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Fog at Santacruz Airport

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ABSTRACT. Rangarajan (1952) studied fogs that occurred at Santacruz airport during the period 1942 to 1951. In the present study cases of low visibility at Santacruz airport due to thick mist or fog during the period January 1952 to April 1959 have been examined taking into account conditions at the surface as well as in the upper air. An unusual case of fog which occurred on 16 October 1960 has also been examined.

1. Data and scope of study

Hourly aeros, M5, B5 messages and upper winds and temperatures have been taken from records of the Santacruz Meteorological Office and from the Indian Daily Weather Reports. Fog is considered to have occurred when visibility deteriorates to one kilometre due to suspended water particles in the air. All such cases have been studied in detail. However as there is ever increasing aviation activity at Santacruz airport and as visibility is of importance for landing and take off of aircraft, cases when lowest visibility was between 1 and 1·6 km have also been included under the category of fog for the purposes of this study. Table 1 gives particulars relating to the 24 cases of fogs which occurred in the period considered.

2. Mode of formation

The formation of fog is favoured by a number of conditions, *viz.*, clear skies, slight turbulence at the ground, a synoptic situation at the surface conducive to the advection of moisture and an upper air circulation above the inversion layer favourable for the maintenance of the inversion and of clear sky conditions.

3. Synoptic situation

Rangarajan (1952) has indicated that the surface synoptic situations favourable for formation of thick mist or fog at Santacruz are the following—(*a*) a relatively lower pressure existing to the north of Bombay and neighbourhood with the prevailing airflow at the surface from west or northwest causing an incursion of moisture from the Arabian Sea, (*b*) the seasonal low in the southeast Arabian Sea being pulled up under the influence of a western disturbance; sometimes there may be a shallow closed trough of low pressure off the Konkan coast. The features of the pressure system favourable for the occurrence of fog may be masked on the 1200 GMT chart due to insolation but will be observed on the 1800 GMT chart. He has also stated that "when due to a low inland, say over north Deccan and adjoining areas, the isobars near Bombay run from north to south or northwest to southeast having little travel over the sea, no fog is found to form". In this study it has been found that fog has occurred on 11 occasions out of 24 when the relevant 1800 GMT chart showed a low over the Deccan. In fact a detailed analysis of the 1800 GMT chart of the days preceding the

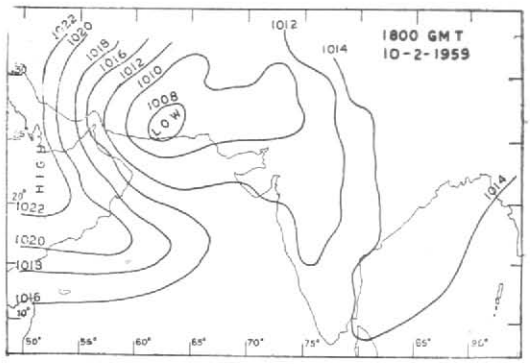

Fig. 1

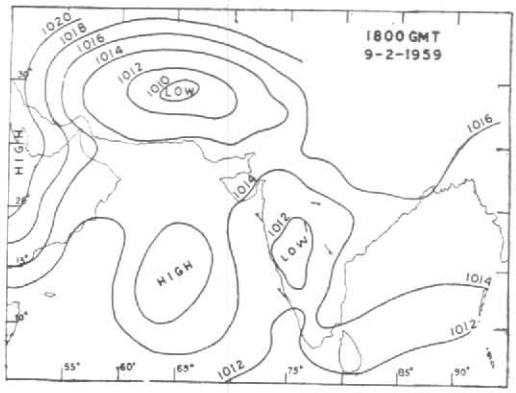

Fig. 2

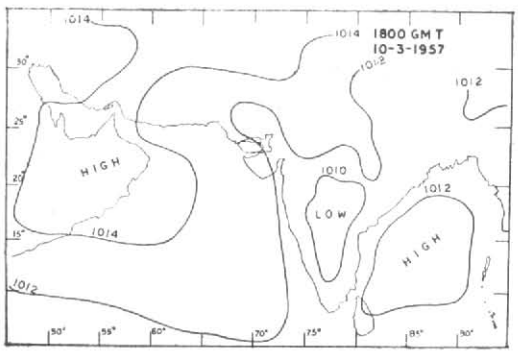

Fig. 3

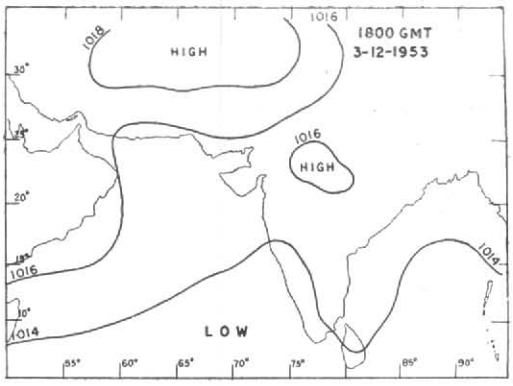

Fig. 4

day of fog revealed that fog occurred in a variety of surface synoptic situations. Four different situations are depicted in Figs. 1 to 4. Fig. 1 gives the synoptic situation which preceded the occurrence of fog on 11 February 1959. This is a case where the isobaric pattern favours the advection of moisture over Bombay due to a low pressure area over Sind and adjoining Rajasthan. Fig. 2 gives a situation where there is a low over Deccan in addition to another further north over Sind and Rajasthan. Fig. 3 gives a situation where a low pressure area exists over the Deccan with increasing pressures west and north of Bombay. Fig. 4 gives an instance where a lower pressure exists towards the south and west favouring a surface wind with an easterly component over Bombay. This is a situation which is not favourable for advection of moisture from the Arabian Sea. Table 1 shows that fog has formed in association with all these four types of pressure distribution. Thick fogs are rare in December and January and occur mostly in February and March, with a higher figure in March. Types 2 and 3 of the synoptic situations were associated with 75 per cent of the cases of fog, type 3 being more frequent in March.

4. Turbulent mixing

A slight amount of turbulent mixing aids the formation of fog. In the case of fogs which form much before sunrise a light surface wind brings about the required mixing, but with sunrise an additional factor becomes effective, namely solar radiation. The solar radiation sets up convection currents near the surface and causes turbulent mixing of the layers near the ground. Table 1 shows that on 16 out of 24 occasions when the visibility lowered to 1·6 km or less, the lowest visibility was reached after sunrise. Out of the remaining 8 occasions the lowest visibility was reached less than fifteen minutes before sunrise on four occasions and about half an hour before sunrise on two occasions. On the remaining two occasions the lowest visibility was reached much before sunrise.

5. Circulation in upper air

An anticyclonic circulation in the upper air over the Deccan and neighbourhood is the feature on a number of days during the winter months. It will be seen from Table 1 that such a circulation existed in the upper air on the day or days preceding the day of fog on all occasions except three. Such a circulation is a favourable factor for occurrence of fogs.

6. Inversion associated with fogs

A temperature inversion near the ground is another factor contributory to fog formation. An inversion restricts the turbulent mixing within the inversion layer and thus helps the thickening of mist or fog. During winter an inversion is usually brought about by radiational cooling of the ground. In this study it has been noticed that an inversion at Santacruz occurs not only due to cooling at the surface but also due to a rise of temperature above the inversion level. This type of inversion often occurs when there is an anticyclonic circulation over Bombay and the Deccan. Table 2 gives the upper air temperatures on a few days when such an inversion was associated with an anticyclonic circulation in the upper air.

7. Moisture associated with fog formation

A large amount of moisture at the surface or in layers above the ground and increase of moisture with height favour the occurrence of fog. Turbulent mixing always acts in such a manner as to make the distribution of moisture nearly uniform vertically in the layers in which mixing occurs. If the upper layers are dry, turbulent mixing will tend to lower the humidity of the air and dissipate the mist or haze if formed. On the other hand, if the moisture content originally increased with height, turbulent mixing will increase the moisture content of the air near the surface and favour the development of fog. But if the moisture content, though not increasing with height, is significant in layers above the ground, turbulent mixing will help the mist or fog to persist longer. An increase of moisture in the layers above the ground in the winter months is generally brought about by a wind with a westerly or southerly component.

The relative humidity at the surface recorded at 2330 IST preceding the day of fog was more than 75 per cent on all occasions except three as will be seen from Table 1.

Of these three occasions the lowest visibility was only 1·6 km on two occasions and 1·4 km on the remaining occasion.

Table 1 gives particulars of the winds at 1000 and 2000 ft during the night preceding the day of the formation of fog. The direction of wind at 1000 ft *vis-a-vis* the duration of fog (visibility 1 km or less) is given below—

Duration of fog (hr)	Direction of wind at 1000 ft				Total
	330-360	010-130	140-220	230-320	
<1	2		1	3	6
1—2			2	2	4
2—3	1			3	4
>3				1	1

TABLE 1

Date	Lowest visibility recorded (km)	Time of lowest visibility (IST)	Time of sunrise (IST)	R.H. at 2330 IST (%)	Duration of fog* (IST)	Upper air anticyclonic circulation (dates)	Upper winds† (ft) 1000	Upper winds† (ft) 2000	1800 GMT synoptic situation corresponds to Fig. No.
4-2-53	1·6	0730	0713	88	0730-0815	2-4	030/2	310/5	2
7-2-53	0·8	0730	0712	91	0715-0750	5,6	360/6	360/9	3
28-2-53	0·02	0630	0700	83	0530-0650	27,28	140/2	040/6	3
1-3-53	1·4	0710	0658	80	0710-0855	27,28	340/13	340/16	2
11-3-53	1·0	0705	0651	85	0640-0742	10,11	290/3	340/7	2
12-3-53	0·03	0640	0651	82	0640-0730	10,11	250/2	290/5	3
21-3-53	1·4	0650	0643	34	0650-0900	19-21	010/6	020/17	3
4-12-53	0·4	0730	0657	89	0645-0930	Nil	360/5	360/6	4
8-3-54	0·01	0230	0654	88	0050-0455	5-7	260/7	190/2	4
17-2-55	0·7	0410	0707	90	0410-0505	16	280/7	280/3	2
8-3-56	1·0	0645	0654	86	0645-0700	6-8	200/3	280/4	3
12-3-56	0	0730	0651	90	0635-0830	Nil	290/5	300/11	3
9-1-57	0·8	0710	0714	84	0710-0800	7,8	270/7	270/12	1
14-1-57	1·6	0705	0715	64	0705-0800	12-14	340/15	360/9	4
11-3-57	0	0730	0651	78	0550-0830	8-10	320/7	320/6	3
16-3-57	0·5	0730	0647	86	0645-0800	14-16	160/4	220/2	1
15-3-58	1·2	0730	0647	86	0700-0800	13-15	140/3	190/2	3
25-3-58	1·0	0645	0639	79	0645-0730	22-25	340/7	030/5	3
18-1-59	1·5	0830	0715	64	0830-0930	14-18	200/4	210/7	4
19-1-59	1·6	0800	0715	88	0800-0900	14-19	320/7	270/3	4
5-2-59	1·5	0730	0713	77	0730-0910	1-5	330/10	330/4	3
10-2-59	0·6	0800	0710	90	0700-0930	8-10	270/4	200/1	2
11-2-59	0·8	0634	0710	90	0634-0900	8-11	230/7	250/4	1
16-2-59	1·5	0745	0707	81	0745-0900	Nil	300/7	320/9	3

*For the purpose of duration of fog the time of observation (Aero, or M5) where the visibility reported was 1·6 km or less was taken as the time of commencement and the fog was considered to have lasted till the time of observation (Aero or B5) where the visibility reported was more than 1·6 km

†Upper winds at 1000 and 2000 ft correspond to 0200 IST on the days of fog upto 16-3-57 and later to 2330 IST on the day preceding the day of fog. As the fog on 8-3-54 commenced at 0050 IST, the upper winds given correspond to 1430 IST of 7-3-54

TABLE 2

Date	Time of ascent	Ground		Top of inversion		900 mb
		PPP	TT	PPP	TT	TT
11-1-59	00	1011	17	984	21	18
12-1-59	00	1012	15	978	20	17
13-1-59	00	1012	17	955	23	20
14-1-59	00	1012	19	942	27	25
15-1-59	00	1012	20	970	27	22
16-1-59	00	1014	20	943	26	23
17-1-59	00	1013	20	962	28	24
18-1-59	00	1013	21	974	24	21
6-2-59	00	1011	16	960	21	18
7-2-58	00	1010	18	944	26	22
8-2-59	00	1010	16	965	26	23
9-2-59	00	1009	16	950	24	22

It will be seen that more than 80 per cent of the occasions when the lowest visibility reached was 1 km or less and the duration of fog was one hour or more were associated with wind at 1000 ft having a westerly or southerly component, winds with westerly component being more frequent.

8. Analysis of occasions when fog occurred

A detailed discussion of the formation of fog on some occasions is made in the following paras to elucidate the considerations given earlier. It is believed that fogs occurred on other occasions in nearly similar circumstances.

Fog on 11-2-1959—This is a case of occurrence of fog due to continued advection of moisture from the Arabian Sea associated with a low over Sind and Rajasthan. The isobars on the 1800 GMT chart were from west to east near Santacruz (Fig. 1). The upper winds at 1000 ft and above were westerly at 1800 GMT on 10 February 1959 and these caused an increase of moisture in layers above the ground. The relative humidity at 1800 GMT on 10th was 90 per cent. The dew point was 18·7°C at 1800 GMT and increased to 20°C at 2100 GMT on 10th. Even at 2130 IST on 10th haze had occurred forming into fog at 0634 IST on 11th. The visibility continued to be 0·8 km from 0634 to 0830 IST.

Fog on 18-1-1959—Visibility went down to 1·5 km at 0830 IST on the morning of 18 January 1959. An anticyclonic circulation was seen at higher levels from 14th onwards, bringing about a temperature inversion (see Table 2). The upper air chart at 1800 GMT of the previous day showed an anticyclonic circulation in the upper air with the wind at 1000 and 2000 ft having a southerly component. The synoptic situation at 1800 GMT was not favourable for advection of moisture from the sea near the ground as the isobars near Bombay were such as to cause an easterly wind over Bombay (see Fig. 5) and the relative humidity at 1800 GMT of 17th was only 64 per cent. It is considered that the lowering of visibility was brought about by turbulent mixing in the inversion layer after sunrise.

Fog on 8-3-1954—Very thick fog reducing visibility to 10 metres occurred from 0130 to 0430 IST of 8 March 1954. The surface chart of 1800 GMT on 7 March 1954 showed a high over Sind—Rajasthan with pressure gradient decreasing towards south (see Fig. 6). It is possible therein to draw an odd closed 1011 mb isobar giving a shallow low

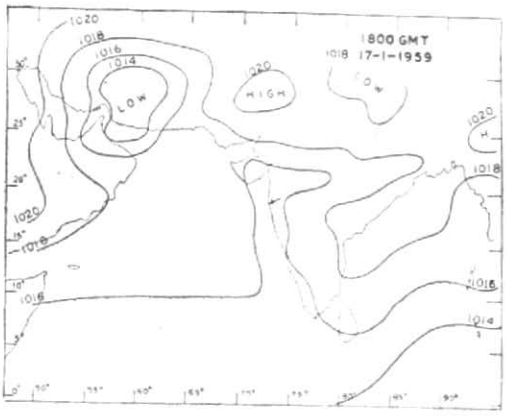

Fig. 5

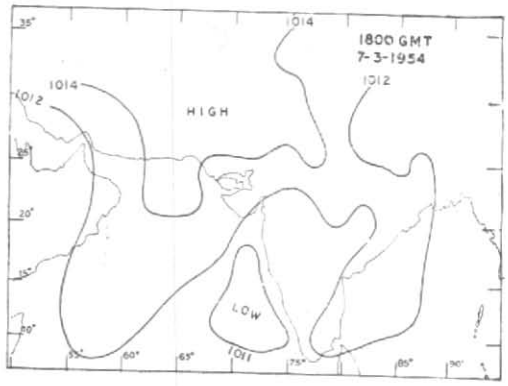

Fig. 6

TABLE 3

15 October 1960	1800 GMT				2400 GMT				
	Ground (1009 mb)	1000	975	915	Ground (1008 mb)	1000	975	916	900
Dry Bulb	26·5	26·8	28·5	24·8	24·8	24·8	24·1	26·5	25·0
Wet Bulb	25·2	23·5	17·2	17·5	24·2	24·1	24·1	15·3	14·9
Mixing ratio	20·0	18·4	12·9	14·0	19·1	19·2	19·9	11·9	11·9

pressure area off Konkan coast. The upper winds at 1000, 2000 and 3000 ft over Bombay and Vengurla at 0900 GMT on 7 March 1954 seem to support the low off the Konkan coast. The dew point at Santacruz at 1800 GMT on this day had increased by about 10°F during the preceding 24 hours. There was favourable anticyclonic circulation at upper levels on 5th, 6th and 7th. In this case a shallow low off the Konkan coast not associated with a western disturbance contributed to the formation of fog.

Fog on 21-3-1953—On the morning of 21 March 1953 visibility was reduced to 1·4 km at 0650 IST. Thick mist continued till 0830 IST when visibility was 1·6 km and improved to 3·6 km by 0900 IST. The relative humidity was 34 per cent at 1800 GMT and became 79 per cent by 2330 GMT on 20th and 83 per cent by 0130 GMT on 21st. The surface wind which was northerly till 0430 IST became calm later and was southerly to southeasterly from 0630 to 0830 IST. On 0300 GMT chart of 21st, a low in the Arabian Sea off Konkan coast is seen, which might have caused the southerly winds at the surface and the increase of relative humidity. On this occasion the

relative humidity was as low as 34 per cent at 2330 IST on 20th with fog forming at 0650 IST on the following morning.

Fog on 16-10-1960—On the early morning of 16 October thick fog occurred at Santacruz airport. Visibility which was 10 km till about 0430 IST decreased to 1 km at about 0500 IST and was 1 km or less till 0930 IST. The lowest visibility which was less than 50 metres was recorded at 0830 IST. This was the first instance of fog having been recorded at Santacruz in the month of October during the period 1944 to 1960. As for the factors which brought about the fog on the 16th, there was a low pressure area over Rajasthan and to the north of Bombay on the night of 15th, as can be seen from the synoptic chart of 1800 GMT of 15th (Fig. 7), which would have caused an advection of moisture at the surface. The relative humidity on 15th was about 75 % at 1730 IST increasing to 90% by 2000 IST, to 95% by 2330 IST and to 100% at 0830 IST on 16th. An inversion which is effective in restricting the moisture to the levels below is seen in the tephigrams of Santacruz at 1800 GMT and 2400 GMT of 15th. Details of the temperatures and mixing ratios at various levels at 1800 and 2400 GMT of 15th are given in Table 3. A marked increase of moisture at 975 mb level had taken place between the period 1800 and 2400 GMT. An increase of mixing ratio with height between ground and 975 mb layer is also seen at 2400 GMT.

The surface wind on the morning of 16th was calm till about 0430 IST and then north to northeasterly with wind speed fluctuating upto 7 kts till about 0930 IST. This northerly air would have provided the turbulence required to bring about the mixing

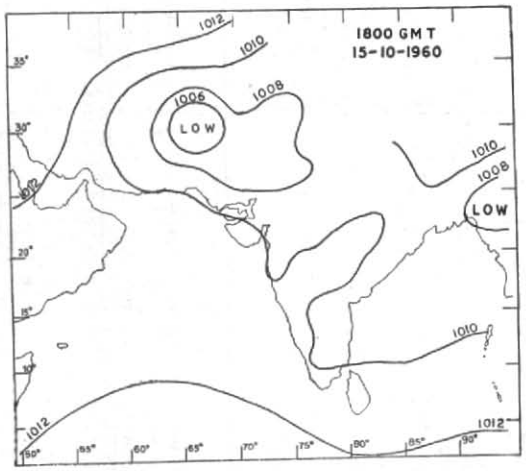

Fig. 7

of the layers very near the ground resulting in fog. As regards the winds in upper levels an anticyclonic circulation existed over Bombay and the Deccan above 3000 ft at 1800 GMT of 15 October 1960. The circulation was well marked at 7000 ft and 5000 ft being very nearly a closed one.

9. Conclusion

The conditions at the surface and in the upper air favourable for formation of fog at Santacruz airport have been discussed above. Fog occurs at Santacruz only when a combination of these factors obtain; this accounts for the fact that in the winter of 1951-52, no fog had occurred while in the winter of 1952-53 as many as 7 days of fog were reported.

10. Acknowledgement

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