551.575:512.1(548.1)

APPLICATION OF BRUNT'S FORMULA FOR FOG OVER MADRAS AIRPORT

Rangarajan (1952), Basu (1952), Basu (1954), Kundu (1952), Natarajan (1959) and Tempe (1957) have studied various aspects of fog. Puri (1971) has attempted to forecast fog for Delhi airport on the basis of Jacob's diagram. He compared the actual time of occurrence of fog and the time of fog likely to occur as per computation and found that they agree very well.

In this present study, an attempt has been made to calculate time of occurrence of fog by applying Jacob's diagram, which is based on Brunt's formula.

A study of the charts, *viz.*, 1800 GMT synoptic charts of the previous independent night of fog reveals that there are four types of synoptic situations favourable for occurrence of fog next day early morning namely :

(1) A high pressure area over the Bay of Bengal adjoining Madras coast and neighbourhood.

(2) A low pressure area over land simultaneously with a high pressure area over the Bay.

(3) In the upper air chart a continuous easterly flow pattern was seen over Deccan Plateau in the lower levels (0.3, 0.6, 0.9 km chart).

(4) A flat pressure gradient over peninsula.

2. *Jacob's diagram* — Radiation fog occurs when the dry bulb temperature falls below the sunset dew point due to cooling. Lee (1955) has presented the tentative values of depression of air temperatures below dew point which will result in fog in the following table :

Dew point (°C)	−2 to +2	3 to 6	7 to 9	10 to 14	15 to 21
Depression of air Temperature below sunset dew point	3	2	1.7	1.0	0.6

The radiation formula put forward by Brunt (1934) can be used to determine the hourly changes of temperature.

$$\Delta t_1 = \frac{2\sigma T^4}{\sqrt{\pi}} \left[1 - \frac{a - b\sqrt{e}}{\rho c \sqrt{k}} \right] \sqrt{t}$$

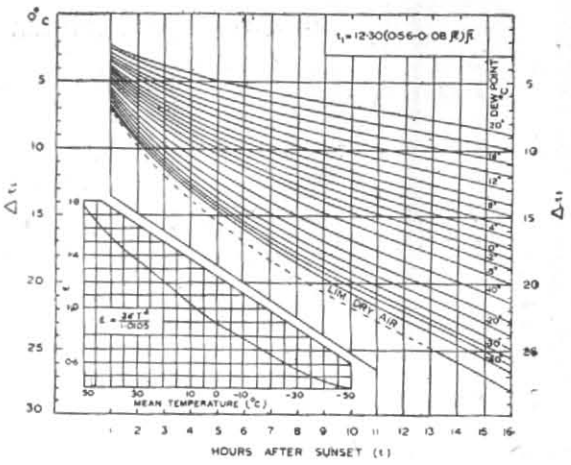

Fig. 1

Where, Δt_1 is change in radiation temperature for t hours after sunset, k is specific conductivity of heat of the surface, ρ density of ground, c-specific heat of ground, σ Stefan's constant, T radiative temperature and e the vapour pressure. This radiation formula has been put in a graphical form known as Jacob's diagram (Fig. 1) for all the hourly temperatures during the night. In the case of fog days the mean radiative temperature can be assumed as temperature at sunset *minus* half of the critical temperature change as given by Lee's table.

3. *Computation of S — the soil constant*

(1) Select a clear calm night for the stations.

(2) Tabulate temperatures accurate to the tenths and determine hourly changes Δt_2

(3) From dew point at sunset tabulate the corresponding values of Δt_1, as given by Brunt's formula.

(4) Determine ratio $\frac{\Delta t_1}{\Delta t_2}$

(5) Calculate the mean radiative temperatures as the average of night hourly temperatures.

(6) Calculate $S = \frac{\Delta t_1}{\Delta t_2} \times 0.082 \times E$

(7) Compute $D = \frac{0.082}{S}$

Then for any fog day for which forecast is needed, determine from t_2 the corresponding

$$\Delta t_1, \text{ as } \Delta t_1 = \frac{\Delta t_2}{DE}$$

Then this can be used along with the sunset dew point to determine the number of hours (t) after sunset at which fog will occur, with the aid of the Jacob's diagram.

An example of the calculation is given in Table 1. Thus the correction factor D can be determined for the station.

TABLE 1

Calculation of $\Delta t_1/\Delta t_2$

S. No.	Hrs. after sunset	0	1	2	3	4	5	6	7	8	9	10	11	12
(1)	T 26.1 Td 16.7 at sunset													
	Δt_2		1.9	4.1	5.4	5.8	6.1	6.2	6.2	6.0	6.9	7.1	—	—
	Δt_1	—	2.8	3.7	4.4	5.2	5.9	6.3	6.8	7.3	7.9	8.3	—	—
	13 January 79 $\frac{\Delta t_1}{\Delta t_2}$		1.48	0.88	0.95	0.97	0.98	1.02	1.11	1.22	1.13	1.16	Average 1.05	
(2)	T 26.3 Td 16.7 at sunset													
	Δt_2		0.4	1.1	1.3	1.3	5.0	5.3	6.2	6.2	6.3	6.3	6.5	6.8
	Δt_1		2.8	3.7	4.4	5.2	5.9	6.3	6.8	7.3	7.9	8.3	8.6	9.0
	19 January 77 $\frac{\Delta t_1}{\Delta t_2}$	—	—	—	—	—	1.18	1.19	1.10	1.17	1.25	1.32	1.32	1.32
													Average	1.23
(3)	T 25.5 Td 17.3 at sunset													
	Δt_2	0.4	0.4	0.7	0.9	3.0	3.9	5.4	5.5	5.6	5.6	5.9	6.5	7.8
	Δt_1		2.8	3.7	4.5	5.0	5.6	6.2	6.7	7.2	7.7	8.0	8.5	8.9
	28 January 77 $\frac{\Delta t_1}{\Delta t_2}$	—	—	—	—	—	1.44	1.15	1.22	1.29	1.37	1.35	1.31	1.14
													Average	1.28

Average $\frac{\Delta t_1}{\Delta t_2} = 1.19$

Calculation of S & D

13 January 79

$\frac{\Delta t_1}{\Delta t_2} = 1{\cdot}05$ sun set dew point = 16·7 deg. C

Mean radiation temp = 20·7 deg. C

E from graph = 1·21

$$S = \frac{\Delta t_1}{\Delta t_2} \times 0.082 \times E = 1.05 \times 1.21 \times 0.82 = 0.1041$$

$$D = \frac{0{\cdot}082}{S} = \frac{1}{1.05 \times 1.21} = 0.787$$

19 January 77

$\frac{\Delta t_1}{\Delta t_2} = 1{\cdot}23$ sun set dew point = 16.7 deg. C

Radiation temp. = 21.5; $E = 1.22$, $S = 0.12$

$$D = \frac{1}{1.23 \times 1.22} = 0.666.$$

Average = 0·727

Table 2 compares the actual setting time of fog (from data in Appendix I) and forecast time calculated from Brunt's formula applying the correction factor for the station.

4. A comparison of the forecast time and actual setting time of fog shows very good agreement in the cases studied. The maximum error is of the order of about ½ hour. The cases of visibility 1000 metres in appendix indicates the just commencement of fog with further reduction in visibility subsequently. Out of the 50 occasions of fog occurrence only cases where the fog has persisted for one hour and more alone were studied due to the following reasons: If the duration of the fog is of the order of half-an-hour or less, this may not be an aviation hazard in the sense that the movement of aircrafts will not be affected much.

5. The authors are indebted to Regional Director, Dr. N. S. Bhaskara Rao and also Sri M. Jayaram, Director M. O., Madras for their guidance throughout the work.

TABLE 2

Comparison of time of occurrence of fog

S. No.	Date	S. set time (IST)	Fog occurrence time from data (IST)	Fog f/c (Number of hrs from S. set IST)	Time of fog by f/c	Duration of fog from data
1	16 Jan 73	1802	17/0220	8½ hr	17/0232	6 hr 10 mnts
2	24 Jan 74	1806	25/0200	7½ hr	25/0136	3 hr 30 mnts
3	19 Feb 74	1816	20/0300	9 hr	20/0316	4 hr 40 mnts
4	19 Feb 76	1815	20/0510	13 hr	20/0715	1 hr 10 mnts
5	30 Dec 77	1751	31/0610	13 hr	31/0651	1 hr
6	18 Jan 78	1800	18/2350	6 hr	18/2400	7 hr 50 mnts
7	29 Jan 79	1808	30/0620	12½ hr	30/0638	1 hr 5 mnts
8	25 Feb 80	1817	26/0050	13 hr	26/0017	1 hr
9	17 Mar 80	1820	17/0540	12 hr	17/0620	3 hr

Appendix I

Data for fog days

S. No.	Date	At sunset (IST) time	At sunset Temp. (°C)	Dew point (°C)	Time of occurrence of fog (IST)	Lowest visibility (m)
1	1 Feb 72	1810	25.7	17.0	0510-0810	100
2	16 Jan 73	1802	25.4	20.4	0220-0820	050
3	24 Jan 74	1806	24.0	19.8	0200-0530	050
4	19 Feb 74	1816	26.2	22.5	0400-0830	050
5	19 Feb 76	1815	26.5	19.0	0510-0720	100
6	20 Feb 76	1816	26.9	19.5	0140-0740	<050
7	27 Feb 77	1810	26.8	19.5	0640-0730	1000
8	21 Feb 77	1813	27.5	21.2	0710-0820	1000
9	27 Dec 77	1750	24.9	19.6	0710-0810	500
10	30 Dec 77	1752	26.8	20.7	0610-0750	300
11	17 Jan 78	1800	25.1	16.5	0640-0750	050
12	18 Jan 78	1800	25.5	22.0	2350-0740	050
13	19 Jan 79	1803	26.1	21.6	0720-0750	300
14	28 Jan 79	1808	25.0	17.5	0650-0810	500
15	29 Jan 79	1808	25.3	18.9	0650-0810	800
16	25 Feb 80	1817	29.8	20.2	0620-0700	800
17	17 Mar 80	1820	29.2	21.8	0540-0840	<050

References

Brunt, D., 1934, *Physical & Dynamical Meteorology*, pp. 46-59.

Basu, S.C., 1952, *Indian J. Met. Geophys.*, **3**, 4, pp. 288-289.

Basu, A., 1954, *Indian J. Met. Geophys.*, **5**, 4, pp. 345-355.

Chakrabarthy, K.C., India Met. Dep. Sci. Note No. 10, 124-142.

Jacob, W.C., 1940, *Bull. Am. Met. Soc.*, **21**, pp. 297-301.

Kundu, T.K., *Indian J. Met. Geophys.*, **8**, 3, pp. 298-301.

Lee, R., 1955, Dept. of Transport Met. Divn., Tech. Circular Note IR 27-25, Tech. 226.

Natarajan, G. *et al.*, 1959, *Indian J. Met. Geophys.*, **10**, 2, pp. 161-168.

Puri, S.R., 1971, India Met. Dep. Pre-published Sci. Note. No. 175.

Rangarajan, S., 1952, *Indian J. Met. Geophys.*, **3**, 3, pp. 186-196.

Tempe, K.D., 1967, *Indian J. Met. Geophys.*, **18**, 4, pp. 505-510.

Viswanathan, T.R., 1963, *Indian J. Met. Geophys.*, **14**, 2, pp. 205-211.

B. MANIKIAM
V. MOHAN
T. H. SUBRAMANIAN

Meteorological Office, Madras

29 August 1980