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AN ANALYTICAL STUDY OF THUNDERSTORMS OVER MUMBAI

1. Thunderstorm is an important mesoscale system. It is also one of the hazards to aviation activities. Thunderstorms exhibit some dependence on the orography of a place and the climatology and signatures of thunderstorms over a place have to be studied specifically and critically. Mumbai is an important metropolis of peninsular India and lies in the west coast. It is the financial capital of India. It has an international airport and a large number of industrial activities go on in and around Mumbai. Occurrence of thunderstorm is relevant to the various activities in this place. There are few studies on thunderstorm over Mumbai, *viz*., Vishvanathan & Faria (1962) discussed the climatological study of thunderstorm over Bombay airport. Dekate & Bajaj (1965) described regarding squalls at Santacruz observatory. Narayanan & Krishnamurthy (1966) presented the radar study of post monsoon thunderstorms over Bombay airport. Agarwal & Krishnamurthy (1969) discussed the line type thunderstorms at Bombay airport and surroundings and Puniah & Rao (1980) tried to forecast thunderstorm over Bombay airport using Showalter and George's indices. Here a detailed study of the thunderstorms over Mumbai is taken up and the results are presented. Since Terminal Aerodrome Forecast (TAF) and local forecast for aviation purpose and local forecast for general public for metropolitan area are the services provided by meteorological offices, Mumbai, an attempt has been made to develop forecast criteria for the local thunderstorms.

2. The current weather registers of Chhatrapati Shivaji International (C.S.I.) Airport, Mumbai give full details of the occurrence of thunderstorms over the place for the period from 1990 to 1999. The autographic charts for the corresponding period have also been studied critically to derive the characteristics of the thunderstorms of the place. Daily weather charts of Meteorological Office, Mumbai and the India Weather Bulletins (IWB) issued by India Meteorological Department were used for identifying synoptic situations responsible for the occurrence of thunderstorms over Mumbai.

Thunderstorm occasions from the records were noted with full details. Cases where thunder has been heard but no precipitation occurred have also been included in the category of thunderstorms. The frequency distribution of thunderstorms over the months and its diurnal variations were computed.

The occurrences of squalls among these thunderstorm occasions were detected and the nature of the squalls was studied. The directions of the occurrence of squalls were found out and presented pictorially. The change of temperature and humidity at the time of onset of thunderstorms were also studied.

3.1. Table 1 presents the frequency distribution of diurnal variation of thunderstorms for the period 1990-99. An initial inspection of data so collected revealed that the thunderstorm (Ts) occurrence over Mumbai is nil during the months from December to March and rare over the months April, May and November. During the study period of one decade only two Ts in April, five in May and three in November were reported. Hence the Ts activities during June through October were studied critically in all the years.

In June, Ts may occur at any time of the day with maximum frequency in the afternoon/evening (0900-1500 UTC) hours. In July and August it is evenly distributed throughout the day except in the early morning when its occurrence is found to be the least. The peak activity comes back to evening again in September and October when SW monsoon is in its receding phase.

3.2. One of the immediate effects of Ts over any location is the fall of temperature and rise in humidity because of the cold downdraft released by the thunder clouds. This brings about the thermal comfort to human beings also. Mumbai experiences generally two types of Ts - (*i*) heat thunderstorm and (*ii*) thunderstorm associated with intense synoptic system(s). Heat thunderstorm occurs generally in the afternoon/evening hours of the day after intense heating of atmosphere when sufficient amount of moisture incursion also take place over the station due to some synoptic system(s). Temperature fall is maximum for this type of Ts. This is found to happen in the pre-monsoon and post monsoon seasons. The maximum fall were recorded as 9.0° C on 5 June 1994 at 1630 hrs (IST) and 8.5° C on 30 September 1992 at 1840 hrs (IST). The average fall in temperature was 2° C during monsoon season with maximum fall of 6° C on 3 July 1994 at 1700 hrs (IST). Thus, there appears to be some differences in the behaviour of thunderstorms of the pre-monsoon/post monsoon season and monsoon season. The temperature fall in any month depends on the time of occurrence of thunderstorm within a day or on the prevailing ambient temperature just at the time of occurrence of thunderstorm.

The maximum increase in humidity was 32% on 4 June 1990 at 1710 hrs (IST) and 30% on 16 October 1993 at 1710 hrs (IST). On an average 10% or more

TABLE 1

Frequency distribution of diurnal variation of thunderstorms over Mumbai during 1990-99

	Time (UTC)								
Month	0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	Total
Jan	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0
Apr	0	1	0	1	0	0	0	0	2
May	0	2	1	0	1	0	1	1	6
Jun	7	6	4	9	11	6	7	5	55
Jul	0	5	4	4	7	6	3	1	30
Aug	2	3	2	1	4	4	4	1	21
Sep	1	2	4	8	9	4	3	4	35
Oct	1	0	1	12	17	6	2	1	40
Nov	0	0	0	2	1	0	0	0	3
Dec	0	0	0	0	0	0	0	0	0
Total	11	19	16	37	50	26	20	13	192

TABLE 2

Diurnal variation of squalls

	Time (UTC)								
Month	0000-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	Total
April	1	0	0	0	0	0	0	0	1
May	0	0	0	0	1	0	0	0	1
June	2	2	0	1	3	1	4	0	13
July	0	0	1	1	0	1	0	0	3
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	2	0	0	0	2
October	0	0	0	4	7	0	0	1	12
November	0	0	0	1	0	0	0	0	1
Total	3	2	1	7	13	2	4	1	33

humidity was found to be increased due to onset of thunderstorms during southwest monsoon months.

3.3. The manifestation of kinetic energy in association with severe thunderstorm is the squalls. A squall is defined as sudden increase in wind speed by at least 28 kmph reaching 44 kmph or more and lasting at least for one minute. A squall of speed 80 kmph is generally categorized as severe squall. Mumbai experiences two types of squalls- (*i*) rain squalls which occurs during active/vigorous monsoon and (*ii*) thunder squalls due to severe thunderstorms. In the present case, only thunder squalls have been considered. In all, 33 squalls were encountered during the decade under study and all of these were ordinary squalls. The highest peak wind speed in association with thunder squall at Mumbai was recorded as 78 kmph. That is, Mumbai experienced no severe thunder squall. The severity of the squall depends on the dryness of the sub-cloud layer. The absence of severe squall over Mumbai may be due to presence of some moisture in the sub cloud layer, which is not favourable for its occurrence. Table 2 gives the

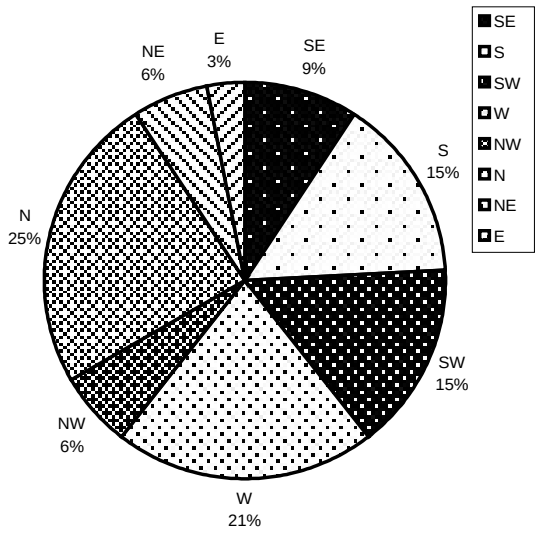

Fig. 1. Squall frequency (distribution of directions)

monthly frequency distributions of squalls over Mumbai during 1990-99. In the month of June, the highest number of 13 squalls have been recorded. The reason may be the arrival of monsoon airmass, which is bound to react with the existing airmass. While no squall has been recorded in the month of August, it is rare in the months of April, May, September and November.

Table 2 presents the diurnal variation of squalls during the period under study. No squall has been recorded in the forenoon hours of the day except in the month of June when it may occur at any time of the day. Most of the squalls occurred during the period from 0900 to 1500 UTC.

Fig. 1 gives the direction wise percentage frequency of squall occurrence during the period under study. While the squall frequency from NE to SE sector appears to be rare, 25% of the squalls occur from north direction and 51% of the squalls occur from west to south sector.

4. The weather charts of Meteorological Office, Mumbai and IWB issued by India Meteorological Department for thunderstorm days were consulted to identify the synoptic features of the day. It is observed that during April and May thunderstorms were caused either by a trough of low pressure/depression formed over the Arabian Sea which favoured incursion of moisture over Mumbai or by a circulation which brought about incursion of moisture from the Bay of Bengal.

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

During the months from June to September after the onset of SW monsoon, the suitable conditions for the development of Ts over Mumbai are the presence of the following synoptic situations :

(*i*) An upper air cyclonic circulation (UACC) / low pressure area (LOPAR) / depression over NW and adjoining WC Bay off south Orissa- north Andhra coast.

(*ii*) An UACC / LOPAR over Gujarat and adjoining west Madhya Pradesh (which was initially originated over Bay of Bengal and then moves to this place).

(*iii*) An UACC / LOPAR / depression over EC Arabian Sea off Karnataka- Konkan coast moving northwards.

It is found that 50% of Ts which develop over Mumbai are associated with the Bay systems mentioned above and the remaining 50% are due to the Arabian Sea systems.

At the withdrawal phase of monsoon *i.e*., during the end of September and in the month of October, Ts reported at Mumbai have been mostly in association with a trough of low pressure or depression in the north Arabian Sea affecting Mumbai.

Forecasting of Ts when there is no cognizable synoptic feature, is really a challenging job to the forecaster. Unfortunately occasions of occurrence of purely local Ts form a little over 35% (68 out of 192) of total occasions over this place. Hence possible thumb rules for forecasting of Ts has been tried.

Since Mumbai has an aerological observatory, upper air data of 0000 UTC was used to get any clue regarding the now casting of Ts. The Showalter (1953) index computed from the data was already established to be successful only for 30% of Ts occasions (Puniah and Rao 1980). George's index was also able to give only 50% success in Ts forecasting (Puniah and Rao 1980).

When the shear aspect is considered, it does not give any meaningful clue regarding the occurrence of thunderstorms over Mumbai.

However, a somewhat reliable parameter from the available data appears to be the relative humidity at 600 hPa levels supported by significant synoptic situation(s). It is observed that on 95% occasions of thunderstorms,

relative humidity at 600 hPa level was 60% or more in the morning. The value of 40% or less relative humidity at this level suggests the remote possibility of thunderstorm occurrence over the station till night 2000 hrs (IST). Perhaps a judicious use of the above informations may help the forecasters to nowcast the local thunder occurrence. The radar observations in the afternoon hours, say at 0900 UTC, may be helpful in this respect as a confirmatory test.

5. From the study following conclusions can be drawn :

(*i*) The thunderstorm activity over Mumbai has two maxima - one in the second week of June which coincides with the onset time of SW monsoon over Mumbai and the other is the fourth week of September/first week of October which is the withdrawal time of SW monsoon from Mumbai.

(*ii*) The thunderstorm over Mumbai is mostly associated with a UACC/lopar/depression/cyclonic storm in the Arabian Sea off Karnataka - Konkan coast or one in the NW and adjoining WC Bay off south Orissa - north Andhra coast moving in WNWly direction.

(*iii*) Here the Ts activity has a preferred time of occurrence usually between 0900 and 1500 UTC.

(*iv*) June gets the highest number of squalls over Mumbai followed by October.

(*v*) Most of the squalls occur from west to south sector.

(*vi*) Squalls over Mumbai are associated with the formation of intense synoptic system over EC Arabian Sea off Karnataka coast and adjoining Lakshadweep area moving north wards.

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BIMAL KRISHNA BISWAS

Meteorological Office, C.S.I. Airport, Mumbai, India
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