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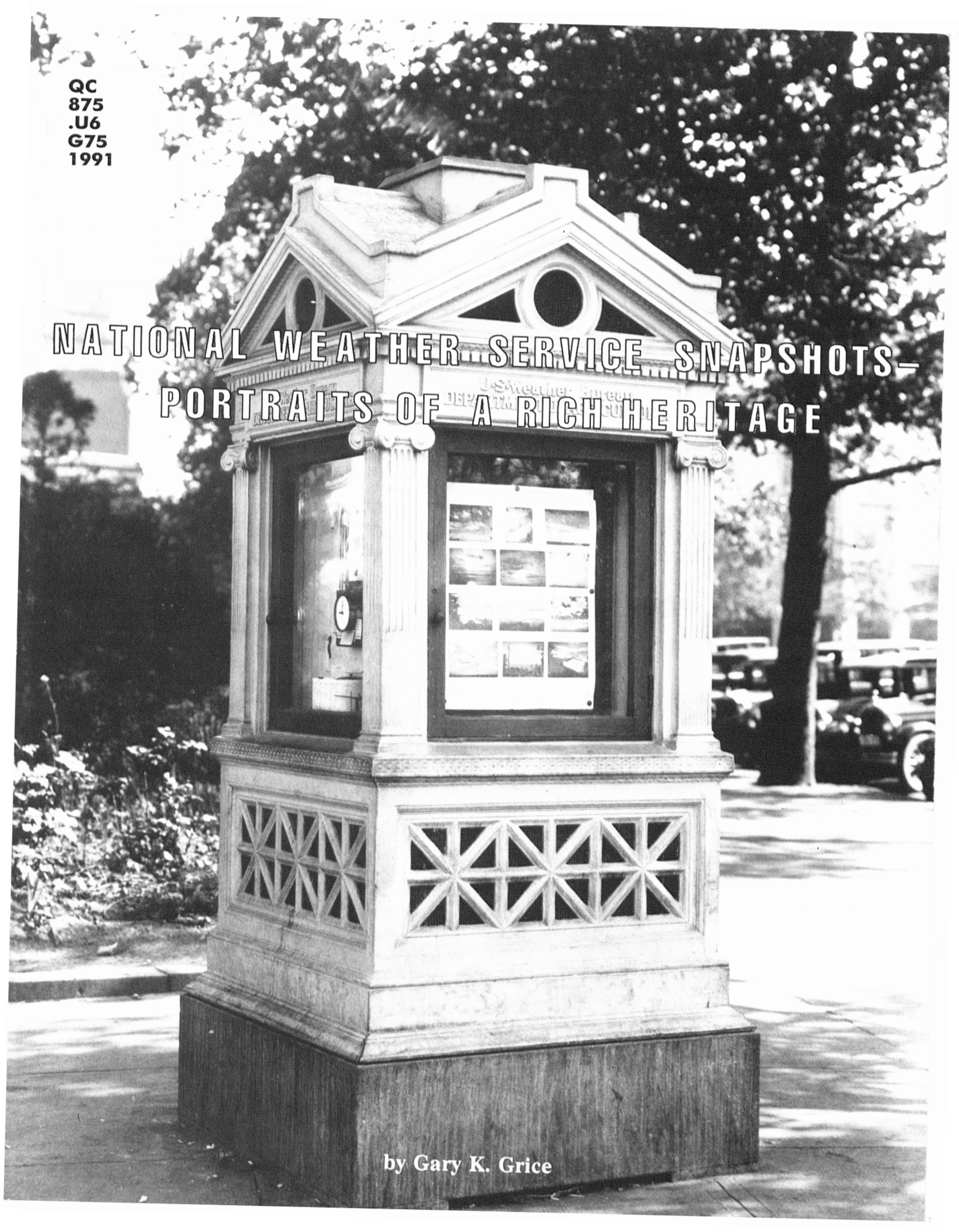

NATIONAL WEATHER SERVICE SNAPSHOTS— PORTRAITS OF A RICH HERITAGE

by Gary K. Grice

National Oceanic and Atmospheric Administration

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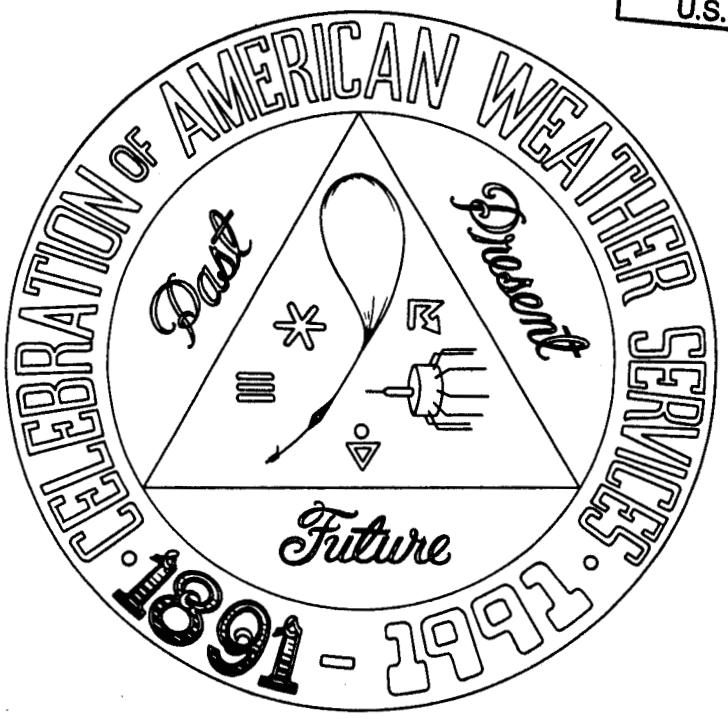

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In Support of

The Celebration of American Weather Services

...Past, Present and Future

ACKNOWLEDGMENTS

This document would not have been possible without Dr. Elbert W. Friday and Robert C. Landis. Because of their interest in the National Weather Service Centennial Celebration, funds were available for this publication.

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Photographs and text were obtained from the National Archives, NOAA Library, and the NOAA Archives.

Many people contributed to this document, making it impossible to acknowledge everyone. I apologize for any omissions.

PREFACE

Over four years ago, I began a project to prepare a comprehensive history of the National Weather Service. The goal was to prepare a document so complete and detailed that the task would never again be required.

Several important lessons have been learned during those four years. The most important lesson is that a comprehensive history of the National Weather Service would require much more time and talent than I was able to provide. The many contributions alone of our agency over the last 120 years would fill several volumes.

The time was not wasted. I now have a better understanding of the National Weather Service, and it was amusing to discover that certain present day methodologies or operations are the result of events which occurred as long as 75 years ago.

I also learned that some things do not change. For example, a document from the early 1940s was uncovered in the NOAA Library which was describing how the Weather Bureau's State Forecast soon would be eliminated because of its lack of practical use.

This document is not a representative history of the National Weather Service, but rather selected moments of time to present a "flavor" of the history. The "snapshots" are not evenly distributed since considerable information exists about the Weather Bureau and Signal Service prior to the 1950s but is almost nonexistent during the past 35 years.

This publication contains many photographs and some text. It was designed for light reading and enjoyment but it also serves two other purposes. For the "oldtimers," it is hoped it will kindle fond memories and perhaps bring on a smile. For those new to the National Weather Service, it is hoped this document will provide an indication of the richness of our heritage.

This document is an indication of the character of the National Weather Service, but it cannot describe its soul. Following several thousands of hours of reading and research, I only have an inkling of the moral aspect of our agency. However, I am confident of three things.

Whether with the Signal Service, Weather Bureau, or National Weather Service, its people have made the agency great. Throughout the history of the organization, the devotion of its employees to go "the extra mile" is the reason major strides have been made. A second item is that service is our only reason for existing. This characteristic has attracted a special type of individual--one which is dedicated to serving humanity. When special individuals work together, extraordinary events occur. Lastly, considerable positive momentum has developed over the past 120 years and this "can-do" attitude is alive and well in the National Weather Service of today.

A taste of these three characteristics may be gained from this document. However, National Weather Service people in the field exhibit this devotion and commitment everyday. It should be rewarding to know that they are maintaining a long and rich tradition.

GKG

THE NATIONAL WEATHER SERVICE

A BRIEF HISTORY

On February 2, 1870, the United States Congress passed a resolution requiring the Secretary of War "to provide for taking meteorological observations at the military stations in the interior of the continent and at other points in the States and Territories...and for giving notice on the northern (Great) lakes and on the seacoast by magnetic telegraph and marine signals, of the approach and force of storms." The Resolution was signed into law on February 9, 1870 by President Ulysses S. Grant, and the precursor to the Weather Bureau and National Weather Service was born.

The new agency, called the Division of Telegrams and Reports for the Benefit of Commerce, was formed under the Signal Service. The new weather agency was placed under the War Department because "military discipline would probably secure the greatest promptness, regularity, and accuracy in the required observations." Because of the long name, the agency frequently was referred to as the national weather service or general weather service of the United States.

SIGNAL SERVICE: 1870-1891

The new weather agency operated under the Signal Service from 1870 to 1891. During that time, the main office was located in Washington, D.C., with field offices concentrated mainly east of the Rockies. Most forecasts originated in the main office in Washington with observations provided by field offices.

During the Signal Service years, little meteorological science was used to make weather forecasts. Instead, weather which occurred at one location was assumed to move into the next area downstream. The weather forecasts were simple and general in content--usually containing basic weather parameters such as cloud and precipitation.

The Division of Telegrams and Reports for the Benefit of Commerce remained under the Signal Service from 1870 to 1891. On October 1, 1890, Congress voted to transfer it to the Department of Agriculture and renamed the Weather Bureau. The actual transfer occurred July 1, 1891, and at that time, organized civilian weather services within the Federal Government began in the United States.

AGRICULTURE DEPARTMENT: 1891-1940

The Weather Bureau was part of the Department of Agriculture for 50 years from 1891 to 1940. During that time, considerable improvements were made in Weather Bureau operations, and the science of meteorology made significant advances.

Weather forecasters in the Signal Service and early Weather Bureau years primarily used information from surface weather observations. The early meteorologists were aware that conditions in the upper-atmosphere controlled surface weather conditions, but technology had not advanced to the point of taking upperatmospheric observations.

EARLY TECHNOLOGY

Around 1900, the Weather Bureau began to experiment with kites to measure temperature, relative humidity and winds in the upper atmosphere. Kite observations were taken intermittently from about 1900 to about 1920 with a kite network of stations established during the 1920s and early 1930s. These pioneers were the first to observe classical meteorological features which significantly impacted weather over the United States. By the early 1930s, kites were becoming a hazard to airplanes in flight, causing kite observations to give way to airplane observations.

In 1931, the Weather Bureau began to replace kite stations with airplane stations. The use of the airplane as an upper-air observational tool, continued to expand during the 1930s. Airplanes were an expensive and dangerous way to obtain upper-air data. Also, it frequently was impossible to use airplanes during bad weather; the time when observations were most important. The disadvantages of the airplane as a sounding platform, coupled with the advent of sounding balloons carrying meteorological instruments and radio transmitters (radiosondes), resulted in airplane observations being discontinued prior to World War II.

The development of the radiosonde was a bench mark to operational meteorology. With the relatively inexpensive instrument, the upper atmosphere could be sampled routinely and simultaneously in both bad and good weather. The radiosonde was one catalyst which increased meteorologists' understanding of the weather. Following the implementation of the radiosonde, the science of weather forecasting began to improve substantially and steadily.

One of the more important advances for the Weather Bureau while in the Department of Agriculture was the advent of the teletype system. The forerunner of the teletype, the telegraph, served the early needs of the agency, but it was readily apparent that this system was labor intensive and not reliable. The system contained many vulnerable areas, any of which could result in an important warning not being received or a critical observation not transmitted.

The teletype was introduced in the Weather Bureau in 1928 and its use spread rapidly. Within two years, teletype circuits covered 8,000 miles, mainly in the eastern part of the country, and by the mid 1930s, teletype circuits covered over 32,000 miles.

DEPARTMENT OF COMMERCE: 1940

While under the Department of Agriculture, aviation weather services of the Weather Bureau expanded rapidly. Initiation of air mail flights and the increase of aviation activity following World War I placed a large demand on the Weather Bureau for forecasts of flying weather. In 1919, daily flying weather forecasts were started primarily for the Post Office and military aviation, but the most significant advances occurred with the passage of the Air Commerce Act of 1926 which made the Weather Bureau responsible for weather services to civilian aviation. The Air Commerce Act increased aviation weather services by the Weather Bureau, but more important, the law provided funds to establish a network of stations across the United States to take surface and upper-air weather observations.

As the Weather Bureau became more associated with the aviation community, it became apparent that the agency belonged in the Department of Commerce. On June 30, 1940, President Franklin Delano Roosevelt transferred the Weather Bureau to the Department of Commerce where it remains today.

The early association of the Weather Bureau with the Department of Commerce was dominated by World War II. Although most Weather Bureau meteorologists were deferred from military duty, many elected to serve their country. As with other sectors of the American work force, women stepped in to perform the job.

WORLD WAR II SPURRED GROWTH

During the war years, meteorological services by the Weather Bureau increased significantly. Following the war, reductions to peace time were required. One exception was in the area of weather support to the aviation community. During World War II, aviation made major strides--improvements which carried over into the post war years. Consequently, Weather Bureau support to aviation also increased.

During the late 1940s and 1950s, the main contribution to Weather Bureau operations was in the area of radar meteorology and computer models of the atmosphere. During the late 1940s, the military gave the Weather Bureau 25 surplus radars which subsequently were renovated to detect weather echoes. Information gained from the operation of these radars eventually led to the formation of a network of weather surveillance radars still in use today.

With the development of computer technology during the 1950s, the way was paved for the formulation of complex mathematical weather models to aid meteorologists in forecasting. The first operational use of these computer models during the 1950s resulted in a significant increase in forecast accuracy.

FIRST WEATHER SATELLITE: 1960

The Weather Bureau entered the satellite age in the 1960s. The first weather photographs from space in the 1950s actually were by-products of films made to record the attitude of rocket nose cones. However, following the launch of Explorer in 1958, the importance of satellites to observing the world's weather soon became apparent.

Most early weather satellites were low orbit versions which viewed small and different sections of the earth's surface. In the 1970s, geostationary weather satellites were launched which provided meteorologists with continuous observations over much of the western hemisphere.

THE NATIONAL WEATHER SERVICE: 1970

In July 1970, the name of the Weather Bureau was changed to the National Weather Service. At the same time, the National Weather Service was placed under the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce where it remains.

Throughout its history, the National Weather Service has strived to balance new technology and fiscal responsibility to provide timely and accurate warnings and forecasts to the American public. Today, the National Weather Service is involved in a complex modernization and associated restructuring program. This program is designed to replace aging equipment to allow National Weather Service meteorologists to practice state-of-the-science weather forecasting. The modernization, when viewed in the context of past accomplishments and milestones, reflects the dedication of the agency and its employees to meeting the weather needs of the United States.

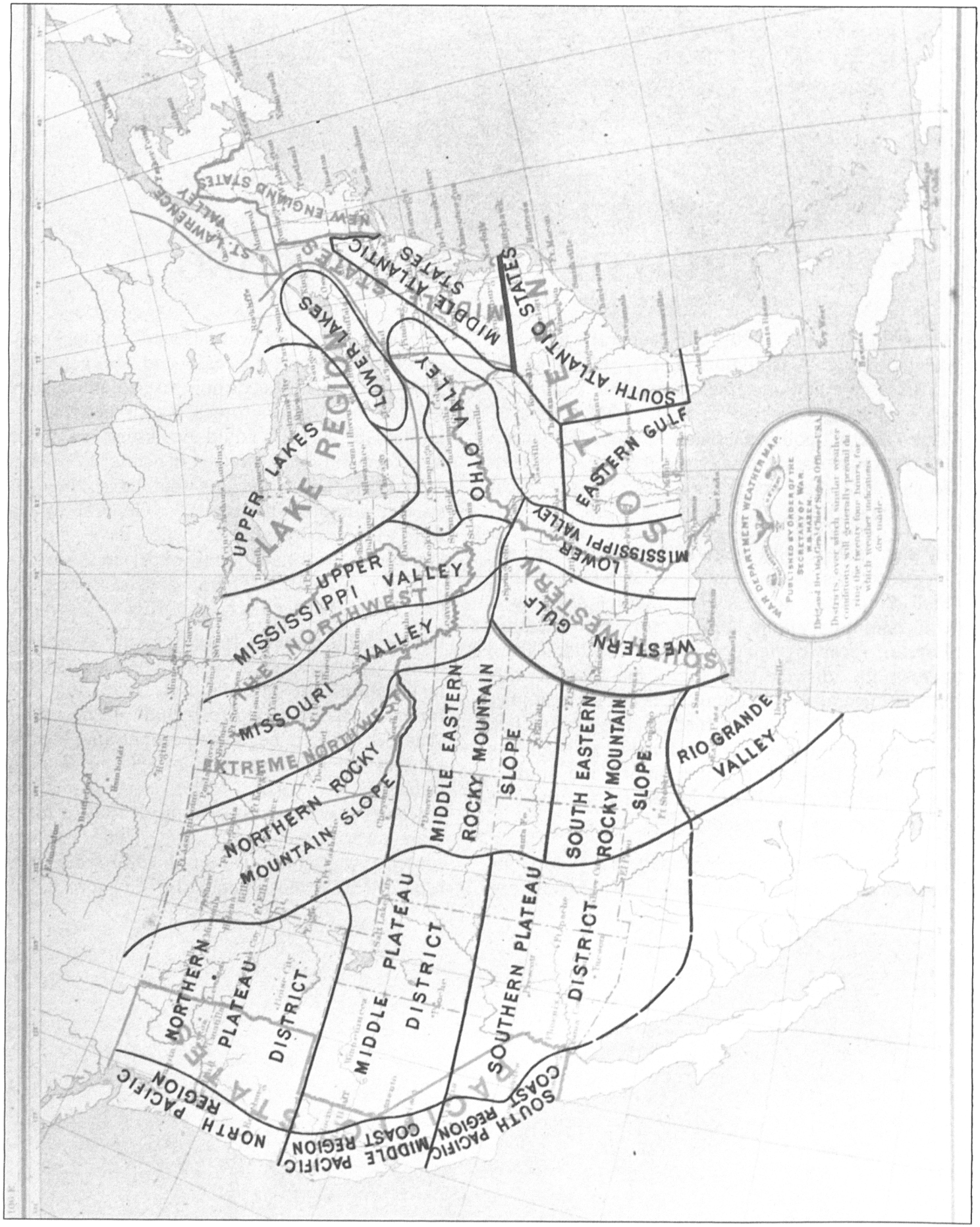
GROWTH OF FORECASTING

From 1870 to 1890, all general forecasts originated at Washington, D.C. However, in 1881, a few stations, including New York City, were given permission to issue local forecasts. This "liberal" policy persisted through 1890 when local forecasters were advised they could amend forecasts, when necessary, to reflect local conditions.

By the early 1900s, general forecasts, covering large sections of the country, were issued by five district forecast offices. The district office was the communications center for the Weather Bureau, receiving telegraphed observations from across the district. However, the district was large, encompassing many states. For example, the district for the Chicago forecast office covered the upper Great Lakes, as well as 12 states. During the 20th Century, the number of district forecast offices increased and the size of the districts decreased.

Forecast duration was expanded just before the turn of the century. About 1900, two basic types of public forecasts were issued in the Weather Bureau--the local forecast and the general (or state) forecast. According to Weather Bureau regulations, local forecasts (issued for the immediate station) could be issued by "section directors and local forecast officials, by reason of their rank, and observers that have been given special authority therefore." General forecasts were issued by "those who have sufficient knowledge, training, and experience in forecasting and atmospheric physics," i.e., those located at District Forecast Offices.

Before 1899, general forecasts were issued twice daily (10 AM and 10 PM), covering 36 hours in duration, but on March 1, 1899, the 10 PM forecast was extended to include 48 hours. The Weather Bureau began experimenting with very general weekly forecasts in 1908 with regular issuances by 1910. This early long range forecasting effort was undertaken to help farmers plan agricultural activities. This "extended" forecast was continued until 1940 when it was replaced by a more detailed 5-day forecast.



Forecast zones during 1880's (Signal Service years).

Transfer of Weather Services from the Signal Service to the Department of Agriculture (1890)

The Chief of the Weather Bureau, under the direction of the Secretary of Agriculture, shall have charge of forecasting the weather; the issue of storm warnings; the display of weather and flood signals for the benefit of agriculture, commerce and navigation; the gauging and reporting of rivers; the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation; the reporting of temperature and rainfall conditions for the cotton interests; the display of frost, cold-wave, and other signals; the distribution of meteorological information in the interest of agriculture and commerce and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or are essential for the proper execution of the forgoing duties. ...the enlisted force of the Signal Service, excepting those hereinafter provided for shall be honorably discharged from the Army on June 30, 1891, and such portion of this entire force, including civilian employees of the Weather Bureau shall, if they so elect, be transferred to the Department of Agriculture...

In parting from the civil employees the Chief Signal Officer feels assured that the new chief in another department will receive from them the same loyal, faithful, and efficient service they have rendered the Government while serving under his orders. The scientific staff have in view important additional duties looking to the extension of the Weather Service in the interests of agriculture and still further development of the science of meteorology. The Chief Signal Officer will follow with deep interest the development on new scientific lines of weather forecasting and the application of meteorology to agriculture, on which grounds this liberal reorganization of the Weather Bureau was planned and carried out.

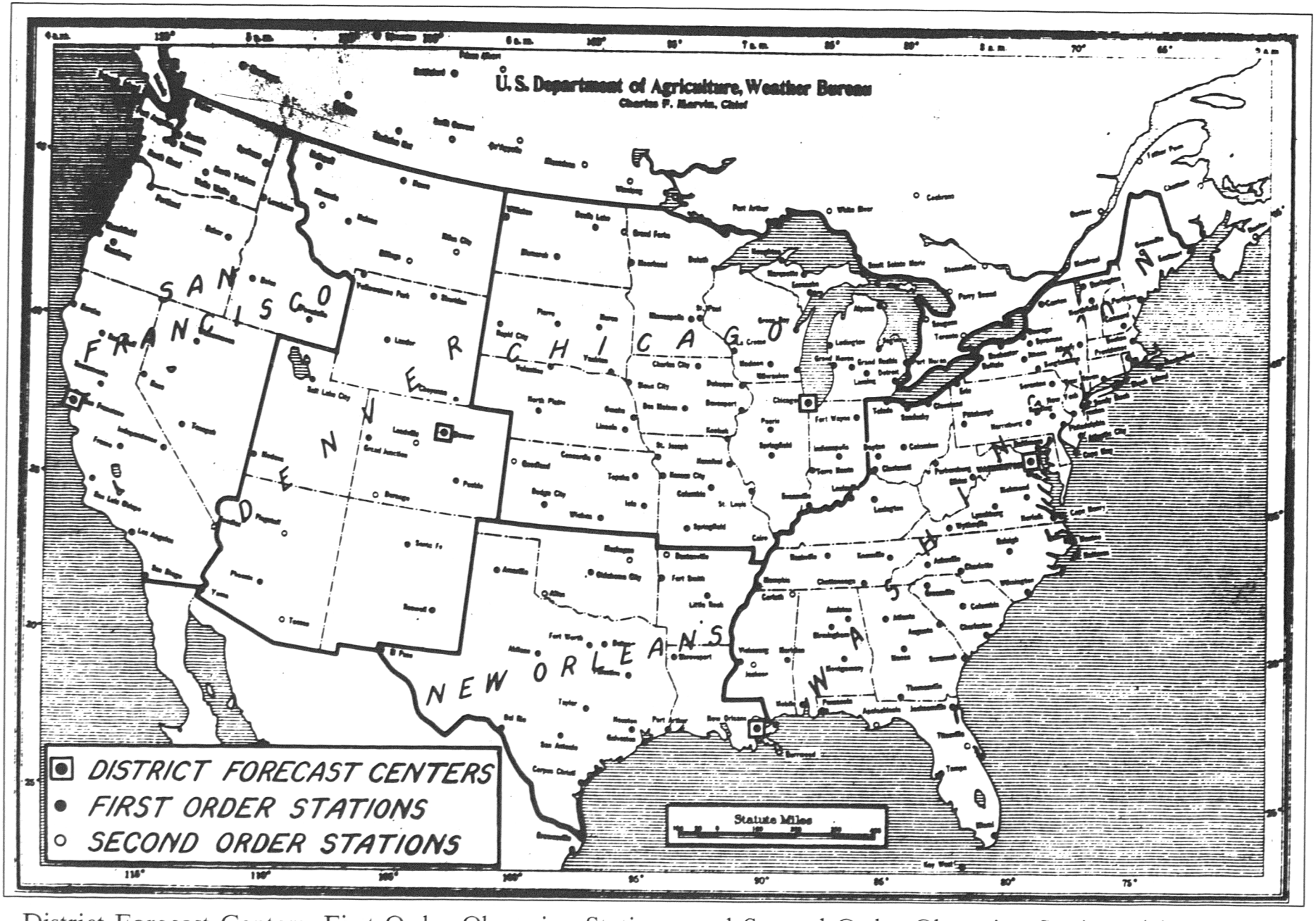
General A.W. Greely
Chief Signal Officer (1891)

The Thunderstorm Experiment in 1892

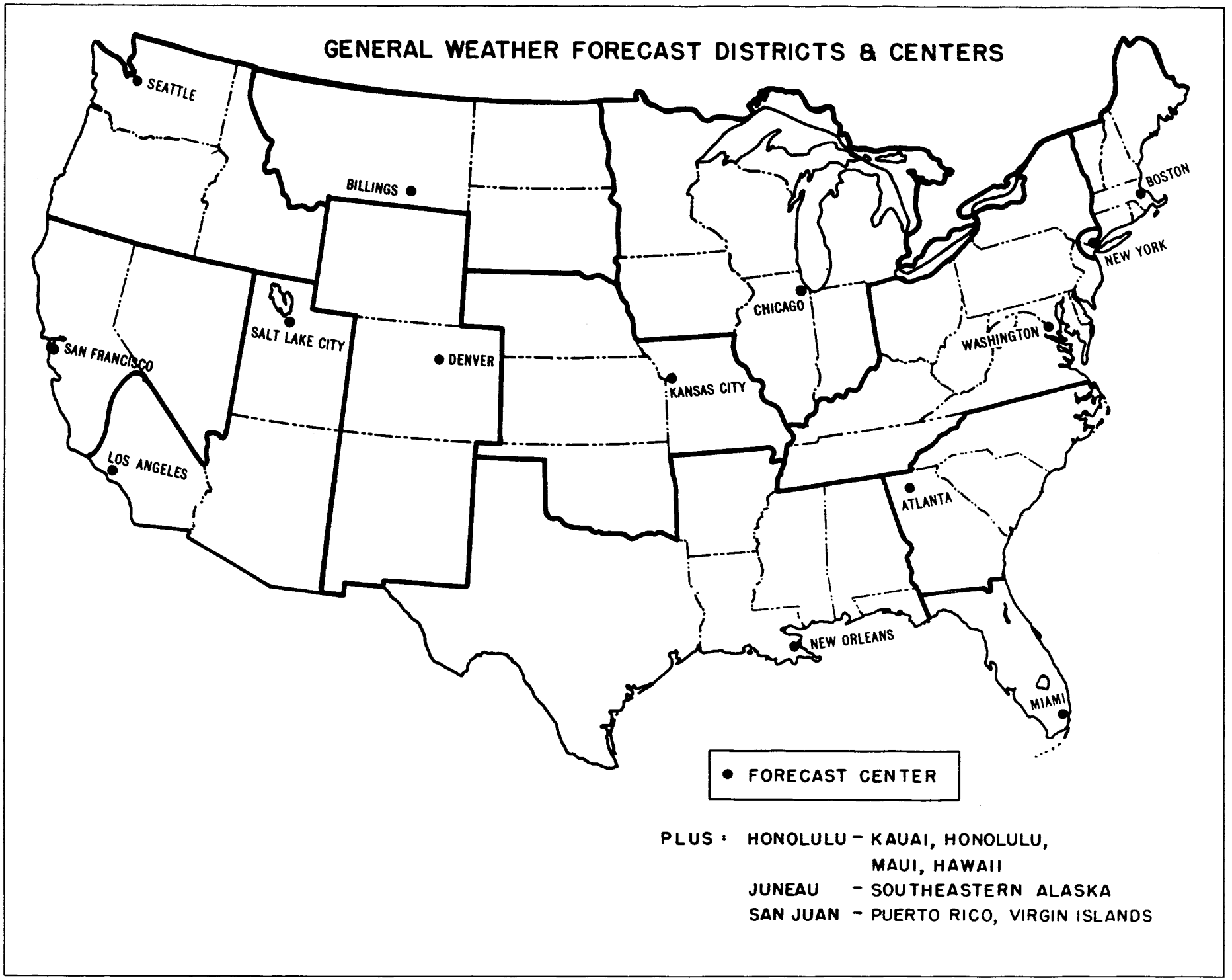
In 1892 an experiment was started by the Weather Bureau in New England, New York, Pennsylvania, New Jersey, Ohio, Michigan, Indiana, Illinois, Wisconsin, and Missouri, to see if thunderstorms could be forecast successfully. As part of the effort, special surface observations were taken in these states.

One important part of the experiment was a "warning network" established along telegraph lines. As thunderstorms would pass over one location, the observer would telegraph the phenomena to the next observer in which the thunderstorm was moving. Essentially, the experiment was unsuccessful. Telegraph lines were not arranged in the proper directions, and thunderstorms frequently occurred at a location before "warnings" were received from upstream stations.

Another attempt was made in Michigan to divide the state into nine sections with one location serving as the communication center for each section. Observers were to phone in thunderstorm reports to the communication center, who in turn, would relay the information to other potentially affected locations. This also failed since up to three hours were required to transmit the observation to the communication center, and for the communication center to retransmit the information to other locations.



District Forecast Centers, First Order Observing Stations, and Second Order Observing Stations (circa 1920).



Forecast Districts and Centers (circa 1930).

Weather Bureau Announcement in the Bulletin of the American Meteorological Society (1920s)

If you don't care to be a millionaire, are not afraid of exacting technical work and are looking for an organization where efficiency and fidelity in performance carry automatic recognition and advance in the course of time, the Weather Bureau offers a fine career for you.

Transfer Of Weather Bureau To Department Of Commerce (1940)

The importance of the Weather Bureau's functions to the nation's commerce has also led to the decision to transfer this Bureau to the Department of Commerce. The development of the aviation industry has imposed upon the Weather Bureau a major responsibility in the field of air transportation. The transfer to the Department of Commerce, as provided in this plan, will permit better coordination of government activities relating to aviation and to commerce generally, without in any way lessening the Bureau's contribution to agriculture.

President Franklin Delano Roosevelt
(June 30, 1940)

No. 236
(Assembled)

C

UNITED STATES CIVIL SERVICE EXAMINATION

JUNIOR OBSERVER IN METEOROLOGY, $1,320

APPLICATIONS MUST BE ON FILE AT WASHINGTON, D. C., NOT LATER THAN JULY 24, 1926

THE DATE FOR ASSEMBLING OF COMPETITORS WILL BE STATED ON THE ADMISSION CARDS SENT APPLICANTS AFTER THE CLOSE OF RECEIPT OF APPLICATIONS

A PERSON WHO ENTERS THIS EXAMINATION WILL NOT BE ALLOWED TO ENTER ANY OTHER EXAMINATION FOR WHICH THE RECEIPT OF APPLICATIONS WILL CLOSE ON THE DATE INDICATED ABOVE

The United States Civil Service Commission announces an open competitive examination for **Junior Observer in Meteorology**, to be held at any of the places listed hereon at which examination is requested in applications received by the Commission at Washington, D. C., on or before the date indicated above. Vacancies in the Weather Bureau throughout the United States, and in positions requiring similar qualifications, will be filled from this examination, unless it is found in the interest of the service to fill any vacancy by reinstatement, transfer, or promotion.

Salary and promotion.—The entrance salary for this position is $1,320 a year. After the probational period required by the civil-service act and rules, advancement in pay, without material change in duties, may be made to higher rates within the pay range for the grade, up to a maximum of $1,680 a year. Promotion to higher grades of observer, with salaries up to $2,400 a year, may be made in accordance with the civil-service rules as vacancies occur, provided the employees possess the qualifications deemed necessary for the corresponding advance in duties and responsibilities.

Certification for field service.—In filling vacancies in positions with headquarters outside of Washington, D. C., certification will be made of the highest eligibles examined nearest the place at which the appointee is to be employed, except that upon the request of the department certification will be made of the highest eligibles on the register for the entire country who have not expressed unwillingness to accept appointment where the vacancy exists.

Citizenship and sex.—All citizens of the United States who meet the requirements, both men and women, may enter this examination; appointing officers, however, have the legal right to specify the sex desired in requesting certification of eligibles. For these positions in the Weather Bureau men are desired. Persons who are unable to accept appointment at a distance from their places of residence, or who would be unwilling or unable to transfer to other stations where their services are required after appointment, because of marital dependents, will not be considered for appointment to this position.

False statements.—False statements in applications concerning age or other matters affecting the applicant's eligibility will result in cancellation of examination and debarment from future examinations, and removal from service in case of appointment.

Duties.—The duties of the junior observer are to perform under immediate supervision, ordinary routine work in meteorology, such as to take regular meteorological readings and to code and decode telegraphic data; to clean and care for the instrumental equipment at a moderate-sized station; to assist in checking, correcting, and computing various climatological and aerological forms and records; to make chalk plates and stereotype casts for weather maps.

Subjects and weights.—Competitors will be rated on the following subjects, which will have the relative weights indicated:

	Subjects	*Weights*
1.	Meteorology and physics	30
2.	English composition on some meteorological subject	20
3.	Mathematics (arithmetic and algebra through quadratics)	20
4.	Geography of the United States	10
5.	Education, training, and experience	20
	Total	100

Ratings required.—Competitors must attain a rating of at least 60 (exclusive of preference allowances) in the first subject, Meteorology and physics, otherwise the remaining subjects of their examination will not be rated. They must also attain an eligible average in the whole examination.

Education and experience.—Under the fifth subject applicants must show that they have been graduated from a full four years' high-school course or that they have completed fourteen units of work acceptable for college entrance, such education to have included the completion of a one-year's course in physics; provided, that applicants who do not fully meet this requirement, but who have completed a one-year's high-school course in physics and who are otherwise qualified, will be admitted to the examination subject to their qualifying in a noncompetitive mental test, in which they will be required to attain a rating of at least 50, exclusive of preference allowances. This test will occupy one hour and fifteen minutes.

For the purposes of this examination the completion of one semester of a course in physics in a college or university of recognized standing will be considered as equivalent to one year's high-school course in physics.

Statements as to education, training, and experience are accepted subject to verification.

Age.—Applicants must have reached their eighteenth but not their thirty-fifth birthday on the date of the examination. These age limits do not apply to persons entitled to preference because of military or naval service, but such applicants must not have reached the retirement age.

Retirement.—Classified employees who have reached the retirement age and have served fifteen years are entitled to retirement with an annuity. The retirement age for positions of this kind is 70 years. A deduction of 2½ per cent is made from the monthly salary to provide for this annuity, which will be returned to persons leaving the service before retirement with 4 per cent interest, compounded annually.

Photographs.—Applicants must submit to the examiner on the day of the examination their photographs, taken within two years, with their names written thereon, and *securely pasted* in the space provided on the admission cards sent them after their applications are filed. Proofs or group photographs will not be accepted. Photographs will not be returned to applicants.

Residence and domicile.—Applicants may be examined at any place at which this examination is held, regardless of their place of residence; but only those who have been actually domiciled in the State in which they reside for at least one year next preceding the examination may become eligible for permanent appointment to the apportioned service in Washington, D. C.

Applicants desiring appointment to the apportioned service in Washington, D. C., must have the county officer's certificate of residence in the application form executed.

Physical examination of appointees.—In view of the benefits granted employees under employees' compensation and retirement legislation, persons appointed may be given a physical examination by a physician in the Federal service before entering on duty.

Applications.—Applicants should at once apply for Form 2415, stating the title of the examination desired, to the United States Civil Service Commission, Washington, D. C., or to the Secretary of the United States Civil Service Board at any place listed hereon. Applications should be properly executed, **excluding the medical certificate**, and must be filed with the United States Civil Service Commission at Washington, D. C., on or before the date indicated above.

The exact title of the examination desired, as given at the head of this announcement, should be stated in the application form.

Preference.—Applicants entitled to preference because of military or naval service should *attach to their applications* their original discharge, or a photostat or certified copy thereof, or their official record of service. If, because of disability, the applicant is entitled to a pension under authorization of the Bureau of Pensions, or to compensation or training under the Veterans' Bureau, he should also *attach to application* his pension certificate, or a certified copy thereof, or a certificate from the Veterans' Bureau showing that he is entitled to pensation or training by that Bureau. Such papers will be returned to the applicant.

Issued June 14, 1926. 41. SP-3 GOVERNMENT PRINTING OFFICE

Weather Bureau Announcement for Junior Observers (1926).

WEATHER OFFICES AND OBSERVATIONS

During the early 1900s, Weather Bureau offices generally consisted of two rooms. The larger room contained a rolltop desk for the meteorologist-in-charge. The room also contained two smaller desks for the two assistants, a stand-up desk for weather-map analysis, and a display cabinet on which was located a "triple register," so called because it recorded the weather elements of wind, rain, and sunshine. All furniture was in solid oak.

There was also a large brass cuspidor, liberally used in those days, and kept shining by the janitor who otherwise paid little attention to the room. The floor was decorated with a number of brown spots, the result of an occasional inaccurate aim at the cuspidor. Above this main room was an access to a three-story tower, on the top of which were the weather instruments: a rain gage, anemometer and wind vane, sunshine sensor, psychrometer, and thermometers and a thermograph. The rain gage, wind instruments, and sunshine sensor were connected electrically to the triple register downstairs.

Signal Service weather office in South Dakota (circa 1890). Instrument shelter is attached to the building with the wind equipment located to the rear of the building.

Chief, Weather Bureau
September 25, 1922
Washington, D.C.

Sir:

It is my honor to report that I have worked the last two years without a day off. I go to work at 6 AM to make the morning request, and stay to make the evening forecast. I have trained one of the observers to make forecasts and ask that he be given permission to make the evening forecasts.

Very Respectfully

Author's Note – Permission was granted by the Chief of the Weather Bureau.

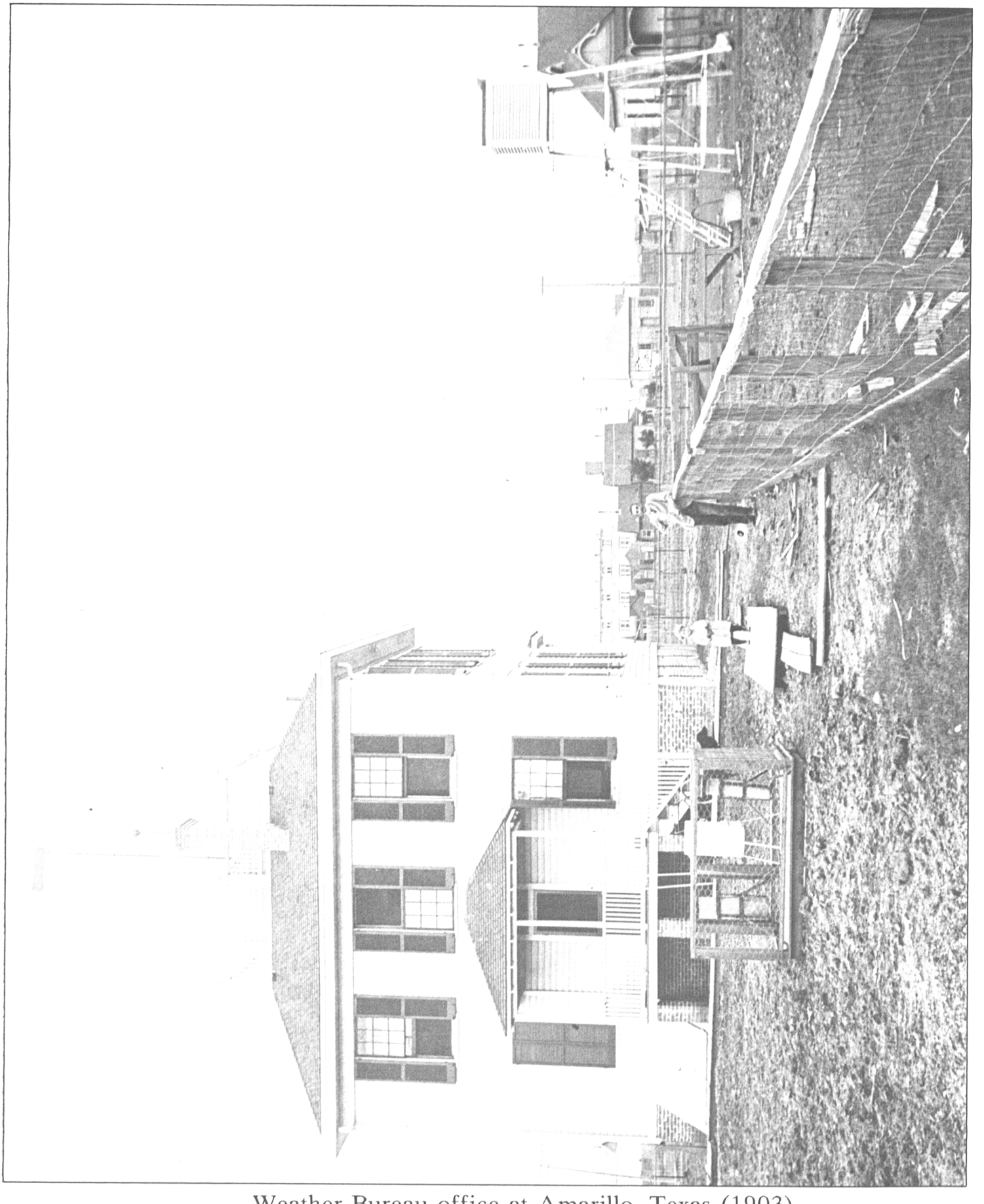
Not all reports from the Signal Service stations dealt with weather observations. For example, the following memo was concerned with locusts:

WAR DEPARTMENT, OFFICE OF THE
CHIEF SIGNAL - OFFICER,
DIVISION OF TELEGRAMS AND REPORTS
FOR THE
BENEFIT OF COMMERCE AND
AGRICULTURE

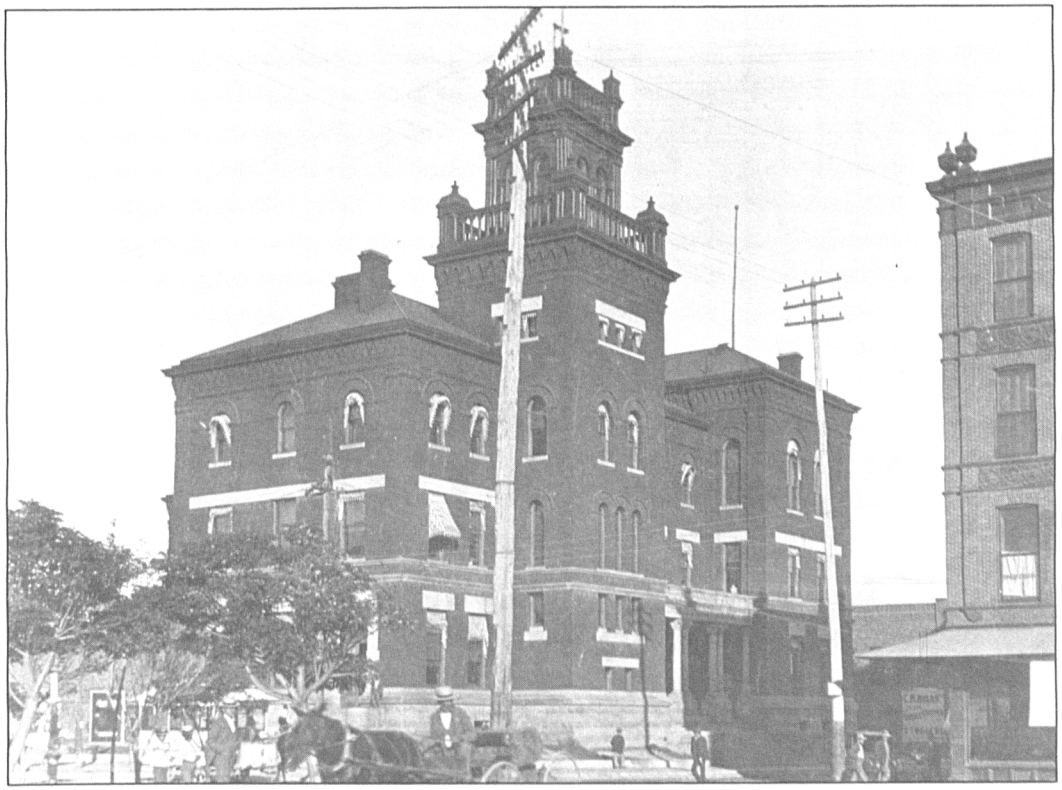
Washington, D.C., May 17, 1877.

SERGEANT: Should the Rocky Mountain locust appear at or near your station at any time during the present year, you will obtain all the information possible relative to the following subjects, viz: The date of appearance of the locusts; the direction from which they came; the direction and velocity of wind and character of weather at time of appearance; the length of time they remain in your neighborhood, and amount of damage done by them; the direction and velocity of flight; direction of flight when they leave your station; whether they fly with or against the wind; whether or not they laid eggs in great quantities in the surrounding country; what means were taken to destroy the eggs or the locusts; any other information you can obtain on this subject. Should the locusts have arrived at your station previous to the receipt of this communication, you will obtain all the information possible from the citizens residing near you and forward it without delay to this office. Make full notes in your daily journal in regard to locusts and forward the same with the abstract.

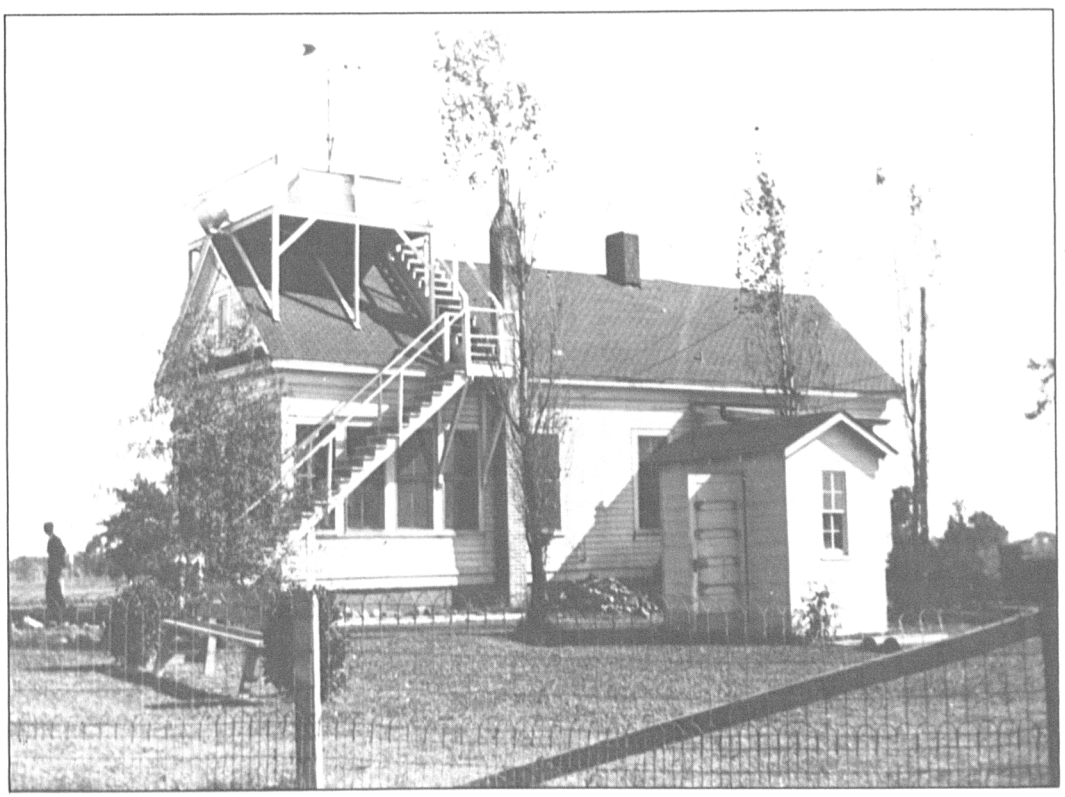
Very respectfully,



Weather Bureau office at Amarillo, Texas (1903).



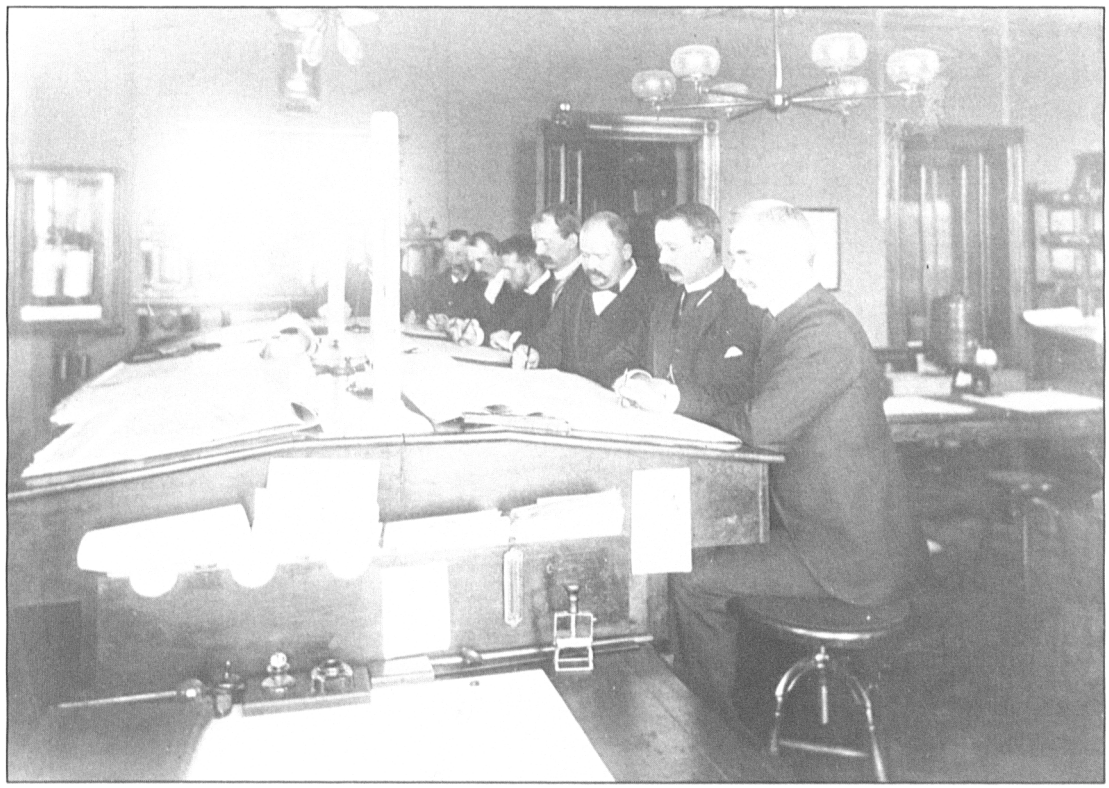
In the 1880s, the Signal Service office at El Paso, Texas, was located in this Court House.



Weather Bureau Office at Jackson, Mississippi (1933).

Weather Bureau Office at Lambert Field (St. Louis) in 1942.

Weather Bureau Office at Lander, Wyoming (1946).

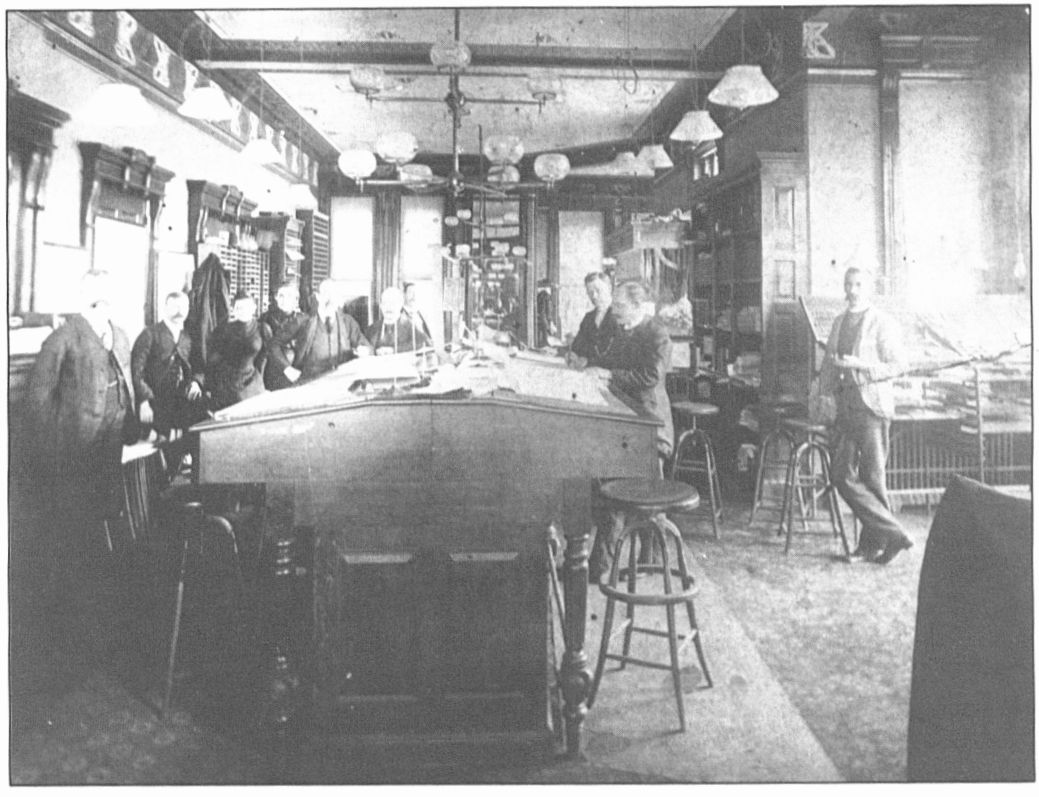


District Forecast Office (location unknown) about 1920.

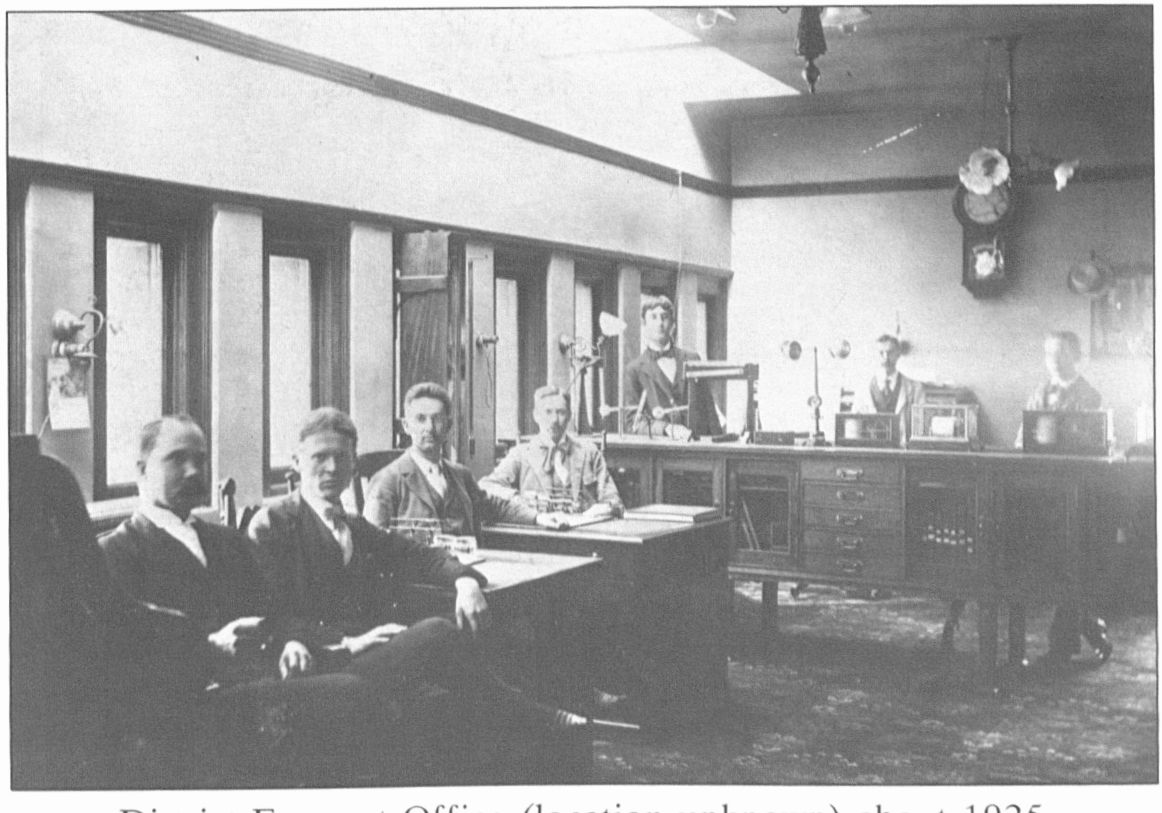
Weather Bureau Office at Juneau, Alaska (1940).

District Forecast Office (location unknown) during the 1920s. In Weather Bureau offices through the 1940s, roll-top desks (center of photograph) were used by Meteorologists-in-Charge.

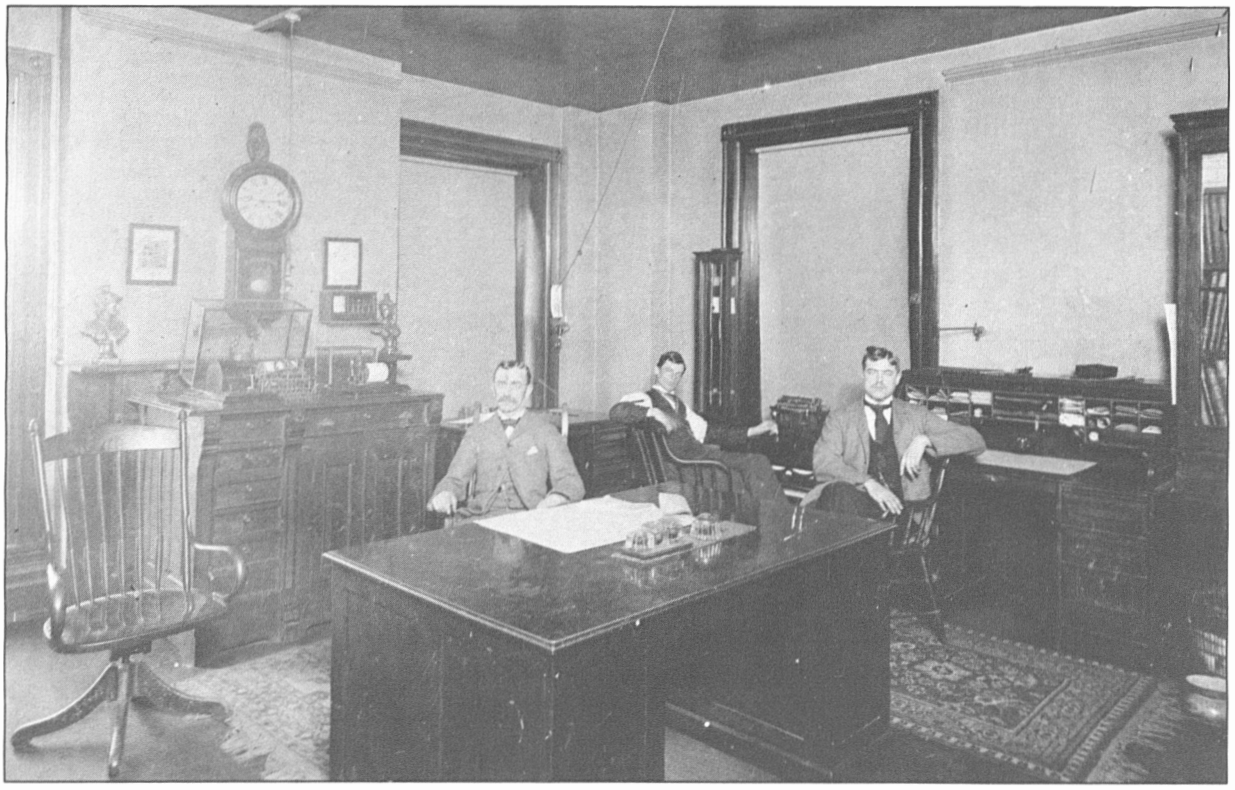
Weather Bureau Office at Montgomery, Alabama (1930).



District Forecast Office (location unknown) about 1910.



District Forecast Office (location unknown) about 1925.

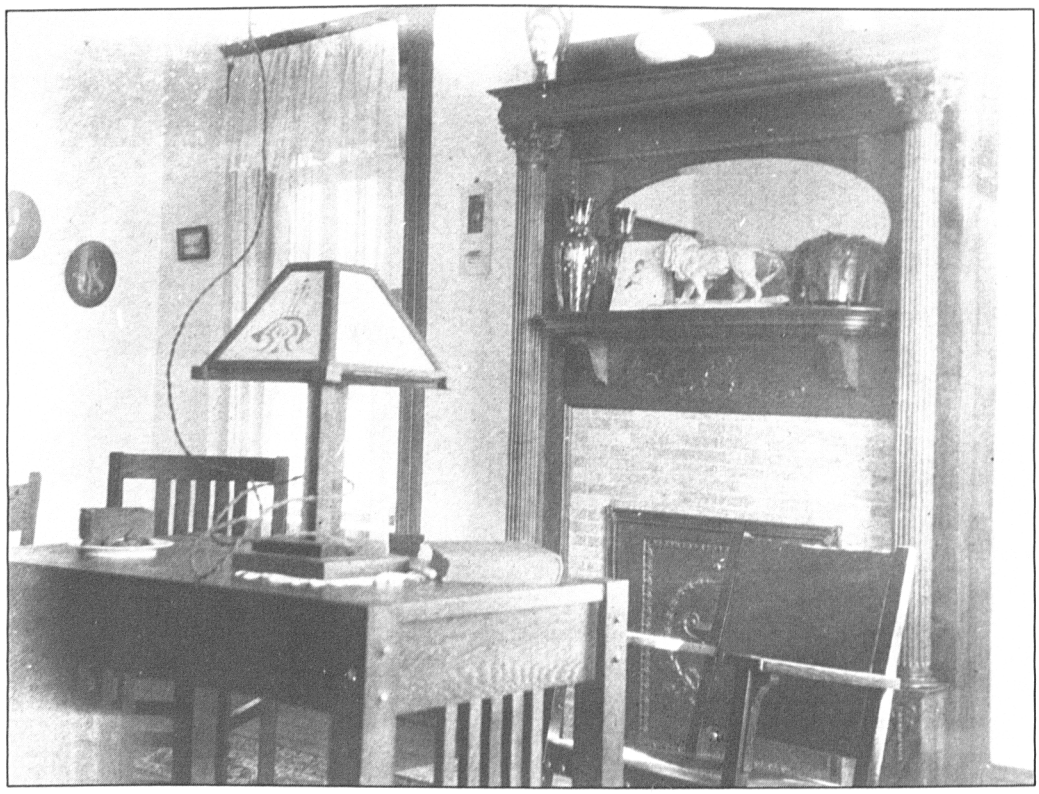


Local Weather Bureau Office in Buffalo, New York (circa 1920s).

District Forecast Office in Chicago, Illinois (1944).

Weather Bureau building in Canton, New York (1915). Weather Bureau offices were located on the first floor (above ground level); (see page 23) and the top floor contained quarters for the family of the Meteorologists-in-Charge (see pages 23 and 24). Because of the nearness of living quarters to the office, Meteorologists-in-Charge were expected to work long, hard hours.

Working area of Weather Bureau building in Canton, New York (page 22).



Family quarters of the Weather Bureau building in Canton, New York (page 22).

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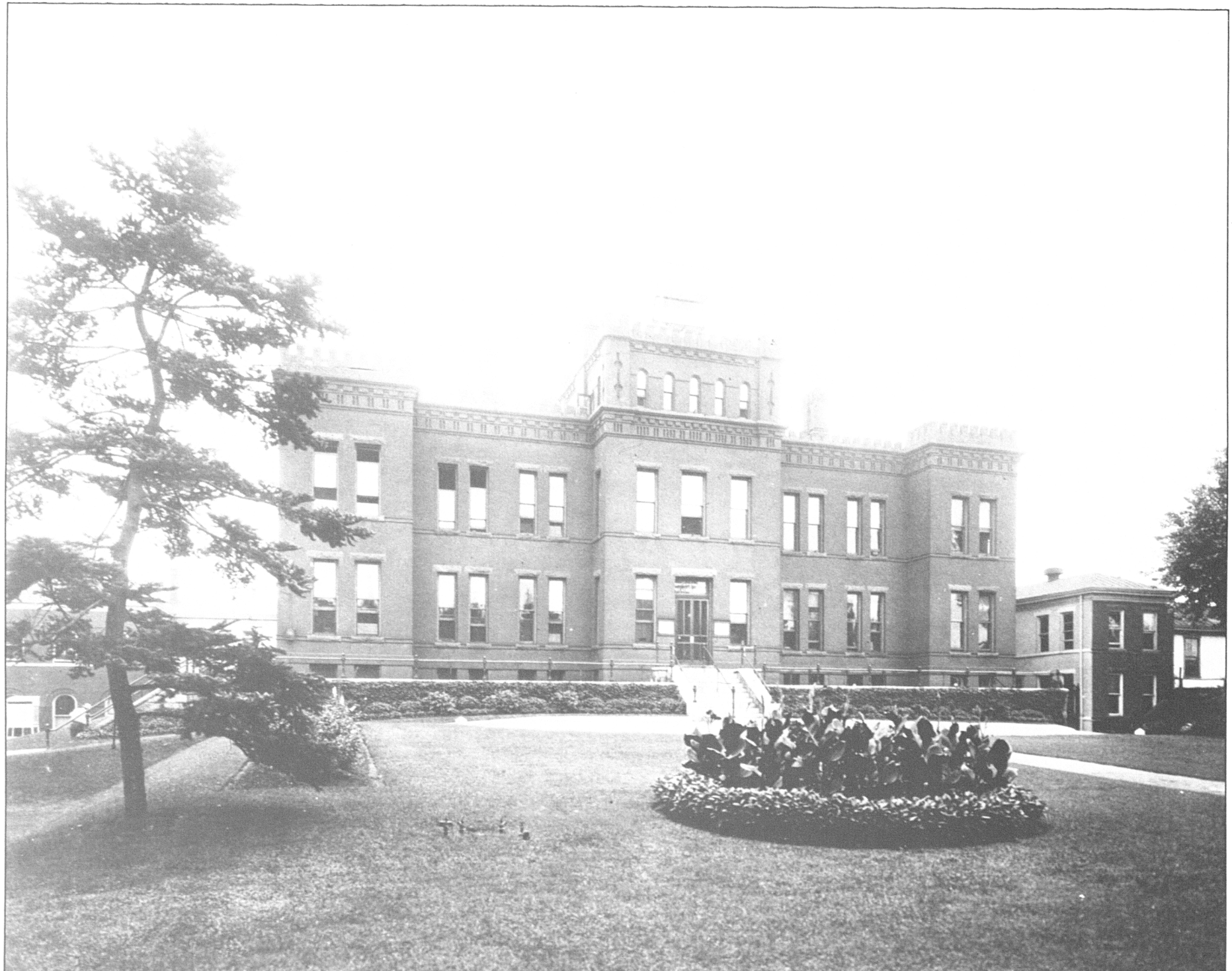
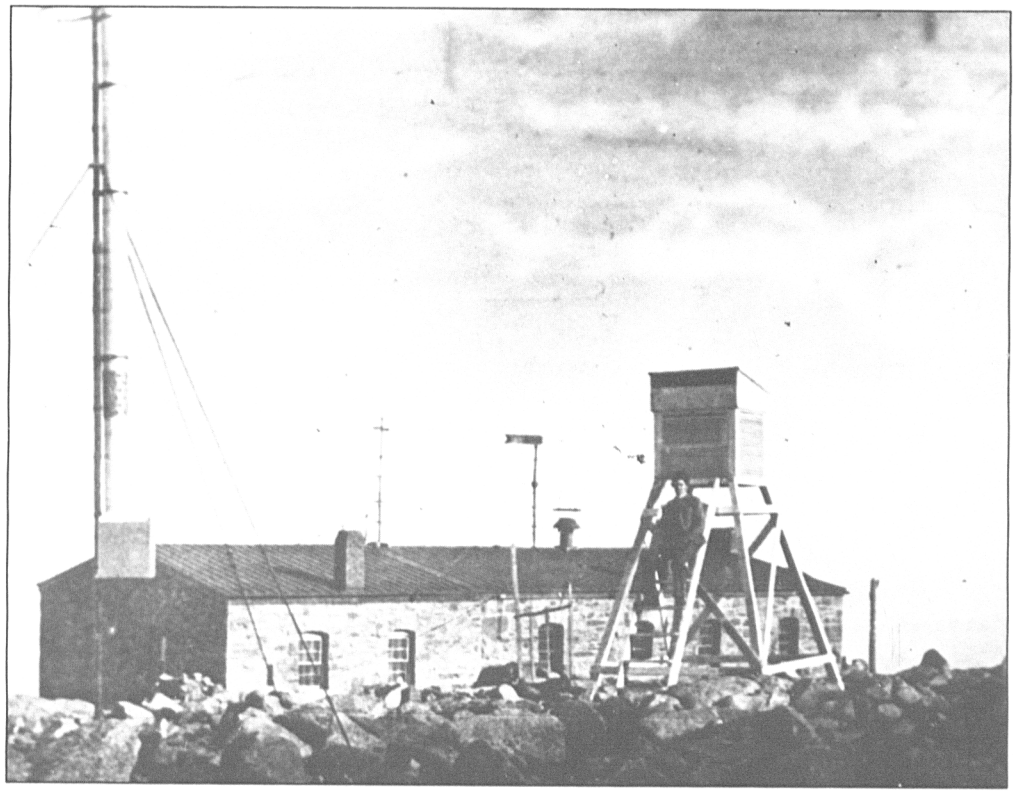
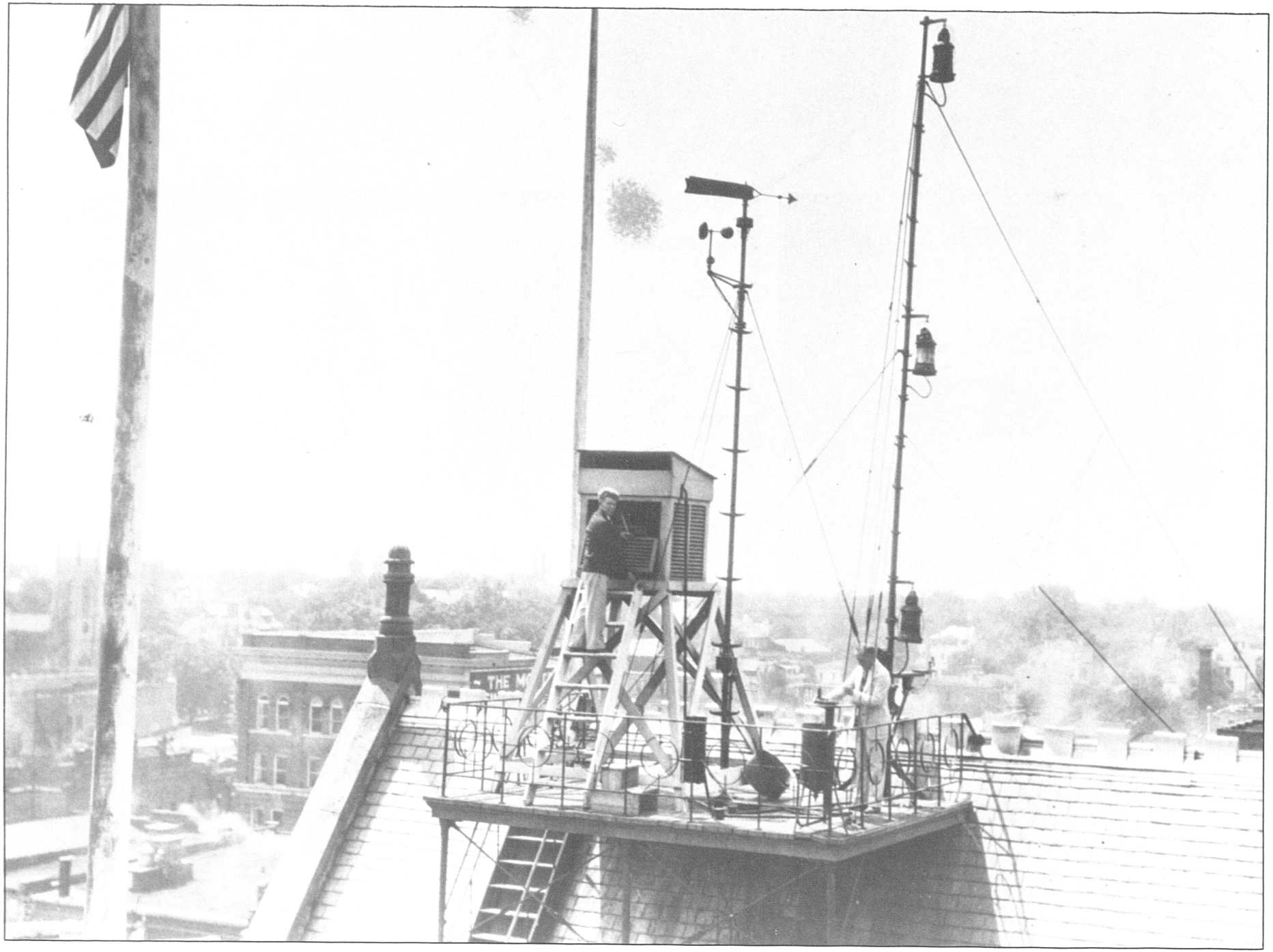


Central Headquarters in Washington, D.C. Called the "Old Ferguson Building," it served as Signal Service and Weather Bureau Headquarters from 1888 to 1941.

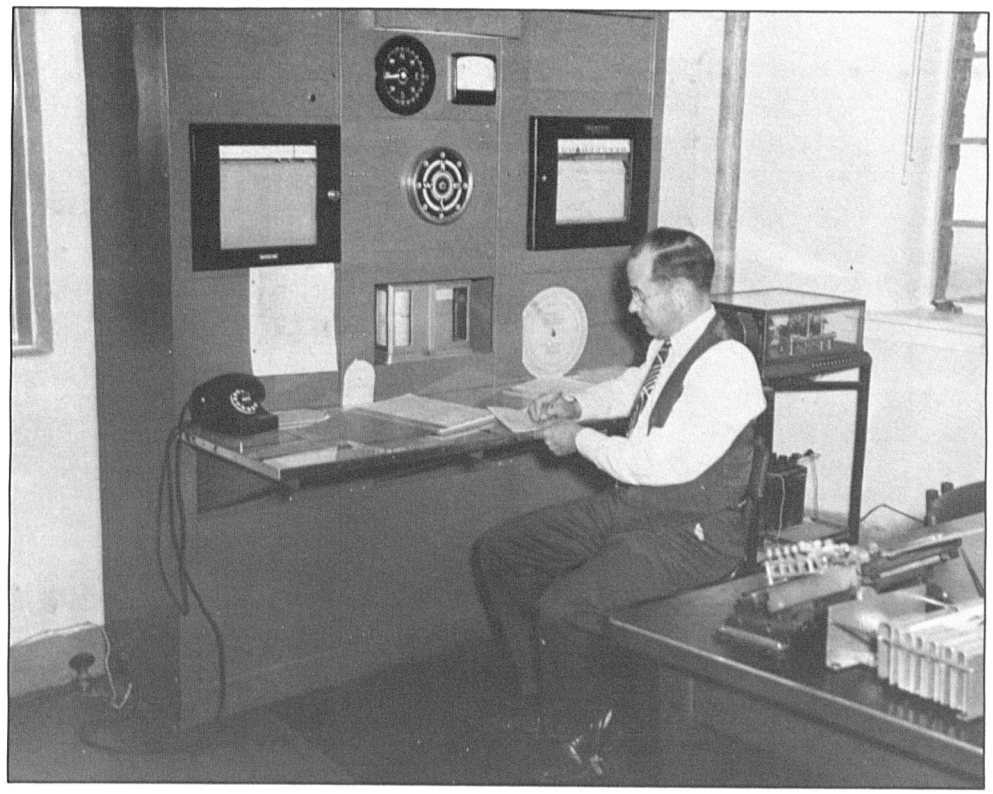


Weather Bureau Office at summit of Pikes Peak, Colorado (circa 1890).

Weather Bureau Office at Mt. Tamalpais, California (circa 1900).



Surface instruments on top of the Post Office building at Wilmington, North Carolina (circa 1930).

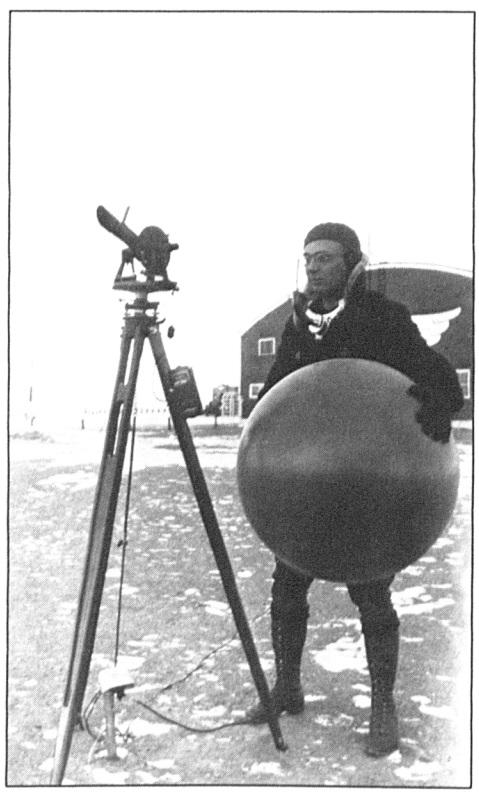


Logging a surface observation (circa 1935).

Adoption of the Millibar as a Unit of Measurement

In 1912, Bjerknes suggested to the International Commission on Scientific Aeronautics that the millibar be adopted as the only unit of pressure to appear in publications of the commission. According to Bjerknes, the use of the millibar would "...tie together the different threads formed up to this time in the development of observational meteorology and theoretical thermo-hydrodynamics." After great controversy, the commission decided that, "...in the publications of the International Commission the pressure must be expressed not in millimeters of mercury, but rather in bars or in some decimal fractions of the latter..." Following this policy statement, sharp objections were published, criticizing the introduction of the new units; however, the use of millibars was confirmed by the meteorological community in 1929.

Taking a Pilot Balloon observation (1942).



Preparing for a Pilot Balloon observation at Rocksprings, Wyoming (1932).

Weather Bureau volunteers take Pilot Balloon observation in the North Atlantic during World War II.

Observer ready to launch a radiosonde at Lander, Wyoming, during World War II.

KITES

Sporadic efforts were made as early as the eighteenth century to obtain measurements of the upper atmosphere. In 1749, thermometers were tied to kites for the purpose of taking upperair observations. Also, some of the eighteenth century observations were from balloon enthusiasts. However, balloons with humans usually sampled the lower atmosphere, at least until 1852 when John Welsh rose to over 21,000 feet above the English countryside, taking observations of temperature, pressure and humidity.

During the 1870s, the United States Signal Service established the first mountaintop weather observatories on Mount Washington, New Hampshire (6,300 feet) and on Pikes Peak, Colorado (14,100 feet). The continuous observations at these stations, when compared with similar observations at nearby lowland or valley stations, provided limited evidence on the vertical structure of the atmosphere.

Although mountaintop information was of research value, attempts to use the daily telegraphed reports in the formulation of daily forecasts were unsuccessful; consequently, the mountain observatories in the United States were closed.

In 1893, the first recording instruments, or meteorographs, were sent up on small free balloons by Hermite and Besancon in France, and a year later instruments were sent up in box kites by Rotch and Fergusson in the United States. In 1895, Professor Charles F. Marvin, a future chief of the Weather Bureau, began experimenting with kites, and in 1896, he perfected his kite meteorograph, an instrument capable of measuring and recording temperature, pressure, and humidity. On the meteorograph, pressure, temperature, and humidity were recorded by pens tracings on paper, or on a smoked copper sheet, which was attached to a clock rotated drum.

On April 27th, 1898, the first Weather Bureau kite was launched from Topeka, Kansas, and by the end of the year, 16 additional kite stations were attempting daily, early morning, simultaneous observations. From these kite stations, considerable information was obtained concerning the temperature profile of the lower atmosphere over a wide area of the central United States. This kite network was short lived; however, considerable experience was gained regarding kite construction and launching procedures which would be used widely by later kite observing networks.

Kites were not limited to the lower part of the troposphere. The average height of kite observations was 8,700 feet, although in 1907, one flight reached 23,111 feet, for which the Weather Bureau claimed a world record. In 1907 a regularly scheduled program of kite observations was begun. Though it never involved more than seven stations, this programed probing of the atmosphere continued for a quarter of a century.

Kites were seldom trouble free. Piano wire was used and flight times were generally four to five hours. Since kites could attain great heights with corresponding strong winds, "runaway" kites frequently caused serious problems. In one instance, the wire to a string of kites broke in south Texas. As the kites and trailing wire moved east, all telegraph lines between Dallas and Houston were cut.

The meteorograph, was attached to the lead kite in such a way that air could pass freely through the sensors for pressure, temperature and humidity. The pressure element was similar to an aneroid barometer. The temperature element was made of "thermostatic" metal consisting of closely spaced strips of "invar" and bronze. Difference in thermal expansion rates were used to measure the temperature. The humidity element was a hair hygrometer. All three elements were connected to pins which made lines on a clock-driven graph. Wind velocity was recorded by a small anemometer placed in the forward end (with respect to the wind) of the kite. In appearance, it closely resembled a small electric fan. As the anemometer fan rotated, it also made a mark on the clock-driven graph.

As many as seven kites would be attached to the kite wire during an observation. These kites were placed at regular intervals with the second kite about 1,500 feet behind the lead (or head) kite, the third about 2,000 feet behind the second, and the fourth about 2,500 feet behind the third. The 2,500 foot spacing would continue for each additional kite.

Ordinarily, the kites were reeled in when the dynamometer on the reel indicated the pull of the kites exceeded 200 pounds. Also, extra kites were forbidden to be launched when the pull was between 160 and 200 pounds, although this depended on the number of kites in flight.

The kites were large "box types" with dimensions of 8 feet long, 7 feet wide, and 3 feet high. They were made from Oregon Spruce, a strong, light wood, and covered with silk fabric. Each kite normally weighed about 12 pounds. They were received at the Weather Bureau stations in kits and assembled to rigid specifications.

Because of the large area required to launch kites, the country surrounding the kite stations was generally free of obstructions. Kite stations also were located within an area of good roads which could be used to recover "runaway" kites. The Weather Bureau selected sites with open country to the east of the site and with a small town located about one mile to the west. The plot used as a kite field usually was square and comprised about 40 acres.

The kite station consisted of a main building, about two stories tall, with space for a carpenter shop and storage. Also, located on the site was a reel house which contained the reel and the accompanying electric motor.

A typical kite station consisted of four Civil Service employees and three general laborers. Normal shift rotation for the civil servants consisted of one week launching kites, one week taking pilot balloon (PIBAL) observations, and one week posting and checking station records.

Kite flights were made daily with each flight lasting about three hours. Prior to kite release, a PIBAL observation would be made to measure the speed and direction of the upper-level winds. The strength of the winds determined the type of kites to be used.

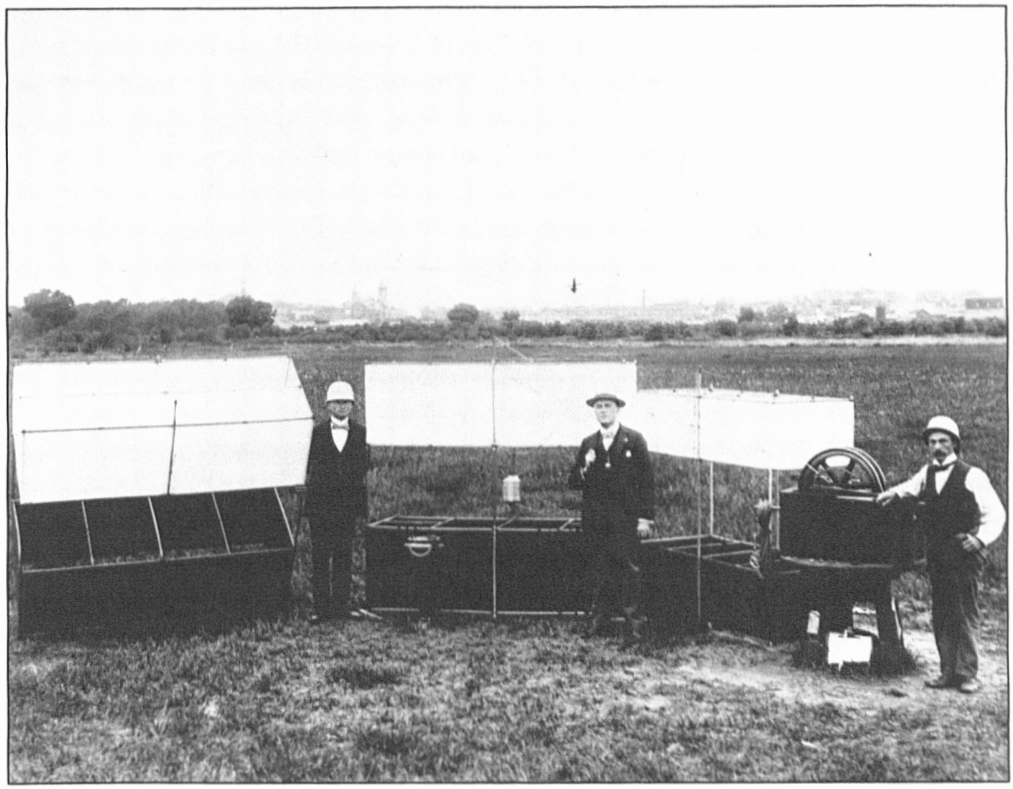
At least two people were required to make a flight, with one to operate the electric reel and another to launch the kite. The kite was tied to the reel by 12 gauge metal piano wire (350 pound strength). Up to 14 miles of wire were on the reel. Weather Bureau instructions called for the man holding the kite to carry it away from the reel house downwind (surface wind), holding it at an angle of about 45 degrees with the horizon, and keeping a good tension on the wire attached to the reel. In moderate winds, the kite was taken about 75 yards from the reel house and during a light wind the kite would be carried over 100 yards from the reel. The electric reel would be turned on, pulling the kite toward the reel house, and causing it to become airborne. When the kite was aloft, the reel would be reversed, permitting the kite to rise.

Lightning was a serious problem. Existing government regulations stated that all personnel would abandon the kites and reel house when thunderstorms were in the vicinity. Government regulations also required operators to wear rubber gloves and boots. Numerous kites and many miles of wire were destroyed by lightning strikes.

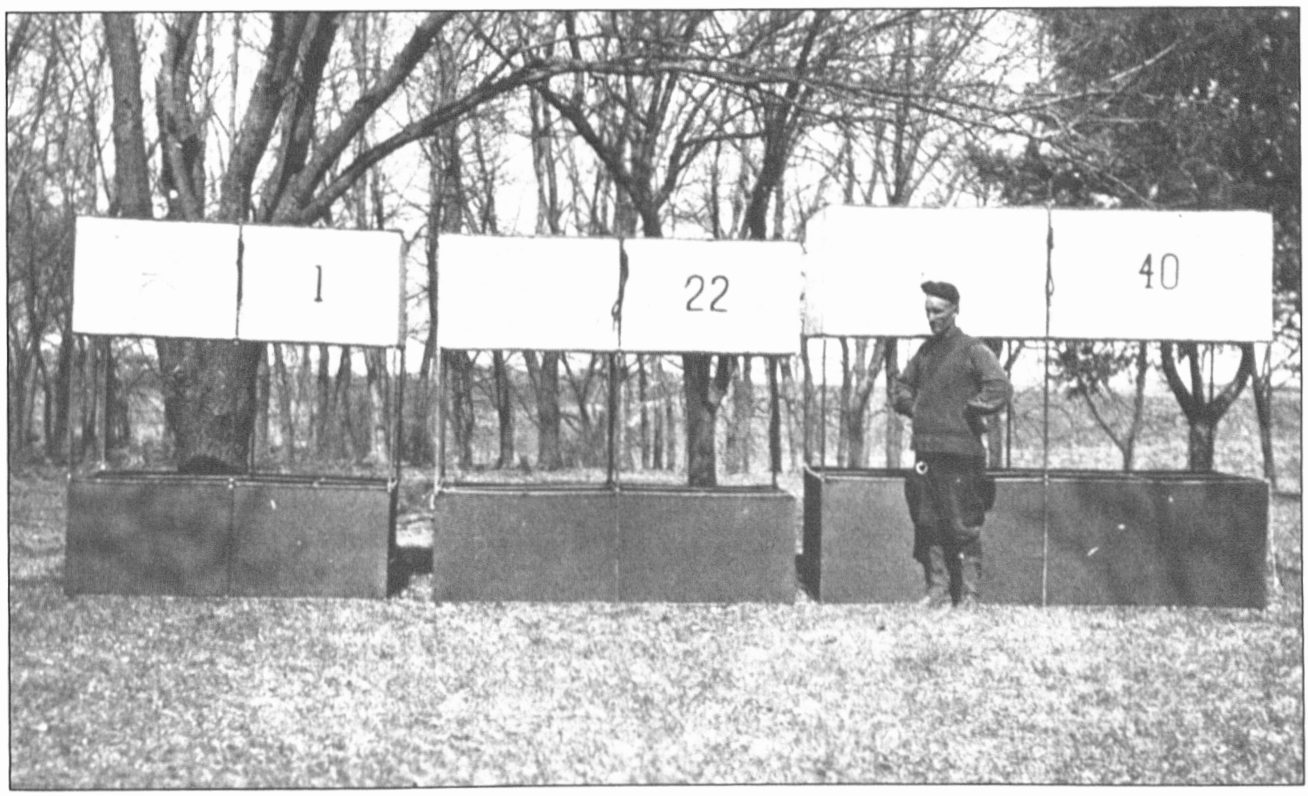
Electrical shocks also could occur without lightning. This usually occurred well in advance of thunderstorms (it also was possible during other situations) when the electrical potential between the atmosphere and earth's surface increased. Since the kite may have extended up to several miles across this potential, the flow of electricity could be induced along the metal wire.

The Weather Bureau used weather kites from the late 1890s to the mid 1930s when they were replaced by airplane observations. Kite observations were discontinued for several reasons. Airplanes were becoming more numerous, and the miles of kite wire during observations was dangerous for flights. Also, high voltage power lines were expanding across the country and kites were falling across these lines, causing fire and safety hazards. Airplane performance was being perfected for high altitude flight, paving the way for routine airplane upper-air observations.

WEATHER
BUREAU
KITE.



Early kite observers at Dodge City, Kansas (circa 1900).



Three sizes of kites.

Chasing a Runaway Kite
(told by a kite observer in 1921)

At Broken Arrow, Oklahoma (1921), the steel wire, which is used as a line, was defective and broke at a pull of 200 pounds, releasing 3 kites and 4700 meters of wire. They traveled about 4 kilometers east-southeast from the station when some coal miners seeing the wire dragging past, fastened it to a machine nearby. The wire carried a considerable electrical potential at the time, but these men were prevented from getting a shock because the end of the wire was on the ground. Station men arrived in a few minutes, clamped the wire fast and grounded it.

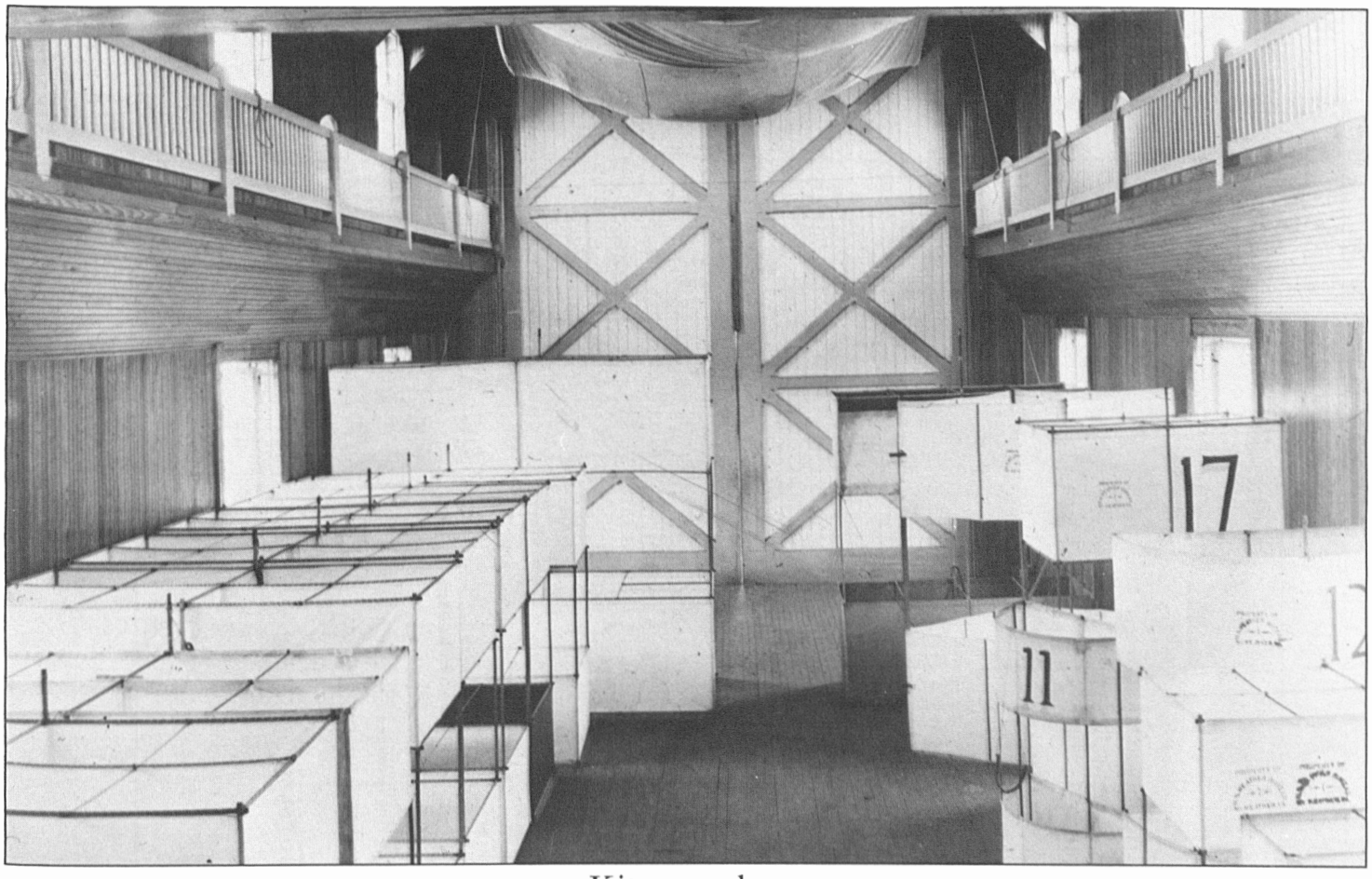
The first kite was landed and 3 kilometers wire was on the ground when the wire broke again, releasing the other two kites and 1700 meters of wire. We started immediately to follow them, but the roads were so muddy that we were soon left behind. After traveling 10 miles we came to a place where the kites were caught in the edge of a large forest in the Verdigris River bottoms. The end of the wire was tied around a small branch in the top of a 75-foot tree. As it was nearly dark and there was a strong probability that if the tree were cut, the wire would break loose again and the kites go farther into the forest, it was decided to return home.

Monday morning we returned to the scene; one kite was seen flying just below the clouds some distance within the forest. Foreseeing the possibility of having to fell some trees, we borrowed an ax and a cross-cut saw and started into the wood. The ground was covered in places with 3 or 4 inches standing water, and the only landmark was a creek which we followed.... After traveling about 2 kilometers into the forest a faint singing of the wire was heard, and eventually it was sighted 100 meters in the air. Some distance away it was caught in the tops of several tall trees.

After dinner the kite was lowered by wrapping the wire around the stumps of two saplings cut off for the purpose 4 feet above the ground. When the kite was within 500 meters it began to fall and came down in a small tree from which it was recovered undamaged.

This is the longest continuous flight ever made here. Although the wind had veered through 270 degrees and fallen to rather low velocities at times, the kites remained in the air about 52 hours. Other kites have gone farther, as on April 8, 1919, when 5 kites broke away and landed 6 hours later in Kansas, 160 miles to the station.

Although kites at this station have collapsed or broken away on numerous occasions, no material damage has ever befallen the delicate meteorograph which is carried in the head kite. This is partly the result of the way the instrument is tied in the kite, which acts as a spring for the instrument when the kite suffers any sudden jolt.

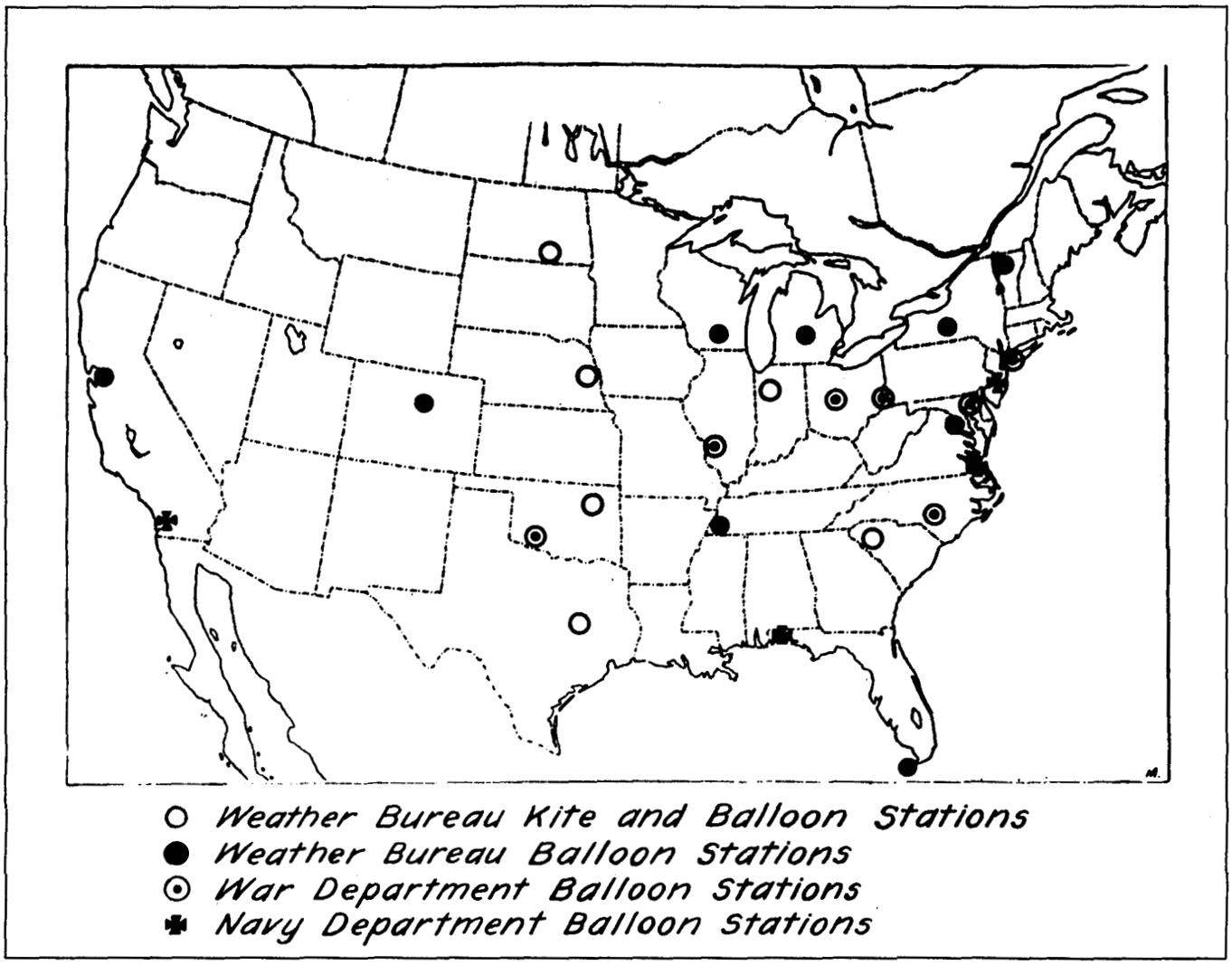


Kite warehouse.

Discovery of the Low–Level Jet Stream

(as told by a kite observer in 1898)

When, at an approximate elevation of 2,500 feet, we found a stronger wind than at the surface, we knew almost certainly that we should have it at the surface before the day was over. Now, it is true that wind velocities depend to a considerable extent upon the barometer changes, and the steepness of the gradients, but there are times in the Dakotas when quite marked depressions pass without much wind. It is noticed that when the barometer leaves us in doubt, the kite reveals the truth.

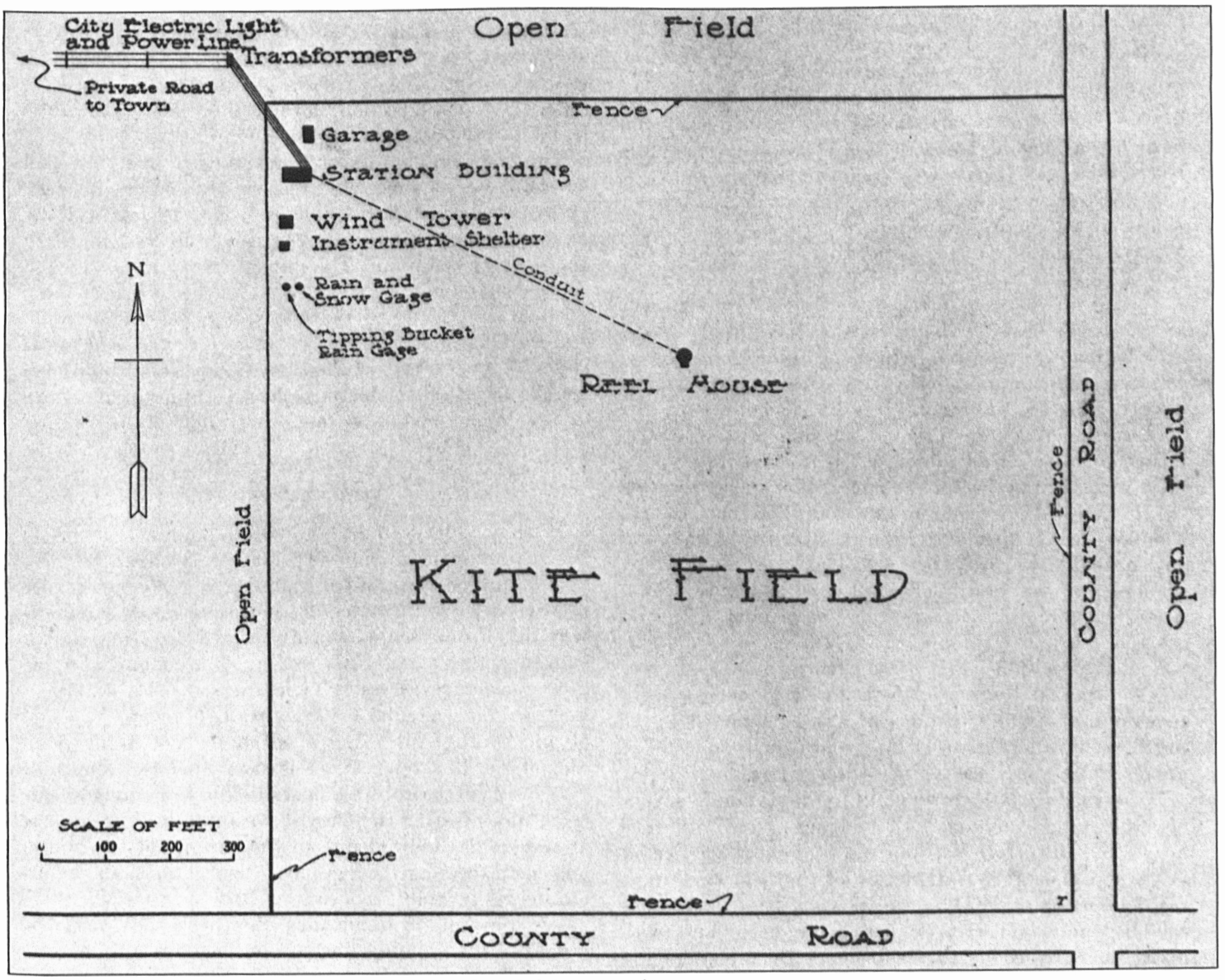


Kite and balloon stations in the United States (circa 1925).

Description of a Temperature Inversion

(as told by a kite observer)

It has been known for many years that the temperature of the air diminished with increasing altitude, but the details remained more or less obscure until revealed by the daily records brought down by kites. It has been found that there are many exceptions to the rule of decrease of temperature with the increase of altitude; thus, a great layer of warm air is sometimes found floating upon a layer of cold air. We noticed early in the summer that sometimes there were inversions of temperature through the first 2,500 feet of the atmosphere and slight decrease of temperature in the continuation of the ascent. Sometimes these inversions were marked--the temperature 2,500 feet above the ground being from 15 to 18 degrees (Fahrenheit) higher than at the surface. These occurrences were invariably followed by a hot wave, and the heat usually became high at the ground by the middle of the same afternoon, and surely so by that night or the next morning.



Standard kite station arrangement.

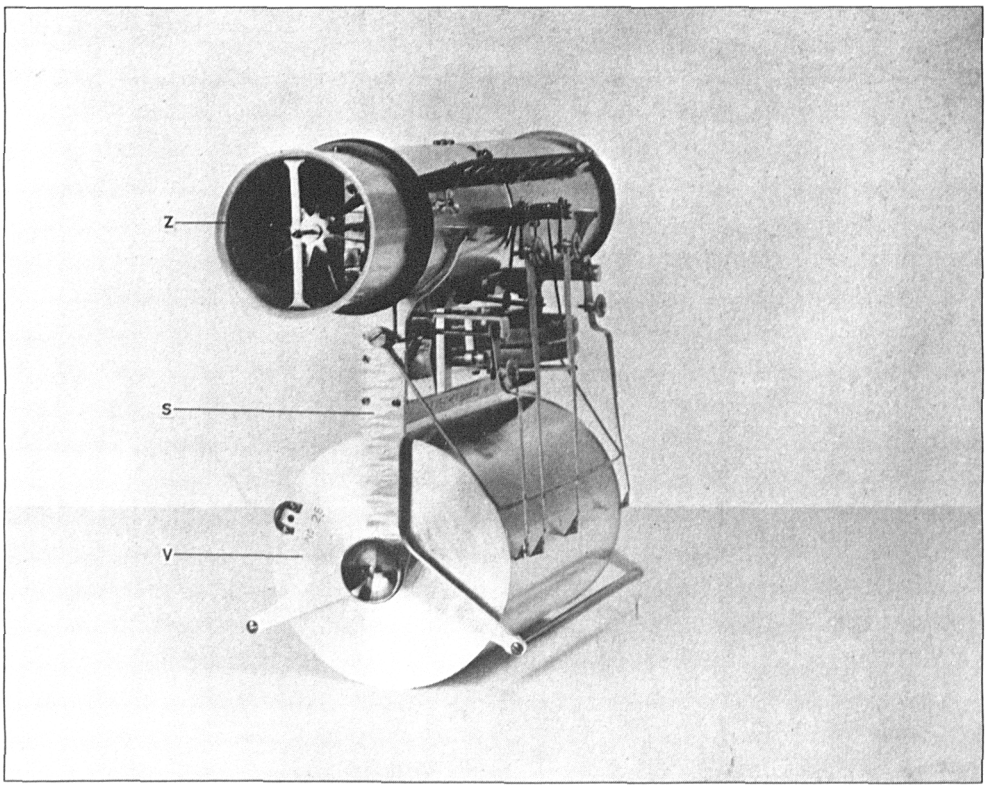
Encounter with a Thunderstorm

(as told by a kite observer)

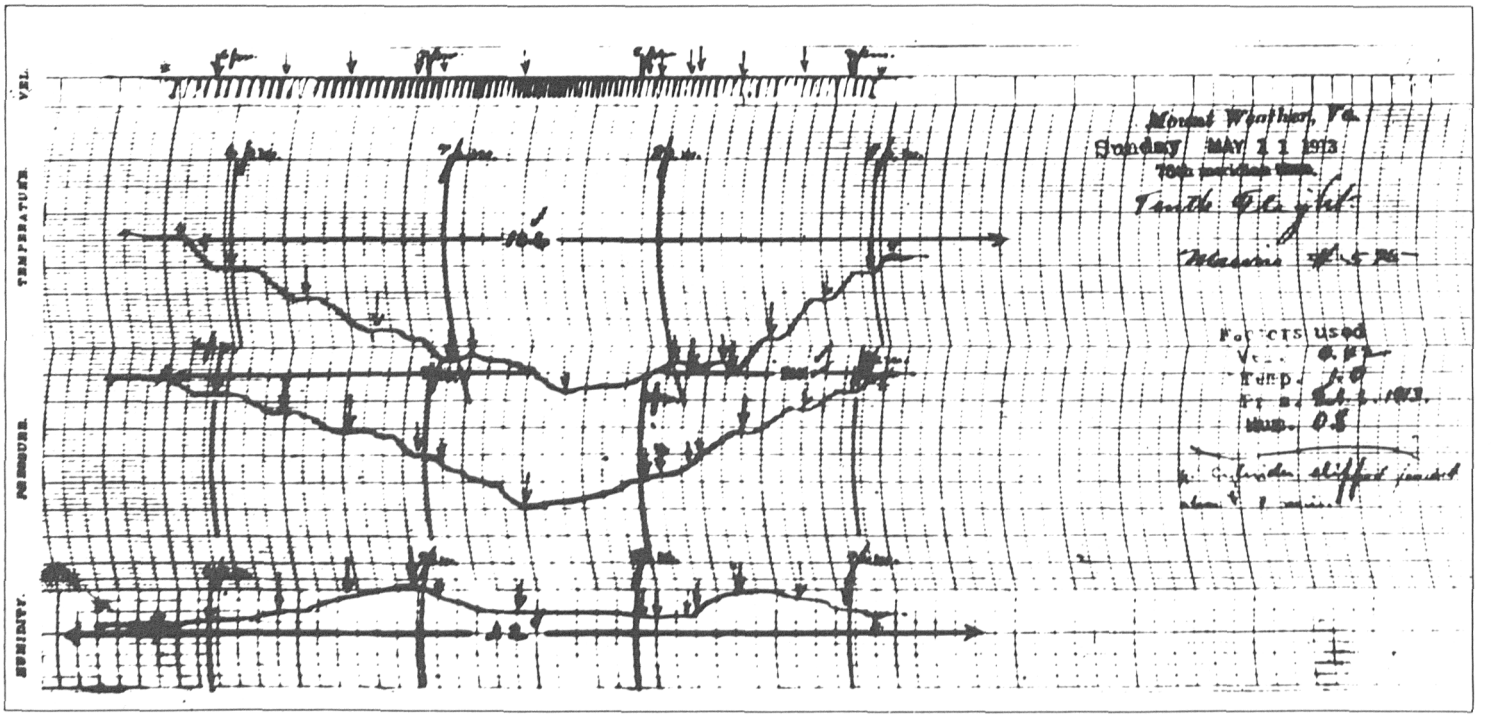
There seemed on May 31, 1898, to be a thunderstorm approaching; no lightning was visible or thunder audible, yet my reeler and I commenced to pull in the kite. When the kite was still 3,000 feet up, at the end of 5,000 feet of wire, a bolt from the clouds was seen, by others, to hit the kite. We stopped reeling; we had to. I have been nearly in front of a 6-inch naval rifle at its discharge, and its noise was very mild compared to the report which we heard at the reel. We were stunned for a brief period and the wire was ruined by the discharge. Fortunately, the kite reeler was rearing rubber overshoes, but I was not, and in consequence got a burn on the sole of my foot; this, however, was of small import in view of the experience gained.

Kite station building (see page 39).

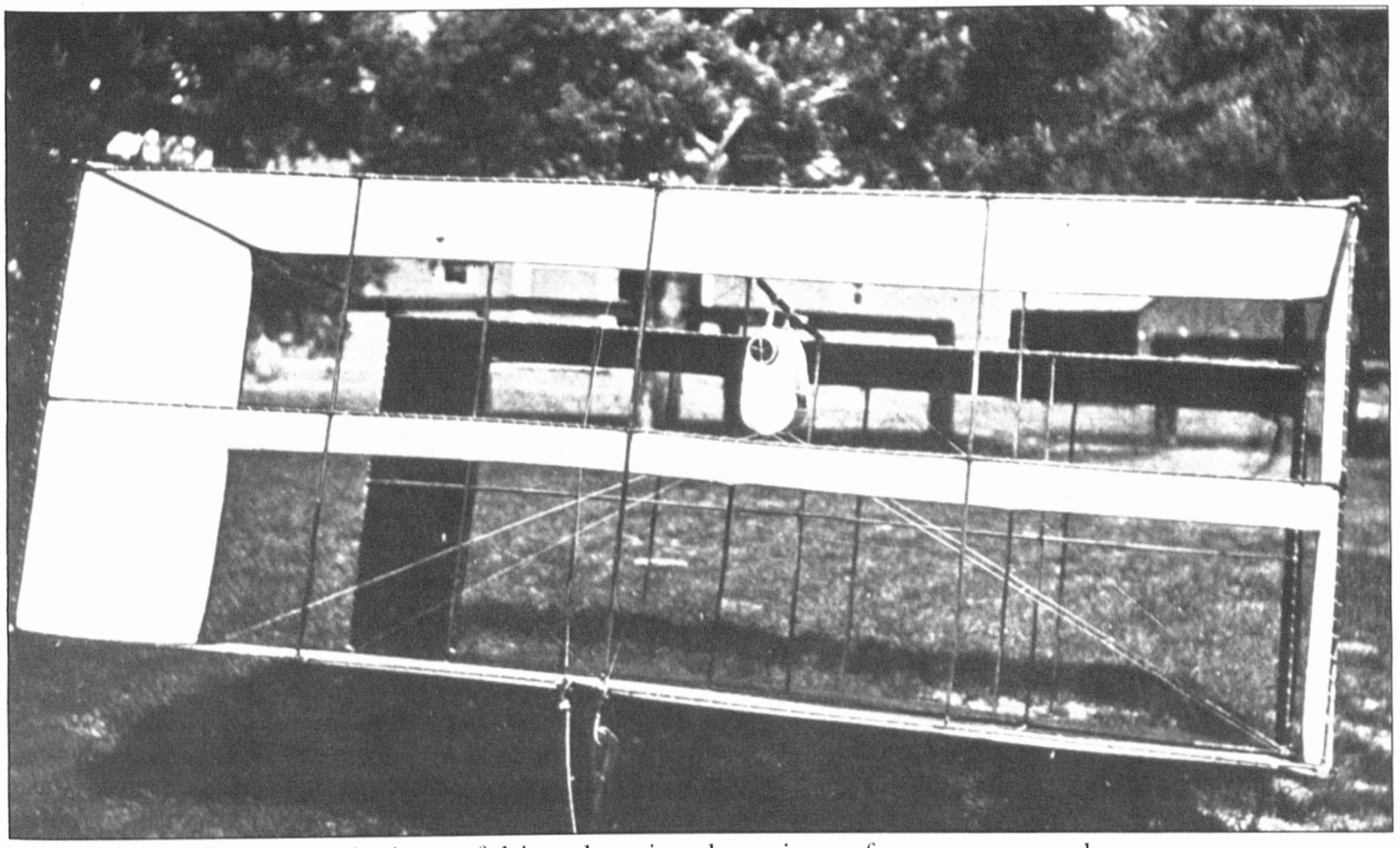
Kite reel house. Kite reel is located on right side of opening. Upper part of reel house rotated so that kites could be launched into the wind (see page 39).



End view of Marvin kite meteorograph. Recording drum (V) is located at bottom of instrument and temperature, humidity and pressure sensors are located on top smaller cylinder (Z). Anemometer located on inside of top cylinder.



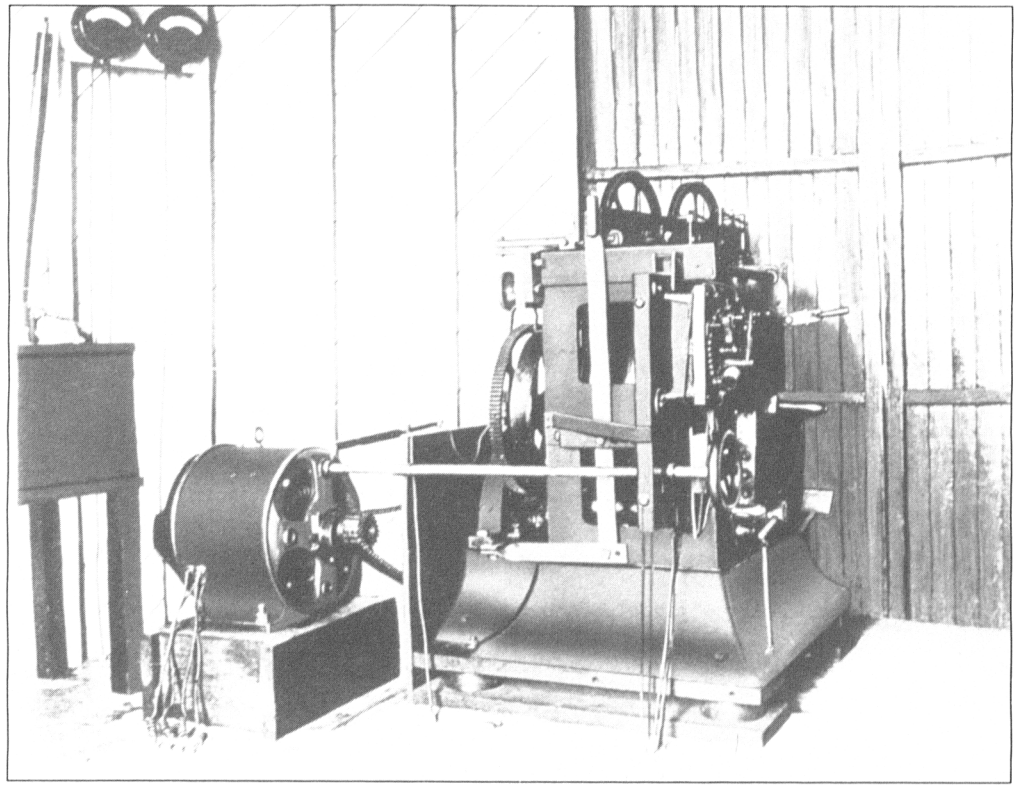
Meteorograph traces of temperature, pressure, and humidity from a kite flight.



End view of kite showing location of meteorograph.

Weather Bureau Instructions to Kite Observers

The circumstance of kites flying at a low angle is often associated with a stratified condition of the air, manifested by a brisk shallow wind, on top of which the kites seem to float as though on a liquid surface, apparently in a calm and all flying at about the same altitude. Kites floating above a shallow wind, other than easterly, can generally be reeled up into higher winds aloft after four or five kites have been launched on a few thousand meters of wire. With easterly winds, however, the change in direction is often so abrupt, and of such angular magnitude in comparatively short intervals of altitude, that repeated reeling in will be useless. A stratification of the air, causing the kites to apparently "float," is quite common, and is due most often to abrupt, though not necessarily large, changes in wind direction with altitude.



Rear view of kite reel.

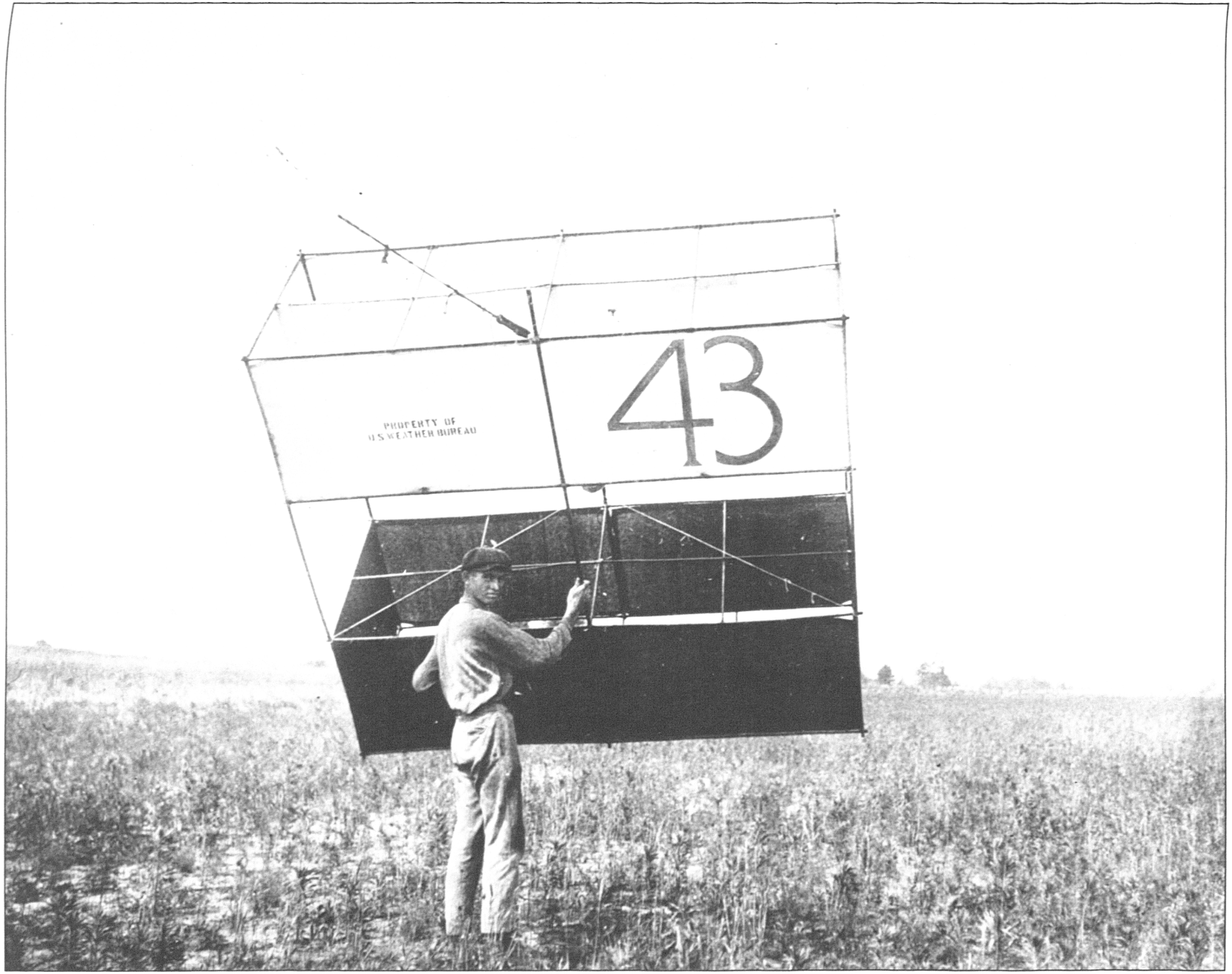
Weather Bureau Instructions to Kite Observers

Too much emphasis can not be laid on the importance of always keeping the wire taut. After being repeatedly wound on and unwound from the reel drum and over pulleys, and particularly if the wire has been run under tension over wheels of too small diameter, or has rubbed against some solid object, such as the side of the reel house, a fence post, or tree, internal strains are developed that will cause the wire to coil as soon as it is slackened. If, on again tightening, a single coil becomes a kink, a breakaway beyond the kink is inevitable.

The tendency to coil varies inversely as the diameter of the wire, and it is therefore advisable to feel out the smaller sizes of wire frequently when reeling in or out. Opportunities for the wire to slacken sufficiently to coil are always present when flying in light winds, and when, under such conditions, it becomes necessary to reel in rapidly to assist in raising the kites the reel should always be slowed down gradually before coming to a stop, if conditions permit.

Rapid reeling out in a light wind, especially when pronounced convection currents are present, will often cause coiling and probably kinking of the wire. With a wind barely strong enough to sustain the kites in the air and convection currents prevailing, a wave-like effect is often observed, the kites rising and falling in succession. Then, if wire is paid out rapidly to the rising kite, the wire between it and the falling kite immediately in advance will slacken and probably coil.

The wire should be kept clean and slightly oiled. Incrustation of ice or frost should be wiped off when reeling in, and the wire again wiped with a piece of oiled waste when reeling out in the next flight. This wiping of the wire should be frequent; it not only serves to prevent rusting, but also, prevents kinks from passing by unnoticed. Few breakaways are caused by the pull exceeding the normal tensile strength of clean undamaged wire. Kinks, sharp bends, rust spots, or flaws in the splices cause the majority of accidents.



Launching a Weather Bureau kite.

UPPER-AIR OBSERVATIONS USING AIRPLANES

The rapid development of the airplane during World War I presented an alternative method to obtain upper air observations, and in 1917–1918, Marvin meteorographs were mounted on the wings of military aircraft flying over France. Airplane soundings frequently were made at most of the Naval Air Stations during the 1920s, and the Weather Bureau soon became an eager partner.

The first routine Weather Bureau airplane observations were made in 1925 in cooperation with the Navy. The place was Anacostia (in Washington, D.C.) and flights were made about 8 AM each day to about 10,000 feet. Included in these early flights were data from the meteorograph (temperature and humidity), as well as visibility, cloud heights, cloud tops, and cloud thickness.

In 1931, the Weather Bureau began to replace kite stations with airplane stations. Four airplane stations were established in the summer of 1931, and together with soundings made by the Navy and one by the Massachusetts Institute of Technology, the total number of observing sites was about one dozen. Although the number of observation locations varied during the program, by the time the program was halted (1938), airplane observations were being taken at 16 locations throughout the U.S.

The use of the airplane as an upper-air observational tool, continued to expand during the 1930s. In 1934, following the recommendations of the President's Science Advisory Board, Congress authorized an increase in the number of Weather Bureau stations and the use of Army planes at other stations. By this time, the total number of airplane sounding stations, including Weather Bureau, Navy, Army, and Massachusetts Institute of Technology, numbered over 20. By 1937, airplane upper air soundings were being made each morning at 30 Weather Bureau locations throughout the country.

Airplane observations were taken during the early morning hours, usually between 2 AM and 4 AM. The pilot would take-off and circle the airport to gain altitude. A crude radio beacon from the airport helped the pilot determine the approximate location of the airplane. As the airplane climbed into the stronger winds of the upper atmosphere, the pilot would point the plane into the wind and continue to climb. Since the airspeed of the climbing airplane was less than 60 mph, upper-level winds frequently would blow the airplane away from the airport. When the airport radio beacon could no longer be heard, the pilot would descend and attempt to find a place to land.

Taking airplane observations was one of the more dangerous occupations in the Weather Bureau. Pilots bid on taking upper-air observations at various stations across the country. The pilot had to furnish the airplane and take the chances. Weather Bureau pilots frequently flew in all types of weather in open cockpits. They frequently were exposed to temperatures well below zero and winds (relative to the airplane) to over 60 mph. During winter, fog would close the airports, leaving the pilot nowhere to land.

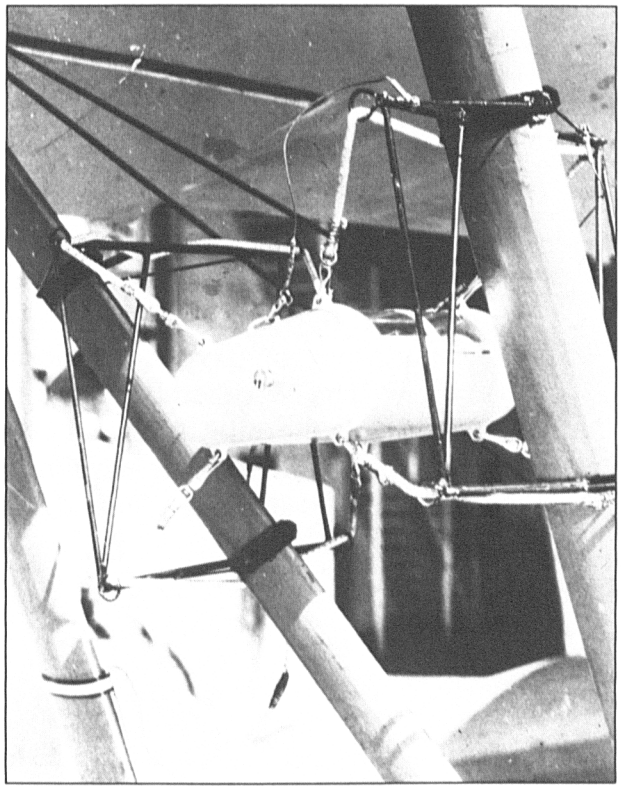
Most dangerous was the requirement that the flight extend to between 16,000 and 17,000 feet--an extraordinary feat considering most planes did not carry oxygen. If the flight made the required height, the pilot was paid about $17 (the pay was later raised to about $28), but if the flight terminated at 15,000 feet, the fee was about $14. Flights to lower altitudes paid even less. At such heights, a pilot might be overcome

by lack of oxygen and lose consciousness. Some pilots tried to guard against this danger by carrying small pets on the flight. When the pet's head dropped from lack of oxygen, the pilot knew it was time to descend.

No consideration was made for low ceilings, reduced visibilities, severe weather, or high winds. If the pilot did not fly, he was not paid. Consequently, many pilots attempted to reach the standard level in unfavorable conditions and many pilots died. For the period 1934–1938, twenty–six major crashes occurred during Weather Bureau observation flights. Ten pilots were killed.

Airplanes were an expensive and dangerous way to obtain upper–air data. The disadvantages of the airplane as a sounding platform, coupled with the advent of the radiosonde, resulted in the airplane observations being discontinued prior to World War II.

Meteorgraph being placed on an airplane for an upper-air sounding. The pilot subsequently was killed while flying an upper-air sounding.



Meteorograph used on weather Bureau airplane observations.

Close Calls During Weather Flights

Frank Knapp flew for the Weather Bureau during the mid 1930s. One December morning, Mr. Knapp took off for a Weather Bureau upper-air observation in his J5 Eaglerock biplane. At 1,500 feet, he leveled off to give the meteorograph time to stabilize. This flight was smooth, but he once hit turbulence so severe that, "...I had to hold on the cross braces to keep from being thrown from the plane."

Knapp does not remember much about this particular flight. The meteorograph showed that he climbed to 14,000 feet, then he crashed. He survived the crash but sustained a broken hip, two broken ankles, a broken jaw, a fractured skull, a broken collar bone, and a mangled left arm. He was paid $14 for his flight since he climbed only to 14,000 feet.

A friend of Mr. Knapp agreed to take his subsequent flights. On his second flight, the weather closed in beneath him and his radio went out. Mr. Knapp's friend headed west, hoping to find a break in the weather. Finally, he ran out of gas and had to bail out. His parachute split but he survived the fall.

Knapp had at least one more major scare while working for the Weather Bureau. One day, while the airplane was climbing, Knapp became very cold. According to Knapp:

> I turned the heater on at 10,000 feet. At 13,000, I leveled off for the last time before reaching altitude (17,000 feet), and I began to feel funny. The air was smooth. I put the pipe (this airplane was equipped with oxygen) in my mouth and began to breath oxygen. Pretty soon my fingertips were numb. It was getting worse. I cut the throttle and dived. My arms doubled up and my stomach was sucking in. I was fighting to breath. There was a tightness in my forehead. I watched the altimeter unwind. I was afraid of passing out. As I got lower, I could feel my breathing coming back. I got the use of my arms but not my fingers. I made a hell of a landing. I got out and told somebody something was wrong. After I got to feeling better, we found the trouble. The exhaust was leaking. I had been getting carbon monoxide. Up there in thin air, it gets at you in a hurry.

Another pilot fell nearly 16,000 feet when he fainted from lack of oxygen and lost control of the airplane. The Weather Bureau airplane went into a spin, but the pilot regained consciousness just in time to "pancake" the airplane into a tree. The pilot suffered a broken shoulder.

Frank Knapp and his airplane for taking Weather Bureau upper–air observations (1936)

DEVELOPMENT OF ELECTRONIC COMMUNICATIONS

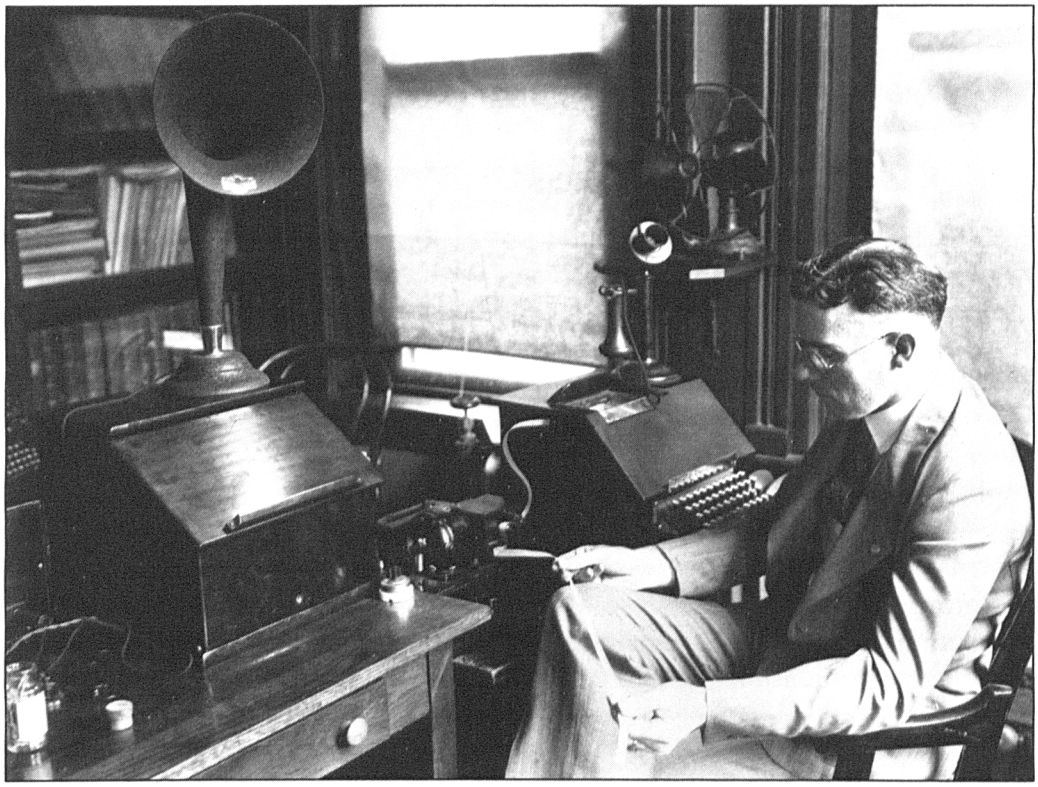
When the telegraph became operational in 1845, the visionaries saw the possibility of "forecasting" storms simply by telegraphing ahead what was coming. Joseph Henry, Secretary of the new Smithsonian Institution, envisioned opportunities of the communication system and suggested that:

> ...a system of observation which shall extend as far as possible over the North American continent... The Citizens of the United States are now scattered over every part of the southern and western portions of North America, and the extended lines of the telegraph will furnish a ready means of warning the more northern and eastern observers to be on the watch from the first appearance of an advancing storm.

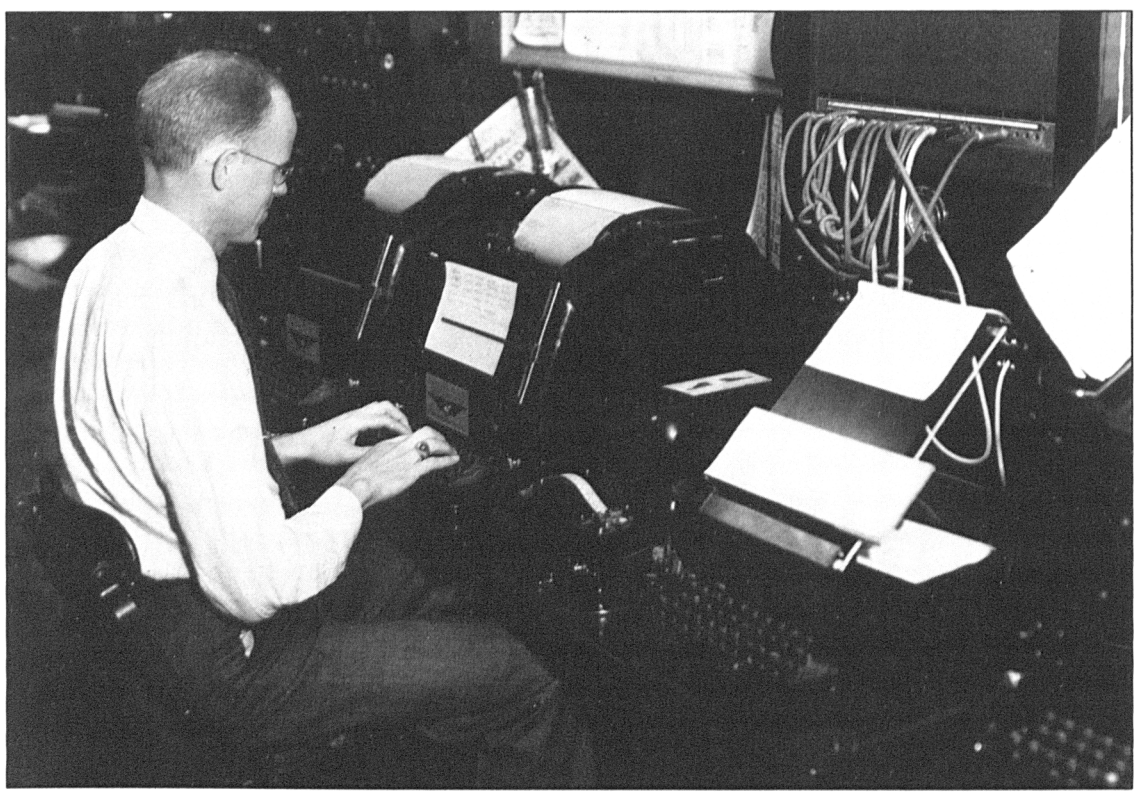
The plan was approved in 1848, and subsequently, a circular was distributed to the press to recruit volunteer observers. Henry also persuaded the telegraph companies to allot free time for the transmission of weather reports to the Smithsonian. By the end of 1849, 150 volunteers throughout the United States were reporting weather observations to the Smithsonian regularly. By 1860, 500 of Henry's stations were furnishing daily telegraphic weather reports to the Washington Evening Star, and as Henry's network of volunteer observers grew, other existing systems were gradually absorbed, including several state weather services.

The ability to observe and display simultaneously observed weather data, through the use of the telegraph, quickly led to initial efforts toward the next logical advancement, the forecasting of weather. However, the ability to observe and forecast weather over much of the country, required considerable structure and organization--a government agency.

This rapid increase of data during the late 1920s caused the Weather Bureau to begin considering a more rapid means of communication--the teletype. By 1940 a sophisticated teletype communications network had been established across much of the country.

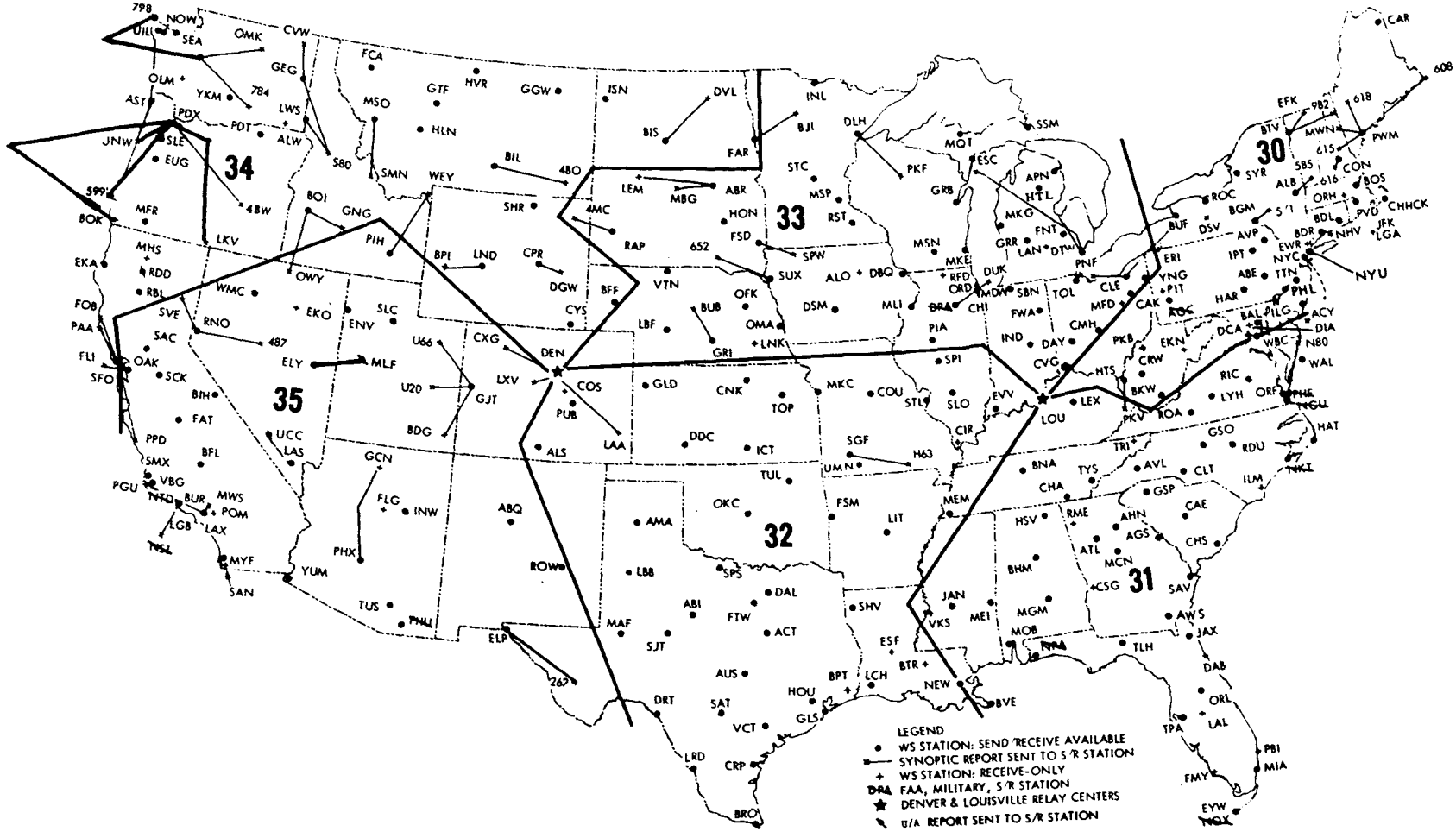


Transmission of weather information from Weather Bureau office in Washington, D.C., to Naval radio transmitter (station NAA) in Arlington, Virginia (date unknown).

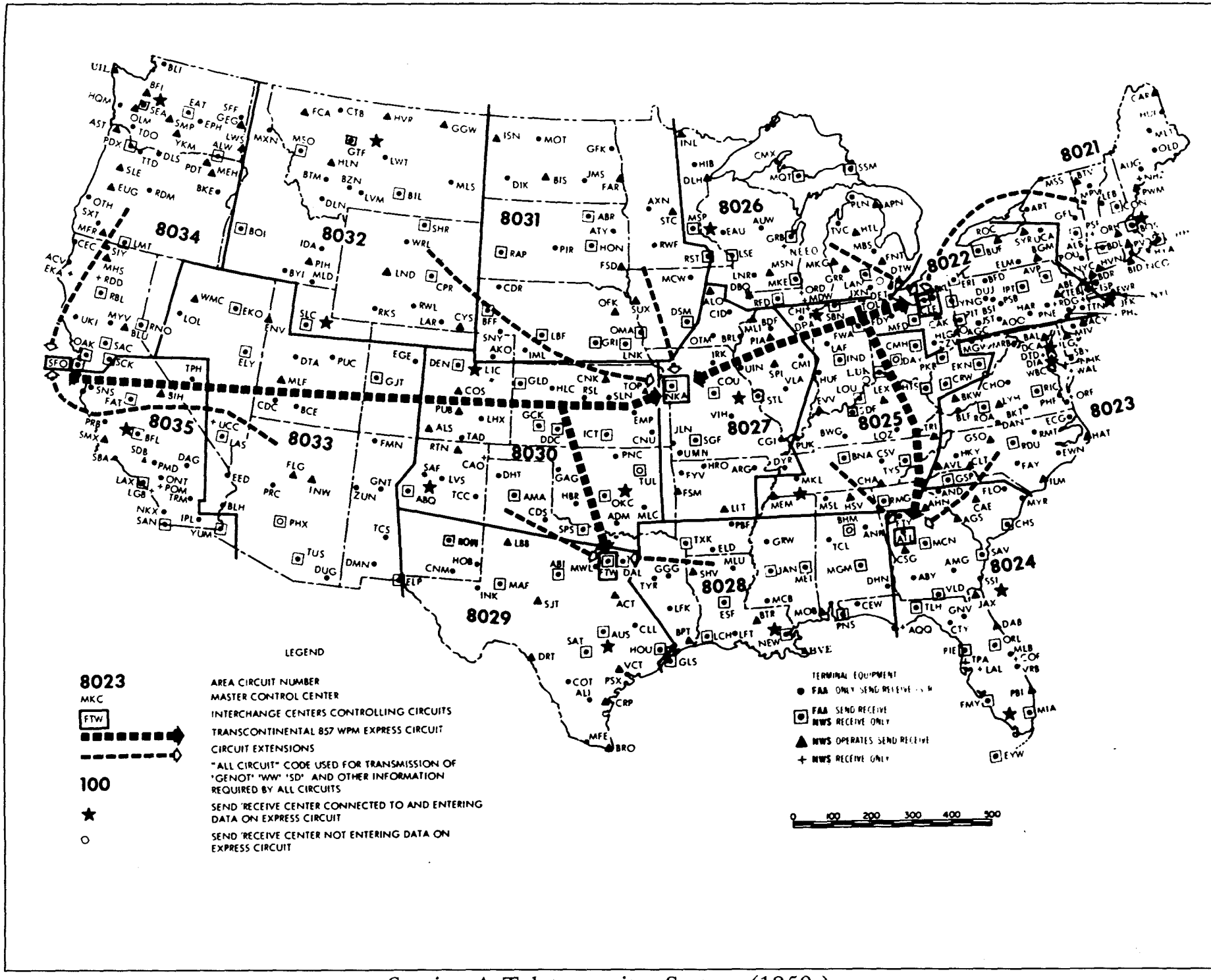


Sending weather information over teletype at Nashville, Tennessee (1938).

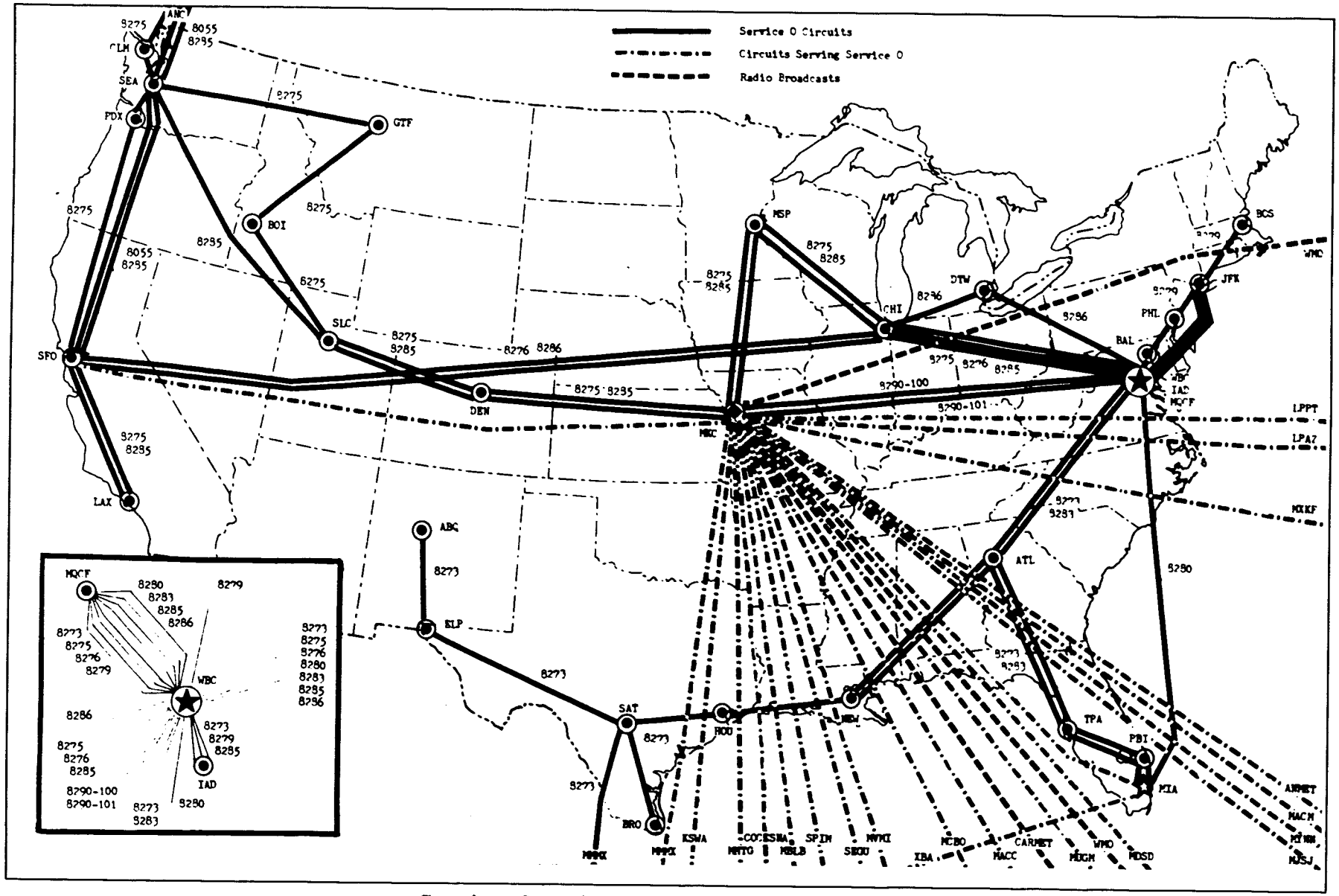
Teletype communication center (circa 1940).



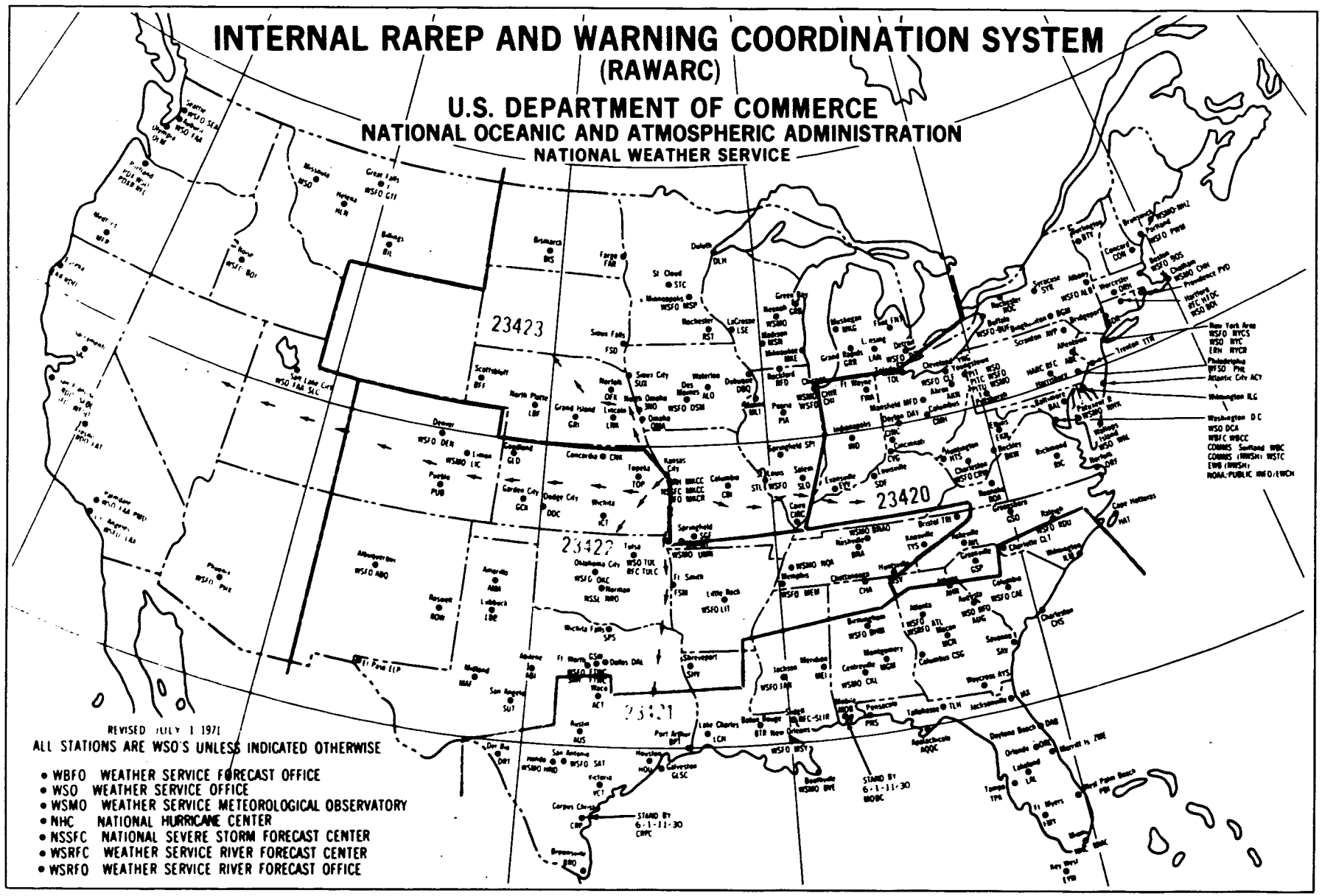
Service C Teletypewriter System (1950s).



Service A Teletypewriter System (1950s).



Service O Teletypewriter System (1950s).



RAREP (radar reports) and Warning Coordination (RAWARC) System (1950s).

The No. 28

KEYBOARD SENDING AND PAGE RECEIVING TELETYPEWRITER

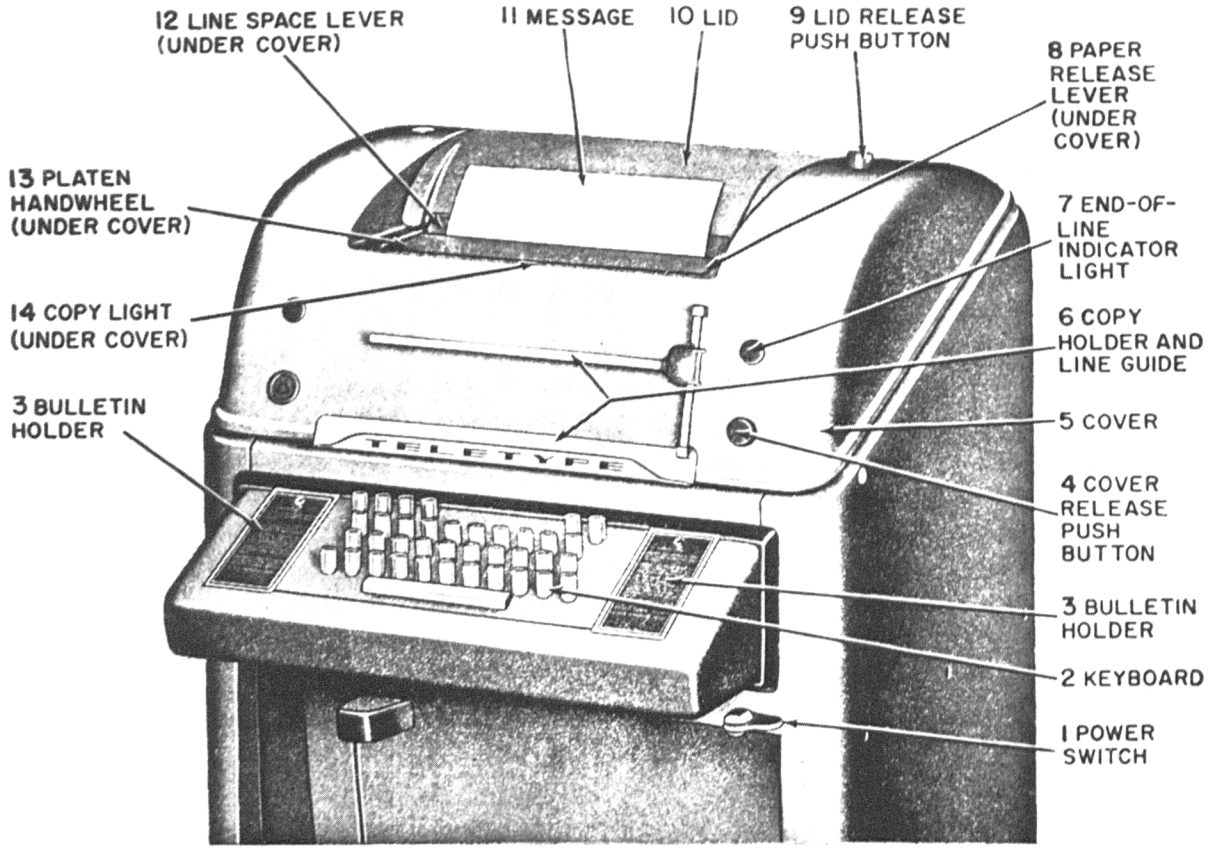


Figure 2

1. **POWER SWITCH**

When turned on, starts the motor in the teletypewriter, which runs continuously while the switch is on. Machine is operative while turned on.

To Turn On Machine

a. Operate the POWER SWITCH up.

b. Depress the red key marked "KBD UNLK" (see Figure 4). This frees the keyboard for typing.

c. Depress the red key marked "LOC LF" (see Figure 4) to see that paper feeds up. This verifies that machine is running.

To Turn Off Machine

Operate POWER SWITCH down.

An individual service may have an automatic power control feature either superseding or operating in conjunction with the POWER SWITCH, in which case special instructions are provided.

DEVELOPMENT OF THE WEATHER MAP

During the early 1900s, the surface chart was an important tool for the forecaster. Two daily weather maps were prepared from surface observations taken at 0100 and 1300 UTC. At those times, about 200 Weather Bureau stations scattered across the United States and the West Indies took observations of pressure, temperature, humidity, rainfall (or snowfall), and cloud cover. During the subsequent 30 to 40 minutes, the observations were transmitted across the country, including to the central office in Washington, D.C.

As observations filtered into the central office, a force of clerks plotted various information on blank charts--information such as amount of cloudiness, wind velocity, and 24 hour changes in temperature and pressure. A general weather chart was also plotted showing all observed weather elements for each station. When the surface maps were plotted, forecasters analyzed the weather data and issued forecasts.

During the early 1900s, forecasting was based primarily on extrapolation, as well as from climatological maps of mean storm tracks and average speed of movement. Since upper-air data was essentially unavailable on a real-time basis, these tools were the only means available to the forecaster. Considerable emphasis was placed on individual observations as well as collected observations in the form of a map. Heuristic rules were numerous and widely used by the forecaster.

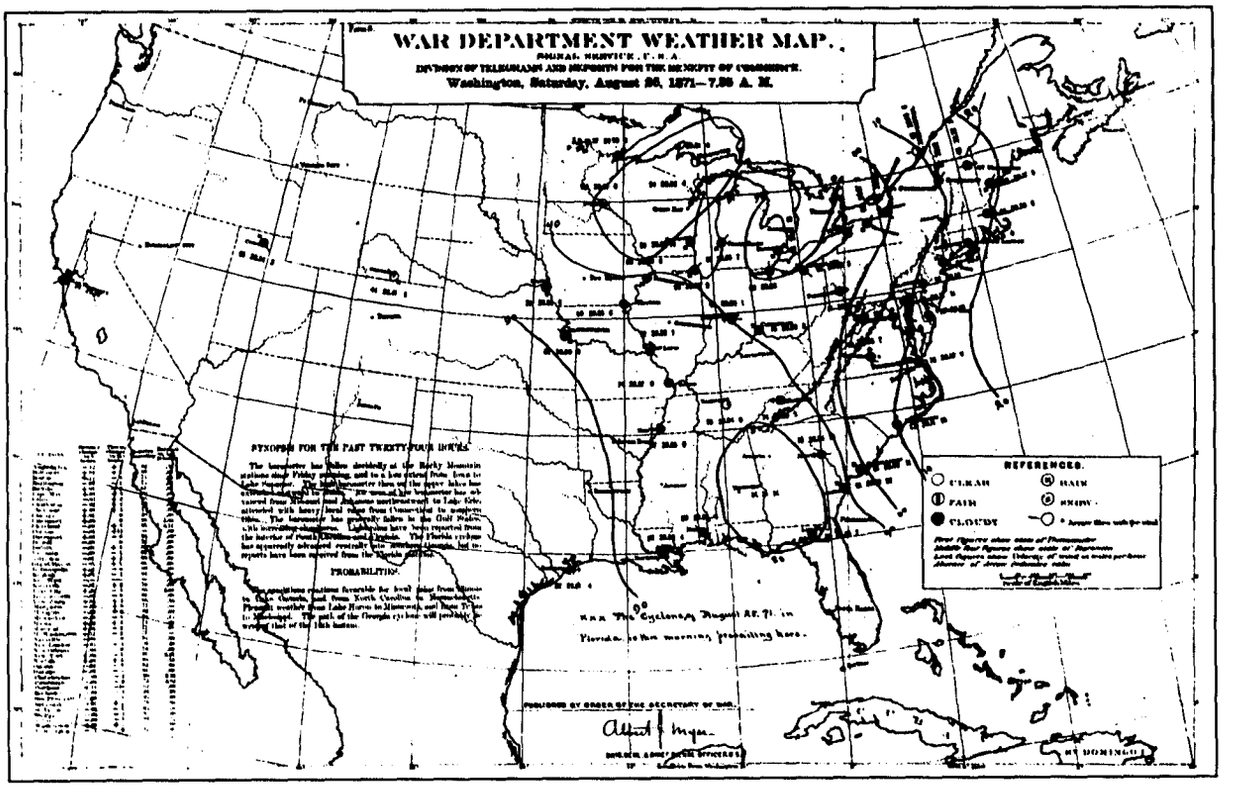
Conceptual models existed during the early 1900s, but due to the lack of upper-air data, these models remained poorly defined. Areas of precipitation, falling or rising temperatures, pressure changes, cloudiness, etc., were depicted on each map. The speed of movement, change in shape, change in orientation, etc., of the phenomena were tracked very carefully by the forecaster. These changes frequently were extrapolated into the forecast period.

Extrapolation of larger pressure surface pressure systems was an important tool of the forecaster. However, in this area, the early operational meteorologist had additional help. At all forecast offices were climatological maps which depicted average tracks and average 24 hour movement of low pressure centers. Entire volumes were published by the Weather Bureau depicting the climatological movement of low and high pressure centers and containing considerable heuristic information. These volumes entitled *Studies of Weather Types and Storms*, were distributed to every Weather Bureau office in the United States.

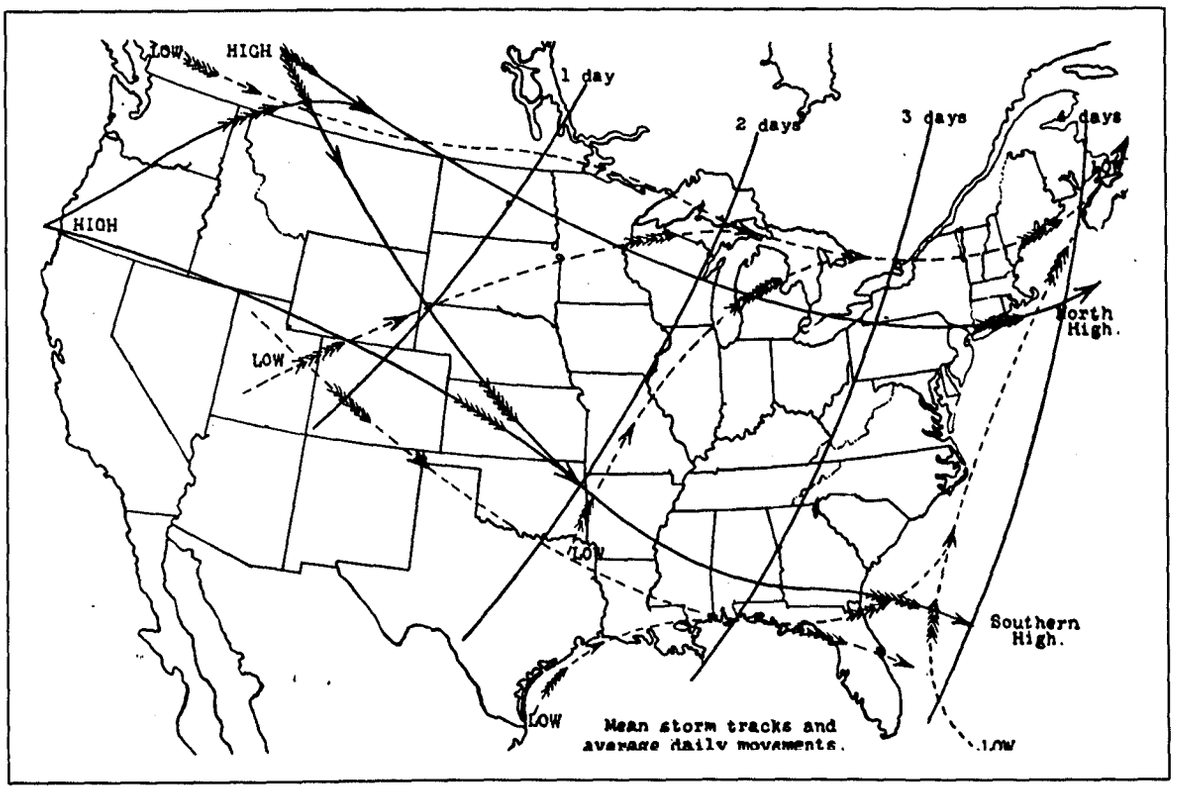
Because of the diversity of movement of low pressure systems in the United States, average tracks would split, converge, or cross. For those early forecasters, concern over the approaching forecast must have heightened when low pressure centers approached an area of the country in which the average storm tracks diverged.

Plotting weather maps (1950s).

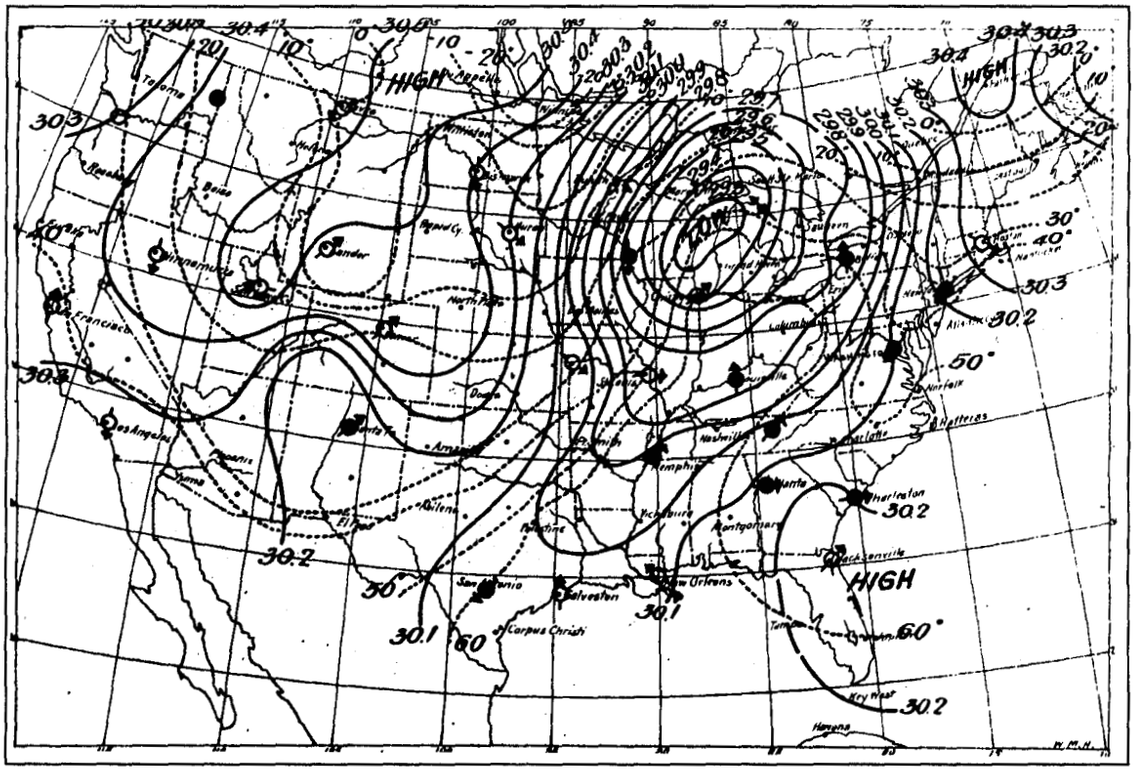
Plotting a weather map at the District Forecast Office in Chicago, Illinois (1944).



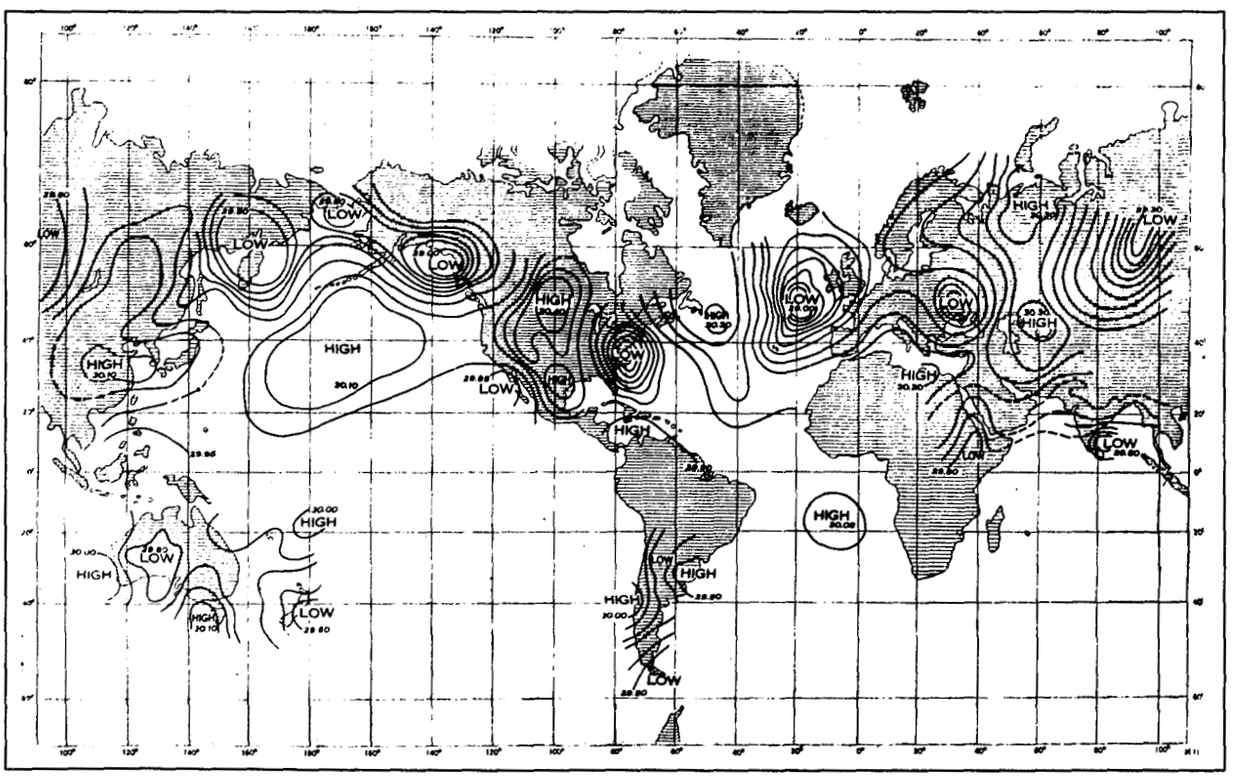
Surface weather map prepared by the Signal Service on August 26, 1871.



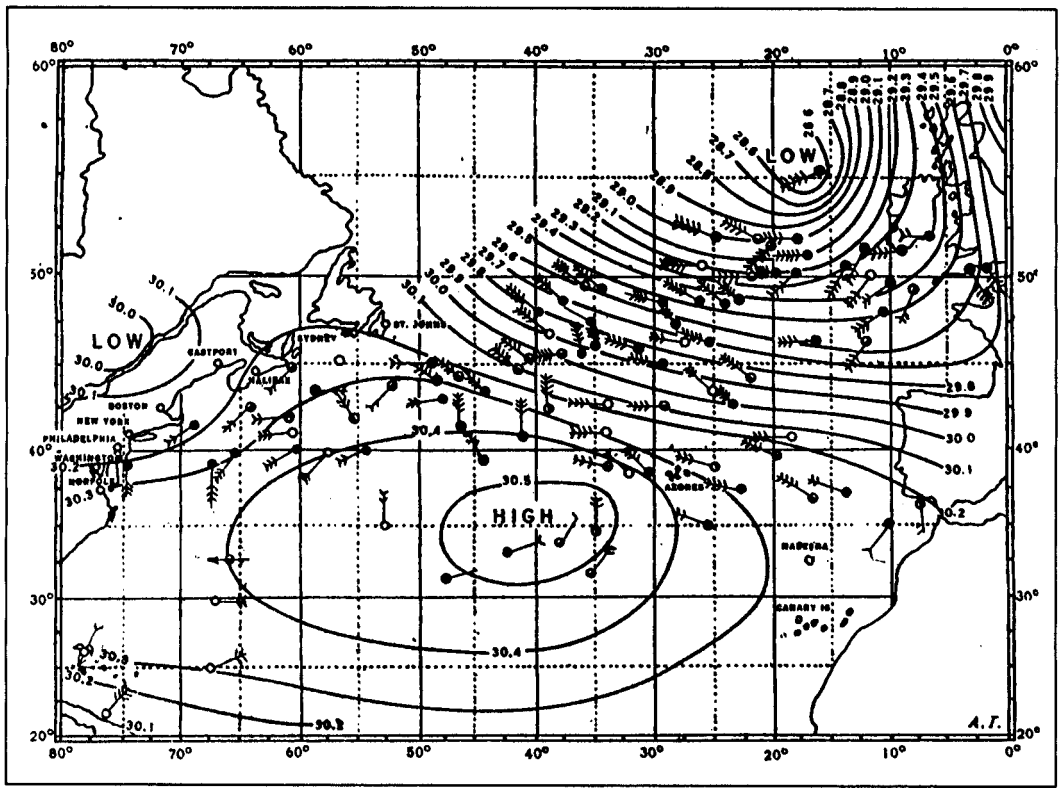
Mean tracks and average daily movements of surface low pressure centers (1905). Average daily movement refers to time after the low pressure crosses the North American Pacific coast.



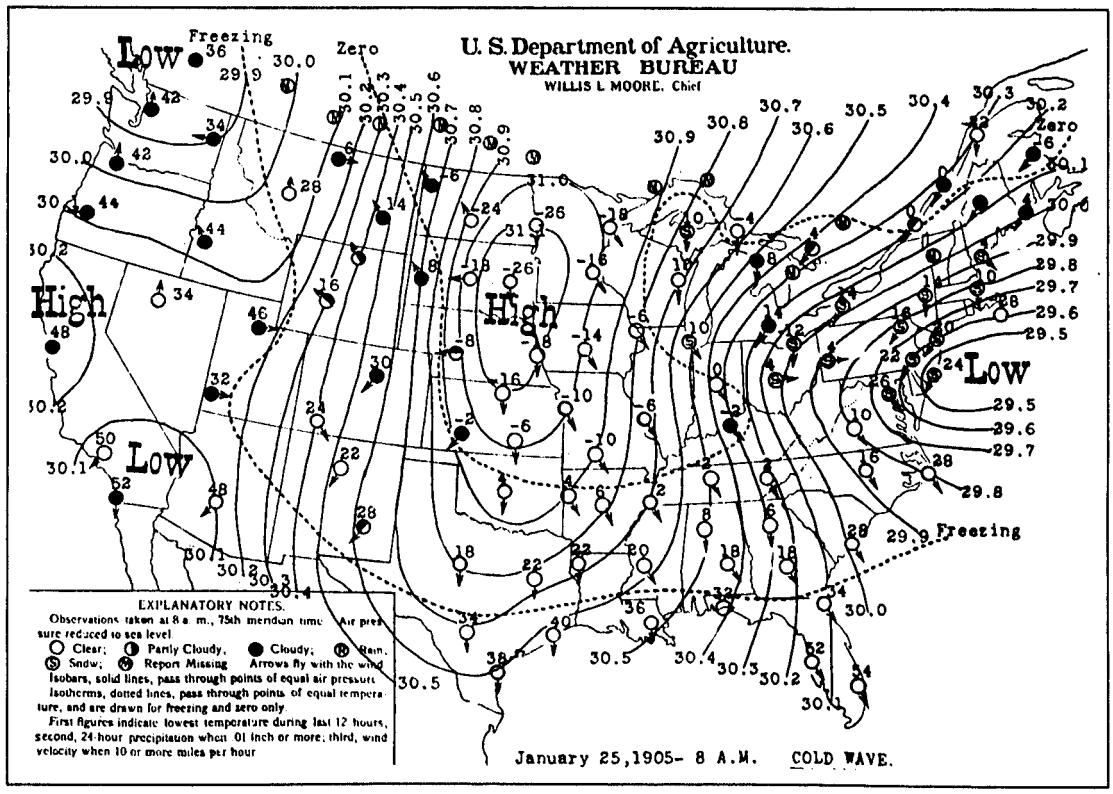
Surface weather map for December 29, 1889. Solid lines are isobars and dashed lines are isotherms. Note the absence of frontal systems.



"World" pressure map for November 9, 1913.



Weather map of North Atlantic for January 11, 1913. Barb on one side of station shaft represents 5 knots. Barbs on both sides of shaft represent 10 knots.



Surface weather map for January 25, 1905. Solid lines are isobars and dashed lines are isotherms.

AVIATION METEOROLOGY

During World War I, aviation grew considerably across the United States. Prior to the war, little interest was paid to the "new" airplane; however, following 1914, considerable funds were given to aviation, especially in the area of navigation. By the close of the war, a vast fleet of aircraft and trained pilots existed. The stage was set for rapid advances in civil aviation.

Immediately after World War I, the Weather Bureau began to provide "basic" meteorological services to the aviation community. Upper-air observations were made at approximately 20 sites around the United States. Upper-air winds were measured through the use of Pilot Balloons twice daily and kites were used to measure upper-air temperatures, humidities, and pressures once each day. Although the Weather Bureau had taken upper-air observations for research purposes and public weather forecasts, the Agricultural Appropriation Act of 1914 and the Army Appropriation Act of 1917 both directed the Weather Bureau to take upper-air observations in support of aviation.

In December 1918, the Weather Bureau initiated aviation forecasts, called Flying Weather, at the request of the War Department. The country was divided into seven zones (later increased to 13 zones), and a separate forecast made for each zone once each morning with a similar forecast for most of the zones during the evening. Similar services were provided to the Post Office Department as an aid to pilots flying the mail routes. An example of "Flying Weather" is shown below:

> Zones Nos. 1 and 2: Poor flying weather today; local thundershowers probable; moderate to fresh south and southwest surface winds, becoming west and moderately strong above 3,000 feet.

As the infant aviation industry evolved, Weather Bureau meteorologists faced a new set of forecast problems. Phenomena such as thunderstorms and high winds were known to pose problems to aviators. More subtle, but just as important were features such as aircraft icing, fog, and cloud heights.

The first aviation forecasts were inadequate and considerable pressure was placed on Congress to increase the Weather Bureau's role in aviation meteorology. On May 20, 1926, Congress passed the Air Commerce Act which was the first attempt to regulate aviation in the United States. The Act established the responsibility and procedure for the issuance of appropriate regulations, license pilots, classify airports, and inspect aircraft. It also provided for navigation and other aids, such as emergency landing fields, beacon lights, and communication facilities. The legislation also directed the Weather Bureau to, "...furnish such weather reports, forecasts, warnings, and advices as may be required to promote the safety and efficiency of air navigation in the United States..." The Act also established offices to, "...observe, measure, and investigate atmospheric phenomena..." As a result, experienced meteorologists were placed at important airports.

Basically, three major services were required of the Weather Bureau by the Air Commerce Act:

1. Frequent reports (initially twice daily) from Weather Bureau offices along the routes showing current conditions, both surface (150 stations) and upper air (50 stations). Upper-air information was primarily wind observations.

2. Short-range forecasts for 1 to 6 hours, depending on the scheduled duration of any given flight.

3. General weather forecasts for the next 12 to 24 hours, although forecast duration was expanded to 36 hours in 1928.

The Air Commerce Act marked the beginning of rapid expansion of aviation forecast services. Before the Act, the budget for aerology totaled $104,400, and by 1927 had risen to $175,000. However, by 1932, over $1,700,000 was targeted for aviation services in the Weather Bureau.

The Air Commerce Act marked the beginning of the airways service. Twenty-two pilot balloon stations were established at existing weather stations along the New York to San Francisco route, as well as over eight other, shorter routes. Seventeen additional observing sites along commercial airways were selected by the Weather Bureau, Department of Commerce, and the Post Office. Observations at the airways sites were taken twice daily, usually 8:00 AM and 8:00 PM EST (to correspond to flight times of scheduled flights), and telegraphed to the rest of the country. A system was established by the Western Union Telegraph Company to speed the weather observations.

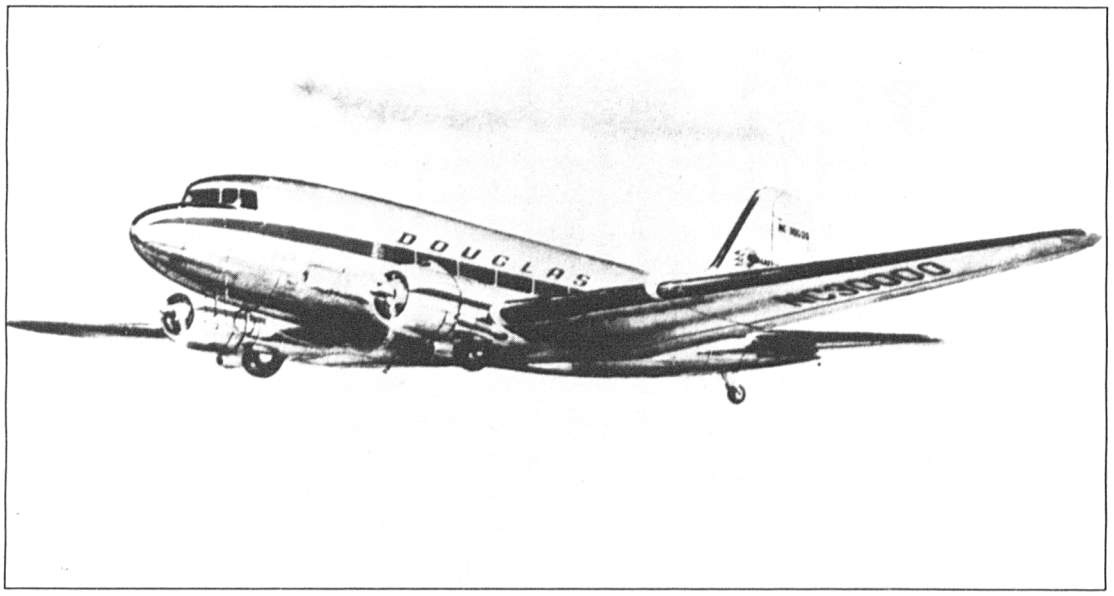
Several other significant changes in operations resulted from the passage of the Air Commerce Act. Weather Bureau airport stations were opened along major air routes; a vast improvement over the previous system of attempting to provide aviation data from downtown offices. More significant was the inauguration of hourly observations and 24 hour operations at the airway stations. No longer did the public have to be without service from about 11:00 PM to 8:00 PM. A third result was the large increase in Weather Bureau personnel and operations for coping with aviation problems.

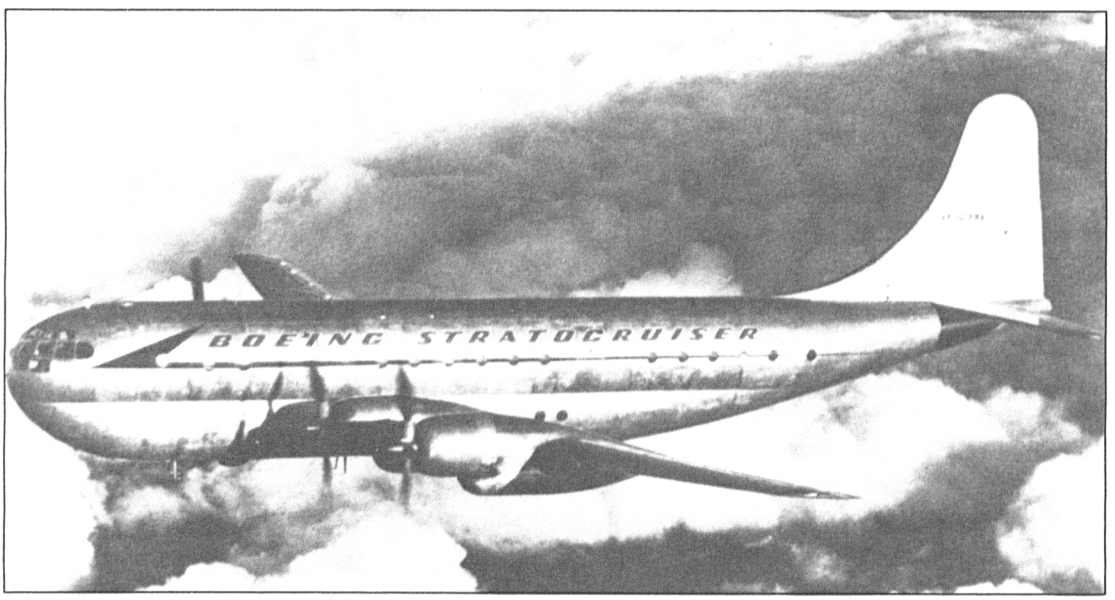
The interest in aviation continued to increase during the Depression, but Weather Bureau services failed to keep pace. In 1937, the total number of miles flown was 50 percent higher than in 1932; yet, the Weather Bureau Airway Service appropriation was 13 percent less. The actual cutbacks in the service consisted mainly of a curtailment of surface observations at airports. However, during 1938 - 1941, the airway service grew rapidly. This growth has continued through today.

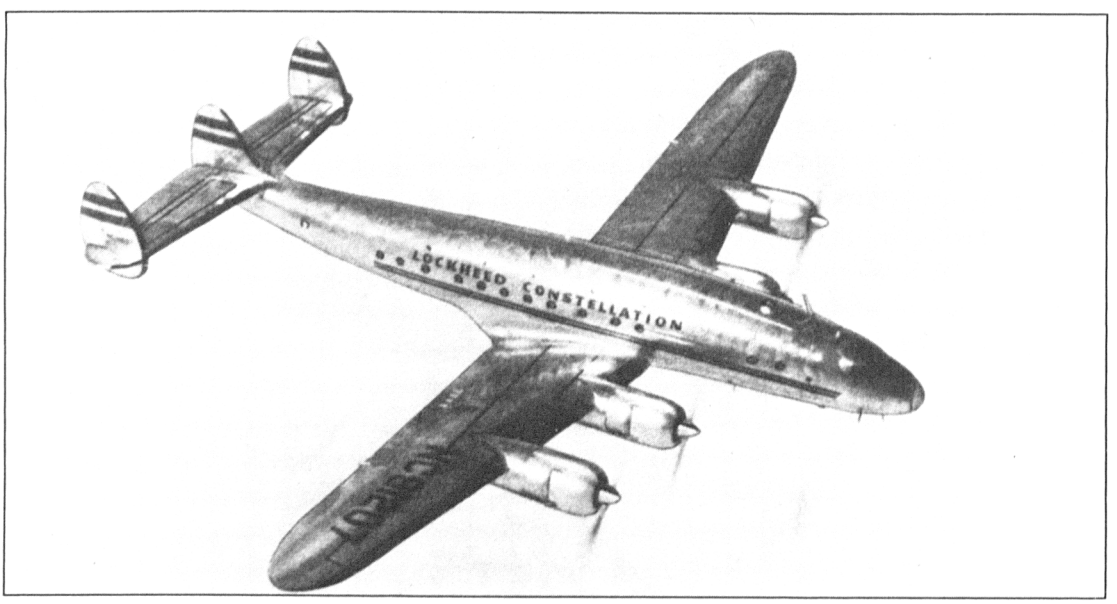
THE B LINE
BRANIFF
AIRWAYS
WORLD'S
FASTEST
AIRLINE!

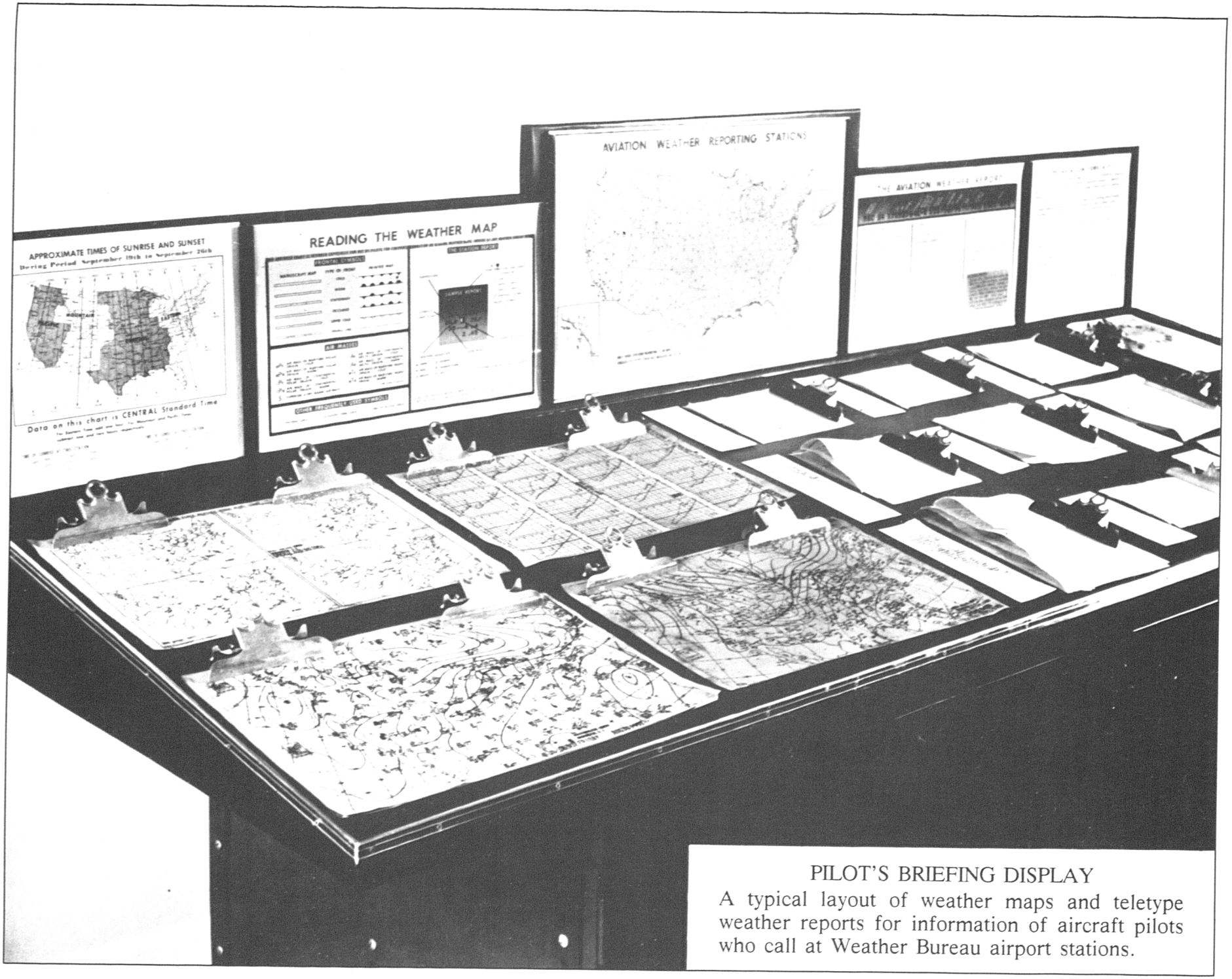
TAT
TRANSCONTINENTAL AIR TRANSPORT, INC.
TAT
COAST TO COAST BY TRAIN AND PLANE

TWA
"The Lindbergh Line"
TRANSCONTINENTAL
& WESTERN AIR, INC.


DOUGLAS

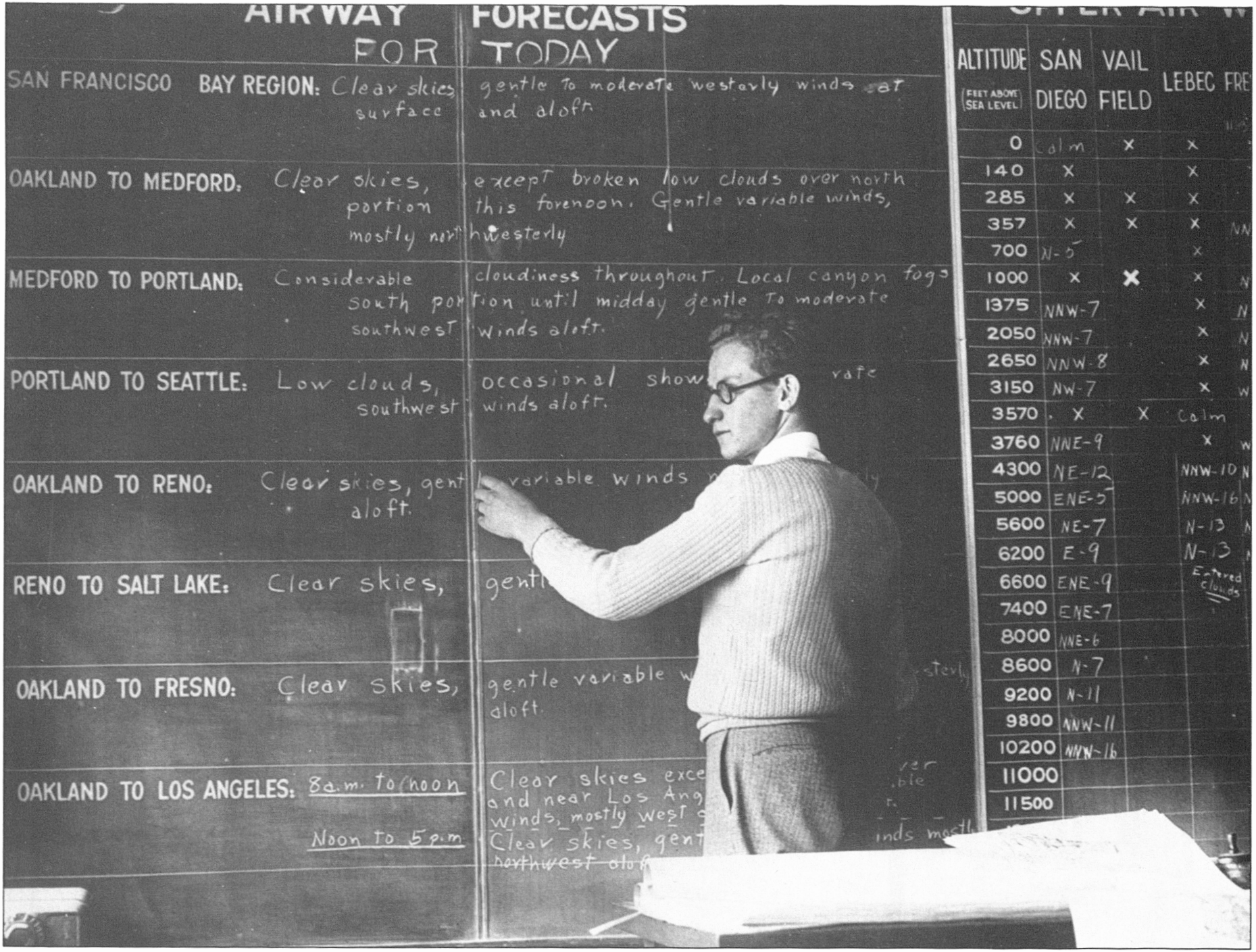

BOEING STRATOCRUISER


LOCKHEED CONSTELLATION



PILOT'S BRIEFING DISPLAY

A typical layout of weather maps and teletype weather reports for information of aircraft pilots who call at Weather Bureau airport stations.



Airways weather briefing board (1920s).

Weather Bureau meteorologist briefing airline pilots (1930s).

Weather Bureau meteorologist briefing military pilots during World War II.

Briefing pilots over the telephone at National Airport in Washington, D.C. (1950s).

Weather Bureau meteorologist preparing a cross-section weather chart for pilots (1950s).

Weather Experience Of Pilots In 1929

The two Army flyers, Lieutenant Johnson and Captain A.W. Stevens, made a high altitude flight at Dayton, Ohio, and flew through a cirrus cloud at a height of about 38,000 feet. At this altitude they "were flying in a temperature of 76 degrees below zero", and upon looking below they saw what appeared to be billows of ice crystals, hung in midair and resembling the formations of a cave. The aviators described the spectacle as a "dazzling sight", with the light rays broken by the fragile crystals into all the colors of the spectrum." They dipped their plane again and again into the crystals, and Lieutenant Johnson removed his glove and thrust his bare hand from the cockpit. "It was pierced as though by a thousand needles."

DISSEMINATION OF WEATHER INFORMATION

The first public weather forecast was issued by Cleveland Abbe and was called "Weather Synopsis and Probabilities." It was based on weather observations taken daily at 7:35 AM. One of the early examples in 1871 is shown below.

> Synopsis for past twenty-four hours; the barometric pressure had diminished in the southern and Gulf states this morning; it has remained nearly stationary on the Lakes. A decided diminution has appeared unannounced in Missouri accompanied with a rapid rise in the thermometer which is felt as far east as Cincinnati; the barometer in Missouri is about four-tenths of an inch lower than on Erie and on the Gulf. Fresh north and west winds are prevailing in the north; southerly winds in the south.
>
> Probabilities; it is probable that the low pressure in Missouri will make itself felt decidedly tomorrow with northerly winds and clouds on the lakes, and brisk southerly winds on the Gulf.

BY POST OFFICES

Beginning in 1873, forecasts were distributed to thousands of rural Post Offices (by local Signal Service offices) for display as "Farmers' Bulletins" in front of Post Office buildings. In some areas, the postal wagon displayed flags to communicate the forecast to the public. This dissemination method continued until 1881 when local signal flags replaced the bulletins. The flags were large (For example, the cold-wave flag measured six-by-eight feet and was white with a black center of two feet square), and were displayed over Post Office buildings. By the end of 1886, display flags were available at 290 cities and towns.

In 1891, 1,200 display stations were in existence across the United States. Forecasts were telegraphed to the stations, which in turn, raised the appropriate flag. There were five basic weather and temperature flags used by the Weather Bureau:

1. A white flag indicated fair weather.
2. A blue flag indicated rain or snow.
3. A white and blue flag indicated local rains.
4. A triangular black flag was the temperature pennant. If hoisted above one of the previous flags, the forecast was for higher temperatures. If the pennant were located below the flag, lower temperatures were forecast.
5. A white flag with a black square in the center indicated a cold wave.

In 1890, the Weather Bureau could afford only 600 sets of display flags. Consequently, the officials at the remaining 600 display stations attempted to obtain money from local officials, local business interests, or from individuals. As a last resort, the Weather Bureau official personally would pay for the flags at a cost of about $7.00 for each set.

RAILWAY BULLETIN SERVICE

Weather forecasts also were disseminated through the Railway Bulletin Service. Weather forecasts were displayed in many railway stations. By 1891, the telephone was being used to distribute weather forecasts, especially to outlying areas, and post cards containing forecasts were distributed by the Postal Service.

The local systems of using flags (for various warnings) and other signals were continued with additional modification and elaboration by some communities. Electric searchlights were used in some areas to warn of hazardous or inclement weather, and whistles were used in other areas; fire alarms, bombs and rockets were also used.

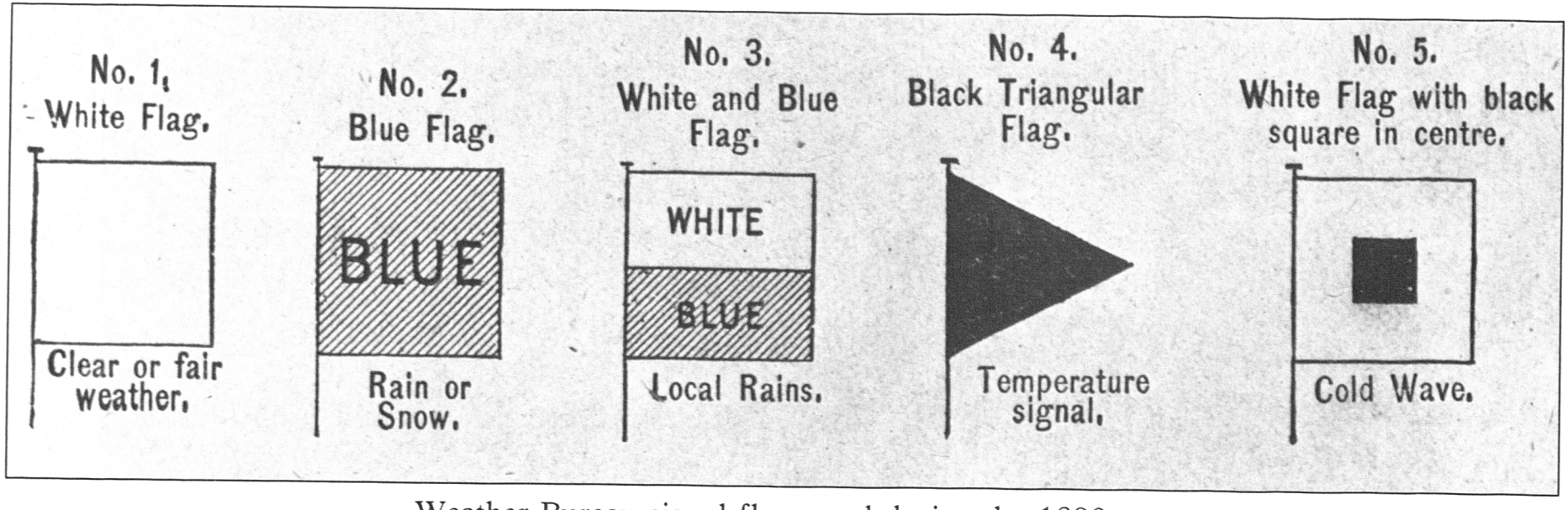
STREET CARS

Forecasts were disseminated through any means available, e.g., news papers, telephone, and displayed in public. One method of dissemination was the street car. According to one Weather Bureau official in 1901:

> The method of disseminating weather forecasts to the general public by posting them in a prominent position in street cars has met with great favor wherever it has been practiced, for in this way the forecasts meet the eye of a large number of people.
>
> When the cards are posted in the cars by 11 AM, they attract the attention of large numbers of people who use the cars thereafter, and thereby the information is disseminated to many of the homes of citizens for their use and benefit in a way that can not be readily accomplished otherwise. In the city of Rochester, N.Y., the distribution of the cards to the cars is made by the switch tender located at the "four corners" where all the cars pass, and as each car goes by a forecast card is handed to the conductor, who immediately posts it in the proper holder at the front of the car. Thus in a short time all the cars are supplied with forecasts, and the patrons of the road have the full benefit of the forecast early in the day.
>
> The first distribution of forecasts by street-car service was inaugurated in Lansing, Michigan, in 1888. The distribution was, however, accomplished by the use of tin symbols carried on the rear of the car, and was prior to the inauguration of the distribution of forecasts by the card system.

As the number, extent and types of forecasts expanded, the problem of dissemination increased. By the early 1900s, daily forecasts were distributed via post cards on rural-free-delivery routes to about 42,000 rural families. The main problem was that the mail carriers left at 7:00 AM and had to use the old forecast from the previous night. Also, the entire country was not yet covered by the mail routes. One suggestion in Congress was to place weather flags on the mail wagons but the cost was prohibitive. Another means of distribution came with the steady increase of telephone lines. Upon request, operators read the weather forecasts to their subscribers, and in Iowa, weather forecasts were phoned to the farmers by 10:30 AM.

Kiosk at Pennsylvania Avenue and E Street (also shown on cover) in northwest Washington, D.C. (circa 1927). Weather Bureau Kiosks displayed weather forecasts, weather maps, and contained a few instruments such as barometers, thermometers, etc.



Weather Bureau signal flags used during the 1890s.

Beginning Of The Daily Public Weather Map

The first official weather map of the Signal Service was prepared on February 9, 1870, by I.A. Lapham at Chicago; however, daily weather maps were not sent to newspapers on a regular basis until January 14, 1871, when a method was devised to make reproductions. The process for reproducing weather maps was devised in Washington, D.C. The method was a slow and laborious process.

These maps contained readings of pressure, temperature, state of the weather, wind velocity, and precipitation. Isobars were not included on the map.

A new, and easier, method of reproducing weather maps was devised by the Weather Bureau a few months later. This version also did not show isobars, but a weather synopsis and forecasts were added. By late 1871, a litho-graphic process was used. With the addition of the lithographic process, isobars were added, but isotherms were not included until 1872.

In 1879 a contract was made with the New York Graphic to print the weather map on a daily basis. The cost to the government was about $25 per day. However, reproduction and distribution of the maps was confined only to a few large places, mainly Washington, D.C, and New York. Since printing was relatively expensive, weather maps could not be disseminated from local offices, but this changed in 1886.

In 1886, a cyclostyle method was tried with success in New York, and within the next few years, it was introduced throughout the service. The method was simple and allowed the reproduction of weather maps on a local basis for dissemination to newspapers.

In the early part of 1896 a chalk-plate process was adopted at Weather Bureau offices, a process that continued well into the 20th Century. With this process, chalk was made to adhere to a smooth steel plate, forming what was known as the chalk plate. With a sharp steel stylus, an outline of the map of the United States and the weather data was drawn through the chalk down to the hard, steel surface. The plate was then placed in a casting box, into which molten type metal was poured. The hot metal filled in all the places cut by the stylus, the result being a perfect cast which could be locked up in a newspaper form.

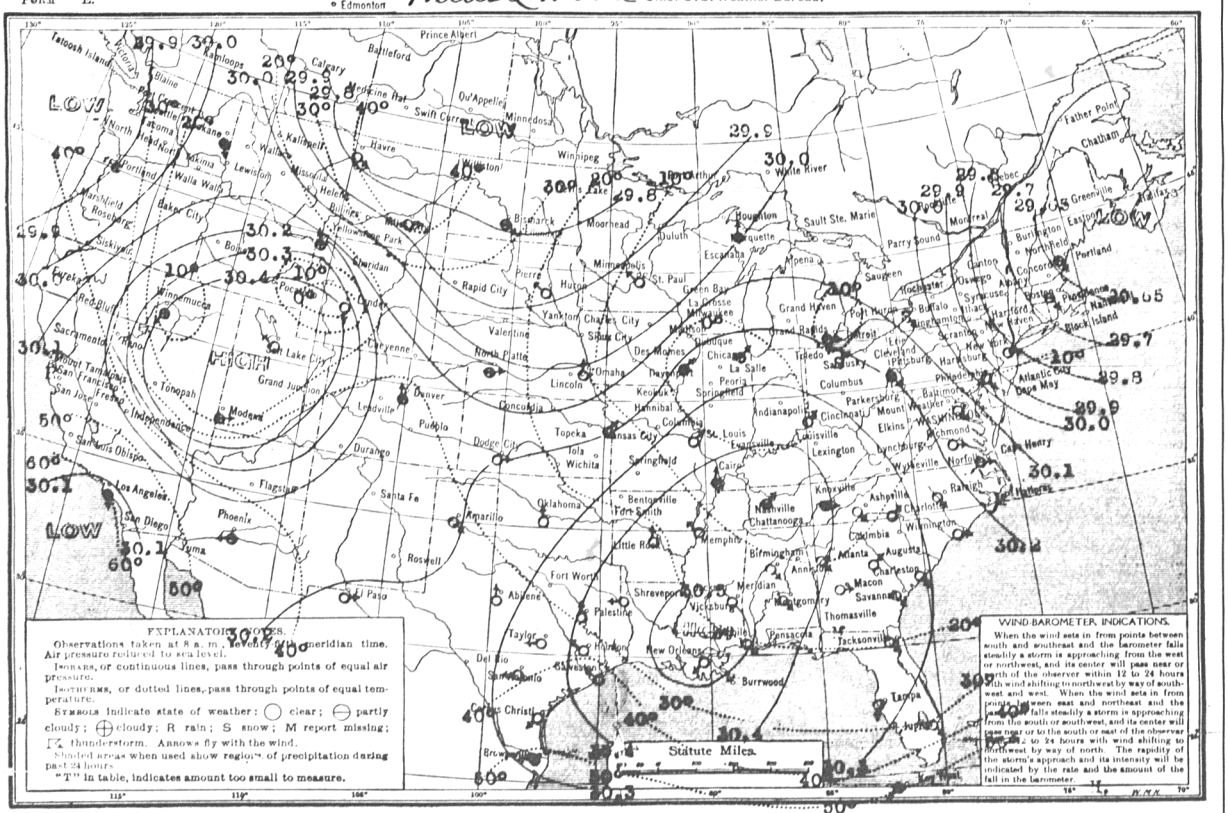
The plates were then used to print the maps which were subsequently distributed to the newspapers. This process was accomplished at most local offices and resulted in weather information being disseminated to many newspapers across the country. For example, in 1887 an average of 480 weather maps were distributed daily in the United States, but by 1898, that number had increased to over 14,000.

U. S. DEPARTMENT OF AGRICULTURE.

WEATHER MAP.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

FORM E. Willis L. Moore Chief U.S. Weather Bureau.



JACKSONVILLE, THURSDAY, DEC. 30, 1909.
Dyal-Upchurch Bldg. Telephone No. 206.

FORECASTS FOR TONIGHT AND FRIDAY.

JACKSONVILLE AND VICINITY: Fair with freezing temperature tonight—lowest about 24°. Friday fair, not so cold; light to moderate north winds becoming variable.

EASTERN FLORIDA: Fair tonight with freezing temperature to the 26th parallel and frost to the extreme south portion of the mainland; temperature from 18 to 20 degrees in north portion. Friday fair, not quite so cold; light to moderate north winds.

WESTERN FLORIDA: Fair, not quite so cold tonight, but with freezing temperature. Friday fair, warmer; variable winds.

WEATHER CONDITIONS.

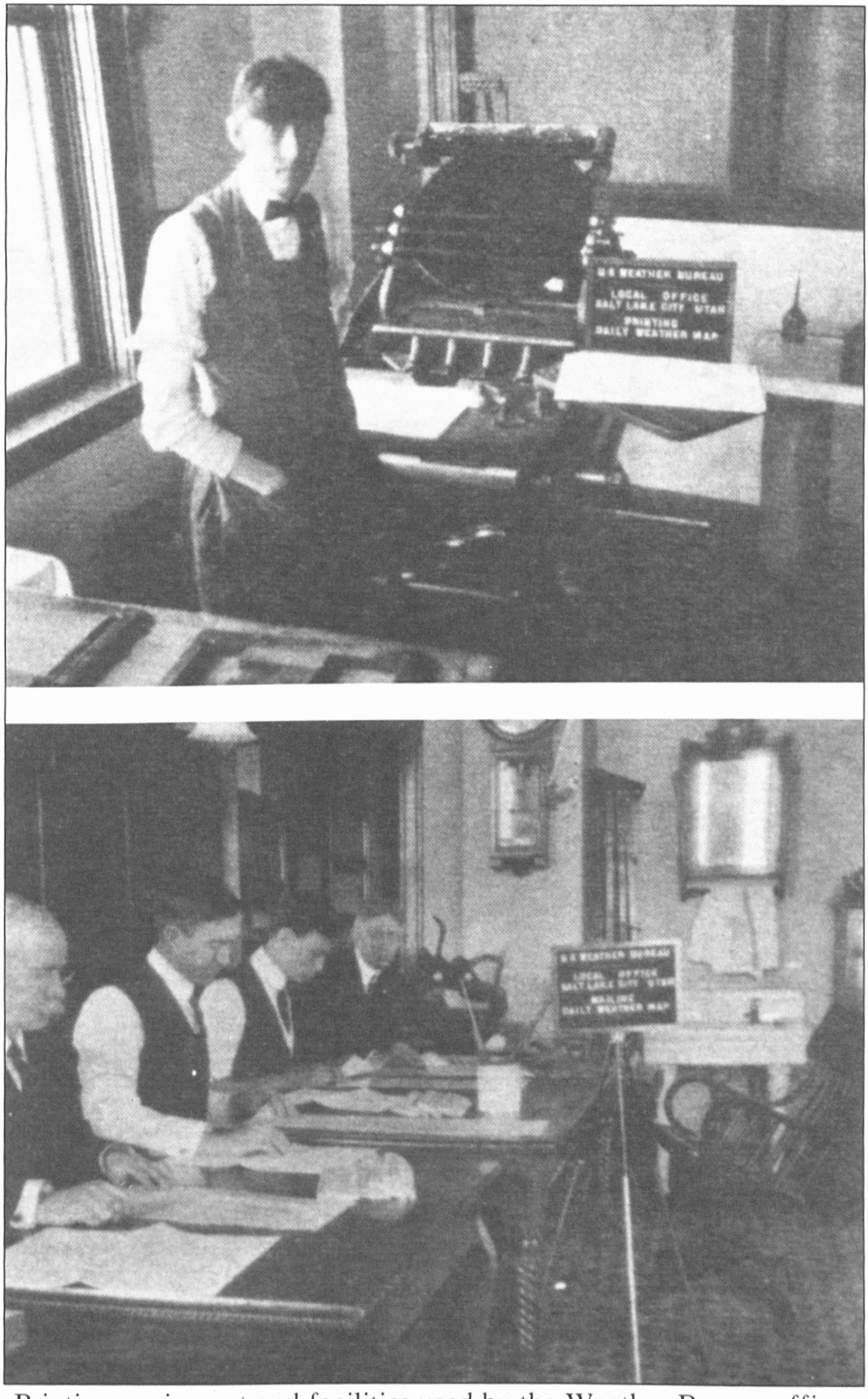
The cold wave has drifted east and south, pushing down the line of 20° to extreme northern Florida, and the 32° isotherm to the upper portion of Dade County. The 10° isotherm touches the upper portion of the Southern States. Except on the Texas coast, freezing temperatures and below prevail throughout the Southern States.

Under the influence of an area of low pressure in the Northwest the temperature is rising from Oklahoma northward, the temperature at Havre at 7 a.m., being 46° as against 20° in Jacksonville. Cold weather continues, however, over the central Rocky Mountain States, where an area of high pressure has remained stationary for several days. Conditions favor fair and continued cold over this section tonight with temperature below freezing—probably 24°, Friday fair, not so cold; light to moderate north winds.

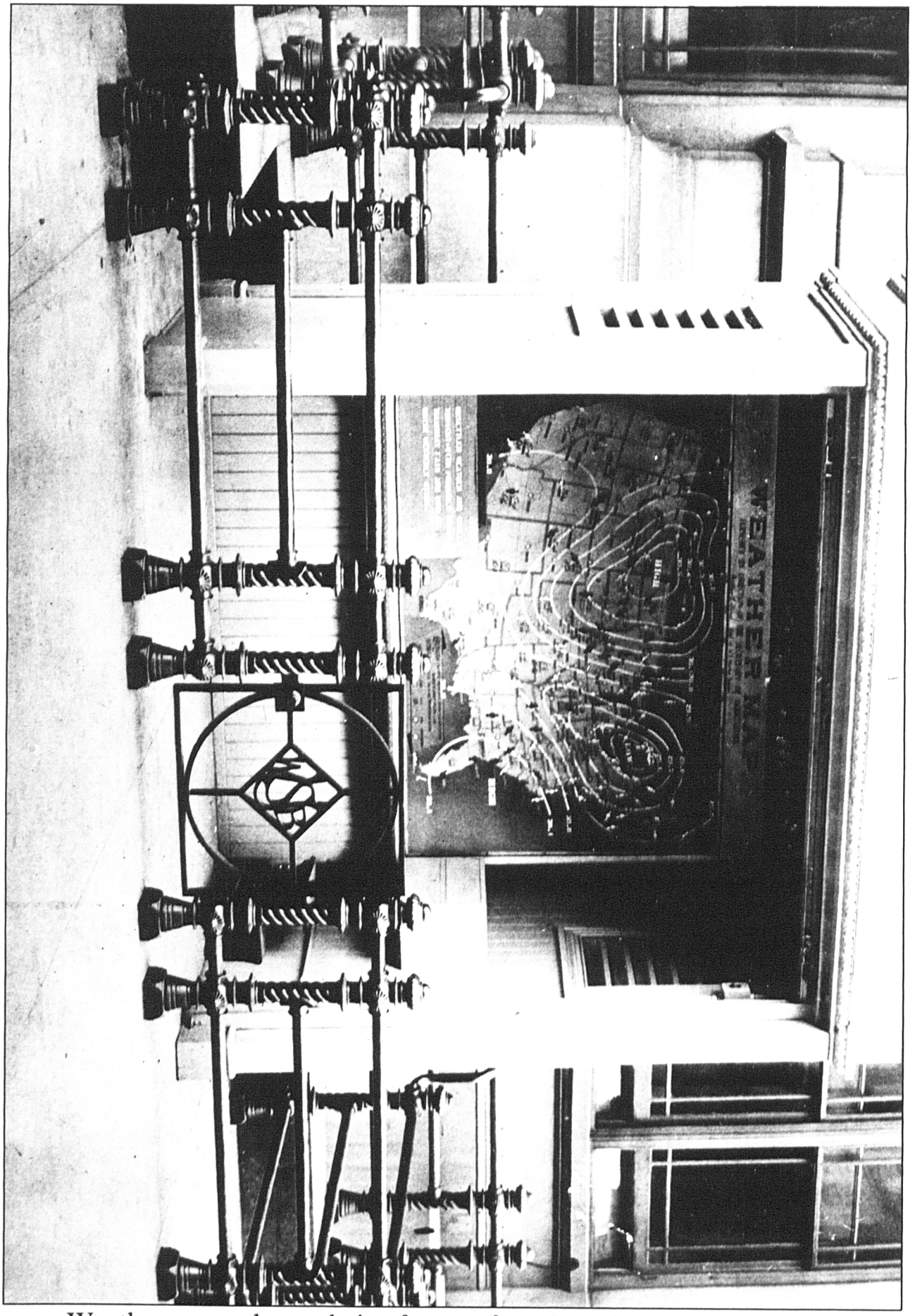
A. J. MITCHELL, Section Director.

STATIONS.	Temperature. Min. in last 12 hours.	Temperature. Max. in last 24 hours.	Wind, miles per hour at 8 a.m.	Max. wind reported in last 12 hours.	Precipitation last 24 hours. Inches.
Observations taken at 7 a.m., 90th meridian time.					
Abilene	34	54	8		
Amarillo	24	50	8		
Asheville	2	14	14	26	.01
Atlanta	10	22	12		
Augusta	14	34	4		
Birmingham	12	28	8		
Bismarck	10	36	12		
Boston	4	22	20		T
Brownsville	46	68			
Buffalo	4	8	12		.04
Cairo	4	16	8		
Charleston	18	42	12		
Charlotte	12	28	4		
Chicago	-6	10	12		
Cincinnati	-2	10	8		T
Cleveland	0	12	22		.06
Corp, Christi	48	56	10		
Davenport	-10	0	8		T
Denver	30	54	8		
Detroit	-2	10	14		
Dodge City	22	28	10		
El Paso	32	58	8		
Galveston	46	52	8		
Hatteras	—	—	—		
Havre	36	42	12		
Houston	34	56	8		
Huron	0	12	6		
JACKSONVILLE	20	52	6		
Jupiter	30	66	12		
Kansas City	6	18	20		
Key West	50	68	18		
Knoxville	8	16	4		
Lander	-6	14	4		
Little Rock	20	28	8		
Los Angeles	56	70	8		
Macon	14	34	4		T
Marquette	4	12	10		.10
Memphis	18	26	4		
Meridian	16	34	0		
Miles City	34	44	8		
Mobile	22	44	4		
Modena	4	28	8		
Montgomery	18	34	4		
Nashville	6	18	6		
New Orleans	26	48	10		
New York	6	26	22		
Norfolk	14	32	12	30	.-
North Platte	22	34	8		
Oklahoma	22	32	26		
Omaha	0	10	4		
Palestine	30	46	6		
Philadelphia	10	26	16		.02
Phoenix	38	68	4		
Pittsburg	0	16	12		.01
Portland, Me.	6	20	18		T
Portland, Or.	30	42	4		
Raleigh	12	30	10		T
Richmond	10	28	8		
Saint Louis	0	6	12		
Saint Paul	-10	6	4		
S. Lake City	12	26	4		
San Antonio	34	58	4		
SanFrancisco	46	58	0		.20
Savannah	16	44	12		
Shreveport	24	42	6		
Spokane	16	28	4		
Tampa	28	58	10		
Taylor	28	52	4		
Thomasville	—	—	—		
Vicksburg	—	—	—		
Washington	8	26	12		T
Wilmington	16	40	12	30	T
Winnemucca	8	22	4		
Yellowstone	18	26	6		
Arcadia, Fla.	26				

Example of daily weather maps issued by most Weather Bureau offices during the early 1900s.



Printing equipment and facilities used by the Weather Bureau offices to print daily weather maps. Most offices contained similar printing equipment.



Weather map located in front of a Weather Bureau office (location unknown; date approximately 1925). Note USWB design on metal gate.

POTPOURRI

Dedication of Weather Bureau Employees

Dedication to duty has always been the pride of the Weather Bureau, and later the National Weather Service. This dedication is shown in early Weather Bureau records with respect to a Convention of Weather Bureau Officials.

In 1898 the first Convention of Weather Bureau Officials was scheduled in Omaha, Nebraska, to cover services of the agency. The following was taken from notice of this convention and reflects the commitment of Weather Bureau employees to improving the service.

> By October 1 nearly seventy Weather Bureau officials had made arrangements to be presen at the Convention, authority to attend having been granted upon condition that station duties would be performed without additional expense to the Bureau during the period of their absence, and that the journey from their respective stations to Omaha and return should be made without cost to the Bureau for transportation, personal or other expenses. That so large a number of officials should attend the Convention under these unavoidably hard conditions, is a matter which forcibly illustrates their zeal and their fidelity to the great work on which they are engaged.

First Convention of Weather Bureau officials at Omaha, Nebraska, in 1898.

Weather Bureau employees disseminating weather information over typewriters during World War II.

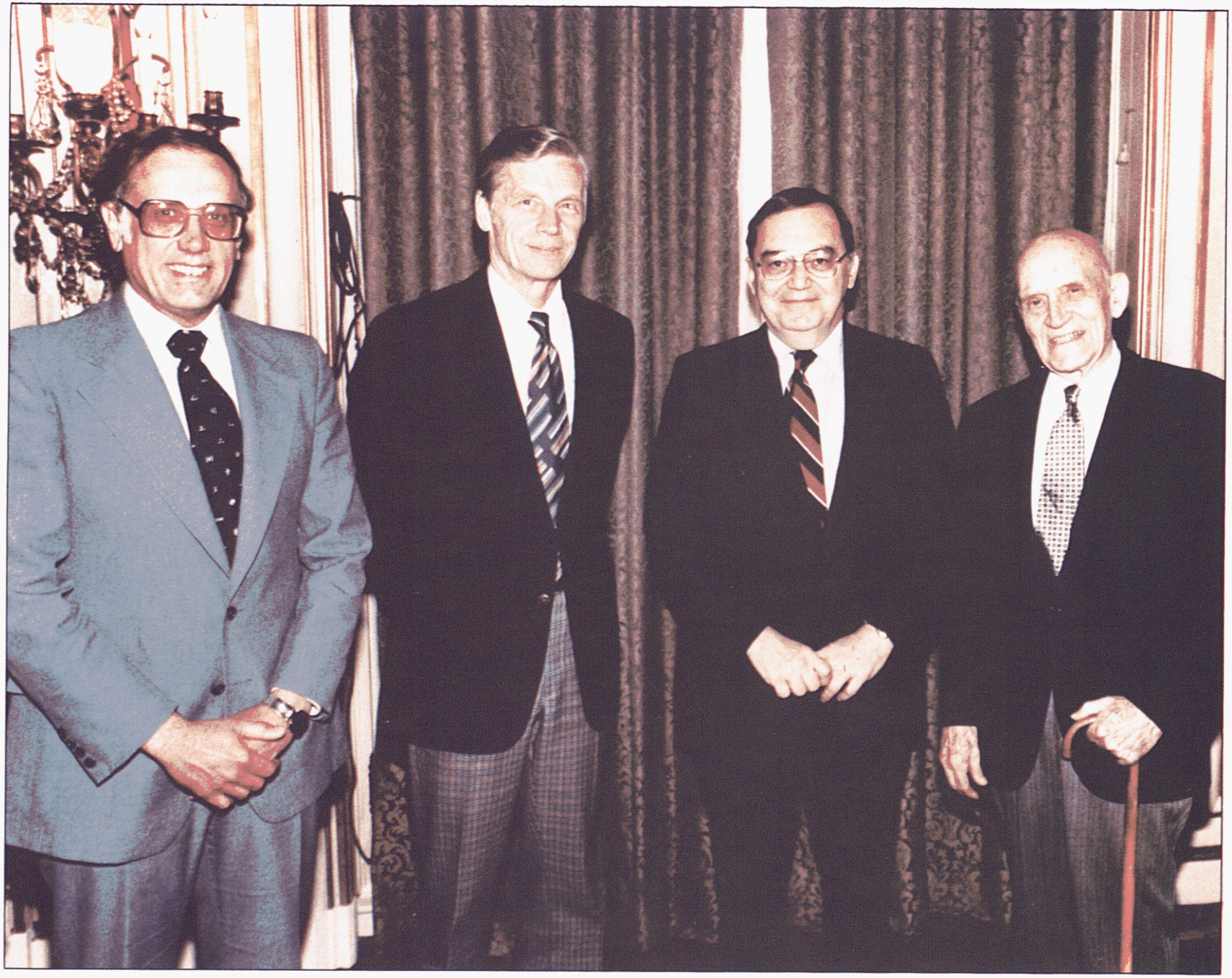
Weather Bureau Library (circa 1915).

Automatic plotter at the National Meteorological Center (1960s).

National Meteorological Center facsimile scanners for 20 fax circuits (1960s).

Dr. Francis W. Reichelderfer (right) and Dr. Joseph Smagorinsky examining elevation contour map of the Northern Hemisphere as printed by the STRETCH computer (1962). The STRETCH console and magnetic tape units can be seen in the background.

Daily weather briefing at the National Meteorological Center (1960s).



Fifty years of Weather Bureau and National Weather Service leadership (1938–1988). From right to left: Dr. Francis Reichelderfer (1938–1963), Dr. Robert White (1963–1965), Dr. George Cressman (1965–1979), Dr. Richard Hallgren (1979–1988).

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