection of the storm by the Bureau and the ability of the Bureau to give the threatened sections of the country information in advance of its coming is the paramount detail. The service rendered shipping at sea and life and property on shore through the timely warnings issued by the Bureau may never be estimated. The Weather Bureau has made impossible occurrences of the past when ships went forth to be caught unaware in the teeth of a hurricane and when people ashore slept in fancied security from the coming of blast and flood that wreck property and destroy lives. In this instance hundreds of ships were held safely in port while people were enabled to make preparations against its coming, and summer population at coast resorts that might have been swept away were advantaged by the warning in having been given opportunity to get to places of safety. Cattle on islands that were threatened with submergence were taken to the mainland, and all the section through which the storm was expected to pass was placed in condition of defense against its coming. The Weather Bureau is a great institution and scarcely a week passes that it does not demonstrate its value to the country.—*Charlotte (N. C.) Observer*, September 23, 1920.

A published record of the storms and noteworthy features of the weather of the year appears regularly in the Monthly Weather Review, and little mention of these need be made here.

A storm of extraordinary violence was experienced along the north Pacific coast during the afternoon and evening of January 29, when a maximum wind velocity of 110 miles from the southwest occurred at Tatoosh Island and an estimated velocity of 150 miles from the southeast at North Head was reported. The North Head station anemometer was destroyed by a falling wireless tower when it was recording 132 miles an hour. A maximum velocity of 150 miles an hour is estimated to have occurred.

The winter of 1920–21 was an unusually mild one and no extremely low temperatures were experienced anywhere. The mild weather of March caused vegetation and fruit trees to advance far beyond normal. As a consequence the cold wave of March 27–29, which was the only cold experienced during the month, succeeding the abnormal warm weather, was destructive of fruit blooms over a very large section of the country east of the Rocky Mountains.

The cold weather of March 27–29 was followed by another frost wave early in April, which completed the destruction of fruit blooms in many sections that had escaped the previous freeze. The completeness of destruction of fruit and the wide area affected was the greatest that has been experienced in many years. Accurate warnings were issued in both cases, but the severity of the frost and the impossibility of applying protective measures made it impracticable to avoid the damage.

Special service was rendered on a number of notable occasions. Among them were:

The national balloon race and the international balloon race, which started from Birmingham, Ala., on September 25, 1920, and Octo-

ber 23, 1920, respectively; and the elimination balloon race from Birmingham, Ala., on May 21, 1921, to determine United States entries for the international balloon race to be held in Brussels in September, 1921. Special forecasts were made and weather reports and advices furnished the contestants in these races. In addition, representatives of the Weather Bureau were assigned to Birmingham, special maps were prepared and detailed information supplied to the balloonists. The elimination balloon race was won by Mr. Ralph Upson. Mr. C. G. Andrus, a meteorologist of the Weather Bureau, was Mr. Upson's aid. It is generally conceded that Mr. Andrus's expert knowledge of meteorological conditions was an important factor in winning the race;

The transcontinental record aeroplane flights by Lieut. W. D. Coney, U. S. Army, in February and March, 1921, and trans-continental aerial mail race in February, 1921;

The international yacht races off Sandy Hook, July 15 to 27, 1920.

The United States Army pathfinder aeroplane flights from New York to Nome, Alaska, during the fall of 1920;

Many special forecasts were made at the request of managers of State fairs, local celebrations, and the like. This form of service is rapidly increasing in popular favor.

Special advices and forecasts were furnished in connection with numerous pigeon races during the year. Nearly all carrier pigeon racing associations now depend largely upon the Weather Bureau and do not release the birds until advised by the forecasters that conditions of wind and weather are favorable for flights.

Special forecasts for national election day, November 2, 1920, were issued. This forecast was made on Monday, the 1st, and given distribution through the press associations and also telegraphed to the chairmen of the national campaign committees and to the presidential candidates. The forecasts in this particular case were accurate in practically every detail.

Special forecasts of wind and weather were prepared and radiographed each day for several weeks in October and November for the guidance of the United States submarine naval vessels *Beaver* and *Mallard*, which were engaged in salvaging the United States submarine *S–5* off Delaware Breakwater.

### FLYING-WEATHER FORECASTS.

The flying-weather forecasts which were begun in July, 1919, were continued during the year. These forecasts were inaugurated for the special benefit of the air service of the Army, Navy, and Post Office Departments. Their great value to aviation is fully recognized, and during this year a number of organizations interested in commercial flying have been added to the list of recipients of these forecasts. The demands for these forecasts are increasing. This is especially true of individual flyers, who, in addition to the regular flying-weather forecasts issued each morning and evening, desire personal information and advices before beginning flights. For the most part the supplemental information is supplied by telephone. Many daily calls of this character are received. Flyers are coming more and more into contact with the Weather Bureau before beginning flights, an indication of the reliance being placed on weather

forecasts and their indispensability to safe and successful flying. However, the forecasters are handicapped because the number of upper-air and local reports available to them is far insufficient. Reports are needed from more upper-air stations and from surface points at close intervals in every flying zone. By this means far more definite and exact information can be given to aviators.

### FIRE-WEATHER FORECASTS.

Fire-weather forecasts were issued during the year and sent to fire wardens and forestry associations in the large forested areas of the country. These forecasts are issued whenever conditions favorable for the inception of forest fires are indicated, and of the approach of rains which may affect their control after fires have started. A protracted dry spell occurred in the Northwest in the summer and fall. Forecasts issued on this occasion, especially in Montana and Minnesota, where the conditions were worse, were of incalculable value in the protection of the forest areas. There is much need for an extension of this work, and forestry and fire-fighting associations have repeatedly petitioned that this service be intensified and extended. A number of stations should be established in the great forest areas for the purpose of collecting more definite meteorological information and studying the whole problem with relation to topography as it affects local wind directions and force. Exceedingly valuable service which would aid in the saving of millions of feet of lumber destroyed each year by forest fires is feasible and practicable if a few thousand dollars were made available therefor. All that it is possible to do with available funds is being done.

### RESUMPTION OF WEATHER MAPS.

It was not possible to resume the issuance of maps at stations where they were discontinued during the war, nor will it be practicable to do so until funds are provided for the purpose. Business men, educators, and a larger part of the general public, through many years of usage, understand the weather maps and obtain from them results that bulletins do not supply. Thousands of applications for maps are received. A comparatively small amount of money would enable the Weather Bureau to again place this service on a basis wherein the public and business needs of the country can be met.

### VESSEL-WEATHER SERVICE.

Although the war crippled the vessel-weather service to a considerable extent it was gradually restored and this year it has been placed on a higher plane of efficiency than ever before. There are now nearly 100 vessels that radiograph weather conditions at least once daily when they are in certain ocean areas from which observations are desired. With the exception of reports radiographed during the entire year from ships in the Pacific, observations are now confined to vessels plying the South Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico during the hurricane season, June to November, inclusive. These reports are invaluable in the forecasting of storms and hurricanes.

During the year cooperative arrangements were perfected with the Shipping Board whereby all ships of that fleet when within prescribed ocean zones radiograph daily weather observations to designated forecast centers. This service was begun June 1, 1921.

Cooperative arrangements were also made with the Texas Co., the Standard Oil Co., and the Gulf Refining Co. for ships in those fleets to take and radiograph reports to Washington. This cooperation is highly appreciated, as these vessels navigate largely in the Gulf of Mexico, from which regions observations are especially valuable in connection with hurricane work.

### HIGHWAY-WEATHER SERVICE.

The highway-weather service has been continued on the same basis as last year. This service is of established popularity and value, and applications have been received from all parts of the country for its extension. Traffic on highways is so large and is growing so rapidly that it is important that an efficient and comprehensive system of advices concerning road conditions as affected by past and future weather be maintained. The Weather Bureau is well fitted to render this service and has the organization whereby it can be accomplished at a minimum cost. Moreover, automobile associations, road commissioners, and the users of the highways look to the Weather Bureau for the service. The work now done is confined to main highways and in a comparatively few sections. Extensions can not be made until appropriations are made available by which the public demands may be met.

### RADIOGRAPHIC DISTRIBUTION OF FORECASTS AND WEATHER INFORMATION.

Radio telegraph and telephony have reached a stage where they must be recognized as potential mediums for the dissemination of weather forecasts, warnings, and information. For some years this has been utilized to some extent, especially in the dissemination of forecasts and storm warnings to ships at sea. A marked extension of the work was made during this year. Since 1914 abbreviated bulletins have been broadcast from the naval radio stations. On November 1, 1920, comprehensive bulletins began to be issued each night at certain scheduled hours from Arlington, Va.; Great Lakes, Ill.; Key West, Fla.; Point Isabel, Tex.; and San Juan, P. R. The bulletins are divided into two parts. The first part consists of reports of barometric pressure, wind direction and velocity and state of weather, taken at 8 p. m. at a number of stations. The second part consists of wind and weather forecasts, storm and hurricane warnings, and advices to shipping.

On June 1, 1921, an extensive morning bulletin began to be broadcast from Arlington containing surface observation (8 a. m.) taken at 42 regular Weather Bureau stations and nine aerological stations maintained by the Navy, Army, and Weather Bureau, a summary of weather conditions over the United States, forecasts and storm and hurricane warnings. This bulletin is for the benefit of marine and aviation interests, but is designed especially to meet the needs of the latter. It is the first wireless weather bulletin for the benefit of aviators ever issued in the United States. A special feature is sepa-

rate flying weather forecasts for six zones covering the entire country east of the Mississippi River. The bulletin is broadcast on high-power wave-length and has a range of about 1,000 miles.

Another bulletin was begun on June 10, 1921, having for its purpose a systematic broadcasting of local weather observations, wind and weather forecasts, storm and hurricane warnings, and advices relating thereto from 26 naval radio stations on the Atlantic and Gulf coasts, in the Caribbean Sea, and on the Great Lakes. This distribution is in the nature of a localized service and supplemental to the general bulletins heretofore referred to.

All of the foregoing bulletins are broadcast from naval radio stations in cooperation with the Office of Communications of the Navy Department.

The use of radiotelegraphy for the benefit of marine interests is well systematized and quite complete, but such is not the case so far as land interests are concerned. However, plans are under way to systematize radio distribution of forecasts and warnings for the special benefit of agricultural and commercial interests and to extend it to every State and section. Forecasts and warnings are now broadcast from a number of colleges and private organizations and from radio stations at Washington, D. C.; Bellefonte, Pa.; Cincinnati, Ohio; St. Louis, Mo.; Omaha and North Platte, Nebr.; Cheyenne, Wyo.; and Reno, Nev., which are operated by the Post Office Department in connection with its transcontinental air-mail service.

The ultimate plan in mind will provide for the distribution on fixed schedules of weather forecasts and warnings from at least one radio station in each State. Existing Government radio stations will be utilized as far as practicable, but cooperative arrangements with commercial companies licensed to engage in radio communicative service will also be made in States where Government agencies are not available.

#### ORCHARD SPRAYING AND HARVEST-WEATHER FORECASTS.

For two seasons special forecasts in connection with orchard spraying activities have been made for the orchardists in northern New York. It has been demonstrated that sprays must be applied to fruit trees just before a rainy spell in order to produce the best results. It requires from 48 to 72 hours to apply the spray in many of the large orchards. Therefore, forecasts for a longer period than is covered by the regular daily forecasts and with the occurrence of rains especially in mind are necessary for this work. Forecasts covering from three to four days were made and with a marked success. The work was so highly commended that there has been a demand for similar service elsewhere. This year a similar service was inaugurated in a limited way for the benefit of orchardists in the region about Gettysburg, Pa.

There has been demand for special weather forecasts having for their direct purpose aid to farmers in the harvesting of hay, oats, wheat, and other crops liable to danger if unfavorable weather occurs between the time of cutting and shocking. Insufficient funds have prevented extensive work of this character, but such service was begun in a limited and experimentative way in the early summer

of 1921 in 10 counties in New York. These forecasts are made daily and not for a fixed period as is the case with the general daily forecasts, but for just as long a period as the forecaster feels that the condition as shown on the current weather maps justifies a reasonable expectation of accuracy. Sometimes this period is for 24 hours and at other times three or four days. Moreover, the predictions are worded to apply to the particular purpose and to convey to the farmer the degree of confidence that the forecaster has in the forecast. For instance: "Conditions excellent for drying weather Wednesday and Thursday; Friday uncertain"; or "Outlook for harvesting next two days uncertain; rain very likely." This is information of great value to the farmer, because in effect it is advice and enables him to proceed with his work with either confidence or caution.

The harvest-weather forecast work is conducted in cooperation with the county agents, who have undertaken to disseminate the forecasts by telephone to individual farmers. A full season of this work has not been completed, but an indication of the interest taken in the service is gained by the fact that in one week the county agents in eight counties reported a total of 483 calls from individual farmers for the forecasts.

## RIVER AND FLOOD SERVICE.

As in other lines of effort, high charges and stationary appropriations precluded improvement or extension of the river and flood service. Equipment has been repaired or renewed only where absolutely necessary, less urgent cases being deferred to some more opportune future time. The extensions that should go hand in hand with the increasing development of the business of the country, and especially of the development of water supply for hydroelectric, irrigation, and other purposes, must also be deferred, and the demands for them still exist and are increasing. At present the greatest demand is for a large increase in the number of precipitation stations and a plan of campaign is in progress of development to meet the situation.

Another legitimate field of expansion lies in the operation of river stations throughout the year. At present many are operated only during the flood season, which is sufficient for flood purposes, but engineering interests engaged in problems involving water run-off and supply constantly need data regarding low as well as high water, and these the Weather Bureau should be in a position to furnish.

The flood-warning service has met all demands upon its present organization, and the only extensions needed apply to some of the smaller rivers not now enjoying the benefits of flood-warning service. Repairs to much of the equipment and more thorough standardization and coordination are really necessary, but under existing conditions they must wait.

While floods were fairly numerous during the year, especially in the South Atlantic and East Gulf drainage basins, they were in the main of moderate character. The outstanding exceptions were the great floods of June in the Arkansas and lower Colorado Rivers. The Arkansas River flood was caused by torrential downpours of

rain over comparatively limited mountain areas in eastern Colorado, and was especially destructive at and in the vicinity of Pueblo, Colo. Here the crest stage of the flood was more than 12 feet above the highest stage of previous record—120 lives were lost and 143 persons were unaccounted for, while the property losses amounted to at least $25,000,000. The Colorado River flood was due to a combination of heavy rains and melting mountain snows, and at some places the highest stages of record were reached.

Mountain snowfall measurements were continued in the West. Here, again, the water-supply interests are demanding increased service. The necessity therefor is admitted and it can be accomplished only by more intensive snow surveys and an extension of the work into the highest mountain regions. The importance of this work to the irrigation and hydroelectric interests is apparent, a preliminary campaign along new lines has been outlined, and a moderate estimate of funds necessary therefor has been submitted.

The Wagon Wheel Gap Experiment Station maintained in connection with the Forest Service of the department has been continued during the year, and a discussion of the results of meteorological and stream-flow observation has been completed and sent to the printer. According to present plans the whole project will be completed within two or three years, and the final results announced within a reasonable time thereafter.

## STATIONS AND ACCOUNTS DIVISION.

### WEATHER BUREAU QUARTERS IN FEDERAL BUILDINGS.

Removals of local offices to Federal buildings were made during the year wherever quarters therein suited to Weather Bureau work were obtainable. Such removals were made at Corpus Christi, Tex., and Moorhead, Minn.

### RENTED QUARTERS FOR WEATHER BUREAU OFFICES.

There were in all 20 stations where existing leases for rented quarters expired by limitation June 30, 1921. The unusual increase demanded generally for these quarters, averaging more than 33 per cent, necessitated drastic action to keep within the limits of the appropriation, and the matter was then taken up in detail, considering the activities of each station with relation to space occupied. In addition, there were considered also seven stations at which leases expired subsequent to June 30, 1921. To have met the proposals of the various landlords in these cases would have imposed an increased expenditure for rents amounting to $8,446.60. This amount was wholly unavailable, and the exigency has been met by the release of a total of 5,112 square feet of floor space, much of which is in reality essential to the proper conduct of the activities at many of the stations involved.

A frame-cottage building rented and utilized for Weather Bureau quarters on Mount Tamalpais, Calif., since the establishment of that station, September 2, 1898, being no longer suitable for the purpose, the station at that place was discontinued May 16, 1921.

The status of Weather Bureau offices on June 30, 1921, at stations outside of Washington is as follows:

| | | |
|---|---|---|
| Free quarters and accommodations: | | |
| Observatory buildings (owned and controlled by the Weather Bureau) | 45 | |
| State university buildings | 5 | |
| Federal buildings | 76 | |
| Total free of rental | | 126 |
| Rented buildings, etc., owned by individuals or corporations: | | |
| Office buildings | 88 | |
| Buildings with grounds, aerological stations | 6 | |
| Total number rented buildings partly or wholly occupied | | 94 |
| Total | | 220 |

## TELEGRAPH DIVISION.

Telegraphic communication by the utilization of commercial services, as heretofore, was maintained at practically all of the field stations in a generally satisfactory manner, except at some corn and wheat and cotton centers. Delays in the early collection and prompt distribution of daily weather and crop reports occurred in certain localities because of the late opening of the telegraph offices. This difficulty could be overcome by resort to use of the telephone or by employment of special operators were funds available.

Telegraphic work at the central office was accomplished during the first half of the year with much difficulty, due to the loss of trained and capable employees by resignation and retirement. Auditing of telegraph, telephone, cable, and wireless accounts and recording became badly delayed in the autumn, but with the assistance of an efficient temporary employee, together with assiduous labor by the older members of the division, this important part of our work was brought up to date in May.

Delay in receipt of cablegrams and wireless reports from ships at sea, especially those in and contiguous to the Caribbean Sea, continued generally throughout the six months' hurricane season, notwithstanding repair of several cables previously reported as broken. Congestion at cable points and unfavorable atmospheric conditions due to static electricity are given as the chief causes of the slow service.

Prompt and efficient telegraph and telephone service is intimately connected with and necessary to reliable forecast work. The gradually increasing volume of telegraphic business resulting from natural expansion of the forecast service at the central office has imposed a corresponding strain upon this division with its number of employees stationary for some years past. Arrangements are now in progress, however, for supplying the need for permanent additional help.

Contracts with the various wireless telegraph companies and also with the numerous telephone companies, with the exception of one operating in Oklahoma, were renewed for the fiscal year 1922 on favorable terms.

The nature and status of the several Weather Bureau telegraph and telephone lines have been more or less fully set forth in the

two or more preceding annual reports, and detailed comments may be omitted here.

The most severe damages and interruptions to service occurred on the line between Tatoosh Island and Port Crescent, Wash., attending the very destructive storm of June 29, 1921. This line is of great value to logging, shipping, fishing, and other commercial interests. Vessel reporting is conducted at Tatoosh, Neah Bay, Clallam Bay, and Port Angeles, and data telegraphed from the latter station to interested parties. The Neah Bay office has been equipped with a radiotelephone set furnished and installed by the Navy Department for use in emergencies to transfer distress warnings to the Coast Guard station at that point. It has been used also to good advantage in transacting business with Tatoosh Island when wire communication was interrupted.

About 10,000 commercial messages were handled during the year, about 3,000 Government messages were transmitted, and about 1,500 long-distance telephone calls.

While all these lines are maintained primarily to carry important Weather Bureau reports and warnings where no commercial lines are available for the service, nevertheless the Government derives a significant amount of income from local commercial messages carried for the public at very small charges, 15 cents, etc. The following table indicates the receipts for the year:

| Month. | Block Island. | Cape Henry. | Beaver Island. | North and and South Manitous. | Port Angeles. |
|---|---|---|---|---|---|
| 1920. | | | | | |
| June | $50.75 | $207.38 | $26.70 | $14.69 | $212.86 |
| July | 178.42 | 197.46 | 38.12 | 14.85 | 210.18 |
| August | 324.53 | 206.11 | 66.14 | 15.10 | 236.70 |
| September | 90.84 | 209.30 | 56.08 | 11.83 | 169.58 |
| October | 19.92 | 224.47 | 42.07 | 5.57 | 168.05 |
| November | 9.45 | 242.62 | 52.82 | 4.25 | 111.97 |
| December | 10.37 | 286.96 | 46.12 | 2.90 | 230.30 |
| 1921. | | | | | |
| January | 7.55 | 255.25 | 35.85 | 1.10 | 82.49 |
| February | 4.52 | 139.58 | 22.78 | 2.68 | 81.47 |
| March | 5.92 | 206.28 | 23.00 | 3.22 | 103.90 |
| April | 14.36 | 154.60 | 45.17 | 13.15 | 144.44 |
| May | 22.94 | 145.24 | 34.72 | 6.78 | 144.81 |
| June | 39.19 | [1] 200.00 | 41.37 | 10.57 | 199.00 |
| Total | 778.76 | 2,675.25 | 530.94 | 112.69 | 2,095.75 |

[1] Estimated.

Grand total, $6,193.39.

## AEROLOGICAL INVESTIGATIONS.

Free-air observations by means of kites and balloons were continued throughout the year. This work has become an important integral part of the Weather Bureau's program, and should be developed and expanded as rapidly as possible, in order that the United States may keep pace with the rest of the world in the investigation of the phenomena of the free atmosphere now so much needed for the advancement of the art of general weather and storm forecasting and for the benefit of aeronautics.

### KITE STATIONS.

Observations with kites were made regularly at Broken Arrow, Okla.; Drexel, Nebr.; Ellendale, N. Dak.; Grosbeck, Tex.; and Royal Center, Ind. The station at Leesburg, Ga., was transferred to Due West, S. C., and observations were begun at that station in March, 1921. Kite flights are made daily, whenever possible, and in addition, when conditions are favorable, a continuous series of flights are made for periods of 24 to 36 hours. Records of air pressure, temperature, humidity, and wind are thus obtained. Brief summaries are telegraphed daily to the central office and other district forecast centers.

### PILOT-BALLOON STATIONS.

Observations by means of pilot balloons were continued at five of the kite stations (all except Drexel, Nebr.) and at Burlington, Vt.; Denver, Colo.; Ithaca, N. Y.; Key West, Fla.; Lansing, Mich.; Madison, Wis.; San Juan, P. R.; and Washington, D. C. During the latter part of the year this work was begun also at San Francisco, Calif. The observations are made twice daily for the most part, and the computed wind conditions at various heights are telegraphed to the central office, where they form the basis for "Flying Weather" forecasts issued to the military, naval, and postal aviation services.

Special observations have been made from time to time in connection with transcontinental airplane flights and the national and international free balloon races at Birmingham, Ala.

### COOPERATION.

Effective cooperation with the Army and Navy meteorological services has been continued throughout the year. Each of these services maintains a number of pilot-balloon stations, whose primary purpose is to furnish data of immediate local interest to aviators at flying fields. These observations are also telegraphed to the central office of the Weather Bureau for use in issuing "Flying Weather" forecasts. They thus supplement in a very helpful way the surface and free-air observations made at Weather Bureau stations. In addition to the stations in the United States proper, the Navy maintains one at Santo Domingo, Dominican Republic, and one at Coco Solo, Canal Zone, which, together with those of the Weather Bureau at San Juan, P. R., and Key West, Fla., furnish information of value in connection with the development and movement of hurricanes. A much larger number of stations is necessary, however, to make this service as effective as it should be.

In order to check the accuracy of the formula used in determining the rate of ascent of pilot balloons, the Weather Bureau and the Army meteorological service each made a large number of double theodolite observations. These formed the basis for a study which resulted in a slight modification of the formula and in the introduction of a small additive correction during the first few minutes of ascent. It is believed that the revised formula gives extremely reliable results, except when there are pronounced vertical movements in the atmosphere. Even then the error is appreciable only in the lower layers.

### CENTRAL OFFICE.

All observations made at kite and balloon stations, by the Army and Navy as well as by the Weather Bureau, are forwarded to the central office of the Weather Bureau for final reduction and study. Data based upon these observations are furnished in answer to numerous inquiries not only from other Government departments, but from commercial aviation concerns as well. In many cases reprints of special discussions and summaries were issued in answer to these requests. A more complete summary than has heretofore appeared is now in preparation and will soon be published. This will be based upon all free-air observations thus far obtained in this country and is designed to meet particularly the needs of aviators and those interested in the development of commercial aviation on a large scale. A manual entitled "Instructions for Aerological Observers" was prepared and published. This gives in detail all the steps necessary (and the reasons therefor) in making and reducing observations by means of kites and pilot balloons; also, a description of all instrumental and other equipment used. It fills a long-felt want and will be of special value in the event that a proper expansion of aerological investigations is made possible.

## CLIMATOLOGICAL WORK.

The examination and checking of station meterological reports of all classes showed some improvement in the general character of the work performed by both the regular and cooperating observing force, due doubtless to the more stable conditions affecting the personnel than had prevailed during several preceding years.

## COOPERATIVE WORK.

Only words of highest appreciation and commendation should be applied to cooperating observers for the loyal and faithful service they have rendered the Government and people everywhere as a result of their painstaking labors in maintaining continuity of observations over a period of trying times and furnishing data necessary to meet the requirements for climatic information during the past few years.

At a time when personal service was highly valued and people everywhere were clamoring for increased compensation, these observers continued their work without any monetary compensation or thought of personal gain.

In the main reports from these observers have been rendered continuously and promptly, and a rigid examination of their reports discloses that scrupulous efforts are made to correctly interpret the indications of the instruments and otherwise to record the exact weather conditions.

## ESTABLISHMENT OF NEW STATIONS.

Despite many offers of cooperation and requests for the loan of instruments for making weather observations, the number of full cooperative stations has been but slightly augmented during the year, partly from the necessity of economy and partly as a result of

a general belief that the number of temperature-reporting stations is now sufficient for practically all needs.

More consideration has been given the establishment of rainfall-reporting stations, however, as it is generally felt that the number of these reports might be considerably increased. Limited funds for the purchase of gages has likewise discouraged the opening of such stations, except at the most desirable points.

## INSPECTION OF COOPERATIVE STATIONS.

The program providing for the regular inspection of cooperative stations once in each three years was greatly abridged during the year just closed, due to the increased cost of travel and the frequent inability of station officials, on account of inadequate assistance, to absent themselves from their regular station duties.

It is felt that the best interests of the Bureau and the country at large are greatly conserved by reasonably frequent visits to these cooperative observers by those responsible for the development of this line of the Bureau's work. Contact with these observers by the proper representatives stimulates the cooperative spirit, affords chance for righting faulty exposures of instruments, correcting erroneous methods of handling them, and recording their indications.

## MATERIAL FOR PUBLICATION.

The text, tables, and charts prepared for use in the regular publications of the Bureau, particularly the Annual Report, the Monthly Weather Review, and the Snow and Ice Bulletins, were available for the printer at the proper time, and those published directly under the supervision of this division were issued promptly.

Material for the reprint of a number of the exhausted parts of Bulletin W were prepared during the latter part of the year. Several have already been issued, and about 10 more are now at the Government Printing Office awaiting opportunity to print.

The monthly and annual section reports printed at the respective State centers were issued in the main at the prescribed times. Lack of efficient printing help at some of the stations delayed the issuance accordingly, and the prompt assembling and binding of the complete sets for all States has been prevented by the late receipt of a few of the sections.

The section annuals for 1920 were available for issue from most of the sections at the usual time, but the delay in issuing the monthly numbers at a few stations was also carried forward to the annuals and at the close of the last fiscal year one or more sections had not yet completed the annuals.

The sets of these monthly and annuals 1919, for station use, about 140 sets, were assembled, bound at the Government Printing Office, and the complete sets mailed from this division as usual.

## CHANGES IN PUBLICATIONS.

On account of the high cost of paper and the general need for economy, the Annual Climatological Summaries, 1920, were materially reduced in size, and, beginning with the January, 1921, num-

ber, the monthly summaries have been issued without the usual cover and in some cases still further reduced in size. Great care was exercised to retain all the valuable features possible, and as no material complaints have arisen it is assumed that though reduced in size the material furnished meets the more pressing needs of the public.

## BINDING AND PRESERVATION OF METEOROLOGICAL RECORDS.

The assembling and binding of the original meteorological records for the regular stations went forward as usual and the work of assembling several years of the cooperative observers' records and their preparation for binding is also nearing completion.

## NEW WORK.

The revision of the parts of Bulletein W, bringing the various tables and other matters down to the end of 1920, is now being carried forward and it is hoped the reprinting of these can be accomplished during the year.

As the first edition of these separates was issued more than 10 years ago, the supply of a number of the important parts has become exhausted and much additional labor in preparing answers to public inquirers can be saved by having them all reprinted. Effort is being made to include much additional material not carried in the earlier issues, necessitated by the constant public demand for more details of the weather and climate over the different parts of the country.

The preparation of new daily, weekly, and monthly normals of temperature, delayed for a considerable period from unavoidable causes, is now being taken up, and it is hoped they may be completed and put in use during the present year.

## OCEAN METEOROLOGY.

In consequence of the operation of the retirement act it was necessary, near the beginning of the year, to reduce the force engaged upon the work of ocean meteorology at the central office. This action in turn resulted in the suspension of work upon certain projects. In general, however, the purely routine work has been carried on as usual.

At Weather Bureau stations in the principal ports, where marine work is carried on, generally less contact with the marine observers has been maintained on account of increased demands on the station force for service which could not be deferred.

The work of ocean meteorology, as conducted by the United States, rests upon the voluntary efforts of masters and officers of the world's merchant marine. Experience has shown that a certain measure of personal contact is necessary to insure keeping this cooperation up to the desired volume and standard and that when this contact breaks down the work suffers accordingly.

The revival of United States shipping and the cordial cooperation with the Weather Bureau on the part of the Shipping Board has for the moment offset the enforced inactivity on the part of the Bu-

reau. The situation can not continue, however, without serious detriment to the work.

The foremost maritime nations have always fostered the work of ocean meteorology as conducted by their several Governments, and it is the belief of officials of the Weather Bureau that the United States in the development of its own merchant marine must follow the examples set by these nations.

Recommendations for the support and extension of this work, believed to be in keeping with the general policy of economy, have been made in the estimates for the ensuing fiscal year.

## AGRICULTURAL METEOROLOGY.

Collection of meteorological data for each week ending Tuesday at 8 a. m. and the effect on vegetation, stock, and farm work, and the publication of these facts in the National Weather and Crop Bulletin on Wednesdays at 11 a. m. has been continued throughout the year. This bulletin has been reduced from eight to four pages during most of the time to conserve time and supplies; during the winter months it was combined with the Snow and Ice Bulletin. Throughout the growing season a special corn and wheat region bulletin has been published at New Orleans covering the cotton belt; local summaries covering individual States have also been issued from each section center. These reports are very popular, as they give in condensed form the only available rainfall and temperature data covering the whole United States.

### SPECIAL SERVICES.

Publication of daily bulletins giving in tabular form rainfall and temperature during the preceding 24 hours was continued in the principal corn, wheat, cotton, sugar, and rice States. The opening of this service was delayed from April 1 to May 1 in 1921 in the interest of economy in salaries to special observers, telegraph service, and supplies. The weekly collection of meteorological data and its publication in bulletin form were continued in the range districts in Texas, New Mexico, Arizona, Utah, and Wyoming. There has been a strong demand for the extension of this service in other cattle-grazing States, particularly Montana.

The collection of temperature data from special stations in the tobacco, fruit, truck, and alfalfa-seed districts to aid in issuing warnings of damaging temperature was continued during the critical frost season. An imperative reduction in the office force at Hartford, Conn., made it necessary, however, to permanently discontinue this service in the Connecticut Valley tobacco district during the spring of 1921. Lack of funds prevented the detail of a field official to continue special temperature studies in the Pomona, Calif., citrus region during the winter of 1920–21, but the work was continued in the Rogue River Valley in Oregon, where it was of especial value in the deciduous fruit orchards. Special weather warning services for spraying operations were continued in New York and Michigan, and this service was inaugurated in a limited way at Wytheville, Va.

### INVESTIGATIONS.

Mathematical studies of the effect of weather on crops have been carried on as opportunity permitted. Papers published on these studies are:

KINCER, J. B. Computing the Cotton Crop from the Weather and Ginning Reports, *Monthly Weather Review*, May, 1921.

YOUNG, F. D. Influence of Exposure on Temperature Observations, *Monthly Weather Review.*

——— Rate of Increase in Temperature with Altitude during Nights in Orange Groves in Southern California, the *California Citrograph*, March, 1920.

——— Effect of Topography on Temperature Distribution in Southern California, the *California Citrograph*, May, 1920.

——— Smoke and Direct Radiation in Frost Protection, *Better Fruit*, December, 1920.

KIMBALL, H. H. Smudging as a Protection from Frost, *Monthly Weather Review*, August, 1920.

Investigations in hand relate particularly to the effect of weather on corn over comparatively small areas in Ohio, Nebraska, and Illinois, and on cotton in South Carolina, Arkansas, and Texas. The further these investigations are carried the more important it seems to establish a number of agricultural meteorological stations at well-distributed experiment stations.

### PRINTING.

The utmost economy was practiced in the issue of publications and the purchase of necessary supplies of paper, tagboard, ink, and other printing materials. No new equipment of consequence was installed throughout the year.

The revision of our mailing lists admitted of dropping 90 addresses from the *Daily Weather Map*, 654 from the *National Weather and Crop and Snow and Ice Bulletin*, 50 from the *Climatological Data of the United States by Sections*, and 128 from the *Monthly Weather Review.*

Paid subscriptions for the *Monthly Weather Review* are filled by the superintendent of documents, Government Printing Office, from the 250 copies furnished him each month by the printing division.

Special arrangements were made with the superintendent of documents in March, 1921, whereby the superintendent agreed to pay the Bureau for 250 copies of the Monthly Weather Review, which for years have been furnished to him free of charge.

### THE MONTHLY WEATHER REVIEW.

The Monthly Weather Review, exclusive of charts, has contained an average of 63 pages of text and tables in each of the 12 issues which have appeared during the fiscal year.

The publication has been and continues to be practically the only medium in the United States for the diffusion of knowledge respecting meteorology, not only as to current and average weather conditions, but also as to any progress which may have been made in advancing the science at home or abroad. It also, in no less degree, aids in the eradication of false ideas, which everywhere abound respecting the weather. At the same time it aims to stimulate and assist in giving wholesome instruction in meteorology in secondary schools, colleges, and universities.

## INVESTIGATIONS IN SEISMOLOGY.

The important work of collecting and publishing earthquake data, begun December 1, 1914, has been continued during the year.

During the calendar year 1920, 106 separate earthquakes strong enough to be felt by the senses were reported from different parts of the continental United States. The great majority of these produced little or no damage, but an earthquake of considerable intensity occurred in the vicinity of Los Angeles on June 22, followed by milder shocks in July, both accompanied by somewhat extensive damage.

The conduct of the work in volcanological observation at the Hawaiian Volcano Observatory, in the Hawaiian Islands, was assigned to the Bureau by legislative action in the appropriation bill for 1919. The standard program of observations has been carried out, as heretofore, under the direction of Dr. James A. Jaggar, jr., who inaugurated the work, and who is assisted by a small staff of specialists. The results of the observations are published from month to month in a small bulletin printed at Honolulu, and supplemented by occasional notices in the newspapers, as circumstances justify.

## LIBRARY.

During the fiscal year 850 books and pamphlets were added to the library, the strength of which is now over 40,000. Routine work has been kept fairly well up to date, in spite of a reduced staff, but no important special undertakings are possible without a much larger trained personnel. In proportion to its size and varied program the Weather Bureau library has probably a smaller staff than any other Government scientific library, and there are cases in which much smaller libraries have staffs at least 10 times as great.

The exhaustive bibliography of the climatology of South America, begun two years ago, is in the hands of the printer, and it is hoped will soon be ready for distribution.

## SUPPLIES.

The purchase of all property and supplies for the Weather Bureau are made by the Supplies Division, and it is responsible for all property in the central office. It is charged with the supervision of all property issued to the stations of the service in various parts of the United States and the West Indies. This division is also charged with the distribution of property and supplies to and from stations. These shipments are made direct under Weather Bureau bills of lading, as a rule, and through the United States dispatch agent at New York and the Quartermaster Department. During the fiscal year 1921 all shipments have been promptly made and carried through to destination without unnecessary delay.

During the fiscal year just ended, the various duties of this division have been fulfilled and the equipment of the central office and the several stations fully maintained. All property and supplies have been purchased and delivered according to law.

The annual property returns from stations were all duly received in this division, examined, discrepancies adjusted, and the papers filed.

All reports relative to property called for, such as motor-propelled vehicles, typewriters, etc., have been promptly made. All worn-out and unserviceable property has been disposed of according to law and the regulations of the department.

## INSTRUMENT DIVISION.

### STATION EQUIPMENT.

The activities of the Instrument Division during the year that ended June 30, 1921, have been devoted largely to the maintenance of regular, special, and cooperative station equipment with a stationary allotment of funds at a time when prices are high. The general policy of the Bureau has been to discourage extensions of the service. This policy has made it possible to get along with existing instruments, repaired in our own machine shop as they become unserviceable.

### STORM-WARNING EQUIPMENT.

Largely as a result of the thorough overhauling and standardizing of the storm-warning display equipment in previous years, the expense of maintaining the towers has been small. The new sherardized conduit has begun to rust, however, and should soon be painted. It is found to rust far more quickly than the towers to which it is attached.

### NEPHOSCOPES.

One hundred nephoscopes have been installed at selected stations of the Bureau. It is hoped that in the near future it may be practicable to formulate and get into practice a regular program for nephoscopic observations of clouds.

### NEW INSTRUMENTS.

Improvements have been effected in a type of weighing rain-gage and a self-contained tipping-bucket rain-gage was designed with special reference to the rainfall-insurance problem.

A wind-vane commutator has been designed by Mr. Kadel for use as regular Weather Bureau station equipment. A description of this will appear in the Monthly Weather Review.

Three sets of apparatus for testing aneroid barometers have been designed. One of these will be retained as laboratory equipment, and the other two will be sent to New York and New Orleans. A triple register or meteorograph for making records in duplicate has been designed and constructed in the division and is now in successful operation at the New York station.

### EVAPORATION.

The following listed evaporation stations are sending monthly reports:

Agricultural College of New Mexico.
Ajo, Ariz.
Arrowrock Reservation, Idaho.
Austin, Tex.
Centerville Lake, Minn.
Chapel Hill, N. C.
Chula Vista, Calif.
Columbia, Mo. (Weather Bureau).
Columbia, Mo. (University).
Columbus, Ohio.

Corvallis, Oreg.
Deer Flat Reservation, Idaho.
Dodgeland, Calif.
Elephant Butte, N. Mex.
Honeae, Upper, Hawaii.
Ithaca, N. Y.
Jerome, Idaho.
Kachess Lake, Wash.
Lincoln, Nebr.
Maunawili Ranch, Oahu, Hawaii.
Mesa, Ariz.
Mud Lake, Idaho.
Myton, Utah.
Oakdale, Calif.
Pahrump, Nev.
Piute Dam, Utah.
Provo, Utah.
Rapid City, S. Dak.
Roosevelt Reservation, Ariz.
St. Croix, Virgin Islands.
San Juan, P. R.
Santa Fe, N. Mex.
Sheridan Field, Wyo.
Silverhill, Ala.
Sun River Canyon, Mont.
Tahoe, Calif.
Tribune, Kans.
Tucumcari, N. Mex.
Walla Walla, Wash.
Willcox, Ariz.
Willow Creek, Mont.
Wichita, Kans.
Wooster, Ohio.
Yuma (Evap.).
Yuma (Citrus).

## INVESTIGATIONS IN SOLAR RADIATION.

Six thermopiles, construction of which was commenced in our machine shop in December, 1920, should be completed as soon as possible. These are designed for two purposes: (*a*) To be exposed horizontally under a glass cover to measure the total solar and sky radiation received on a horizontal surface; (*b*) to be exposed in a diaphragmed tube on an equatorial mounting, which permits of keeping the tube pointed to the sun, so that the intensity of direct solar radiation may be continuously measured.

In order to obtain continuous records from these thermopiles a register is required, the present price of which is $460. The purchase of one of these was requested during the year 1921–22, and another should be purchased during the year 1922–23 for use outside of Washington. It is expected that this instrument will practically eliminate the necessity of eye readings of pyrheliometers, thereby saving in one year in labor nearly the equivalent of its cost.

It is hoped that by the use of absorption screens in connection with the apparatus described above it may be possible to obtain continuous records of the luminous intensity of solar and sky radiation. Such records are urgently requested by members of the Illuminating Engineering Society and others. Eye measurements of sky brightness and of the intensity of daylight illumination upon surfaces facing in different directions are now being made in Washington, and measurements at other points, and especially in smoky cities, are contemplated. For this purpose the purchase of a photometric outfit, costing about $250, has been requested during the fiscal year 1921–22. A similar purchase should be made during the fiscal year 1922–23.

The observations and measurements in solar radiation by the Weather Bureau are confined to intensities at the surface of the earth. Nevertheless, a problem of great importance attaches to the question of possible day-to-day variation of intensity of the radiation of the sun as it reaches the outer limits of the earth's atmosphere. Measurements of this quantity are made only with great difficulty, but for many years the Astrophysical Observatory of the Smithsonian Institution has been making such determinations, and very recently systematic arrangements have been made for the maintenance of