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Fog forecasting over Calcutta and neighbourhood

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ABSTRACT. Effect of temperature, dew-point temperature, wind and synoptic situation on the formation of fog at Calcutta (Alipore) during winter months have been studied and prediction diagrams for temperature and dew-point as well as fog have been prepared. It has been concluded that successful fog prediction is possible on the basis of forecast of dew-point which is likely to prevail during late night hours particularly during the minimum temperature epoch and that such accurate dew-point forecast is only possible by watching hourly variation of dew-point till 2200 IST.

1. Introduction

Fog is considered to be a dangerous weather phenomenon by the aviators especially at the time of landing and take off. In recent years, with the rapid growth of aviation in India, Dum Dum aerodrome at Calcutta, has become one of the busiest aerodromes in the world, with close landings and take offs during all hours of the day and night. Accurate and timely warning for the occurrence of fog at Dum Dum has, therefore, become a very important item of work for the weather forecasters during winter months, demanding constant and close attention all through the night. Actual experience at Calcutta and Dum Dum has shown that accurate fog forecasting depends, to a large extent, on full utilisation of knowledge of local meteorological factors besides the general rules governing the incidence of fog. An attempt has, therefore, been made in this note to find out the local meteorological factors which are favourable for fog formation over Calcutta and neighbourhood.

2. Type of fog

Fog formation is the result of condensation of atmospheric water vapour into water droplets in a state of suspension in the air close to the ground surface, and with a concentration which is sufficient to reduce visibility below 1100 yds. For condensation to take place, air initially unsaturated must be saturated by some physical process, and sufficient condensation nucleii should also be present in the surface layers. The physical processes which help saturation and consequent fog formation are evaporation of water into the air and cooling which result in condensation in the form of fog or fresh influx of moist air and subsequent cooling to cause condensation. Of these, radiation fog, which belongs to the group of cooling fog, is the main type of fog experienced over Calcutta and neighbourhood and will be discussed in this note.

Radiation fog is formed when moist air is in contact with ground which has been cooled during night by outgoing radiation. To help maximum heat loss from ground to outer space by radiation during night, sky must remain clear or lightly clouded during major portion of the night. Maximum frequency of radiation fog is also associated with light winds (1-5 mph). With wind speed exceeding these values, vertical mixing counteracts fog formation. Thus for the formation of radiation fog, the most favourable conditions are —

(1) Clear or lightly clouded sky

(2) Calm or light surface wind

(3) Air with initially high dew-point.

This type of fog is invariably associated with an inversion of temperature in the surface layers. When the wind speed increases sometime after sunrise, inversion layer is raised and thereby fog dissipates or stratus clouds are formed.

3. General rules of Fog Forecasting

The general rules of fog forecasting consist of the following—

(1) Forecasting of minimum temperature

(2) Forecasting of surface wind velocity during night hours

(3) Forecasting of sky condition during night hours

(4) Forecasting of the nearest value of dew-point at the minimum temperature epoch

4. Local meteorological factors

It has been found from experience that due weightage has to be given to certain local factors before the above mentioned general rules can be applied for fog forecasting. This necessitates a statistical approach to the study of local variations of different meteorological factors which affect fog formation. The local meteorological factors for the years 1944 to 1948 have, therefore, been examined carefully with a view to find out their associations with winter fog at Calcutta. Diagrams of temperature and dew-point as well as fog prediction diagram for Calcutta based on above 5 years' data have been prepared in this connection.

5. Location of the station

Calcutta (Lat. 22° 32'N Long. 88° 20'E) is at a distance of about 70 miles to the north of Bengal coast. Bay current towards north/northeast, can, therefore, readily reach the area. Also this being an industrial area smoke or dust particles are available in plenty to provide condensation nucleii.

6. Data

For the necessary statistics utilised in this note, Calcutta (Alipore) autographic records of thermograph, hygrograph and Dines P. T. Anemograph during the months December to March for the years 1944 to 1948 have been studied. Temperature and dew-point values as obtained from autographic records have had to be used, as no records of actual hourly readings are available.

7. Temperature

Mean hourly values of temperature, during the period 1800 to 0600 IST on clear and calm (or light wind) nights of winter months for the years 1944 to 1948 were calculated. With these values, graphs, showing trend of fall in night temperature, have been drawn separately for each of the months

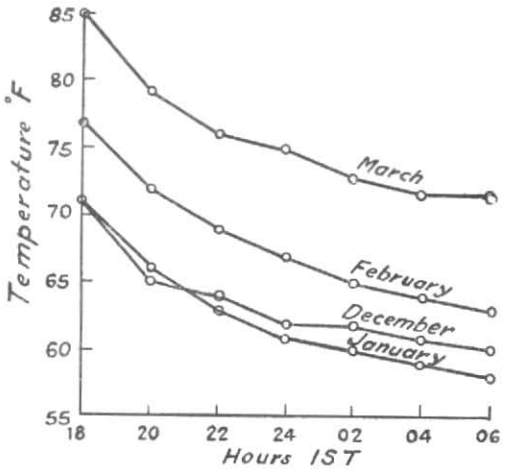


Fig. 1. Fall in temperature in calm and clear nights during December-March at Calcutta (1944-48)

December to March (Fig. 1). It will be seen that the maximum fall in temperature of the order of 9° to 10°F occurs during the period 1800 to 2400 IST, while during the period 2400 to 0600 IST it falls only by 2° to 4°F. Thus, the average fall is 1·5° F per hour in the first six hours, and 0·5° F per hour in the last six hours. For the period 1800 to 0600 IST taken as a whole, the rate of fall is about 1° F per hour, on the average. Knowing this trend of fall of temperature and utilising the general technique of short range temperature forecasting, it is possible to forecast with a fair degree of accuracy the temperature at any hour during the night and also the minimum temperature on any particular night.

8. Synoptic situation

It has already been stated that high dew-point temperature is one of the favourable conditions for fog formation. On any particular evening, if the dew-point is found to be reasonably high, it remains to be forecast whether the observed dew-point will rise further or continue to be the same, or fall during night hours. Although an accurate forecasting of this is not easy, it has been observed that the following evening synoptic situations during the winter months generally lead to high dew-point in the surface layers rising gradually during night hours.

(*i*) *Anticyclonic circulation over the head Bay of Bengal extending to coastal Orissa and Bengal* (Fig. 2)

This circulation, if shallow (upto 2000 or 3000 ft), causes influx of moisture from the Bay over Calcutta and neighbourhood, increasing the dew-point temperature at the surface layers. If the dew-point is reasonably high, outgoing radiation from the earth's surface may cool the surface air below the dew-point and fog is likely to form. But if this circulation is rather deep (upto 7000 ft or more), layers of medium clouds are often formed, which considerably reduce radiation cooling of the surface air.

(*ii*) *A low to the west of 85° E* (Fig. 3), *a feature which is often observed during February and March when secondaries to the western disturbances move eastwards across the country*

The cyclonic circulation round this low causes influx of moisture in the surface layers over Calcutta and neighbourhood, causing favourable conditions for fog formation. During these months, occasionally steep pressure gradient round such a low causes strong and gusty surface winds during noon and afternoon but the winds often tend to become light by evening or early part of night. Under such conditions, there is considerable vertical mixing of air, with upward flux of moisture and downward flux of heat during the day time and, inspite of the influx of moisture the dew-point temperature at the surface does not show a corresponding rise. By evening or early night, however, the wind speed decreases rapidly and the downward flux of heat and the upward flux of moisture also ceases, and the dew-point temperature of the surface layers begins to rise steadily.

(*iii*) *Post-frontal situation*

The passage of western disturbances through Bengal sometimes causes overcast sky with low and medium clouds and occasional light rain during the day. Following this, if conditions are favourable for rapid clearance at night, marked fall of temperature may cause the minimum to reach a value below the dew-point, resulting in fog.

9. Surface wind speed

The frequencies of surface wind speed at different hours (1600 to 2400 IST) on foggy nights at Calcutta during the years 1944 to 1948 were determined with the help of Calcutta (Alipore) Dines P. T. Anemograms and are given in Table 1. It is seen that the frequency of fog was maximum when the wind was calm or light (0-3 mph). There were only two occasions in 5 years when wind greater than 9 mph at 1800 IST was followed by fog in the morning and there were 5 cases of fog, with speed greater than 5 mph at midnight.

TABLE 1

Frequencies of wind forces on foggy nights at different hours at Calcutta (1944-48)

Wind velocity (mph)	Hours (IST)				
	1600	1800	2000	2200	2400
0 —3	21	34	36	35	39
3 —5	11	11	10	12	13
5 —9	24	10	11	10	5
9—14	1	2	Nil	Nil	Nil

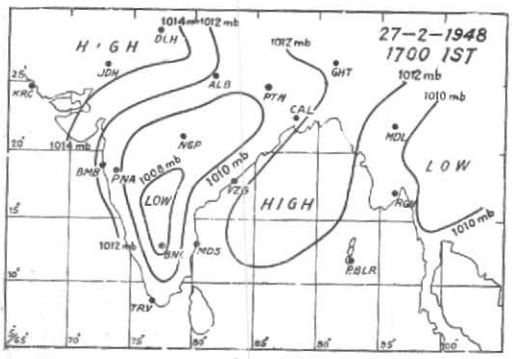


Fig. 2

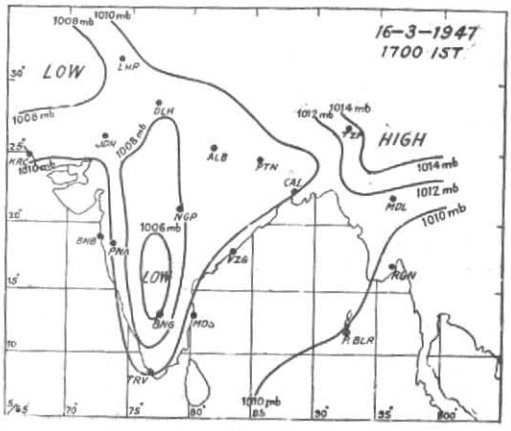


Fig. 3

10. Upper Winds

An examination of the afternoon and midnight Calcutta upper wind charts on days when fog occurred during night or early morning shows that shallow (limited to 2000 or 3000 ft) S to SW winds with speed 10-15 mph with moderate to strong NW to N winds aloft at Calcutta are most favourable for fog formation over Calcutta and neighbourhood. Relevant portion of the pibal charts at 1430 IST on 18 December 1950 and at 0030 IST on 19 December 1950 which represents the ideal condition of upper wind circulation both in the afternoon and midnight upto 3000 ft on foggy nights has been reproduced in Fig. 4.

11. Boundary cases

The following boundary cases have been noticed—

(*i*) No indication of S to SW current over Calcutta and neighbourhood either in the evening synoptic chart or afternoon upper wind chart, but after midnight, due to a sudden change of synoptic situation, S to SW current set in culminating in fog by early morning. Such a situation is illustrated by the relevant pibal charts at 1430 IST on 30 January 1950 and at 0030 IST on 31 January 1950 (Fig. 5).

(*ii*) Conditions, both in the evening synoptic chart and afternoon pibal chart, are favourable for fog formation, but due to abrupt reversal of synoptic situation (Fig. 6), fog does not form.

(*iii*) During the last half of February and the whole of March, steep pressure gradient on the evening synoptic chart, often causes high wind at the surface as well as in the upper levels upto 3000 ft. Such a situation, if it persists throughout the night, naturally prevents fog formation, and one would ordinarily forecast stratus clouds during night or in the early morning in such circumstances. It has, however, been noticed that this synoptic situation sometimes changed completely after midnight, and calm or light wind prevailed during the rest part of night, and fog or fog with stratus clouds above formed by the morning.

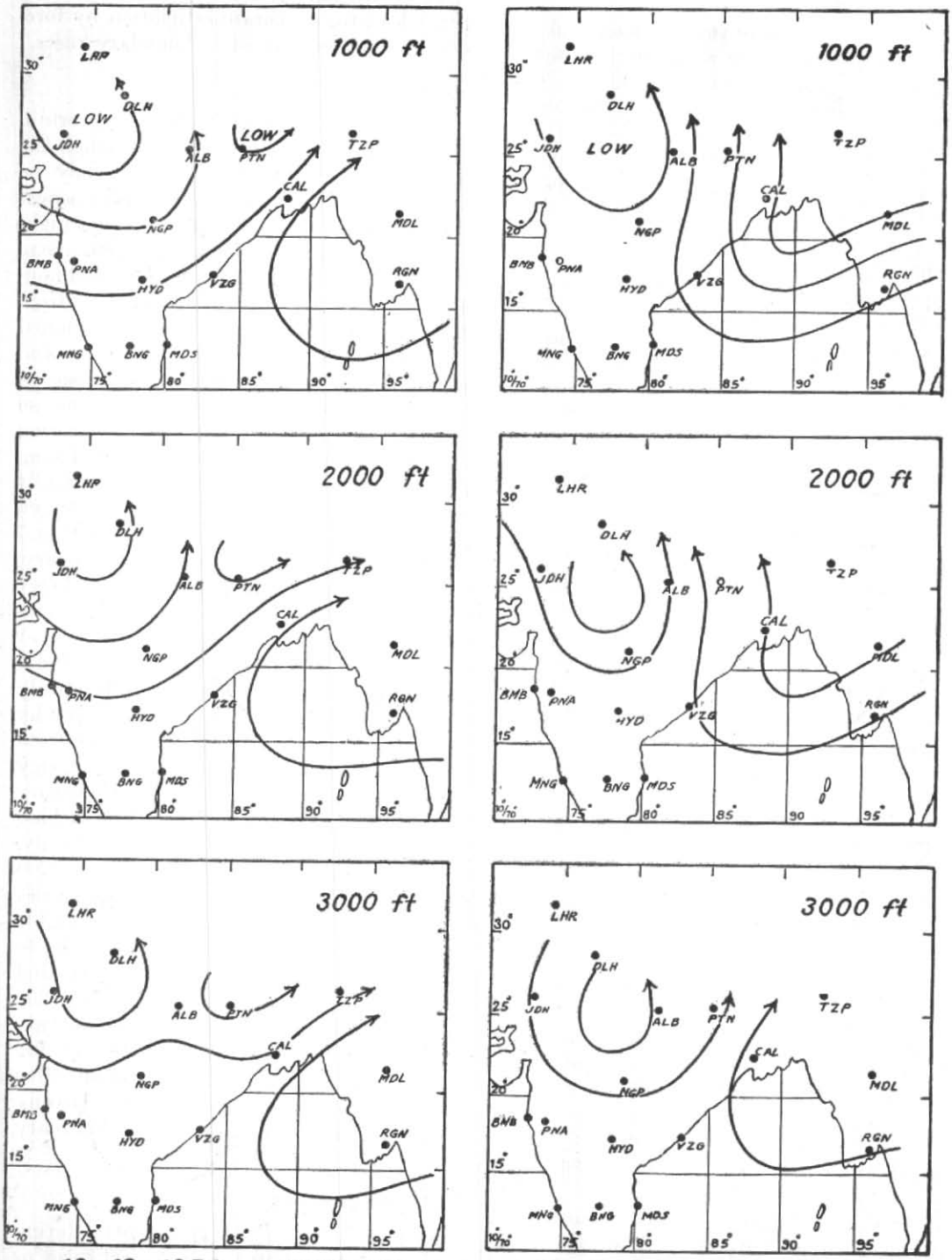
The conditions as above, which may sometimes lead to inaccurate estimation by forecasters, may be termed as boundary cases.

12. Dew-point

It has been noticed that under certain favourable synoptic situations, although the afternoon dew-point temperature may be high, this high value does not always persist but undergoes marked changes during night hours. To see the nature of variation, mean hourly values of dew-point on foggy and non-foggy nights have been calculated from temperature and humidity values obtained from Calcutta (Alipore) thermograms and hygrograms for the months December to March of 1944 to 1948. With the values so obtained, graphs showing dew-point variation during 1800 to 0600 IST on foggy and non-foggy nights have been prepared separately for each of the months December to March —Figs. 7 (*a*) to (*d*). It will be seen from Figs. 7 (*a*) and (*b*) that in December and January, dew-point rises both on foggy and non-foggy nights upto 2200 IST, the rise being more on foggy nights reaching about 60°F at 2200 IST ; thereafter it either rises by a degree or so or remains practically steady on foggy nights, while it falls generally by 2°F on non-foggy nights. It will be seen from Figs. 7 (*c*) and (*d*) that dew-point on foggy nights rises appreciably by 7° F in February and 16° F in March upto 2200 IST reaching values above 60°F and 70°F respectively, and then rises by 2° to 3°F between 2200 and 0200 IST and thereafter practically remains steady, whereas on non-foggy nights it rises (both in February and March) to values less than 60° F upto 2200 IST and then slightly rises between 2200 and 0200 IST and thereafter falls by a degree or two. Thus there is a reasonable chance of fog occurring at Calcutta if the dew-point value at 2200 IST reaches 55° to 60° F in December and January, 60° to 65° F in February and 70° to 75°F in March.

13. Fog prediction diagram

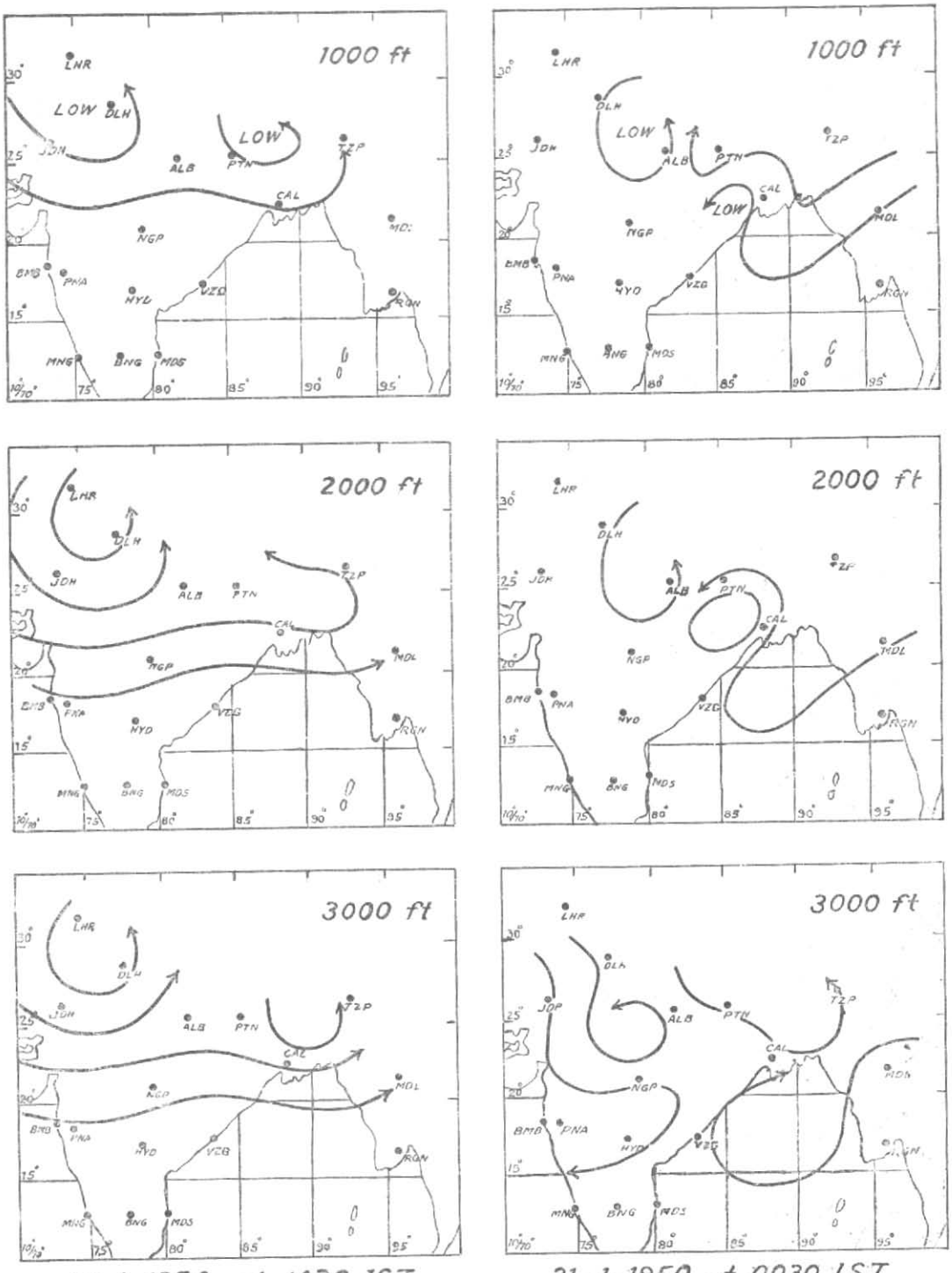
Each instance of fog at Calcutta during the years 1944 to 1948 and several cases of no fog there, have been considered for preparation of certain fog prediction diagrams.



18-12-1950 at 1430 IST

19-12-1950 at 0030 IST

Fig. 4


1000 ft
LOW
LOW
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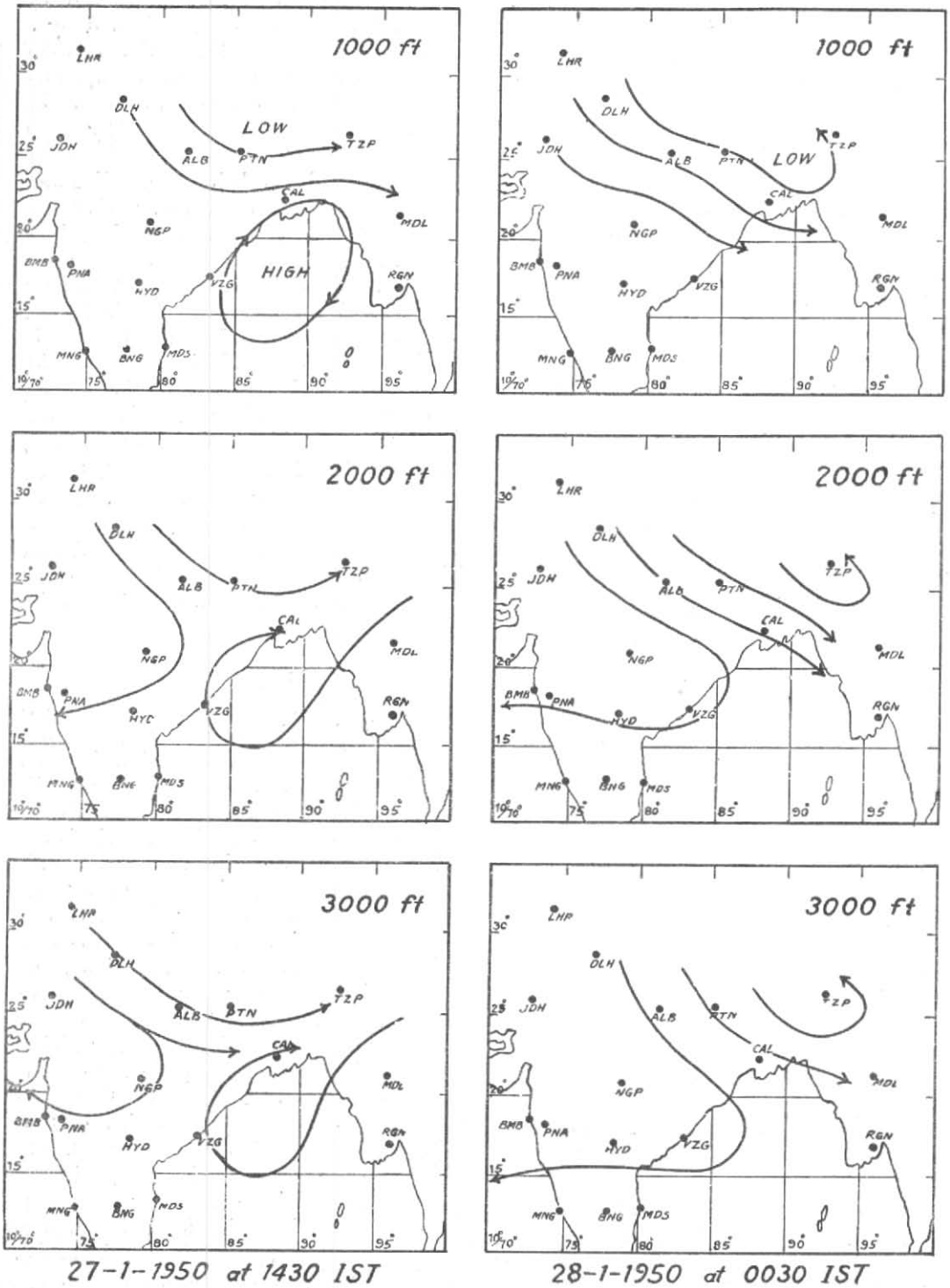
30-1-1950 at 1430 IST
31-1-1950 at 0030 IST

Fig. 5


1000 ft
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27-1-1950 at 1430 IST
28-1-1950 at 0030 IST

Fig. 6

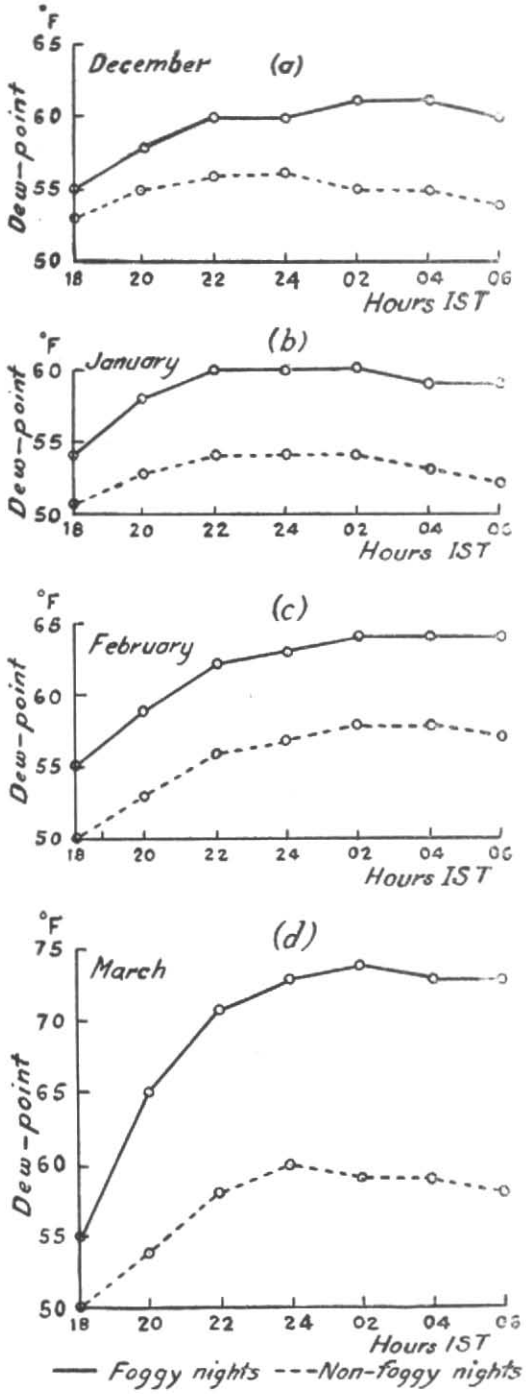

Fig. 7. Dew-point variation during night at Calcutta (1944-48)

Each of the cases examined has been marked on the diagrams (Figs. 8 and 9) representing the state of the air at 1800 and 2200 IST by points, with temperature as the abscissa and the depression of dew-point as the ordinate. Every case of fog is marked by a round dot, and no fog is indicated by a cross. It is seen from Fig. 8 that cases of fog and no fog are rather mixed up, and no definite inference can be drawn from the diagram. The prediction of fog by 1800 IST of the previous evening is, therefore, not feasible with the help of this diagram. It is, however, seen from Fig. 9 that fog occurred almost on all occasions when dew-point depression was less than 10° F at 2200 IST. The dot diagram based on 2200 IST values thus appears to be of help, and a forecast can be made with reasonable confidence that cases which fall below the line separating the dots from the crosses are likely to be followed by fog in the morning while cases above this line will be without fog.

A prediction diagram for 2000 IST was also prepared. It has been observed that a well defined line separating the cases of fog from the cases of no fog cannot be drawn although the mix up of fog and no fog cases is less marked in comparison with that on the 1800 IST diagram.

14. Conclusion

In conclusion, the possibility of fog formation over the Calcutta area need be considered only when the evening synoptic situations are of the types as discussed in the note. If under such situations, winds, sky conditions etc., also are favourable, the forecasting of dew-point temperature during night hours and more specially at the time of the minimum temperature epoch is the main point to be given consideration by the forecaster. To this end one has to watch the variation of dew-point till 2200 IST and the dew-point value of that hour may be taken as an important guiding factor. It will be seen from the dew-point curves that on foggy nights there is a sharp rise of dew-point from about 55° F at 1800 IST to about 60° F (in December and January), to more than 60°F in February and to 70°F or more in March. It will also be seen from the fog prediction diagram (Fig. 9) that fog usually forms over Calcutta area when the dew-point depression at 2200 IST happens to be less than 10°F. The study shows that accurate warnings of fog over Calcutta are possible only after watching the situation upto 2200 IST.

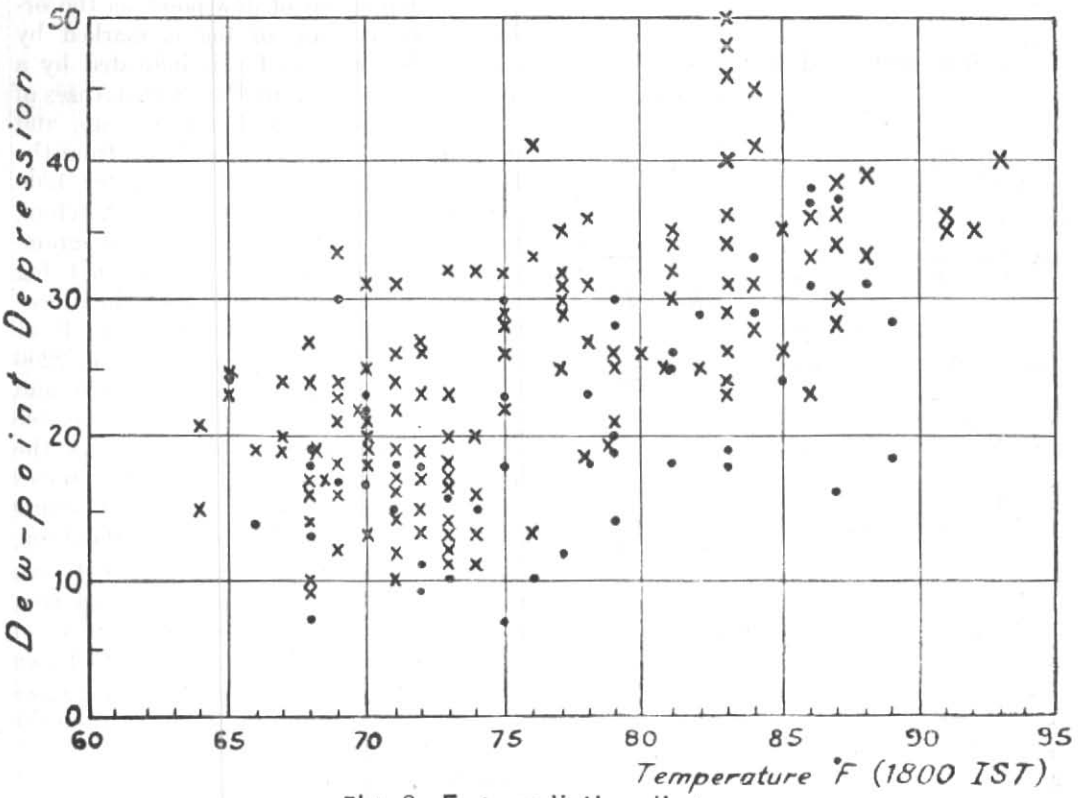

Fig. 8. Fog prediction diagram

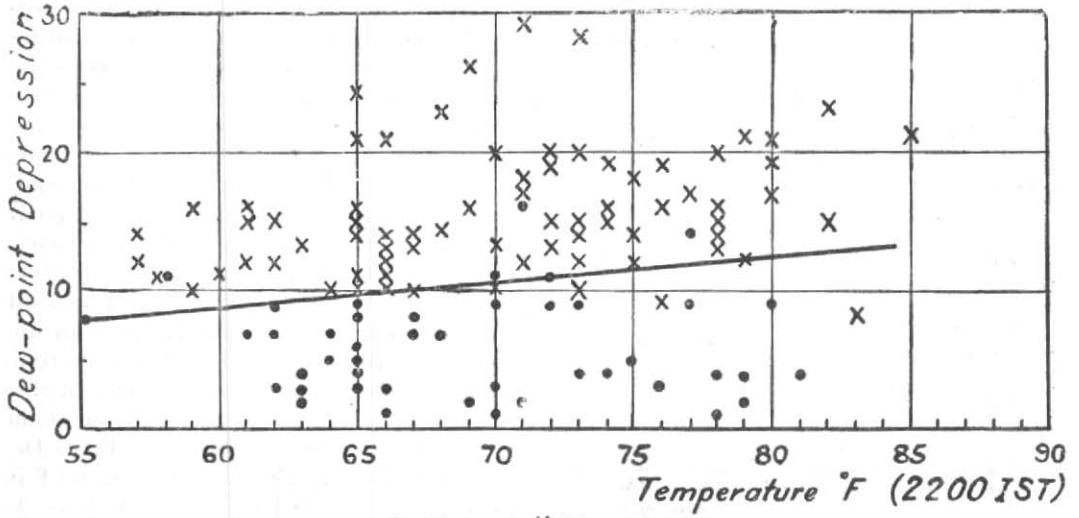

Fig. 9. Fog prediction diagram

15. Acknowledgement

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REFERENCES

1. Roy, A. K., *Ind. J. Met. Geophys*, **2**, 4, p. 305 (1951).
2. Taylor, G. I., *Quart. J. R. met. Soc.*, **43**, 183, p. 241 (1917).