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Changes of Atmospheric Electric Potential Gradient at Poona during disturbed weather

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ABSTRACT. A detailed study of the changes of atmospheric potential gradient during disturbed weather at Poona for 5 years 1936-40 has been made. From the analysis it is seen that if during rainfall the potential gradient is negative but without rapid variations the rainfall is associated with a quite atmosphere, whereas large and rapid changes in the potential gradient are usually associated with atmospheric disturbances having appreciable local ascending air currents just as the rainfall occurring in showers. Changes in potential gradient are not closely associated with either the intensity or the variations of the rainfall. The field at the ground is not essentially different in thunderstorms from that associated with showers. Two main types of potential gradient patterns have been recognised, (*a*) Wave Patterns (*b*) Symmetrical Patterns. Some of the patterns are seen to be associated with definite types of weather.

1. Introduction

The origin of electricity carried by rain and other forms of atmospheric precipitation has been the subject of much discussion in recent years (Simpson 1909, 1915, 1923; Simpson and Scrase 1937; Simpson and Robinson 1941; Simpson 1919, 1942, 1949; Scrase 1938; Whipple and Scrase 1936; Whipple and Chalmers 1944; Wilson 1925, 1929; and Chalmers 1939). In the India Meteorological Department systematic registration of Atmospheric Electric Potential Gradient is made at the Colaba Observatory, Bombay and at the Meteorological Office, Poona and contributions to the subject have been made by a number of workers (Sil 1938; Sil and Agarwala 1940; Mukherjee and Pillai 1940; Pillai 1940; and Banerji 1930, 1932). These papers treat the potential gradient during disturbed weather in a general way and no systematic study of changes of potential gradient during precipitation appears to have been made. The method of analysis in the present paper closely follows the method adopted by Simpson (1949) with a view to find out how far observations from India corroborate his conclusions.

2. Instruments

The systematic recording of Atmospheric Electrical Potential Gradient at Poona Observatory is done by a Cambridge Instrument Company's photographic recorder. For collecting the potential a radium spiral collector is used. It projects outside the room, where the electrometer is housed, through a hole at a height of about 60 ft above ground. Normally, the collector is kept at a distance of 60 cm from the zero potential surface and the reduction factor is determined by taking observations with an ionium collector connected to a stretched horizontal wire at a height of 1 metre above ground on the neighbouring open ground. The corresponding rainfall records are obtained from the Casella Syphon Raingauge.

3. Potential Gradient and Weather

The undisturbed days of earth's electric field at Poona are few and far between. Poona is situated near the western margin of the Deccan plateau. Its height above mean sea level is 1830 ft and its position is latitude 18° 30′ N and longitude 73° 53′ E. Here the monsoon season extends from June to September when the sky remains overcast with low clouds and it drizzles or rains occasionally, the two post-monsoon months (October and November) are sultry and calm, the winter (December to February) marked with frequent mist or fog in the morning and haze in the evening, while during the summer preceding the monsoon, wind is high and the atmosphere is laden with dust, and thundery weather prevails off and on in the afternoon.

The precipitation at Poona has been classified into three main types (*a*) steady rain, (*b*) showers and (*c*) thunderstorms.

(*a*) *Steady rain*—For steady rain three arbitrary conditions, as was done by Simpson are chosen.

(1) The rainfall must continue for at least one hour

(2) No large variations in the rate of rainfall

(3) The rate of rainfall must not fall below 4 cents per hour.

(*b*) *Showers*—All periods of rainfall not included in steady rain are grouped under showers. Majority of these periods can, however, be classified as showers in the strict meteorological sense.

(*c*) *Thunderstorms*—Wherever possible, records obtained during thunderstorms are made use of.

The characteristics of potential gradient for each of the above three types of precipitation at Poona are considered. The periods of steady rain have been divided under two categories.

(1) Periods in which the potential gradient was negative throughout

(2) Periods in which there were some positive and negative potential gradients.

4. Discussion of results

(*a*) *Steady rain*—During the period 1936-[illegible]40 there were 76 distinct cases of steady [illegible] having negative potential gradient and [illegible]ses having both negative and positive [illegible]ntial gradient. Figs. 1 and 2 show [illegible]cal electrograms showing negative poten- [illegible] gradient and both negative and positive [illegible]ential gradient, with the corresponding [illegible]sella Syphon Raingauge charts. In an endeavour to find the cause of this difference the cases were analysed with regard to types of weather associated with them. For example, on 21 June 1937 (Fig. 1) the skies were completely covered with stratocumulus clouds at 1700 IST and there was intermittent steady rain practically the whole night and the next day morning. The potential gradient during the precipitation is found to be mostly negative between 1900 and 2300 IST on 21 June 1937 and from 0400 to 1000 IST on 22 June 1937. It is seen from the weather notes for the day that rain has been mostly falling from clouds of stratified type and the atmosphere may be considered as " quiet " without any instability or other disturbing conditions. On the other hand, the potential gradient between 1710 and 2000 IST on 22 September 1937 and between 2330 IST of 22 September 1937 and 0200 IST of 23 September 1937 is found to swing between positive and negative values (Fig. 2). On 22 September 1937 the skies were covered with *Ns* and *Cb* clouds at 1700 IST with thunderstorm from 1710 IST. The rainfall associated with the above periods can be said to have fallen from an atmosphere having instability and vertical currents. A number of similar cases were analysed and from the survey it may be said that *the potential gradient is found to be negative when the rain falls from a " quiet atmosphere "* and is found to have *both positive and negative values when the rain falls from an atmosphere having instability and vertical currents.*

It is also seen that the changes in the gradient are not associated with either the intensity or the variation of rainfall. For example, on 22 June 1937 (Table 1) between 0700 and 0715 IST the intensity of rainfall was one cent per hour whereas from 0730 to 0745 IST the intensity was 20 cents per hour. But the potential gradient did not show a corresponding variation. It is also interesting to see from Fig. 3 that no large changes in potential gradient had occurred on 22 July 1937, even though there was steady continuous rain for the whole day and the next day. It was a typical monsoon day at Poona.

(*b*) *Showers*—Figs. 4 to 7 illustrate the various aspects of potential gradient during showers. A comparison of Fig. 2 with Fig. 4 shows that both the curves

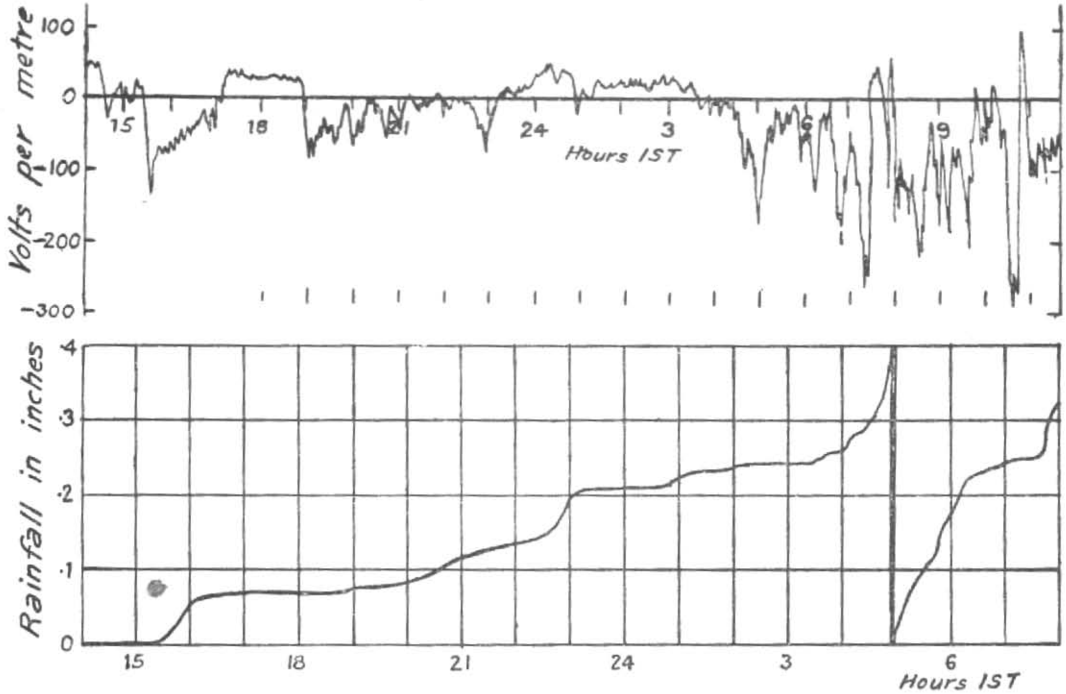

Fig. 1 — 21-22 June 1937

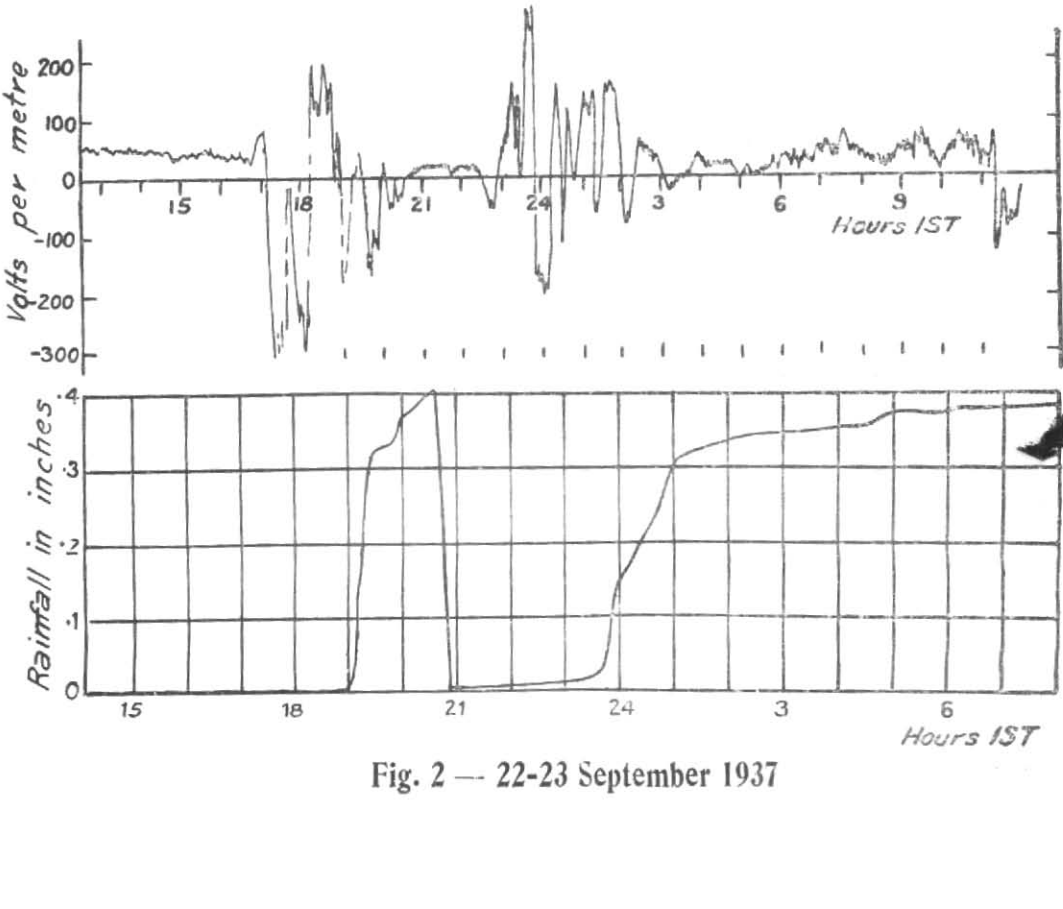

Fig. 2 — 22-23 September 1937

TABLE 1

Intensity of rainfall for selected periods of steady rain with negative potential gradient

Date	From (IST)	To (IST)	Amount of rainfall (cents)	Intensity of rainfall (cents/hr)
21-6-1937	1530	1545	3	12
	1545	1600	2	8
	1600	1615	1	4
	1615	1630	1	4
	1900	1915	..	1
	1915	1930	..	1
	1930	1945	..	1
	1945	2000	..	1
	2000	2015	1	4
	2015	2030	1	4
	2030	2045	1	4
	2045	2100	1	4
	2130	2145	..	1
	2145	2200	..	1
	2200	2215	..	1
	2230	2245	2	8
	2245	2300	3	12
	2300	2315	2	8
22-6-1937	0400	0415	2	8
	0415	0430	1	4
	0430	0445	4	16
	0445	0500	9	36
	0500	0515	5	20
	0515	0530	3	12
	0530	0545	2	8
	0545	0600	6	24
	0600	0615	4	16
	0615	0630	1	4
	0630	0645	1	4
	0645	0700	..	1
	0700	0715	..	1
	0730	0745	5	20
	0745	0800	3	12
	0800	0815	..	1

TABLE 2

Intensity of rainfall for selected periods of steady rain with positive and negative potential gradient

Date	From (IST)	To (IST)	Amount of rainfall (cents)	Intensity of rainfall (cents/hr)
22-9-1937	2315	2330	1	4
	2330	2345	2	8
	2345	2400	11	44
23-9-1937	0000	0015	3	12
	0015	0030	4	16
	0030	0045	3	12
	0045	0100	5	20
	0100	0115	2	8
	0115	0130	1	4
	0145	0200	1	4

TABLE 3

Intensity of rainfall for selected periods of showers with positive and negative potential gradient

Date	From (IST)	To (IST)	Amount of rainfall (cents)	Intensity of rainfall (cents/hr)
11-6-1937	2315	2330	40	160
	2330	2345	22	88
	2345	2400	..	..
12-6-1937	0000	0015	5	20
	0015	0030	13	52
	0030	0045	30	120
	0045	0100	26	104
	0100	0115	5	20
	0115	0130	1	4
	1930	1945	4	16
	1945	2000	36	144
	2000	2015	18	72
	2015	2030	1	4
	2030	2045	2	8
	2045	2100	3	12
	2100	2115	4	16
	2115	2130	..	1
	2130	2145	..	1
24-9-1938	1500	1515	1	4
	1515	1530	21	84
	1530	1545	8	32
	1545	1600	34	136
	1600	1615	16	64
	1615	1630	2	8
18-10-1939	1800	1815	18	72
	1815	1830	6	24
	1830	1845	2	8
	2115	2130	12	48
	2130	2145	1	4
	2145	2200	1	4
	2215	2230	2	8
	2230	2245	27	108
	2245	2300	13	52
	2300	2315	4	16
	2315	2330	2	8

TABLE 4

Intensity of rainfall for selected periods of thunderstorm rain with positive and negative potential gradient

Date	From (IST)	To (IST)	Amount of rainfall (cents)	Intensity of rainfall (cents/hr)
18-9-1936	1530	1545	14	56
	1545	1600	6	24
	1600	1615	10	40
	1615	1630	90	360
	1630	1645	26	104
	1645	1700	4	16

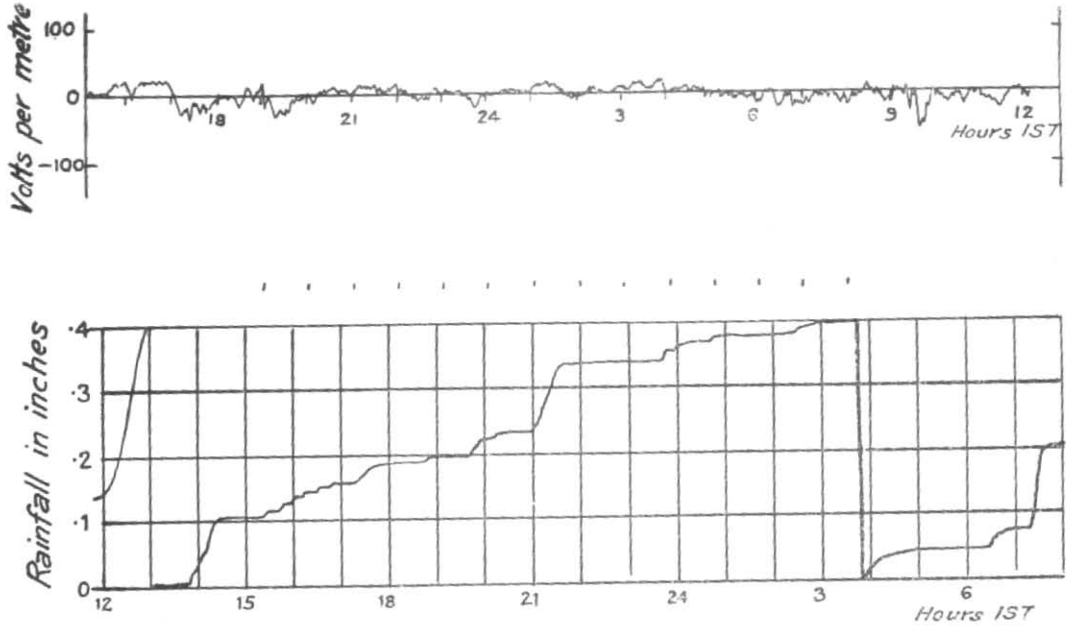

Fig. 3 — 22-23 July 1937

agree in showing alterations of positive and negative gradient; the variations are greater and more rapid in the period of showers than in the period of steady rain. This is the characteristic difference between showers and steady rain. Such showers are found to be associated with disturbed potential gradient but the record shows no relationship between the quantity of rain or intensity of rain in the shower and the sign of the magnitude of the potential gradient disturbance. For example, on 12 June 1937 (Fig. 4) between 1945 and 2000 IST the intensity of rainfall was 144 cents per hour. The corresponding variation in potential gradient was very large, the trace having gone off the paper. On the other hand between 2015 and 2030 IST the intensity was only 4 cents per hour, but the fluctuations in the electrograph record are so violent that here also the trace has gone off the paper showing clearly that there is no relationship between the intensity of rain in the shower and the magnitude of the potential gradient disturbance. Similar examples can be seen in Figs. 5, 6 and 7.

(c) *Thunderstorms*—Figs. 8 and 9 illustrate the changes of potential gradient during thunderstorms. It is difficult to draw a hard and fast line between showers and thunderstorms. Except for the momentary fields due to lightning discharges the electric field at the ground during thunderstorms is not greater than during many showers which are not accompanied by lightning discharges. Also during thunderstorms as during showers the field at the ground bears no relationship to the intensity of rainfall. In Fig. 8 for example, on 18 September 1936 there are periods (1615 to 1630 IST) in which the rainfall reached a rate of 360 cents per hour and between 1645 and 1700 IST, it did not exceed 16 cents per hour.

It is interesting to see on 24 April 1940 that there is no rain recorded (Fig. 9) during the whole day, yet large fluctuations in potential gradient are recorded between 1500 and 1800 IST. This is due to the presence of large charged clouds. From the weather diary of that date it was seen that thunder was heard off and on from 1500 IST till late in the evening.

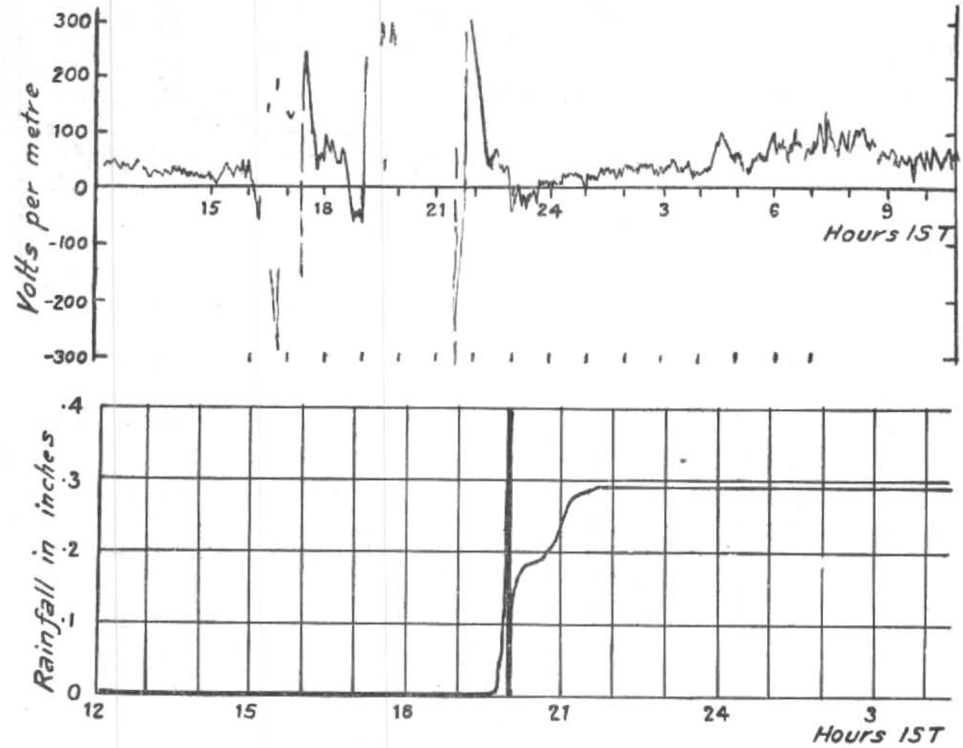

Fig. 4 — 12-13 June 1937

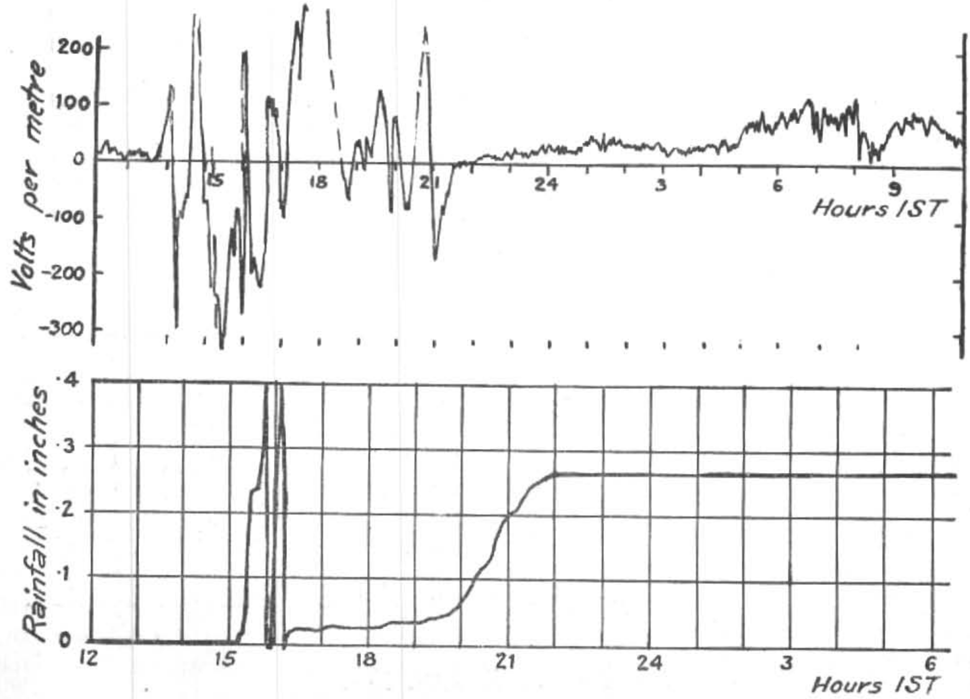

Fig. 5 — 24-25 September 1938

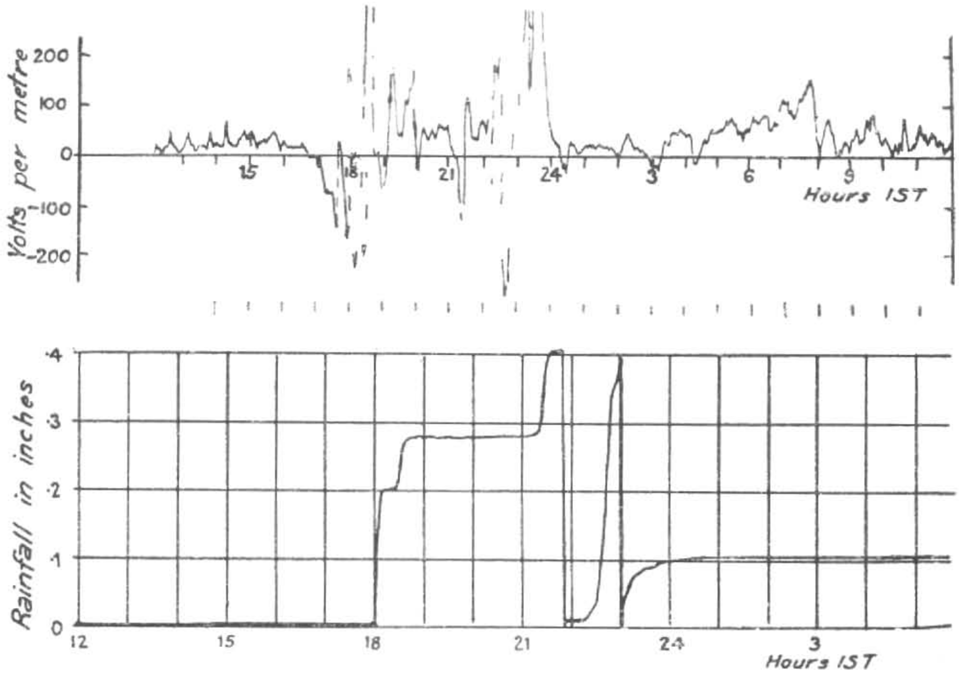

Fig. 6 — 18-19 October 1939

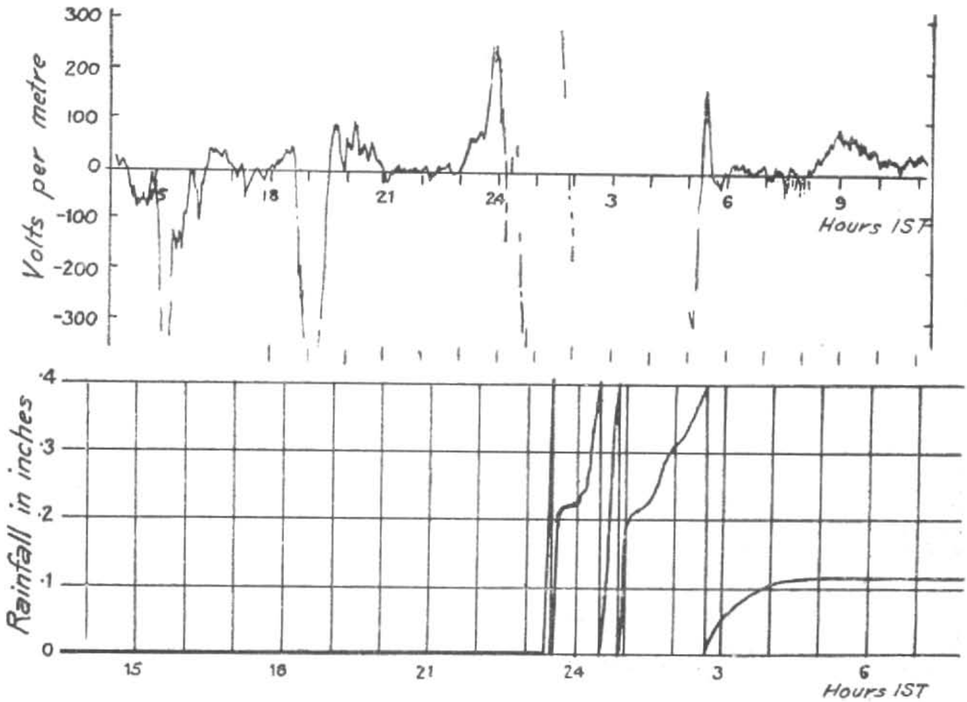

Fig. 7 — 11-12 June 1937

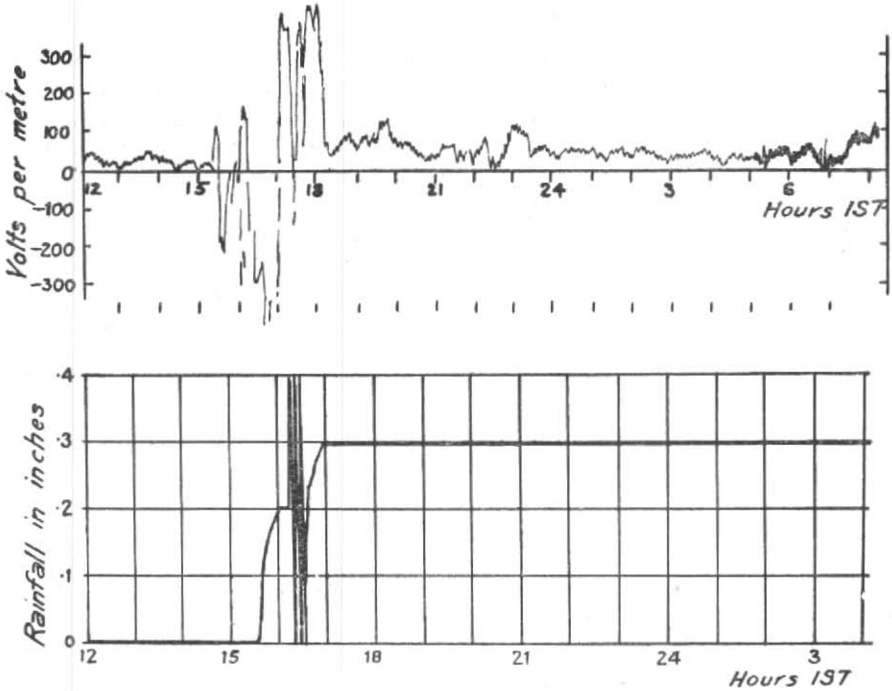

Fig. 8 — 18-19 September 1936

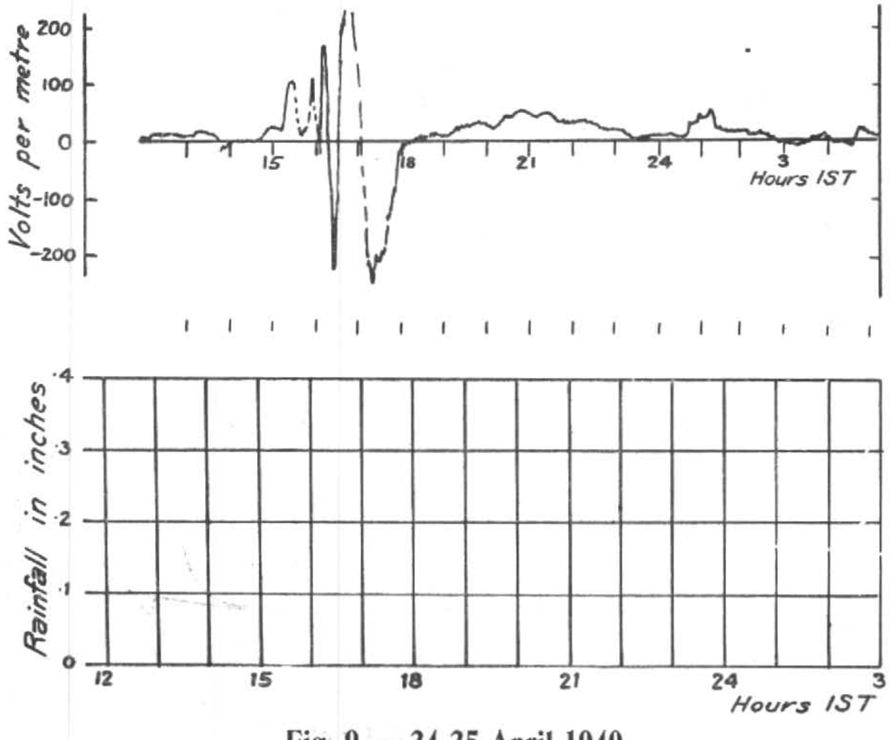

Fig. 9 — 24-25 April 1940

5. Potential Gradient Patterns

A perusal of the potential gradient records shows clearly the recurrence of certain regularities in the curves. For the greater part during disturbed weather especially, the curves consist of irregular ups and downs, sometimes on one side of the zero and sometimes on the other but over and over again there is a regularity in the run of the curves which is correctly described by Simpson as a pattern. The patterns have been classified under two types (*a*) wave pattern (*b*) symmetric patterns.

(a) Wave Pattern

Figs. 10 and 11 show examples of this pattern of variation. In Fig. 11 five waves increasing in range with a mean period of a little over an hour are seen clearly between 2000 and 2400 IST on 20 September 1938. The original records were carefully measured up and replotted with the same vertical scale but with the horizontal scale increased nearly three times. The results are reproduced in Figs. 10(*c*) and 11(*c*) in which the position of the original records are shown as dotted lines and smooth curves

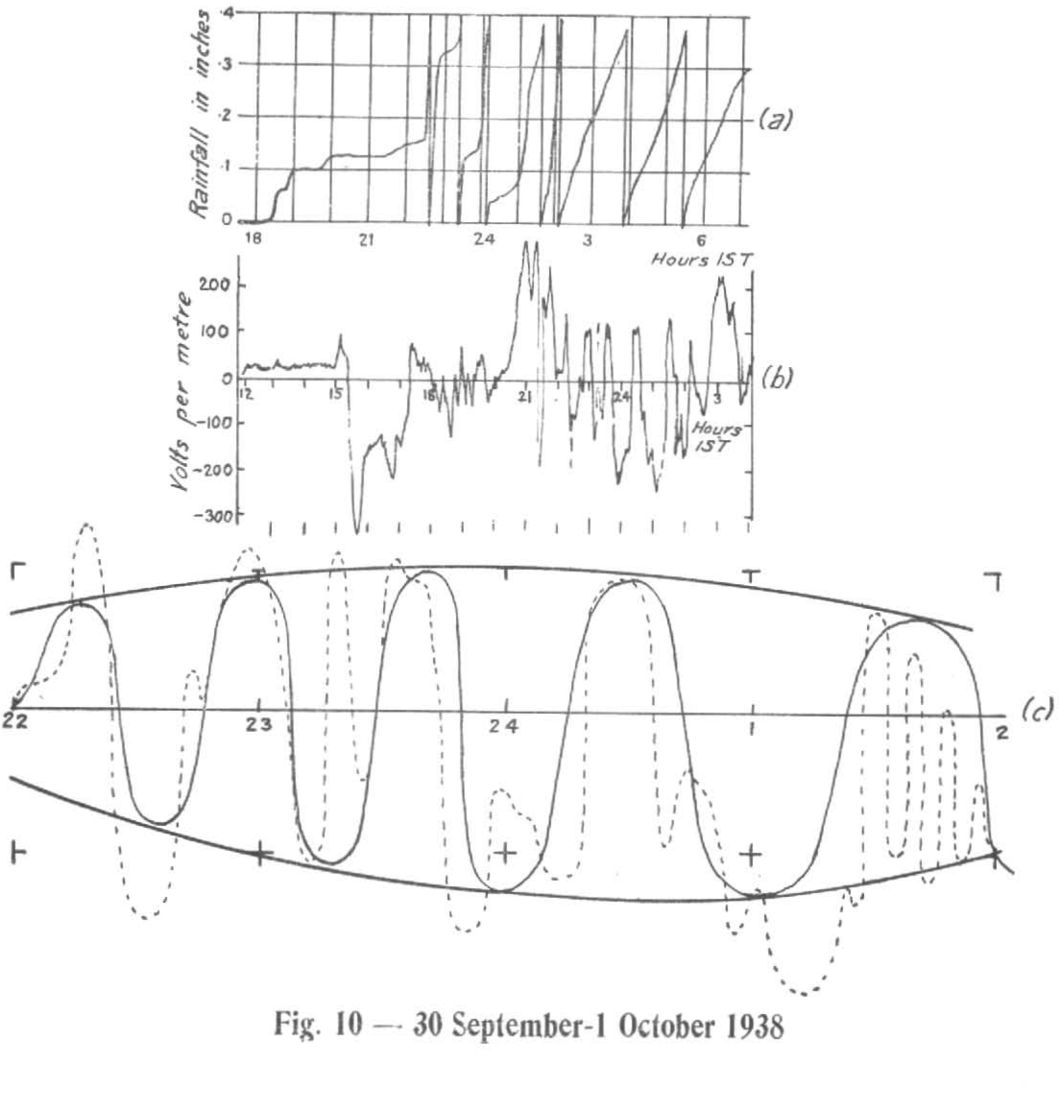

Fig. 10 — 30 September-1 October 1938

have been drawn free-hand through them. It is interesting to see from both diagrams that the amplitudes of successive waves behave as though *they* were subject to a harmonic control for the two curves connecting the crests and the troughs appear to be parts of sine curves.

The weather associated during this remarkable train of waves, for example on 20 September 1938 may be described as follows—

It was a cloudy day overcast with *Sc* or fractocumulus clouds, brisk showers from 0215 to 0245 IST, moderate continuous drizzle from 0345 to 0400 IST and continuous rain from 0650 to 0850 IST. A thunderstorm burst at 1525 IST and continued till midnight. Showers occurred from 1345 to 1348 IST and from 1530 to 1615 IST. Brisk showers from 2000 to 2045 IST were followed by moderate continuous rain till midnight. However, during the period of harmonic waves the intensity

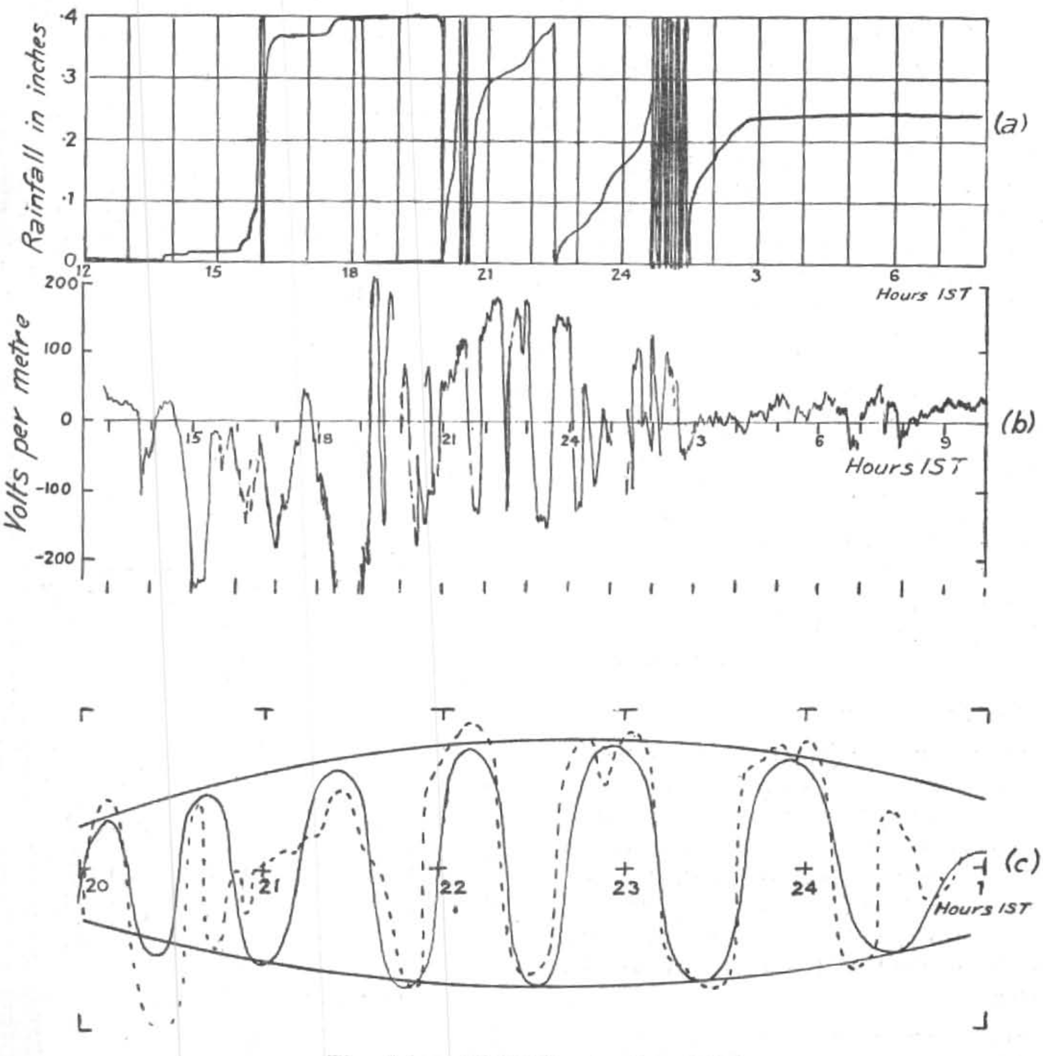

Fig. 11 — 20-21 September 1938

of the precipitation was fairly steady. It is also seen that the waves of the wave-pattern swing about the zero with positive and negative amplitude of approximately the same amount unlike the fog-waves which are in the nature of fluctuations from a base of large positive field.

(b) Symmetrical Patterns

From an analysis of the Poona electrograms three distinct patterns were noticed which may be described as V, W, S patterns just as Simpson has described, as these letters reproduce to some extent the forms of the pattern.

(i) The V *pattern*

During the period under review 14 distinct cases of V pattern are observed. It frequently happens during periods in which the potential gradient is fairly steady and the curve suddenly takes a rapid move in the negative direction, and then rapidly regains its original value, after which the curve continues as though the disturbance had not occurred. Figs. 12, 13 and 14 show good examples of the V, W, S patterns. Cases of V pattern generally occur with low cloud and in the majority of cases there is a sharp shower which lasts for a few minutes only. There are cases of the disturbances giving an inverted pattern. It is significant that in almost all cases the V pattern has commenced when the potential gradient has been positive. A V pattern is probably associated with an isolated shower of rain. It may be positive or negative but negative V's predominate.

(ii) The W *pattern*

During the period under review 30 distinct cases of the W pattern are observed and the W pattern is the most remarkable of all symmetrical patterns. Two examples (Figs. 12 and 13) are given with the corresponding syphon raingauge charts. The types of weather associated with the W pattern on 19 September 1937 (Fig. 13) are given below.

On 19 September 1937 the day was rather warm from early morning. *Cb* clouds began to appear slightly before noon. At 1300 IST the skies were completely overcast with *Cu* and *Cb* clouds. From 1330 to 1445 IST, *i.e.*, during the period of the "pattern" there was a sharp shower followed by some continuous rain. The wind velocity rose from 4 miles to 29 miles as shown by the Dine's record (Fig. 15) between 1300 and 1400 IST and there was a remarkable fall in temperature from 85° to 71°F, nearly 14°F as shown by the thermograph record (Fig. 15). The wind veered from *SW* to *NNW* between 1300 and 1400 IST. It is seen, therefore, from the above weather remarks that a discontinuity in the atmosphere or disturbed conditions must have happened during the period of the pattern.

(iii) The S *pattern*

Fig. 14 gives an example of the S pattern. It shows a disturbance in an otherwise normal period of potential gradient. This also is a case connected with some particular motion of the atmosphere. The S pattern is not generally common and is associated with some shower.

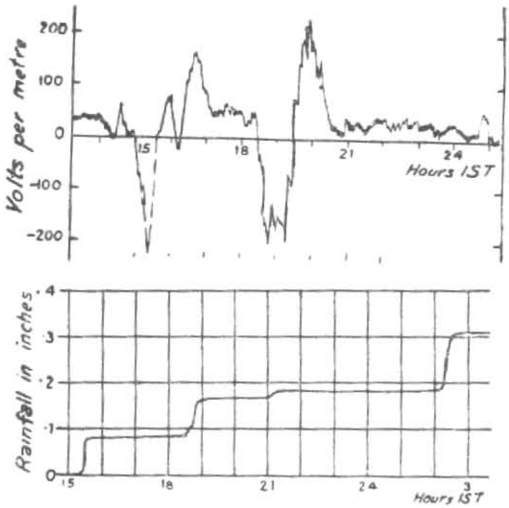

Fig. 12 — 19-20 September 1938

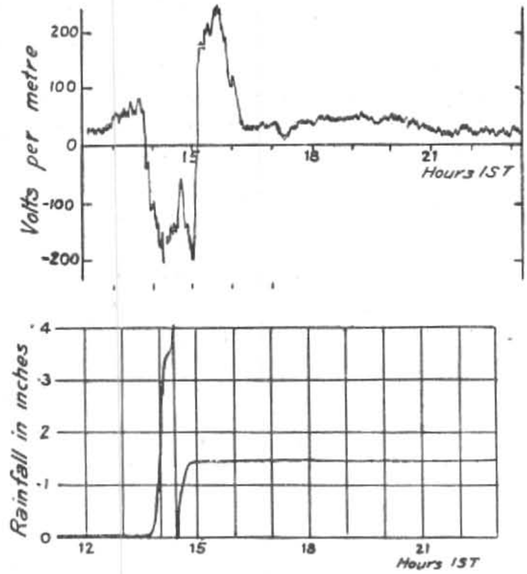

Fig. 13 — 19-20 September 1937

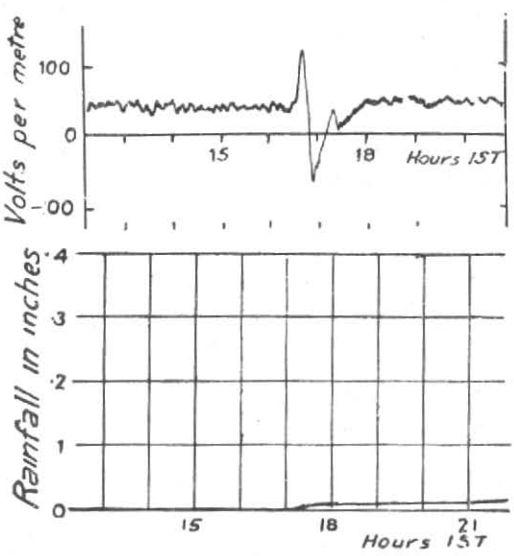

Fig. 14 — 6-7 August 1938

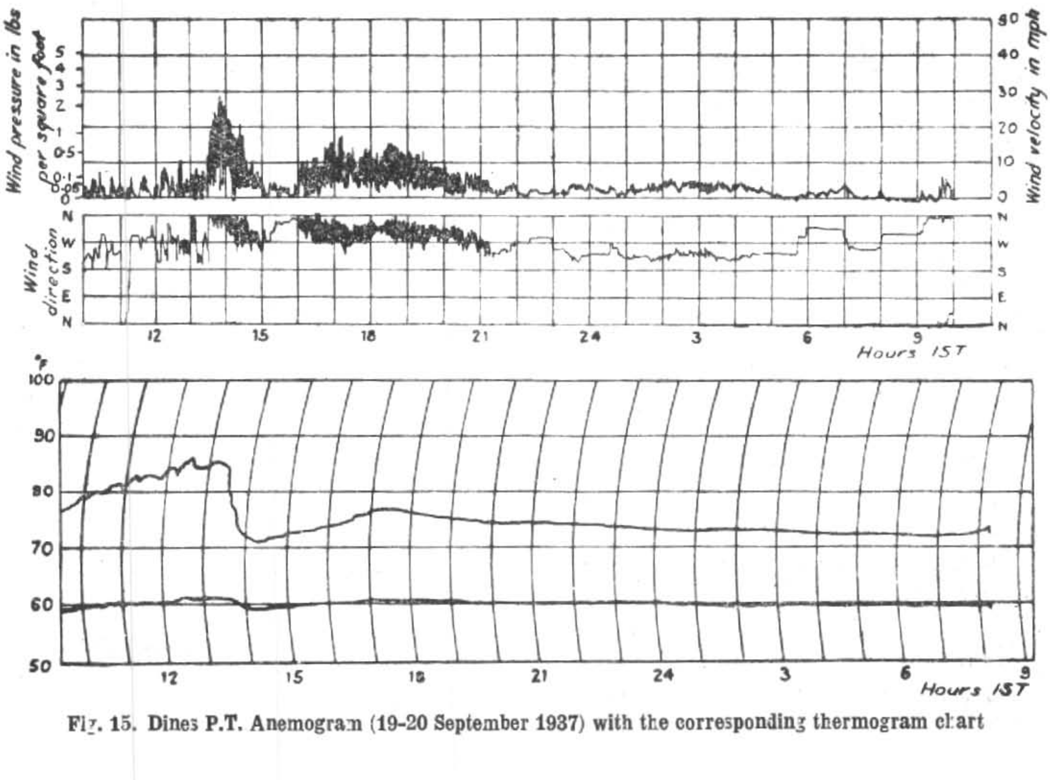

Fig. 15. Dines P.T. Anemogram (19-20 September 1937) with the corresponding thermogram chart

It is probable as Simpson has suggested from his detailed study of "Atmospheric Electricity during disturbed weather" that the character of the gradient and the character of the rainfall are governed by the character of the air motion in the atmosphere and the association of disturbed potential gradient with rainfall is not that of cause and effect, but that of two secondary effects of the air motion. As regards the potential gradient patterns, there can be little doubt that each pattern is connected with some process in the cloud which causes differential displacements of positive and negative electricity; but as to what that process may be the present analysis gives no indication. The patterns are, however, always accompanied by disturbed weather and some are associated with definite types of weather.

6. Conclusions

From the analysis of the potential gradient at Poona, in different types of weather, the following conclusions stand out clearly.

(1) During fine weather, the potential gradient is positive and undergoes only small and regular changes chiefly due to the daily variation. Rapid and intermittent variations especially leading to negative and positive potential gradient are signs of atmospheric disturbance, accompanied generally by precipitation. (At Poona, the fine weather gradient is found to be between 60—90 volts per metre).

(2) If during rainfall, the potential gradient is negative, but without rapid variations, it is found that the rainfall is associated with a "quiet" atmosphere.

(3) Large and rapid changes in the potential gradient with the gradient swinging from positive to negative and *vice versa*, are usually associated with atmospheric disturbances having appreciable local ascending air currents. These conditions are generally indicated by the rainfall occurring in showers.

(4) From an examination of the simultaneous records of rainfall and potential gradient, it is seen that the changes in the gradient are not closely, if at all, associated with either the intensity or the variations of the rainfall.

(5) The field at the ground is not essentially different in thunderstorms from that associated with showers, except that in thunderstorms very high momentary fields accompany the lightning discharges.

(6) Two main types of pattern have been distinguished--

(*a*) Wave patterns (*b*) Symmetrical patterns.

The wave patterns are composed of a succession of more or less regular waves, resembling a series of harmonic waves, so to say. Three symmetrical patterns, V, W and S have been recognised from the analysis of Poona electrograms. There can be no doubt, as Simpson has remarked, that each pattern is connected with some process in the cloud which causes differential displacements of positive and negative electricity, but as to what that process may be, the observations give no indication.

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