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Use of Tephigrams in the prediction of Radiation Fog

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1. Introduction

In a previous paper (Chakravortty 1948), the author discussed the conditions favourable for the formation of fog at Calcutta and its neighbourhood and suggested a method for the prediction of fog at Calcutta in the early morning by a study of dry and wet thermograms of the previous afternoon and evening. The object of the present paper is to show how the radiosonde observations taken at 2030 IST at Calcutta can be used to predict the occurrence of fog during the course of the night or in the following morning with a greater degree of confidence. For this purpose the 2030 IST radiosonde data along with the surface temperature and fog data of Calcutta for the periods January 1950 to February 1952 and November 1953 to February 1954 have been examined.

2. Method of analysis

A preliminary examination of data for the days of fog has revealed the following important points—

(*a*) Fog is generally preceded by the occurrence of a surface inversion in the evening which can be well identified in the 2030 IST tephigram.

(*b*) Before the occurrence of even the advection type of fog (not to speak of the radiation type) the rise of wet bulb during the previous night after 2030 IST is very small in comparison with the fall of dry bulb. Hence the anticipated fall of dry bulb temperature with the advance of night is more important to determine whether saturation at the surface layer will take place or not (Chakravortty 1948).

(*c*) If from the 2030 IST tephigram of the evening preceding the occurrence of fog, the portion of the curve indicating the surface inversion is wiped out and the straight portion of the curve immediately above the inversion layer is produced to meet the surface isobar, the surface temperature indicated by this new curve is very near the late afternoon temperature in shade corresponding to the time from which the surface cooling has started. (The exact time is found from the thermogram of the day).

From the results of the preliminary examination mentioned above one can, on the basis of the 2030 IST tephigram, picture roughly the following idealised changes in the tephigram from afternoon to 2030 IST and again from 2030 IST to the time of onset of fog, when DBC is the actual dry bulb curve and EF is the actual wet bulb curve at 2030 IST as shown in Fig. 1—

(*a*) In the afternoon, say at 1600 IST (the exact time to be obtained from the thermogram) when the surface temperature began to drop continuously, the dry bulb curve was ABC (obtained by producing the straight portion of the 2030 IST tephigram above the inversion layer to meet the surface isobar).

(*b*) With the advance of time the dry bulb curve became YXBC, say at 1900 IST, the portion AX of the afternoon curve being wiped out and the inversion portion YX being taken to be parallel to DB of the actual 2030 IST tephigram.

(*c*) At 2030 IST the portion AB of the afternoon curve has been wiped out and the

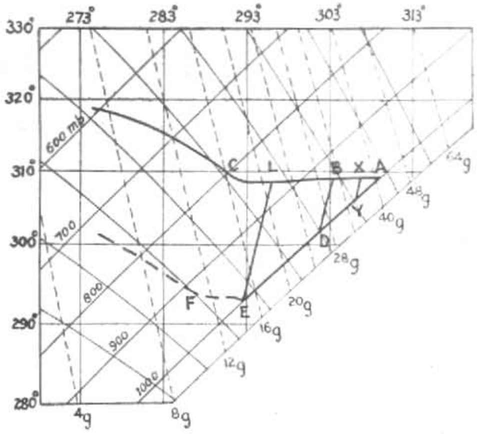

Fig. 1

DBLC —2030 IST D.B. curve (actual)

AXBLC—Afternoon D.B. curve (imaginary)

ELC —Early morning D.B. curve at the time of onset of fog (imaginary)

EF —2030 IST W.B. curve

inversion layer DB at that hour is parallel to YX.

(*d*) With further radiational cooling of the surface layers during the course of the night fog forms at a time when the dry bulb curve become ELC. The surface wet bulb temperature has remained practically constant since 2030 IST and as before the inversion portion EL remains parallel to DB. The portion AL of the afternoon curve is now wiped out.

For the idealised pictures in (*a*) ,(*b*) and (*d*) above it has been assumed that the original temperature distribution of the layers of air upto about 1·5 km above ground has been affected only due to surface cooling and not by any other cause. Hence the present method excludes those cases in which a substantial change in the air mass takes place due to any sudden development in the synoptic situation during the rest of the night. Since such developments are rather infrequent in winter months in the Calcutta area this assumption does not materially affect the utility of the method under discussion. In winter months development of land breeze towards the later part of the night which is practically independent of the prevailing synoptic situation is not uncommon at Calcutta. But this breeze, being generally very light and short-lived, is not likely to upset completely the condition for the development of fog during the night but may affect its time of onset and intensity. Thus even the incidence of land breeze at Calcutta does not affect adversely the utility of the method under discussion. As the cooling of the surface layers is a continuous process practically under calm conditions, the inclinations of the inversion line with the surface isobars in the different stages have been assumed to be constant.

From an examination of the idealised pictures mentioned above one can see that with the fall of surface temperature the inversion portion of the tephigrams makes larger and larger triangles with the surface isobar and the idealised tephigram for the afternoon (AXBLC in Fig. 1), AXBL being a straight line. The triangles thus formed are AYX, ADB and AEL corresponding to the surface temperatures Y, D and E respectively. At each stage the area of the triangle represents the amount of heat lost due to the cooling of the surface layers (Pisharoty 1945). Thus in order to anticipate the occurrence of fog one has to determine, on the basis of the 2030 IST tephigrams and the surface data available at the time—

(*a*) Whether the area of the triangle described during the course of the night is sufficient to bring the surface temperature to the wet bulb temperature E, *i.e.*, whether the final position of the triangle can come upto AEL during the course of the night. Earlier the triangle attains the required area AEL, earlier will be the onset of fog, if other conditions are favourable.

(*b*) What change is effected in the inversion layer in the final position of the triangle. If the portion EL in the final position still shows a marked inversion for a sufficient height (stable condition), the onset of fog is assured; while on the other hand if the inversion is not sufficiently marked in the final position of EL, this goes against the formation of fog.

Thus the degree of confidence regarding the forecast of fog depends upon both the factors mentioned above.

In Fig. 1, $\triangle ADB : \triangle AEL = AD^2 : AE^2$ (1) (DB being parallel to EL)

$$\therefore \triangle AEL = \frac{AE^2}{AD^2} \times \triangle ADB \qquad \ldots \quad (2)$$

Let δs be the area of the triangle described per unit of time

$$\delta s.\, t_2 = \frac{AE^2}{AD^2} \times \delta s.\, t_1 \qquad \ldots \quad (3)$$

When t_1 is the time interval corresponding to AD and t_2 is the time interval corresponding to AE.

$$\therefore t_2 = \frac{AE^2}{AD^2} \times t_1 \qquad \ldots \quad (4)$$

AD and AE being obtained from the 2030 IST tephigram and t_1 with reference to dry thermogram, t_2 can be found out. If t_2 falls near about the normal hour for night minimum, the condition becomes favourable for the onset of fog. If t_2 falls beyond the normal hour for night minimum temperature, the condition becomes unfavourable.

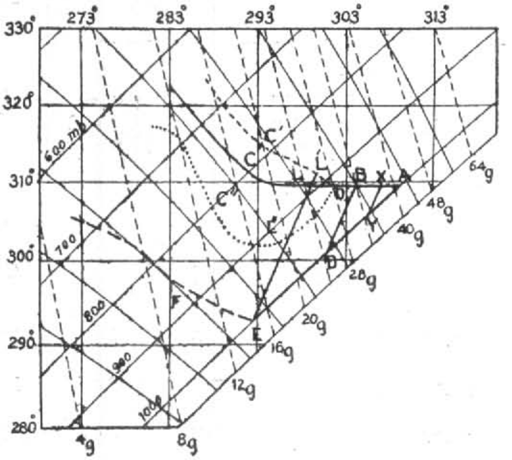

Fig. 2

DBLC — 2030 IST D.B. curve with adiabatic lapse rate above inversion layer

DBL′C′ — 2030 IST D.B. curve with pseudo adiabatic lapse rate above inversion layer

DBL″C″ — 2030 IST D.B. curve with super-adiabatic lapse rate above inversion layer

EF — 2030 IST W.B. curve

It has already been stated that if EL shows marked inversion (stable condition) for a greater height above ground than DB, the condition favours the formation of fog. If EL shows an inversion comparatively less marked, this goes against the formation of fog. This will no doubt depend upon the nature of the tephigram BLC. It is obvious that if AXBLC is not a straight line and BLC tends towards BD (becoming more and more superadiabatic) the condition becomes less favourable for fog, although DB has to cover a less area and hence less time to come upto the point of condensation (*i.e.*, to EL). This result will be apparent from a comparison of the three typical 2030 IST tephigrams, *viz.*, DBOL′C′, DBOLC, and DBOL″C″ in Fig. 2 with corresponding idealised pictures as discussed before. It has actually been observed that time rate of cooling of surface layers remaining constant (*i.e.*, δs in equation 3 remaining constant), a superadiabatic lapse rate above the inversion layer in 2030 IST tephigram had, in some cases, resulted only in mist within a few hours, without any subsequent development of fog; whereas a dry adiabatic or pseudoadiabatic lapse rate above the inversion layer (practically of the same depth) resulted in thick fog though sufficiently belated.

Even when a 2030 IST tephigram shows a curve line above the inversion portion (for instance the curve BOL′C′ or BOL″C″ in Fig. 2), the same method as mentioned before is adopted to obtain the desired result but in calculating the value of t_2, instead of applying the equation (4), the actual areas enclosed by ABD and AEL′ or AEL″ are measured.

$$t_2 = \frac{\text{Area AOL}'\text{E}}{\text{Area ABD}} \times t_1 \text{ or } t_2 = \frac{\text{Area AOL}''\text{E}}{\text{Area ABD}} \times t_1$$

3. Results of analysis

The method under discussion was tried on the radiosonde and surface data of Calcutta for the periods January 1950 to February 1952 and November 1953 to February 1954

TABLE 1

Date	Ht. of 2030 IST inversion layer above ground (*ft*)	t_1 (*hrs*)	t_2/t_1 as obtained from areas covered	t_2 (*hrs*)	Calculated time for anticipated onset of fog or mist (*IST*)	Anticipated ht. of inversion layer a.g. at the time of onset of fog (*ft*)	Time of actual onset of fog or mist (*IST*)
1-1-50	600	5·5	2·0	11·0	0200 (2nd)	900	Mist at 0300, fog at 0500
30-1-50	600	5·0	2·9	14·5	0600 (31st)	900	Fog at 0730
13-2-50	900	4·0	4·4	17·6	No fog expected	2000	No fog or mist
29-11-50	1200	6·0	2·8	16·8	0715 (30th)	1800	Mist at 0500
18-12-50	Isothermal upto 1500	4·5	2·9	13·0	0500 (19th)	Isothermal	Fog at 0630
26-12-50	900	5·5	2·4	13·2	0400 (27th)	1500	Fog at 0507
15-1-51	1800	6·5	2·0	13·0	0300 (16th)	2700	Mist at 0437, Fog at 0507
16-1-51	1000	6·5	2·0	13·0	0300 (17th)	1500	Fog at 0422
9-2-51	900	3·5	2·8	9·8	0250 (10th)	1500	Fog at 0400
4-3-51	2400	7·0	2·0	14·0	0300 (5th)	3300	Fog at 0257
16-11-51	1200	7·0	2·3	16·1	0540 (17th)	1500	Mist at 0530
5-12-51	1200	7·0	2·0	14·0	0300 (6th)	1500	Fog at 0530
9-12-51	900	6·0	6·3	37·8	No fog expected	2400	No fog or mist
29-12-51	600	5·5	2·9	15·9	0650 (30th)	900	Fog at 0530
13-1-52	750	5·0	2·6	13·0	0430 (14th)	1200	Fog at 0430
18-1-52	900	5·5	13·0	71·5	No fog expected	3000	No fog or mist
2-11-53	1000	7·3	4.0	29·2	Do.	2300	No fog or mist
13-11-53	1400	8·3	2.0	16·6	Do.	1900	No fog or mist
28-11-53	600	7·1	1·6	11.0	0100 (29th)	1000	Mist at 0715
2-12-53	1100	7·1	2·6	18.0	0700 (3rd)	1900	Mist at 0530
18-12-53	800	7·5	1·6	12.0	0100 (19th)	2000	Haze at 2200
7-1-54	500	6·7	2·0	13.0	0250 (8th)	1500	Mist at 0610
8-1-54	700	6·8	1·4	9.0	2300 (8th)	1600	Fog at 0600

TABLE 1—(*contd*)

Date	Ht. of 2030 IST inversion layer above ground (*ft*)	t_1 (*hrs*)	t_2/t_1 as obtained from areas covered	t_2 (*hrs*)	Calculated time for anticipated onset of fog or mist (*IST*)	Anticipated ht. of inversion layer a.g. at the time of onset of fog (*ft*)	Time of actual onset of fog or mist (*IST*)
22-1-54	700	6·6	2·3	15.0	0400 (23rd)	1500	Fog at 0230
2-2-54	800	6·8	1·8	12.0	0145 (3rd)	1000	Mist at 0005
12-2-54	1100	7·3	1·7	12.0	0110 (13th)	2000	Mist at 0532
26-2-54	1300	6·3	2·0	13.0	0310 (27th)	2100	Fog at 0250

TABLE 2

Date	Condensation level at 2030 IST (mb)	Potential temperature (°A) at the C.C.L. for the first km above surface at 2030 IST	Date and time (IST) of onset of fog or mist if any
1-1-50	940	300	Fog at 0500 of 2nd
30-1-50	960	303	Fog at 0730 of 31st
25-11-50	890	318	Mist at 0500 of 26th
29-11-50	890	332	Mist at 0500 of 30th
18-12-50	970	311	Fog at 0630 of 19th
26-12-50	940	305	Fog at 0507 of 27th
16-1-51	950	302	Fog at 0422 of 17th
9-2-51	940	317	Fog at 0400 of 10th
23-2-51	900	319	No fog on 24th
28-2-51	820	326	No fog on 29th
5-3-51	920	316	Fog at 0427 of 6th
29-12-51	920	310	Fog at 0530 of 30th
4-1-52	960	299	Fog at 0547 of 5th
8-1-52	950	297	Fog at 0545 of 9th
12-1-52	850	325	Mist at 0607 of 13th
13-1-52	880	315	Fog at 0430 of 14th
7-2-52	940	299	Fog at 0530 of 8th
27-2-52	900	313	Fog at 0530 of 28th
2-11-53	900	296	No fog or mist
13-11-53	960	296	No fog or mist
28-11-53	960	290	Mist at 0715 of 29th
2-12-53	920	292	Mist at 0530 of 3rd
18-12-53	980	286	Haze at 2200 of 19th
7-1-54	920	285	Mist at 0610 of 8th
8-1-54	960	292	Fog at 0600 of 9th
2-2-54	970	292	Mist at 0005 of 3rd
26-2-54	930	293	Fog at 0250 of 27th

and it has been observed that barring the cases associated with sudden changes in the synoptic situation during the course of the night after 2030 IST, one can, with the help of this method, predict the occurrence of fog or mist with a fairly high degree of confidence, although the calculated value of time for the occurrence of fog or mist may not exactly coincide with the actual value. Table 1 gives a few cases at random illustrating the method.

4. Potential temperature at the convective condensation level and time of onset of fog

Martin and Baner (see reference) claim that with the help of a graph representing the relation between the potential temperatures at the convective condensation levels and times of onset of fog for a particular place a reasonably accurate forecast can be made on the basis of evening soundings. An attempt in the same line was made to draw a curve representing the relation between the potential temperatures at convective condensation levels on the basis of 2030 IST soundings at Calcutta and the corresponding times of onset of fog at the station, but no regular curve could be obtained. It will be seen from Table 2 that while fog is generally associated with fairly low potential temperatures at C.C.L., lower values of these potential temperatures do not always result in earlier onset of fog. In analysing the fog data of Alipore the usefulness of the potential temperatures at C.C.L. has been found to the extent that very high values of C.C.L. go against the formation of fog.

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REFERENCES

Chakravortty	1948	*India met. Dep. Sci. Note*, **10**, 124.
Martin, Donald E. and Baner, Paul N.		*Forecasting fog in the Brahmaputra valley.*
Pisharoty, P. R.	1945	*India met. Dep. Tech. Note*, 12.