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Fog over Safdarjung Airfield

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1. Introduction

It is well known (George 1952) that after nightfall, on calm clear nights, the radiational cooling of surface objects is much more rapid than that of the air; consequently the surface layers of the air are cooled by conduction and if this process is carried far enough, dew forms. If there is an increase of specific humidity with altitude, an eddy flux of vapour downward is established to replace that which has condensed. At the same time, if there is any amount of turbulence at all, heat is conducted towards the surface layers along with the moisture and some of the cooled air is forced aloft and slightly cooled further by adiabatic expansion. This process, if continued, is supposed to cool the entire surface layer of air to saturation and thus fog forms. If there is no turbulent interchange of air or if the moisture content of air decreases vertically, there will only be a deposition of dew. Obviously the presence of a cloud cover will offer counter radiation to that of the earth and permit so little cooling of the surface layers of air that the possibility of fog is practically eliminated. Likewise if the movement of air is sufficiently rapid for the surface roughness of the area concerned there will be established a turbulent layer deep enough so that more cooling will be required than is available. Thus for the formation of radiation fog, the most favourable conditions are the following— (1) Clear or lightly clouded sky, (2) Calm or light surface wind and (3) Air with initially high dew point.

We generally call it fog when fine droplets in a state of suspension in the air close to the ground surface is in such a concentration as to reduce the visibility below 1100 yds.

In this paper we shall deal with radiation fog which affects very badly the visibility of Safdarjung airfield.

2. Fog season in Delhi

In the Safdarjung airfield, fog is generally experienced during early morning hours of the winter months of the year. Sometimes it also occurs in the evening hours in this season; this is not radiation fog but smoke fog.

3. Sources of data

Data utilised in this paper have been extracted from the current weather registers and the autographic records of the thermograph, hygrograph, Dines P. T. anemograph of New Delhi (Safdarjung) during the months of January, February and December of each year from 1951 to 1955. Temperature and dew point values have been taken from autographic records as no actual values of hourly readings were available. The upper wind data for New Delhi were taken from *Indian Daily Weather Report* published from Poona. For simultaneous occurrence of fog over Safdarjung airfield and other neighbouring airfields, registers of M5 and B5 reports of Safdarjung Meteorological Office and current weather registers of Palam and other neighbouring stations have been consulted.

4. Frequency of occurrence

Table 1 shows the distribution of number of days with fog in different months during 1951—1955.

It is seen that the frequency of occurrence of fog varied widely from year to year. There was only one day of fog in the year 1951

TABLE 1

Year	Jan	Feb	Dec	Total
1951	1	Nil	Nil	1
1952	2	1	1	4
1953	3	Nil	3	6
1954	4	Nil	5	9
1955	7	2	Nil	9
Total	17	3	9	29

whereas 1954 and 1955 had 9 days each. It is also seen that January has got the highest and February the lowest frequency of fog days during the period.

5. Occurrence of fog at Safdarjung and other neighbouring airfields

When fog covers Safdarjung airfield, aircrafts bound for Safdarjung have to be diverted to a neighbouring airfield. Before diverting, however, it has to be considered whether the alternate airfield is not also likely to be affected by fog. For this purpose a knowledge of the conditions at the neighbouring airfields on the occasions when Safdarjung is covered with fog is necessary. Therefore, the records of the neighbouring airfields have been examined for all occasions when Safdarjung airfield was covered with fog and the number of occasions when these airfields were affected by fog within two hours of its occurrence at Safdarjung have been enumerated. The results are shown in Table 2.

It is noticed from Table 2 that the occasions of occurrence of fog at the neighbouring airfields within two hours of its occurrence at Safdarjung were maximum in January and minimum in February. When the Palam airfield is considered alone it is noticed that the maximum simultaneous occurrence of fog takes place also in January, it being nil in December and only on one occasion in February.

TABLE 2

Name of airfield	No. of occasions with fog when Safdarjung airfield was covered with fog			
	Jan	Feb	Dec	Total
Palam	9	1	0	10
Agra	5	1	4	10
Allahabad	7	0	4	11
Lucknow	4	0	2	6
Kanpur	5	1	3	9
Gorakhpur	1	0	0	1
Bareilly	3	0	3	6
Banaras	1	1	0	2
Jaipur	1	0	0	1
Bikaner	1	0	0	1
Ambala	3	0	0	3
Amritsar	5	0	0	5
Srinagar	6	1	1	8
No. of occasions when Safdarjung was affected	17	3	9	29

Out of 29 occasions of fog over Safdarjung airfield during 5 years from 1951—55, the number of simultaneous occurrence of fog was 11 over Allahabad, 10 over Palam and Agra each, 9 over Kanpur, 8 over Srinagar, 6 each over Lucknow and Bareilly, 5 over Amritsar, 3 over Ambala, 2 over Banaras and one each over Gorakhpur, Jaipur and Bikaner (*vide* Table 2). It is, therefore, inferred that the best alternate airfield in the Delhi region will be Gorakhpur or Jaipur or Bikaner when Safdarjung airfield will be under M5 condition due to fog.

6. Duration and intensity

Out of the 29 occasions of fog studied, on one occasion only the fog lowered down the visibility to 30—50 yds and it lasted for 4 hours or more. On three occasions such lowering of visibility lasted for 2—3 hours. It is noticed that there is a close relationship between the duration of fog and the visibility. With higher visibility figures the frequencies of occurrence of fog is found to be higher and the duration correspondingly less. This is illustrated in Table 3. There are two exceptions in cases of visibility figures 50—150 yds and 600—900 yds when frequencies and duration of fog are higher though the visibility figures are comparatively less.

TABLE 3

Frequencies of visibility

Duration	30—50 yds	50—150 yds	150—300 yds	300—600 yds	600—900 yds	900—1100 yds
4 hrs or more	1	Nil	Nil	Nil	Nil	Nil
2—3 hours	3	Nil	Nil	Nil	Nil	Nil
1—2 hours	Nil	7	3	3	Nil	Nil
Less than 1 hour	Nil	2	4	3	11	8

In the month of January, the fog became very thick and the visibility lowered to 30—50 yds in 1951 and 1954.

7. Times of commencement and dissipation

In winter months, fog generally forms in the early morning hours. It is found from the analysis of five years' data (1951—55) that fog forms from 0600 IST and lasts generally up to 0800 IST. Of course, on some occasions it forms from 0400 to 0500 IST and lasts upto 0900 to 1000 IST. Generally fog lasts from ½ hr to 3½ hrs in the morning but on some occasions it lasts even for 4 to 4½ hours. On a single occasion on 17 January 1951 fog lasted for 8 hrs from 0700 to 1500 IST.

On rare occasions fog forms in the evening hours of winter months. Generally this type of fog is not called radiation fog but smoke fog, as smoke spreads out in the evening hours of the winter months and remains trapped under the inversion layer causing the lowering of the visibility. On 24 January 1955 the fog which occurred over Safdarjung airfield was partly due to smoke in the neighbouring area.

8. Relation between fog and humidity figures and dew point temperatures

When fog occurs the humidity figure generally goes above 75% and it has been found from the analysis of the data (Table 4) that on days of fog the humidity figure lies between 75% and 99%. It may be noticed that in January 1954 when fog became thickest the humidity figure on all the four days of fog was very high with values 98% and more whereas in any other year the value was not so high on all the days of fog of the year. This indicates clearly that the thickest fog requires very high humidity in the atmosphere.

A high value of humidity is, however, not essential for the formation of fog. For instance in the year 1952 fog formed in the months of January and February on two occasions (1 January and 5 February) with very low values of humidity, *viz.*, 54% and 58% respectively.

When we compare the hourly values of dew point temperatures in the early morning hours (from 0400 to 0800 IST) on fog days and no-fog days (Table 4) it is seen that on fog days they generally vary between 45° and 56°F whereas on no-fog days they are much below 45°F and their values lie below 40° F. It will appear, therefore, that for the formation of fog over Safdarjung airfield the dew point temperature in the early morning hours should not be below 45°F.

9. Relation between fog and surface wind

It is found that on all the fog days the surface wind is calm or light and the speed is between 02—05 knots on most of the occasions (Table 4). Even the speed of the upper winds (Table 4) from 1000 to 5000 ft above sea level on fog days lies between 03—10 knots at 0200 IST and 04—15 knots at 0700 IST. But on no-fog days both surface

TABLE 4

Date	Speed of surface wind during fog (knot)	Speed of upper winds from 1000 to 5000 ft a.s.l. during fog (knot) 0200 (IST)	0700 (IST)	Humidity (%)	Dew point temp. (°F)	Mean inversion temp. (°F)	Synoptic situation associated with fog	Remarks
17-1-51	02—05	*	*	91—93	46—56	†	R	(a)
1-1-52	Calm	09—11	12—14	54	39—42	63	F	(b)
8-1-52	Calm	05—10	04—07	71	51—52	†	F	(a)
5-2-52	02	03—10	03—10	58	46—50	64	R	(b)
23-12-52	Calm	03—12	07—15	85	49	†	F	(b)
2-1-53	04—05	05—10	*	92—94	44—45	55	R	(a)
14-1-53	Calm	02—04	04—10	75	50	60	R	(b)
15-1-53	02—04	19—33	09—19	82—85	51—53	69	F	(a)
24-12-53	Calm	08—15	08—10	95—96	48	63	F	(b)
25-12-53	05	04—10	06—14	95—96	50	64	F	(b)
31-12-53	04—07	15—35	13—17	92	49	61	R	(a)
1-1-54	02—04	05—09	07—13	98	46—47	†	R	(a)
2-1-54	02—04	05—09	07—13	99—100	43—46	54	R	(b)
8-1-54	02	19—28	20—25	98—99	53—54	63	F	(a)
9-1-54	02—05	01—10	*	98—99	46—50	68	R	(b)
10-12-54	Calm	03—05	02—09	75—94	47—49	62	R	(b)
18-12-54	Calm	02—08	04—06	81—85	39—47	56	F	(b)
19-12-54	Calm	03—09	04—09	85—89	48—49	57	R	(b)
25-12-54	Calm	03—09	02—07	79—80	42	56	F	(b)
30-12-54	Calm	06—08	01—04	77—82	35—37	56	R	(b)
12-1-55	Calm	07—15	07—13	92	48	58	R	(b)
21-1-55	Calm	05—12	06—08	77	41—46	†	F	(b)
24-1-55	02—05	*	*	97—98	56—57	†	F	(a)
25-1-55	Calm	07—10	02—04	100	56	†	F	(a)
26-1-55	02—03	03—10	09—10	97	48	58	R	(b)
29-1-55	02—04	*	*	94—97	49	57	F	(b)
31-1-55	02—04	*	*	95—100	59	†	F	(b)
1-2-55	05	12—14	11—18	85—88	47	59	R	(b)
17-2-55	Calm	08—14	03—10	88	45—48	68	F	(b)

* No ascents or data not available

† No inversion

R=Fog occurred at the rear end of a western disturbance

F=Fog occurred in front of a western disturbance

(*a*) Rain had fallen on the previous day

(*b*) No rain on previous day

and upper winds attain high values. The surface winds at the hour of commencement of fog on the fog days and at about the same hour on no-fog days have been shown in Figs. 1 and 2.

10. Fog and its relation to inversion

It is found on analysis of data of fog and the corresponding inversion of upper air layers that inversion is not always essential for the formation of fog. On fog-days it is found that the mean temperature of inversion is always higher than the corresponding dew point temperature (Table 4) so that fog is generally confined to the small layers above the surface of the ground at the beginning but as the sun's rays fall and due to turbulence, the fog layer extends upwards and spreads to a sufficiently higher layer of the atmosphere and it thickens. When there is no inversion, fog is generally confined to a small surface layer from the ground and it becomes thinner. Actually in case of inversion, the two opposing elements react, one is "downward flux of heat" and the other "upward flux of moisture" (Berry, Bollay and Beers 1945). At the balanced point, if the mean temperature of inversion is near about that of dew point or below the dew point temperature, fog generally spreads out to the higher layer of the atmosphere and it thickens. On the other hand at the balanced point if the mean temperature of inversion is always higher than the dew point temperature, which means that the upward flux of moisture is less than the corresponding downward flux of heat, fog becomes thinner and it is confined to the small layers of surface from the ground.

11. Synoptic situation associated with fog

In this paper we are dealing with radiation fog and not advection fog. Still excess of moisture must be brought from some source to increase the humidity of the atmosphere for the formation of the radiation fog. Generally excess of moisture is brought by moist air mass from the Arabian Sea and the Bay of Bengal in association with the western disturbances. Sometimes fog occurs in front of a western disturbance or in the rear of the same depending upon the lowering values of dew point depression. If dew point depression is low in front of the western disturbance fog occurs in front of the disturbance but if it is low at the rear end of the western disturbance, fog occurs at the rear end. From a scrutiny of five years' (1951—1955) data it is seen that out of 29 occasions of the occurrence of fog, 14 occasions were at the rear end and the remaining 15 occasions were in front of the western disturbance. Also out of 29 occasions of fog, 20 occasions were without history of rain on the previous day and on the remaining 9 occasions there was rain on the previous day.

The directions of surface winds of Delhi in 1730 IST surface chart on the previous day and 0830 IST surface chart on the day of occurrence of fog and also directions of upper winds in tephigram on the previous day at 1500 GMT show clearly whether fog will occur or has occurred in front or at the rear end of western disturbance. If the direction of surface wind of Delhi on the previous day and on the day of occurrence of fog and directions of upper winds of Delhi on the previous day are easterly or southeasterly, fog generally occurs in front of the western disturbance but if those directions are northerly, northwesterly or westerly, fog generally occurs at the rear end.

12. Relation between minimum and dew point temperatures before and after fog-days over Safdarjung airfield

In the case of the occurrence of fog in front of a western disturbance, minimum and dew point temperatures of the atmosphere are different at first but as the incursion of the moist current (*viz.*, southeasterly or easterly from the Bay of Bengal or southwesterly from the Arabian Sea) takes place, the dew point temperature gradually increases and reaches near about the value of minimum temperature. Ultimately it is noticed that there is a very little difference between these two temperatures. But in case of occurrence of fog at the rear end of a western

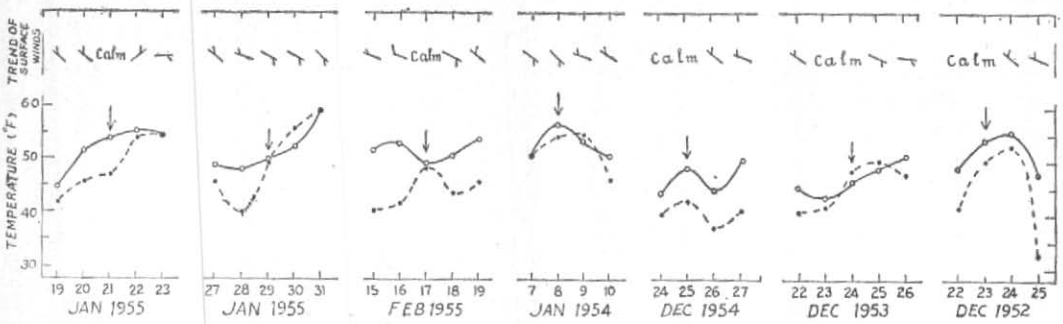

Fig. 1. Curves showing the relation between the minimum and dew point temperatures during occasions of fog in front of a western disturbance

(Days of fog are indicated by arrow, o–o–o minimum temperature curve, .– –.– –. dew point temperature curve)

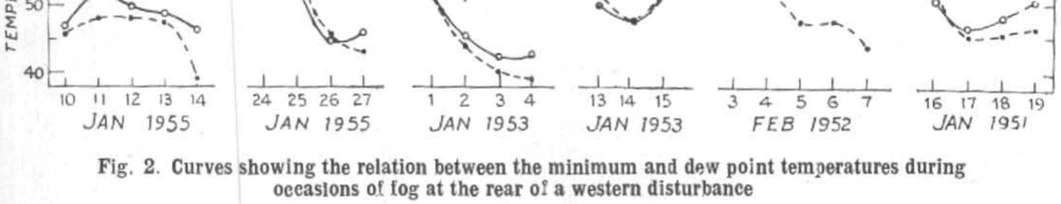

Fig. 2. Curves showing the relation between the minimum and dew point temperatures during occasions of fog at the rear of a western disturbance

(Days of fog are indicated by arrow, o–o–o minimum temperature curve, .– –.– –.dew point temperature curve) disturbance, both minimum and dew point temperatures of the atmosphere are more or less equal or there may be a very slight difference between them in the beginning. Thereafter when the skies begin to clear up the minimum temperature starts falling as a result of radiational cooling. With drier conditions being set up, the dew point temperature, however, falls still further with the result that the two curves of minimum and dew point temperatures begin to separate. This fact has been illustrated in Figs. 1 and 2 by drawing different curves showing the relation between minimum and dew point temperatures before and after fog-days over Safdarjung airfield. The dew point temperature on the fog-day has been taken as the actual dew point temperature at the commencement of fog and the dew point temperature on the no-fog day was taken as the actual dew point temperature at the same hour of the commencement of fog on the fog days.

It will also be seen that the occurrence of fog does not depend on the actual lowering of the dew point temperature in the early morning hours of the fog-day but on the trend of the change of dew point temperatures with respect to the minimum temperatures for it is clearly seen from the curves that the fog has occurred at different dew point temperatures on the fog days.

Another interesting point is revealed from Fig. 2. Both the minimum and the dew point temperatures approach nearer together one or two days before the fog-day but the occurrence of actual fog takes place afterwards. When these two curves are drawn beyond one or two days of the fog-day, it is noticed that on both sides of the fog-day they are separated by wider difference which is also theoretically expected.

It is noticed from Fig. 1 that both the minimum and dew point temperatures approach equal values and they go higher up but in one single occasion on 8 January 1954 both the curves of the minimum and dew point temperatures came down instead of going up. This can be easily explained because on the very next day, *i.e.*, on 9 January 1954 the fog took place at the rear end of the western disturbance and so both the curves came down which is the characteristic of the occurrence of fog at the rear end of the western disturbance over Safdarjung airfield.

13. Acknowledgements

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