551·515·4 : 515·58

A climatological study of Thunderstorms at Bombay Airport

T. R. VISVANATHAN and J. F. FARIA

Regional Meteorological Centre, Bombay

(*Received 5 August 1961*)

ABSTRACT. A study has been made of thunderstorms and the occurrence of *Cb* clouds over Bombay (Santacruz) Airport for the decade 1950 to 1959. Statistics have been collected giving the monthly frequency of days of occurrence of thunderstorms in each of the years 1950 to 1959 and also of thunderstorms and thundery conditions (*i.e.*, occurrence of *Cb*) for the same period. The diurnal distribution of thunderstorm activity, *i.e.*, thundery conditions a id of thunderstorms for each of the months has been discussed and the duration of such activity in each month has been classified. The diurnal distribution of the time of commencement of thunderstorms for each month has been tabulated. The synoptic situations connected with typical cases of thunderstorms have been referred to.

1. Introduction

Thunderstorms are one category of weather hazard experienced at the Bombay Airport. They are more likely to occur at certain times of the year than at others. Once a thunderstorm has commenced, its probable duration is a question of practical importance to aviation interests. Statistics have been collected to provide a basis for an answer to this and connected questions. The synoptic situations in which certain typical or unusual thunderstorms occurred have been referred to with a view to facilitating forecasting in broadly analogous situations.

2. Data and discussion

The data processed relate to the decade 1950 to 1959 and have been collected from Current Weather Registers, *Indian Daily Weather Reports* and *Weekly Weather Reports* at Santacruz. Table 1 gives the monthwise frequency of thunderstorm days for each of the years 1950 to 1959. Cases where thunder has been heard but no precipitation has occurred have also been included in the category of thunderstorms. During the period under study no thunderstorm occurred in the winter months of January and December. They have been comparatively rare in the months of February, March, April and May, there being only one or two occasions in each of these months, except in May 1956 when 10 thunderstorm days were reported. Thunderstorms are more frequent in the months June to October with a peak in June and a subsidiary peak in October.

The formation of a cumulonimbus, the occurrence of a thunderstorm without precipitation and its evolution into a thunderstorm with rain are such stages in thunderstorm activity that one stage may under favourable circumstances develop into the next. In Table 2, which gives information similar to Table 1, all occasions when *Cb* has been reported have been added to those where thunderstorms have occurred. It will be seen that the seasonal distribution indicated in this table is similar to that shown by Table 1.

An attempt has been made in Table 3 to show the three-hourly distribution of occurrence of *Cb* and thunderstorms for each of the months January to December. In this table the day has been divided into eight intervals of three hours duration each. A *Cb* or thunderstorm reported in one or consecutively in two or more of the observations 0000, 0100 or 0200 GMT on a particular day has been taken as one occurrence

TABLE 1

Distribution of the number of days of thunderstorms

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Jan											0
Feb					1						1
Mar					1						1
Apr		1		2					1	2	6
May		1			1	1	10	2	2	2	19
Jun	1	4	10	10	5	3	7	7	7	8	62
Jul	1	4	1		2	1		1	3		13
Aug					1	4		1	5	1	12
Sep	4	1	2		1	6	3		2	4	23
Oct	3	5	5	4	1	6	7			3	34
Nov									1		1
Dec											0
Total	9	16	18	16	13	21	27	11	21	20	172

TABLE 2

Distribution of the number of days of thunderstorms and thundery (*Cb*) conditions

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Jan									1		1
Feb					2						2
Mar	1		1		9	5		2	1		19
Apr	2	5	4	12	3	4	4	6	9	8	57
May	3	13			6	8	19	8	5	15	77
Jun	5	20	19	12	9	7	9	12	12	10	115
Jul	1	7	3	2	4	3		2	4	1	27
Aug		4			2	4	2	2	10	2	26
Sep	11	11	3	3	4	14	6	6	5	7	70
Oct	10	15	15	17	2	12	13	8	9	11	112
Nov		6				2	8	6	7	5	34
Dec			1								1
Total	33	81	46	46	41	59	61	52	63	59	541

TABLE 3

Diurnal distribution of thunderstorm activity, *i.e.*, thunderstorms and thundery (*Cb*) conditions

	Time (GMT) of occurrence of thunderstorm activity								
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	Total
Jan					1				1
Feb	1			1			1	1	4
Mar	3		1	11	14	14	3	2	48
Apr	5	2		28	39	29	11	10	124
May	9	4	1	34	57	44	19	12	180
Jun	30	26	20	47	58	55	43	39	318
Jul	6	5	3	5	7	10	7	6	49
Aug	6	2	5	9	9	11	3	4	49
Sep	14	12	9	40	49	43	22	20	209
Oct	23	8	8	66	99	77	31	18	330
Nov	4	4		10	26	20	11	4	79
Dec					1				1
Total	101	63	47	251	360	303	151	116	1392
Percentage	7	5	3	18	26	22	11	8	100

in the interval 00 to 03; and similarly for other intervals. Analysing the table it will be seen that the period of maximum activity is from 0900 to 1800 GMT. 18 per cent of the cases were reported in the interval 09–12, 26 per cent in the interval 12-15 and 22 per cent in the interval 15-18 GMT. The activity was at a minimum in the intervals 3-6 and 6-9 GMT.

Table 4 attempts to give an idea of the duration of thunderstorm activity for each month of the year classified according to the time of commencement. For this purpose, the day has been divided into eight intervals, *i.e.*, 00–03 03–06, 06–09, 09–12 12–15, 15–18, 18–21 and 21–24, as in Table 3. A thunderstorm or *Cb* cloud occurring on a particular day and being reported for the first time in the hourly observation at 0000, 0100 or 0200 GMT has been considered to have commenced in the interval 00–03. As regards the duration of the activity, if it is reported in one or two consecutive hourly observations (GMT) only it has been placed in the range 'less than 3'. If the activity has been reported in 3, 4 or 5 consecutive hourly observations it has been placed in the range 3-5. An activity reported in 6 to 12 consecutive hourly observations has been included in the range 6–12 and if reported in more than 12 consecutive hourly observations, in the range 'greater than 12'. In cases where the phenomenon has been reported in one observation, not reported in the subsequent one but again reported in the third observation it has been considered to have been persisting at all the three hours. Such cases are few.

The table reveals the following significant features of thunderstorm activity at Bombay Airport—

(1) Thunderstorm activity in the months of January, February and December, is so limited as to preclude any conclusions being drawn therefrom.

(2) In March nearly half the reported occasions of thunderstorm activity (11 out of 26) have occurred in that part of the day represented by the intervals 9-12 GMT and 12-15 GMT and has the duration 3-5

TABLE 4

Frequency of time of commencement of thunderstorm activity, *i.e.*, thunderstorms and thundery (*Cb*) conditions *vis-a-vis* duration

Month	Duration (hrs)	Time (GMT) of commencement of thunderstorm activity							Total
		00–03	03–06	06–09	09–12	12–15	15–18	18–21	21–24	
Jan	<3					1				1
Feb	<3					1				1
	6-12							1		1
Mar	<3	3			1		3	3	1	11
	3-5				6	5	1			12
	6-12			1	2					3
Apr	<3	2			9	8	5	1	4	29
	3-5	1			11	7	3	2		24
	6-12				8	1		1		10
	>12				2	1				3
May	<3	2	1		2	13	8	2	1	29
	3-5	2		1	12	9	1	4	3	32
	6-12				18	4		2		24
	>12				2					2
Jun	<3	10	9	4	9	5	11	7	9	64
	3-5	6	3	6	10	12	4	7	3	51
	6-12			5	11	2	4	1	2	25
	>12		3		3	3				9
Jul	<3				1	3	5	2	1	12
	3-5	1	2		2		3		1	9
	6-12	1					1	1		3
	>12				2					2
Aug	<3	2		2	3	4	3		1	15
	3-5		2	1	2	1	1		2	9
	6-12				1					1
	>12				1					1
Sep	<3	4	2		5	4	2		2	19
	3-5	2	2	2	9	8	4	1	2	30
	6-12		3	1	15	2	4	1	1	27
	>12			1	4		1	1		7
Oct	<3	3			6	10	3	2	3	27
	3-5	3	1		15	16	2	1	3	41
	6-12	1		2	37	8	1		1	50
	>12	1		1	5	2				9
Nov	<3	1			1	3	2	2	1	10
	3-5	3	1		2	8		1		15
	6-12				7	6				13
Dec	>3					1				1

TABLE 5

Frequency distribution of time of commencement of thunderstorms

	Time (GMT) of commencement of thunderstorms								Total
	00–03	03–06	06–09	09–12	12–15	15–18	18–21	21–24	
Feb							1		1
Mar	1								1
Apr	1				1	2		1	5
May	4			2	8	1	3	1	19
Jun	8	6	9	10	19	8	5	9	74
Jul	2			1	2	1	4	1	11
Aug	1	2	2	3				2	10
Sep	1	2	2	2	6	4	5	3	25
Oct	3	1	1	11	11	3		2	32
Nov				1					1
Total	21	11	14	30	47	19	18	19	179

hours. About 75 per cent of the reported cases commenced in the combined intervals 9–12, 12–15 and 15–18 GMT.

(3) In April, the greater part of the thunderstorm activity (53 out of 66 cases) lies however in the ranges 'less than 3' and 3–5, being more or less equally divided between these two ranges.

(4) In May, thunderstorm activity is broadly distributed in ranges 'less than 3', 3–5 and 6–12, with a predominance in the range 3–5 (32 out of 87). The pattern of duration *vis-a-vis* time of commencement is similar in September.

(5) In June, there is some activity in the ranges 6–12 and 'more than 12', but by far the greater part (115 out of 149 cases) is in the ranges 'less than 3' and 3–5, occasions occurring in the range 'less than 3' predominating.

(6) There is a similarity between July and August, thunderstorm activity being more or less distributed in the ranges 'less than 3' and 3–5 being greater in the range 'less than 3' with, in addition, a small percentage in the longer ranges.

(7) In October, the activity is distributed mainly in the ranges 'less than 3', 3–5 and 6–12, but is mostly in the range 6–12. 37 cases out of 125 occurred in that part of the day represented by the interval 09–12 and were in the range 6–12. The pattern of activity in November resembles that in October but with lesser incidence.

Table 5 gives for various parts of the day the number of occasions when thunderstorms have commenced in each of the months January to December in the period under study. The day has been divided into eight intervals as in Table 4. During the decade there have been no thunderstorms in December and January. The occasions in February and November are too few to allow any generalisations to be made from them. As regards the remaining months the following generalisations can be made—

(1) In March and April the time of commencement lies mainly in the intervals 12–15 and 15–18 GMT.

(2) In May, a large percentage of the thunderstorms have commenced in the interval 12–15. There is a gap in the intervals 03–06 and 06–09 GMT.

(3) In June, thunderstorms have commenced more or less evenly throughout the day. The incidence is, however, higher in the intervals 09–12 and 12–15 GMT.

(4) In July, the time of commencement is more or less evenly distributed throughout the day with a gap in the intervals 3–6 and 6–9. In August, the distribution is similar to that in July but with a gap in the intervals 12–15, 15–18 and 18–21 GMT.

(5) In September and October thunderstorms have commenced in all the intervals with a maximum incidence in the intervals 12–15 and 15–18 in September and in the intervals 09–12 and 12–15 in October.

3. General synoptic situations associated with thunderstorms in Bombay

As stated earlier, no thunderstorms have occurred during the months of January and December, during the decade 1950-59.

During February, March and November, one thunderstorm occurred in each month. The one in February occurred on the night of 3rd/4th. In association with a western disturbance a secondary developed over Saurashtra, Kutch and adjoining areas on 3/4 February 1954, and there was a cyclonic circulation upto 7000 ft which affected Bombay. The occurrence of thunderstorms in Bombay during February is unusual as the secondaries do not form at such low latitudes during this month.

The one in March occurred on 17 March 1954. A trough of low pressure existed in Arabian Sea on 14th and became less marked on 15th. A good incursion of moist air over the Peninsula including Bombay took place in association with the trough in the Arabian Sea till 17 March, and this was favourable for the occurrence of thunderstorm over Bombay.

A thunderstorm occurred on 24 November 1958. At 03 GMT on 24th there was a depression in east Arabian Sea centered 225 km to the westsouthwest of Karwar. A moisture discontinuity at 1500 metres existed between Bombay and Veraval.

During the premonsoon months of April and May thunderstorms which occurred during the decade were caused either by a trough or depression in the Arabian Sea which favoured incursion of moisture over Bombay or by a circulation which brought about incursion of moisture from the Bay of Bengal.

In June, thunderstorms have occurred over Bombay with the onset of the monsoon often ushered in by a trough of low pressure or depression in the Arabian Sea off Kanara Konkan coasts. In some of the years when monsoon was late, thunderstorms of the premonsoon type have occurred in Bombay in early June as in 1959.

During the months June to September after the onset of the monsoon thunderstorms have occurred in all phases of monsoon activity. They have occurred with the strengthening of the monsoon over Bombay or when the monsoon was active in north Konkan mostly in association with a low or a depression in the Arabian Sea or one in the Bay moving in some westerly direction. Thunderstorms have also been reported both when the monsoon was weakening as well as when it revived in the north Konkan after a break. There have been cases of thunderstorms over Bombay associated with the withdrawal of the monsoon from the north Konkan in the latter half of September. During the end of September and in the month of October the thunderstorms reported at Bombay have been mostly in association with a trough of low pressure or depression in the north Arabian Sea affecting Bombay.

4. Acknowledgement

The authors are thankful to Shri K. N. Rao, Director, Regional Meteorological Centre, Bombay, at whose suggestion the work was taken up.