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Diurnal wind variation in the planetary boundary layer during southwest monsoon over Sriharikota

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सार — जुलाई 1988 में चार दिनों के दौरान शार में एकत्रित तीन घंटेवार-पायलट गुब्बारा पवनों का विश्लेषण किया गया और निम्न स्तर पवनों में विविधता के दैनिक चक्र के अस्तित्व को स्थापित किया गया। पवन गति में अधिकतम परिवर्तन अर्द्धरात्रि के समय हुए। याम्योत्तरी और मंडलीय एकक पवनों दोनों का प्रसंवादी विश्लेषण किया गया और इनसे प्राप्त परिणामों को प्रस्तुत किया गया। परिणामों से यह सुझाव मिलता है कि शार में पी बी एल लगभग 1000 मीटर मोटा होना चाहिए। अपरूपण और स्थिर कारक मानों का भी मूल्यांकन किया गया और इस पर विचार-विमर्श किया गया।

ABSTRACT. Three hourly pilot balloon winds collected over SHAR during four days of July 1988 were analysed and existence of a diurnal cycle of variation at low level winds was established. Maximum changes in the wind speed occurred towards midnight. Harmonic analysis was performed for both the meridional and zonal component winds and the results are presented. The results suggest the PBL over SHAR to be about 1000 m thick. The shear and the steadiness factor values have also been evaluated and discussed.

1. Introduction

Planetary Boundary Layer (PBL) plays a prominent role in the atmospheric processes and weather, since this is the vital link between the lower troposphere and the solid earth. The frictional effect of the terrain and the effect of insolation received by the solid earth and also the meso-scale features like "local winds" as well as the environmental effects like "pollution" are prominently felt in the PBL (Donald 1986). The wind in the PBL is a parameter wherein the above effects manifest considerably. Besides the winds in the lower tropospheric layers have significant practical application, like the take off and landing of aircraft, dispersal of pollutants. In aerospace meteorology these winds have critical importance like the performance of launch vehicles, applying corrections to the launcher settings both in elevation and azimuth and the like. The vertical wind shears in these layers is a significant parameter in finding application in the design and operation of aerospace vehicles.

The climatology of low level winds over a station including a rocket launching station generally gives the mean wind profile for a day. These representative values are available for two different times of the day, as two main synoptic hours (0530, 1730 IST) are normally the hours of observations for all the stations internationally. For class-I observatories, surface data may available at three hourly intervals, and hence the climatology is also possible valid for three hourly interval. However, upper air stations take the upper wind measurements either twice a day (main synoptic hours) or maximum four times a day. Hence, vertical wind profile at three hourly intervals is not normally possible. However, some stray attempts have been made to study the diurnal variation of low level winds. Thiruvengathan *et al.* (1985) analysed the six hourly wind variation overBombay from the regular balloon data. Mukherjee and Mukhopadhyay (1985) have observed the local effect on the diurnal variation of the wind over Bombay. A somewhat planned study of the low level wind variation over Trivandrum (Thumba) has been reported by Narayanan & Devassey (1972), Narayanan & Nair (1980). For some of the U.S. coastal stations Blackadar (1957) and Hacker (1963) have made an analysis of low level winds, while Miles (1959) made for winds and pressure for Washington, D.C. During July 1988, an intensive three hourly Pilot Balloon (PB) measurement of wind was made over SHAR (Sriharikota Islands 13.7°N, 80.2°E) and the presence of any diurnal and similar variations are investigated and the results are presented here.

2. Programme and data

SHAR centre of the Indian Space Research Organisation has a well equipped aerological observatory. During the southwest monsoon period of 1988, pilot balloons (32g) inflated with hydrogen gas, were released at 0530, 0830, 1130, 1430, 1730, 2030, 2330 and 0230 IST between 1130 IST of 9 July and 1430 IST of 13 July. The balloons were tracked by optical theodolite and the winds at different heights were derived by the standard method of trajectory using computer software used at Meteorology Facility, SHAR. While, the actual rate of ascent could be considered during the day time flights using the graticule readings of the attached flag, the average rate of ascent of the five-day time ascents were tacitly taken to be the rate of ascent of the balloon flights for the

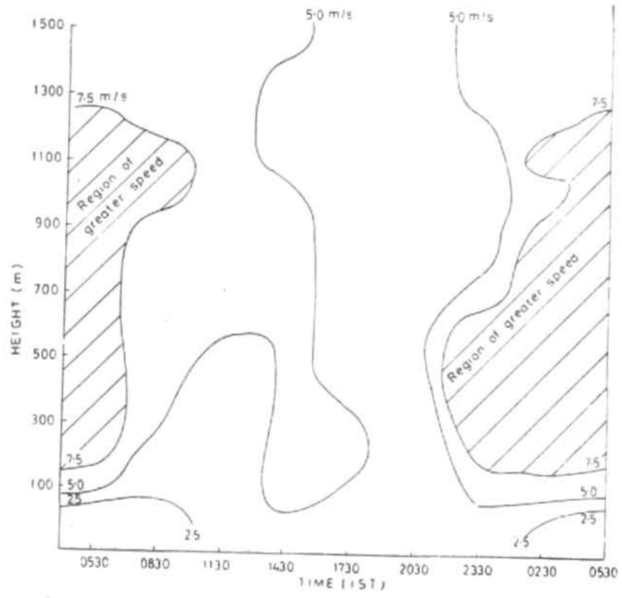

Fig. 1. Time height cross-section of mean wind speed (m/s)

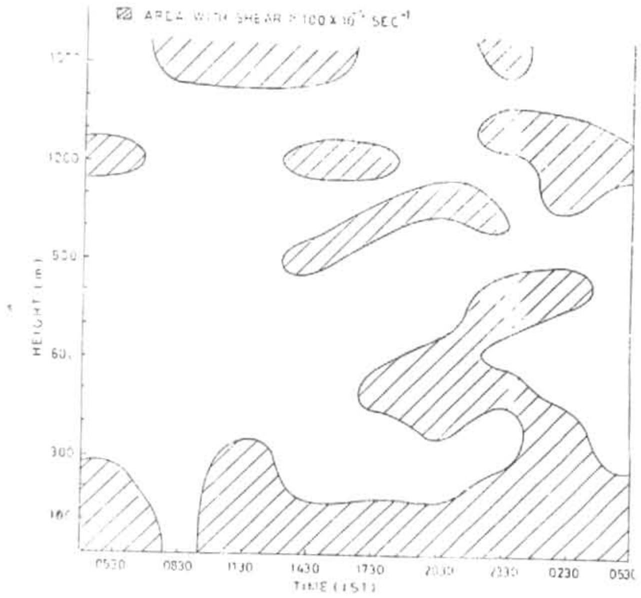

Fig. 2. Average wind shear ($\times 10^{-4}$ sec^{-1}) at different levels

night time. Since PBL thickness varies between 300 m & 1200 m, the winds up to 1500 m were considered at 100 m intervals.

3. Method of analysis

From the data collected during the span of five days, mean vertical profile of wind valid for each synoptic hour is evaluated. The mean meridional and mean zonal wind field valid for the synoptic hours of the day were also computed. The change of wind speed between the consecutive synoptic hours and the steadiness factors were also analysed and discussed. A quantitative estimate of wind shear between the consecutive layers has been made.

Since a sort of regular variation in the wind is noticed, the data is subjected to harmonic analysis and the diurnal and semi-diurnal tendencies, if any, are quantitatively studied.

4. Results and discussions

Fig. 1 presents the time-height cross-section of mean wind speed in metres per second during a day. It can be seen that comparatively stronger winds (> 7.5 m/s) prevail in the layer 200 to 1100 m during late night. Around 1430 IST winds start strengthening up to 500 m level. This may be the sea breeze effect as it was the time of sea breeze during the month.

In order to find the presence of any significant change in the wind speed, the difference between the consecutive synoptic hours in the winds at each level are computed and shown in Fig. 3. It is found that between 2030 and 2330 IST the change in wind speed is maximum, *i.e.*, of the order of 5 m/s. This is the case up to 600 m level. There is also an increasing trend between 0530 and 1430 IST up to about 300 m level. The change of wind speed between consecutive synoptic hours is more or less steady above 900 m level. These informations may be of practical importance to aviators and aerospace engineers.

TABLE 1
Harmonic analysis results (Diurnal oscillation)

	Zonal component			Meridional component		
Height (m)	D.C. (m/s)	Amp. (m/s)	Phase (in IST)	D.C. (m/s)	Amp. (m/s)	Phase (in IST)
18	0.3	1.1	0942	1.3	1.9	2142
100	0.6	2.0	1000	2.2	3.4	2236
200	1.1	2.8	0924	2.6	4.2	2236
300	1.8	3.2	0924	2.7	4.9	2254
400	2.5	3.0	0924	2.6	5.2	2312
500	2.8	2.8	1000	2.1	4.3	2312
600	2.9	2.9	1054	1.8	3.8	2312
700	3.2	2.7	1054	1.6	3.5	2312
800	3.1	3.0	1112	1.0	2.9	2254
900	3.4	3.3	1148	0.7	2.7	2236
1000	3.6	3.5	1206	0.6	2.5	2254
1100	3.4	3.3	1130	0.9	2.4	2218
1200	3.3	2.9	1224	0.6	1.4	2124
1300	3.2	2.7	1318	0.7	1.9	2048
1400	3.2	3.5	1354	0.7	1.7	2106
1500	3.5	3.6	1354	0.4	2.1	2142

The component winds may present a clearer picture. The mean zonal and meridional winds at different hours are shown in Fig. 4. The establishment of the sea breeze front from the east to the station can be identified by the clear dip from 1430 IST in the zonal wind distribution. The westerlies reach the peak around early morning 0530 IST. The prevailing wind during southwest monsoon over this area at low levels will have a pronounced zonal (westerly) component. During day time, because of the strong insolation and the consequent turbulence superposed by the sea breeze front, the westerly component gets severely affected. However, during night time the atmosphere in PBL is comparatively stable, free from turbulence. The land breeze is also from west to east because of topography. This cumulative effect manifest in the strongest westerly winds in the early

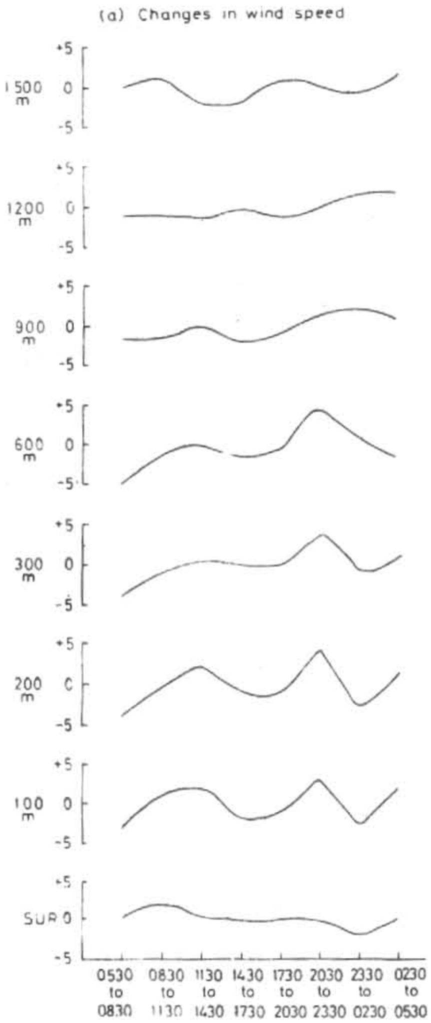

Fig. 3. Change in wind speed (m/s) between consecutive observations

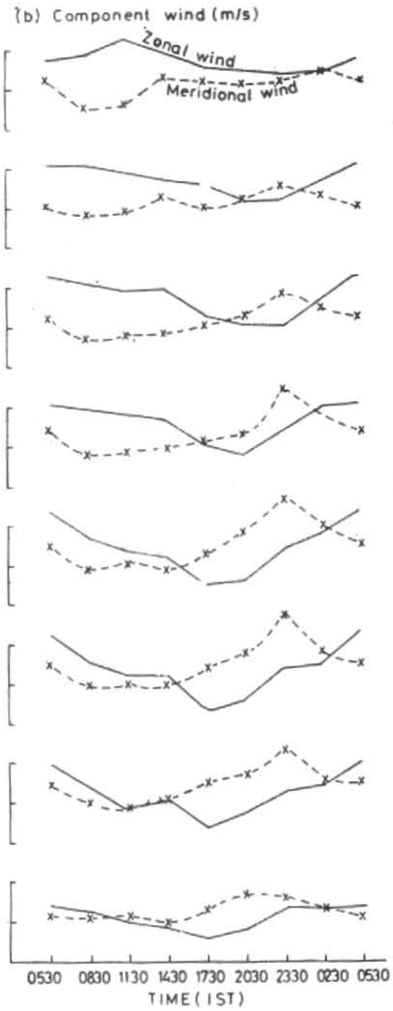

Fig. 4. Components winds (m/s)

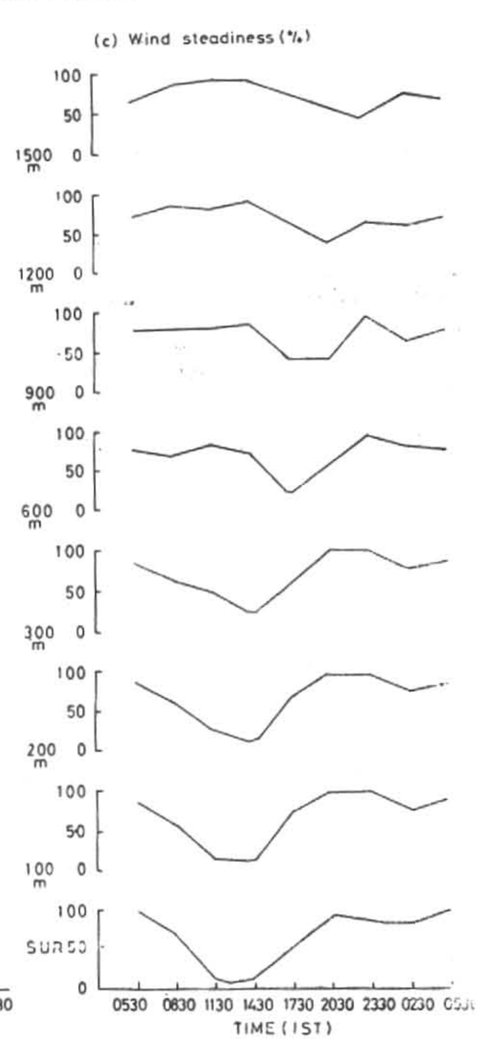

Fig. 5. Wind steadiness (%)

morning just before sunrise. It appears that the sea breeze front influences up to about 600 m level.

The meridional component is practically steady during day time. But there is an increasing trend from evening to about mid night (2330 IST) and then a fall towards the morning.

Fig. 5 gives the wind steadiness factor at different levels. As expected, during night time the steadiness is more compared to the day time. The large variations in the steadiness factor during the course of the day is mainly confined to layers up to about 1000 m. The similarity of the varying tendency of the winds up to 1000 m level and then trying to become steady at higher levels is also seen in both zonal and meridional components. The above observation suggests the thickness of PBL over this place may be around 1000 m.

The wind shear is a parameter of utmost importance in aerospace and aviation meteorology. The wind shear between two levels Z_1 & Z_2 is defined as $[V(Z_2)—V(Z_1)]/(Z_2—Z_1)$ and indicated at the height of Z_2. The shear was calculated separately for zonal and meridional component winds between two consecutive layers and then compounded to arrive at the resultant shear for the individual profiles and the average values for each synoptic hour are obtained. They are presented in Fig. 2. It is seen that, the large shears exceeding 100×10^{-4} per sec are observed in the layers up to about 200 m level during any part of the day except around 0830 IST. In addition there are pockets of similar high shear values in the higher layers also especially during night time.

Since a sort of sinusoidal variation was suggested by the findings as above, harmonic analysis was attempted. Table 1 presents the results of zonal and meridional component winds. It is found that the zonal component has got considerable amplitude (about 3 m/s) from 300 m level onwards. In the meridional component, the amplitude increases to about 5 m/s up to 400 m level and subsequently falls off steadily to about to 2 m/s near about 1100 m level. The semi-diurnal cycles in both zonal and meridional wind components were found to be insignificant.

In this analysis the phase of the cycle is considered as time (in IST) of occurrence of maximum displacement. It can be understood from Table 1, that the phase difference between the zonal and meridional components of diurnal oscillation is about 10 to 13 hours up to 1100 m height and less than 10 hours at levels above 1100 m.

5. Conclusions

(*i*) There exists a diurnal cycle of variations at low level winds during southwest monsoon over SHAR.

(*ii*) Maximum changes in the wind speed occur towards mid-night. The harmonic analysis indicates the amplitude of the zonal wind oscillation to be 3 m/s from 300 m level onwards. The amplitude of meridional component winds is maximum (5 m/s) at 400 m height and then steadily decreases as one goes to higher levels.

(*iii*) The behaviour of wind variation gives an impression that the PBL is about 1000 m thick over this place.

(*iv*) The wind shear values at different places have been evaluated.

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