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Vertical wind shear in the lowest layers of the atmosphere over Thumba during winter months—A preliminary study

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(*Received 20 June 1964*)

ABSTRACT. Vertical wind shear in the lowest layers of the atmosphere over Thumba — an equatorial station — has been studied. Wind data from the surface up to 200 ft were collected at different altitudes (8, 31, 56, 134 and 200 ft) during the months December 1963 and January 1964, for the above study. Analysis reveals that appreciable wind shear exists very close to the surface, *i.e.*, in the layer up to 31 ft. On the other hand, in the layer 31—200 ft, the shear values are not considerable. It is further observed that the shear magnitude reaches maximum in the afternoon. The frequency of occurrence of shear magnitudes more than 10 kts/30 m (which, as indicated by ICAO, is important for supersonic transport operation) is high in the lowest layer round about 1430 IST during the winter months.

1. Introduction

The Third Session of the Commission for Aeronautical Meteorology held recently in Paris has recommended the study of vertical wind shear in the lowest layers of the atmosphere — such study being of great value in the design and operation planning of supersonic transport. The Commission has noted (WMO/CAeM-III 1964) that vertical wind shear is of interest not only to pilots but also for satisfactory operation of automatic landing devices. Keeping this in view, a study of the vertical wind shear was undertaken at Thumba. Thumba Equatorial Rocket Launching Station (TERLS) is situated on the Kerala Coast of South India, a few miles north of Trivandrum. Its geographical co-ordinates are Lat. 08° 32′ N and Long. 76° 52′ E. A 200-ft meteorological tower facilitates wind observations at different altitudes. The meteorological tower and a 58-ft met pole are situated very close to the sea. Distant Indicating Wind Equipment (DIWE) instruments have been installed at heights 31 and 56 ft on the met pole and on 12 ft booms at heights 54, 134 and 200 ft on the met tower. For the construction of the wind profile the surface (8 ft) wind data, wind data from the DIWE on the met pole at 31 and 56 ft and those from the met tower at 134 and 200 ft have been taken. The general vegetation in the area consists of coconut trees of average heights 30—35 ft. On the landward side a semi-circular area of radius 250 ft around the met tower, and an area of radius 150 ft around the met pole have been cleared of trees and other obstacles. The terrain is sandy and flat.

The installation of wind intruments on the tower has been made to suit the convenience of maintenance and servicing, and a planned height distribution has not been maintained.

The wind observations were recorded at six synoptic hours 00, 03, 06, 09, 12 and 15 GMT during December 1963 and January 1964.

2. Results

The mean wind speed and direction profiles have been constructed (Figs. 1a, 1b, 2a and 2b) from the monthly mean wind data for the six synoptic hours for the months of December 1963 and January 1964. Polar diagrams have been constructed showing the vectorial wind shear in different slabs.

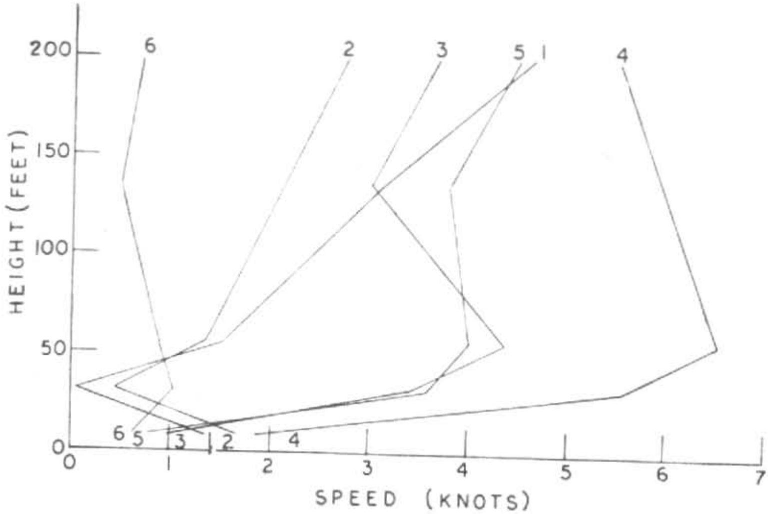


Fig. 1(a). Mean tower wind speed profile for December 1963

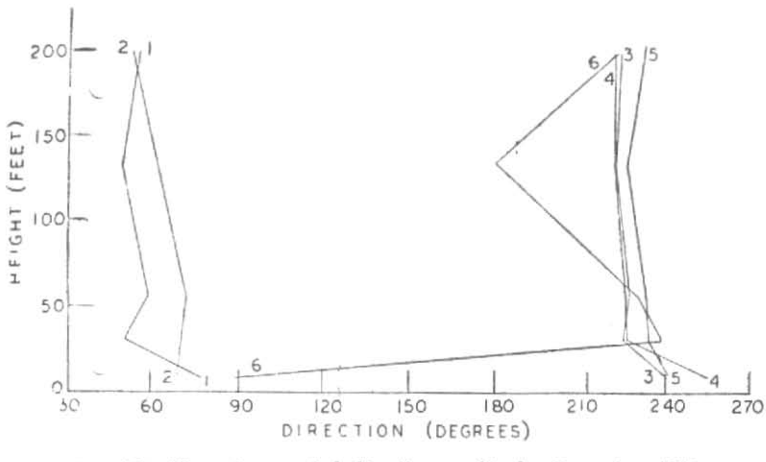


Fig. 1(b). Mean tower wind direction profile for December 1963

In Figs. 1(a) and 1(b) —1, 2, 3, 4, 5 and 6 refer to 00, 03, 06, 09, 12 and 15 GMT respectively

At each hour of observation, the wind shear vectors for the various slabs are presented (Figs. 3a and 3b). Frequency tables have been constructed, generally on the lines recommended by the ICAO Conference. The N and E components of shear in the various slabs have been considered separately. The frequencies of occurrence of these components are presented in Tables 1 and 2. It should be emphasised that these frequencies are based on data for winter months during one year only. The vertical time sections of the mean N and E velocity components of the actual winds are presented in Figs. 4(a) and 4(b).

3. Discussion

The component winds from surface up to 56 ft are very light (2-3 kts) till about 0830 IST and strengthen thereafter to the maximum magnitude (5-6 kts) round about 1430 IST (Figs. 4a and 4b). This variation is no doubt associated with the incoming solar radiation. In the early hours of the

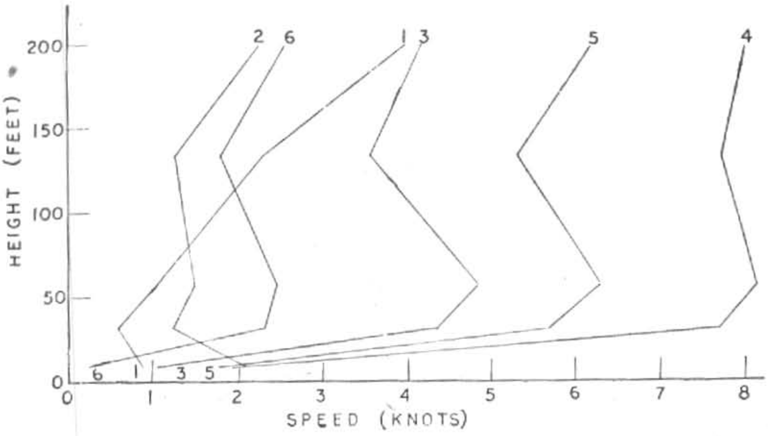


Fig. 2(a). Mean tower wind speed profile for January 1964

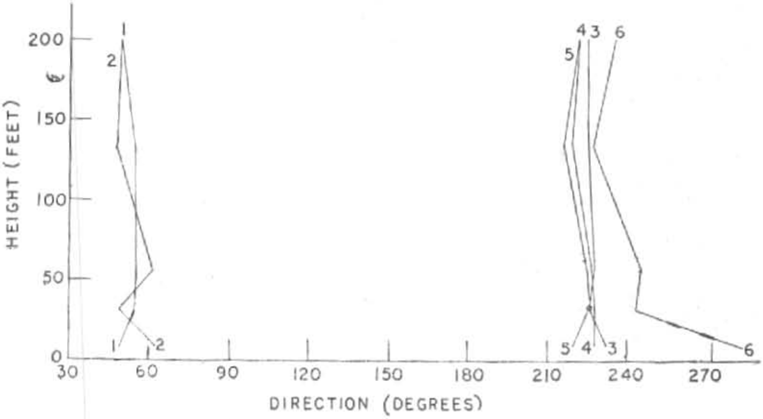


Fig. 2(b). Mean tower wind direction profile for January 1964

In Figs. 2(a) and 2(b) — 1, 2, 3, 4, 5 and 6 refer to 00, 03, 06, 09, 12 and 15 GMT respectively

day, the wind generally increases with height above 31 ft (Figs. 1a and 2a). In the mid-day and afternoon hours, it appears from Figs. 1a and 2a, that the wind speed generally increases with height up to 56 ft. Above 56 ft, there appears to be either no wind gradient or a slight negative wind gradient extending up to 134 ft. Above 134 ft there is a general tendency for wind speed to increase. The velocity profiles, in general, do not appear to fit in with a power law.

From Figs. 3a and 3b, the following information is revealed — In the layer 8-31 ft shear magnitude is maximum at 1430 IST in both December and January, the values being $17 \cdot 2 \times 10^{-2}$ sec^{-1} and $22 \cdot 1 \times 10^{-2}$ sec^{-1} respectively. It may be noted that the average shear value at 1430 hrs in December is approximately equal to 10 kts/ 30m — the figure indicated by ICAO as of importance to SST operation — and the average value for January exceeds this figure. It is also worthy of note that the directions of the wind shear in the layer 8-31 ft appear to be confined to the sector 215°—260°.

In the layer 31—56 ft maximum shear in December occurs at 2030 hrs whereas in January it occurs at 1730 hrs. In this

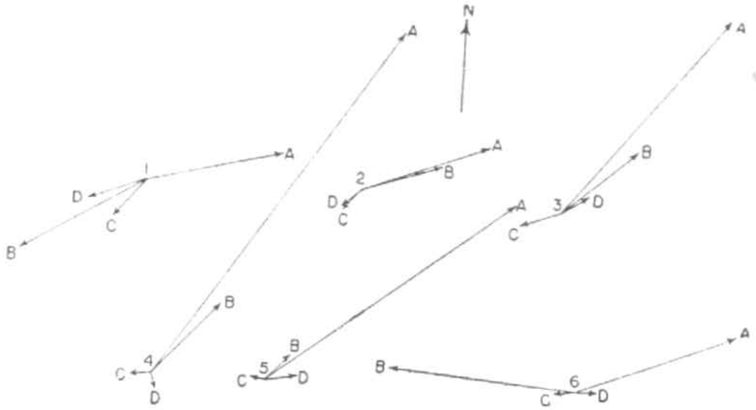


Fig. 3(a). Distribution of mean vertical wind shear for December 1963

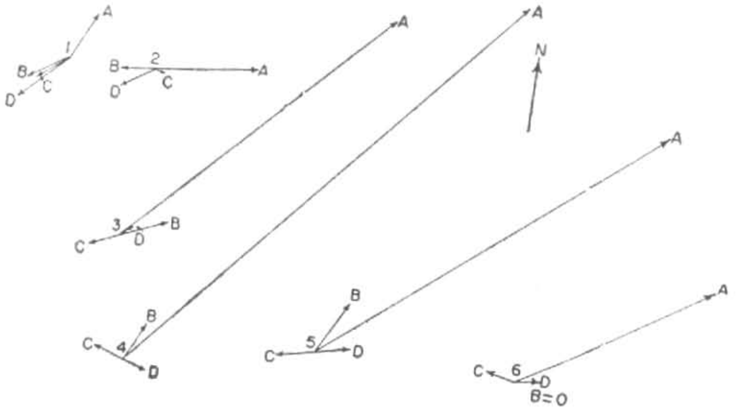


Fig. 3(b). Distribution of mean vertical wind shear for January 1964

In Figs. 3 (a) and 3(b) — 1, 2, 3, 4, 5 and 6 refer to 00, 03, 06, 09, 12 and 15 GMT respectively
Layers A — 8 to 31 ft, B — 31 to 56 ft, C — 56 to 134 ft and D — 134 to 200 ft

layer the wind shear does not appear to be confined within any narrow limits.

In the layer 56—134 ft maximum shear occurs at 0530 hrs although in January the magnitudes of the shear seem to be distributed almost uniformly with time. Further, in this slab almost during the whole day the shear appears to be confined in direction in the sector 040°—100°.

In the layer 134—200 ft the shear magnitude is maximum at 0530 hrs. The direction of shear appears to be confined to the sector 235°-045° (through north).

Even from a casual look at Figs. 1(b) and 2(b) and also at 4(a) and 4(b), it is evident that the transition in wind field takes place round about 1000 hrs. This transition is doubtless linked with the onset of sea breeze. It must be remembered that the actual wind at any time is the vectorial combination of the gradient wind, due to the prevailing synoptic situation, and the antitriptic wind at the coast. Studies of such transition have been made by Ramdas (1931) and Ray Choudhuri (1948). It must be mentioned here that the coast line at Thumba runs along direction 145° to 325°,

TABLE 1

Frequency table showing N and E component shear values in different slabs in the layer 0—200 ft over Thumba — December 1963

Time of observation (GMT)	Shear kts/30m	Height intervals: 31′—8′		56′—31′		134′—56′		200′—134′	
		N	E	N	E	N	E	N	E
0000	0— 3	11	13	13	12	24	23	22	22
	4— 6	9	3	9	5	4	6	7	5
	7— 9	7	9	3	8	1	0	0	2
	10—12	1	2	3	2	0	0	0	0
	13—15	1	2	1	2	0	0	0	0
	16—18	0	0	0	0	0	0	0	0
	19—24	0	0	0	0	0	0	0	0
0300	0— 3	14	11	20	16	28	27	25	28
	4— 6	6	3	3	2	2	2	4	2
	7— 9	7	7	2	7	0	1	0	0
	10—12	1	4	2	3	0	0	0	0
	13—15	1	2	2	1	0	0	1	0
	16—18	0	2	0	1	0	0	0	0
	19—24	1	1	1	0	0	0	0	0
	25—30	0	0	0	0	0	0	0	0
0600	0— 3	2	10	12	13	23	23	21	22
	4— 6	6	4	8	7	2	3	3	4
	7— 9	6	4	6	4	1	0	1	0
	10—12	5	3	0	1	0	0	1	0
	13—15	2	1	0	1	0	0	0	0
	16—18	3	1	0	0	0	0	0	0
	19—24	0	3	0	0	0	0	0	0
	25—30	2	0	0	0	0	0	0	0
0900	0— 3	2	4	17	17	24	25	24	25
	4— 6	1	3	3	6	1	0	1	0
	7— 9	4	2	2	2	0	0	0	0
	10—12	1	0	3	0	0	0	0	0
	13—15	4	4	0	0	0	0	0	0
	16—18	6	7	0	0	0	0	0	0
	19—24	3	4	0	0	0	0	0	0
	25—30	3	1	0	0	0	0	0	0
	31—36	0	0	0	0	0	0	0	0
	37—42	1	0	0	0	0	0	0	0
1200	0— 3	10	7	17	14	28	26	26	26
	4— 6	3	3	7	9	0	2	2	1
	7— 9	5	4	3	3	0	0	0	1
	10—12	4	4	0	1	0	0	0	0
	13—15	2	6	1	0	0	0	0	0
	16—18	2	1	0	0	0	0	0	0
	19—24	2	2	0	1	0	0	0	0
	25—30	0	0	0	0	0	0	0	0
	31—36	0	0	0	0	0	0	0	0
	37—42	0	1	0	0	0	0	0	0
1500	0— 3	15	6	22	17	29	25	28	23
	4— 6	5	4	4	4	0	4	1	4
	7— 9	5	13	1	4	0	0	0	2
	10—12	2	4	2	1	0	0	0	0
	13—15	0	1	0	1	0	0	0	0
	16—18	0	0	0	1	0	0	0	0
	19—24	2	0	0	0	0	0	0	0
	25—30	0	0	0	0	0	0	0	0
	31—36	0	0	0	1	0	0	0	0
	37—42	0	0	0	0	0	0	0	0
	43—48	0	1	0	0	0	0	0	0

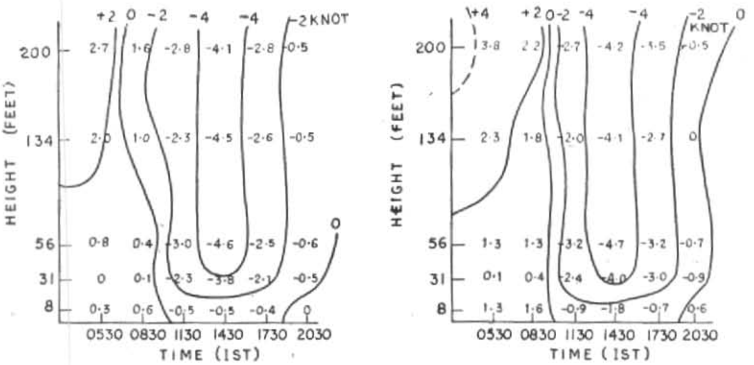
Note: This frequency table for December is based on data of only one year

TABLE 2

Frequency table showing N and E component shear values in different slabs in the layer 0—200 ft over Thumba — January 1964

Time of observation (GMT)	Shear kts/30m	Height intervals							
		31′—8′		56′—31′		134′—56′		200′—134′	
		N	E	N	E	N	E	N	E
0000	0— 3	20	16	21	18	28	25	18	15
	4— 6	8	6	4	4	2	3	8	10
	7— 9	1	5	2	6	0	2	4	5
	10—12	1	3	2	2	0	0	0	0
	13—15	0	0	0	0	0	0	0	0
	16—18	0	0	1	0	0	0	0	0
	19—24	0	0	0	0	0	0	0	0
0300	0— 3	15	8	24	19	26	26	24	22
	4— 6	4	8	2	4	2	2	6	6
	7— 9	7	7	1	4	0	0	1	0
	10—12	1	3	0	0	0	0	0	0
	13—15	1	0	1	0	0	0	0	0
	16—18	0	2	0	1	0	0	0	0
	19—24	0	0	0	0	0	0	0	0
0600	0— 3	4	4	20	19	22	19	21	22
	4— 6	4	5	5	6	5	8	6	5
	7— 9	3	4	3	3	1	0	1	1
	10—12	3	3	0	0	0	1	0	0
	13—15	6	3	0	0	0	0	0	0
	16—18	1	2	0	0	0	0	0	0
	19—24	7	6	0	0	0	0	0	0
	25—30	0	0	0	0	0	0	0	0
	31—36	0	1	0	0	0	0	0	0
0900	0— 3	5	2	11	13	22	20	27	27
	4— 6	0	1	9	9	6	8	2	2
	7— 9	2	1	7	4	0	0	0	0
	10—12	1	3	1	1	0	0	0	0
	13—15	2	2	0	0	0	0	0	0
	16—18	3	5	0	1	0	0	0	0
	19—24	7	6	0	0	0	0	0	0
	25—30	7	5	0	0	0	0	0	0
	31—36	1	2	0	0	0	0	0	0
	37—42	0	2	0	0	0	0	0	0
	43—48	1	0	0	0	0	0	0	0
1200	0— 3	4	5	18	20	24	24	28	25
	4— 6	3	3	8	5	4	4	0	3
	7— 9	5	3	1	2	0	0	0	0
	10—12	1	1	1	1	0	0	0	0
	13—15	4	2	0	0	0	0	0	0
	16—18	4	3	0	0	0	0	0	0
	19—24	6	7	0	0	0	0	0	0
	25—30	1	2	0	0	0	0	0	0
	31—36	0	2	0	0	0	0	0	0
	37—42	0	0	0	0	0	0	0	0
	43—48	0	0	0	0	0	0	0	0
1500	0— 3	15	10	20	20	28	26	27	26
	4— 6	5	3	6	7	0	2	1	2
	7— 9	2	7	1	1	0	0	0	0
	10—12	1	0	0	0	0	0	0	0
	13—15	1	0	1	0	0	0	0	0
	16—18	2	2	0	0	0	0	0	0
	19—24	0	5	0	0	0	0	0	0
	25—30	2	1	0	0	0	0	0	0
	31—36	0	0	0	0	0	0	0	0

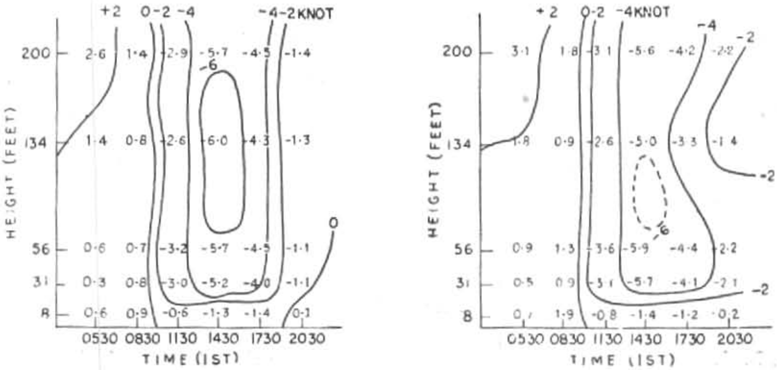
Note: This frequency table for January is based on data of only one year



Vertical time section of mean N-component winds

Vertical time section of mean E-component winds

Fig. 4 (a). December 1963



Vertical time section of mean N-component winds

Vertical time section of mean E-component winds

Fig. 4 (b). January 1964

and so the direction of the antitriptic component should be along the direction 235°–055°. Further, December and January are relatively cloud-free months, during which the sea-breeze effect should be pronounced.

If attention is focussed on the lowest slab, below 31 ft (*i.e.*, shear vectors marked A in Figs. 3a and 3b), it is observed that the shear value jumps more or less suddenly between 0830 and 1130 hrs. The increased value of shear is more or less maintained up to 2030 hrs. The explanation appears to be the following. The normal wind at 31 ft in December and January at Thumba is l'ght westerly. At night, ow.ng to land breeze this wind is reduced or becomes light easterly—the shear in the layer surface to 31 ft being kept low. Between 0830 and 1130 hrs sea breeze commences and the normal light westerlies at 31 ft strengthen enormously. This causes a large increase in the shear value in the lowest slab.

Following the recommendation on Agenda Item 11 of Commission of Aeronautical Meteorology (Third Session, 1964), frequency tables have been constructed. The frequency tables for December and January (Tables 1 and 2) indicate that the N and E component wind shear of magnitudes more than the value 10 kts/30m occur at all times in the layer 8-31 ft, the maximum frequencs being in the afternoon. At other slaby

(31—200 ft) the shear values are mostly confined to the class intervals 0-3 kts or 4-6 kts/30m and the number of occurrences of shear 10 kts/30m is very few.

A study of the climogram for Trivandrum reveals that the wind speed at lower levels up to 0·3 km is very weak during the months December and January. Morning surface wind is calm almost on all the days. Our observations fit in, in general, with the climogram.

The climograms for the other months are markedly different — in particular during the months June to September the wind speeds are high. It is to be expected that the frequency of high shear values will increase considerably when the above analysis is made during the summer and monsoon months.

4. Conclusion

During the winter months December and January, significant wind shear is observed in the layer 8-31 ft, especially in the afternoon period. In the other layers (31-200 ft) the wind shear is generally low. The study is being continued during the other seasons when it is expected that the frequency of occurrence of significant shear will be much higher. The relationship between the shear and temperature profile will be investigated as soon as proper temperature sensors are installed at various levels on the meteorological tower.

5. Acknowledgement

The 200-ft meteorological tower at Thumba was set up mainly due to the interest and efforts of Dr. Vikram A. Sarabhai, Chairman, INCOSPAR and Shri P. R. Krishna Rao, Director General of Observatories. We wish to express our thanks to them. Thanks are also due to Miss A. Mani, Director (Instruments), who was responsible for the installation of the instruments on the tower, in the first instance.

REFERENCES

Ramdas, L. A. 1931 *India met. Dep. Sci. Notes*, **4**, 41, p. 115.

Ray Choudhuri, S. N. 1948 *Ibid.*, **10**, 119, p. 51.

W.M.O./CAeM-III 1964 WMO-No. 157. R. P. 58. Report on Agenda Item 1, p. 1—1.