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Squalls at Bangalore

K. SOUNDARA RAJAN

Meteorological Office, Airport, Madras

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ABSTRACT. A study of the squalls at Bangalore has been made from analysis of the autographic records of the Central Observatory, Bangalore, and their statistical feature discussed in this paper.

1. Introduction

A study of the characteristics of the surface squalls at Bangalore has been attempted in this paper. Statistical analysis regarding monthly frequency, diurnal variation, maximum speed etc, together with changes in pressures and temperatures associated with the incidence of squalls, has been made, based on the data from self-recording instruments at the Central Observatory, Bangalore during a period of 20 years (1937-1958) excluding the years 1944-45, for which the D.P.T. anemograms are not available. The Central Observatory is located in the city at a distance of 5-7 miles to the westnorthwest of the HAL airfield at Bangalore.

1·1. *Data*—For the purpose of this study, a squall has been taken to mean a sudden increase in wind speed by at least three stages in B.F. scale, reaching 28 mph (45 kmph) or more and lasting for at least one minute. A squall of 40 mph (64 kmph) or more is considered as severe. The autographic records of D.P.T. anemographs, as well as those of Photo barograph and Photo thermograph for the period 1937-1951 (April) and of Friez microbarograph and S. & M. thermographs from May 1951 to 1958, have been made use of, for the analysis. Owing to the proximity of the airfield at HAL to the Central Observatory in Bangalore City, the squall analysis on the basis of records at the Central Observatory, is assumed to apply to the airfield at HAL. Results of the analysis are summarised and discussed below.

2. Results and Discussions

2·1. *Monthly frequency of squalls*—Monthly distribution of surface squalls for the different years is given in Table 1. The data relating to the maximum number of days of squall in different months, the average number of days of squall and the percentage frequency of squalls with reference to the annual total, given in Table 1, are shown graphically in Fig. 1. It will be seen that (*i*) the frequency of squalls increases with the advance of the year, from February onwards, reaching a maximum in May, the highest monthly frequency in any year during the period under study, being 10 in each of the months of May in 1953 and 1954; (*ii*) 76 per cent of the squalls in the year occur in the months of April to July; and (*iii*) the period November to January is free from squalls for which reason, these months have not been included in the table.

2·2. *Diurnal distribution*—Table 2 shows the number of squalls in different months which occurred in each of the three-hour periods of the day. The above frequency expressed as percentages of the total occurring in each month, is also given in brackets. It may be seen that, (*i*) 79 per cent of the squalls occur between 1500—2100 IST, taking the year as a whole; (*ii*) during the months April to July, which are characterised by the highest frequency of squalls at Bangalore, roughly three out of every five squalls occur during the period 1500—1800 IST; (*iii*) majority of the severe squalls of the year occur between

TABLE 1

Frequency of occurrence of squalls

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total for the year
1937	1	1	3	6	1	1	..	..	1	14
1938	..	..	3	4	2	..	3	..	..	12
1939	..	2	..	1	3	1	..	..	..	7
1940	..	1	1	7	..	1	..	1	1	12
1941	..	..	7	8	1	..	..	..	..	16
1942	..	..	1	4	4	1	2	..	..	12
1943	..	..	4	2	1	1	..	2	..	10
1946	..	..	1	2	1	6	3	1	1	15
1947	..	1	2	4	2	5	1	2	..	17
1948	..	..	2	4	5	2	2	..	1	16
1949	..	..	2	1	3	4	1	1	2	14
1950	..	..	1	4	1	1	2	1	1	11
1951	..	1	3	9	1	..	2	..	..	16
1952	..	..	1	5	..	..	5	1	2	14
1953	..	1	6	10	5	4	2	..	1	29
1954	..	1	..	10	1	3	1	2	..	18
1955	..	1	3	3	8	6	3	..	..	24
1956	1	..	5	2	2	3	..	2	1	16
1957	..	..	2	2	3	..	1	..	..	8
1958	..	3	4	7	4	8	6	..	..	32
Total Number	2	12	51	95	48	47	34	13	11	313
Max. No. of days of squalls	1	3	7	9	8	8	6	2	2	..
Average No. of days of squalls	0·1	0·6	2·5	4·7	2·4	2·3	1·7	0·7	0·5	..
Percentage of squalls in different months to the year as a whole	1	4	16	30	15	15	11	4	4	..

NOTE—(*i*) Jan, Nov and Dec — Nil

(*ii*) Anemograms for 1944 and 1945 not available and hence not tabulated

1500-1800 IST; and (*iv*) the period 0000-0900 IST is practically free from squalls except in May.

2·3. *Direction of squalls*—Actual number as well as the precentage frequencies of squalls occurring from the different direction are given in Table 3 in 8 points of the compass in accordance with the departmental practice. It will be seen that (*i*) about 60 per cent of the squalls occurring in the months of April and May are from the N, NE and E; (*ii*) 66 per cent of the squalls in June, about 90 per cent of those of July and August and 54 per cent of those in September, are from the directions SW, W and NW; (*iii*) squalls occurring in March and October do not favour any particular direction; and (*iv*) about 75 per cent of the severe squalls are from directions NW to E through N.

In all the cases, a comparable correspondence was noticed between the direction of the squall and those of the wind flow at 3·0 to 4·5 km a.s.l. over Bangalore, prior to the outbreak of the squall.

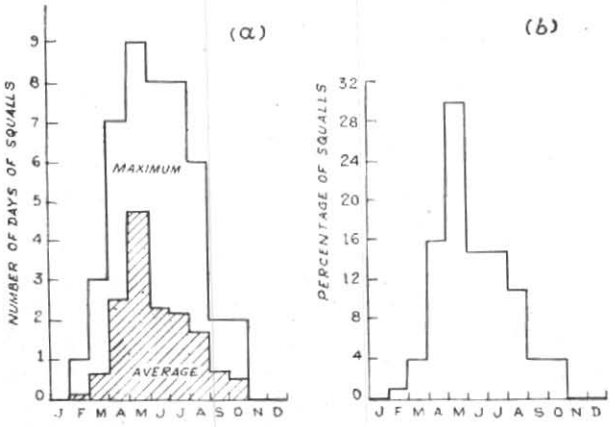

Fig. 1. Frequency of occurrence of squalls

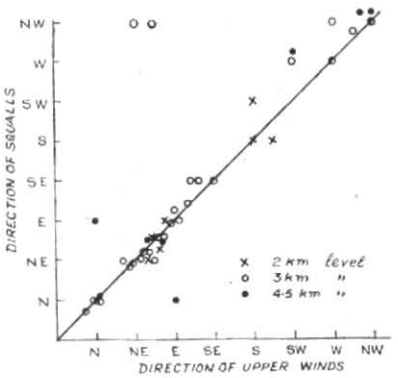

Fig. 2. Direction of squalls and upper winds

TABLE 2

Diurnal distribution of squalls

	Hours (IST)								Total No. of squalls
	00—03	03—06	06—09	09—12	12—15	15—18	18—21	21—24	
	Number (Percentage)								
Feb	..	..	..	..	1(50)	..	1(50)	..	2
Mar	..	..	..	..	2(17)	5(41)	3(25)	2(17)	12
Apr	..	..	..	1 (2)	8(16)	27(53)	11(22)	4 (8)	51
May	4 (5)	1 (1)	..	1 (1)	5 (5)	58(61)	17(18)	9 (9)	95
Jun	..	..	..	..	9(19)	26(54)	10(21)	3 (6)	48
Jul	..	..	..	..	8(17)	36(75)	3 (6)	..	47
Aug	..	..	..	..	2 (6)	26(76)	3 (9)	3 (9)	34
Sep	..	..	..	..	..	9(69)	4(31)	..	13
Oct	..	..	..	..	3(27)	4(37)	3(27)	1 (9)	11
Total for the year	4 (1)	1(-)	..	2(-)	38(12)	191(61)	55(18)	22 (7)	313
Total of severe squalls (40 mph and more)	2 (4)	..	..	2 (4)	9(17)	27(52)	9(17)	3 (6)	52

TABLE 3

Direction of squalls

	N	NE	E	SE	S	SW	W	NW	Total No. of squalls
				Number (Percentage)					
Feb	..	..	..	..	..	1(50)	..	1(50)	2
Mar	2(17)	..	2(17)	1 (8)	2(17)	5(42)	..	..	12
Apr	6(12)	15(30)	10(20)	11(21)	3 (6)	2 (4)	3 (6)	1 (2)	51
May	14(15)	23(24)	16(17)	16(17)	2 (2)	6 (6)	9(10)	9(10)	95
Jun	3 (6)	3 (6)	1 (2)	6(13)	3 (6)	10(21)	14(29)	8(16)	48
Jul	1 (2)	..	..	..	1 (2)	6(13)	22(46)	17(36)	47
Aug	2 (6)	..	..	1 (3)	1 (3)	5(15)	13(38)	12(35)	34
Sep	4(30)	1 (4)	1 (4)	1 (8)	..	2(19)	4(35)	..	13
Oct	1 (5)	2(13)	2(23)	1 (9)	..	2(23)	2(18)	1 (9)	11
Total for the year	33(11)	44(14)	32(10)	37(12)	12 (4)	39(12)	67(21)	49(16)	313
Total of severe squalls (40 mph and more)	9(17)	18(35)	7(13)	4 (8)	2 (4)	1 (2)	3(6)	8(15)	52

A graph connecting the direction of squalls with the direction of upper winds at 2·0 to 4·5 km a.s.l. is presented in Fig. 2, in respect of 43 cases of severe squalls, for which morning upper winds on the days of squalls, were available. In cases where the direction of the squall agreed with the direction of the upper winds in more than one level, the direction of the highest level which fitted in with the direction of the squall, was plotted in the graph. Straight line showing the perfect fit between the direction of squall and upper level wind, is also shown in the graph. The agreement is striking in respect of summer squalls coming from a N, NE, and E'ly direction.

2.4. *Maximum gust speeds*—Table 4 gives the percentage frequencies of the maximum or peak speeds in squalls (percentages in brackets) within certain limits. The chief features shown by the table are —(*i*) 60 per cent of the squalls in the whole year have peak speeds between 30 and 39 mph and (*ii*) only 3 per cent of the squalls in the whole year have peak speeds exceeding 50 mph—all in April, May or June.

The highest speed recorded during the years under study was 66 mph (106 kmph) on 3 May 1950.

2.5. *Pressure changes during squalls*—Pressure changes in association with the passage of squalls together with their percentages of the total number in each of the groups of months March-May, June-September and in October are given in Table 5. It may be noticed that (*i*) over 80 per cent of the squalls in all the groups show a pressure rise below 2·0 mb; (*ii*) 16 out of 159 cases of squalls, registering a pressure rise exceeding 2 mb occurred in the pre-monsoon months of March to May; (*iii*) some 4 per cent of squalls is also associated with a decrease of pressure which is less than 1 mb. Mull and Rao (1950) have shown that such instances are a dynamical possibility. The

TABLE 4

Maximum gust speed of squalls

	Peak speed (mph)					Total No. of squalls	Highest speed recorded	Date of record of highest speed
	30 (a)	30—39 (b)	40—49 (c)	50—59 (d)	60 and more (e)		(mph)	
	Number (Percentage)							
Feb	..	2(100)	..	..	..	2	33	15 Feb 1937*
Mar	4(33)	6(50)	2(17)	..	..	12	41	19 Mar 1937
Apr	16(31)	24(47)	10(20)	1 (2)	..	51	55	22 Apr 1951
May	20(21)	51(53)	19(20)	3 (3)	2 (2)	95	66	3 May 1950
Jun	8(17)	32(67)	6(13)	1 (2)	1 (2)	48	61	3 Jun 1948
Jul	7(15)	35(74)	5(11)	..	..	47	48	1 Jul 1956
Aug	5(15)	27(81)	2 (4)	..	..	34	42	4 Aug 1946
Sep	7(54)	6(46)	..	..	..	13	37	24 Sep 1954
Oct	8(73)	3(27)	..	..	..	11	39	4 Oct 1948
Total for the year	75(24)	186(60)	44(13)	5 (2)	3 (1)	313	66	3 May 1950

*An unusual severe squall of maximum speed 62 mph (99 kmph) from a northerly direction has since been recorded on 2 Feb 1959 (Mooley and Soundara Rajan 1960)

TABLE 5

Pressure changes in squalls

Period	Pressure rise (mb)					Pressure decrease	Chart not available	Total No. of squalls
	<1·0 (a)	1·0—1·9 (b)	2·0—2·9 (c)	3·0—3·9 (d)	⩾4·0 (e)	(<1 mb)		
	Number (Percentage)							
Mar to May	93(58)	40(25)	12 (8)	4 (2)	..	2 (1)	8 (5)	159
Jun to Aug	99(77)	13(10)	1 (1)	..	..	7 (5)	8 (6)	128
Sep to Oct	19(73)	5(20)	..	..	..	2 (8)	..	26
Total for the year	211(68)	58(19)	13 (4)	4 (1)	..	11 (4)	16 (5)	313

Highest rise 3·9 mb on 27 May 1947

Highest fall 0·9 mb on 9 May 1941

TABLE 6

Temperature falls in squalls

	Temperature range (°C)						Trace not available	Total No. of squalls	Largest fall(°C)
	1·0 or less (a)	1·1–2·0 (b)	2·1–4·0 (c)	4·1–6·0 (d)	6·1–8·0 (e)	>8·0 (f)			
Feb	1(50)	1(50)	..	..	..	..	..	2	2·8
Mar	1 (8)	2(17)	6(50)	3(25)	..	..	..	12	5·4
Apr	4 (8)	3 (6)	5(10)	16(31)	11(22)	4 (8)	8(16)	51	12·1
May	6 (6)	5 (5)	10(11)	40(42)	21(22)	9 (9)	4 (4)	95	12·5
Jun	5(10)	7(15)	8(17)	8(17)	17(35)	..	3 (6)	48	8·2
Jul	6(13)	13(28)	9(19)	18(38)	1 (2)	..	..	47	6·7
Aug	4(12)	6(18)	6(18)	17(50)	..	..	1 (3)	34	5·6
Sep	2(15)	1 (8)	4(31)	5(38)	..	..	1 (8)	13	4·4
Oct	3(27)	1 (9)	2(18)	4(36)	1 (9)	..	..	11	6·1
Total for the year	32(10)	39(12)	50(16)	111(35)	51(17)	13 (4)	17 (6)	313	12·5

data examined do not reveal any dependence of the pressure rises on the speed of the squalls. Even feeble squalls were found to be associated with relatively large rises of pressure.

The highest rise of 3·9 mb and largest fall of 0·9 mb were recorded by the squalls on 27 May 1947 and 9 May 1941 respectively.

2·6. *Temperature falls in squalls*—Frequencies of fall of dry bulb temperature of different order of magnitude, associated with the passage of squalls in different months are given in Table 6 together with their percentages. It may be seen that (*i*) in the majority of the squalls, dry bulb temperature fell by less than 6°C and (*ii*) in about 8-9 per cent of the squalls of April and May, the fall is over 8°C and a few among them caused a fall over 10°C. In the months of April and May, the more severe the squall, the greater was the fall in dry bulb temperature.

The largest fall of 12·5°C during the period under study, occurred with the passage of squall on 3 May 1950.

In majority of the squalls, wet bulb temperatures fell below 2°C. There was, however, one instance on 13 May 1942, when there was a rise in wet bulb by 2·2°C.

2·7. *Other aspects of squalls*—

(*a*) *Duration*—(*i*) 50 per cent of the squalls in whole year lasted for less than 20 min, 67 per cent for less than 30 min and 89 per cent for less than 45 min and (*ii*) about 40-45 per cent of the squalls of August, September and October were of less than 1 min duration.

(*b*) *Multiple squalls*—There were 11 occasions when squalls occurred twice or thrice on the same day during the period April to July, with speeds of comparable

magnitude. In six of the above cases, the directions of the first and the subsequent squalls agreed. However, in five cases, the directions of the later squalls varied by more than 90 degrees and in two among them, the variation was between 135 to 180 degrees.

3. Weather phenomena with which the squalls were associated

The weather diary of the Central Observatory, Bangalore, was scrutinised, on the different days of squalls during the years 1946-1958, for determining the weather phenomena which occurred within an hour on either side of the time of passage of the squall. The study showed that more than 75 per cent of the squalls were accompanied by thunderstorms. Every squall with a maximum speed exceeding 40 mph (64 kmph) was invariably associated with thunderstorm. Of the rest, 40 per cent were in the nature of rain squalls which occurred in the months of July and August. However, in many of them, development of large *Cu* or *Cb* had been reported.

4. Conclusions

The following aspects of surface squalls at Bangalore are brought out in the foregoing paragraphs—

Highest frequency of squalls at Bangalore is observed during the months of April to July, majority of them occurring during the period 1500-2100 IST. The months November to February are practically free from squalls. Even in the remaining months, squalls occur only outside the period 0001-0900 IST. About one squall in every four, of April and May, may be severe with speed exceeding 40 mph (64 kmph), invariably accompanied by thunderstorm. Relatively greater fall of dry bulb temperature is associated with such squalls. There was, however, no observable dependence of pressure rise on the speed of squalls. Even feeble squalls caused larger rises of pressure than those produced by stronger squalls. While majority of squalls is associated with thunderstorms, a few occur as rain squalls during the southwest monsoon period.

In a fair number of cases, the direction of the severe squalls, corresponds with the direction of winds between 3·0 to 4·5 km a.s.l. over Bangalore, prior to the outbreak of squall. Two or three squalls of comparable magnitude can occur on the same day during the months of April to July.

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