ON ATMOSPHERICS AT BANGALORE DURING THE POLAR YEAR.

By S. P. Chakravarti and B. H. Paranjpye.

1. INTRODUCTION.

Atmospherics or electromagnetic disturbances of the atmosphere have been studied on long and short wavelengths by a number of investigators* in different parts of the world, for a knowledge of their origin and characteristics is of great value for determining the best measures to be adopted to minimise their effects on radio reception and supplying information for weather forecasting on account of their close relation to meteorological conditions.

The work of these investigators has been mainly restricted to observations in temperate climates and can therefore give little information regarding atmospherics in the tropics. In India atmospheric disturbances are prevalent throughout the year. In certain months they are so severe that radio reception is practically impossible, while in other months they are tolerable. As far as the authors' information goes, no work relating to observations in this country has yet been published and it was therefore considered desirable to undertake similar studies in this climate and to compare the results with those obtained elsewhere.

The following lines of investigation have been mainly followed by the previous investigators:—

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* Wilson, *Proc. Royal Society*, **92,** 555, 1916.

Watt and Appleton, *Proc. Royal Society*, **103,** 84, 1923.

Round, Eckersley, Tremellen and Lunnon, *Journal Inst. Elec. Engrs.*, **63,** 933, 1925.

Watt and Herd, *Journal Inst. Elec. Engrs.*, **64,** 611, 1926.

Watt, *Journal Inst. Elec. Engrs.*, **64,** 596, 1926.

Appleton, Watt and Herd, *Proc. Royal Society*, **111,** 615, 1926.

Cairns, *Proc. Inst. Radio Engrs.*, **15,** 985, 1927.

Austin, *Proc. Inst. Radio Engrs.*, **15,** 837, 1927.

Armstrong, *Proc. Inst. Radio Engrs.*, **16,** 15, 1928.

Potter, *Proc. Inst. Radio Engrs.*, **19,** 1731, 1931.

Potter, *Proc. Inst. Radio Engrs.*, **20,** 1512, 1932.

Munro and Huxley, Radio Research Board, Australia, 1932, *Report* No. 5.

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(i) Determination of the direction of arrival of the atmospherics and location of their sources.

(ii) Examination of the wave-form of atmospherics.

(iii) Determination of the number of atmospherics per minute.

(iv) Determination of the distribution of noise due to atmospherics in long and short wave bands.

The present paper relates to observations recorded at Bangalore (12°58′ North and 77°38′ East) in response to the request of the International Polar Year Sub-Commission for such measurements being carried out at the Indian Institute of Science during the Second International Polar Year, extending from 1st August 1932 to 31st August 1933. In the absence of any definite instructions in the matter in August 1932, it was originally intended to record the observations on 15 kc/s. (20 Kms.) and this was the wavelength used up to 21st November 1932. However, subsequently, on receipt of information from the Polar Year Sub-Commission to the effect that it would be preferable to carry out the recording on 27 kc/s. (11·11 Kms.) in order to make the observations comparable with those made elsewhere, this latter wavelength was used after 21st November 1932.

The investigation comprises (*a*) the determination of the direction of arrival of maximum disturbance during each month, (*b*) the determination of daily and monthly averages of the number of atmospherics per minute, and (*c*) the correlation of daily and monthly averages of the number of atmospherics per minute with local and distant thunderstorms, mean local temperatures, sunspot numbers and number of magnetically disturbed days. An automatic directional recorder lent by the British Radio Research Board to the Department of Electrical Technology, Indian Institute of Science, Bangalore, in 1924, was available for the investigation and a 24-hour record was obtained on practically every day of the Polar Year. As a cathode ray direction finder was not available, the determination of the "sense" of arrival of the atmospherics and the examination of the intensity of individual atmospherics could not be undertaken.

2. THE DIRECTIONAL RECORDER AND ITS OPERATION.

The recording gear consists of a wooden frame-work supporting a frame aerial which is belt driven by a turret clock and which carries a drum on which the pen of an oscillograph, actuated by the output of an amplifier connected to the aerial, traces the record of the atmospherics. The constructional and other details of the recorder equipment are described in the paper on "The Directional Recording of Atmospherics" by R. A. Watson Watt (*J.I.E.E.*, 1926, **64**, 596) and have therefore been omitted here. A brief description of the circuit is, however, given below.

The winding of the frame aerial is in four sections, two of 20 turns each and two of 10 turns each, of 1·2 mm. diameter bare aluminium wire with a winding pitch of 50 mm. A variable mica condenser of 0·01 microfarads maximum capacity is connected across the winding for tuning the aerial to any desired frequency. The aerial has an inductance of 13·5 mH. and a d.c. resistance of 10·8 ohms with all the four sections in series.

The multi-stage amplifier consists of five resistance-capacity coupled high frequency stages, followed by a detector stage and two transformer-coupled low frequency stages. The triodes used in all the stages except the last are of the Osram D.E.R. type (R_a = 30,000 Ω; $\mu = 8$) and the output stage contains Marconi H.L. 210 type (R_a = 23,000 Ω; $\mu = 20$). The plate batteries are 50 V units of about 2 ampere-hour capacity and the filament batteries are 2 V units each of 120 ampere-hour capacity. A milli-ammeter inserted in the common plate circuit lead to the first seven stages measures the sum of anode currents in these stages and a second milli-ammeter measures the anode current in the output stage. The former milli-ammeter can also be used for measuring the plate voltage by means of a switch and a series resistance. A circuit diagram of the aerial and the amplifier is given in Fig. 1.

The oscillograph inserted in the plate circuit of the output stage consists of a permanent horseshoe magnet with four radial poles each having a coil which carries the output current. The coils are so connected that when a current passes through them, the soft iron armature is deflected from its normal position. A tongue on the armature shaft carries an aluminium girder which holds a siphon pen made of silver tube dipping into an inkwell of adjustable height.

The turret clock drives the frame continuously at a speed of 4 revolutions per hour. This rotation is transmitted to the drum carrying the chart. The drum descends through 3 mm. per revolution. Thus, in the absence of impulses from the amplifier, the oscillograph pen describes a helical trace of 3 mm. pitch on the chart. The arrival of an atmospheric impulse deflects the oscillograph needle and is noted on the chart by a vertical kink transverse to the helical base. The height of this kink can be taken as a measure of the voltage produced across the aerial tuning condenser and its position on the trace gives the time and direction of arrival of the atmospheric. When the paper is taken off the drum and straightened out, the helical trace on the chart resolves itself into 96 approximately horizontal lines each representing one revolution (360° angle) of the drum and fifteen minutes in time at the above speed of rotation.

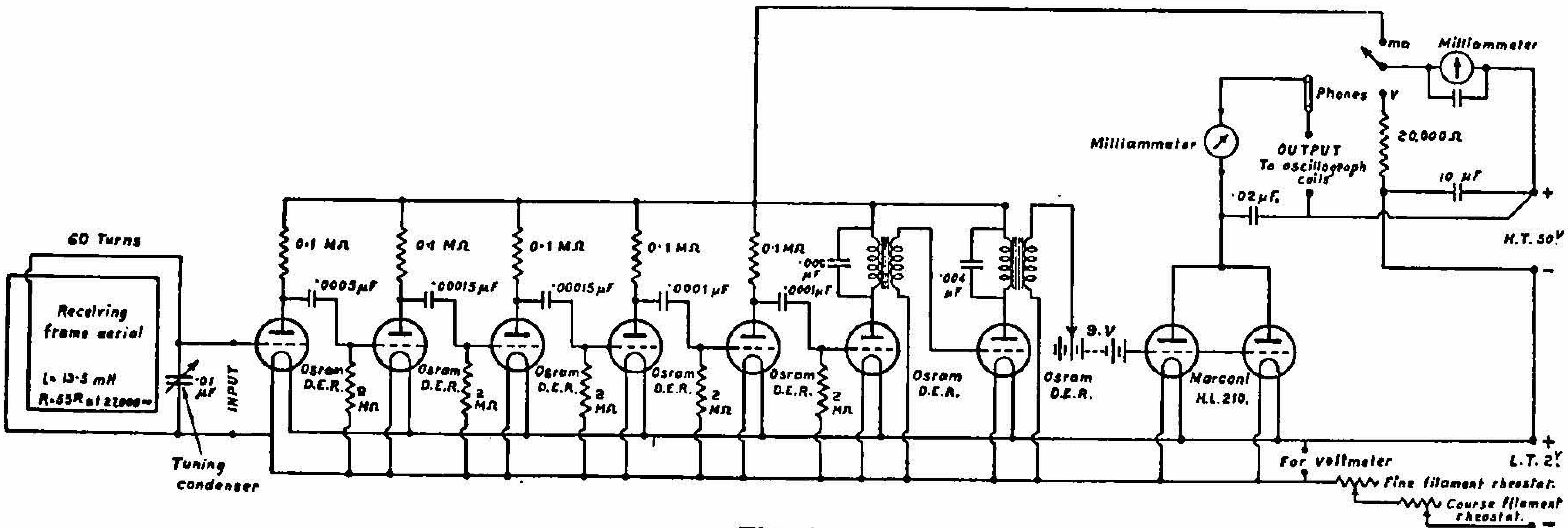

Fig. 1.

Circuit Diagram of the Aerial and the Multistage Amplifier.

3. REDUCTION OF DAILY RECORDS.

Each of the daily records during the month is examined line by line and the most probable direction of arrival of maximum disturbance during each of the 24 hours is marked on the record. The direction which shows the maximum number of kinks of the largest size during the hour is taken as the direction of arrival of the maximum disturbance. Due to the presence of the 180° ambiguity, another direction of arrival of maximum disturbance was always observed, displaced from the first by about 180°. A careful examination of the records further shows that two or more independent directions of disturbance similar to the direction of maximum disturbance may exist only during a quarter or a half-hour.

This multiple distribution was also observed by R. A. Watson Watt and mentioned in his paper on "The Directional Recording of Atmospherics" (*J.I.E.E.*, 1926, **64**, 596).

For determining the hourly direction of arrival of maximum disturbance for the month, the daily records are reduced to the form of a frequency chart, which shows, by means of dots placed underneath the various directions, the number of times the disturbance has arrived from a particular direction at a particular hour during the month. A specimen of the frequency chart is shown in Fig. 2. In the charts there are dense blocks having the largest number of dots

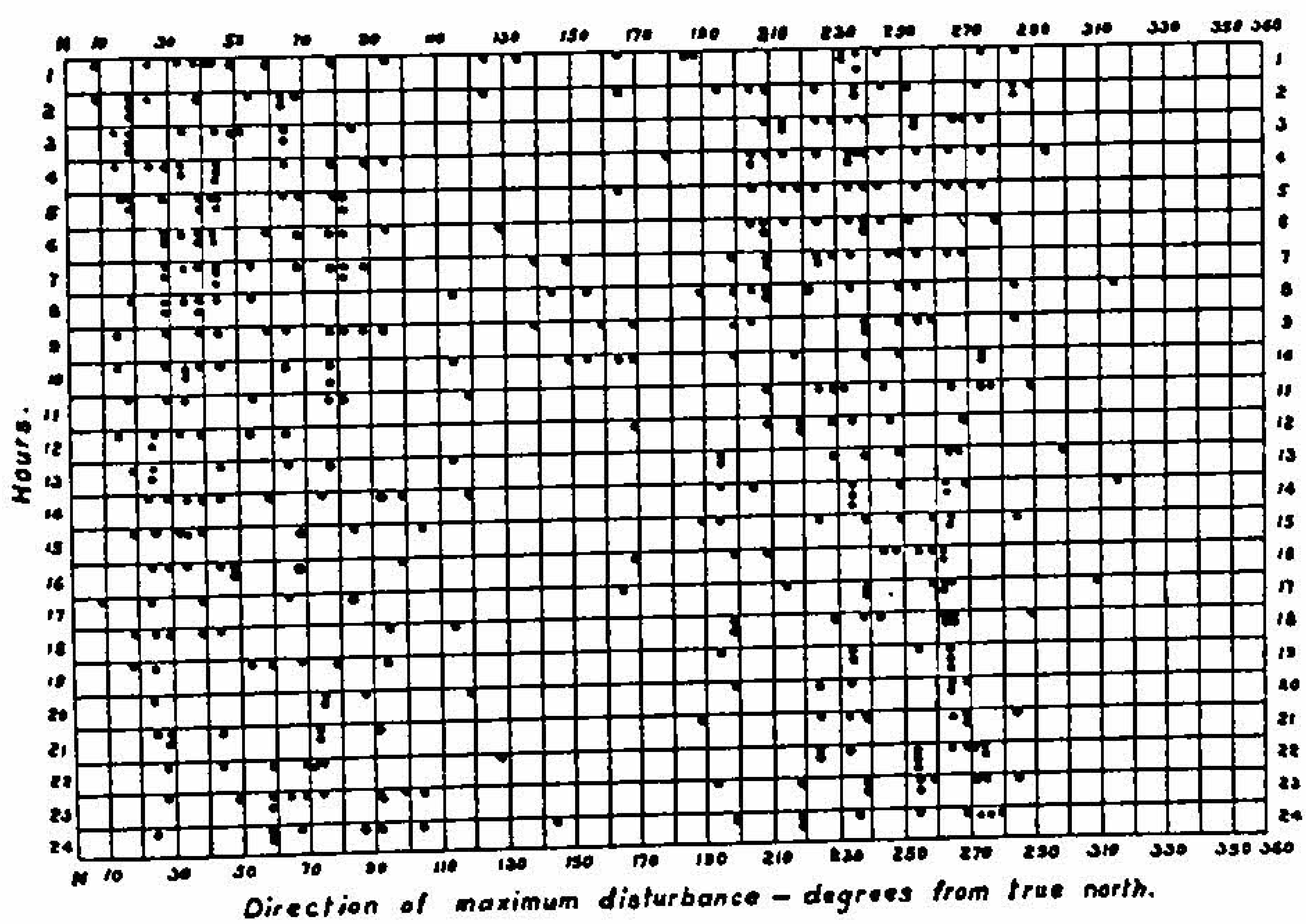

Fig. 2.

Frequency Chart of Hourly Variation of Direction of Maximum Disturbance, (February 1933.)

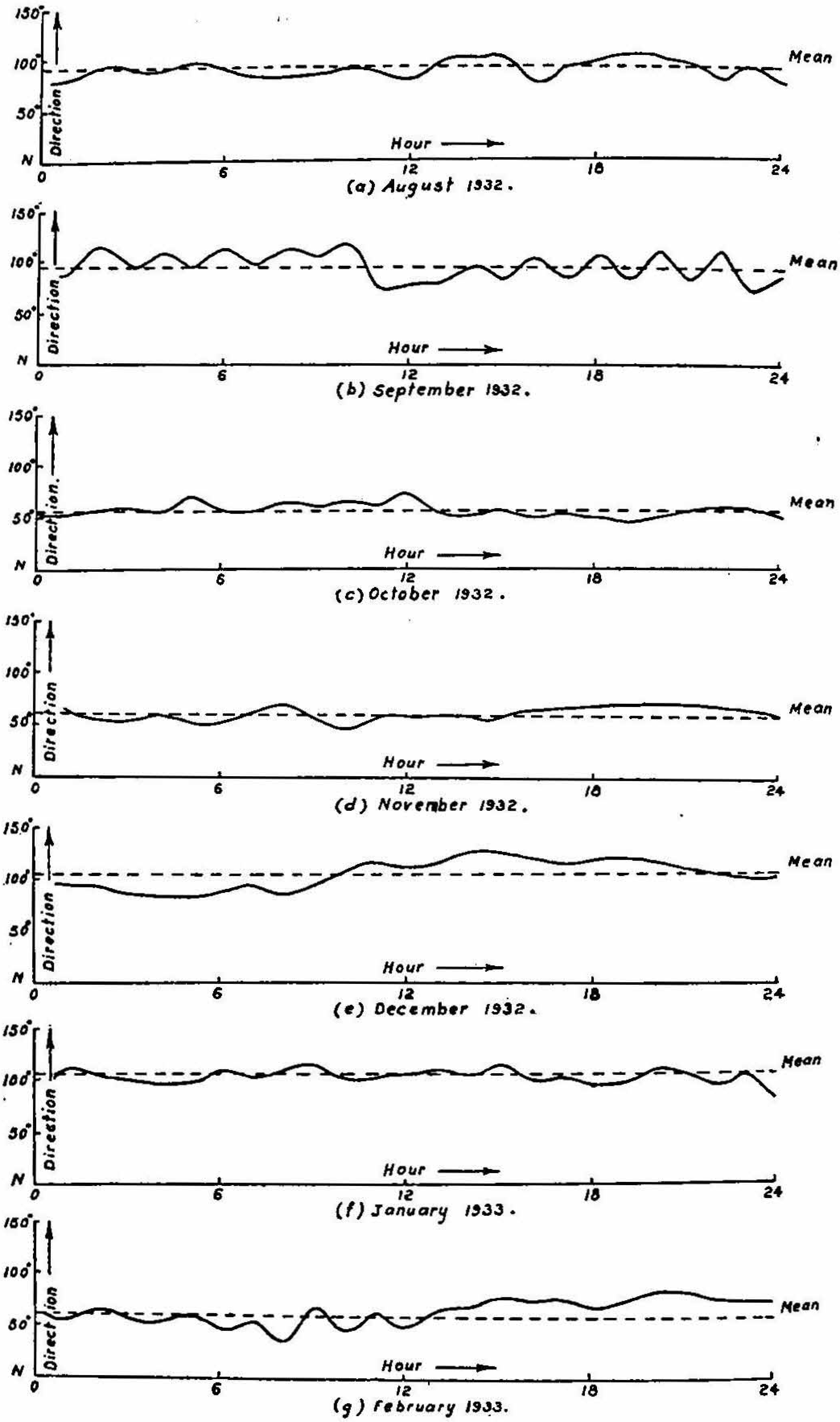
150°
100°
50°
N
Direction
Mean
Hour
0
6
12
18
24
(a) August 1932.
(b) September 1932.
(c) October 1932.
(d) November 1932.
(e) December 1932.
(f) January 1933.
(g) February 1933.

Fig. 3.

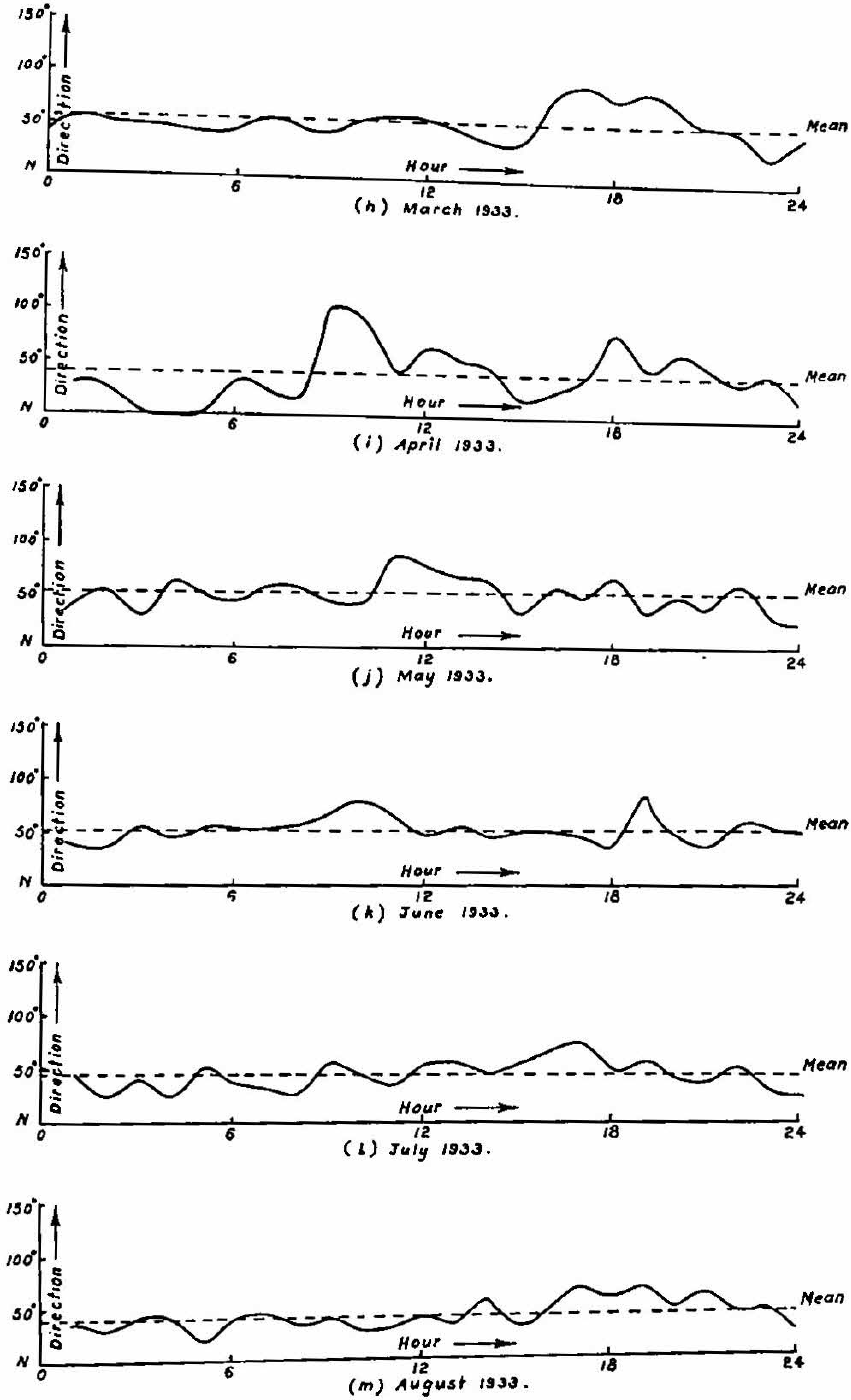

Fig. 3.

Variation of the Hourly Direction of Maximum Disturbance during the Months.

separated by sparse blocks having few or no dots. The "median curve" of these dense blocks, *i.e.*, the direction which has as many dots on one side as on the other is then taken to be the most predominant hourly direction of arrival for the month. The median curve for each month is plotted on a separate sheet for further study as shown in Fig. 3. The median curves appear to vary from hour to hour about mean directions marked in dotted lines in Fig. 3 and plotted against the months as shown in Fig. 4.

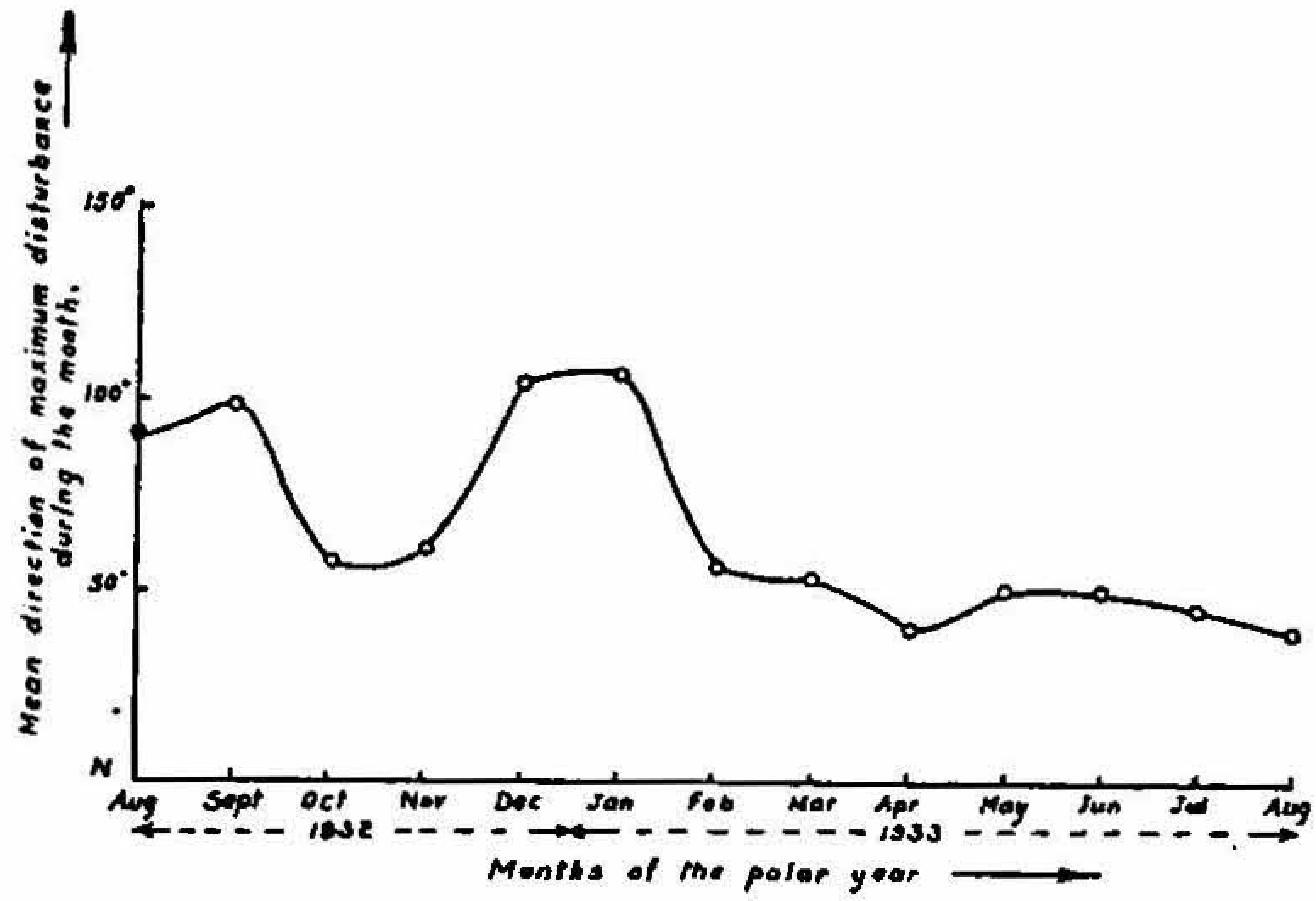

Fig. 4.

Variation of the Monthly Mean Direction of Maximum Disturbance.

The monthly average of the number of atmospherics per minute is arrived at from the daily average of the number of atmospherics per minute which in turn is determined from the hourly number of atmospherics per minute. For determining the hourly number, the number of noticeable kinks in each line of the record (corresponding to fifteen minutes) is counted and divided by fifteen and an average figure for four such lines is then worked out. Fig. 6 shows the daily averages plotted against the days of the month and Fig. 7 shows the monthly averages plotted against the different months. Fig. 8 shows the variation of hourly numbers on a typical summer and a typical winter day during the period under observation.

The change-over from 15 to 27 kc/s. on the 21st November 1932 has resulted in a discontinuity in the graphs for atmospherics shown in Figs. 7, 9, 10 and 11.

4. DEDUCTION OF RESULTS.

Fig. 4 shows that, during the period under observation, the *mean* of the hourly direction of arrival of maximum disturbance for the month varies from 40 to 105 degrees East of true North. Fig. 5 shows the directional limits for the whole year marked (in dotted lines) on a map of South India. It is interesting to observe that the directions of South-West and North-East Monsoons and the directions of the most active thunderstorm areas in Africa and in the East Indies—both of which

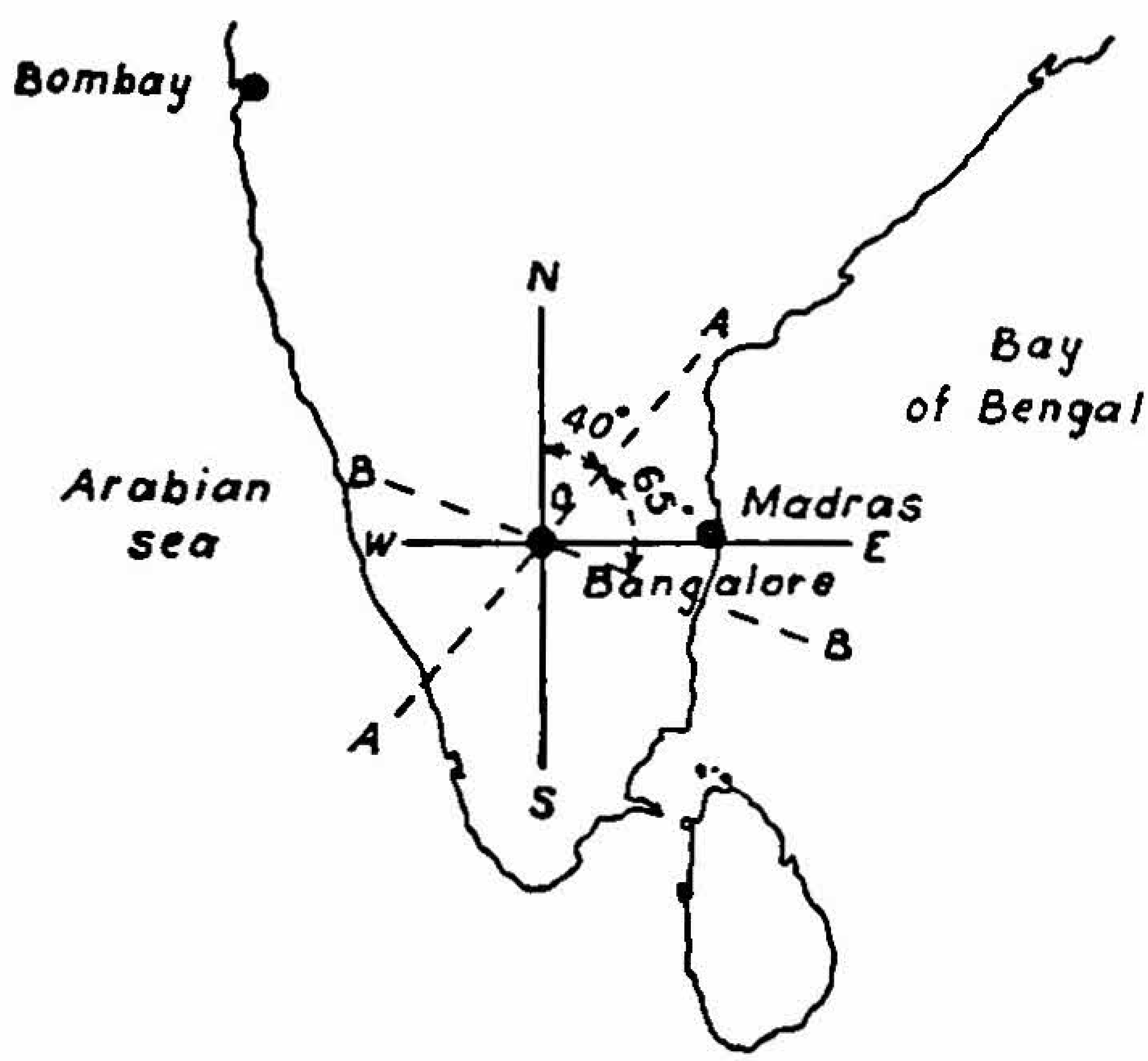

Fig. 5.

Map of Scuth India, showing the Limits within which all Mean Directions of Maximum Disturbance lie.

areas, according to the Australian investigators, Munro and Huxley (Radio Research Board, Australia, *Report* No. 5, 1932) are responsible for the major portion of the atmospherics of the world—fall within the angle marked by the dotted lines.

Fig. 3 indicates that during each month the hourly direction of arrival of disturbances varies with the hour of the day about a mean direction. The amplitude of departure is small during the winter months and large during the summer months. Table I shows the maximum and average amplitudes of departure for the various months.

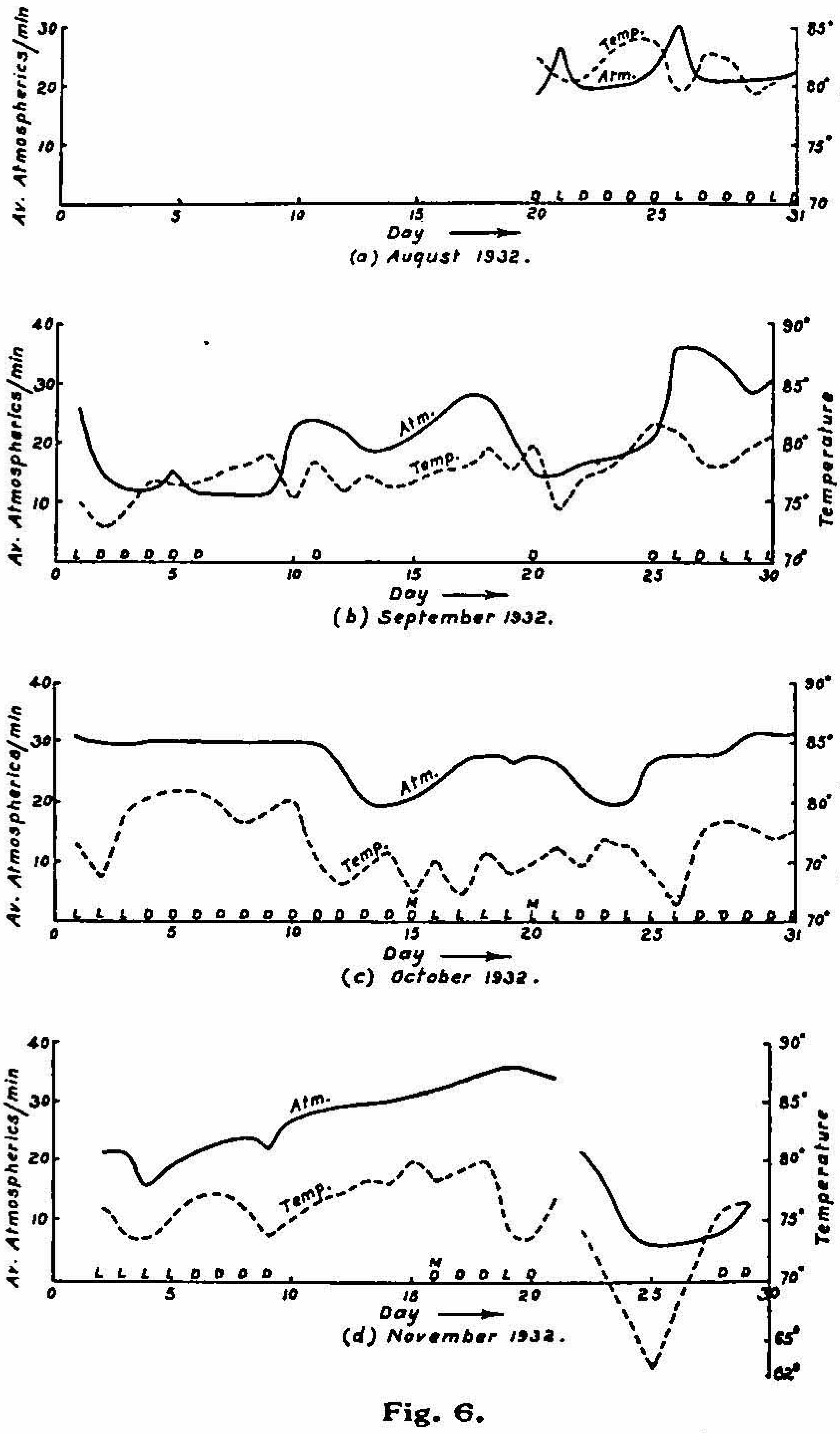
Av. Atmospherics/min
Temperature
Temp.
Atm.
Day
(a) August 1932.
(b) September 1932.
(c) October 1932.
(d) November 1932.

Fig. 6.

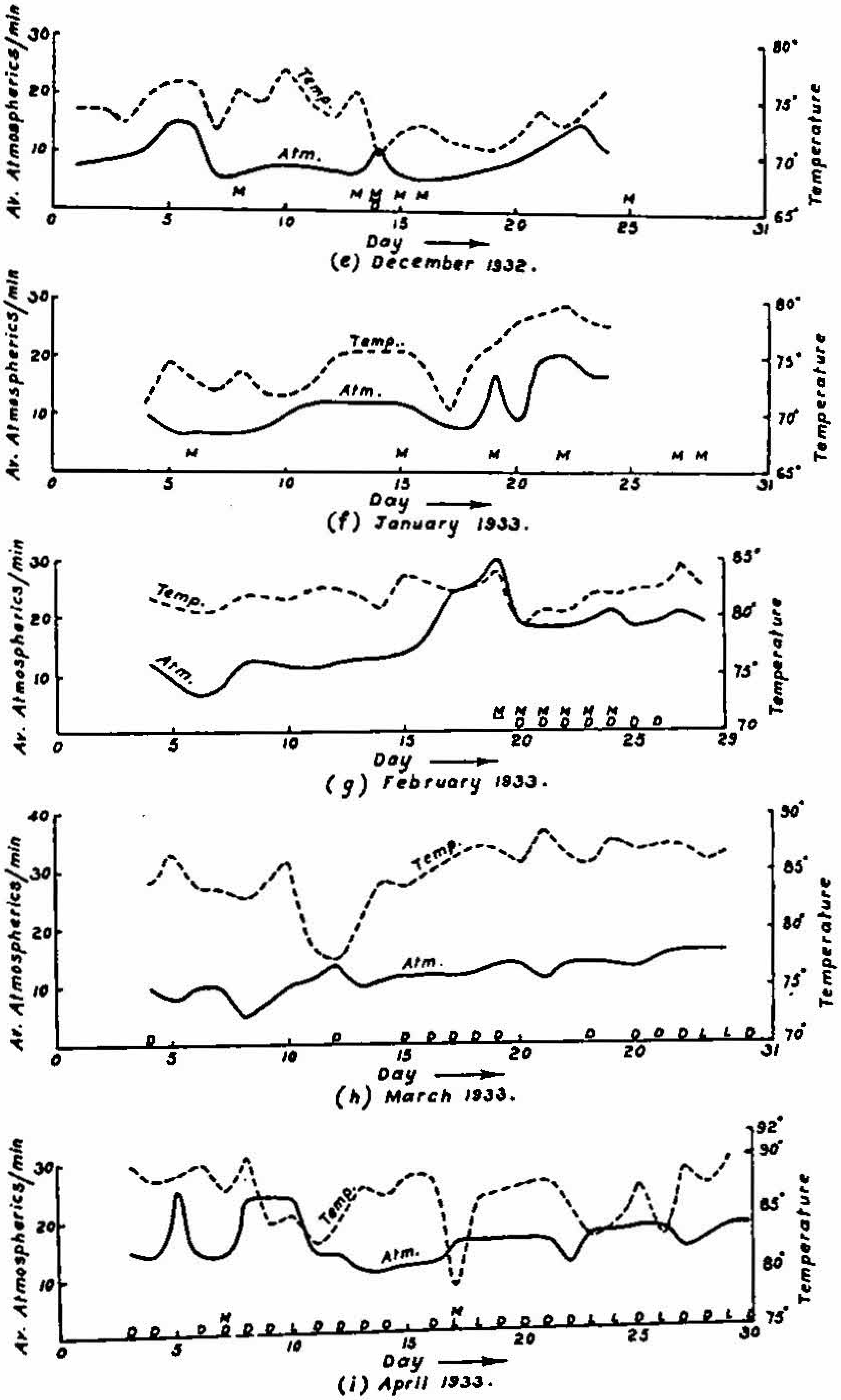
Av. Atmospherics/min
Temperature
Temp.
Atm.
Day
(e) December 1932.
(f) January 1933.
(g) February 1933.
(h) March 1933.
(i) April 1933.

Fig. 6.

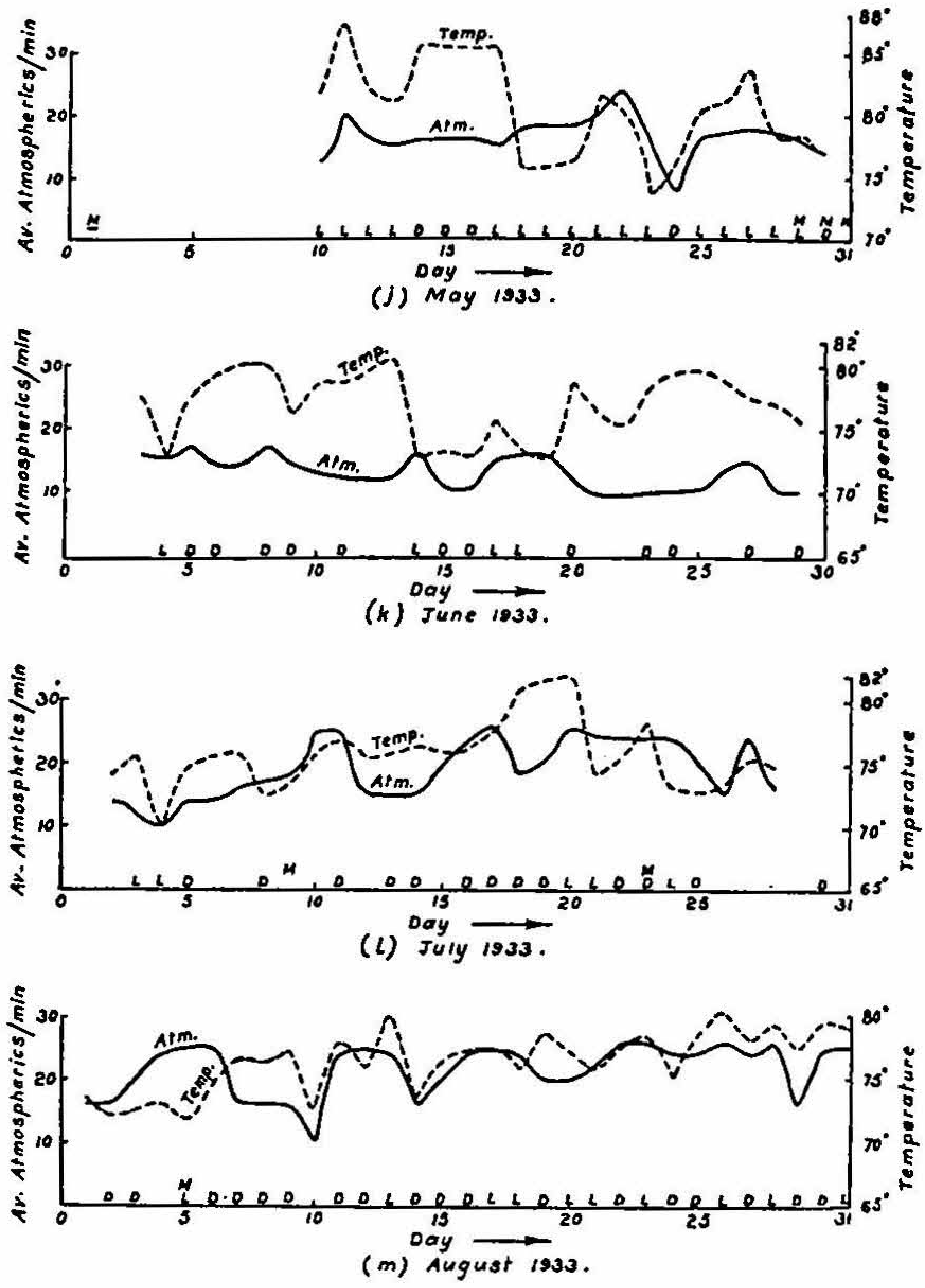

Fig. 6.

Variation of the Daily Average of the Number of Atmospherics per Minute during the Months.

L = Local thunderstorm,
D = Distant thunderstorm,
M = Moderate magnetic disturbance, and
<u>M</u> = Great magnetic disturbance.

TABLE I.

Months			Amplitude of Departure from the Mean	
			Maximum	Average
August	1932	..	14°	8°·75
September	,,	..	20°	13°
October	,,	..	15°	5°·4
November	,,	..	13°	7°·7
December	,,	..	20°	10°
January	1933	..	10°	5°
February	,,	..	30°	10°·8
March	,,	..	40°	17°
April	,,	..	64°	21°·2
May	,,	..	37°	12°
June	,,	..	32°	10°
July	,,	..	28°	11°
August	,,	..	26°	11°·5

It appears therefore that there is a greater constancy as regards the direction of arrival of the maximum disturbance of the atmospherics in winter than in summer. Figs. 6 and 7 show that the average number of atmospherics per minute is higher in summer than in winter months. The monthly averages are given in Table II.

TABLE II.

Months			Monthly Average of the Number of Atmospherics/Min.	
			on 15 kc/s.	on 27 kc/s.
August	1932	..	22	..
September	,,	..	20	..
October	,,	..	27·5	..
November	,,	..	26*	10†
December	,,	..		9
January	1933	..		11
February	,,	..		15
March	,,	..		12
April	,,	..		16
May	,,	..		17
June	,,	..		13
July	,,	..		19
August	,,	..		21

* 20 days' average. † 8 days' average.

Fig. 8 shows that, in general, the hourly number of atmospherics per minute is greater on a summer day than on a winter day. On a winter day, the hourly number of atmospherics per minute is small between the hours 7 and 17 I.S.T. and increases beyond the above limits. On a summer day the hourly number of atmospherics per minute is three to eight times that on a winter day between the same hours (7 and 17 I.S.T.) and increases beyond the above limits.

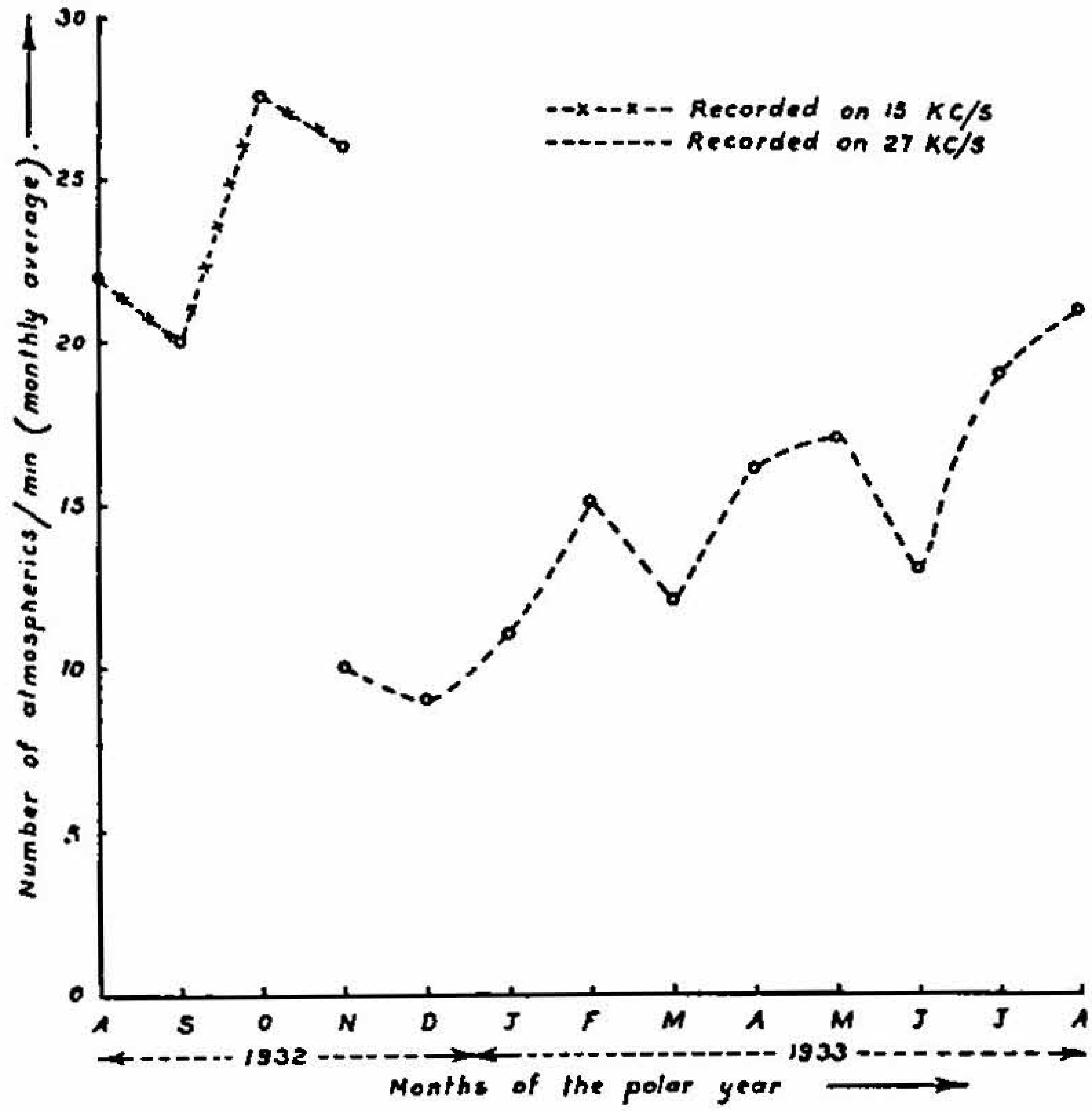

Fig. 7.

Variation of the Monthly Average of the Number of Atmospherics/Min.

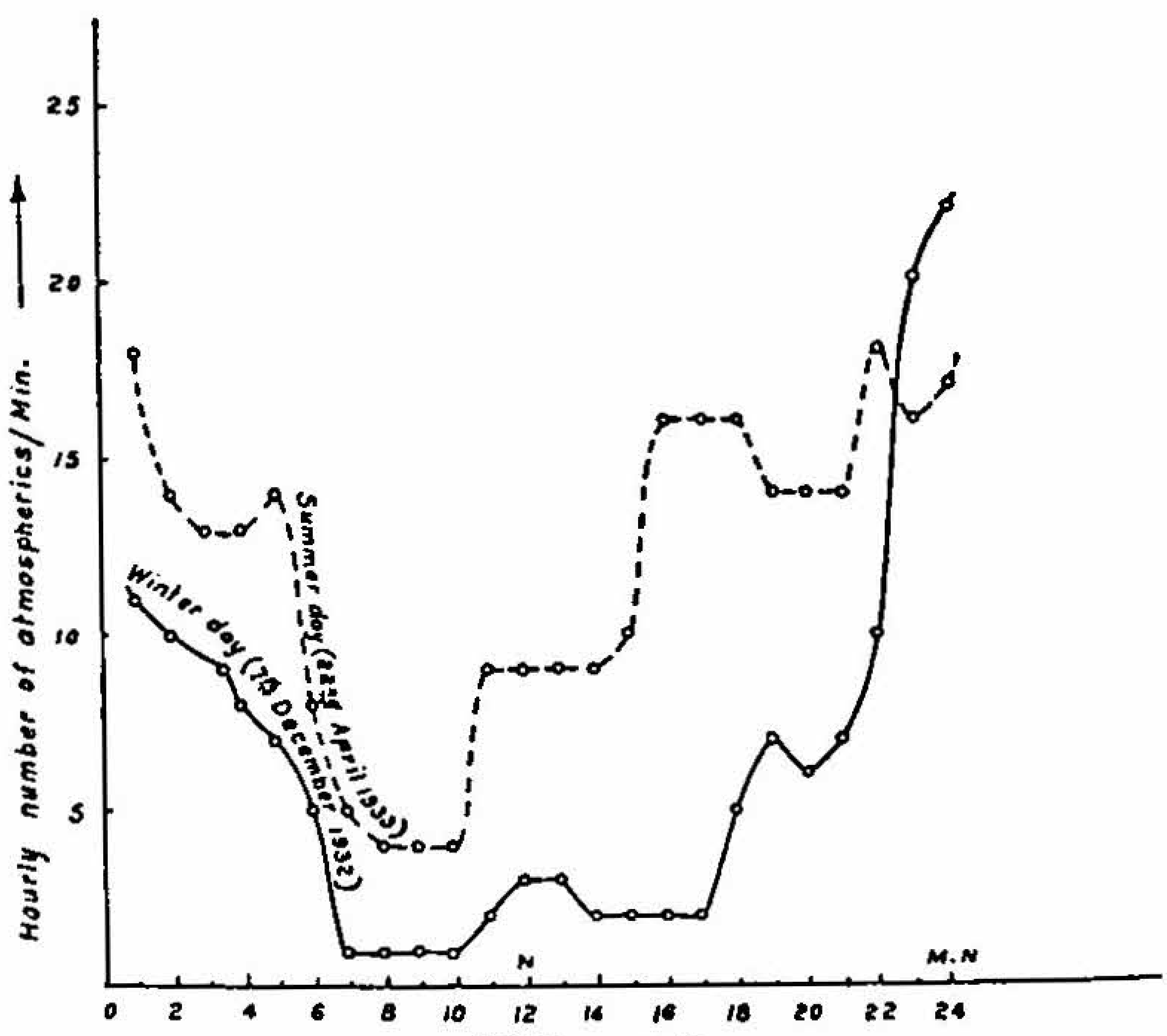

Fig. 8.

Variation of Hourly Number of Atmospherics/Minute during Summer an Winter Days.

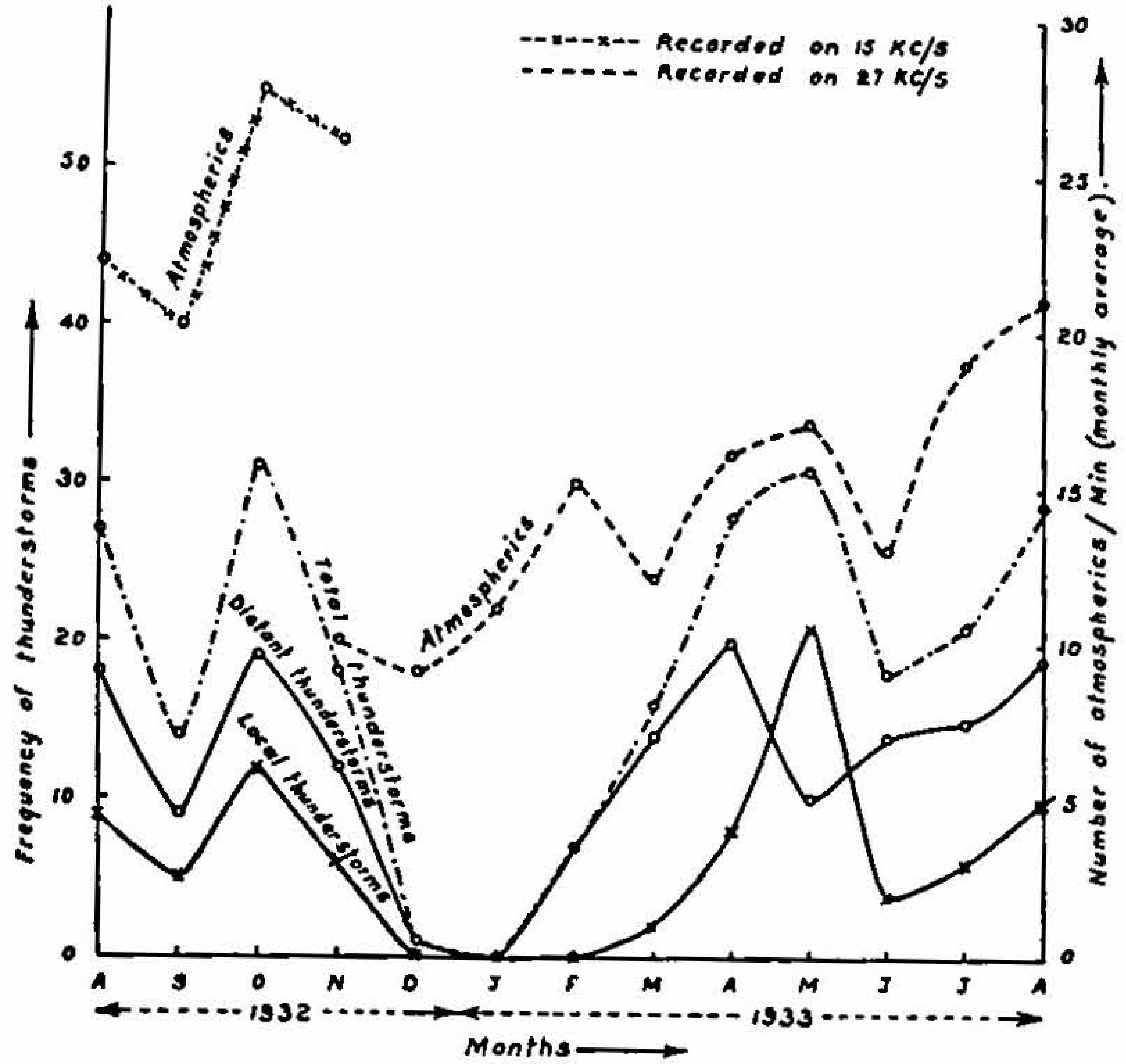

Fig. 9.

Relation between Thunderstorms and Atmospherics.

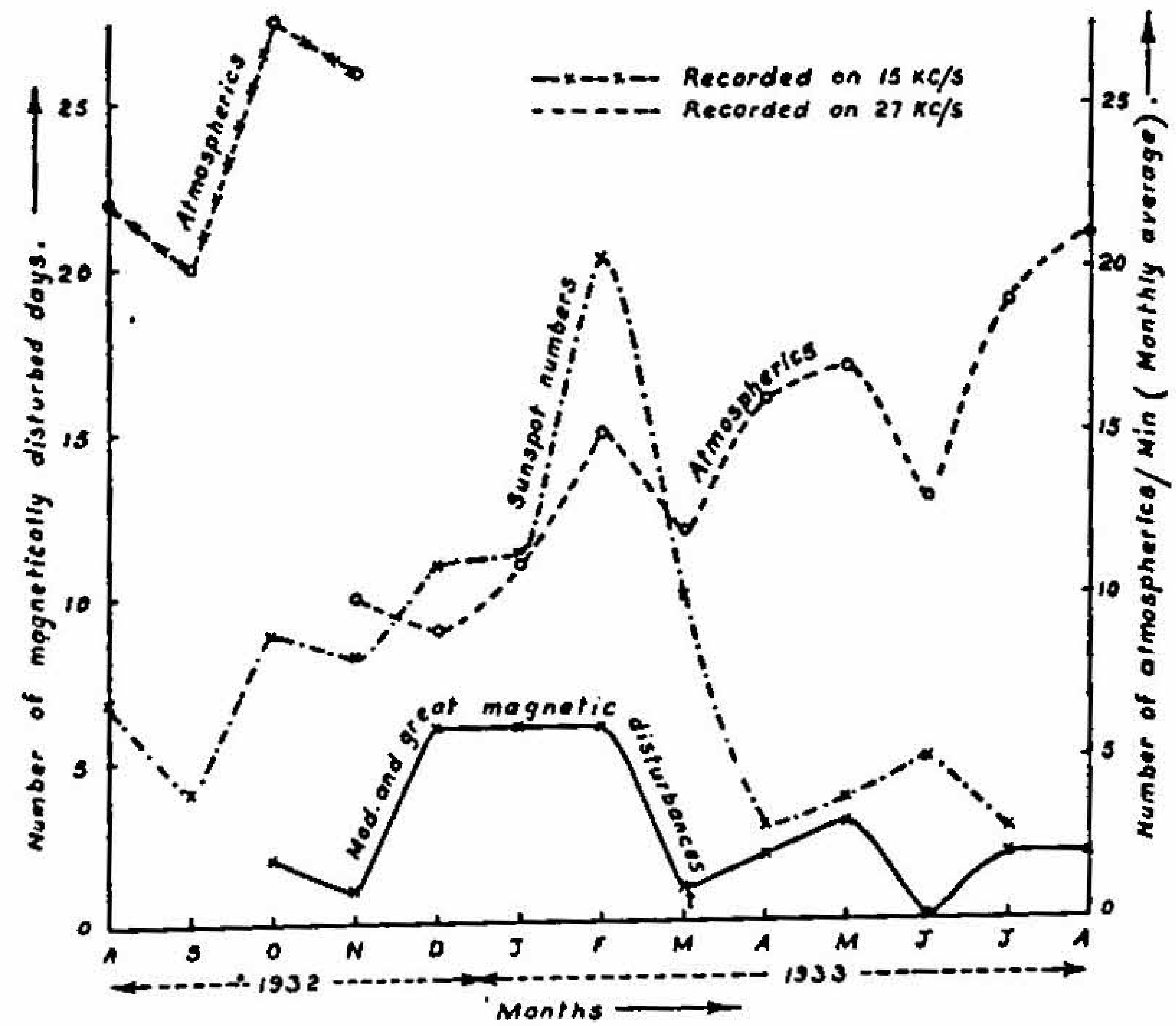

Fig. 10.

Relation between (A) Magnetic Disturbances and Atmospherics, and
(B) Sunspot Numbers and Atmospherics.

5. CORRELATION WITH METEOROLOGICAL DATA.

An attempt has also been made to ascertain whether any relationship, direct or inverse, exists between the atmospherics and (*a*) the local and distant thunderstorms, (*b*) the magnetic disturbances, (*c*) the sunspot numbers, and (*d*) the local temperatures in the morning and the afternoon. As so many different factors appear to affect the number of

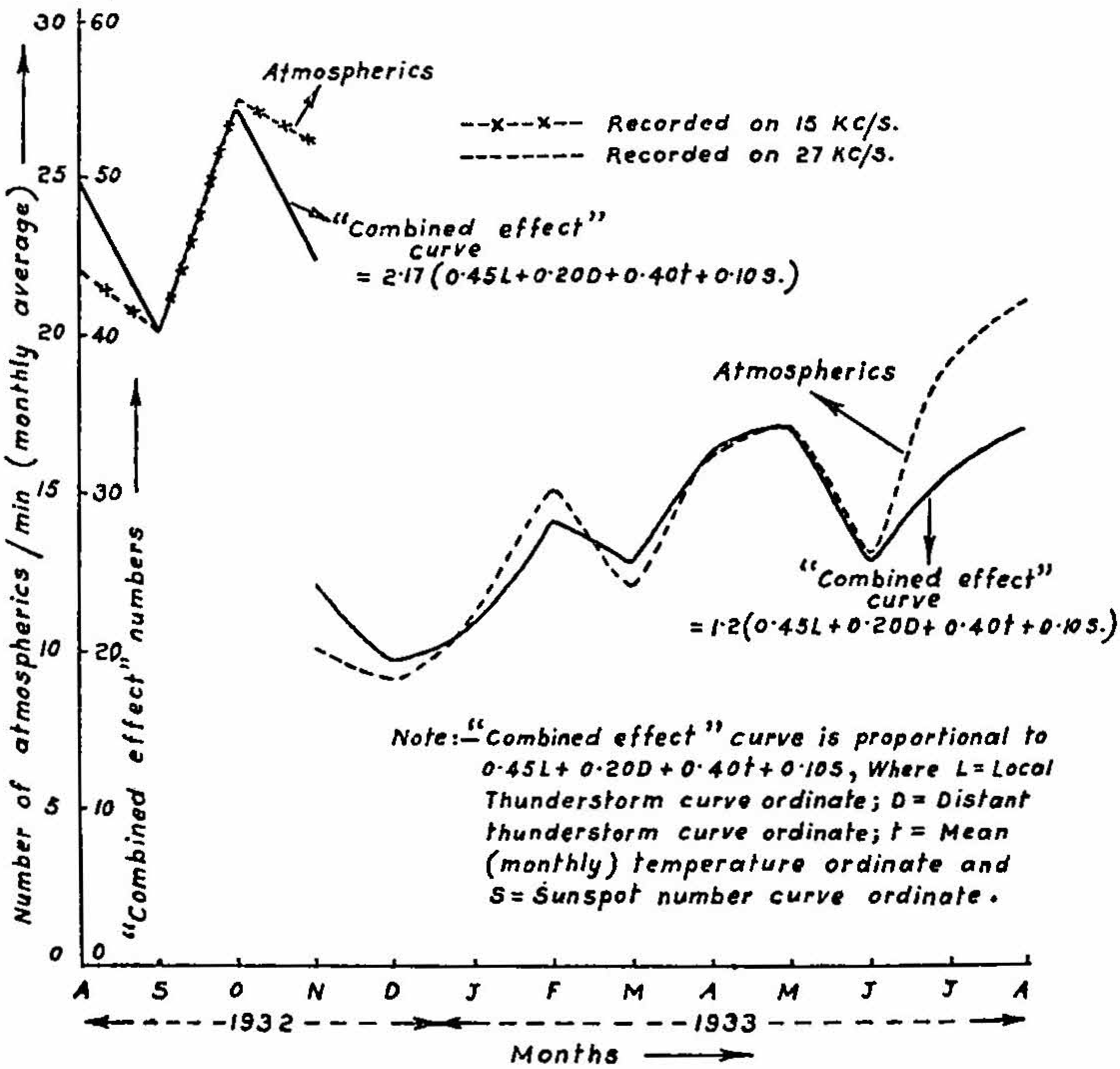

Fig. 11.

Comparison between Atmospherics and Quantity representing the Combined Effect of Local and Distant Thunderstorm Frequencies, Mean Local Temperature and Sunspot Numbers during the Month.

atmospherics, it is not possible to expect an exact correlation between the number of atmospherics and any one of the above factors taken separately. However, Figs. 6, 9 and 10 indicate some correlation in each case. An attempt has been made to correlate the monthly number of atmospherics with the combined effect of local and distant thunderstorms, local temperatures and sunspot numbers during the month and for this purpose "weighted" figures have been used representing the effect of the individual factors. The result is shown in Fig. 11, which shows a similarity between the atmospherics curve and the "combined effect" curve.

(*a*) *Effect on Thunderstorms.*—Since it has been concluded by Watson Watt and other investigators that thunderstorms supply the greater portion of the atmospherics of the world, the correlation of the thunderstorms at Bangalore (*i.e.*, local thunderstorms) and thunderstorms within 120 miles of Bangalore (*i.e.*, distant thunderstorms) with the daily average of the number of atmospherics per minute is of special interest. Fig. 6 shows that on every day on which local thunderstorm occurred the atmospherics reached a high value. The days of local thunderstorms correspond, in general, to peaks in the atmospherics curve.

Fig. 9 further shows that the monthly average of the number of atmospherics per minute bears direct relationship to the frequency of thunderstorms (*i.e.*, total thunderstorms) during the month for the whole of the period under observation except between December 1932 and January 1933 and between February and March 1933.

(*b*) *Effect of magnetic disturbances.*—Fig. 6 shows that on the days of great magnetic disturbances, the atmospherics reach a high value and that on the days of small or moderate disturbance no appreciable increase is observed. Fig. 10 further shows that the monthly average of the number of atmospherics per minute bears a direct relation to the number of days of moderate and great disturbances during the months from February 1933 to August 1933.

(*c*) *Effect of sunspot numbers.*—Fig. 10 indicates that an increase or decrease in the number of sunspots is accompanied by an increase or decrease of atmospheric disturbances respectively between August 1932 and March 1933.

(*d*) *Effect of local temperature.*—Fig. 6 suggests, in general, a direct relationship between the daily number of atmospherics per minute and the mean of the local temperatures at 1020 and 1700 I.S.T. A careful examination of the atmospherics and the temperature curves further shows that the atmospherics curve varies directly as the temperature curve or the curve shifted forward by a day.

During some months, the atmospherics curve varies directly as the temperature curve for a portion of the month and then varies directly as the temperature curve shifted forward by a day for the rest of the month.

It appears therefore that the atmospherics on a particular day may be related either to the mean temperature of the same day or to the mean temperature of the previous day.

It may be stated that Austin's experiments carried out near Washington during 1924-26 indicated a direct relationship between the atmospherics and (a) distant thunderstorms within 200 miles of Washington, and (b) local temperatures averaged in 10-day periods. The direct relationship of the atmospherics with the local thunderstorms, mean local temperature of the same or previous day, sunspot numbers and moderate and great magnetic disturbances as shown by present experiments are, however, new results.

6. CONCLUSION.

The following conclusions have been arrived at by the authors:—

(1) The mean of the hourly direction of arrival of maximum disturbance at Bangalore for the period August 1932 to August 1933 varies from 40° to 105° East of true North and there is a greater constancy of the hourly direction of arrival of the maximum disturbance in winter than in summer months.

(2) The average number of atmospherics per minute is higher in summer than in winter. The hourly average number of atmospherics per minute is several times higher on a summer day than on a winter day.

(3) On each day that a thunderstorm occurs at Bangalore, the daily number of atmospherics per minute reaches a high value. In the month in which the frequency of occurrence of thunderstorms is high the monthly average of the number of atmospherics per minute is also high.

(4) A day of "great" magnetic disturbance is associated with a high daily number of atmospherics per minute. An increase or decrease of sunspots appears to be accompanied by an increase or decrease of atmospheric disturbances respectively during eight months of the period under observation.

(5) The atmospherics on a particular day appear to be related to the mean local temperature of the same day or to the mean local temperature of the previous day.

7. ACKNOWLEDGMENTS.

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