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Squalls at Delhi

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ABSTRACT. The paper gives a number of statistical facts about squalls at Delhi. Change of surface wind direction at the onset of squalls and during their progress and the time taken to reach the peak speed have also been briefly discussed. Squally winds which do not strictly conform to the definition of squall but have all the important features of squall, have also been examined. A list of severe squalls (with peak speed of more than 50 mph) is given in Appendix 1.

1. Introduction

The results contained in this paper have been derived from a study of squalls which were recorded during the 10 years 1943—52, at the meteorological observatory at Safdarjung Aerodrome, New Delhi. The squall data and the associated changes in pressure, temperature and relative humidity were obtained respectively from the records of a Dines P. T. Anemometer (the head of the anemometer being at a height of 65 ft above ground), a daily microbarograph, a bimetallic thermograph and a hair hygrograph installed at the Observatory.

2. Definitions

For the purpose of this study, a squall has been taken to mean a sudden increase of wind speed by at least 3 stages on the Beaufort scale, reaching at least 25 mph and lasting for at least one minute. The time of commencement of a squall has been taken to be the time at which the sudden increase in wind speed occurred and the time of cessation as the time at which the gust velocity decreased to less than 25 mph and remained below it for at least 10 minutes.

3. Monthly distribution of squalls

Table 1 shows the distribution of squalls in different months of the year.

It is seen that

(*i*) About 70 per cent of the squalls occur during the hot season April—June. The months of November and December are practically free from squalls.

(*ii*) As many as 16 squalls have occurred in a month in June and as many as 4 in a single day in April and May. Any month of the year excepting May and June can be free from squalls.

(*iii*) The frequency of squalls progressively increases with the advance of the year reaching a maximum in May and decreases thereafter reaching zero in November.

4. Diurnal distribution of squalls

The diurnal distribution of squalls is shown in Table 2. The figures show the squalls occurring in each three-hour period as a percentage of the total number of squalls in each month.

It is seen from this table that

(*i*) Maximum number of squalls, about 60 per cent, occur between 1500 and 2100 IST, showing that insolation plays an important part in the development of squalls.

(*ii*) The period 0700-1200 IST is practically free from squalls. No squall occurred during the hour 1100-1200 IST and the maximum number of squalls occurred in the hour 1800-1900 IST during the 10 years investigated (Fig. 1).

(*iii*) During the period 1200-1500 IST, there is a progressive increase in the frequency of squalls as the season advances from July to October. This progressively early development of squalls is apparently due to the increased real latent instability available which counterbalances the retarding effect of decreased insolation in this period.

TABLE 1

Month	Number of squalls during										Total No. of squalls	Monthly percentage	Max. No. of squalls in a day	Average No. of days of squall	Max. No. of days of squall
	1943	44	45	46	47	48	49	50	51	52					
Jan	0	1	0	0	1	0	0	2	0	0	4	1·3	2	0·3	1
Feb	0	3	0	1	0	0	1	0	0	1	6	2·0	1	0·6	3
Mar	0	9	1	0	2	0	0	2	2	7	23	7·7	2	1·8	7
Apr	5	6	5	2	1	1	1	0	11	4	36	12·0	4	2·6	8
May	7	2	15	6	9	10	11	8	7	12	87	29·1	4	5·7	8
Jun	12	16	4	6	5	7	6	7	5	12	80	26·7	3	5·9	11
Jul	6	2	0	2	2	8	2	1	4	3	30	10·0	2	2·8	8
Aug	1	1	2	1	0	0	1	1	3	2	12	4·0	1	1·2	3
Sep	1	1	3	0	3	0	2	0	1	0	11	3·6	2	0·9	3
Oct	0	2	1	0	2	4	0	0	0	0	9	3·0	2	0·7	3
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	1	0	0	0	0	0	0	1	0·3	1	0·1	1
Total	32	43	31	19	25	30	24	21	33	41	299				

TABLE 2

Month	Hours (IST)								Total No. of squalls
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	
	Percentage								
Jan	25·0	25·0	0	0	0	25·0	25·0	0	4
Feb	0	0	50·0	0	0	0	33·3	16·7	6
Mar	21·7	4·3	4·3	0	4·3	17·4	30·4	17·4	23
Apr	8·3	11·1	5·5	0	2·8	30·5	36·1	5·5	36
May	5·7	9·2	2·3	1·1	19·5	24·1	24·1	13·8	87
Jun	11·3	6·3	2·5	0	5·0	33·7	23·7	17·5	80
Jul	0	6·7	0·0	6·7	10·0	46·7	26·7	3·3	30
Aug	0	0	0	0	16·7	50·0	25·0	8·3	12
Sep	9·1	18·2	0	0	18·2	36·4	18·2	0	11
Oct	0	11·1	0	0	22·2	55·5	0	11·1	9
Nov	—	—	—	—	—	—	—	—	0
Dec	—	100·0	—	—	—	—	—	—	1
Percentage frequency for the year as a whole	8·0	7·7	3·0	1·0	10·7	31·1	26·1	12·0	299
Percentage frequency for squalls of 50 mph or more	4·3	4·3	3·0	0	10·0	27·1	31·4	20·0	70

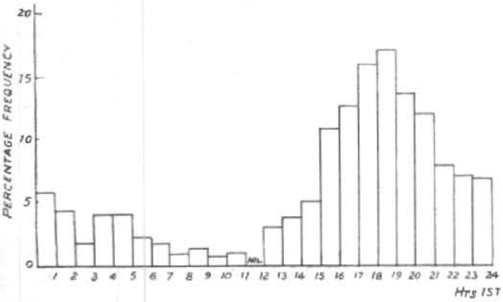


Fig. 1. Diurnal distribution of squalls at Delhi

Note: A squall with a period spreading over, say 3 hrs, has been taken to belong to all the three hours

(*iv*) Squalls occurring late in the evening are generally severer than those occurring at other times. One out of every three squalls in the period 1800–2400 IST, one out of every five during 1200–1800 IST and only one out of every eight in the period 0000–0600 IST, attain peak velocity of 50 mph or more.

5. Direction of squalls

The percentage frequencies of the number of occasions on which squall occurred from different directions* are given in Table 3.

It can be seen from this table that

(*i*) 80 per cent of the squalls during the year come from SW to N, 66 per cent from SW to NW and 47 per cent (almost half the total number) from W to NW.

(*ii*) The frequency of squalls from W to NW is highest in winter months (Dec–Feb) and lowest in the monsoon period.

(*iii*) Squalls from NE to SE occur mostly in the monsoon months and are completely absent in the winter months (Dec–Feb).

(*iv*) Squalls from SW to NW are generally severer, more than 25 per cent of these having peak velocity of 50 mph or more ; 20 per cent of the squalls from N and NE and less than 7 per cent from E to S attain velocity of 50 mph or more.

6. Speed of squalls

The percentage frequencies of the number of occasions on which the maximum speed of squalls was within certain limits are given in Table 4.

It is seen that

(*i*) More than 70 per cent of the squalls have peak speeds between 30 and 50 mph ; 40-50 mph is the most frequent speed from March to July during which period most of the squalls occur.

(*ii*) Hot season squalls are generally severer and monsoon and winter squalls comparatively milder.

7. Duration of squalls

The percentage frequencies of the number of occasions when duration of squalls was within certain limits are given in Table 5.

It is seen from this table that

(*i*) 50 per cent of the squalls last 20 minutes or less, 65 per cent 30 minutes or less and 85 per cent 1 hour or less.

(*ii*) Squalls of unusually long duration (1 hour or more) occur mostly in the hot season. Winter squalls are particularly short-lived.

(*iii*) The duration of late afternoon and evening squalls is generally larger and that of morning and forenoon squalls comparatively smaller.

8. Change of wind direction

The percentage frequencies of the change of surface wind direction which occurred at the time of approach of squalls and during their progress, are shown in Table 6.

Except for a few occasions, ground wind direction changes at the approach of squalls and the chances of it changing clockwise and anti-clockwise are equal. One out of every five squalls changes direction during the time of its occurrence. Such squalls would be particularly hazardous to any aeroplane landing ; veering or backing of as much as 145° has been noticed during their progress.

* An occasion of squall from WNW has been taken as ½ from W and ½ from NW

TABLE 3

Month	N	NE	E	SE	S	SW	W	NW	Total No. of squalls
					Percentage				
Jan	0·0	0·0	0·0	0·0	0·0	0·0	37·5	62·5	4
Feb	8·3	0·0	0·0	0·0	16·7	25·0	25·0	25·0	6
Mar	6·5	0·0	2·2	8·7	4·3	26·1	19·6	32·6	23
Apr	3·5	1·0	0·0	5·5	1·4	18·1	26·4	36·1	36
May	18·0	5·8	0·6	0·0	5·8	26·2	11·6	32·0	86
Jun	19·4	8·7	1·3	5·0	3·1	16·9	13·1	32·5	80
Jul	8·3	8·3	8·3	15·0	11·7	11·7	15·0	21·7	30
Aug	8·3	16·7	29·2	12·5	0·0	0·0	0·0	33·3	12
Sep	4·5	18·2	9·1	0·0	0·0	27·3	18·2	22·7	11
Oct	22·2	11·1	0·0	0·0	16·9	5·5	16·7	27·8	9
Nov	—	—	—	—	—	—	—	—	0
Dec	0·0	0·0	0·0	0·0	0·0	0·0	50·0	50·0	1
Percentage frequencies for the year as a whole	14·3	6·8	3·0	4·7	5·0	19·1	15·4	31·6	298
Percentage frequencies for the year as a whole for squalls of 50 mph or more	13·0	5·8	0·0	2·2	1·4	20·3	18·8	38·4	69

TABLE 4

Month	Speed in mph					Max. speed reached	Total No. of squalls
	25-29	30-39	40-49	50-59	60-70		
			Percentage				
Jan	0·0	100·0	0·0	0·0	0·0	37	4
Feb	0·0	33·3	50·0	16·7	0·0	50	6
Mar	4·3	26·1	47·8	17·4	4·3	63	23
Apr	2·5	25·0	50·0	22·2	0·0	58	36
May	4·6	26·4	37·8	21·8	9·2	70 (on 25-5-45)	87
Jun	5·0	28·7	40·0	20·0	6·3	68	80
Jul	3·3	26·7	53·3	16·7	0·0	54	30
Aug	16·7	41·7	33·3	8·3	0·0	54	12
Sep	0·0	63·6	27·3	9·1	0·0	52	11
Oct	0·0	44·4	44·4	11·1	0·0	50	9
Nov	—	—	—	—	—	—	0
Dec	0·0	100·0	0·0	0·0	0·0	37	1
Percentage frequencies for the year as a whole	4·4	30·8	41·5	18·7	4·7		299

TABLE 5

Month	Duration (in minutes)											Maximum duration	Total No. of occasions
	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	>100		
	Percentage												
Jan	100·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	10	4
Feb	50·0	33·3	16·7	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	21	6
Mar	21·7	17·4	8·7	17·4	13·0	0·0	8·7	4·3	8·7	0·0	0·0	85	23
Apr	41·7	16·7	19·4	8·3	5·5	0·0	0·0	5·5	0·0	0·0	2·8	155	36
May	32·2	11·5	14·9	14·9	8·0	2·3	2·3	0·0	4·6	2·3	6·9	145	87
Jun	23·7	20·0	10·0	8·7	6·3	5·0	2·5	5·0	7·5	3·7	7·5	142	80
Jul	36·7	26·7	13·3	13·3	3·3	0·0	0·0	3·3	0·0	0·0	3·3	135	30
Aug	25·0	33·0	25·0	0·0	8·3	8·3	0·0	0·0	0·0	0·0	0·0	60	12
Sep	36·4	27·3	9·1	27·3	0·0	0·0	0·0	0·0	0·0	0·0	0·0	40	11
Oct	44·4	22·2	22·2	0·0	0·0	0·0	0·0	0·0	0·0	0·0	11·1	137	9
Nov	—	—	—	—	—	—	—	—	—	—	—	—	0
Dec	100·0	—	—	—	—	—	—	—	—	—	—	—	1
Percentage frequencies for the year as a whole	32·1	18·4	13·9	11·4	6·6	2·3	2·0	2·6	4·0	1·7	5·0		299

TABLE 6

Nature of wind shift	Percentage frequencies of total number of occasions	
	At approach	During progress
Veering	52	12
Backing	45	9
No change	3	79

9. Peak velocity of squalls

About 70 per cent of the squalls attain peak velocities within 10 minutes of the time of commencement, a considerable number of these attaining the peak almost instantaneously. The number of squalls taking more than half an hour to attain peak velocity is small, *viz.* 4 per cent, such squalls occurring mainly during hot season. Winter squalls, in particular, take less time to reach peak velocity. In a few squalls, mostly of the hot weather, and occurring during afternoon or evening, peak velocity is reached more than once.

10. Multiple squalls

There were a number of occasions during the hot season, particularly in the afternoon or evening, when two, three or four squalls occurred in quick succession. Such squalls, known as Multiple Squalls, came from same or different directions and with random speeds. For example, on 24 April 1952, a series of four squalls commenced at 1500 IST; the first came from N with peak velocity of 39 mph, second from N with 50 mph at 1520 IST, third from WNW with 56 mph at 1745 IST, and the fourth from SW with 46 mph at 1955 IST. On 29 May 1952, a double squall occurred with peak velocities of 58 mph at 1250 IST and 40 mph at 1320 IST from diametrically opposite directions N and S respectively. Obviously such squalls are particularly dangerous, the forecaster not knowing how many of the series are going to occur and what will be the period of lull between two members. Such squalls occurred on 30 per cent of the squally days during the hot season, April to June.

11. Pressure changes associated with squalls

Number of occasions of pressure rise, fall, both rise and fall, and insignificant or no change of pressure, are tabulated below as percentages of the total number of occasions.

TABLE 7

Rise	Fall	Both rise and fall	Little or no change
62	2	7	29

(*i*) The rise of pressure in squalls is most predominant and cases of fall of pressure are very few. The biggest rise of 6·2 mb occurred in a squall on 31 May 1949 and highest fall of 3·5 mb on 4 June 1952.

(*ii*) In one out of every 3 squalls there was no change in pressure.

(*iii*) In about 5 per cent of the squalls, pressure fell immediately before the commencement of the squalls. The largest of such fall of pressure was 1·3 mb on 14 March 1950.

(*iv*) In a few cases rise of pressure was noticed immediately before the main squall and no change occurred during the squall. The highest of such rise was 1·5 mb on 1 August 1946.

(*v*) The following variations of pressure associated with squalls have also been noticed :

(1) Rapid rise of pressure followed by rapid fall during the progress of the squall, rise and fall being so quick some time that only a single vertical line was traced on the barogram.

(2) Rapid rise during the period of the squall and rapid fall immediately after the squall.

(3) Rise at the commencement of squall and no change or fall at the time when peak was being reached.

(4) No change or fall at the commencement of squall and at the time of peak and rise thereafter.

(5) Rise and fall occurring alternately so that a wavelike curve is traced (Fig. 2).

(6) In the case of multiple squalls, every squall of the series did not cause a fresh rise of pressure nor did the first one cause always the most significant change.

The percentage frequencies of the number of occasions when pressure change was within a certain limit, are given in Table 8.

It is seen that

(*i*) In about 40 per cent of the squalls, pressure rises only by 0·5 mb or less. Pressure rise of more than 2 mb takes place only in 20 per cent of the squalls and is mostly associated with hot season squalls ; exceptionally high rise of pressure, more than 4 mb, occurring only in the hottest months of May and June. Generally speaking, the extent of pressure rise during squalls increases as the season advances reaching a maximum in May, as in the case of the velocities of squalls.

TABLE 8

Month	Pressure change in mb 0·5 or less	0·6—1·0	1·1—2·0	2·1—3·0	3·1—4·0	more than 4	Total number of squalls
	Percentage						
Jan	75·0	0·0	25·0	0·0	0·0	0·0	4
Feb	33·3	0·0	66·6	0·0	0·0	0·0	6
Mar	39·1	30·4	21·7	0·0	8·7	0·0	23
Apr	36·1	27·8	19·1	17·1	2·9	0·0	36
May	32·6	12·8	27·9	15·1	4·7	7·0	86
Jun	35·0	13·7	30·0	11·2	0·0	10·0	80
Jul	50·0	10·0	23·3	10·0	6·7	0·0	30
Aug	50·0	25·0	25·0	0·0	0·0	0·0	12
Sep	72·7	18·2	9·1	0·0	0·0	0·0	11
Oct	33·3	33·3	22·2	0·0	11·1	0·0	9
Nov	—	—	—	—	—	—	0
Dec	—	—	—	—	—	—	1
							Total 298
Percentage frequencies for the year as a whole	39	17	26	11	3	5	

(*ii*) The percentage frequencies of rise of more than 1 mb, in respect of different limits of squall velocities, are as given in Table 9.

TABLE 9

Velocity (mph) 25-30	31-40	41-50	51-60	61-70	Total No. of squalls
23	33	46	70	90	297

This shows that, in general, smaller pressure rise is associated with squalls of smaller speed and higher pressure rise with squalls of higher speed. But pressure rise is not proportional to the velocity of squall and there are a number of cases when only slight rise occurs during severe squalls and comparatively larger rise in minor squalls.

Examples :

Date	Period of squall (IST)	Velocity of squall (mph)	Pressure change (mb)
14-6-45	1505-1515	68	Rise 0·5
1-6-49	2140-2200	29	Rise 1·5
10-5-52	2340-0010	40	Rise 3·0

(*iii*) In squalls associated with duststorms, pressure rise was generally smaller than in those associated with thunderstorms. In 60 per cent of the thundersqualls, pressure rise was more than 1 mb while in only 40 per cent of the duststorm squalls pressure rise was more than 1 mb. This is as is to be expected because of the larger amount of suspended and falling water associated with the thunderstorm.

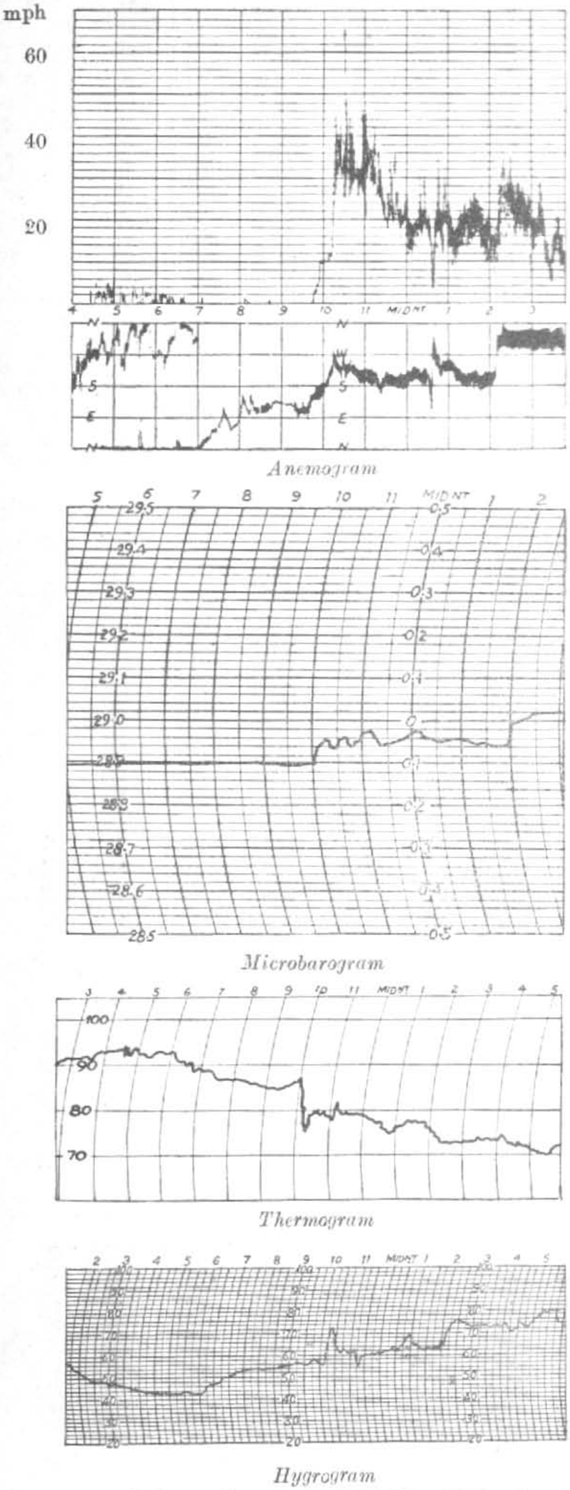


Fig. 2. Self-recording charts of 21 May 1946 when a thundersquall occurred at Delhi

12. Change of temperature

(*a*) The number of occasions of change of temperature during squalls worked out as percentage of the total number of squalls is as shown in Table 10.

TABLE 10

Fall	Rise	Both rise and fall	No change
70	10	11	9

The highest fall of 25°F was recorded on 25 September 1951 and 26 May 1949. The highest rise of 11°F occurred on 9 June 1943 in a thundersquall following thunder and heavy rain which had caused considerable fall of temperature; the rise occurred at the onset of squall and was abrupt. Another sharp rise of 8°F was recorded on 16 June 1945 in a duststorm with peak velocity of 62 mph (Fig. 3).

Fall of temperature in a squall is the most common occurrence. Rise of temperature occurs in a few squalls. Out of 27 cases of rise of temperature, 24 occurred before 0600 or after 1800 IST. On most of these occasions either ground inversion was present as seen from the radiosonde ascent prior to the time of squall or rain had fallen or a squall associated with fall of temperature had occurred immediately before it. There is no relation between change of pressure and change of temperature. Fall of temperature has been seen both with rise and fall of pressure and *vice versa*; temperature changes have occurred without changes in pressure and *vice versa*.

(*b*) The monthly percentage frequencies of fall of temperature of various values are given in Table 11.

It is seen that

(*i*) In 44 per cent of the squalls, fall of temperature is 5°F or less. There are only 25 per cent of the squalls causing a fall of temperature of more than 10°F. Temperature fall of more than 15°F occurs mostly in the hot season or monsoon season.

(*ii*) The frequency of occasions of fall of temperature of more than 10°F increases as the season advances reaching a maximum in May, then falls reaching a minimum in August and then rises again. This corresponds directly to the normal mean lapse rates, between 1·5 km and 6·0 km, over Delhi which increase and decrease similarly.

13. Change of relative humidity during squalls

Variations of relative humidity during squalls are similar to temperature variations and are as given in Table 12.

14. Weather during squalls

The number of occasions when thunderstorm, duststorm, rain etc occurred during the *period of squalls* is given in Table 13.

It is seen that

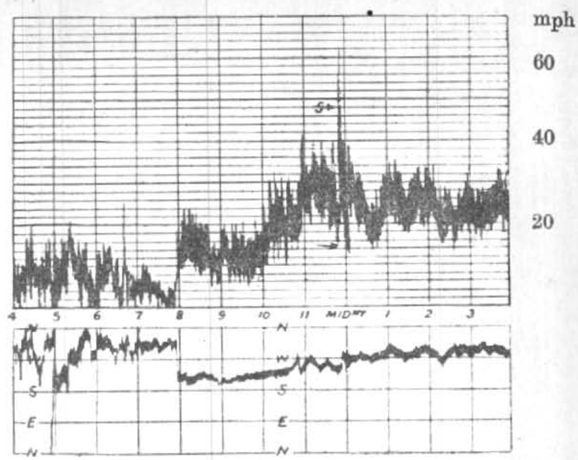
(*i*) More than 70 per cent of the squalls are accompanied with thunderstorms, duststorms or both.

(*ii*) Frequency of squalls associated with duststorms is highest in the hot season, small in the monsoon season and nil in the winter months (Dec—Feb). The frequency of these squalls is usually less than that of thundersqualls but is very close to the latter during May, June and July.

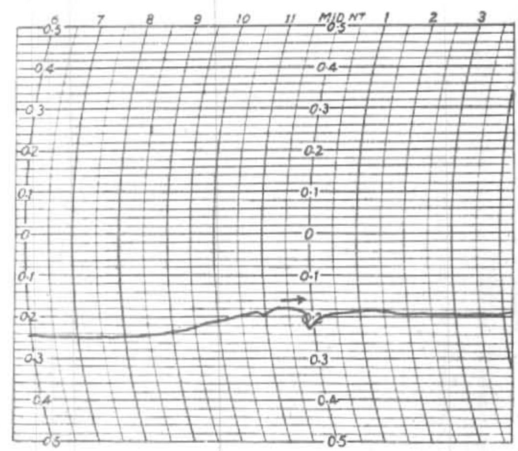
(*iii*) Almost all the rain squalls were associated with *Cb* clouds and in some cases thunderstorm preceded or followed the squall. A few squalls occurred when only large *Cu* was present.

(*iv*) The severe squalls with peak speed of more than 50 mph were all associated with duststorms and or thunderstorms. During most of the rain squalls or squalls associated with *Cb* or large *Cu* only, peak velocity was less than 40 mph.

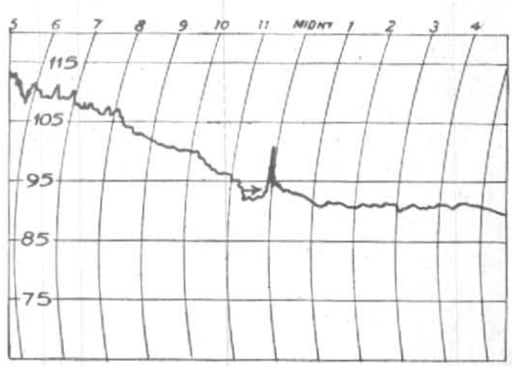
(*v*) The 7 squalls mentioned under 'other cases' were all minor squalls and occurred during night or early morning. No *Cb* or large *Cu* cloud was reported on these occasions. In 3 cases clouds were reported at the time of squall (rugged clouds of bad weather in two cases and in the third case *Cb* was reported after two hours) and it is



Anemogram



Microbarogram



Thermogram

Fig. 3. Self-recording charts of 16 June 1945 when a duststorm occurred at Delhi

TABLE 11

Month	Temperature fall in °F Insignificant	1-5	6-10	11-15	16-20	21-25	Total No. of observations
			Percentage				
Jan	0·0	50·0	50·0	0·0	0·0	0·0	2
Feb	50·0	50·0	0·0	0·0	0·0	0·0	4
Mar	18·7	56·3	18·7	6·3	0·0	0·0	16
Apr	14·3	53·6	10·7	17·9	3·6	0·0	28
May	13·8	32·3	18·5	18·5	10·8	5·9	65
Jun	9·1	25·8	34·8	21·2	1·5	7·6	66
Jul	0·0	20·8	62·5	8·3	4·2	4·2	24
Aug	14·3	14·3	71·4	0·0	0·0	0·0	7
Sep	0·0	30·0	50·0	0·0	10·0	10·0	10
Oct	12·5	37·5	12·5	37·5	0·0	0·0	8
Nov	—	—	—	—	—	—	—
Dec	—	—	—	—	—	—	—
							Total 230
Percentage frequencies for the year as a whole	10·4	33·5	30·4	16·1	4·8	4·8	

presumed that either *Cb* cell was embedded in them or was present in the neighbourhood. On three occasions rise of pressure (abrupt rise of 0·7 mb on two occasions) together with temperature changes (rise of 5°F in two cases and fall of 2·5°F in the third) occurred at the time of squall. On the seventh occasion clear sky was reported and no change in pressure occurred (thermogram for the day was not available). An examination of the radiosonde ascents on the day of squall and a day before the squall did not indicate that sinking cold air could have caused the squall according to Margule's theory of liberation of energy by vertical interchange of air masses.

TABLE 12

Rise	Fall	Both rise and fall	No change
65	8	12	15

15. Squally winds

There were a number of occasions (Table 14) when associated with duststorms and thunderstorms etc, change of wind direction occurred but the wind speed did not rise suddenly by 3 stages on the Beaufort scale, strictly according to the definition of squall. The wind speed rose gradually and reached the speed of 25 mph in 5-10 minutes or sometimes took even much more time. Such winds closely resemble squalls and cause changes of pressure, temperature and humidity similar to typical squalls.

16. Taking squalls and squally winds together the average number of days of these in each month is as follows :—

Jan	Feb	Mar	Apr	May	Jun	Jul
0·4	0·8	2·2	3·5	6·6	7·1	4·1

Aug	Sep	Oct	Nov	Dec	Total
1·6	1·5	0·9	0·0	0·1	28·8

Average number of days in the year on which thunderstorms were accompanied with typical squalls is 11·6, the number being 15·0 for squalls and squally winds taken together. It is seen from the I.M.D. Aviation Climatological Tables that the average number of days of thunderstorms in the year for Delhi is 35. As such only one third of the thunderstorms are associated with typical squalls and more than half do not cause squalls or squally winds. The number of thunderstorms causing squalls or squally winds is least in monsoon and winter months and largest in the hot season.

17. Details of severe squalls (with peak speeds higher than 50 mph) which occurred during the period under investigation are tabulated in Appendix 1.

TABLE 13

Month	Thunder-storm	Dust-storm	Both dust-storm and thunder-storm	Rain	*Cb* and large *Cu*	Other cases	Total No. of squalls
Jan	1	0	0	0	2	1	4
Feb	3	0	0	0	3	0	6
Mar	12	4	4	0	2	1	23
Apr	18	9	2	3	3	1	36
May	25	16	25	1	17	3	87
Jun	24	23	16	6	10	1	80
Jul	4	5	5	8	8	0	30
Aug	4	1	0	4	3	0	12
Sep	4	0	1	5	1	0	11
Oct	5	1	0	1	2	0	9
Nov	—	—	—	—	2	—	0
Dec	1	0	0	0	0	0	1
Total	101	59	53	27	52	7	299
Percentage	(34)	(20)	(18)	(9)	(17)	(2)	

TABLE 14

Percentage number of occasions of squally winds associated with					
Thunder-storms	Dust-storms	Both dust-storms and thunder-storms	Rain	*Cb* and large *Cu*	Total number of occasions
40	14	6	21	18	97

APPENDIX 1

Severe squalls at Delhi

(Peak velocity of more than 50 mph)

S. No.	Date	Time of commencement (IST)	Duration (min)	Peak velocity (mph)	Time of peak vel. (IST)	Rise in vel. (mph)	Dir. of squall	Dir. of wind before squall	Associated weather	Maximum change at a time in: Pressure (mb)	Temperature (°F)	Relative humidity (%)	Remarks
1	9-6-43	2136	5	52	2138	43	SE	NNW	TS*(2125–2215)	−1·0	+11	−30	
2	20-6-43	1950	70	60	1950	53	WNW	SW	DS*(1945–2055)	+0·4	−8	+12	
3	23-6-43	2240	85	54	2242	44	NW	W	DS(2245–0020)	+1·0	−6	+10	
4	30-6-43	1855	45	52	1858	39	NNW	NW	DS(1855–1945)	+1·6	−11	+20	
5	12-3-44	2106	38	54	2114	44	W	NW	TS(2035) DS/TS (2055–2155)	+0·7 +1·6	−6 −3·5	+8 +6	
6	14-3-44	1905	67	63	1905	58	SW	SE	TS(2245–0020)	+1·0	−4·5	+7	Pressure and temperature fluctuating
7	2-4-44	0323	78	52	0326	52	WNW	ESE	DS(0325–0445)	+2·0 (abrupt)	−4·5	+22	
8	3-4-44	1720	5	54	1724	44	NW	S	TS(1620–1840) TS(1630–1715)	+1·1 (abrupt)	−11	+24	
9	4-6-44	0102	88	53	0102	43	NE	WSW	DS(0100–0230) TS(0300)	+2·7	−22·5	36	
10	4-6-44	2300	98	57	2325	54	NW	ENE	TS	+2·2	−13	+33	Pressure rose later
11	10-6-44	1751	80	58	1818	50	WNW	NNW	DS(1740–1935) Shower (1915–1917)	+0·7	−9·5	+9	
12	24-6-44	2318	22	55	2324	49	NW	SW	DS/TS(2325) TS with rain (2400—0040)	+4·8	−21	+59	Pressure fell immediately. Changes rapid
13	11-5-45	1755	25	52	1803	40	WSW/SW	WNW	DS(1745–1815)	Nil	−3·5	+2	
14	13-5-45	1215	7	54	1217	48	SW	WNW	DS(1205–1305)	+2·5	−30	No change	
15	13-5-45	1230	7	51	1232	51	N	NW	TS(1235–1305)	+1·5	−8	+5	
16	20-5-45	1756	85	58	1758	36	NW/WNW	NNW	DS(1815–2000)	+1·4	−9	+6	Pressure and humidity rose further later
17	20-5-45	2155	40	60	2203	44	..	..	TS(2140–2240) Drizzle (2250–2305)	+2·4 (rapid)	−10	+30	
18	22-5-45	0604	35	54	0614	46	WNW to NW	N	TS with rain (0620—0750) Rain drizzle (0545–0515)	+1·7 (abrupt)	−7	+22	
19	25-5-45	1923	45	70	1928	66	NW/WNW	NNW	DS(1915–1940) TS(1935–2040)	+3·7 (rapid)	−11	+14	
20	26-5-45	1710	20	51	1710	35	SW	W	DS(1710–1730)	Nil	Nil	Nil	
21	14-6-45	1505	10	68	1510	50	N backing to NW	NW	DS(1510–1535)	+0·5	−14	+6	

*TS—Thunderstorm DS—Duststorm

APPENDIX 1—(*contd*)

S. No.	Date	Time of commencement (*IST*)	Duration (*min*)	Peak velocity (*mph*)	Time of peak vel. (*IST*)	Rise in vel. (*mph*)	Dir. of squall	Dir. of wind before squall	Associated weather	Maximum change at a time in: Pressure (*mb*)	Temperature (*°F*)	Relative humidity (%)	Remarks
22	16-6-45	2352	38	62	2354	52	WNW	WSW	DS(2400–0015)	−1·3 (abrupt)	+ 8	−4	
23	24-9-45	0355	42	52	0425	36	SE	NE	TS(0350–0700)	+ 0·6	− 4	−4	
24	20-5-46	1430	90	54	1430	42	W backing to SW	WNW	DS(1430–1530) TS(1530–1545)	+ 1·4	−10	+ 10	
25	21-5-46	2205	145	66	2230	56	W backing to SSW	S	TS(2218) TS(2225–2356)	+ 1·7	−11	+ 17	Rapid oscillation of pressure and temperature
26	22-5-46	2045	120	60	2045	50	N backing to WNW	WNW	DS(2045–2130) Drizzle (2038–2040) Rain (2145)	+ 5·4	−12	+ 24	Rapid oscillation of temperature
27	5-6-46	2150	12	54	2152	48	W backing to SW	NNW	DS(1520–1915)	Nil	Nil	Nil	
28	1-8-46	1510	28	54	1513	44	NNE veering to SSE	SE	TS(1525–1850) Rain(1515–1910)	+ 1·5	−10	+ 22	
29	18-3-47	1802	3	57	1802	49	NW	S	DS(1810–1820) TS(1810–2400)	+ 0·7	Nil	Nil	
30	20-4-47	1832	10	58	1833	58	SW veering to NW	SE	TS with rain (1840–1930)	+ 0·7	− 7	+4	
31	25-5-48	1750	40	61	1758, 1805	53	NNW veering to NE	NNE	DS(1808–1850)	+ 2·7 (abrupt)	−13	+ 8	
32	26-5-48	1710	20	60	1711	60	SW	WSW	DS(1710–1715) TS(1705–1718) Rain (1718–1735)	+ 2·8 (rapid)	−18	+ 22	
33	1-6-48	1602	80	63	1627	53	N	NNW	DS(1620–1645) TS(1635–1900) Rain(1658–1705)	+ 5·4	− 6 − 5	+2	Temperature fluctuating
34	12-5-49	1945	27	54	1950	44	NW	E	DS/TS(1940–1958)	+ 5·5	−14	+ 32	
35	20-5-49	0032	95	53	0047	53	NNW	ESE	DS(0035) TS(0015–0200) Rain(0110–0200)	+ 1·5	− 9	Nil	
36	26-5-49	1750	35	55	1815	54	SW	ESE	DS(1745–1815) TS(1815–1850)	+0·5	−24	+ 57	
37	31-5-49	1300	55	58	1307	58	NW/ WNW	SE	TS(1240) DS/TS(1315–1324)	+ 6·2	−13	+ 15	
38	3-7-49	1620	135	53	1635	53	S	NNW	DS(1630–1640) Rain (1705–1720)	+ 0·7	−20	+ 14	
39	14-3-50	2248	67	57	2253	47	WNW	ESE	TS(2230–0150) DS(2255–2305)	+ 4	+ 3·5	—23	
40	20-5-50	1655	145	68	1729	68	WNW backing to SW	N	DS(1650–1900)	−4·5	−4·5	—8	Pressure rose earlier

APPENDIX 1—*(contd)*

S. No.	Date	Time of commencement (IST)	Duration (min)	Peak velocity (mph)	Time of peak vel. (IST)	Rise in vel. (mph)	Dir. of squall	Dir. of wind before squall	Associated weather	Maximum change at a time in, Pressure (mb)	Temperature (°F)	Relative humidity (%)	Remarks
41	30-4-51	2145	155	52	2150	35	W backing to SW	WSW	DS(2150–0130)	+ 0·5	− 3	+ 12	
42	1-5-51	1825	110	56	1855	46	SW backing to SE	SSW	TS(1750–1900) Drizzle(1750–1835) Shower(1835–1845)	−3·5 (rapid fall)	−18	+ 42	Pressure rose earlier
43	29-5-51	1215	15	58	1220	48	N	NE	TS(1240–1500) Rain (1205–1235)	Nil	−17	+ 21	Changes abrupt
44	17-6-51	1745	75	52	1824	46	WNW/NW	WSW	DS(1745–1840)	+0·5	− 5	—10	
45	18-6-51	1650	135	52	1651	48	SW/WSW	NNW	DS(1650–1735)	+ 1·0 (rapid)	− 9	+ 20	
46	3-7-51	1508	43	54	1512	44	N/NNE	WSW	TS/DS(1515-1535) Shower(1515-1518)	+ 1·2	−15	+ 27	
47	24-4-52	1745	30	56	1750	38	NW	WNW	TS(1430–2045) Rain shower (1445–1455)	+ 1·2	Nil	Nil	
48	4-5-52	1615	19	65	1630	53	W	SW	TS(1555–2005) DS(1610–1630) Rain shower (1622–1700)	+ 1·7	−21	+ 39	
49	11-5-52	0327	40	55	0336	45	NW	NE	TS(2353(10th)–0720) Rain (0345–0400)	+ 2·5	− 9	+ 29	
50	31-5-52	1337	40	58	1345	42	WSW	NW	TS/DS(1335–1350) TS with rain (1400–1402)	−1·0	..	} + 38	
51	31-5-52	1507	33	56	1515	49	NW	N	TS with rain (1442–1448)	Rise and fall 1 mb	..		
52	2-6-52	2141	111	55	2206	51	ESE	ENE	DS/TS(2143–2300)	+ 3·2	−16	+ 62	
53	4 6-52	0058	37	54	0105	47	N veering to NE	SE	TS with rain (2318(3rd)–2320) TS with rain (0105–0109)	+ 2	−2·5	+ 12	
54	6-6-52	2215	80	59	2225	54	NW veering to N	SW	DS/TS(2220–2230) TS(2310)	+ 1·7 at 2212	− 8	Nil	
55	29-6 52	1630	10	68	1635	67	NW	SE	TS with rain (1640–1732)	+ 3·0	−15	+ 22	Changes abrupt