

Thunderstorms and Sporadic *E* Layer Ionisation

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ABSTRACT. The paper describes the results of vertical P' - f recordings of ionospheric reflections carried out during the passage of thunderstorms over Ahmedabad. The thunderstorms were found to be accompanied by an increase in sporadic *E* ionisation as shown by a rise in the maximum frequency of the *Es* or an increase in the intensity of reflection from *Es*.

1. Introduction

Various agencies such as meteors, thunderstorms and solar corpuscles have been suggested as possible causes of *Es* ionisation. Wilson (1925, 1926) was first to suggest that thunderstorms might cause ionisation in the upper layers of the atmosphere. His idea was taken up by several workers and some observational evidence was produced to show that the ion content of *Es* was affected by thunderstorms. Ratcliffe and White (1933, 1934) found that the nocturnal *E* region ionisation was associated with thunderstorms. Other workers (Appleton and Naismith 1933, Watson Watt 1933, Bhar and Syam 1937) reported that abnormal day-time *E* region ionisation were associated with thunderstorms. Later, however, Appleton, Naismith and Ingram (1936) obtained a low correlation coefficient between *Es* and thunderstorms and held that the effect of thunderstorms on *Es* had not been established. Bhar and Syam (1937) got a correlation coefficient of 0.50 between thunderstorm index and *Es*. In 1938 Best, Farmer and Ratcliffe stated that statistically there was not much evidence of thunderstorms affecting *Es*. In 1944 Stoffregen found close relationship between intense *Es* and thunderstorms and showed that the effect was more pronounced during magnetically quiet days. Mitra and Kundu (1954) reported an increase in fEs soon after the arrival of Nor'wester thundersqualls at

Calcutta and subsequent decay of *Es*. But Rangarajan (1954) at Kodaikanal did not find any effect of thunderstorms on *Es*. Isted (1955) found that lightning discharges had strong correlation with abnormal bursts of *E* region ionisation in vertical P' - f records on 10.6 Mc/sec and also observed that there were bursts of increased signal strength in oblique incidence transmissions at 53.25 Mc/sec. Besides the direct measurements of *Es* ionisation, other effects of thunderstorms on *Es* have been reported. For example, Mimmo (1937) observed increased multiple reflections from *Es* during a thunderstorm and Chatterjee (1953) reported increased reflections from *Es*.

In view of this conflicting evidence, a study of ionospheric reflections during thunderstorms was undertaken at Ahmedabad. Isolated thunderstorms sometimes occur at this place on days which are otherwise free from *Es* and this makes it easy to see the effect of the thunderstorms.

2. Observations and results

There was a thunderstorm on the evening of 8 June 1954. The microbarograph record of the day between 17 and 22 hr is shown in Fig. 1. The P' - f records taken during the period are shown in the left hand column on page 51. During the thunderstorm, fEs values were much higher than the normal values. Moreover, the number of multiple

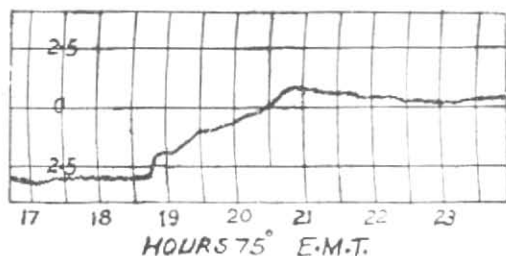


Fig. 1. Microbarograph record on 8 June 1954 during a thunderstorm

reflections from the *Es* also increased considerably. There occurred another thunderstorm on the evening of 10 June 1955. The *Es* critical frequencies were very high during the period and more than 12 multiple reflections from the *Es* region were recorded.

An examination of the *P'-f* records in some more instances showed that in general thunderstorms did affect *Es* at Ahmedabad. It was considered desirable therefore, to study with special vertical soundings at short intervals the changes during individual thunderstorms. When a thunderstorm was seen approaching the station, more frequent *P'-f* recordings were started till the storm had passed over. This article describes the results of such a study.

There occurred an isolated thunderstorm on the afternoon of 1 October 1955. The monsoon had ended by then and the weather was calm. The disturbance started suddenly at about 1445 hr and lasted for about an hour. The anemograph and microbarograph charts for the period are shown in Figs. 2 and 3. The variations of *fEs* are shown in Fig. 4. There was a sudden increase in *fEs* shortly after 1500 hr about 10 minutes from the onset of the surface storm. This increase continued till 1640 hr about half an hour after the storm had passed over. The portions of the *P'-f* records taken during the period are shown on p. 52. At 1500 hr there were only very weak echoes from *Es* at 100 km below 3.5 Mc/sec and normal *E* and *E₂* reflections were quite clear. At 1510 hr the reflections from *Es* at 100 km grew stronger and weak sporadic reflections appeared from a height of 140 km. At 1520 hr *Es* reflections from 100 km

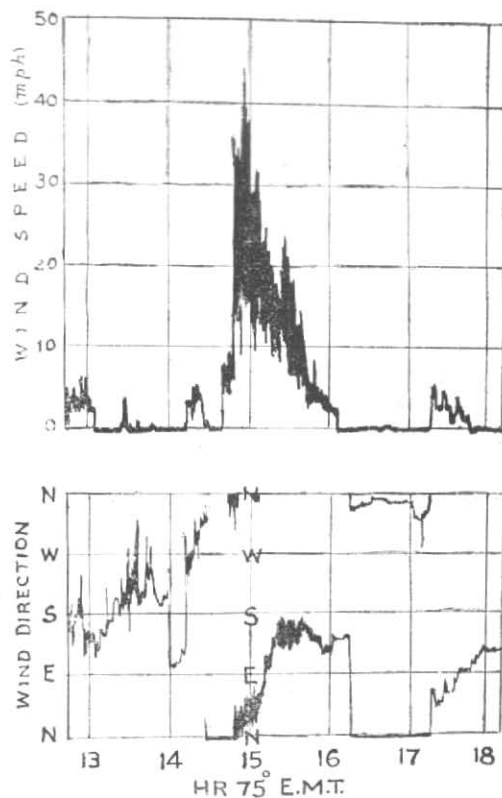


Fig. 2. Anemograph chart on 1 October 1955 during the passage of a thunderstorm over the station

increased in strength and the maximum frequency went up to 3.9 Mc/sec. The *Es* reflections from 130 km strengthened and merged with *E₂* reflections. At 1530 hr *Es* from 130 km grew still stronger, *fEs* increased to 5.0 Mc/sec and the *F₁* reflections were completely blanketed. At 1600 hr six multiples of *Es* reflections were recorded. At 1640 hr *fEs* reached the maximum value of 6.2 Mc/sec. It then decreased and came down to the normal value at about 1700 hr. Alibag Observatory reported the magnetic character of the day as Ca (a quiet day) and International character figure was very low (0.7).

There occurred another isolated thunderstorm on the afternoon of 23 October 1955. The international magnetic character figure for the day was 0.3. Thunder on the day started at about 1445 hr and was overhead

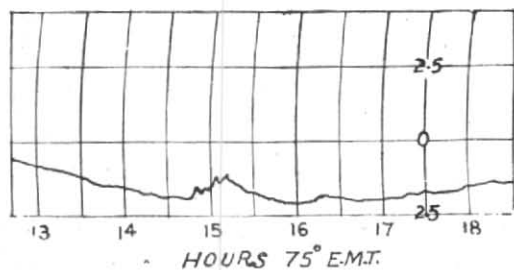


Fig. 3. Microbarograph chart on 1 October 1955 during the passage of a thunderstorm over the station

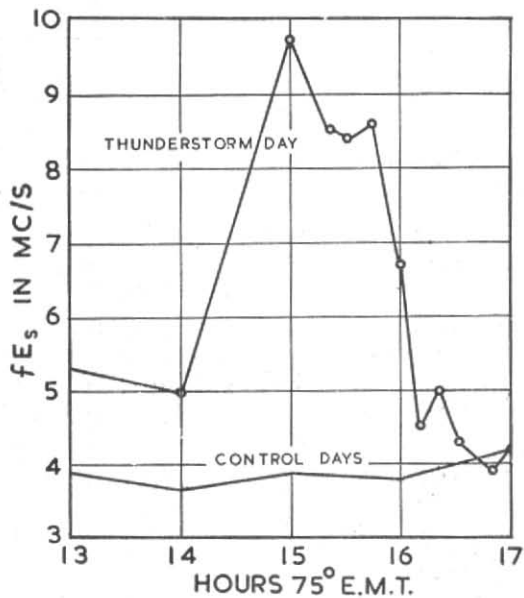


Fig. 5. The variation of fE_s during the thunderstorm on 23 October 1955 and on the control days

(Note the high values of fE_s during the thunderstorm period)

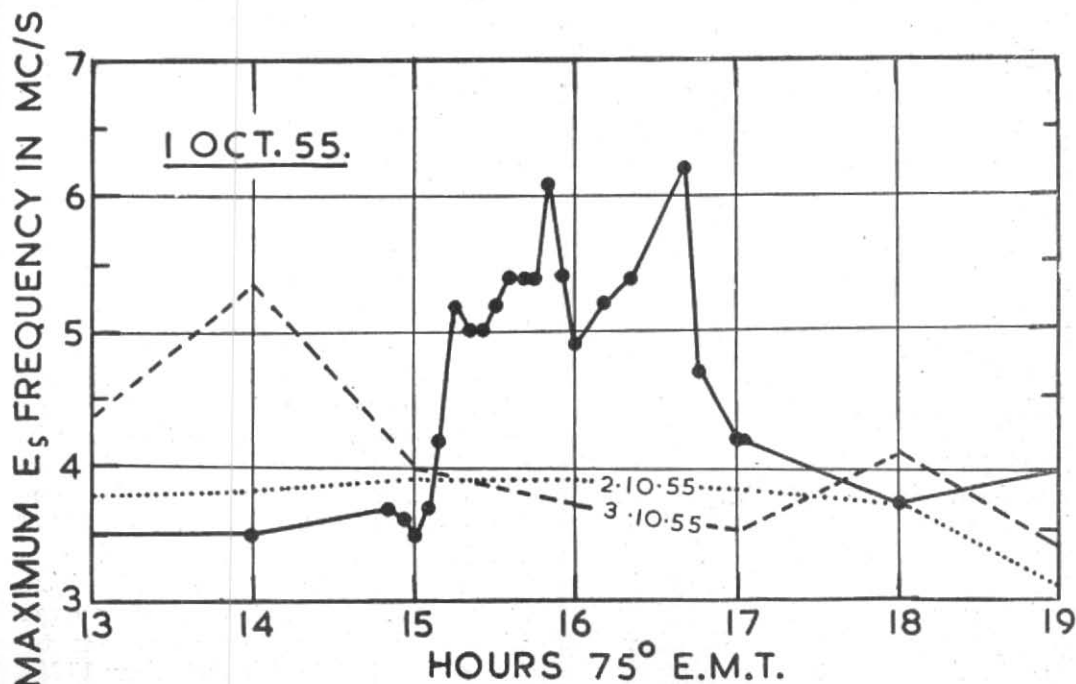


Fig. 4 The variation of fE_s during the thunderstorm on 1 October 1955

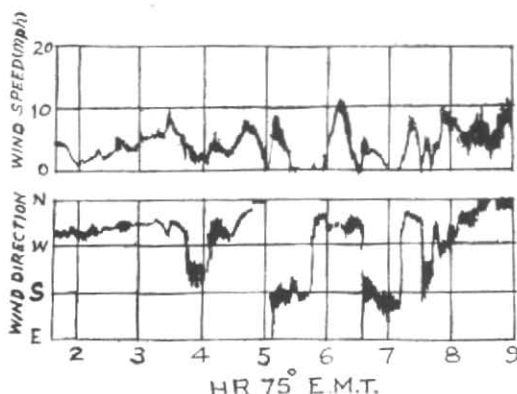


Fig. 6. Anemograph chart on 27 February 1956 during the thunderstorms

at 1500 hr and subsided by 1600 hr. Fig. 5 shows increased fEs during 14 to 16 hr corresponding to the period of the thunderstorm activity.

Another set of observations was taken in the early morning hours of 27 February 1956. The weather on the 26th was clear except for a few scattered clouds; the night was more disturbed and there started a succession of thunderstorms in the early morning hours followed by rain and hail. The anemograph and the microbarograph charts for the period are shown in Figs. 6 and 7. The thunderstorm and disturbed conditions continued till about 0800 hr after which the weather cleared up. This disturbance was of a frontal type and on the days before and after, the weather was calm. The international C figure was 1.1. Kodaikanal magnetogram did not show any magnetic disturbance on 27th. During these days fEs were very low, particularly during the early morning hours. On some days, there were no Es reflections at all during these hours. The variations in fEs on 27 February 1956 are shown in Fig. 8 and a few $P'-f$ records are reproduced in the right hand column on page 51. fEs suddenly increased soon after the first impulse on the microbarograph at about 0340 hr. In this case there were large variations in fEs during the period because of successive storms. An interesting feature is evident from the above $P'-f$ records. At 0450 hr there were only weak Es reflections. These later became stronger and at

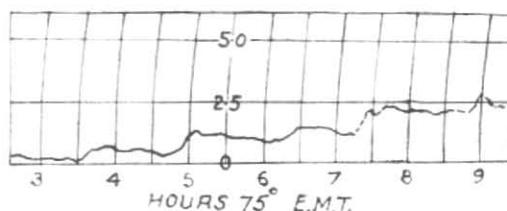


Fig. 7. Microbarograph chart on 27 February 1956 during the thunderstorms

0520 and 0540 hr there were six multiples of Es reflections. According to Rawer (1949) the reflection coefficient (number of multiple reflections) is a good index of Es ionisation. So, this corresponds to increased general ionisation of Es . There occurred an isolated thunderstorm on 14 March 1956. This storm was weak and of short duration. Es reflections on these days were weak and fEs values were low. There were no Es reflections on the days before and after 14 March 1946 during 17-19 hr. The magnetograms of Kodaikanal showed slight agitations only and there was no magnetic storm. $P'-f$ records taken during the period are shown on page 53. The formation of Es ionisation during the thunderstorm on 14 March 1956 is shown in Fig 9.

The most convincing instance of the thunderstorm affecting Es was observed on 28 May 1956. The microbarograph chart for the period is shown in Fig. 10. On 28 May 1956 no magnetic disturbance was recorded by Kodaikanal. Lightning was first seen at about 1930 hr to the east of the station and the thunderstorm came overhead at about 2000 hr. It continued upto about 2300 hr. The variation of fEs on 28 May and on the normal days (25 to 31 May 1956) are shown in Fig. 11. The values of $h'Es$ and changes in surface pressure are also shown in the figure. A few $P'-f$ records taken during the period are reproduced on p.54. At 1930 hr there were Es reflections upto 4.5 Mc/sec. At 1940 hr there appeared a few diffused Es reflections from frequencies upto 14 Mc/sec from a height of 150 km. fEs at 115 km increased to 8 Mc/sec at 1945 hr and to about 15 Mc/sec at 1950 hr. Es reflections grew stronger when the thunderstorm approached the station and at 1955 hr fEs went above 15 Mc/sec. As Es reflections became stronger,

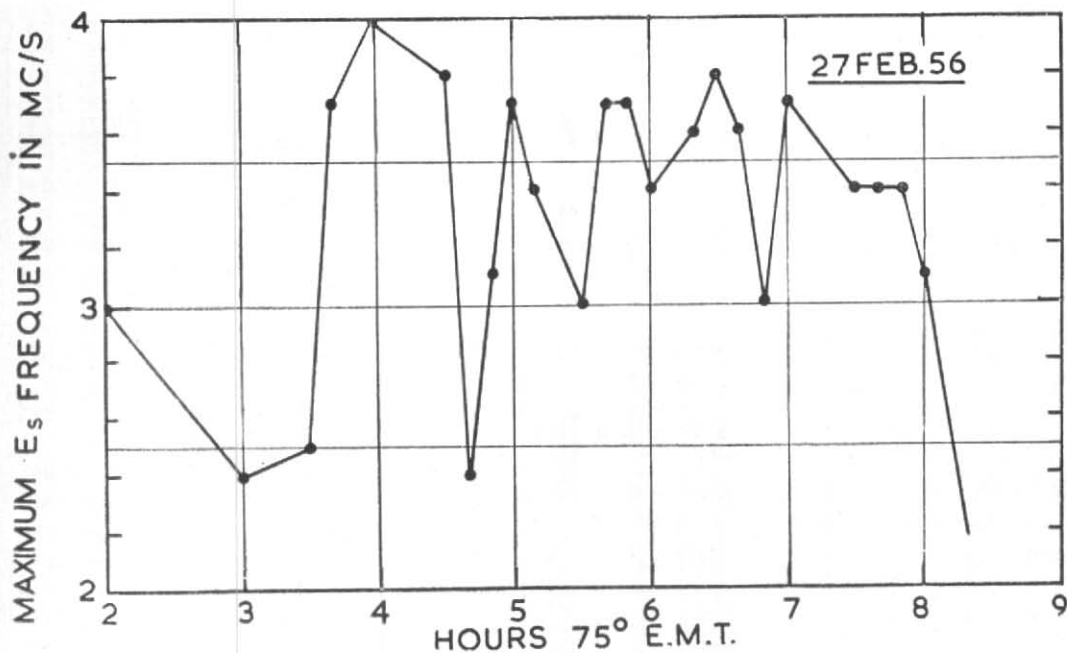


Fig. 8. The variation of fE_s during the thunderstorms on 27 February 1956

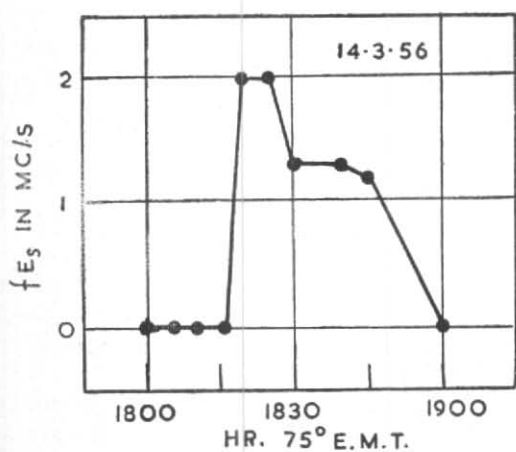


Fig. 9. Formation of E_s ionisation during the thunderstorm on 14 March 1956

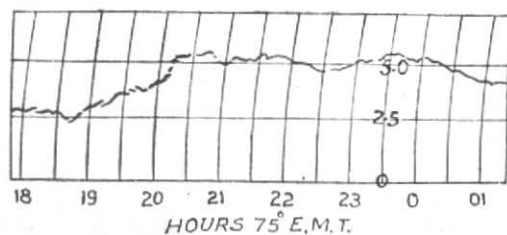


Fig. 10. Microbarograph chart during the thunderstorm on 28 May 1956

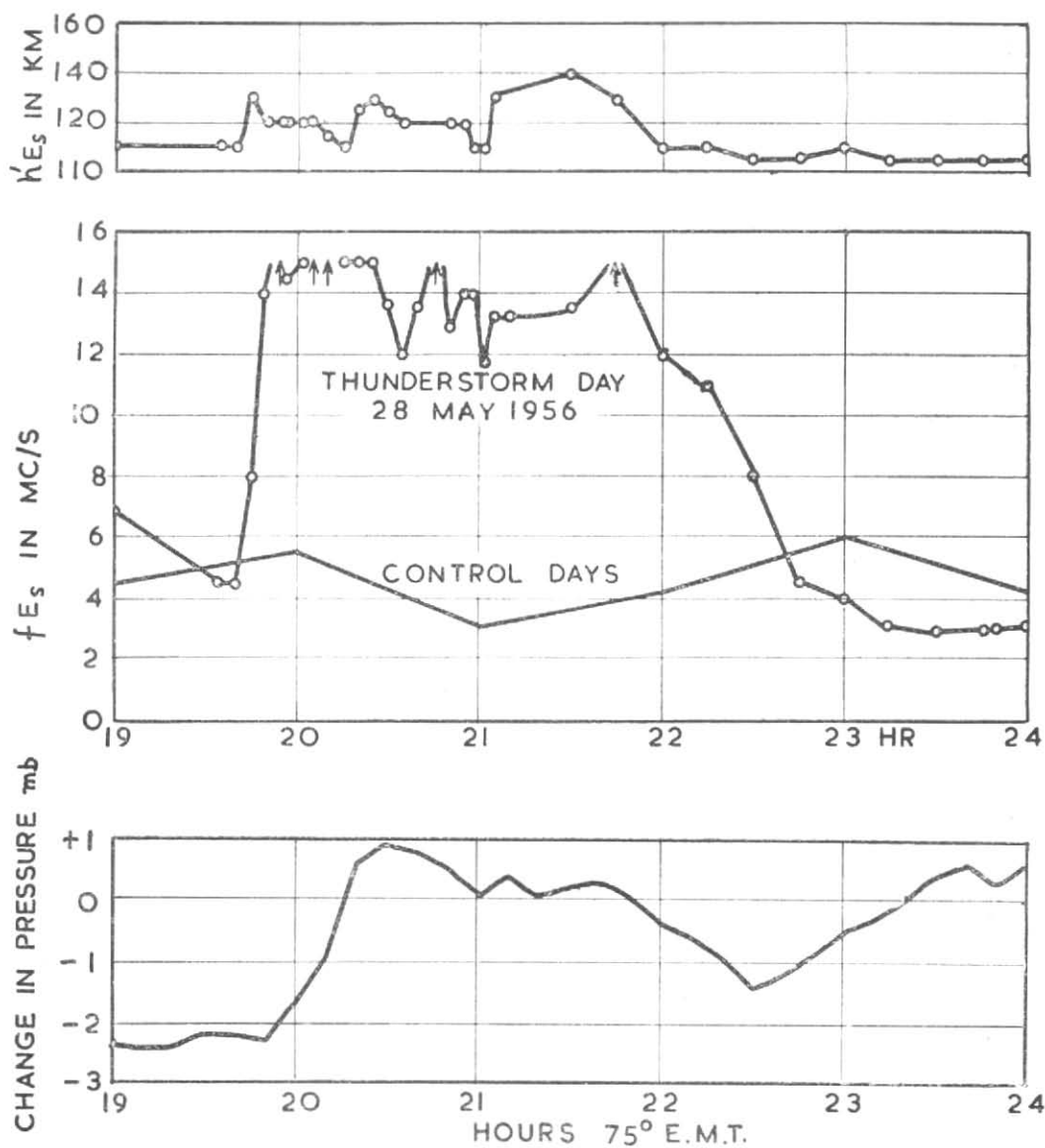


Fig. 11. The variation of maximum frequency of sporadic E reflections, virtual height of E_s reflection and the surface pressure during the thunderstorm on 28 May 1956

F_2 reflections got weaker and portions of F_2 trace were blanketed by *Es*. F_2 reflections were completely blanketed at 2010 and 2015. They started reappearing at 2020 when the thunderstorm activity began to decrease in intensity. The multiple reflections from *Es* were more in number during the period of the blanketing by *Es*. Another interesting feature was that there were indications of $h'Es$ increasing with frequency during the high *Es* period (see record at 2145 hr). This may be due to a tendency for the formation of a homogeneous thin layer in the *Es* region during the thunderstorm. Chatterjee (1953) found that during thunderstorms *Es* obliterates *F* echoes and the *Es* ionisation then is preponderately of the thin layer type. The magnetogram at Kodaikanal was practically calm on 28 May 1956.

It may be interesting to note that on 3 September 1955 there was continuous lightning with rain and there was a lightning discharge over the antenna system of the ionospheric station at 1819 hr. Short period records taken during the period did not show any change in *Es* reflections. Further, in June-July 1956 when the rainy season had well developed at Ahmedabad, thunder did not seem to influence *Es*. It appears that low thunderstorms during the monsoon and lightning discharges between the cloud and the earth do not affect *Es* region ionisation.

Regarding the mechanism of production of ionisation by thunderclouds, two processes have been suggested by Wilson (1925). According to the first, electrons inside a thundercloud are accelerated by the electric field inside the cloud and a stream of electrons moving upward from the upper boundary of the clouds are created. These electrons moving with larger velocity would reach the *E* region and increase the ionisation there. Wilson pointed out that while the electric force due to the thundercloud falls off as $1/r$, the electric field required to cause the sparking falls off approximately as $1/r^3$. This is due to the decrease of density with height. Thus if the electric moment of the cloud is not too small, there will be a height above the cloud

where the electric field due to the cloud would exceed the sparking limit. Appleton and Naismith (1933) showed from theoretical considerations that even when a field near the cloud was only $1/27$ of the sparking value, the field at a distance of only 7 km below the *E* layer could reach the sparking value. Thus, because of the large potential difference between the thundercloud and *E* layer, upward discharges are possible in spite of the great distance between them. Wormell (1953) has stated that thunderclouds could drive a vertical current upward from the earth through the cloud and on to the highly conducting regions above. Gish and Wait (1950) have measured from aircraft upward currents from the top of a thundercloud towards the upper atmosphere. Thus there are probably continuous discharges from a thundercloud besides the impulsive discharges, and these too may modify the *E* region ionisation.

3. Conclusion

Observations of *Es* made at Ahmedabad during some isolated thunderstorms indicate that they cause a temporary increase in the electron content of the ionosphere. The effect takes the form of an increase in fEs or merely increase in the intensity of the *Es* reflections. The effect of a thunderstorm is localised and temporary. The *Es* changes generally appear within half an hour of the change at ground level during the passage of a moving thunderstorm; *Es* gradually returns to normal value after the storm passes over the station. The ionisation due to a thunderstorm may be produced below the normal *E* layer at 100 km or above it upto 140 km. It is known that there is a stable region at 140 km for ionisation as evidenced by the occurrence of E_2 layer and occasional night ionisation. During thunderstorms the *Es* region tends to become a homogeneous layer and sometimes produces group retardation effects. The number of multiple reflections increases during the thunderstorms.

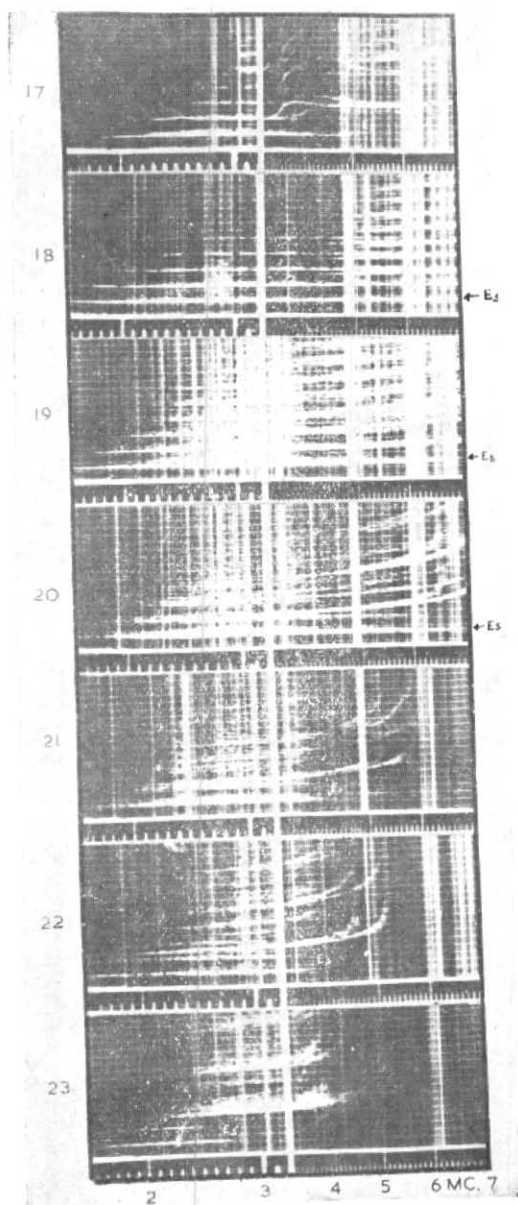
4. Acknowledgements

The work described is a part of the programme of ionospheric research in this laboratory

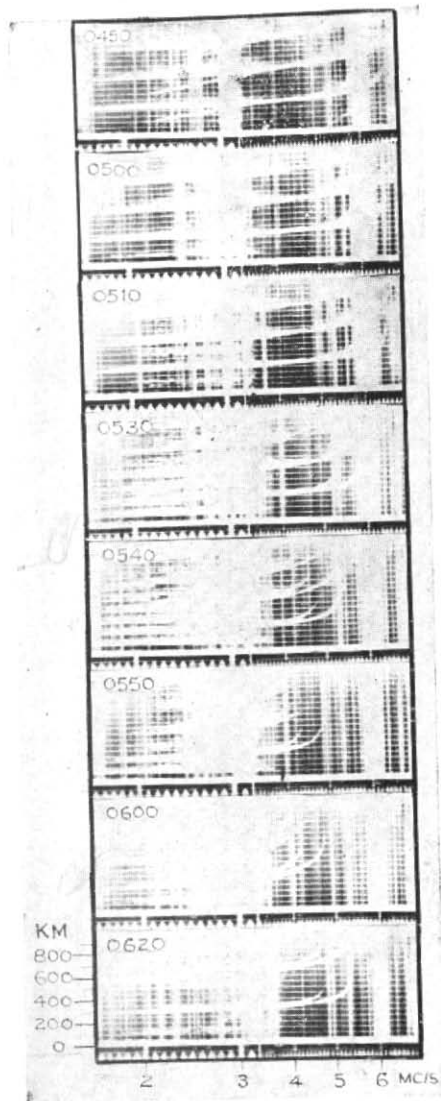
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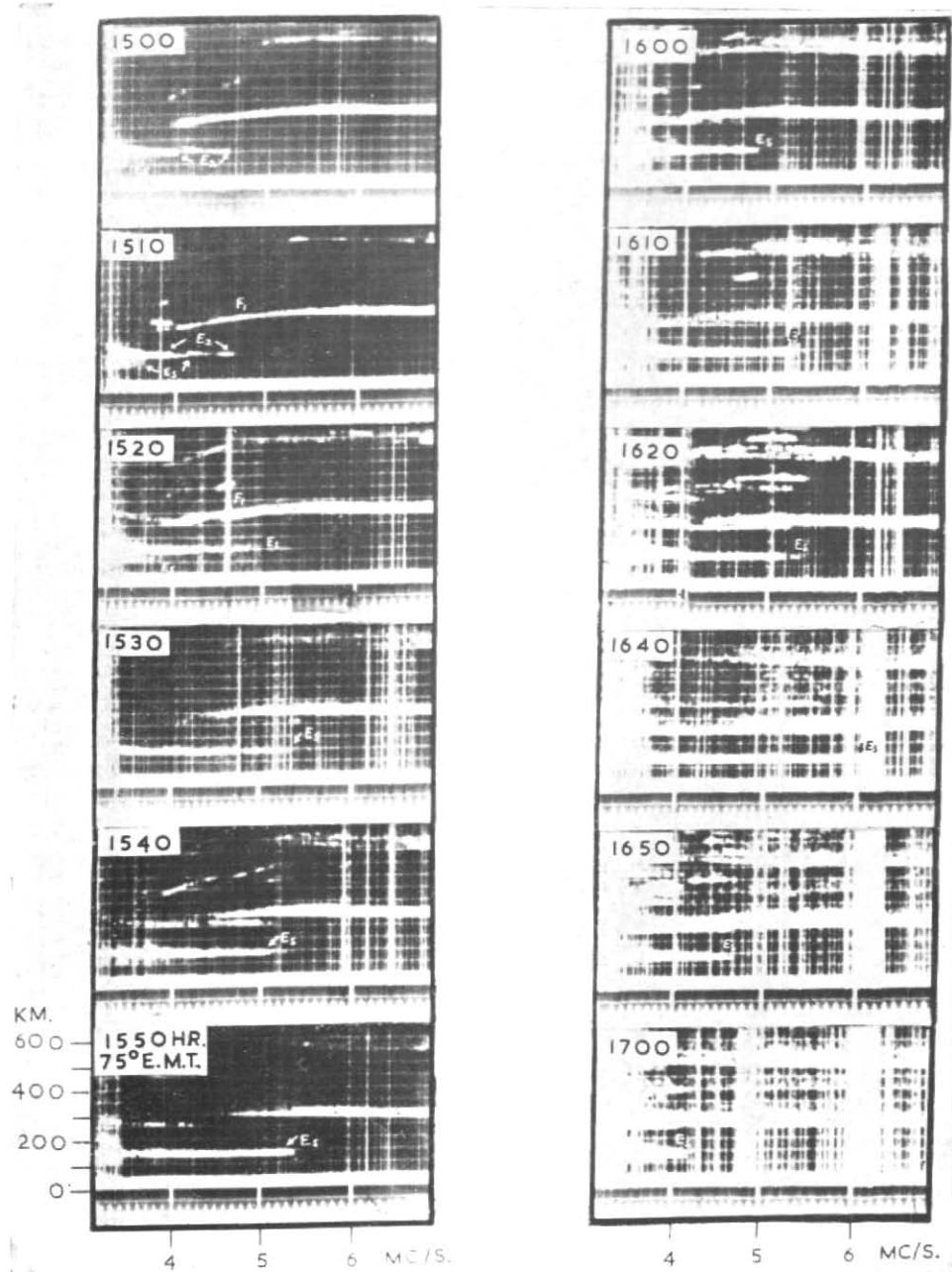
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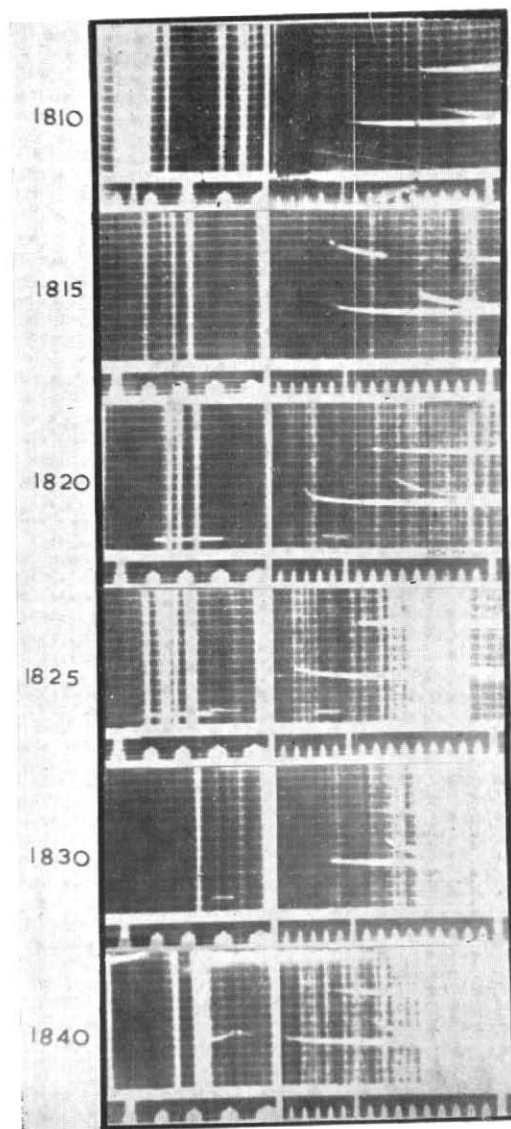
P-f records on 8 June 1954 during a thunderstorm
 (Note high *fEs* and multiple reflections
 between 18 and 20 hr)



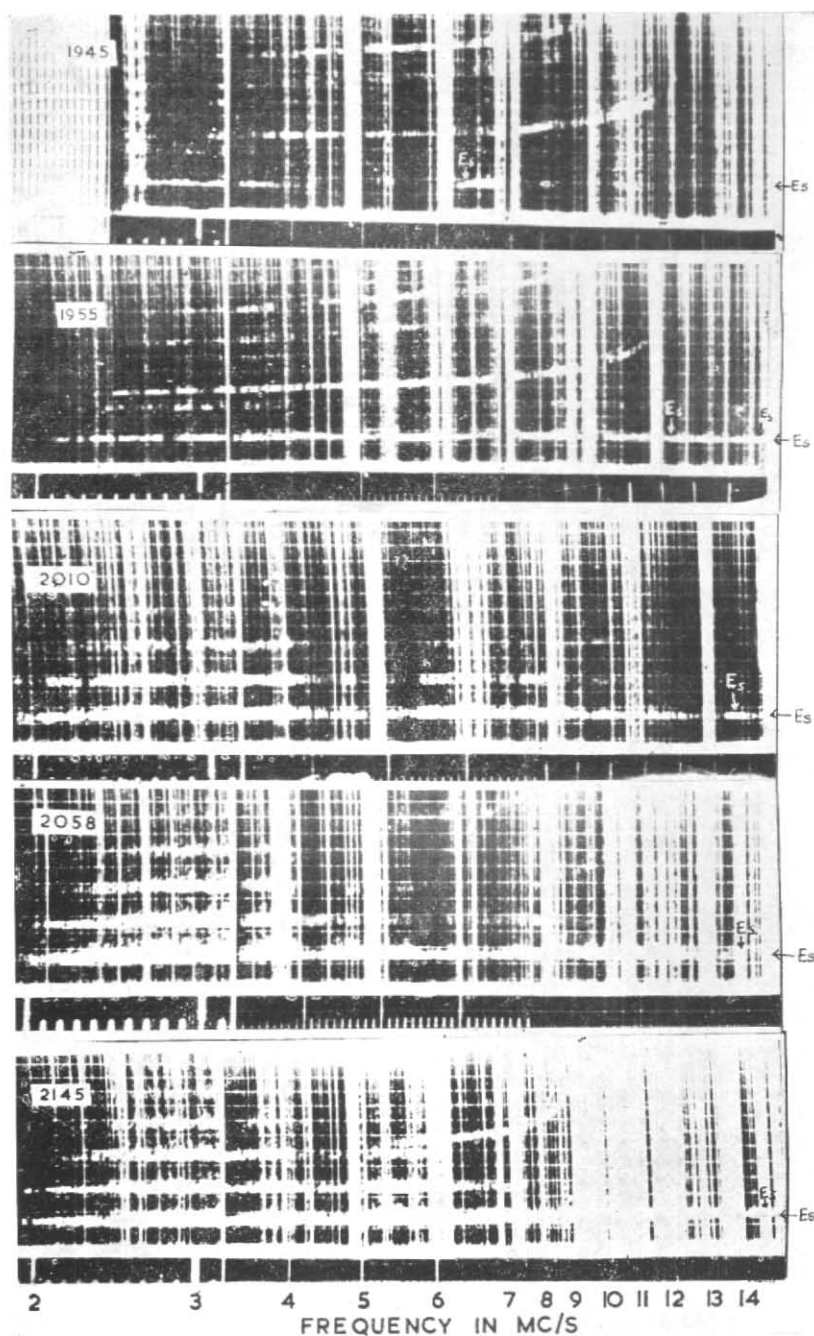
P-f records on 27 February 1956
 (Note the large number of multiple
 reflections at 0530 and 0540 hr)



P'-*f* records on 1 October 1955 showing the effect of thunderstorm on the E_s region of the ionosphere



P-f records on 14 March 1956
(Note the formation of fE_s ionisation
during the thunderstorm)



P'-*f* records during the thunderstorms on 28 May 1956

(Note fE_s increased above 15 Mc/sec at 1955 hr and afterwards, complete blanketing of *F* reflections at 2010 and 2058 hrs and gradual increase of $h'E_s$ at 2145 hr)