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Monsoon squalls over Thumba during the year 1966

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ABSTRACT. In this paper monsoon squall is considered as distinct from thundersquall of low wind speed and is defined as the sudden increase in wind speed to 15 kt or more with less than 25° change in direction. The main features of such squalls recorded at Thumba by the electrical anemographs at three different altitudes (58, 136 and 200 ft) during the monsoon season of 1966 are discussed with reference to their diurnal variation, duration, speed and direction.

The monsoon squall data has been analysed and scatter diagrams of mean squall wind profiles upto 200 ft height have been constructed. The mean vertical wind shears in two different layers 136–58 ft and 200–136 ft under squally weather conditions are described with the help of shear vector diagrams. The mean vertical shear does not exceed 5 kt/30m. Monsoon squall wind veers with height.

The wind in the layer 58–200 ft is found to obey the power law—

$$u/u_1 = (z/z_1)^p$$

under squally weather conditions. The computed values of power index $p=0\cdot115$ and the atmospheric turbulence parameter $n=0\cdot2$ are described briefly.

1. Introduction

One of the main features of the Indian monsoon over the West Coast is the occurrence of squalls. Radar observation of a monsoon squall has been reported by Narayanan (1967). Alvi and Punjabi (1966) have pointed out the peculiarities of monsoon squalls in the Trivandrum-Cochin-Bombay region. The highest frequencies of squall occur in the Trivandrum-Cochin sector of west coast of which an overwhelming majority are in the monsoon season and they are of short duration less than 10 minutes. Surface squalls exceeding 40 knots are very rare. These west coast squalls may be called monsoon squalls in order to distinguish them from the well-known thundersquall. The changes associated with the passage of monsoon squall and thundersquall in the surface meteorological elements are similar with the exception that no appreciable change in wind direction is observed during the monsoon squall. The statistical analysis of these squalls during 1966 is discussed in the paper. Monsoon squall has been defined as a sudden increase in wind speed to 15 kt or more with the change in wind direction, if any, not exceeding 25°. Frequently it is accompanied by heavy shower for a few minutes. The monsoon squalls reported in this note refer to the features recorded by the electrical anemograph at three different heights 58, 136 and 200 ft on the Met. Tower nearly 300 ft away from the water edge at Thumba Equatorial Rocket Launching Station (TERLS).

2. Instrumentation

A 200-ft meteorological tower with 7 sets of Distant Indicating Wind Equipments (DIWE) available at TERLS is a unique facility for low level wind measurements. In March 1966, three sets of electrical anemographs developed by Srivastava and others (1965), designed and constructed at the Instrument Section of the Meteorological Office, Poona, were added to the tower instruments at the above three levels.

Wind direction is recorded on strip chart recorder whose recording head is coupled electrically through a selsyn generator and received to a wind vane. Wind speeds are recorded on a 0-1 MA DC milliammeter recorder by amplifying the AC output from a cup generator anemometer by a transistorised amplifier. A high/low switch provided in the amplifier triples the range from 0-25 to 0-80 kt for full scale deflection. Normally the recorder is kept run at low range. But when squally weather condition is expected it is switched over to the higher range.

Chart drive system in the direction recorder is capable of driving the chart at 20, 60 and 120 mm/hr by means of a lever arrangement changing the rate of feed as and when required. The speed charts are run at a constant rate of feed 20 mm/hr. Analysis of the strip chart records for 1966 showed that 88 squalls passed over Thumba during the monsoon season. A typical monsoon squall recorded on 12 July 1966 at 1512 IST is shown in Fig. 1.

3. Main features of monsoon squalls recorded at Thumba

(*i*) *Diurnal variation* — The diurnal frequency of the squalls, June through September, is given in

TABLE 1

Diurnal frequency of monsoon squalls

	Period (hours in IST)					
	01–05 (EM)	05–09 (M)	09–13 (F.N.)	13–17 (A.N.)	17–21 (E)	21–01 (N)
Jun	24(6)	9(3)	15(5)	15(5)	32(11)	12(4)
Jul	4(1)	32(8)	12(3)	12(3)	22(7)	8(2)
Aug	32(4)	16(2)	—	29(3)	16(2)	16(2)
Sep	36(6)	12(2)	6(1)	24(4)	6(1)	18(3)

E.M.—Early morning, M—Morning, F.N.—Forenoon, A.N.—Afternoon, E—Evening, N—Night

Figures given in brackets indicate the actual number of cases

TABLE 2

Duration of squall

Duration (min)	Jun	Jul	Aug	Sep	Total
0—5	9+4*	5+1*	5+4*	1*	19+10*
5—10	10	10	2	9	31
10—20	8	5	2	7	22
20—30	2	3	—	—	5
30 and above	1	—	—	—	1
Total	34	24	13	17	88

*Indicates squalls not accompanied by rain

Table 1. There are two maxima, one in the morning and the other in the evening. The diurnal variation of the monsoon squalls at Thumba is similar to that at Cochin reported by Alvi and others (1966) where 75 per cent squalls occur either between 03–09 or between 15–21 IST.

(*ii*) *Duration* — The squalls are generally of short duration less than 10 minutes followed by heavy rain for a few minutes. The duration of the squall is determined from the electrical anemograms which are run at 20 mm/hr and it is compared with the duration of rainfall recorded by the S.R. raingauge whenever rainfall is accompanied by squall. The duration of the squalls in various time intervals is presented in Table 2. 10 out of 88 squalls were not accompanied by rain. The squall duration conforms to that at other west coast station like Santacruz (Dekate 1966).

(*iii*) *Speed* — The maximum squall speed recorded was 35 kt. Table 3 gives the frequency distribution of the squalls in 4 speed ranges 15-19, 20-24, 25-29 and 30 kt and above. The squalls of more than 30 kt are confined to June and July and about 90 per cent squalls are in the range 15-25 kt.

TABLE 3

Frequency distribution of monsoon squall speed

Speed range (kt)	Jun	Jul	Aug	Sep
15—19	60(20)	58(14)	80(10)	72(12)
20—24	35(12)	37(9)	20(3)	18(3)
25—29	—	—	—	10(2)
30 and above	5(2)	5(1)	—	—

Note—Figures given in brackets indicate the actual number of cases

TABLE 4

Frequency distribution of monsoon squall direction

Direction range (degrees)	Jun	Jul	Aug	Sep
270—289	12(4)	—	16(2)	48(8)
290—309	50(17)	8(2)	24(3)	18(3)
310—329	33(11)	44(11)	56(7)	12(2)
330—360	6(2)	44(11)	8(1)	24(4)

Note—Figures given in brackets indicate the actual number of cases

(*iv*) *Direction* — All the squalls lie in the direction range 270° to 360°. The frequency distribution of the squalls at 20° interval is given in Table 4. The squalls are mainly from 270°—300° during June and September and 320°—350° during July and August.

4. Monsoon squall with profile

The statistical analysis of the monsoon squalls shows that the mean squall wind profile fits well in majority of individual cases when squalls of 25 kt and more are omitted. As 90 per cent of the monsoon squalls are in the speed range 15-25 kt and need not satisfy all the three criteria at the same time for the squall (as laid down by the code*) mean monsoon squall wind profiles have been constructed (Fig. 2) from the monthly mean squall data given in Table 5. Fig. 3 shows the shear vectors for the two different layers 136-58 ft and 200-136 ft. The shear vector backs with height during monsoon squall. The mean shear vector is found to be less than 5 kt/30 m, 10 m above the surface.

*Weather code of India met. Dep. (1955)

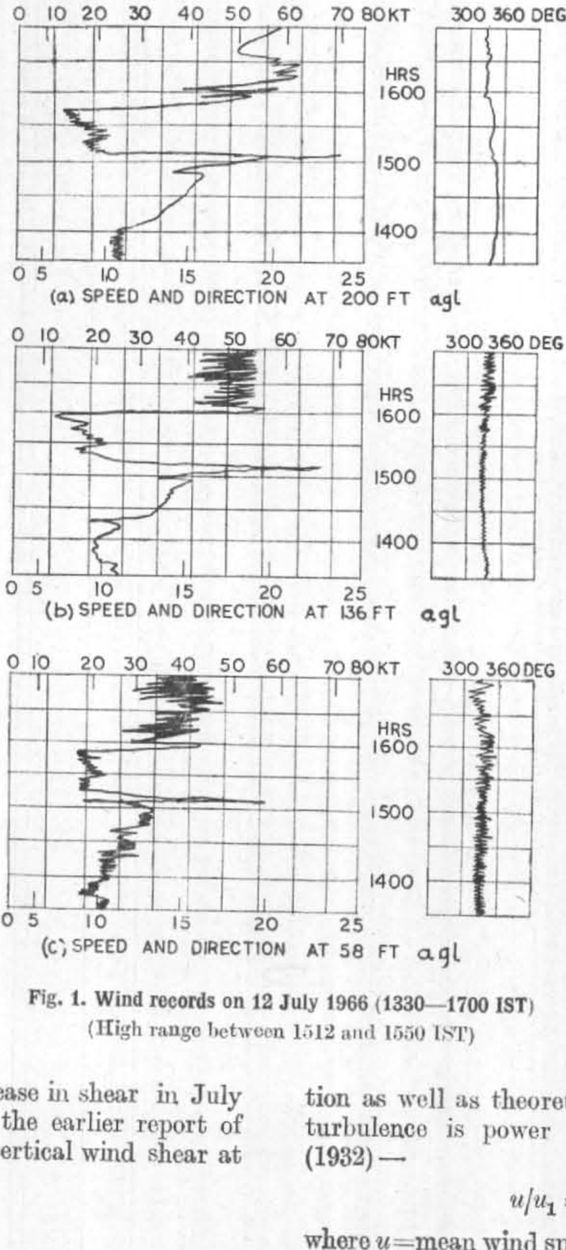

Fig. 1. Wind records on 12 July 1966 (1330—1700 IST)
(High range between 1512 and 1550 IST)

There is definitely an increase in shear in July and August. This supports the earlier report of Rao *et al.* (*see Ref.*) in the vertical wind shear at Thumba.

5. Vertical wind shear

A frequency table of the vertical wind shear for the monsoon squalls is given in Table 6. The north and east components of shear in two layers 136—58 ft and 200—136 ft have been calculated separately.

Shear exceeding 10 kt/30 m is rare (about 10 per cent). In July, shear magnitude is maximum in the layer 136—58 ft while in August it is so in the layer 200—136 ft.

6. Power Law

The simplest expression for the mean wind profile from the point of analysis of the observation as well as theoretical study of atmospheric turbulence is power law proposed by Sutton (1932) —

$$u/u_1 = (z/z_1)^p$$

where u=mean wind speed at a height z, u_1=mean wind speed at a reference height z_1, and p=power index whose limits are 0 and 1.

The value of p is a measure of the stability of the atmosphere and is subject to diurnal variation in clear weather changing from 0·17 and in large inversion to about 0·07, a lower value of p indicating more turbulent atmosphere. In practice, $0{\cdot}11 < p < 0{\cdot}25$ represent stable profile. The wind in the layer 58—200 ft is found to obey the power law under squally weather conditions. The computed value of power index p is 0·115. Mean rainfall wind profile is a neutral profile. The layer 200 to 58 ft obeys roughly one ninth power law. The atmospheric turbulence parameter n is calculated assuming the equation $p=n/(2-n)$ where n is a

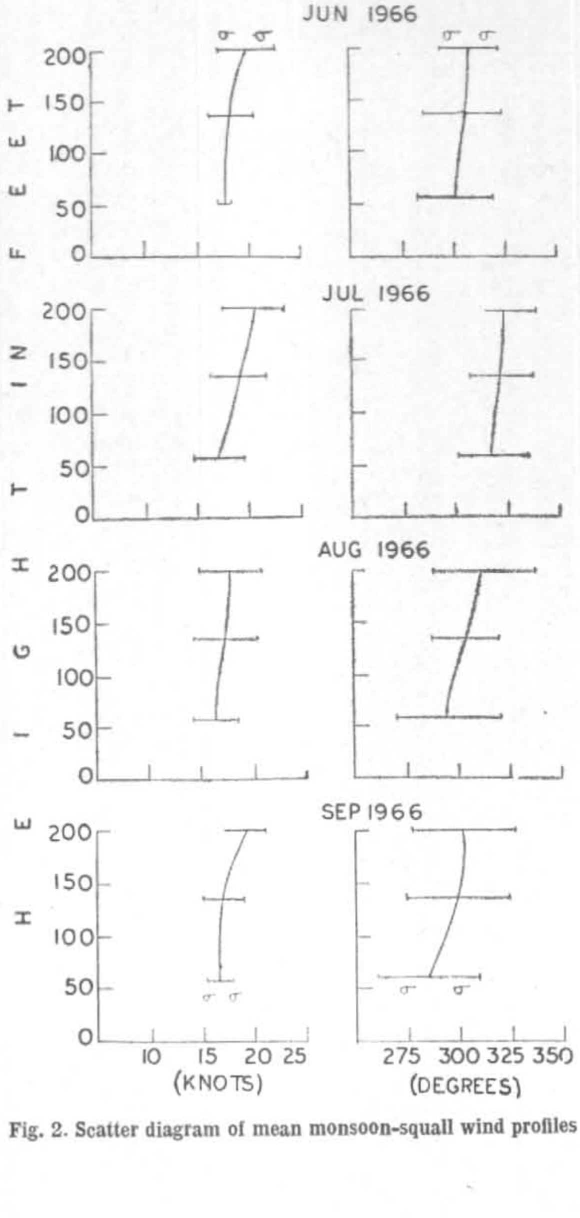

Fig. 2. Scatter diagram of mean monsoon-squall wind profiles

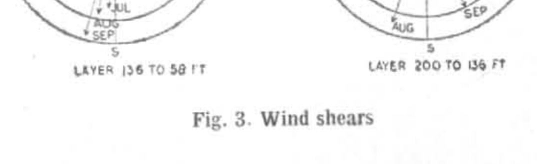

Fig. 3. Wind shears

dimensionless number known as Sutton's parameter. The computed value of $n=0\cdot2$ is useful in the analysis of eddy diffusion problems.

7. Concluding Remarks

The squall studies made so far in India were all based on Dines Pressure Tube anemograph at one

TABLE 5

Mean monsoon squall direction and speed at 58, 136 and 200 ft

Month	At 58 ft				At 136 ft				At 200 ft			
	Speed (kt)	σ (kt)	Direction (deg)	σ (deg)	Speed (kt)	σ (kt)	Direction (deg)	σ (deg)	Speed (kt)	σ (kt)	Direction (deg)	σ (deg)
Jun	17·7	0·5	302	18	18·5	2·5	306	18	20·0	2·8	308	14
Jul	17·0	2·2	317	20	19·0	2·6	323	15	20·5	2·7	325	12
Aug	16·3	2·1	295	25	17·2	2·9	304	17	18·0	2·9	313	25
Sep	16·7	1·4	285	25	17·0	2·0	297	25	19·0	2·0	302	25

TABLE 6

Frequency table showing North (N) and East (E) component shear associated with the monsoon squalls in two different slabs 136-58 ft and 200-136 ft in the layer 58-200 ft over Thumba during the monsoon months

Shear (kt/30m)	136—58 ft N	136—58 ft E	200—136 ft N	200—136 ft E	Total
JUNE 1966					
0—3	66	78	39	66	
4—6	24	12	39	24	
7—9	0	12	12	12	
10—12	3	0	6	0	34
13—15	6	0	3	0	
16—18	0	0	0	0	
19—21	1	0	0	0	
22—24	0	0	6	0	
JULY 1966					
0—3	36	68	68	64	
4—6	22	8	16	36	
7—9	12	12	4	8	
10—12	12	8	4	0	24
13—15	0	0	4	0	
16—18	4	0	0	0	
19—21	0	0	0	0	
22—24	0	0	0	0	
AUGUST 1966					
0—3	64	80	48	40	
4—6	16	16	32	24	
7—9	8	0	0	16	
10—12	0	8	8	24	13
13—15	8	0	0	0	
16—18	0	0	8	0	
19—21	0	0	0	0	
22—24	8	6	8	0	
SEPTEMBER 1966					
0—3	72	78	48	60	
4—6	6	18	30	18	
7—9	12	6	6	24	
10—12	6	0	6	0	17
13—15	0	0	6	0	
16—18	6	0	6	0	
19—21	0	0	0	0	
22—24	0	0	0	0	

level only. The records of electrical anemographs at three levels are utilised in the present study. The response of Dines P.T. anemograph is better, but their installation on a tower at various levels for remote recording is difficult and hence electrical anemographs are preferred. Both the speed and direction transmitters in the electrical anemograph have very small time of response and can attain the wind condition during a squall within about 2-3 seconds.

One serious limitation of this above electrical anemograph is that there is no synchronising arrang ment for direction and speed charts. However, this limitation has not affected adversely the present study. Time marks were put atleast twice a day during the synoptic observations. Special time marks were also given whenever special phenomena like squall occurred.

It should be pointed out that the frequency of monsoon squalls in terms of time, duration, speed and direction and shear are based on a single year monsoon period. The data fits well with the previous climatological studies. More detailed study and verification of the power law are possible when temperature data upto 200 ft are collected. This may be taken up when temperature sensors are added to the tower instrumentation.

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