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Thunderstorms in Kutch-Saurashtra

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1. In this note thunderstorms over the area Kutch-Saurashtra have been studied. The data taken into consideration are for the years 1945-1951 for the stations Veraval, Bhavnagar, Rajkot, Jamnagar and Bhuj.

2. The number of thunderstorms in each month for the period of seven years is given in Table 1. The criterion for reckoning a thunderstorm is that thunder should be heard at the Observatory. The period June to October accounts for at least 85 per cent of the thunderstorms at all these stations, many of them, nearly 50 per cent occurring in June-July.

3. The total number of thunderstorms is more at Bhavnagar and Rajkot than either at Veraval or Jamnagar. The difference in the frequency is mostly in line with the thunderstorm frequencies published in the India Meteorological Department Climatological Tables, 1951, which refer to a different period of ten years. It is also interesting to note that according to these tables, Surat and Baroda which are very near the east coast of the Gulf of Cambay have an annual thunderstorm frequency of 5 and 6 respectively compared to 18 at Bhavnagar which is on the western coast of the Gulf. The relatively greater number of thunderstorms at Rajkot compared to either Jamnagar or Veraval may be due to hillocks which lie immediately to the east of Rajkot and which may contribute to orographic lifting during southwest monsoon when the prevailing winds are from WSW, besides the greater heating due to insolation at Rajkot which is located in the interior of the Saurashtra Peninsula and not on the coast like Veraval or Jamnagar. On similar considerations it should be expected that Junagadh near Girnar hills would have a higher frequency of thunderstorms than Veraval. It is, however, difficult to explain satisfactorily the very large number of thunderstorms at Bhavnagar compared to all the neighbouring stations, particularly when it lies to the east of the hill ranges in Central Saurashtra. It is not clear whether marked changes in the thickness of the E_m, T_c and T_c T_m air-masses near Bhavnagar may not be responsible to some extent for a large number of thunderstorms, particularly as a majority of them occur in monsoon months. Bhuj, though it lies farther north of Jamnagar gets twice as many thunderstorms. The hillocks near Bhuj probably contribute to this excess; it is also possible that as majority of thunderstorms occur from June to September the replacement of T_c T_m and T_c air over the area by easterly T_m air in upper levels might have some influence.

4. Table 2 gives the hourly distribution of time of commencement of thunderstorms at

TABLE 1

	Number of thunderstorms in different months during 1945—51													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average per year
Veraval	0	0	0	0	0	12	8	2	4	4	3	0	33	5
Bhavnagar	1	2	1	3	8	27	25	14	18	9	2	0	110	16
Rajkot	1	0	1	4	5	26	12	8	10	3	2	0	72	10
Jamnagar	1	0	0	0	2	9	11	2	6	2	1	0	34	5
Bhuj	3	1	1	3	0	12	21	13	10	8	0	0	72	10

these stations during the whole year for the same period. There is preponderance of thunderstorms in the afternoon near about 3 to 4 P.M.

5. While it is possible to fix exactly the time of commencement of thunderstorms when the first peel of thunder is heard, it is rather difficult to note the exact time of cessation of the phenomenon : for it is subjective depending on the observer who may reckon the time of the last peel of thunder or the cessation of the associated rain and subsequent breaking up of the sky. With this limitation the data given in the Monthly Meteorological Registers for times of commencement and cessation of thunderstorms have been taken and their durations worked out. Table 3 gives the distribution of thunderstorms according to the duration of their activity. About 30 per cent are of less than half an hour's duration and 60 per cent less than one hour's duration. Only less than 10 per cent of the thunderstorms are of a duration of more than 4 hours.

TABLE 2

Hourly distribution of the time of commencement of thunderstorms during 1945—51

Hour (IST) ending	Veraval	Bhavnagar	Rajkot	Jamnagar	Bhuj
00	1	1	0	0	0
01	0	0	1	0	2
02	1	2	0	0	0
03	1	0	0	0	2
04	1	1	1	0	1
05	0	1	0	1	0
06	0	0	0	0	0
07	0	0	0	0	0
08	1	0	0	1	2
09	0	0	0	0	1
10	1	0	0	0	0
11	2	2	0	0	2
12	0	4	2	1	1
13	1	10	3	0	4
14	3	15	2	2	10
15	5	23	6	4	7
16	5	13	17	11	5
17	5	13	9	6	14
18	0	15	12	5	8
19	0	5	9	0	4
20	1	3	8	1	3
21	1	2	2	1	2
22	2	0	0	0	2
23	2	0	0	1	2

6. Though there was no self-recording raingauge at any of these stations it has been possible from the data recorded in Monthly Meteorological Registers to estimate the rain associated with the individual thunderstorms. Table 4 gives the classification of the thunderstorms with respect to associated rainfall under the heads (1) no rain, (2) light to moderate rain and (3) heavy rain. 50 per cent of the thunderstorms are associated with light to moderate rain. It is found that out of the total rainfall, 15 per cent at Veraval, 24 per cent at Jamnagar, 26 per cent at Rajkot, 41 per cent at Bhavnagar and 53 per cent at Bhuj are associated with thunderstorms.

7. In the absence of self-recording instruments at these stations, it is difficult to assess the frequency of any squalls with the thunderstorms. At Veraval Observatory manned by full time meteorological staff strengthening of winds has been reported on four occasions, the speed reaching B.F. 8 on one occasion. The part time observer at Bhavnagar has not recorded any squalls. But it is not possible to presume that squalls have not occurred with the very large number of thunderstorms recorded at the station. At Rajkot part time observatory wind speeds increased to more than 25 mph on 6 occasions in association with thunderstorms. At Jamnagar between 1948 and 1951 when the observatory was being run by whole time meteorological staff, strong winds were reported on three occasions while the total number of thunderstorms during the same period was 27 ; on 4 June 1949 the wind speed reached 60 mph. At Bhuj there have been only three occasions when wind speed reached 25 mph.

8. From a study of the synoptic situation, the thunderstorms at these stations have been classified under the following types—

(*i*) Thunderstorms in association with low pressure systems other than western disturbances

(*ii*) Thunderstorms in association with strong monsoon conditions

(*iii*) Thunderstorms in association with weak monsoon conditions

(*iv*) Thunderstorms associated with western disturbances and

TABLE 3

	No. of thunderstorms of duration (*hr*)					
	$<\frac{1}{2}$	1	2	3	4	>4
Veraval	8	11	7	4	0	3
Bhavnagar	34	28	18	15	7	8
Rajkot	23	33	4	7	2	3
Jamnagar	10	11	6	3	1	3
Bhuj	29	15	11	9	3	5

TABLE 4

	Number of thunderstorms associated with		
	No rain	Slight to moderate rain	Heavy rain
Veraval	6	19	8
Bhavnagar	23	57	30
Rajkot	23	33	16
Jamnagar	3	22	9
Bhuj	19	36	17

TABLE 5

Analysis of associated synoptic situations

Station	No. of thunder-storms associated with	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Veraval	Lows	0	0	0	0	0	4	4	1	4	4	2	0	19
	Strong monsoon	0	0	0	0	0	7	4	0	0	0	0	0	11
	Weak monsoon	0	0	0	0	0	0	0	1	0	0	0	0	2
	Heat	0	0	0	0	0	1	0	0	0	0	0	0	1
	Western disturbance	0	0	0	0	0	0	0	0	0	0	1	0	1
Bhavnagar	Lows	0	0	0	0	0	5	6	5	9	2	1	0	28
	Strong monsoon	0	0	0	0	0	10	14	6	2	0	0	0	32
	Weak monsoon	0	0	0	0	0	0	5	3	5	0	0	0	13
	Heat	0	0	0	2	8	12	0	0	2	7	0	0	31
	Western disturbance	1	2	1	1	0	0	0	0	0	0	1	0	6
Rajkot	Lows	0	0	0	0	1	10	6	4	8	1	2	0	32
	Strong monsoon	0	0	0	0	0	11	4	2	0	0	0	0	17
	Weak monsoon	0	0	0	0	0	2	2	2	2	0	0	0	8
	Heat	0	0	0	4	4	3	0	0	0	2	0	0	13
	Western disturbance	1	0	1	0	0	0	0	0	0	0	0	0	2
Jamnagar	Lows	0	0	0	0	0	3	9	2	5	1	1	0	21
	Strong monsoon	0	0	0	0	0	6	0	0	0	0	0	0	6
	Weak monsoon	0	0	0	0	0	0	2	0	1	0	0	0	3
	Heat	0	0	0	0	2	0	0	0	0	1	0	0	3
	Western disturbance	1	0	0	0	0	0	0	0	0	0	0	0	1
Bhuj	Lows	0	0	0	0	0	4	15	8	10	2	0	0	39
	Strong monsoon	0	0	0	0	0	8	4	3	0	0	0	0	15
	Weak monsoon	0	0	0	0	0	0	2	2	0	0	0	0	4
	Heat	0	0	0	1	0	0	0	0	0	6	0	0	7
	Western disturbance	3	1	1	2	0	0	0	0	0	0	0	0	7

(*v*) Heat thunderstorms.

In Table 5, is given the number of thunderstorms of each type at each station.

9. The strength of the monsoon has been judged from the intensity of rainfall along the Konkan-Kathiawar coast. Those thunderstorms that occur with a simultaneous strengthening of monsoon in association with Lows within 500 miles of the area have been classified under 'Lows' only. Time of strengthening of monsoon is more favourable for occurrence of thunderstorms than its weak phase.

10. It will be seen that practically all the thunderstorms at Veraval are in association with low pressure systems or strengthening of monsoon. Thunderstorms purely due to insolation are very rare at Veraval. Thunderstorms at Bhavnagar are fairly evenly distributed among all types, except that only a few are due to western disturbances. At Rajkot many of the thunderstorms are due to low pressure systems and very few are due to western disturbances. Bhuj gets a substantial number from low pressure systems and strengthening of monsoon while the number in other situations is less. But about seven thunderstorms at Bhuj are in association with western disturbances. Of all stations Bhuj gets the highest percentage from western disturbance on account of its proximity to the track of the secondaries.

TABLE 6

Distribution of thunderstorms with respect to location of low pressure systems

	No. of thunderstorms associated with					
	Trough towards		Lows towards			
	South	West	North	East	South	West
	Within 250 miles					
Veraval	1	2	2	..	3	1
Bhavnagar	2	..	..	5	3	2
Rajkot	5	4	3	3	4	3
Jamnagar	2	4	3	1		1
Bhuj	6	3	15	2	3	..
	More than 250 miles but within 500 miles					
Veraval	5	..	1	3	..	1
Bhavnagar	1	..	1	13	1	..
Rajkot	..	..	1	5	4	..
Jamnagar	..	1	2	3	..	..
Bhuj	1	..	..	9	..	..

11. The thunderstorms in association with low pressure systems have been further classified both with reference to the distance, (*i*) systems within 250 miles and (*ii*) systems at more than 250 miles but within 500 miles and direction in which the system was located with reference to a central point in Kathiawar peninsula, *viz.*, Rajkot. Thunderstorms in association with troughs in Arabian Sea are grouped separately. The results are given in Table 6.

The outstanding points are—

(*i*) Out of a total number of 29 thunderstorms at Bhuj due to troughs and lows within 250 miles, 15 were associated with those to the north.

(*ii*) There were 13 thunderstorms at Bhavnagar and 9 at Bhuj with lows to the east located between 250 and 500 miles out of a total of 16 and 10 respectively due to systems within that distance.

12. An attempt has been made to correlate the upper air flow characteristics with occurrence of thunderstorms of various types. In more than 60 per cent of the cases of heat thunderstorms, anti-cyclonic circulation was observed to develop at 5000 ft over the area probably bringing in more moist air along the western end of the circulation. This sort of development seems to be associated with the passage of western disturbance farther to the north. Similar circulation was also noticed on some of the days of thunderstorms associated with weak monsoon. Majority of the thunderstorms at Bhuj and Jamnagar during strong monsoon appear to be associated with the winds becoming easterly at Bhuj.

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