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Some statistical characteristics of occurrence of fog over Patna airport

S.I. LASKAR, S.K. ROY BHOWMIK and VIVEK SINHA

India Meteorological Department, New Delhi – 110 003, India

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e mail : drsebul@gmail.com

सार – इस शोध पत्र में वर्ष 2000 से 2010 तक 10 वर्षों के नवंबर से फरवरी माह की अवधि के आँकडों का उपयोग करते हुए पटना हवाई अडडे पर छाने वाले कुहरे की सांख्यिकीय विशेषताओं जैसे – कोहरा छाने की बारम्बारता, छाने का समय, अवधि, सघनता तथा विसरित होने के समय का अध्ययन किया गया है। इस अध्ययन से प्राप्त हुए परिणाम से पता चला है कि विगत 10 वर्षों के दौरान पटना हवाई अडडे पर चारों ही महीनों में कुहरे की बारम्बारता में वर्ष 1961–90 तथा 1951–80 के जलवायविकी में उपलब्ध सिनॉप्टिक तथा तत्कालिक मौसम प्रेक्षणों की तुलना में विशेष रूप से वृद्धि हुई है। पटना हवाई अडडे पर कुहरा छाने का सबसे अनुकूल महीना दिसम्बर और उसके बाद जनवरी का माना गया हे। दिसंबर और जनवरी के महीनों में 5 घंटें से अधिक अवधि तक कुहरा छाने की आवृत्ति की प्रतिशत्ता अधिकतम रही है जबकि नवंबर एवं फरवरी के महीनों में 2 घंटे से कम अवधि की आवृत्ति सबसे अधिक रही है। कुहरा का बनना अक्सर 0000–0200 यू.टी.सी. के दौरान और इसका क्षय होना 0200–0500 यू. टी. सी. के दौरान देखा गया है। बहुत घने कुहरे की अधिकतम आवृत्ति – प्रतिशतता नवंबर माह में देखी गई है। दिसंबर और जनवरी के महीनों की अधिकतर स्थितियों में 1200 यू.टी.पर अगली रात/सुबह के समय पड़े कोहरे के रेडियों सौंदे के आँकडों के आधार पर तैयार किए गए कुहरा स्थायित्व सूचकांक (एफ.एस.आई.) 40 से कम पाया गया है।

ABSTRACT. In this paper some statistical characteristics of fog, such as frequencies of occurrence, time of onset, duration, intensity and time of dispersal over Patna airport are studied making use of 10 years data for the period November-February, 2000-2010. The result shows that during the last ten years frequency of fog over Patna airport has increased significantly in all the four months as compared to the climatology based on available synoptic and current weather observations during 1961-90 and 1951-80. The most favourable month for occurrence of fog over Patna airport has been identified as December followed by January. Percentage frequency is highest for duration of fog for more than 5 hours in the months of December and January whereas in the months of November and February frequency is highest for duration less than 2 hours. The formation of fog mostly observed during 0000-0200 UTC and dissipation during 0200-0500 UTC. Percentage frequency of very thick fog was found to be highest in the month of November. In the months of December and January in most of the cases Fog Stability Index (FSI) based on 1200 UTC radiosonde data leading to occurrence of fog during following night/morning has been found to be less than 40.

Key words – Fog, Fog stability index (FSI), Patna airport, Percentage frequency.

1. Introduction

Patna Airport (25° 35′ 37″ N, 85° 05′ 31″ E) is also known as Jaiprakash Narayan International airport, Patna. It is one of the major airports of east central India. The height of Patna airport is 52 meter above mean sea level. The orientation of the Runway is ENE-WSW and it is flanked by a densely vegetative Botanical garden at the eastern end. Being a short runway measuring around 1800 meter only, the occurrence of fog at airport has a crippling effect on flight operation.

Fog is the suspension of microscopic droplets of water of the size $\leq 10\mu m$ in the atmosphere at or near the earth's surface that reduces the visibility to below 1000 meter. It is considered as an important weather phenomenon in India during winter season as it not only prevents the aircraft operation such as landing or take-off but also has indirect impacts like monetary loss and inconvenience due to re-scheduling or cancellation of flights etc. Occurrence of fog during late in the night or early in the morning over Patna airport is very common in winter, particularly during the second half of December and first half of January. During December and January months most of the days fog over Patna airport lead to cancellation /diversion of flights.

The atmospheric conditions favourable for the formation of fog are (*i*) presence of high relative humidity near the earth's surface so that only little cooling is required to reach the dew point (*ii*) clear or partly cloudy sky condition which permits strong radiative cooling

TABLE 1

Statistical characteristics of fog over Patna airport

Parameter	2000-2010			
	November	December	January	February
Mean	4.9	17.4	16.4	5.8
SD	4.0	6.3	6.4	4.0
CV (%)	82	36	39	69
	1961-1990 (IMD, 2011)			
Mean	3.8	6.3	7.2	2.4
	1951-1980 (IMD, 1999)			
Mean	3.7	7.1	6.4	2.1

(*iii*) light surface wind(speed in the range of 2 to 8 knots) for gentle mixing of cooled air (*iv*) inversion layer (layer wherein the temperature increases with height) which inhibits vertical mixing of particulate matters thereby the condensed particles stagnate [Her Majesty Stationery Office (HMSO), 1960; Critchfield, 1987; World Meteorological Organization (WMO), 1978]. These conditions are often observed during late night and early morning hours in the months November to February over Patna Airport.

Roy Bhowmik *et al*., (2004) examined the occurrence of fog over Delhi in terms of synoptic evaluation using model analysis field and upper air sounding analysis of Delhi. Ram and Mohapatra (2008) studied some characteristics of fog over Guwahati airport. Suresh *et al*., (2007) and Mishra and Mohapatra (2004) have studied some climatological characteristics of fog over Chennai and Bhubaneswar airport respectively. Holtslag *et al*., (2010) examined the skill of numerical weather prediction model MM5, relative to simple empirical methods *viz*.; Fog Stability Index (FSI) and found that FSI scores better than direct model output from MM5 for fog forecasting of 12 stations in the Netherlands.

As it appears that no study has been done on the climatological aspects of fog over Patna airport, an attempt has been made in this study to find out climatological aspects of fog over Patna airport in recent years which can be used as a tool for the aviation forecaster and help the aviators to know about the favourable period of occurrence, duration of fog and expected visibility etc.

2. Data and methodology

The study has been carried out based on data of four months from November to February over a period of ten years from 2000 to 2010. The data on the day of occurrence of fog, time of onset, time of dispersal, associated visibility and lowest visibility etc. are collected from the current weather register of Meteorological Office, India Meteorological Department, Patna airport. Upper air data for calculation of Fog Stability Index (FSI) collected from the web link (http://weather.uwyo.edu/upperair/sounding.html).

3. Results and discussion

3.1. *Average monthly frequency of fog*

Table 1 gives the mean, standard deviation and coefficient of variation of fog over Patna airport for the months of November, December, January and February during 2000-2010 and climatology of fog over Patna airport for the months of November, December, January and February based on the period 1961-1990 and 1951-1980. From the Table it is observed that frequency of fog is highest in the month of December followed by January, February and November. The occurrence of fog over Patna airport is consistent during December-January while it is highly variable and unreliable during November and February as the coefficient of variation is very high. As per climatology of Patna airport (IMD, 2011), 7.2 days of fog has occurred in the month of January followed by 6.3 days in December, 3.8 days in November and 2.4 days in February during 1961-90 and 7.1 days of fog has occurred in the month of December followed by 6.4 days in January, 3.7 days in November and 2.1 days in February

TABLE 2

Percentage frequency of duration of fog

Month	Percentage frequency of duration (hours)						Max. Duration (Date, Year)	Min. Duration (Date, Year)
	<1	1-2	2-3	3-4	4-5	>5		
November	6	39	12	12	6	25	14 hours (22, 2004)	25 minutes (20, 2008)
December	4	18	19	12	9	38	16 hours 20 minutes (17, 2004)	30 minutes (10, 2007)
January	6	6	16	13	11	48	20 hours (12, 2004)	30 minutes (22, 2009) (4, 2008), (5, 2003) (23, 2002)
February	12	28	26	10	12	12	8 hours (7, 2010)	30 minutes (1, 2008) (3, 2007) (13, 2006) (17, 2004)

during 1951-80 (IMD, 1999). We find that during 2000-2010 frequency of fog has increased significantly in all the four months as compared to the climatology. During the period under study, we observed that there was no fog during November in one, and during February in another year.

3.2. *Duration of fog*

Table 2 gives the percentage frequency of fog lasting for different durations during the months November to February. It has been observed that the percentage frequency is highest during November for duration of 1 to 2 hours and during December and January for the fog duration of more than five hours. It has been observed that in the month of November in 57% occasions fog lasted for less than 3 hours duration and in 43% occasions fog lasted for more than three hours duration, in the month of December in 41% occasions fog lasted for less than 3 hours duration and in 59% occasions fog lasted for more than three hours duration, in the month of January in 28% occasions fog lasted for less than 3 hours duration and in 72% occasions fog lasted for more than three hours duration, similarly, in the month of February in 66% occasions fog lasted for less than 3 hours duration and in 34% occasions fog lasted for more than three hours duration. Comparing individual months, the duration of fog is generally more during January followed by December and less durable during February followed by November.

3.3. *Onset of fog*

Percentage frequencies of onset of fog for different time intervals for all the four months are shown in Table 3. During the period of study the largest percentage frequency of onset of fog is in between 0000 and 0100 UTC followed by 0100 and 0200 UTC in the month of November, December and January and in the month of February the largest percentage frequency of onset of fog is in between 0100 and 0200 UTC followed by 0000-0100 UTC. It has also been observed that considerable frequencies of onset of fog could be noted right from 1800 UTC in all the four months though relatively low frequencies are still seen from afternoon (1200 UTC) itself-the reason for which is yet to be understood.

TABLE 3

Percentage frequency of onset of fog over Patna airport during November-February for the period 2000-2010

Time of onset (UTC)	Percentage frequency			
	November	December	January	February
0000-0100	43	28	23	27
0100-0200	25	25	15	36
0200-0300	4	6	7	7
0300-0400	0	1	1	2
0400-0500	0	0	1	2
0500-0600	0	0	0	0
0600-1200	0	0	0	0
1200-1500	2	2	4	0
1500-1800	2	8	8	0
1800-1900	10	6	14	0
1900-2000	0	4	3	2
2000-2100	2	2	7	2
2100-2200	8	7	8	7
2200-2300	2	3	6	10
2300-2400	2	8	3	5

3.4. *Dispersal of fog*

Table 4 shows the percentage frequency of time of dispersal of fog for all the four months during the period

TABLE 4

Percentage frequency of dispersal (UTC) of fog over Patna airport during November-February for the period 2000-2010

Time of dispersal	Percentage frequency			
	November	December	January	February
0000-0100	0	1	1	0
0100-0200	14	4	3	10
0200-0300	35	24	12	43
0300-0400	29	26	23	21
0400-0500	12	20	19	21
0500-0600	6	10	18	5
0600-0700	0	5	11	0
0700-0800	2	3	5	0
0800-0900	0	1	3	0
0900-1200	0	1	2	0
1200-1500	0	1	0	0
1500-1800	0	2	0	0
1800-2100	0	0	1	0
2100-2400	2	2	2	0

under study. It can be seen from the table that in the months of November and February fog dispersed mostly between 0100 UTC and 0600 UTC and in the months of December and January between 0100 UTC and 1000 UTC. The percentage frequency of fog dispersed during the other time of the day is either zero or negligible. The earliest dispersal has been observed at 0040 UTC of 30th December, 2006. Once the sun rises, the surface temperature rises and the fog dissipates or lifts.

3.5. *Intensity of fog*

Fog is generally classified into four categories depending on the surface visibility conditions, *viz*., light fog when visibility less than 1000 meter but more than 500 meter, moderate fog when visibility less than 500 meter but more than 200 meter, thick fog when visibility less than 200 meter but more than 50 meter and very thick fog when visibility less than or equal to 50 meter (IMD, 1982).

Figure 1 gives the percentage frequency of fog under different categories for all the four months during the period of study. It is seen from the figure that the percentage frequency is largest for light fog for the month of November, December and February and for the month of January percentage frequency for both light and

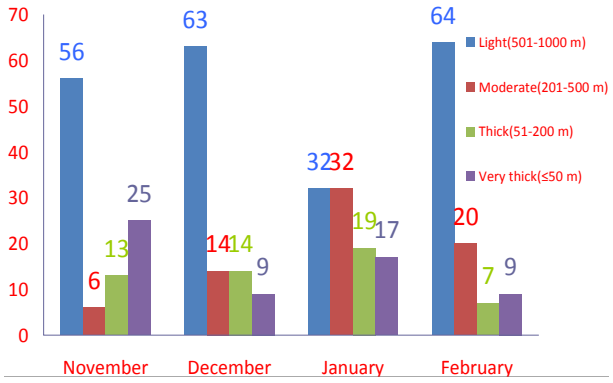

Fig. 1. Percentage frequency of different categories of fog

moderate categories are equal. In the month of November the second largest percentage frequency is for very thick fog. Thus, in the month of November though fog occurs less number of days, there is a good chance to drop the visibility less than 50 meter. It can be inferred that in the month of November in 62% occasions light to moderate fog and in 38% occasions thick to very thick fog occurred, in December in 77% occasions light to moderate fog and 23% occasions thick to very thick fog occurred, in January in 64% occasions light to moderate fog and in 36% occasions thick to very thick fog occurred and in

TABLE 5

Percentage frequency of occurrence and non occurrence of fog in the different ranges of Fog Stability Index (FSI) over Patna airport for the month of December during 2005-09 and for January during 2006-10

Range of FSI	December		January	
	Fog	No fog	Fog	No fog
1-10	6	0	4	2
11-20	1	2	21	2
21-30	24	9	17	19
31-40	32	20	24	7
41-50	23	23	21	34
51-60	11	23	9	17
61-70	3	14	4	12
>70	0	9	0	7

February in 84% occasions light to moderate fog and in 16% occasions thick to very thick fog occurred during the period under study.

3.6. *Meteorological parameters leading to fog*

It has been observed that the surface wind at Patna airport at 1200 UTC leading to fog during following night/morning was either calm in almost all the days or very light wind prevailed. The mean values of dry bulb temperature, dew point temperature and dew point depression for 1200 UTC leading to fog and no fog during following night/morning have been calculated. It has been observed that in all the four months the 1200 UTC mean dry bulb temperature and average dew point depression on fog days are less than the mean values on no fog days whereas average dew point temperature leading to fog are more than the values leading to no fog.

3.7. *Fog stability index (FSI)*

The Fog Stability Index (FSI) is an empirical method, developed by the US Air Force (Freeman and Perkins (1998)) for use in Germany in the late 1970s. Its simplicity is its main advantage: it requires only four variables that are directly available from radiosonde observations. The FSI is defined as:

$$FSI = 2(T_{Sfc} - Td_{Sfc}) + 2(T_{Sfc} - T_{850}) + W_{850}$$

where,

T_{Sfc} = Surface temperature in °C.

T_{850} = 850 hPa temperature in °C.

Td_{Sfc} = Surface dew point temperature in °C.

W_{850} = 850 hPa wind speed in knots.

Fog formation is favoured for high humidity (*i.e*., when $T_{Sfc} - Td_{Sfc}$ is small), the atmosphere is stable (*i.e*., when $T_{Sfc} - T_{850}$ is small) and low wind speed (*i.e*., when W_{850} is small).

Table 5 gives the percentage frequency of occurrence and non occurrence of fog over Patna airport based on the available upper air data of 1200 UTC during the period 2005-2009 for the month of December and 2006-2010 for the month of January corresponding to different ranges of Fog Stability Index (FSI). It has been observed that during the month of December (January) percentage frequency of occurrence of fog is 63 (66) when the value of FSI is less than 40. The percentage frequency of non-occurrence of fog during December (January) is 31 (30) when the value of FSI is less than 40. Thus, it can be inferred that during the month of December and January, the value of FSI less than 40 based on the 1200 UTC upper air data is a favourable condition for occurrence of fog over Patna airport in the following night/morning. But one has to critically examine other meteorological parameters along with FSI at 1200 UTC, because several other factors which play a great role in fog formation were neglected in FSI definition and also the forecast lead time is unclear.

4. Conclusions

Following conclusions can be drawn from the above study.

(*i*) During last decade (2000-2010) the frequency of occurrence of fog over Patna airport has increased significantly in the months of November, December, January and February as compared to the climatology based on available synoptic and current weather observations during the period 1961-1990 and 1951-1980.

(*ii*) During 2000-2010, the frequency of occurrence of fog over Patna airport is highest in the month of December followed by January. The most favourable time for commencement of fog is during 0000-0200 UTC and dissipation is during 0100-0600 UTC.

(*iii*) Percentage frequency of thick fog (less than 200 m visibility) is highest in November followed by January.

(*iv*) In the month of December and January, the value of FSI less than 40 based on 1200 UTC upper air data is a favourable condition for prediction of occurrence of fog over Patna airport in the following night/ morning.

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