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Multiple squalls over central India

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सार – इस शोधपत्र में, दस वर्ष की अवधि अर्थात 1969 से 1978 तक के मध्य भारत (विदर्भ और मध्य प्रदेश) में बहु चंडवातों का विवेचनात्मक विश्लेषण प्रस्तुत किया गया है। बहु चंडवातों की विभिन्न विशेषताओं की जांच की गई और मौसम प्राचलों के साथ उनके सम्बन्ध की चर्चा की गई है।

ABSTRACT. A critical analysis of the multiple squalls over central India (Vidarbha and Madhya Pradesh) for the 10-year period from 1969 to 1978 has been presented in this paper. Various characteristics of the multiple squalls have been examined and their association with weather parameters discussed.

1. Introduction

Multiple squalls is a rare phenomenon and extremely important from aviation point of view. These squalls occur one after another in a short span of time and are generally associated with high speed winds which cause extensive damage to property as well as loss of life. Therefore, records of three principal stations in the central India have been analysed to determine important features of multiple squalls such as expectancy, time of occurrence, direction and speed. The present analysis is based on the data of 38, 14 and 13 multiple squalls recorded at Nagpur (Vidarbha), Bhopal and Jagdalpur (Madhya Pradesh) during the ten-year period from 1969 to 1978.

2. Features of multiple squalls

2.1. *Frequency distribution*

The percentage frequency distribution of multiple squalls in various months of the year is shown in Fig. 1. It is seen that the percentage frequency of squalls progressively increases from February over southeast M.P. where as it increases from March onwards over northwest M.P. and Vidarbha. The peak values are reached in the month of June and thereafter, generally, the activity diminishes. Thus, a wide variability in squalliness during different seasons of the year has been noticed. In central India months of April to June are most favourable for occurrence of multiple squalls every year. The highest numbers of multiple squalls that occur during May at Nagpur, Bhopal and Jagdalpur are 9, 5 and 7 respectively whereas in June on an average 16 and 4 squalls occur at Nagpur and Bhopal. However, squall activity at Jagdalpur is vigorous in the month of April also and on an average 4 multiple squalls occur. It is observed that the period, from August to March, is comparatively calm over the central India.

2.2. *Diurnal variation of squalls*

Fig. 2 shows the histogram of percentage frequency of diurnal variation of squalls in a three-hourly period. It is seen that about 40, 42 and 54 per cent of multiple squalls over Nagpur, Jagdalpur and Bhopal occur during the period from 1500 to 1800 IST. Therefore, the three-hourly period between 1500 & 1800 IST is most susceptible to multiple squalls in the central India. If the period from 1500 to 2100 IST is taken into account most of the multiple squalls occur during this time alone. However, the periods 0300-1200, 0300-0900 and 0000-1200 IST at Nagpur, Jagdalpur and Bhopal respectively are practically free from squalls. Thus, a marked diurnal variation has been noticed in multiple squalls over the central India.

2.3. *Direction of squalls*

The directional distribution of multiple squalls for the ten-year period is given in Table 1. It is observed that on an average 20 per cent of squalls over Nagpur come from NW direction whereas 16 per cent over Jagdalpur and 15 per cent over Bhopal come from NW and N directions respectively. Further, it is noticed that about 45 per cent multiple squalls over Nagpur and Jagdalpur and 52 per cent over Bhopal account for the quadrant W-N in all the months of the year. Banerjee (1961) while studying the thunderstorms over central India observed that the elevated terrain situated to the NW of Nagpur (Panchmarhi hills) is very effective for generating thunderstorms affecting Nagpur in course

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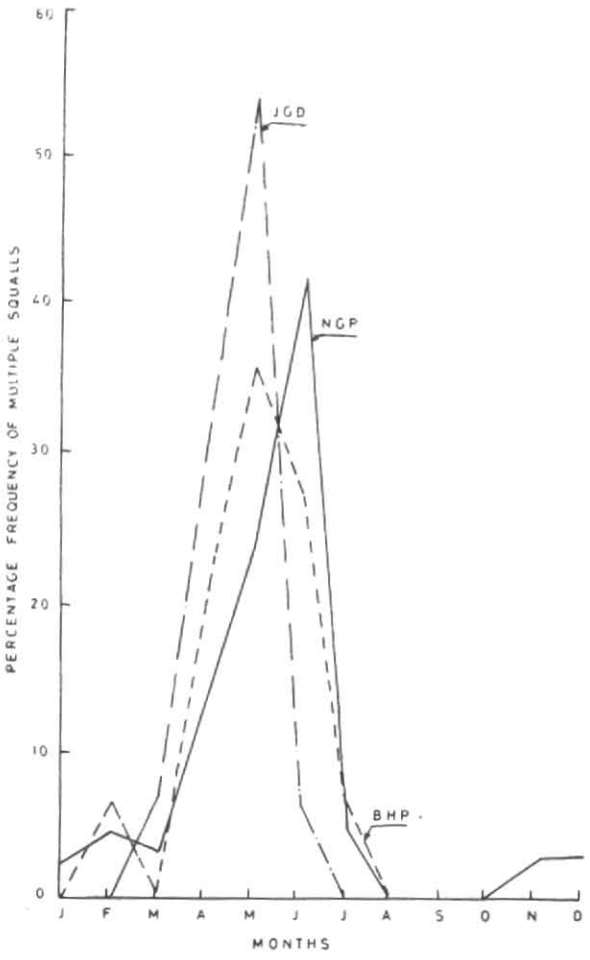

Fig. 1. Percentage frequency of squalls in different months

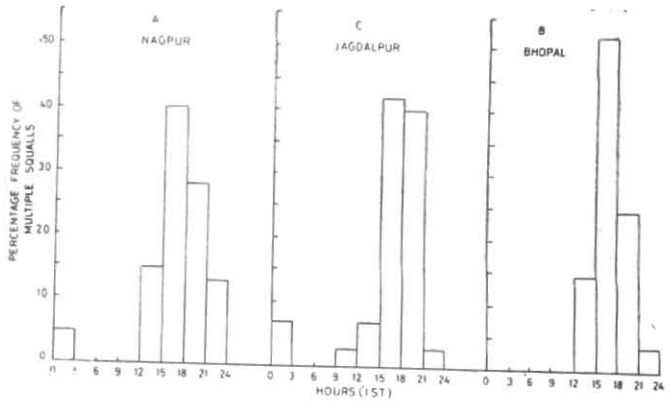

Fig. 2. Histogram of diurnal variation of multiple squalls

TABLE 1

Directional distribution of multiple squalls

Station	Most probable direction of multiple squalls	Percentage (per annum)	Probable quadrant	Percentage
Nagpur	NW	20	W-N	45
Bhopal	N	15	W-N	52
Jagdalpur	NW-N	16	W-N	45

TABLE 2

Directional distribution of multiple squalls for different speed ranges

(Values in percentage)

Station	Speed range (km)				
	35-49	50-64	65-79	80-94	95-109
Nagpur	1	45 (NNW)	32 (N)	18	3
Jagdalpur	—	12 (NW)	9 (N)	—	—
Bhopal	—	21 (N)	40 (NW)	25	—

of their movement towards SE. The above criterion not only holds good for pre-monsoon months but for the entire year also. Generally, the directions of initial and subsequent squalls are different. However, it is interesting to note that the direction of the first and subsequent squalls agreed in 12, 4 and 6 cases over Nagpur, Jagdalpur and Bhopal respectively. A change of direction between 20° and 70° has been noticed in 5, 3 and 1 cases whereas in 7 cases each at Napgur and Jagdalpur and 5 cases at Bhopal a change of 90° has been observed. A dramatic change between 90° and 180° has been observed in 3, 2 and 1 cases at these stations.

2.4. *Direction and speed of multiple squalls*

To study directional distribution of multiple squalls for various speed ranges, the data have been grouped according to different speed ranges and shown in Table 2. It is seen that most of the multiple squalls over Nagpur, Jagdalpur and Bhopal approach from NW-N sector and attain gust speeds between 50 and 79 kmph. On the other hand the frequency of multiple squalls of speed ranges 35-49 and 95-109 kmph and approaching from NW-N sector is insignificant. Pendse *et al.* (1967) observed that the most probable peak speed that a a thundersquall at Nagpur on any day is likely to attain is in the range of 50 to 79 kmph. These results agree well with those obtained for multiple squalls at Nagpur.

2.5. *Maximum speed of multiple squalls*

Fig. 3 shows the histogram for a maximum gust speeds from 35 to 124 kmph at an interval of 15 kmph. It is seen that 44, 12 and 40 per cent of multiple squalls over Nagpur, Jagdalpur and Bhopal respectively occur in the maximum gust speed range of 50-64 kmph.

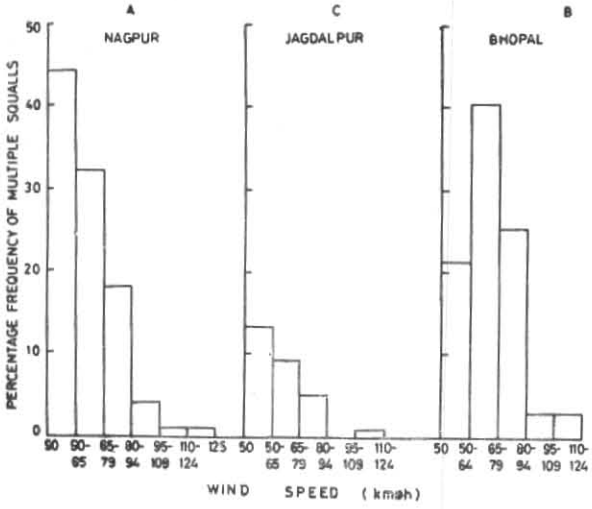

Fig. 3. Maximum gust speed of the multiple squalls

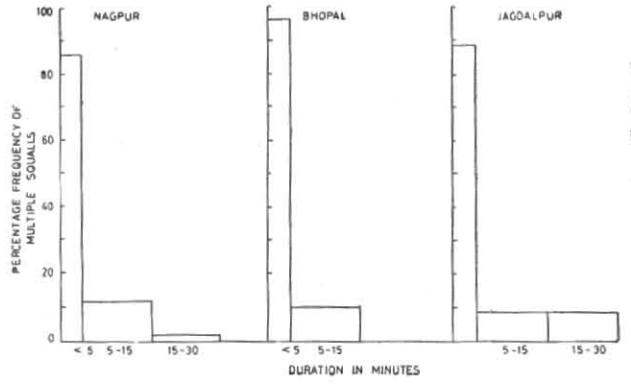

Fig. 4. Histogram of duration of the multiple squalls

It is pertinent to note that during the whole year 19, 8 and 24 per cent of multiple squalls over Nagpur, Jagdalpur and Bhopal respectively reach peak speed of 80 kmph whereas squalls occurring between April to June reach peak speeds of 95 kmph the percentage being 6, 3 and 8. The highest speeds recorded during the period of study are 130 kmph on 6 June 1978 at Nagpur, 114 kmph on 9 May 1978 at Jagdalpur and 120 kmph on 19 May 1971 at Bhopal.

2.6. *Pressure changes in multiple squalls*

The distribution of squalls in relation to pressure rise, fall and no change for each month of the year showed that 45 per cent of multiple squalls over Nagpur and Jagdalpur and 64 per cent over Bhopal are accompanied by pressure rise of less than 1 mb and 13, 22 and 3 per cent by pressure rise of 1 mb. Further, 28, 10 and 8 per cent of squalls over Nagpur, Jagdalpur and Bhopal are accompanied by no change of pressure whereas 13, 23 and 18 per cent squalls are accompanied by pressure fall of 1 mb. Only 1 per cent multiple squalls at Nagpur are accompanied by pressure falls between 1 & 2 mb. For the purpose of record the highest rise of pressure during the period of study are 1.5 mb on 7 March 1978 at Nagpur, 2.6 mb on 2 May 1972 at Jagdalpur and 1.7 mb on 24 April 1972 at Bhopal.

2.7. *Temperature changes in multiple squalls*

Distribution of squalls corresponding to different temperature variation groups each month of the year showed that 71, 73 and 52 per cent of multiple squalls over Nagpur, Jagdalpur and Bhopal are accompanied by temperature falls of less than 6° C whereas 5, 3 and 14 per cent of squalls are accompanied by falls of over 8° C. The highest recorded temperature falls are 10° C on 6 June 1978 at Nagpur, 9.2° C on 2 May 1972 at Jagdalpur and 13.2° C on 19 May 1971 at Bhopal. Only two cases of rise in temperature with the passage of multiple squalls have been reported, *viz.*, on 19 May 1971 at Nagpur a rise of 1.3° C with the peak gust speed of 68 kmph and on 4 April 1974 at Jagdalpur a rise of 2.3° C with the peak gust speed of 53 kmph. On three occasions, no rain, slight rise in wet bulb temperature and fall in pressure, have been reported.

2.8. *Duration of multiple squalls*

Since damage to various structures and vegetation depends on the speed and duration of multiple squalls, the time analysis of squalls has been carried out and shown in Fig. 4. About 85, 93 and 86 per cent of squalls over Nagpur, Bhopal and Jagdalpur last for 5 minutes whereas 13, 7 and 8 per cent last between 5 and 15 minutes. Thus, majority of multiple squalls in the central India last for five minutes only. On the other hand, 2 per cent squalls over Nagpur and 8 per cent over Jagdalpur last between 15 and 30 minutes. Though few in number the high speed squalls at Nagpur are more destructive. Incidently, an examination of a few press reports of extensive damages which occurred in the vicinity of Nagpur showed that the damage was confined to narrow tracts. Eye witness accounts of the associated phenomena matched with those of tornadoes.

2.9. *Relative humidity in multiple squalls*

Table 3 gives the variations in relative humidity due to multiple squalls. From the analysis of humidity data it is seen that fall of 13, 22 and 14 per cent occurs during the passage of multiple squalls at Nagpur, Jagdalpur and Bhopal respectively whereas humidity rise occurs in 71, 51 and 57 per cent cases. However, in 10, 26 and 29 per cent cases no change in humidity has been observed. The highest humidity fall of 23, 20 and 36 per cent occurred on 4 June 1974 at Nagpur, on 15 May 1976 at Bhopal and on 8 May 1969 at Jagdalpur. These observations show that the relative humidity of downdrafts from a thunderstorm cell decreases although they descend in the presence of large concentration of liquid water in the cloud which results in humidity dip at the surface. Byers and Braham (1949) in the report on thunderstorm project attributed humidity dip to desiccation by the cloud precipitation particles and time lag between rate of evaporation of

TABLE 3

Relative humidity variations due to multiple squalls

(Values in percentage)

Station	Fall in humidity	Rise in humidity	No change	Highest fall in humidity
Nagpur	13	71	10	23
Jagdalpur	22	51	26	36
Bhopal	14	57	29	20

TABLE 4

Multiple squalls associated with different weather phenomena

(Values in percentage)

Station	Multiple squalls occurring during thunderstorms			Weather system		Squall	
	Pre-monsoon	Monsoon	Post monsoon	Lopar	Dep. or deep depression	Before ppt	During ppt
Nagpur	80	7	13	24	58	64	20
Jagdalpur	83	5	12	28	57	71	10
Bhopal	78	6	16	25	54	66	15

water drops and increase in the saturation mixing ratio as the down draft descends fast to the lower levels. Mull and Rao (1950) while explaining the origin of the down draft in the thunderstorm cell remarked that fall of ice crystals into regions warmer than the freezing point is responsible for the cooling of the air (evaporational cooling), no moisture is added and the downdraft becomes drier than the environment.

3. Weather phenomena associated with the multiple squalls

It is observed that the multiple squall in the central India are mainly due to the convective activity at or around the station. About 80 per cent of multiple squalls occur during the passage of pre-monsoon thunderstorms where as remaining are associated with monsoon as well as post monsoon thunderstorms (Table 4). Most of the severe squalls originate from the thunderstorm occurring ahead of depression or deep depression. About 80 per cent of multiple squalls occur either before or during the rain.

4. Conclusions

From the foregoing analysis and discussion following conclusions are drawn :

(*i*) The frequency of occurrence of multiple squalls is maximum in the months of May and June at Nagpur and Bhopal whereas it is maximum in April and May at Jagdalpur.

(*ii*) Three-hourly period between 1500-1800 IST is the most favourable period for the development of multiple squalls over the central India.

(*iii*) The most probable direction from which a multiple squall may hit Nagpur on any day is between west and north Jagdalpur between southwest and north and Bhopal between northwest and north.

(*iv*) The most probable maximum gust speed with which a multiple squalls may hit any station in the central India lies in the speed range of 50 to 79 kmph.

(*v*) A rise in pressure and fall of temperature are most prominently manifested in multiple squalls of the central India. There are strong tendencies in multiple squalls producing a pressure rise of less than 1 mb and fall of temperature greater than 1° C, occurring in the month of June at Nagpur and in May at Bhopal and Jagdalpur.

(*vi*) Most of the multiple squalls in the central India last for about five minutes.

(*vii*) Generally, rise in relative humidity associated with multiple squalls occurs either during the rain or just after it.

(*viii*) About 80 per cent of multiple squalls in the central India are associated with the pre-monsoon thunderstorm activity whereas the remaining with thunderstorms occurring during monsoon and post monsoon months.

(*ix*) Madhya Pradesh is less susceptible to severe multiple squalls and their duration is also less than those of Vidarbha.

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