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Radar-Climatology of Delhi and neighbourhood: Occurrence of severe weather

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ABSTRACT. Occurrence of severe weather, observed within a range of 200 miles around Delhi, has been investigated with reference to the maximum heights of echo tops reported in the area. While the number of severe weather reports increases with the increase in maximum heights of echo tops in the area, no significant increase in severe weather activity is observed when the echo tops reach or penetrate the tropopause. The monthly distribution of the number of hail occurrences as well as their preferred hours of occurrence have also been studied for the region.

1. Introduction

1.1. Kulshrestha and Jain (1964), stressing the need for radar-climatological studies in different regions where records of radar-observations are available for the last few years, mentioned various aspects of radar-climatological information that can be usefully derived from the accumulated radar-weather data. Two such studies have already been published by the present authors (Kulshrestha and Jain 1964, 1965).

1.2. The present paper constitutes the third contribution in the authors' continuing series of studies on radar-climatology of Delhi and neighbourhood and deals with the occurrence of severe weather phenomena within a range of 200 miles around Delhi.

2. Scope of the present study

2.1. The present study deals with the observations of severe weather within a range of 200 miles around Delhi observed between December 1957 and June 1960. The following have been assumed to constitute severe weather — thunderstorm (with or without rain), duststorm, squall, hail.

2·2. Occurrence of severe weather observed in the area has been investigated with reference to the maximum heights of echo tops reported from the area. The association of severe weather activity with the penetration of tropopause by echo tops has been investigated.

2.3. Occurrence of hail has been specially studied. The monthly distribution of the number of hail occurrences reported in the area has been investigated. An attempt has also been made to find out the preferred hours of occurrence of hail in the region around Delhi.

3. Data and the method of analysis

3.1. The radar data for this study was obined from the routine records of the New Delhi Weather Radar Unit which has a high power X band (3 cm) radar CPS—9.

3.2. The data relates to the period December 1957 to June 1960. This is the period for which radar observational data is available almost without any interruption due to radar breakdown etc. The earlier radar-climatological studies for the area (Kulshrestha 1962, Kulshrestha and Jain 1964, 1965) also pertained to this period only.

3.3. During the 31-month period, 289 days of extensive radar echo activity were selected. For each of these days the maximum height of echo tops, attained in the area on that day, was noted from the weather radar records.

3.4. The evidence of severe weather activity in the area was collected from the records of the 27 surface observatories scattered almost evenly within a range of 200 miles around Delhi. The surface observatories, whose records were used for this purpose, are —

1. Agra	10. Dholpur	19. Nainital
2. Aligarh	11. Hissar	20. Najibabad
3. Alwar	12. Jaipur	21. New Delhi
4. Ambala	13. Karnal	22. Patiala
5. Bareilly	14. Ludhiana	23. Roorkee
6. Bhatinda	15. Mainpuri	24. Simla
7. Chandigarh	16. Meerut	25. Sikar
8. Churu	17. Mukteswar	26. Sriganganagar
9. Dehra Dun	18. Mussorie	27. Tonk

3.5. The instances of occurrences of severe weather phenomena were picked out from the Monthly Meteorological Registers (MMRs) of these observatories. These observations were plotted on polar diagrams of the area for each day selected for the study.

TABLE 1

Occurrence of severe weather over Delhi and neighbourhood
Total number of severe weather reports during the period December 1957 to June 1960

Period of year	Maximum heights attained by echo tops in the area (thousands of ft)	Number of days	No. of severe weather reports within a range of 200 miles around Delhi: Light-ning	Dust-storm	Thunder-storm	Squall	Hail	Total No. of reports
December to April	30—34	3	2	3	18	1	1	25
	35—39	16	17	14	99	3	10	143
	40—44	24	38	20	179	11	9	257
	45—50	3	5	13	33	2	2	55
	***							
May to November	30—34	10	5	6	24	1	—	36
	35—39	36	30	48	137	11	—	226
	40—44	46	58	30	206	12	1	307
	45—50	117	245	62	629	27	2	965
	Above 50	34	81	17	204	6	3	341

*** During the period December to April, echo tops are confined to heights below 50,000 ft

TABLE 2

Occurrence of severe weather over Delhi and neighbourhood
Average number of reports of each of the various severe weather phenomena on a day of severe weather activity

Period of year	Maximum heights attained by echo tops in the area (thousands of ft)	Average number of reports of different phenomena in the area on a day of severe weather: Lightning	Duststorm	Thunderstorm	Squall	Hail
December to April	30—34	1	1	6	1	1
	35—39	1	1	6	1	1
	40—44	2	1	8	1	1
	45—50	2	4	11	1	1
	***					
May to November	30—34	1	1	2	1	—
	35—39	1	1	4	1	—
	40—44	1	1	4	1	1
	45—50	2	1	5	1	1
	Above 50	2	1	6	1	1

*** During the period December to April, echo tops are confined to heights below 50,000 ft

3.6. For each of the polar diagrams thus completed, the total number of instances of each type of severe weather phenomena reported by all the observatories in the area were totalled up and noted against the maximum height of echo tops reported by the radar on that day. Such data were compiled for the various echo height-intervals and are presented in Table 1.

3.7. Table 1 is divided in two parts pertaining to two different periods of year, *viz.*, December to April and May to November. This was done because the tropopause heights and characteristics in this area around Delhi are different in these two parts of the year.

3.8. From Table 1, we have derived Table 2. Here the *average* numbers of reports of different phenomena, on a day of severe weather activity in the area, have been worked out.

3.9. As thunderstorms are by far the most frequent and noteworthy of the severe weather phenomena, histograms showing the average number of thunderstorms in the area on a day of severe weather activity *versus* the maximum heights attained by echo tops in the area are shown in Fig. 1. As will be seen, this figure also is divided into two parts : one corresponding to the period May to November, and the other for the period December to April. The mean positions of the tropopause layer(s) have also been indicated on these histograms in Fig. 1.

3.10. The height and thickness of tropopause layer, for the days selected for the study of severe weather occurrence, were attempted from the records of routine morning and evening radiosonde ascents of New Delhi. But on many occasions, height of the tropopause layer was not available due to either the ascent terminating below the tropopause layer or due to other causes. It was, therefore, considered advisable to adopt mean values for the height of tropopause layer for this region. These mean values were available from the results of the analysis made earlier by the India Meteorological Department in regards to the applicability of the trial definition of tropopause to the Indian region. These investigations revealed that for the area around Delhi, there are two distinct parts of year when the tropopause exhibits different types and heights as indicated.

May to November	Tropical type	15—18 km
December to April	Double tropopause	
	Lower layer	10—12 km
	Upper layer	15—17 km

3.11. There were only 44 hail reports available during the 31 months (December 1957 to June 1960) in the area. This being a small number for any radar-climatological analysis, it was decided to extend the analysis of hail reports upto December 1963, by which time about 100 hail reports were available from the observatories in the area. Table 3 gives the month by month distribution of hail reports for the six years (1958—1963). The last column in this table gives the average number of hail reports during each month. The histogram in Fig. 2 shows these results in a diagramatic form.

3.12. For all the hail reports, times of occurrence were found out from the MMRs of the reporting observatories and the data are presented in the form of a histogram in Fig. 3.

4. Discussions and Conclusions

4.1. Table 1 shows very clearly that the number of severe weather reports in the area during the period May to November was significantly larger than that during the period December to April.

4.2. It will be seen from Table 2 that the number of severe weather reports received, increased with the maximum height of echo tops in the area.

4.3. It is also seen from Table 2 that the above statement is much more true for the reports of thunderstorms and lightning. For other severe weather phenomena like duststorm, squall, and hail, their reported number does not vary sensitively with the maximum height of echo tops in the area.

4.4. Fig. 1 shows that the average number of thunderstorm reports increases steadily with the increase in the maximum heights of echo tops. This fact is much more pronounced during the period December to April than between May and November.

4.5. Fig. 1 also shows that during the period December to April on almost all days of thunder

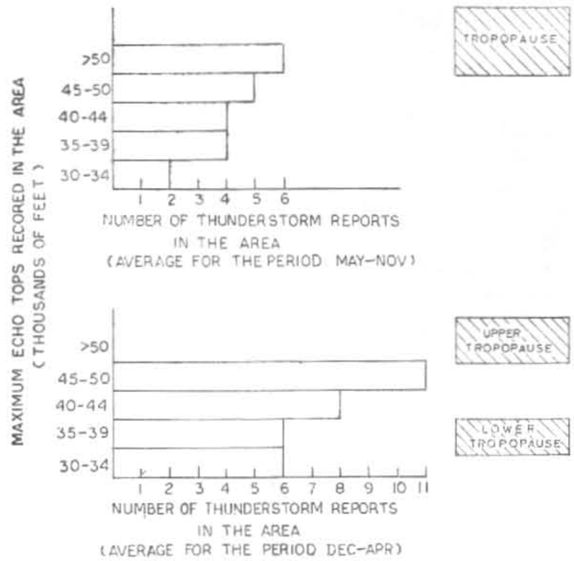

Fig. 1. Maximum heights of echo tops in the area *vs* number of thunderstorm reports on a day of severe weather activity

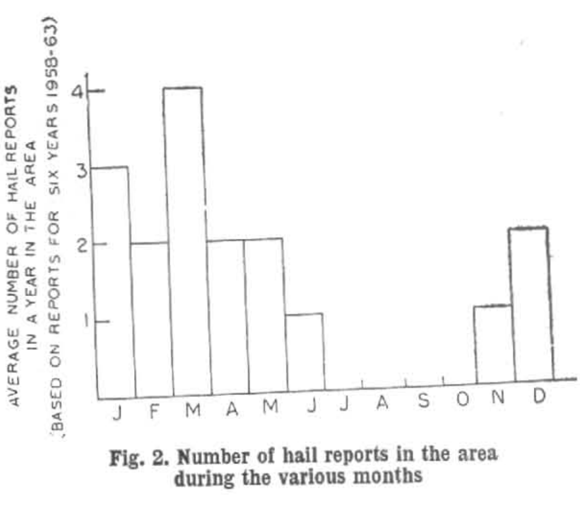

Fig. 2. Number of hail reports in the area during the various months

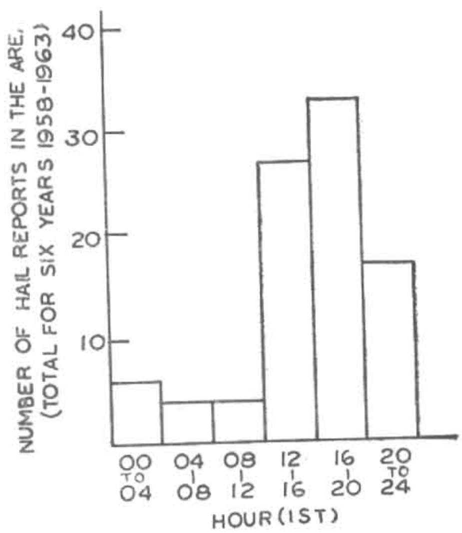

Fig. 3. Preferred time for occurrence of hail

TABLE 3

Occurrence of hail over Delhi and neighbourhood (1958—1963)

	Number of hail reports in the area during each calendar month							
	1958	1959	1960	1961	1962	1963	Total	Average
January	—	4	6	3	5	1	19	3
February	1	1	—	4	5	1	12	2
March	2	2	11	1	5	3	24	4
April	3	2	1	3	—	2	11	2
May	2	1	2	1	1	3	10	2
June	1	—	—	2	1	1	5	1
July	—	—	—	—	—	—	—	—
August	—	—	—	—	—	—	—	—
September	—	—	—	—	—	—	—	—
October	—	1	—	—	—	—	1	—
November	—	2	—	1	2	1	6	1
December	2	—	3	2	2	3	12	2
Total No. of hail reports for each year	11	13	23	17	21	15	100	17

storm activity, the tops of the echoes had penetrated the lower layer of tropopause (base approximately 33,000 ft) while on no occasion they penetrated the upper layer of tropopause (base approximately 50,000 ft).

4.6. It is also seen from Table 1 that during the period May to November, the single layer of tropopause (base approximately 50,000 ft) was observed to have been penetrated by the echo tops on about 14 per cent of the days of extensive thunderstorm activity in the area.

4.7. The above analysis, therefore, reveals that the penetration of tropopause layer by echo tops cannot be used as a useful indicator of the severe weather activity at least in the area around Delhi because no significant increase in severe weather activity is observed when the echo tops reach or penetrate the tropopause.

4.8. Fig. 2 shows that while no hail is reported in the months July through October, the maximum number of hail reports in the area are received in March followed closely by January. The average number of reports during December, February, April and May is even smaller. The minimum number of hail reports is received in June and November—the two months which are on either side of the hail-free months, *viz.*, July through October.

4.9. The analysis of preferred times of hail occurrence in this area reveals (Fig. 3) that mostly hail occurs in the second half of the day, *i.e.*, between noon and midnight. In this period also, the largest number of hail occurrences takes place between 16 and 2000 IST followed closely by the number occurring between 12 and 1600 IST and between 20 and 2400 IST.

5. Acknowledgement

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