U.S. Weather bureau

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Weather Bureau

Introduction.—News surveys show that more space in the daily press is devoted to weather news year in and year out, and greater interest is evidenced by the reading public in items on weather than in any other single subject except war news. An index of the broad individual interest in weather is given by the statistics of telephone calls for weather information in the six cities where the automatic weather forecast announcement system is available.

	Average number of daily calls during fiscal year 1948	Maximum number of calls within 24 hours
Baltimore	13,550	67,904
Boston	15,300	65,554
Chicago	46,175	223,989
Detroit	51,196	267,952
New York	46,865	149,888
Washington	55,874	113,120

Weather reports are used in almost every field of business activity and the warnings given in a single forecast of a hurricane or severe cold wave and blizzard often save hundreds of lives and result in protection of livestock and property where losses would otherwise amount to hundreds of millions of dollars.

The original purpose in establishing the Weather Bureau was to provide storm warnings for navigation on the Great Lakes. To this basic function there was logically added the responsibility for forecasting storms and other weather conditions affecting life and property elsewhere in the United States and on contiguous oceans inasmuch as the widespread system of weather reporting stations required for forecasting over the Great Lakes was also the means for forecasting the weather from day to day throughout the country. And since prolonged rain, "cloud bursts," spring thaws, and gale winds are the most frequent causes of flooding in rivers and coastal waters it was logical also for the forecasting of river stages and floods to be added to the public services for which the Weather Bureau was made responsible. The forecasting of floods, storms, and other dangerous weather conditions is still one of the foremost services of the bureau, but the daily reports and forecasts which appear in the press and are heard over the radio, and the climatological summaries which are published periodically have come to be as vital in the economic life of the Nation.

When aeronautics became important, Congress added to the basic functions of the Bureau the special weather reporting and forecasting services for aviation. In February 1946, Congress directed the

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

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Bureau to organize an international weather reporting system for the Arctic; and in June 1948, the importance of research and development in meteorology was reemphasized by enactment of Public Law 657 referring specifically to analysis and prediction of thunderstorms and other atmospheric disturbances which are hazards to aviation. The principal statutes that establish these several interdependent and integrated meteorological functions of the Weather Bureau are the Organic Act approved October 1, 1890 (15 U. S. C. 311–313); Amendment of Civil Aeronautics Act of 1938 (with respect to meteorology) Public Law 691, Seventy-ninth Congress; act authorizing establishment of Arctic meteorological stations, Public Law 296, Seventy-ninth Congress; section 308, Philippine Rehabilitation Act, Public Law 370, Seventy-ninth Congress; Enabling Act of 1948, Public Law 573, Eightieth Congress; International Aviation Facilities Act, Public Law 647, Eightieth Congress; and act to provide safety in aviation and to direct a study of the causes and characteristics of thunderstorms and other atmospheric disturbances, Public Law 657, Eightieth Congress.

The meteorological services of the Weather Bureau can be grouped into three general categories: (1) The daily or current weather information services, (2) the hydrologic or hydrometeorological services and, (3) the climatological services. The daily weather services include several forms of service and the year's work in these fields is reviewed briefly in the following paragraphs.

DAILY WEATHER SERVICES

The General Public Service

This service operates through 17 general forecasting centers and approximately 350 field offices which serve as local weather reporting stations, forecast dissemination points, and in some cases pilot balloon stations and other multiple purpose offices. In order to meet the increased demands for weather information without increase in staff, local stations have developed greater use of commercial publication and broadcasting channels and have encouraged the public to look to the mass distribution facilities of press and radio rather than call individually for weather reports. During 1948 about 50 communities were added to the list of those served by the Bureau through telephoned or telegraphed bulletins from existing stations without increase in field offices.

A new weather forecasting center authorized by Congress was organized at Seattle. It began operation on February 1, 1948, and encompasses the States of Idaho, Oregon, and Washington which were formerly included in the San Francisco forecast district. Subdivision into smaller districts has enabled the forecast centers to give more attention to local weather variations and thus provide better forecasts for the public.

In number of stations and employees the general public weather service changed little during 1948 but the volume of service in the dissemination of daily reports and forecasts, storm warnings, and other

weather advisories increased considerably. Distribution of storm warnings was improved by arrangements with a number of new commercial radio stations which agreed to join the long list of those that broadcast weather information to the public without cost to the Government. The number of Weather Bureau offices manned by full-time paid personnel decreased by 4 while the unpaid cooperative weather "stations" increased about 100.

One of the most important units in the operation of the general public weather service is the Analysis Center in Washington where weather reports from all over the hemisphere are collected, charted and analyzed preparatory to issue of prognostic charts and weather forecasts. The 1947 plan to consolidate this unit and include staff from the Air Force and Navy in order to avoid duplication in separate military analysis units was put into effect and the consolidated office was renamed the WBAN Combined Weather Analysis Center. This Weather Bureau, Air Force, and Navy center in the main office of the Bureau in Washington distributes analysed weather maps and prognostic charts by teletype, radio, and facsimile to civil and military weather offices in the United States, to merchant and naval shipping and to international aviation offices. It exchanges analyses with meteorological offices of foreign countries.

The WBAN center receives reports each hour from approximately 600 stations in the United States and southern Canada. The total number of individual weather reports received daily from domestic and foreign stations, from ships at sea, and other sources amounts to about 25,000. The analyzed data are transmitted to field stations four times daily in form that enables stations to quickly chart the latest weather map and the extrapolated maps for 12, 30, and 54 hours in advance. Current charts are transmitted also for upper air levels at the 850, 700, 500, and 300 millibar levels (approximately 5,000, 10,000, 18,000, and 30,000 feet altitudes, respectively). A prognostic chart for the 700-millibar level is transmitted twice daily for the period 36 hours ahead. The vagaries of weather are common knowledge and in order to describe and predict the endless variations in weather conditions from hour to hour and place to place, Weather Bureau forecast centers and field offices issue more than 100,000 separate local forecasts and several hundred different storm and cold-wave warnings each year. These figures do not include numerous detailed warnings and advisories for limited local use.

Aviation Weather Services

Domestic aviation.—Every new airport wants a Weather Bureau station and many of them require one to meet minimum regulations for safety in the air. During 1948 the Bureau was under strong pressure to provide weather services to the many new airports, especially to those used by personal aircraft in large numbers. Rapid expansion in nonscheduled air carrier operations was particularly evident in smaller cities where the Weather Bureau usually does not have offices. In order to meet the requirements as fully as practicable, within the limitations of current funds, a system of cooperative airway stations

has been organized. At approximately 150 airports where air line and/or personal aircraft pilots require weather observations for flight clearances and landings, the local airport or air-line personnel have agreed to provide official weather observations in cooperation with the Weather Bureau.

Cooperative airway stations, however, do not provide means by which pilots can obtain briefing and advices required for safe flight. To enable pilots to obtain this information, forecasters and briefers at existing offices have been called on to increase their services. New terminal forecasts have been added to the already heavy list regularly transmitted over the teletype circuits. In other cases selected Weather Bureau offices have been asked to prepare the terminal portion of a route or operational forecast and to turn it over directly to the air line concerned, for distribution over company teletype circuits. This arrangement spreads out the preparation of forecasts and prevents overload on aviation forecasters and teletype circuits although it introduces difficulties in coordination.

For several years airways forecasts have been prepared by 16 airway forecast centers in the United States and 3 in Alaska. There are also 26 Flight Advisory Weather Service offices which work directly with the Air Traffic Control Centers of the CAA. The closest teamwork is required between the controller and the communicator to meet emergencies which develop rapidly when weather conditions are bad for flying. Safety depends upon prompt receipt of reports and transmission of advices not only for pilots en route but also for terminal landing conditions when the weather is near the minimums and changing rapidly.

During the year an experimental service known as "flow-control forecasts" was undertaken in several FAWS units. The purpose is to provide weather forecasts of marginal conditions when aircraft are likely to be "stacked up" over busy terminals unless the conditions are anticipated and pilots diverted to alternate terminals before traffic becomes congested. It is very difficult to prepare such forecasts in sufficient detail to distinguish between conditions that will lead to congestion and those which permit aircraft to land without undue loss of time for passengers and added expense for the operators. If proven successful the service will contribute much to safety and efficiency in air transportation.

International aviation.—During 1948, the Weather Bureau participated in the following ICAO (International Civil Aviation Organization) regional air navigation meetings: South American, at Lima; South Atlantic, at Rio de Janeiro; second European-Mediterranean, at Paris; and second North Atlantic, at Paris. Preparations were also completed for the North Pacific regional meeting, to be held at Seattle in July 1948. As in previous ICAO regional air navigation meetings, the Bureau was responsible for developing the regional agreements on meteorological service and procedures for international civil aviation.

Weather Bureau members of the Commission for Aeronautical Meteorology of the International Meteorological Organization participated in the Commission's first postwar meeting at Toronto in August 1947; and in the subsequent sessions of the Meteorological Division of ICAO, at Montreal in September.

In Toronto, the meteorological requirements for aviation were discussed in detail and the IMO General Regulations for the Provision of Meteorological Service for International Aeronautics were revised. In Montreal, these regulations, together with weather codes for aviation developed at Toronto, were coordinated with ICAO requirements and a common text was prepared for the publications of both international organizations. During the year ICAO regional supplementary meteorological procedures were placed in effect in the Middle East, Caribbean, and South Pacific regions. The general operation of the weather service for International Aviation has been described in previous annual reports and other documents.

Service to sailplane soaring contests.—In recent years the Weather Bureau has furnished temporary weather reporting and local forecasting service for important meets of the Soaring Society of America. This year, service was given to the Northeastern States Soaring Championship at Elmira, N. Y., August 29 through September 1, 1947, and the national soaring meet of the society at Wichita Falls, Tex., in July 1947. Sailplane operations provide information on atmospheric turbulence and circulation of value in advancement of weather analysis and forecasting techniques.

Hurricane Warning Service

From the viewpoint of loss of life and property the hurricane season of 1947 must be listed among the most destructive since establishment of the Hurricane Warning Service in 1873. In all, 53 lives were lost in the United States and approximately $135,000,000 worth of property destroyed but these losses in a year of very severe hurricanes, which struck densely populated coastal areas, were low compared with the potential losses under similar conditions before organization of the warning service. On a relative basis casualties now number less than 3 percent of those 20 years ago. The reduction in loss of life has come from the issue of accurate hurricane warnings which enable the Coast Guard, the Red Cross, and other agencies to evacuate the populace when necessary. Residents have come to rely on the warnings and take prompt safeguards for protection of life and property.

During the 1947 season, 10 tropical storms were reported. Of these, five developed hurricane- or near-hurricane force winds. The most intense was that of September 10–19, which crossed the southern portion of Florida on the 17th, traversed the eastern Gulf of Mexico, and moved inland on the Louisiana and Mississippi coasts on the morning of the 19th. Its center passed directly over the business section of New Orleans. This hurricane took a toll of 51 lives in Florida, Louisiana, and Mississippi, with total property damage estimated at $110,000,000.

The principal forecast centers of the Hurricane Warning Service are in Miami, New Orleans, and San Juan, with the regular District Forecast Centers in Washington and Boston serving as relief units when storms interrupt communications at the principal centers or move northeastward into the middle Atlantic and New England regions where they come under the direct province of the Washington and Boston centers. A special hurricane teletype circuit connects

all Weather Bureau offices on the Gulf coast from Brownsville to Key West and continues up the Atlantic coast to Charleston. Another circuit ties in a few of the largest offices in the Atlantic States for emergency use.

The principal center in Miami was moved to new quarters in the Vocational Educational Building where a consolidation of facilities and services was accomplished just prior to the beginning of the hurricane season in the summer of 1948. Through this center the weather reporting facilities and the radar observations and reconnaissance flights of the Air Force and Navy were coordinated with the synoptic network of the Weather Bureau and provided a cooperation which contributed much to the effectiveness of the Hurricane Warning Service.

Fire-Weather Warning Service

New mobile weather units were assigned to fire-weather warning centers at Pendleton, Oreg., and Olympia, Wash. These two units, with the seven previously in use, now provide service to the national forests and grazing lands in the West where the largest and most damaging fires occur. In operation, these mobile units supplement but do not replace the forecasting service rendered to forestry areas by district forecast centers within whose districts they are located. The fire-weather district centers collect, chart, and analyze special weather reports pertaining to forest-fire conditions, and issue daily guidance forecasts regularly throughout the season of fire hazard. While these district forecasts are localized to allow for topographical influences as far as possible, they cannot usually give sufficient detail for deployment of fire suppression crews and best use of available manpower to bring fire under control. The mobile weather unit on the other hand enables a forecaster to move his office and facilities to the scene of the fire where his weather service becomes a component part of the fire-suppression organization. In close touch with the director of the fire fighters, he gives information of changing weather conditions and local weather effects on the fire in time to dispatch the fire-fighting forces to best advantage.

Many smaller fires are brought under control without action to assign a mobile forecast unit. On request special forecasts are prepared by the district center for use in controlling smaller fires. During 1948, 225 of these special forecasts were issued in 5 of the western States. Slash burning operations for logging jobs are also governed by the fire-weather forecasts, that is periods were selected when the meteorological conditions were sufficiently dry and settled to permit burning of slash without danger of losing control. Burning operations are also used at times under conditions selected for the control of certain tree diseases.

At the time of the severe drought in New England, during the summer of 1947, the serious fire hazards were pointed out in daily warnings broadcast by the Weather Bureau beginning 10 days before the most devastating fire developed. While several fires got beyond control, many others were prevented or brought under early control as result of timely warnings. When large fires were burning, weather

forecasts aided in controlling and directing the burn so as to minimize the resulting damage. Evacuation of residents endangered by the fires was planned through information in the weather forecasts. During the year fire weather-warning services were extended to two new State forestry districts—those in Michigan and Tennessee.

Horticultural Protection Service (Fruit-Frost Warning Service)

In May 1948 the Bureau's horticultural service was extended into Wisconsin to give frost warnings to cranberry growers. The service is centered at Wisconsin Rapids and is known locally as the Wisconsin Cranberry Frost Warning Service. As in other special frost protection services of the Bureau, the expenses are shared by the agricultural cooperating organizations. Other farming interests in Wisconsin are also making practical use of the localized frost forecasts.

The service operates from about May 1 to October 15, and protects the two major bog areas of the State. The areas are subdivided into 10 sections for which detailed local forecasts are issued. Frost warnings for the individual sections are prepared as required. Distribution of forecasts and warnings is mainly by radio. They are entered on press association news wires each morning and evening, and are promptly received by 28 Wisconsin radio stations for broadcast to the thousands of cranberry growers.

Although this new service is still in an experimental stage, it is already of much value, giving the growers advance information on expected minimum temperatures in the various sections of the bog areas. In addition to advising when bogs should be flooded to protect the crop from frost damage, the forecasts tell when frost is unlikely even though temperatures are relatively low and thus enable farmers to conserve the water supply.

The Horticultural Protection (Fruit-Frost) Services in Florida, California, Oregon, and Washington were continued without major change during the year. In addition to these special cooperative frost-warning services similar warnings on a less-detailed scale were furnished to agricultural interests throughout the country by general forecast centers and local offices.

State Weather Service Centers

The six State service centers established experimentally in 1947 have shown their value in giving to agriculture, commerce, transportation, and the general public more definite and localized weather bulletins and forecasts. There have been some adjustments of operating program in the light of experience and although no funds were available for establishment of additional State centers during 1948, the existing centers have improved and amplified their services to these broad sectors of public interest.

Service to agriculture continued to receive particular attention. Detailed agricultural forecasts for harvesting, spraying, fruit drying, live-stock raising, processing and marketing, etc., were carried on by the several State service centers and by many local officers of the

Bureau. In some cases, the weather information was broadcast directly from Weather Bureau offices without charge by commercial radio stations; in others, bulletins were furnished to radio stations for studio broadcast on farm programs often in cooperation with State extension services and county agents. The Albany, N. Y., State service unit began State-wide broadcasts of weather information to farmers over a recently established rural FM radio network. The network program director reports that, all program elements considered, these agricultural weather broadcasts in New York State have received not only the most numerous but also the most favorable audience comments.

Daily Temperature Bulletin for Shippers

The long established and widely used forecasts of representative temperatures throughout the country are distributed in a bulletin by teletype each morning to the principal Weather Bureau offices for local application. The bulletin gives the forecasts for maximum and minimum temperatures for important areas surrounding more than 70 of the largest cities. Its primary purpose is to provide field offices with definite temperature predictions for their guidance in giving forecasts for long-distance shipments. The predictions are given in degrees and include the highest for the current day and the highest and lowest for the next day. At times they are extended into the third day when there is reasonable assurance that the trend of weather can be foreseen for that length of time.

Weather Forecasts for Winter Sports Areas

Although this activity is often referred to as the "winter sports service" it is not a separate organization or service but is simply a seasonal extension of information for use of the hundreds of thousands of people in winter sports areas where weather information is needed for week-end planning. At least 90 percent of the winter sports enthusiasts who made inquiry of the Bureau were interested in skiing. The sport depends on condition of snow surface and amount of snow on the ground. A special weather code was adopted to provide information quickly and economically about snow conditions. This information together with regular weather forecasts was the basis for decision of hundreds of thousands of metropolitan residents to journey to the mountains for week-end skiing. The service enabled the railroads, the bus lines, the winter resort hotels, and other facilities to plan adequately for the probable crowds when weather was favorable and to avoid the expense of unnecessary facilities when weather was unfavorable.

The forecasting service for winter sports was operated at practically no additional cost to the Weather Bureau. The basic weather reports were available from other forecasting services. Spot reports from resort areas were furnished without cost by residents associated with the industry and the Weather Bureau's summaries and forecasts were prepared by regular employees without additional assistance. Weather Bureau offices in or near the 24 States where winter recreation is featured issued bulletins and forecasts for dissemination by press,

radio, chambers of commerce, auto clubs, ski clubs, and other interested groups. Due to public interest many organizations rented offices and employed personnel to aid in disseminating weather information for winter sports for the numerous callers interested in planning trips. In New Mexico alone more than 31,000 people traveled to the skiing areas of that State. This is twice the number during the preceding year and it is estimated that in the United States as a whole more than 5,000,000 people used outdoor recreational facilities during the winter season 1947–48. Transportation facilities, highway maintenance crews, hotel and lodge managers were better able to provide for the comfort and safety of visitors, and sports enthusiasts could make their plans more effectively from information in the official weather forecasts.

Marine Weather Services

The system of weather reporting from ships at sea and the weather forecasts for ocean shipping lanes and other marine interests have not completely recovered from the disorganization incident to radio censorship during the war. In 1948 special attention was given to obtaining better coverage of ocean areas in weather reports transmitted by radio from vessels in North Atlantic and North Pacific waters. Essential parts of the program have been to improve the accuracy and regularity of shipboard weather observations, records, and reports and to provide better weather-broadcast service to ships at sea.

The Weather Bureau now receives approximately 300 radio weather reports daily from the western North Atlantic and eastern North Pacific, and these form the basis for preparing weather forecasts and warnings of storms at sea for guidance of merchant shipping and transocean air transportation. To assure the best possible spread of these reports at 6-hourly intervals each day, arrangements have been made with masters of nearly 1,200 merchant vessels to radio weather observations when in United States reporting waters. At the same time, 3,500 additional ships have been enlisted to cooperate in taking and forwarding weather reports from all ocean areas of the world by mail. These data contribute to research and climatological studies of maritime meteorology. Marine specialists at Weather Bureau port stations are engaged in enlisting additional ships to furnish reports by mail.

Early in 1948, in cooperation with the United States Navy, the Weather Bureau assumed the responsibility for preparation of western North Atlantic weather forecasts and storm warnings for broadcast twice daily to merchant shipping over radio station NSS, from Washington, D. C. Included in the program was a provision for rebroadcast of storm-warning messages at short intervals as long as intense disturbances are within western North Atlantic waters.

In order to furnish the best practical weather service to ships at sea, arrangements were made early in 1948 with operators of various shipping companies to invite Weather Bureau forecasters on trans-Atlantic voyages. This first-hand sea experience helps the weather forecaster to understand and emphasize elements of importance in navigation.

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During the year the Weather Bureau obtained a new type of microbarograph for installation on a small number of United States merchant ships to improve ships' reports of barometric pressure. The results from the new-type instrument have been encouraging not only from the viewpoint of improving the recording of the data at sea, but also in developing the interest and cooperation of ships' officers.

In the western Pacific the Weather Bureau, under provisions of the Philippine Rehabilitation Act, has assisted the Philippine Weather Bureau in reestablishing its marine reporting program. Arrangements have been made with several vessels of United States registry to furnish radio weather reports to Manila when plying routes in the western North Pacific. In addition, procedures have also been established to make available to the Philippine Weather Bureau, copies of certain ships' weather observations which the United States Weather Bureau receives by mail.

HYDROLOGIC SERVICES (RIVER AND FLOOD FORECASTS)

Water supply forecasts.—Water supply forecast offices were established at the Salt Lake City, Utah, and Portland, Oreg., Weather Bureau offices. Working with the existing River Forecast Center at Kansas City, Mo., these units prepared and issued bulletins containing seasonal forecasts for over 200 points in 5 major drainage areas. Bulletins for the Missouri Basin were issued from Kansas City, for the Columbia Basin from Portland, and for the Colorado, Rio Grande, and Great Basins from Salt Lake City. This decentralization of forecasts formerly prepared in Washington made possible earlier distribution to the users. Bulletins were issued as of the first of each month from January through May to provide farmers, irrigation companies, power utilities, and industry with information necessary to the planning for most efficient use of spring and summer stream flow. The water supply forecast units at Salt Lake City and Portland continued development of procedures for forecasts at other points not hitherto included.

River and flood forecasting and warning service.—Modernization of the river and flood forecasting service recommended to Congress several years ago was continued during the 1948 fiscal year by establishing special river forecast centers at St. Louis, Mo., and Tulsa, Okla. Centers were established at Kansas City and Cincinnati during the previous fiscal year. Cooperating with the Commonwealth of Pennsylvania, a new center was also inaugurated at Harrisburg, Pa., to serve the Delaware and Susquehanna Basins. These new centers will be engaged for some time in development of stage forecasting procedures and will not begin active forecast operations prior to the 1949 flood season. The two older centers were active in flood forecasting during the past year and many commendations of the improved service were received. Research was continued in development of methods for quicker and more accurate flood forecasting, and a pilot model of an electronic flood routing machine was devised as an aid in this work.

There are many small basins where disastrous flash floods rise so rapidly that forecasts cannot be issued in time to be of use. Following experience gained in an experimental project in the Elkhorn Basin of Nebraska, flash flood warning networks have been established for the Bradford, Pa., area and at Cambridge, Nebr., on Medicine Creek. These networks communicate reports of rainfall and stream rise in time for brief warnings as distinguished from the longer range flood forecasts on principal rivers. In June 1948 a severe flood occurred in the Cambridge area but no lives were lost and property damage estimated at about $100,000 was prevented by timely warnings in contrast with the 13 lives lost in a disastrous flood in the Cambridge basin last year.

Major floods in the Columbia and Ohio River Basins, together with numerous lesser floods, brought the toll of losses during the 1948 fiscal year to about $160,000,000 and 48 lives on the basis of data currently available. Surveys indicate about $40,000,000 in property damage was prevented through use of forecasts and warnings issued by the Weather Bureau.

Hydrometeorological investigations.—Continuing its investigations for and in cooperation with the Corps of Engineers, Department of the Army, the Weather Bureau provided hydrometeorological information essential to proper design of flood-control structures. The Bureau received $103,000 of transferred flood-control funds for the purpose.

Forty-eight storm studies were completed during the year. In addition, an exhaustive report on thunderstorm rainfall was published and a study of maximum possible precipitation, including snow-melt contribution, over the San Joaquin Basin in California was completed. Charts were prepared showing, in a generalized manner, estimates of maximum possible precipitation for the United States east of the 105th meridian for areas of 10, 200, and 500 square miles. Eleven estimates of maximum possible precipitation, four of which included critical storm sequences, were completed for river basins in the United States. Representative dew points for major storms east of the Continental Divide were compiled and published. Study continued on the determination of maximum possible precipitation over the Osage and Meramec Basins in Missouri. A study of mean precipitable water in the United States, with accompanying maps, has been completed and accepted for publication as Weather Bureau Technical Paper No. 8. A set of precipitable-water computation tables, two of which will be included in condensed form in the forthcoming revision of the Smithsonian Meteorological Tables, have been completed and are in the process of final revision.

Work was begun on the determination of the "design" windstorm for Lake Okeechobee, a project which will involve an intensive study of both the theoretical aspects and the observed characteristics of hurricanes.

In a project supported by $27,500 in funds transferred by the Bureau of Reclamation, the Weather Bureau carried on studies required for the planning of irrigation and conservation projects in the West. During the 1948 fiscal year, efforts were particularly directed to the

development of new hydrometeorological techniques suitable for application to reclamation problems in the western mountain regions. A report describing a technique for computing normal annual precipitation from known topographic features of an area, an analysis of maximum persisting dew points in the Western States, and a study of the departures of the true wind from the geostrophic as an index of convergence were published during the fiscal year.

Cooperative flood-control activities.—Data from a network of 4,311 precipitation stations (mostly using automatic recording gages) were published in monthly hydrologic bulletins. This network was maintained in part by transfer of $360,000 from the Corps of Engineers and $6,500 from the Bureau of Reclamation. In addition, the Corps of Engineers provided approximately $60,000 to cover the expenses of collecting daily reports of rainfall, river stages, and other data necessary for operation of flood-control works. In further aid of flood-control operations, forecasts of the amounts of anticipated rainfall, 24 to 48 hours in advance, were made by the Weather Bureau and supplied to field offices of the Engineers. General weather forecasts, river forecasts, and in some cases current synoptic weather information, were also made available to these offices where needed.

METEOROLOGICAL COMMUNICATIONS

There are now three extensive teletype networks for the transmission of the weather reports and forecasts required for the national meteorological service. These systems are known as services A, C, and O. Service A comprises approximately 31,000 miles of wire circuit, service C 28,000 miles, and service O 11,000 miles, making an over-all total of 70,000 miles. The circuits are leased by the Civil Aeronautics Administration from commercial communications companies. Primary relay stations on all three services are equipped with CAA-owned teletypewriters and are operated for the most part by CAA personnel. Weather Bureau offices are provided with drops on these circuits to meet service needs. The scheduling of all weather information carried on these circuits is a function of the Weather Bureau. The Bureau is also responsible for the exchange of weather information with other countries.

Facsimile transmissions of charts at New York and San Francisco are made over local leased-wire circuits. Experiments in local facsimile transmission by radio are in progress in the New York and Chicago areas. Facsimile transmission by radio is much faster than by wire but frequencies now available do not permit direct transmission beyond a limited radius.

Radio broadcasts.—The number of daily broadcasts over microphones furnished to Weather Bureau offices by commercial radio stations was increased by 67 during the year. Weather information is now broadcast direct from 155 Weather Bureau offices on 457 programs daily. In addition, the number of radio stations to which weather bulletins were furnished by local Weather Bureau offices for regular scheduled studio broadcasts was increased by about 75. Voice broadcasts are a very effective method of distributing weather information.

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In addition to providing listeners with complete and timely forecasts and reports daily, they build up a regular audience, so that the public may be promptly warned when severe weather conditions are expected. Without regular scheduled broadcasts it would be difficult to get warnings promptly to the populace of the affected areas.

Many of the new broadcasts cover agricultural regions and furnish complete and timely weather reports and forecasts for the farmers. In Iowa, for example, detailed weather bulletins are now available to all radio stations in the State and frequent broadcasts keep the farmers in that great food-producing area fully informed of expected weather changes. Coverage in other important agricultural States is also improving.

Demand from aviation interests for broadcast of more weather information of interest to pilots has greatly increased. Brief aviation weather summaries are now included in some of the broadcasts made from Weather Bureau offices, primarily for information of pilots of personal aircraft.

The Washington Daily Weather Map

The published edition of the daily weather map began its appearance in a new and improved form at the close of the fiscal year. Emphasis on upper air information in weather analysis and forecasting in recent years gave rise to a demand for publishing an upper air chart on the daily weather map. Moreover the public interest in weather conditions in parts of the continent outside of the United States has increased since the war and the new form of the map (Washington edition) meets these needs and makes the map more interesting and useful for the layman subscriber and the practicing meteorologist.

A 700-millibar constant pressure chart has been added to the map as a daily feature in addition to the large-scale surface chart of the United States. The temperature and precipitation charts, are continued as previously printed. Inclusion of the 700-millibar chart permits simultaneous study of the surface and upper air analyses. Another innovation was the extension in area of the small 1:30 p. m. surface chart to cover all of North America.

The printing of feature articles and other useful information on the back of the map has been continued. These articles are designed to increase the value of the printed daily weather map by explaining the ways in which weather information is of service to the public. Including the monthly analyzed series, 29 new map-back articles were published during the year. In addition, 12 articles were reprinted and each month 5 sets of climatological charts were published. The Washington edition of the weather map is reported to be one of the finest published weather maps to be found anywhere.

CLIMATOLOGICAL SERVICES

Collection of data.—With small changes, the network of more than 6,000 climatological observing stations operated during the year essentially as heretofore. These stations, placed for the most part in small towns and at homes of farmers, are manned by unpaid cooperative

observers and extend throughout the United States, Alaska, Puerto Rico, and the Hawaiian Islands. They observe and record rainfall, temperature, and general weather conditions each day. The recorded data, supplemented by observations from about 4,000 stations maintained with part-time paid observers, are published weekly, monthly, and annually in the climatological service bulletins of the Weather Bureau.

Although the data are most widely used for agricultural purposes, there is an increasing demand for climatological information from a wide range of business, industrial, transportation, and public utility interests as well as from the general public. To these climatological reports from cooperative observers are added the detailed weather records from full-time Weather Bureau stations to comprise the meteorological archives of the United States. The detailed weather records give not only precipitation and temperature but also atmospheric pressure, humidity, visibility, cloud form, and ceiling and wind direction and velocity. The climatological data are published monthly and annually and the information is used extensively by business and industry as well as by aviation interests in the analysis of their operations and in their long-range planning.

Mechanization of weather records processing.—Funds were made available in final year 1948 for checking and processing of weather records for the entire United States by means of punched-card machines. This method was tested in 1947 and found to be efficient and more satisfactory in a trial project conducted at Fort Worth, Tex., on records from the States of Mississippi, Louisiana, Arkansas, Oklahoma, Texas, and New Mexico.

Hand-operated card-punching machines are installed at all full-time Weather Bureau offices in the continental United States, and the observing personnel make up record cards for each weather observation immediately after its completion. These records are then forwarded to designated processing centers for accuracy checks and for compilation of data for publication. In addition to the unit previously organized at Fort Worth, six regional machine units were set up during the year—at Albany, Chattanooga, Chicago, Kansas City, Seattle, and San Francisco. As the necessary machines were obtained and installed, the work of checking and processing the various types of weather records, formerly processed manually, was taken over by these centers. This made possible the closing of the two records checking centers at Elkins, W. Va.; and Chattanooga, Tenn. In the same period, the regional hydrologic units, formerly engaged in evaluation and publication of detailed records from a special network of rainfall stations, were incorporated into the Weather Records Processing Centers. Early in calendar year 1948, the machine units began taking over from the State Climatological Section Centers, the responsibility for checking, tabulating, and preparing for publication the daily records from the basic network of 6,000 cooperative climatological stations. This was done 1 State at a time and by the close of the fiscal year the records from 25 States were being mechanically processed. The change-over from manual to mechanical processing will be completed during the ensuing fiscal year.

Another phase of the mechanization program which was implemented during the year was the current microfilming of all weather records. This part of the new work assigned to the seven Weather Records Processing Centers. Upon completion of checking and processing, all records are microfilmed before they are forwarded to the inactive files. These films provide a convenient means of furnishing copies of original records, for which thousands of requests are received by the Bureau each year.

To facilitate publication of climatological data, it became necessary to set up regional photo-offset printing plants convenient to the machine units. Most of the copy for these publications will be produced hereafter by automatic typewriters operated by punched cards. Approval was obtained from the Joint Committee on Printing to establish four new photo-offset plants at Albany, Chattanooga, Fort Worth, and Kansas City in place of hand composition and letter-press plants previously maintained by the Weather Bureau for producing the climatological bulletins. Existing Government Printing Office plants are being used at Chicago, Seattle, and San Francisco, to round out the new type of publication for all areas.

When plans for the machine methods of checking and processing weather records have been fully implemented, the Bureau will be in a position to handle efficiently the enormous volume of climatological data that accumulates each year. Among the benefits of machine methods are: (1) Increased accuracy in the permanent climatological records of the Bureau. A more complete check of the records is possible by machines than could be made by the former manual methods. (2) Greater accessibility of original climatological records. Climatological records both on punched cards and on microfilm provide more flexible methods of making these data available than by hand transcriptions. (3) Better climatological service to all phases of our national economy at little additional cost. Records on punched cards make possible the preparation of many types of valuable weather statistics not feasible by manual methods. By machine, frequency tabulations, duration statistics, and tabulations of combinations of different weather elements can be produced quickly and economically. By manual methods, the cost and time involved to produce such summaries have been prohibitive. After relieving our State climatological section directors of the routine of checking and summarizing the records from the cooperative climatological stations, more time will be available for attention to broad problems in weather and climate and for greater contribution to the practical use of the records by the public.

Publication of climatological data.—Considerable effort was given to improvement and expansion of published climatological data so the bulletins will more adequately meet the needs of business and industry. The information formerly published as two separate series, titled "Hydrologic Bulletins" and "Climatological Data" has been combined in a single publication. The first issue combining the precipitation data of the one and the temperature, precipitation and miscellaneous weather data of the other, was for the State of Oklahoma for the month of March 1948. From experience gained in the issuance of this first

bulletin, standard formats and procedures have been developed and combined bulletins for other States were undertaken. By the end of the fiscal year these new bulletins were being issued for 13 States.

The publication of weekly weather and crop bulletins for farmers, grain exchanges, and other agricultural interests, was continued. These consist of brief summaries by each State climatological section center combining information from the corn and wheat bulletins issued at Chicago, the cotton region bulletins issued at New Orleans, and the national bulletins issued at Washington, D. C. To increase the usefulness of the bulletins to all concerned, release time was advanced an hour to 12 noon e. s. t. each Tuesday during the early part of the 1948 crop season.

In accordance with the agreement reached by the International Meteorological Organization, the exchange of monthly climatological data with other countries began with January 1948. This information is now assembled and published regularly in an international "Climat" bulletin, the first issue of which contained world-wide data for the month of May 1948. These bulletins carry useful data of particular value to our representatives in United Nations agencies, and to various Government Offices interested in world-wide agricultural and economic conditions, and to interests engaged in shipping and foreign trade.

The publication of condensed climatological data of a national scope, in the Monthly Weather Review, continued as in previous years except that the upper air data and charts were expanded to include the entire North American continent.

The New Orleans machine unit.—This unit consists of a machine card processing section for handling special projects, a section for card punching, filing, and summarizing weather records, a section for checking upper air records made by the military, and a section for filing and maintaining the master library of weather records in cards and microfilm. It was operated jointly by the Weather Bureau, the Air Force, and the Navy. Personnel from the unit, because of their wide experience in the pilot projects for machine processing weather records, aided greatly in activating the mechanization program described above for the entire country.

Special projects in climatology.—Among the special climatological projects and studies during the year were:

1. Continuation of the wind-rose project involving preparation of special wind summaries for use by CAA in the Nation-wide airport construction and improvement program. A study was made to provide a method for adjusting the number of wind observations from each point of the compass to eliminate any bias in the existing record. It is a valuable aid in interpreting wind-rose data when planning airport runways.

2. A study to develop techniques for estimating the annual variation in amount of leaf area produced by crops and vegetation in various acreages devoted to differing land uses. This contributed to the study of loss of water supply by transpiration.

3. A study for an objective and quantitative determination of drought as it affects growth of corn, with the associated probabilities

of drought occurrence in Iowa, was completed in cooperation with Iowa State College.

4. A study of weather factors affecting cotton yields was made by the Weather Bureau in cooperation with North Carolina State College. This work analyzed the effect of weather on cotton yield over 3 years (1939, 1940, and 1941) at five experimental stations in the Cotton Belt.

5. Continuation of the study of the effects of weather on the growth of pineapples in the Hawaiian Islands.

6. Report on freeze and normal studies, prepared by the Weather Bureau in cooperation with Iowa State College, presents a technique for estimating freeze probabilities and a statistical study of precipitation and temperature normals.

SERVICE PROJECTS

In preceding paragraphs the Weather Bureau's permanent or continuing service operations during 1948 have been reviewed. The statutes authorize and direct the Bureau to carry on certain other services or activities which because of their special or temporary nature are best organized on a project basis. Some of these are international in nature and are incident to postwar developments; others have to do with temporary national or domestic requirements. They are reported for the fiscal year 1948 as follows:

Arctic Weather Stations

Extension of the network of meteorological stations in the Far North was encouraged by Public Law 296 in 1946 to provide information for forecasting cold waves and other disturbances. The stations were resupplied in late summer of 1947 by naval vessels cooperating with the Weather Bureau. One of the principal stations is at Thule, Greenland, and is operated jointly by Denmark and the United States. A secondary station at Eureka Sound, Ellesmere Island, established early in 1947 entirely by air lift through cooperation of the United States Air Force, is only about 450 miles from the North Pole, and is operated jointly by Canada and United States. During the year the station personnel at Eureka, over and above their regular station duties, completed construction of a new unsurfaced landing strip.

A new weather station was established at Resolute Bay, Cornwallis Island, Canada, by the Canadian and United States Governments in August 1947. Daily transmission of weather reports of surface and upper air observations by radio were begun by this station in late October 1947. Construction of a year-round serviceable air strip was completed by a detachment of Air Engineers (USAF) about November 1, 1947.

In the spring of 1948 new operations began with reconnaissance flights from Resolute Bay to Prince Patrick Island and Isachsen Land, Northwest Territory, Canada. In early April the sites for two new weather stations were selected, one at Mould Bay, Prince Patrick, and the other at Deer Bay, Isachsen Land. Construction of houses

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and other station facilities, including an airstrip at each station was undertaken by the respective station personnel. Regular radio transmissions of surface- and upper-air weather observations began from Mould Bay about June 15. For the present, surface observations only are made at Isachsen but it is expected that upper-air observations will soon begin at that station when full equipment becomes available. By international agreement the weather stations in extreme northern Canada are established jointly by Canada and the United States. Canada provides the fixed structures and other facilities involved in permanent possession, and half of the staff. The United States Weather Bureau furnishes the other half of the staff and certain technical equipment. Logistics are provided through cooperation of the United States Navy and the United States Air Force.

"Hypo" Project

The operation known as "Hypo" was extended through 1948 and the Weather Bureau continued its responsibility for recruiting and assigning forecasting and observing personnel for approximately 50 air-weather stations in Central and South America, Europe, North Africa, Asia, and several Pacific Islands. Approximately 200 men were employed by the Weather Bureau to work with the Air Weather Service of the United States Air Force in order to carry on essential meteorological service for both military and commercial flights. As the requirements decreased or were again filled by military recruits, these employees were gradually returned to the States, many being reassigned to other positions in the Weather Bureau. With the program successfully completed, the supervising offices that had been set up for administrative control of this program in London, San Juan, and Honolulu were closed on June 30, 1948.

Philippine Rehabilitation

The Weather Bureau continued work with the Philippine Government as authorized by the Rehabilitation Act of 1946. On June 30, 1948, the Philippine Weather Bureau had under its employ 272 people operating 46 stations, of which 7 were making 2 upper-wind observations daily. By that date only a small number of the operating stations had been fully rehabilitated; building construction was in progress at some of the remainder but most of the field stations were still awaiting adequate facilities. In the climatological service, which operates with very simple equipment, 129 stations were reporting daily rainfall and 44 rainfall and temperature, on monthly data forms. A constant difficulty in the rehabilitation of the Philippine Weather Service has been inadequate communication facilities and this continues to hamper collection of weather information at Manila where daily forecasts are made and meteorological data exchanged with other countries through cooperation of a United States Navy Fleet Weather Central and Radio Station NPO at Sangley Point, Cavite.

Cooperation With American Republics

Four radiosonde stations were operated in Mexico in cooperation with the Mexican Meteorological Service. The rawinsonde station at Havana continued in operation and an additional radiosonde station was established at Camaguay, Cuba. Only two Latin-American students, one from Peru and the other from Brazil, were awarded training grants during 1948.

International Meteorological Organization

In its first general meeting ever held outside Europe, the Conference of Directors of the International Meteorological Organization convened in Washington on September 22, 1947, for the twelfth meeting since its founding in 1876. More than 60 different national meteorological services sent delegates to the meetings, representing approximately 56 separate nations, dominions, or territories. After its closing session on October 11, the conference was characterized by delegates and diplomatic observers long experienced in international meetings as one of the most successful on record, despite strong differences of opinion on fundamental issues when the meeting opened.

The business transacted by the conference fell into four general categories. First, the regular administrative items consisting of reports of officers of the conference and presidents of commissions, election of members to the International Meteorological Committee, rules of procedure, fiscal matters. Second, review and final action on more than 400 technical resolutions on meteorological subjects proposed by the 6 regional and the 10 technical commissions. The Commissions had labored in joint sessions for 6 weeks in Toronto during August and early September in the effort to solve the many technical problems in weather service accumulated since the last regular Conference of Directors in Warsaw in 1935. These problems included many important questions that grew out of wartime meteorological developments. Third, the drafting of a new convention (constitution) for the proposed World Meteorological Organization to succeed the International Meteorological Organization. Fourth, decision as to future relationship of the International Meteorological Organization or the World Meteorological Organization to the United Nations.

Of the approximately 414 original resolutions, about 300 had been produced by the technical commissions and the remainder by the regional commissions. Most of them dealt with units and standards in weather observations, code forms for international exchange of weather reports and other aspects of international coordination in meteorology, including climatology.

After many redrafts of the new convention and much debate, with the general feeling at times almost to the point of abandoning the plan because of the seemingly irreconcilable differences, an acceptable draft was finally produced and in plenary session on October 11, the document was signed by representatives of 33 of the nations present. The principal difficulties had been over fear of diplomatic and political interference with the work of technical and scientific bodies; equality

of representation of meteorological services of small nations or territorial countries; and recognition of the services of certain nations. The World Meteorological Organization will not come into being until after formal ratification by the governments of at least 30 signatory nations. The conference also reached tentative agreement on affiliation with the United Nations subsequent to establishment of the World Meteorological Organization.

Important factors contributing to the ultimate success of the conference were the excellent facilities and hospitality provided by the United States as the guest nation, factors that led to closer acquaintanceship and better understanding among delegates. In the closing session the president of the conference expressed deep appreciation to the United States and to the Weather Bureau for the thorough planning and detailed arrangements for the meetings. Appreciation was due also to civic and industrial organizations for financing most of the hospitality essential to the success of the meetings, a requirement in excess of the modest sum available to the State Department for the purpose. The official United States delegation consisted of seven technical advisers in addition to Chief Delegate F. W. Reichelderfer, namely—Dr. H. R. Byers, representing nongovernmental meteorological institutions; John M. Cates, State Department; Commander G. V. A. Graves, United States Coast Guard; D. M. Little, Weather Bureau; Capt. H. T. Orville, United States Navy, I. R. Tannehill, Weather Bureau, and Gen. D. N. Yates, United States Air Force. The detailed planning and arrangements were accomplished by the regular staffs of the State Department and Weather Bureau where many employees devoted time and effort far beyond their normal duties to make the meetings a success.

Other IMO Meetings

The meetings of the 10 technical commissions in Toronto during August and September 1947 were attended by Weather Bureau representatives who were members of the respective Commissions and their technical advisers. The technical commissions eventually succeeded in reaching agreements on many points of difference in the international exchange of weather information resulting from developments during the 12 years since the last previous Conference of Directors. General meetings of Regional Commissions III and IV comprising the Americas, were also held in Toronto.

In March 1948 the Telecommunications Subcommittee of IMO Regional Commission VI (Europe) convened in Brussels for the purpose of restoring essential meteoroligical communications in that area. N. R. Hagen, Weather Bureau representative in London, attended the meeting. He also attended a meeting of the parent Regional Commission VI (Europe) which convened in April in Paris to implement the technical resolutions adopted by the Conference of Directors in Washington. A meeting of Regional Commission V (South Pacific) in Wellington, New Zealand, in April was attended by Charles M. Woffinden, Weather Bureau official from Honolulu.

International Aerological Days

Research and development in meteorology for the purpose of extending the time range of weather forecasts and improving their accuracy depend to a large extent upon more detailed knowledge of the general circulation and behavior of the atmosphere. The obstacle to fuller knowledge is the practical impossibility of obtaining sufficient observations throughout the atmosphere to give a true picture of the circulation. To fill these gaps in our knowledge and give a more accurate picture of what goes on in the atmosphere the IMO adopted the practice 40 years ago or more, of selecting 10 days each year on which all meteorological organizations were requested to augment their upper air observations. The first 10 days of April 1948 were selected for observance of International Aerological Days, and 58 national meteorological services, including the United States Weather Bureau, were expected to participate in the project. During the war, International Aerological Days were suspended but on recommendation of the Conference of Directors in Washington in 1947, the program was resumed with increased interest, and under the current program two 10-day periods were designated during 1948, the second to be some time during November.

Weather Maps and Forecasts by Television

When television became available meteorologists were quick to recognize the possibilities for broadcasting the weather forcast on the background of a graphic picture of the weather map itself. It was believed that telecasting could eventually become a much better method of distributing weather maps, forecasts, and warnings that the printed maps and bulletins issued by local Weather Bureau offices. They would reach the public more promptly and more economically. Early in 1948 the Bureau therefore organized several demonstrations of the possibilities in various cities, among them Baltimore, New York, and Washington. The plan was to persuade television program managers to set up their own facilities for broadcasting weather maps and forecasts already available through the Bureau every day. Before the year closed a few television stations had agreed to schedule such programs while others expected to do so as soon as practicable. Although the Bureau probably will be required to telecast weather information of national interest such as the general weather maps, forecasts, and storm warnings for the public from one or two centers like Washington and San Francisco, local weather telecasts are expected to be the function of commercial organizations who would utilize maps and forecasts released by the Bureau for general distribution.

Projects for Consulting Meteorologists

For many years the Bureau has advocated extension of the private practice of meteorology in order to speed progress in the applied science and develop individualized services beyond the scope of a Government bureau. This would not only spread the economic benefits

of meteorology but would also relieve demands upon the Bureau for services that would require enlarged staffs and new office facilities. Many services in applied meteorology that await development are within the field of private enterprise and not functions of the Government. This is true of consulting services designed to meet specialized needs of an individual enterprise, services which are not of general public interest or widespread economic use or of a kind which the Government is expected to provide as a contribution to the general welfare. In conferences, administrative instructions and public announcements during the past 10 years or more, and in cooperation with the American Meteorological Society and the meterological departments of the military services and the universities, the Bureau has worked for development of applied meteorology through private practice as well as through governmental services. In March 1948 and again in June, lengthy meetings were held with representatives from commercial meteorological agencies and the American Meteorological Society to work out better ways for extension and cooperation with private consultants in meteorology. Statements on this subject were summarized in a pamphlet entitled "Weather Bureau Policy With Respect to the Private Practice of Meteorology." The conference did not question that weather reports, forecasts and warnings for general use are a function of Government. These services are vital to national security and the public welfare and the costly system of Nation-wide observations and reports and the international exchanges of collective synoptics are beyond the normal reach of private enterprise. Many questions however were raised involving the special services for aviation and other broad industrial fields. Private consulting meteorologists, the American Meteorological Society, and the Weather Bureau are endeavoring to solve these problems.

The Bureau urged the interest and support of all meteorologists in extending applied meteorology and it informed business and industrial concerns who need individual weather information about the services of consulting meteorologists and the fact that Government cannot fill business requirements for such individual services. The Bureau also published statements informing business organizations of the benefits of company consulting meteorologists. In climatological survey work and research projects financed by private funds, the Bureau has made it a practice to call on consulting meteorologists whenever their services are applicable to development of the particular project.

RESEARCH AND DEVELOPMENT

The research facilities and staff of the Bureau were increased somewhat during the year but they remained very inadequate to carry out the purpose under Public Law 657 which directs the Weather Bureau to expedite studies of severe atmospheric disturbances with a view to establishing methods by which their characteristics may be forecast and their hazards avoided whenever possible. Research facilities were small also in comparison with the importance of developing the knowledge of weather and climate and their best utilization as some of the Nation's most valuable natural "resources."

Physical Research

Late in 1947 a Division of Physical Research in Meteorology was organized to plan and direct fundamental studies in the physical processes involved in the formation of fog, clouds, rain or snow, and conditions that develop into severe atmospheric disturbances. Incomplete understanding of these factors prevents meteorologists from finding better techniques for applied meteorology. The work of this new division should add knowledge that will enable forecasters to improve their predictions of storms and other weather phenomena. The Division was headed by Dr. Ross Gunn and its major project during the year has been organization and direction of the Cloud Physics Project, popularly called the Artificial Precipitation Project. Because of the strong public interest and the potentially great economic value of producing rainfall artificially where it would supplement natural precipitation in arid or drought-stricken localities, the Bureau was requested to investigate the possibilities. With major cooperation of the United States Air Force, scientifically controlled experiments were carried on near Wilmington, Ohio. The research on stratus clouds during the winter showed that use of dry ice as a precipitation agent is ineffective in producing rain or snow in appreciable quantities, at least under the conditions and with the winter type stratus found in the vicinity of Wilmington. Results were negative except when precipitation was occurring in the vicinity from natural causes and in all cases the quantities produced artificially were too small to be of economic importance. Tests on summer type clouds, especially of the cumulus, shower type, were begun early in the summer of 1948. Final report awaits completion of the experiments and careful analysis of data. Although there may be special conditions under which it would be economically worth-while, investigations now indicate that artificial methods will not have the wide-spread applications which the public was led to expect by premature commercial publicity on the subject last year.

Thunderstorm Research Project

The field work of the project which was started 2 years ago in Florida to analyze in more detail the conditions that give rise to thunderstorms and the best methods, if any, for controlling or avoiding their hazards was terminated in September 1947 after accumulation of an excellent series of data at the Clinton County Air Force base in Ohio during the summer thunderstorm season. The number of thunderstorms "intercepted" by the observing network was 50 percent greater than expected from climatological averages. Several new elements were recorded by use of instruments developed during the previous year. Analysis of observations has been carried on through contract with the University of Chicago and its completion is expected in 1949. Although additional thunderstorm observations may be necessary for the research, they must await the development of instruments to measure factors not heretofore observed. The micronetwork of observations used for the thunderstorm research was modified for use of the cloud physics project described in the preceding paragraph.

Storm Detection by Radar

Experimental storm detection units were installed at Wichita, Kans., Norfolk, Nebr., and Wichita Falls, Tex., where they could serve for locating not only destructive thunderstorms but also tornadoes that frequent these portions of the Middle West. The equipment was obtained by transfer from the Navy, essentially type AN/APS-2 radar. It is operated by regular Weather Bureau employees who have been trained for the special purpose at these stations. They observe and report the location and direction of movement of significant precipitation areas within range of radar "vision." These stations are part of the radar-weather plan started by the Bureau in 1946 when the first unit was installed at Washington National Airport. In May 1948 an SCR-784 type radar storm detector was modified and installed by an industrial organization at Freeport, Tex., for operation in collaboration with the Weather Bureau as an aid in hurricane forecasting. These radar units are of special value in detecting severe storms that develop suddenly and cause destructive winds and flash floods. Usually the places that will be affected by destructive local storms cannot be determined exactly for inclusion in the regular weather forecast, but when detected immediately after development, brief warnings can be broadcast by the Weather Bureau in time for protection of lives and movable property.

Weather Forecasting Research

Five important projects in 24- to 48-hour forecasting are described here. They were designed to develop objective methods for use of selected field stations and for the WBAN Analysis Center at Washington, and to investigate and evaluate new methods that may be used by field forecasters and research associates in improving routine forecasting techniques, and to assist and advise field and research forecasters in the use of these research methods.

1. *Winter cyclones—their development and direction of movement.*—This project, begun in 1945, is part of the general weather-forecast improvement program. The method is to evaluate quantitatively the factors entering into prediction of intensification or decay of winter cyclones and their direction of movement, especially in the regions east of the Rocky Mountains. The project has provided the Washington Analysis Center with better techniques for forecasting the deepening or filling and the movement of general storm centers.

2. *Quantitative forecast of winter precipitation.*—This project to develop systematic methods for predicting the amount of snowfall produced by winter storms in certain areas was directed primarily during 1948 toward conditions in the 5,000 square miles immediately southwest of Washington, D. C. This area is typical of those for which quantitative precipitation forecasts are quite necessary. The project aims to estimate the time of beginning of snowfall and the probability that the total amounts will reach any one of several extremes. In May work was started on another phase, namely, the more definite forecasting of heavy snowfall in the New York metropolitan area.

3. *Quantitative forecast of summer precipitation.*—During the warm months rainfall in most parts of the United States comes from weather situations that differ essentially from those associated with winter snowfall. Research in these fields therefore calls for separate projects. During 1948 the study was directed primarily toward forecasting of daily rainfall amounts in eastern Kansas. A tentative method developed in earlier years was tested by the district forecast center at Kansas City.

4. *Forecasts of minimum temperature in winter.*—One of the most difficult problems is to forecast accurately the local minimums when the temperature is falling rapidly. The special purpose of this project is to develop criteria for forecasting extreme temperature declines from one day to the next. The localities of Pittsburgh, Philadelphia, Richmond, and Washington were made the object of the study.

5. *Forecasts of cloud ceiling and visibility.*—Progress was made in this project by developing a special method for forecasting the height of the cloud ceiling at Washington National Airport during prefrontal rain associated with warm fronts. This condition represents one of the most difficult to forecast and because it frequently brings low cloud ceilings which interfere with air transportation, its prediction is extremely important. The method has been used with good results by the airways forecast staff at the Washington Airport.

Other short-range work included: (*a*) Preparation of a preliminary manual of airway forecasting aids as a basis for obtaining recommendations from forecasters on what climatological data are needed for forecasting and their best form of presentation; (*b*) a preliminary study of fog forecasting at Elkins, W. Va., for use of airway forecasters at Washington Airport; and (*c*) preparation of a summary of methods of turbulence forecasting based on the work of Eastern Air Lines meteorologists and data published by the NACA.

Further research in methods of extended and long-range forecasting embraced four projects. For convenience in reference, meteorologists commonly use the term "extended forecasts" for predictions covering a period of about a week to distinguish them from the short-range daily forecasts. For predictions covering 30 days or more, the term "long-range forecast" is used. Usually the methods used for the three general periods are different. The 1948 research work included studies for the following:

(1) Development of an objective method of estimating surface temperature from prognostic contour charts of pressure aloft. The first step in the forecasting process is to predict accurately the air flow as indicated by the pressure patterns; the second is to predict the temperature and other weather elements in the light of the derived air flow. The project also gave attention to extended and long-range precipitation forecasts for eastern United States under winter conditions.

(2) Development of statistical formulae for use in forecasting pressure patterns. The formulae were adapted for high-speed punch-card machine work.

(3) Sources of heat energy in the atmosphere over the Northern Hemisphere in the possibility that there is relationship between heat

sources and weather abnormalities which persist for a month or more.

(4) A new procedure for integrating the individual efforts of forecaster specialists. The purpose is to make the final forecast an adequate combination of the several component parts, each analyzed under a specialist who gives full attention to his phase of the problem.

(5) *The 30-day outlook.*—This project is an effort to develop methods for prediction of weather a month, a season, or a year in advance, a goal long sought by agriculturists, commercial concerns and industrialists whose success in planning and production often depends upon long-term weather trends. The economic and social importance of monthly or seasonal weather predictions has led meteorological organizations all over the world to search diligently for better methods. Research of one kind or another for this purpose began long before establishment of national weather bureaus more than 75 years ago. Because of the complex circulation of the atmosphere and the various unknown factors, progress has been extremely slow. In recent years the Extended Forecast Section of the Weather Bureau has focused its efforts on an experimental 30-day temperature and precipitation outlook based on study of general circulation patterns. The outlook is prepared twice monthly and is in the form of charts showing average temperature and precipitation conditions for the 30-day period just ended and the predicted values for the coming 30 days in each case. Data are given in terms of anomalies or departures from normal and in order to apply the outlook it must be compared with normal conditions which are also shown by charts in each issue. Since it deals with large scale movements of the atmosphere, the outlook is scaled to large geographical areas. It does not show day-by-day variations nor is it applicable to localized operations. It is best used for general planning preliminary to the more specific 5-day and daily forecasts and special warnings issued by the Bureau. In its present stage of development the outlook is not greatly superior to expectancies based on climatic frequencies.

Because of its limitations and the need for expert interpretation, the outlook was not released for general circulation until recently when as result of unexpected publicity and popular demand it was made available for subscription through the Superintendent of Documents. Representatives of agriculture, commerce, industry and other interested activities urged publication because the best official information available on the subject was believed to be preferable to complete lack of guidance. The basis for and limitations of the Monthly Outlook are stated clearly on the cover page of each issue.

Research by Statistical Methods

Progress in extended and long-range forecasting has been retarded in part by limitations in manual computation. Last year all basic computations involved in the preparation of mean and trend or regression maps for routine 5-day and 30-day prognostic charts were converted for machine computation. This has permitted an increase in the utilization of observational data from points over the Northern Hemisphere amounting to about 65 percent above previous capacity.

A slight saving in time required for computations has also resulted. The gain is even more significant for future progress in processing and utilizing data from regions of the globe not now represented in the over-all analysis of atmospheric circulation, especially in the Southern Hemisphere, and the possible relationship to weather in the Northern Hemisphere.

Statistical methods have been used in further studies of sea-level pressure data extracted from the 40-year period of daily weather charts of the Northern Hemisphere produced during the war. The nature and extent of changes in the general circulation of the atmosphere during the 40-year period are being analyzed. Indices have been devised for classifying the circulation patterns on the monthly maps according to winter or summer types. The indices will be studied for persistence characteristics, trends, and correlation with solar radiation.

Another project pertains to air turbulence, of practical concern in several fields of business. Turbulence affects aircraft operation. It enters into the formation of clouds and storms, and it largely determines the diffusion of industrial products and their dissipation in population centers. Statistical theories of turbulence were studied in an attempt to obtain experimental data on how eddy diffusion takes place in the atmosphere. The experiment was based on the scatter of swarms of balloons whose paths were followed by radar. The effects of vertical wind shear and balloon size have been studied in relation to measurements of scale and intensity of turbulence. Attempt has been made to generalize the theory of diffusion of particles as developed by Taylor and others. The approach has been to devise a new expression which takes account of the distance between small parcels of air in the free atmosphere.

Weather and Solar Radiation

New pyreheliometers and recorders were furnished to 25 additional field stations of the Weather Bureau to provide basic data on the radiant energy received from the sun. The data are necessary for research on the effects of possible variations in solar radiation on weather conditions as well as for practical climatological purposes relating to effects of radiation on plant growth and other products. For the latter purpose average monthly maps showing the radiation received from the sun on cloudless days were completed; also maps showing the average solar radiation for all days. The maps apply to ground level in the United States.

With cooperation of the Office of Naval Research and the United States Air Force, cloud albedo measurements were made from a B–29 airplane. Other albedo measurements up to heights of 38,000 feet have been made over snow, over ocean waters, and over other selected areas. The albedo of the earth as a planet and the average albedo of clouds have been recomputed. The generally accepted values were found to be too high.

Measurements of the total ozone in the atmosphere are being made almost daily by a spectrograph developed for this purpose. The instrument was loaned to the Naval Research Laboratory for several weeks for comparison with data obtained from rocket flights.

Cooperative Research Projects

Joint studies of special meteorological problems were carried on as follows: (1) With New York University, an investigation of atmospheric energy and its transformations; (2) with the University of California at Los Angeles, (a) analysis and comparison of conditions in the lower and middle stratosphere, and (b) continuation of objective methods for forecasting rainfall at Los Angeles; (3) with the Massachusetts Institute of Technology, continuation of studies for improved methods of forecasting for extended periods; (4) with Lowell Observatory, a study of planetary atmospheres from which it is expected that basic information on meteorology applicable to the earth's atmosphere will be obtained; (5) with Iowa State and North Carolina State Colleges, a continuation of agricultural climatological studies to develop statistical methods for the treatment of data needed in agricultural production; (6) with the Atomic Energy Commission, special studies at Brookhaven, Oak Ridge, and Knolls Laboratories.

Technical Publications

The following research and technical papers were published during the year:

Research Paper No. 27. Objective Methods of Forecasting Winter Minimum Temperatures at Washington, D. C.

Research Paper No. 28. Possibility of Long-Range Precipitation Forecasting for the Hawaiian Islands.

Research Paper No. 29. An Objective Method of Forecasting Five-Day Precipitation for the Tennessee Valley.

Technical Paper No. 3. Extreme Temperatures in the Upper Air.

Technical Paper No. 4. Topographically Adjusted Isohyetal Maps for Western Colorado.

Technical Paper No. 5. Highest Persisting Dewpoints in Western United States.

Technical Paper No. 6. Upper Air Average Values of Temperature, Pressure, and Relative Humidity over United States and Alaska.

Technical Paper No. 7. A Report on Thunderstorm Conditions Affecting Flight Operations.

Other publications: Publication of sunspot data in the Monthly Weather Review was discontinued with the December 1947 issue in order to permit resumption of technical articles on practical meteorology and climatology which have been curtailed for a number of years because of high cost of printing. The revised format and contents of the daily weather map published at Washington have been described in an earlier paragraph. Exchange of publications with foreign meteorological services which was interrupted by the war and which has always been an important factor in disseminating knowledge and stimulating further progress has been resumed. During the year the Bureau exchanged more than 40,000 articles of meteorological literature with 62 different foreign institutions, principally national meteorological services.

Instrument Development

Direct reading wind measuring equipment.—A new type of equipment is being installed at field stations to give wind speeds directly by reading a speed indicator without use of a watch or other timing device. Wind directions are also read directly in degrees of azimuth rather than to 16 points of the compass as with equipment previously in field use.

Electronic sunshine switch.—This new electronic switch developed to measure duration of sunshine is practically instantaneous in its response. Its sensitivity assures operation when the sun is close to the horizon. This is a distinct improvement over the mercury type sunshine recorder used in the past.

Facsimile equipment.—High-speed facsimile equipment was procured for use between the forecast center in downtown Chicago and the Weather Bureau office at the Municipal Airport in the southwestern part of that city. This equipment permits rapid transmission of synoptic charts and weather data prepared at the central transmitting point, and is adapted for wider use at nearby stations and airports.

Electronic flood-wave analyzer.—The basic work on the development of an electronic circuit and accessories for use in analyzing and reconstructing the curves of flood waves in rivers was completed during the year. With this equipment it is possible to determine the wave pattern of outflow from reservoirs or successive reaches within a stream, when the inflow hydrograph is known. Inflow data from two or more upstream sources also can be routed through the machine simultaneously to produce an outflow pattern, thus giving an efficient means of treating and evaluating tributary inflow with respect to anticipated flow or stream stages below the confluence of two or more streams. The outflow hydrographs can be traced quickly and accurately by the flood wave analyzer.

ADMINISTRATION AND FINANCE

During Fiscal Year 1948 special surveys were made to find where the organization and operations of the Bureau could be consolidated and further streamlined. For more than a decade the Weather Bureau has received relatively large percentage increases in appropriations each year. The administrative problems incident to this expansion were the subject of careful consideration and planning from the beginning. The essential facts are summarized below because without them the tables showing field establishment and expenditures may be very misleading.

Prior to 1935 appropriations for the Bureau had shown practically no increase for many years. No provision had been made for enlarging the service to keep pace with rapid growth of aviation and to meet its need for flying weather reports and forecasts, nor for expanding agricultural and industrial requirements. During the 1930's the Bureau was severely criticized by agricultural and aviation agencies in Government as well as in private enterprise and by engineering and

scientific institutions and by Congress for not having developed the facilities to meet urgent national needs. The President's Science Advisory Board and its subsequent Weather Bureau Advisory Committee gave special attention to the problem and after an investigation made recommendations for bringing the Bureau's establishment up to modern standards. Estimate was made that the Bureau's annual appropriations should be approximately doubled at that time to place the national weather service on a parity with those of other leading nations. On this basis the Bureau's appropriation in 1938 should have been about $10,000,000. The Bureau's long tradition for economical administration and an acute shortage of meteorologists who might be recruited to enlarge the Bureau led to careful planning during the years of increasing appropriations. Wherever practicable, operations were consolidated. Almost 10 years ago a systematic program of consolidation was begun when aviation required an airport office in localities where a Weather Bureau city office already existed. By 1946 offices had been merged in more than 50 cities. Also, airways forecast centers have been moved and consolidated with general district forecast centers wherever possible. Field administration and service activities throughout the organization have been critically reviewed each year in order to curtail less important services or functions and make room for new and more urgent services. Since 1940 most of the Bureau's field stations for weather observations and forecasting have been converted from part-day to continuous 24-hour services in order to maintain constant watch over weather developments and provide immediate warnings of storms. Again, international commitments of the United States have required the Bureau to collaborate in developing synoptic networks in the Arctic, over the Atlantic and Pacific, and in the Carribean and Central America. The Flight Advisory Weather Service was organized to work with air traffic controllers of the CAA for increased safety in air traffic. Public needs in air transportation, in local predictions of severe storms and flash floods and other meteorological problems have placed upon the Bureau responsibility for more research into basic weather problems.

In 1948 the field operations and administration of the Bureau were examined by disinterested outside investigators as well as by Bureau officials and they found that most Weather Bureau offices are working at maximum capacity. There is little possibility for further consolidation or retrenchment without curtailment of important functions or closing of local stations. Most field offices have small staffs and keep only one employee on duty at a time. Over-all administrative costs are still low in comparison with industrial averages. They are less than 6½ percent of the total expenditures of the Bureau. Because of necessity to staff for continuous operation at a large number of local weather stations the salary roll is relatively high—about 80 percent of the total—but individual salaries are conservative in comparison with those paid for professional employees with similar requirements and qualifications in other scientific organizations. In general, grades and salaries are not above civil-service averages. More than 30 percent of the increase in salary roll during the last 10 years is charge-

able to statutory pay raises and reclassifications, and not to increases in staff. If allowance is made for the substandard level of maintenance in 1935 and for the current monetary inflation which is reflected in present appropriations, the increases during the period have been conservative, and especially so when intervening developments in aviation and meteorology are remembered. Appropriations for the Bureau are still relatively smaller than those of Canada and other leading countries in comparison with national incomes and economic importance.

Regional administration.—Despite genuine need for additions to staff to enable them to carry out their functions, regional offices suffered some curtailment in personnel toward the close of the fiscal year. From 1941 when the field was organized into regions the personnel allowances of regional administrative offices have been kept relatively low. In fiscal and other business management functions regional offices have broad responsibilities, but in policy making, program planning and professional services their duties are limited to certain advisory functions leaving the service program under the leadership of specialists in its respective divisions in the Washington Central Office. This form of administration is advantageous in the multiple service work of most meteorological field stations.

Because of the many effects of weather on agriculture, commerce, and transportation and the broad public use of weather reports and warnings there is constant pressure to open Weather Bureau offices in localities which have none. Hundreds of requests and resolutions for new stations are received each year from civic bodies and officials. Most of them represent a real public need. Regional and Central administrative offices have screened such requests carefully, and very few additional first-order stations have been approved during the past year or two. Several older offices have been closed. Although the Bureau aims to maintain the national weather service at a level consistent with the Federal establishment as a whole as regards public demand, benefits and relative cost, it is economically impracticable to expect unlimited expansion in local weather service stations or to establish and maintain a Weather Bureau office in every important locality. Only the high priority requirements can be filled. The formula used for screening requests for new offices was that the prospective economic returns in form of increased production in agriculture, etc., as result of information provided by a Weather Bureau office must be many times the total cost of the new office; or when safety of life is the major factor as it is in the hurricane belt or in air transportation, it must be shown that the warnings cannot be provided from an existing Weather Bureau office. Whenever possible, the services requested by official agencies and civic organizations reflecting a vital public need are furnished from the nearest established forecasting center. In general, agricultural and business surveys have shown that the economic returns in form of the damage prevented from storm or cold wave and the more efficient operation by use of favorable weather factors as result of reports provided by the Weather Bureau exceed a billion dollars annually, fifty times the total cost of the Bureau. The improved services made available by

increasing the facilities of the Bureau during the last decade have made possible these monetary gains in addition to the large reduction in loss of life in hurricanes and other severe storms through development of the storm-warning services.

This administrative review is incomplete without reference to the problems in research brought to the front by enactment of Public Law 657 in June 1948 "to provide safety in aviation and to direct a study of the cause and characteristics of thunderstorms and other atmospheric disturbances." The research facilities of the Bureau are small. A start was made years ago on fundamental problems looking toward better understanding of weather phenomena and how to predict them and possibly forestall their effects, but compared with the actual and potential benefits of such research and the problems involved, the research establishment of the Bureau in 1948 was very inadequate.

Employment.—Weather Bureau full-time employment increased slightly from 4,744 to 4,769 during the fiscal year. Part-time employment increased from 3,065 to 3,169. Total paid employment on June 30, 1948, was 7,938. Of this number 2,658 were veterans, an increase of 544 from the preceding year. The number of full-time employees holding war service or temporary-indefinite appointments was reduced from 2,521 to 1,224 during the year. It is expected that civil-service examinations now planned will eliminate nearly all remaining war service and temporary-indefinite appointees within the next year.

Use of group judgment in selecting the best qualified employees for responsible assignments and promotion has been carefully followed as a standard practice. Pertinent data for each employee relative to work performance, education and length and types of experience are coded on punched cards for ready reference in making placement selections. New professional appointees recruited during the year have been veterans in most cases with advanced meteorological training and several years of professional experience as weather officers in the armed forces.

Training.—Under the university scholarship program, 10 Weather Bureau employees were assigned to 1-year courses in advanced meteorology beginning in September 1947. Students attended New York University, the University of Chicago, or the University of California at Los Angeles. The Weather Bureau also had an employee selected as a participant in each of the sixth and seventh administrative intern programs of the Civil Service Commission.

Job training for weather observers was improved with special emphasis on the improvement of upper air observations. The results have been worth while both in improved quality and greater economy in weather observations. Some progress was made in developing training aids and techniques for personnel who must prepare weather bulletins for publication over direct broadcasting channels.

Employee awards.—Records of the employee awards program, instituted in the Weather Bureau during October 1947, indicate that four of each hundred suggestions merit cash awards. Awards suggestions are estimated to be worth about $12,500 in total annual savings to the Bureau.

1947-48

Organization of the Weather Bureau field service indicating types of stations and activities performed as of June 30, 1948

Weather Bureau offices manned by full-time personnel		388
Functional activities (Not all different stations. Functions combined into 1 office where possible.):		
Regional offices	8	
General forecasting centers	17	
Airway forecasting centers	21	
Climatological section centers	43	
River district offices	86	
Weather records processing centers	7	
River forecast centers	4	
Radiosonde observation stations	68	
Pilot balloon observation stations	170	
Rawinsonde observation stations	34	
Vessel contact stations	34	
Number and type of substations (furnished by cooperative or part-time personnel):		
A. Activities under regular appropriations:		
1. Aviation weather service	598	
(Frequent weather observations reported for aviation.)		
2. Climatological service	6,086	
(Weather data furnished to determine the climatological characteristics of the United States. These stations are for the most part manned by unpaid observers.)		
3. General weather service	1,007	
(Observations reported for the benefit of agricultural interests, and stations maintained to provide warnings of approaching storms and hurricanes.)		
4. River and flood service	2,361	
(River stage and rainfall reports furnished for the preparation of streamflow and flood forecasts.)		
Total substation activities related to regular appropriations		10,052
B. Activities under transfers from other appropriations:		
1. Hydroclimatic service		2,981
(Reports from recording rain gages giving precipitation intensities for storm studies and flood control.)		
Total substation activities (separate types of reports, etc.)		13,033
Total reporting stations		9,397
(Number of reporting stations is less than number of "activities" as some are multi-purpose stations.)		

Financial summary, fiscal year 1948

A. Obligations against direct appropriations:

Purpose		
1. General weather forecasting service		$838,264
2. Localized daily weather services for the general public		3,333,570
3. Specialized weather services:		
(a) Hurricane	$151,939	
(b) Horticultural	239,299	
(c) Fire weather	151,734	
(d) Ocean and lake forecasting	44,704	
(e) Marine	144,365	
Total, specialized weather services		732,041
4. Climatological service		2,668,837
5. Observation stations and activities serving both aviation and general public requirements		7,152,984
6. Direct aid to aviation:		
(a) Terminal and route forecasting for domestic airways	$520,878	
(b) Terminal and route forecasting for international airways	484,423	
(c) Flight advisory weather service	511,182	
(d) Localized airways weather services	2,049,529	
Total, direct aid to aviation		3,566,012
7. Research		743,697
8. River and flood forecast and warning service		682,937
9. Administration		1,408,439
Grand total—obligations against direct appropriations		21,126,781

B. Obligations against funds transferred from other appropriations:

1. Meteorological studies and statistics:		
(a) Civil Aeronautics Administration	$47,789	
(b) Department of the Interior	30,827	
(c) National Military Establishment	245,925	
Total	$324,541	
2. Observations and forecasts:		
(a) Department of the Interior	$10,695	
(b) National Military Establishment	906,779	
(c) Tennessee Valley Authority	155	
Total	917,629	
3. Scientific and technical cooperation, including meteorological training:		
(a) Department of State	131,058	
4. Rehabilitation of Philippine Meteorological Service, including meteorological training:		
(a) Department of State	742,338	
Total obligations against transferred funds		2,115,566

C. Grand total obligations, all funds 23,242,347

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