are the departures from normal of the annual means of temperature smoothed by the formula \( a + 2b + c/4 \). The first solar period was somewhat longer than 34 years. The last three periods averaged 33.6 years.

Beginning with 1920, these data are plotted in an accompanying diagram together with the mean of the sunspot numbers and data from St. Louis all treated in a similar manner. Under these is the rainfall curve for New York. In the case of New York the annual precipitation was first smoothed by the formula \( a + 2b + c/4 \), but since that was not sufficient smoothing the data were further smoothed by overlapping means of 5.

In the first half of the New Haven curve the high and low points of the curve occur somewhat ahead of the sunspots. In the second half they occur somewhat later. Whether this fact is significant can only be determined from future observations.

**SOME RECENT PAPERS ON RADIO ATMOSPHERICS AND DIRECTION FINDING**

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Considerable attention is being given to the study of radio-atmospherics in relation to meteorological phenomena and the closely related topic of direction-finding by radio. Radio-direction-finding (radiogoniometry) is being developed in connection with determining the upper air wind direction and velocity from free balloons in cloudy or foggy weather, particularly for military service, and also in locating the source direction of atmospherics. Direction-finding to determine wind velocities and direction must be relatively accurate, while for the study of atmospherics the requirements are not so rigid. In general, the accuracy requirement in wind study is similar to that in double-theodolite tracking of pilot balloons. In the study of atmospherics a general identification of the source of the disturbance is sufficient.

Radio-direction-finding may be divided into two general methods: manual and automatic recording. Manual methods depend upon the observer's ability to distinguish the relative intensities of the signal as indicated by a sound or by a visual meter, while he rotates a control. A radio antenna, when mounted in a horizontal position, receives much more energy from a signal coming in a direction at right angles to its axis than it does from one coming along its axis. When using the very short waves, five meters or less, the necessary length of the antenna is short enough to be conveniently rotated. On the longer waves, however, the resonant antenna is impracticably long for rotation so that it is customary to coil it up in the form of a loop of moderate dimensions. Other methods employ two antennas fixed in space at right angles to each other, with a scheme of coils which can be rotated instead, giving much the same result as if the antenna in the first described case were being rotated. This is the familiar Bellini-Tosi loop system.

Manual methods of radio-direction-finding have been most highly developed as aids to navigation, and descriptions of such equipment may be found in modern texts on radio engineering (1). It is concluded that the error in reading bearings by these methods is seldom as much as two

degrees for distances up to one hundred miles. While satisfactory for some purposes this would not be adequate for securing wind direction and velocity. With the very short waves the possibility of using relatively elaborate beam antennas appears attractive. When the radio wave is short enough the beam antenna, which has a most pronounced directive characteristic, could be designed for rotation (2). An example of the careful development of the rotating loop antenna for direction-finding is found in the work of Blair and Lewis (3). In this case a light vacuum-tube radio-transmitter deriving its power from a battery-operated buzzer-transformer was sent aloft carried by free balloons. Wind directions and velocities for military purposes could be obtained by observing the direction with the rotating antenna. Bearings accurate to within half a degree were secured at distances up to five miles and useful bearings were secured within ten miles. The wave length employed was about 125 meters.

Some experiments have been conducted at the Blue Hill Observatory, Harvard University, during the development of a radio-meteorograph, in which very short waves of 5 and of 2½ meters were used for direction finding. In this case resonant antennas were used instead of loops. While useful bearings were obtained it was found that the accuracy was not sufficient for determining all significant changes in wind direction and velocity with altitude. It was also apparent that the continuous operation of the equipment by the observer was a most exacting task. Considerations of this nature have led to the development of automatic recording equipment, an example of which is found in the recent work of Corriez and Perlat (4). Continuous recording gives a mean bearing which is much superior to successive instantaneous observations. Accuracy to better than half a degree is claimed. The method consists in sending up by free balloon a radio transmitter of two to three watts power, using a wave of 120 meters. The signal from this transmitter is received on a loop antenna being rotated in synchronism with the recording device. From the loop the signal passes to a sensitive superheterodyne receiver of special design which amplifies the signal to a sufficient level to operate relay mechanisms. By means of an ingenious and complicated device a mark is made on the record when the loop is oriented towards the distant transmitter. The loop is continuously rotated at 10 r.p.m. Thus a continuous record of direction is obtained. Bearings have been secured at distances up to 300 km. The equipment is portable and operated from storage batteries and may be used in the field. This type of equipment appears to have important possibilities for tracking radio-meteorographs.

Of more direct interest to meteorologists is the study of radio-atmospherics. Techniques have been developed for recording the number, intensity, and direction of the atmospherics and interpreting this information to assist in weather forecasting. A detailed analysis of the period and wave-forms of atmospherics has just been published by Norinder (5). Of especial interest is a recent report by Dr. Lugeon describing his years of work with automatic recording equipment for the study of atmospherics (6). This pamphlet of 95 pages gives a full treatment of the author's method. The observations of radio static are not intended to supplant other meteorological observations but to supplement them, particu-
larly in the great polar and ocean areas, where observations are scanty. From the atmospherics recorded it is possible to locate the cyclonic and anticyclonic areas and certain fronts over distant regions not providing synoptic reports. Electric waves originating in thunderstorms for instance, are propagated thousands of kilometers. Most of the recordings are made on a frequency of 27 kc., or 11000 meters, and, in general, most investigators use long rather than short waves. In Europe it is found that the curve of the number of atmospherics with time shows a nocturnal maximum which is almost always divided into two peaks, the first due to African disturbances, and the second to atmospherics arriving from the Atlantic and America. Atmospherics of the first type are associated with the typical continental anticyclonic condition, while those of the second type are associated with the thunderstorms found along the southwestern Atlantic polar front. The frequency per minute of atmospherics is found to be directly related to the difference of temperature between the cold air mass to the north of the polar front and the warm mass south of it.

The instruments used in this work are described in some detail. First is a device to register the number of atmospherics per minute. Essentially, this is a sensitive radio-receiver tuned to the required wavelength and an amplifier arranged so that the burst of static closes a relay circuit. These contacts are carried to a Richard cinemograph for recording. This arrangement is termed the atmoradiograph. Operating in conjunction with this is the radiogoniograph which records the direction from which the atmospherics are arriving. The author describes two types. The first employs a rotating loop-antenna system with which is synchronized a rotating drum. As the antenna assumes a position favor-
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SOME STATIC ELECTRIC PHENOMENA AT MT. WASHINGTON OBSERVATORY

Excerpts from letter by A. A. McKENZIE, radio operator and observer.

All during the afternoon of March 23, 1935, there were discharges of static electricity across the springs of the jacks in which the telephone line terminates at the radio rack. This is not unusual when we have a high wind and blowing snow, since the line extends for approximately ten miles down the mountain and out to Fabyans, often across bare, wind-swept stretches.

At 8:35 p.m. I made the regular evening contact with W1XW on Blue Hill and shortly after, having transacted all business with no difficulty turned to W1FGA in Exeter. Soon after making contact with Mr. Shaw who was operating on 60 megacycles, I began to have great difficulty in understanding everything he said owing to some form of atmospheric interference. We concluded that “snow static” might be causing the impairment to his signal and I turned on our Bosch broadcast receiver to verify the conclusion. With the exception of a few strong stations, the entire broadcast band was blanketed by the characteristic hissing or frying sound which we are likely to hear under the conditions mentioned above in connection with the telephone line.

I then turned on the signal measurement receiver which is tuned to W1XAV at Squantum, Mass., on 61.5 megacycles. Although their carrier suppression of the receiver background noise was very good, probably as a result of a warm layer of air moving in (our temperature had gone from 17.8°F. at 1:45 p. to 30.5°F. at 7:35) the actual measurement showed