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L E T T E R S

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A CLIMATOLOGICAL STUDY OF THUNDERSTORM ACTIVITY OVER AURANGABAD (CHIKALTHANA) AIRPORT WITH SPECIAL RELEVANCE TO AVIATION IN FLIGHT PLANNING

1. Thunderstorm is an important mesoscale weather system of space scale a few kilometers to a couple of hundred kilometers and time scale of less than an hour to several hours. It produces heavy rain showers, lightning, thunder, turbulence, icing, hailstorms, dust-storms, surface wind squalls, downbursts, microbursts and tornadoes. These cause loss of life, damage to crops and property. The aviators dread it and try to keep away from it, as thunderstorm is a well-known hazard to aviation and a large percentage of aircraft's weather related accidents have been due to thunderstorms. They are more likely to occur at certain time of the year than at others. So, knowledge of thunderstorm climatology of a particular station with respect to its frequency of occurrence, diurnal variation and duration, synoptic situation(s) favourable for its development is essential particularly in the interest of safe air navigation and taking precautions to avoid the loss of life and minimize the loss of property.

Many authors in India have studied the climatological aspects of thunderstorms for various stations. Viswanathan and Faria (1962) and Krishnamurthy (1965) studied the climatology of thunderstorms over Bombay and Pune respectively. The diurnal frequency of incidence and duration of thunderstorms at international aerodromes of Bombay, Kolkata, Chennai and Delhi were studied by Rao *et al.* (1971). A similar work on the thunderstorms at the aerodrome stations of Ahmedabad, Bangalore, Agartala and Hyderabad was done by Philip *et al*. (1974). Various statistical aspects of occurrence of thunderstorms at Lucknow airport were studied by Kumar (1992). A similar study of thunderstorms at Mohanbari airport was conducted by Moid (1996) and at Thiruvananthapuram, Kochi and Kozhikode airports by Santosh *et al*., (2001). Biswas (2005) studied analytically the thunderstorms over Mumbai.

Aurangabad (19°51′N, 75°24′E) is an important city of Marathwada region of Maharashtra, in India. It has an airport and a considerable amount of industrial activity goes on in and around Aurangabad. Most importantly, Ajantha and Ellora caves which are very near to Aurangabad, is a famous tourist place for its ancient artistic works. Occurrence of thunderstorms is relevant to the various activities in this place. As it appears that no study has been done on the climatological aspects of thunderstorms over Aurangabad, an attempt has been made in this study to identify the climatological aspects of thunderstorms for this airport based on 20 years data.

2. The data for the period 1990-2009 have been collected from the Monthly Meteorological Registers (MMR) of Aurangabad (Chikalthana) airport as Current Weather observations are not round the clock. Cases where thunder has been heard but no precipitation occurred have also been included in the category of thunderstorms. The formation of a cumulonimbus (Cb) and its evolution into a thunderstorm with rain or without rain are such stages in thunderstorm activity that one stage may under favourable circumstances develop into the next. So, all occasions when Cb have been reported, have been added to those when thunderstorms have occurred and are termed as thunderstorm activity. Month-wise and year-wise frequencies of thunderstorm days and thunderstorm activity days in different months and years have been shown in Table 1 and Table 2 respectively. Month-wise percentage frequency of these has also been computed. Week-wise total frequency of thunderstorm activity for each month has been presented in Table 3. Month-wise frequency distributions of diurnal variation of thunderstorm activity have been analysed and presented in Table 4. Month-wise three hourly frequency distributions of diurnal variation of thunderstorms have also been computed and shown in Table 5. Month-wise three hourly frequency distributions of commencement of thunderstorm activity *vis-à-vis* its duration has been presented in Table 6. As regards to duration of thunderstorm activity, frequencies for the period of less than 3 hours, 3-6 hours, 6-9 hours, 9-12 hours and >12 hours have been calculated.

Weather charts of Meteorological Watch Office, Mumbai, India Daily Weather Reports and Weather Summaries in Mausam, published by India Meteorological Department for thunderstorm days were consulted to identify the synoptic features of the day. Synoptic situations which caused thunderstorms in different months have been analysed and discussed month-wise in general. The synoptic situations of certain typical thunderstorms occurred here have been discussed with a view to

TABLE 1

Distribution of the number of days of thunderstorms at Aurangabad airport (1990-2009)

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1990	0	0	0	0	8	7	0	3	3	2	0	0	23
1991	0	0	0	0	1	3	1	0	0	0	0	0	5
1992	0	0	0	0	0	3	0	2	0	0	0	0	5
1993	0	0	1	1	1	2	1	2	3	7	0	0	18
1994	0	0	0	5	4	4	0	0	0	2	3	0	18
1995	0	0	1	2	2	1	1	3	1	2	0	0	13
1996	0	0	0	0	2	8	5	0	0	0	0	0	15
1997	0	0	0	1	0	2	0	0	2	3	6	2	16
1998	0	0	0	1	7	8	2	5	3	7	3	0	36
1999	0	2	0	0	7	9	6	0	7	8	0	0	39
2000	0	0	0	1	10	7	3	5	3	3	0	0	32
2001	0	0	1	0	3	5	1	2	7	6	1	0	26
2002	0	1	1	3	0	12	0	1	1	0	0	0	19
2003	1	1	0	2	0	4	6	3	2	0	0	1	20
2004	1	0	0	0	2	2	3	0	8	2	1	0	19
2005	0	1	1	3	2	3	2	0	6	1	0	0	19
2006	0	0	2	0	6	9	0	0	12	2	1	0	32
2007	0	0	0	2	0	8	4	4	0	0	0	0	18
2008	0	0	3	3	0	3	1	3	8	2	0	1	24
2009	0	0	2	1	2	4	5	5	1	0	2	0	22
Total	2	5	12	25	57	104	41	38	67	47	17	4	419
Percentage	<0.5	1	3	6	14	25	10	9	16	11	4	1	100

facilitate issuing Terminal Aerodrome Forecast (TAF) and Route Forecast (ROFOR) for aviation purpose in broadly analogous situations.

3. (*i*) Table 1 shows month-wise and year-wise number of thunderstorm days during the study period 1990-2009. Maximum thunderstorm days were in June (25%) followed by September (16%). Seasonally thunderstorm days in winter (January & February) were rare (1%). Maximum thunderstorm days (60%) were in SW monsoon season (June to September) followed by (23%) in premonsoon season (March to May).

(*ii*) Table 2 presents the month-wise and year-wise number of days of thunderstorm activity which is similar to Table 1. Here along with number of thunderstorm days, those are also included when only Cb cloud developed.

(*iii*) Table 3 presents the week-wise frequency distribution of thunderstorm activity over Aurangabad airport. It is seen that thunderstorm activity is maximum in the second week of June which is the onset time of SW Monsoon season of the station. Again the frequency is maximum in the fourth week of September which coincides with the withdrawal time of SW Monsoon of the station.

(*iv*) Table 4 shows the frequency distributions of diurnal variation of thunderstorm activity over Aurangabad airport. It is observed that thunderstorm activity may occur here at any time of the day with maximum occurrence between 1200 & 1500 UTC (37%) followed by 0900-1200 UTC (28%). Occurrence of thunderstorm activity was the least between the time interval 2100 & 0600 UTC.

TABLE 2

Distribution of the number of days of thunderstorms and thundery (Cb) conditions at Aurangabad airport (1990-2009)

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1990	0	0	0	0	8	9	1	4	4	2	0	0	28
1991	0	0	0	0	1	3	1	0	0	0	0	0	5
1992	0	0	0	0	0	4	0	2	0	0	0	0	6
1993	0	0	1	1	2	4	2	2	4	7	1	0	24
1994	0	0	0	5	4	5	0	1	1	2	3	0	21
1995	0	0	1	2	2	3	2	3	1	2	0	0	16
1996	0	0	0	0	2	11	5	0	0	0	0	0	18
1997	0	0	0	1	0	2	0	0	5	3	9	5	25
1998	0	0	0	1	8	10	3	5	10	9	4	0	50
1999	0	4	0	0	10	9	8	0	9	13	0	0	53
2000	0	0	0	1	12	9	5	6	5	4	0	0	42
2001	0	0	1	1	4	6	1	3	9	9	1	0	35
2002	0	2	1	4	0	14	0	1	1	0	0	0	23
2003	1	1	1	2	0	7	7	3	3	1	0	1	27
2004	1	0	0	0	3	3	3	0	9	2	1	0	22
2005	0	1	1	3	2	4	3	0	6	1	0	0	21
2006	0	0	2	0	6	11	0	0	14	2	1	0	36
2007	0	0	0	2	0	8	4	4	0	0	0	0	18
2008	0	0	3	3	0	4	1	4	8	3	0	1	27
2009	0	0	2	1	2	6	6	5	3	1	2	0	28
Total	2	8	13	27	66	132	52	43	92	61	22	7	525
Percentage	<.5	1.5	2.5	5	13	25	10	8	18	12	4	1	100

(*v*) Table 5 gives the frequency distribution of diurnal variation of time of commencement of thunderstorms. The frequency of time of commencement of thunderstorms was maximum in the time interval 0900-1200 UTC (36%) followed by 1200-1500 UTC (27%). The frequency of commencement of thunderstorms was also the least between 2100 & 0600 UTC.

(*vi*) Table 6 presents the frequency distribution of time of commencement of thunderstorm activity *vis-à-vis* its duration. Most of the thunderstorm activity (66.7%) here were of short duration (<3 hrs) followed by (23.7%) of duration 3-6 hrs. From the study it is also found that the most of the thunderstorm activities (47 out of 50) of long duration (≥6 hours) have occurred here during the months May to October in association with synoptic scale disturbances. Only 2% of thunderstorm activities were of duration 9 hrs or more (14 out of 625).

TABLE 3

Total frequency of thunderstorm activity week-wise (1990-2009)

	Week				
Month	I	II	III	IV	Total
Jan	0	1	0	1	2
Feb	5	5	0	1	11
Mar	1	11	3	3	18
Apr	10	9	9	6	34
May	9	11	19	43	82
Jun	47	64	29	21	161
Jul	24	10	15	10	59
Aug	11	6	2	28	47
Sep	15	28	20	39	102
Oct	26	32	12	2	72
Nov	2	12	6	9	29
Dec	6	0	1	1	8
					625

TABLE 4

Frequency distribution of diurnal variation of thunderstorm activity at Aurangabad airport (1990-2009)

	Time (UTC) of occurrence of thunderstorm activity								
	0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	Total
Jan	0	0	0	0	1	0	1	0	2
Feb	2	0	0	1	3	4	1	0	11
Mar	1	1	1	2	2	6	4	1	18
Apr	0	0	5	7	11	6	3	2	34
May	0	0	7	25	34	13	2	1	82
Jun	1	2	10	53	61	19	14	1	161
Jul	0	1	8	14	23	11	1	1	59
Aug	0	0	3	17	17	8	2	0	47
Sep	0	3	17	27	36	7	11	1	102
Oct	1	0	10	19	30	8	3	1	72
Nov	0	0	1	9	11	6	1	1	29
Dec	1	0	0	1	3	3	0	0	8
Total	6	7	62	175	232	91	43	9	625
Percentage	1	1	10	28	37	15	7	1	100

TABLE 5

Frequency distribution of diurnal variation of thunderstorms at Aurangabad airport (1990-2009)

	Time (UTC) of commencement of thunderstorms								
Month	0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	Total
Jan	0	0	0	0	1	0	1	0	2
Feb	2	0	0	1	1	3	0	0	7
Mar	2	1	1	3	1	5	5	0	18
Apr	0	0	2	10	7	8	3	2	32
May	0	0	3	26	25	12	2	1	69
Jun	1	2	9	55	35	16	12	0	130
Jul	0	2	6	13	13	8	2	0	44
Aug	0	0	3	16	12	7	1	1	40
Sep	0	2	16	23	19	4	5	1	70
Oct	1	0	9	20	12	7	3	0	52
Nov	0	0	1	7	2	4	1	0	15
Dec	0	0	0	1	0	3	0	0	4
Total	6	7	50	175	128	77	35	5	483
Percentage	1	2	10	36	27	16	7	1	100

TABLE 6

Frequency distribution of time of commencement of thunderstorm activity *vis-à-vis* duration at Aurangabad airport (1990-2009)

		Time (UTC) of commencement of thunderstorm activity								
Month	Duration (hr)	0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	Total
Jan	<3	0	0	0	0	1	0	1	0	2
Feb	<3	2	0	0	0	1	3	0	0	6
	3-6	0	0	0	1	2	1	0	0	4
	6-9	0	0	0	0	0	0	1	0	1
Mar	<3	1	1	1	2	2	4	3	0	14
	3-6	0	0	0	0	0	2	1	1	4
Apr	<3	0	0	5	6	6	6	3	1	27
	3-6	0	0	0	1	5	0	0	1	7
May	<3	0	0	6	15	23	9	2	0	55
	3-6	0	0	0	3	9	3	0	1	16
	6-9	0	0	0	5	2	1	0	0	8
	9-12	0	0	0	2	0	0	0	0	2
	>12	0	0	1	0	0	0	0	0	1
Jun	<3	1	2	6	37	32	14	12	1	105
	3-6	0	0	2	9	25	3	2	0	41
	6-9	0	0	1	7	4	2	0	0	14
	>12	0	0	1	0	0	0	0	0	1
Jul	<3	0	1	6	9	16	8	0	1	41
	3-6	0	0	1	4	4	3	1	0	13
	6-9	0	0	0	1	3	0	0	0	4
	9-12	0	0	1	0	0	0	0	0	1
Aug	<3	0	0	1	15	11	5	1	0	33
	3-6	0	0	2	1	3	3	1	0	10
	6-9	0	0	0	1	2	0	0	0	3
	9-12	0	0	0	0	1	0	0	0	1
Sep	<3	0	3	11	22	18	6	6	1	67
	3-6	0	0	4	1	14	1	3	0	23
	6-9	0	0	2	4	2	0	2	0	10
	9-12	0	0	0	0	2	0	0	0	2
Oct	<3	1	0	7	14	14	6	3	1	46
	3-6	0	0	3	5	6	2	0	0	16
	6-9	0	0	0	0	5	0	0	0	5
	9-12	0	0	0	0	4	0	0	0	4
	>12	0	0	0	0	1	0	0	0	1
Nov	<3	0	0	1	4	5	5	1	0	16
	3-6	0	0	0	4	5	1	0	1	11
	6-9	0	0	0	1	0	0	0	0	1
	9-12	0	0	0	0	1	0	0	0	1
Dec	<3	1	0	0	1	1	2	0	0	5
	3-6	0	0	0	0	2	1	0	0	3
Total		6	7	62	175	232	91	43	9	625

4. General synoptic situations associated with the occurrence of thunderstorms in Aurangabad. It is observed that occurrence of thunderstorm activity in the month of December, January & February in Aurangabad was very rare and was associated with the approach of western disturbance and its induced low / upper air cyclonic circulation (cycir). The one such case of thunderstorm occurred here on the night of 10 February 2002. In association with a western disturbance an induced low developed over Saurashtra & Kutch and adjoining areas and there was an upper air cycir in lower tropospheric levels over north Maharashtra coast and adjoining land areas which caused thunderstorms here. The occurrence of thunderstorms in Aurangabad during the month of January, February and December is unusual as the induced lows form rarely at such low latitudes during these months.

In March, thunderstorms have occurred over Aurangabad were associated with either an induced cycir of western disturbances that passed through Rajasthan and Madhya Pradesh or with a trough of low pressure / cycir in lower troposphere over East- Central Arabian Sea and adjoining areas. One such case occurred on 21 March 2008 when a trough of low pressure existed in Arabian Sea on 20 March 2008. A good incursion of moist air over Aurangabad took place in association with the trough of low pressure in the Arabian Sea and there was favourable condition for the occurrence of thunderstorms over Aurangabad. Another case of thunderstorm that occurred on 8 March 2005 was associated with the induced cycir of western disturbance which passed through central Rajasthan and adjoining areas moving east wards.

In April, thunderstorms occurred over Aurangabad either when a trough in westerlies / induced cycir existed over East Rajasthan and adjoining Madhya Pradesh and moved east wards or when an embedded cycir in lower tropospheric levels existed over Telengana and adjoining Marathwada. For example, the thunderstorms which occurred during the period 7 to 9 April 2008 over Aurangabad when an induced cycir between 3.1 & 5.8 km amsl formed over central Rajasthan and neighbourhood and moved east-wards.

In May, thunderstorms which occurred during the study period were caused either by a trough of low pressure / upper air cycir / depression in the Arabian Sea which favoured incursion of moisture over Aurangabad or by a circulation which brought about incursion of moisture from the Bay of Bengal. Thunderstorms occurred over Aurangabad during the period from 1 to 4 May and on 13 & 14 May 1998 when an embedded cycir in lower tropospheric levels were present over Marathwada and adjoining areas during the aforesaid periods.

In June, thunderstorms have occurred over Aurangabad with the onset of SW monsoon often ushered in by a trough of low pressure or upper air cycir or depression in the Arabian Sea off Karnataka-Konkan coasts. In some of the years when onset of SW monsoon was late, thunderstorms of the premonsoon type have occurred in Aurangabad.

During the months June to September after the onset of SW monsoon, thunderstorms have occurred here when the monsoon was active in north Konkan mostly in association with either a low pressure area / depression / cycir in the Arabian Sea or one in the north west Bay of Bengal and adjoining south Orissa- north Andhra coasts moving in some west north westerly direction.

During the end of September and in the month of October, the thunderstorms reported at Aurangabad have been mostly in association with either a trough of low pressure / an upper air cycir / depression / cyclonic storm over east central / north Arabian Sea and adjoining areas or one which forms over north-west Bay of Bengal and adjoining areas off south Orissa-north Andhra coasts. One such case occurred on 14 October-1995 over Aurangabad when a cyclonic storm formed over east central Arabian Sea off Maharashtra coasts. Another case, when thunderstorm occurred on 8 & 9 October 1990 over Aurangabad in association with a depression that formed over north west Bay of Bengal and adjoining areas and moved in north northwesterly direction.

In November, thunderstorms occurred here which were associated with either a trough of low pressure / cycir / depression over south west Bay of Bengal and adjoining areas / south east Arabian Sea and neighbourhood or an induced cycir in lower tropospheric levels over Saurashtra & Kutch moving east south east wards and reached north Madhya Maharashtra and adjoining areas. Such cases of thunderstorms occurred at Aurangabad on 10 & 11 November 1997, when a deep depression formed over south east Arabian Sea and neighbourhood. Another case occurred on 12 November-1994 over Aurangabad, when an embedded cycir in lower tropospheric levels formed over Saurashtra and Kutch areas and moved east south east wards and reached north Madhya Maharashtra and adjoining Marathwada.

5. From the study the following conclusions can be drawn:

(*i*) Both thunderstorm days and thunderstorm activity days are the maximum in Aurangabad during SW monsoon season followed by premonsoon season.

(*ii*) The thunderstorm activity over Aurangabad airport mostly occurs during SW monsoon season and it has two

maxima-one in the second week of June which coincides with the normal onset time of SW monsoon over Aurangabad and the other in the fourth week of September/first week of October which is normal the withdrawal time of SW monsoon from Aurangabad. Incidence of thunderstorm activity is the minimum in winter followed by post monsoon seasons.

(*iii*) The majority of the thunderstorms occur here are of duration less than 3 hours. Thunderstorm activity of long duration (6 hrs or more) occurs here during the months May to October in association with the synoptic scale disturbances. The thunderstorm activity has a preferred time of occurrence usually between 0900 and 1500 UTC.

(*iv*) During premonsoon and postmonsoon seasons, occurrence of thunderstorms over Aurangabad are associated with either an induced cycir of western disturbance which passes through southern part of Rajasthan and adjoining Madhya Pradesh and moved east wards or a system like a trough of low pressure / cycir / depression /cyclonic storm which forms over north west Bay and adjoining areas / east central Arabian Sea and adjoining areas of Karnataka-Konkan coasts.

(*v*) During SW monsoon season the occurrence of thunderstorms here are mostly associated with either an upper air cyclonic circulation / low pressure area / depression / cyclonic storm in east central / north Arabian Sea off Karnataka-Konkan coasts or one which forms in the north west and adjoining west central Bay off south Orissa- north Andhra coasts moving in west north westerly direction.

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