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Letters to the Editor

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WIND VARIABILITY AND ELLIPTICAL APPROXIMATION OF WIND HODOGRAPHS IN THE SURFACE BOUNDARY LAYER (SBL) OVER SRIHARIKOTA, INDIA

Meso-scale contribution arising from differential heating and radiational cooling of land, and its interactions with synoptic-scale weather patterns is the cause of diurnal cycle of wind variability. On this topic study was carried out by the help of a ratio (α) between diurnal wind variability and interdiurnal wind variability (Alpert and Eppel, 1985). Same technique is adopted at the outset of this study in order to classify the monthly wind variability in the SBL over the tropical coastal station Sriharikota (13.7° N/80.2° E) and thereby the dominancy of meso and synoptic-scale forcings. Later part of the study is confined to mean diurnal oscillations of wind components at different height levels in SBL for each month.

A 100 m tower facility with cup anemometers and wind vanes for indicating wind speed and direction is available at Sriharikota and wind instruments are installed at 6 levels *viz*., 10, 20, 30, 40, 60 and 100 m at about 400 m fetch from the coast of Bay of Bengal. The coastline orientation is having azimuth 360-180° *i.e.*, exactly N-S direction. Wind speed and direction from these six levels are scanned at one second interval round the clock by a PC based data acquisition system. At the end of full fifth minute, the average wind speed and direction of last 120 samples are estimated for each level to represent as quasi-steady state wind of that level (Powel, 1993).

Data from May 1993 to April 1996 are considered as the input data for the analysis. Computation of wind variability ratio (α) is carried out on each full fifth minute zonal wind components at each level for each month. The zonal flow is taken into consideration because the momentum advection for meridional component will be very small difference between its local and total derivatives compared with zonal advection. Also variance of x-component velocity is not so sensitive to changes in stability (Lumley and Panofsky, 1964) and less dependence to surface roughness parameter (Z_0) (Ramachandran *et al.*, 1994). As the coastline lies in 360-180° azimuth the zonal wind component represents the wind component normal to the station which is having significance in boundary layer studies as stated above. The wind variability ratio (α) derived with zonal wind component and the wind component derived normal to the coastline (head wind component) shows similar values for all months in all SBL levels which confirms zonal flow consideration is enough for such studies over the station. For the construction of wind hodographs, every half an hour zonal (u) and meridional wind (v) components are computed and averaged out. Three point moving average technique on the components decreased the noise level of the data used to construct wind hodographs.

The method proposed by Alpert and Eppel (1985) to study the meso and synoptic-scale wind variability is as briefed below.

The normalised diurnal wind variability or diurnal relative gustiness

$$\bar{I}_b = \left[\sum_{i=1}^{n}\left(U_{ij} - U_j\right)^2\right]^{1/2} / \left(nU_j\right) \qquad (1)$$

where U_{ij} is the zonal component of wind at i^{th} minute in the hour and day j, n the number of samples. In the present study each five minute data constitute a total of 288 samples per day and

$$U_{ij} = \left(\sum_{i=1}^{n} U_{ij}\right) / n$$

is the average diurnal wind in the zonal direction for the j^{th} day. The average value of I_b over a period of N days is given by

$$\bar{I}_b = \left(\sum_{j=1}^{n} I_b\right) / N \qquad (2)$$

In similar fashion it is concluded the normalized interdiurnal wind variability I_a as

$$I_a = \left[\sum_{j=1}^{n}\left(U_j - \bar{U}\right)^2\right]^{1/2} / \left(N^{1/2}\bar{U}\right) \qquad (3)$$

where

$$\bar{U} = \left(\sum_{j=1}^{n} U_j\right) / N$$

A ratio (α) between $\bar{I}_b$ to I_a gives an index for the meso-scale activity over the station such as, if $\alpha = \bar{I}_b / I_a > 1$, predominancy for diurnal wind variability and

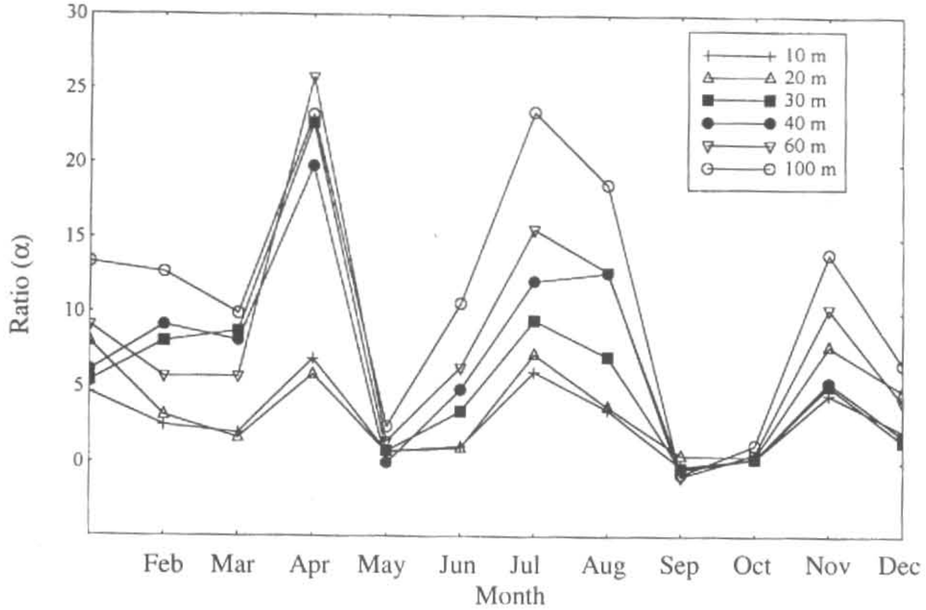

Fig.1. Wind variability over Sriharikota : Ratio (α) between diurnal to interdiurnal wind variabilities

thereby meso-scale forcing $\alpha = \bar{I}_b / I_a < 1$, dominancy for interdiurnal wind variability and thereby synoptic-scale forcing.

Generally speaking $\bar{I}_b$ is the representation for micro-meso contributions to the station and I_a the synoptic contribution. The α index will serve as a measure of the extent that the faithfulness of mean hodograph constructed by taking zonal and meridional components (u,v) with time during the course of a day to actual wind observations.

Fig.1. depicts the monthly wind variability ratio (α) for different levels in the SBL. Generally mean speed in SBL increases with altitude as going up from the ground level. Diurnal and interdiurnal wind variability will have same sort of increase as going up, and thereby in the wind variability ratio (α) also.

In winter months December, January and February, the land-sea temperature contrast over this region is very less and thereby meso-scale systems like land-sea breezes and thunderstorms are infrequent. Also these months are free from migrating low pressure synoptic-scale systems. Because of least effect of large scale features affecting the weather over the station, the dominancy for diurnal wind variability compared to interdiurnal wind variability and thereby giving moderate α of about 2 to 13.5 from 10 m to 100 m level is noticed.

The summer month March behaves like a change over between winter and summer months (March and April) and it keeps it's behavior as earlier winter months.

The April month of summer season is characterised by very strong diurnal differential heating over the SBL and it enables to create large local pressure gradient forces. Hence, it is a month of higher percentage of occurrence of the large diurnal wind variability producing mechanism, the sea-land breezes. (Sivaramakrishnan and Prakash Rao, 1989). A shooting up in the ratio is seen for all levels and it is the maximum in the year, having ratio values from 6 to 26 for 10 to 100 m levels. This indicates a clear picture of strong local diurnal boundary layer forcing.

Overall in the pre-monsoon month of May, Bay of Bengal and adjoining land areas will be under the influence of change overs of high-low pressure systems. Generally lower atmospheric wind flow is so strong compared to other months and is from south east. (Rama *et al*., 1994). This is the month of highest sea breeze occurrence over the station. The sea breeze component of wind gets interacted and boosted up from most persistent high pressure over adjacent Bay of Bengal regions. So in total, eventhough strong diurnal differential heating is noticed over the region, station experiences synoptic-scale *i.e.*, interdiurnal forcing and gives α less than 1. This confirms the dominancy of interdiurnal wind variability in the month of May.

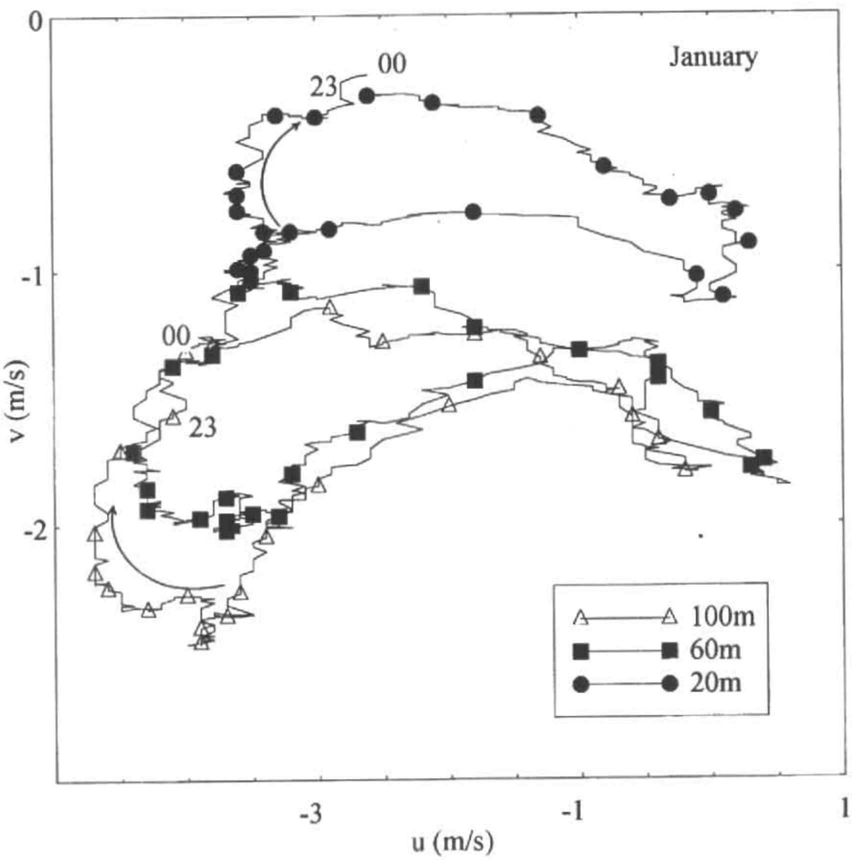

Fig. 2. Mean wind hodograph for January

In the southwest monsoon months, from June to August, this zone is under the influence of southwest monsoon currents carrying more moisture. The strong diurnal heating and sea breeze enhance conditional instability aloft for sufficiently moisturised air mass and develops into thunderstorms is a very common feature of the season (Namboodiri *et al*., 1994). Generally the station is having its own "entity" in having local weather dominated by meso-scale systems. Overall features in these months are unaffected by synoptic-scale forcing and giving another maxima region in the monthly distribution of α from June to August, in which July is the highest ratio value of 6 to 23 from 10 to 100 m. In September passage of troughs over the station is quite common. As a result, the effect of diurnal forcing reduces, thereby reduction in α values to less than 1 is noticed, which shows the predominancy of interdiurnal wind variability implies synoptic-scale forcing.

In October average position of Inter Tropical Convergence Zone (ITCZ) is concentrating over the region (Menon and Rajan, 1989) usually affecting the coastal weather situations, and gives a least α value of the order as that of earlier month. So in October also station experiences interdiurnal wind variability domination.

In November month, the station is prone to low pressure systems brewing over Bay of Bengal. Generally, the life span of such systems is about a week. Hence, diurnal boundary layer forcing playing a dominant role. November month is giving a tertiary maximum in α value of less intensity compared to other two maxima of the order of 4.5 to 14 from 10 m level to 100 m level.

Overall observations on the monthly variations of wind variability ratio in the lowest 100 m of atmosphere over Sriharikota shows an increasing trend as going upward and their distribution is having three maxima during April, July and November respectively. Moderate value from December to March through January. May, September and October months give minimum ratios and are slightly less than 1.

The significance of any meso-scale modelling is lying on to what extend the station is affected by diurnal boundary layer forcing. Alpert and Eppel's proposed index (α) applied to SBL of Sriharikota giving a vivid overall

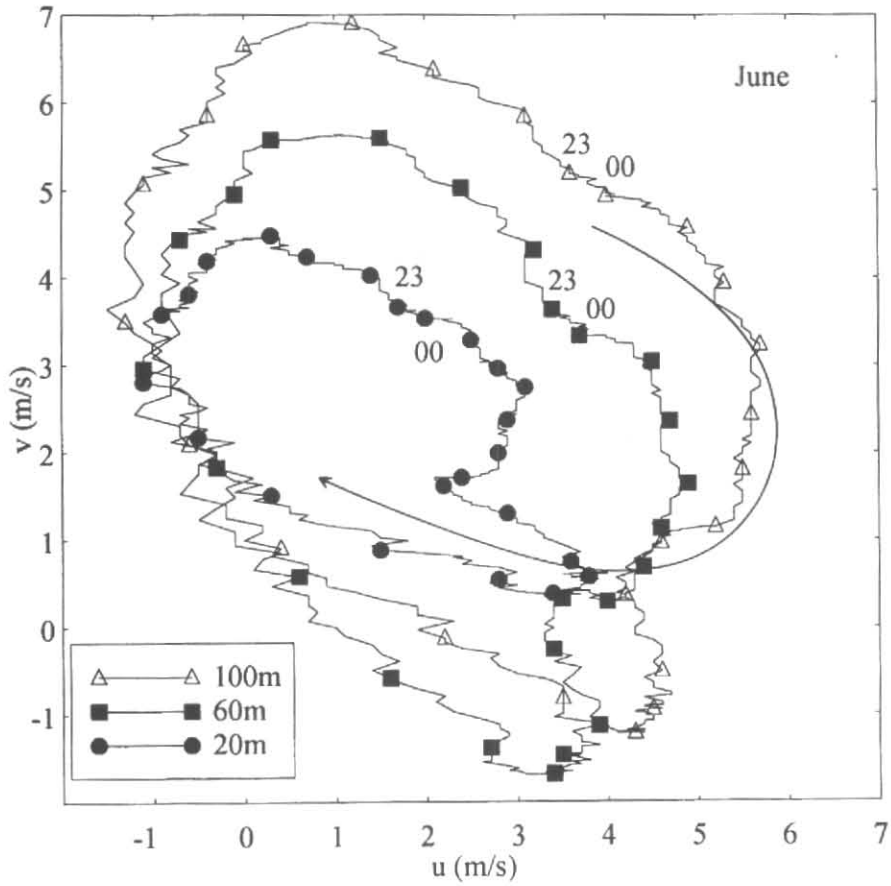

Fig. 3. Mean wind hodograph for June

dominancy of diurnal wind variability. Keeping in view the general dominancy of diurnal wind variability in the SBL, wind hodographs were constructed on different levels.

Figs. 2 & 3 represent the mean wind hodographs for a winter month (January) and for a south west monsoon month (June). For clarity of the phenomenon under discussion three level hodographs (20 m, 60 m and 100 m) are presented in these plots. Generally the mean wind hodographs are showing circulation feature during the course of the day in association with α value more than 1 and thereby higher chance for successful prediction of the SBL wind by meso-scale models as suggested by Alpert and Eppel (1985). In all hodographs, initial observation starting at 0000 IST and closing the hodograph at 2330 hour IST in clockwise time progressing manner. Points are of interval 30 minute. A clockwise rotation showing arrow has drawn in hodographs, wherever an almost ellipticity approximation holds good at its maximum extend. Monthly variations in wind components show strong oscillations in both u and v components during strong diurnal wind variability dominating months and is from 5.3 to 8 ms^{-1} in u component and 1.2 to 8.4 ms^{-1} in the case of v component between 10 m and 100 m of SBL.

Generally during early morning or morning hours, the hodograph is disturbed in its course, when land breeze prevails over the station. During months having strong meso-scale forcing in the boundary layer, such as May to September, this period of disturbed non-uniform turning of the wind ellipse is from about 0100 IST to 1000 hour IST. This may be attributed by the pressure gradient force which contributes significant modifications in the geostrophic wind and thereby the loss of uniform turning in actual wind. The portion of nonuniformity in the turning lies in the right hand side of the wind hodographs.

Generally the hodograph size increases with height. Among all levels 10 m hodograph shows much disturbed path which may be contributed by high surface roughness parameter of average value of the order 0.5 m for this station. From May to September, very close approximation of ellipse forms at all levels. The size of ellipse in these months show large variations with v component amplitude and thereby v component of geostrophic wind places a major criteria on the size of the ellipses. More rapid increase or decrease in v component can be seen in the left hand side and right hand side of the hodographs, corresponding to morning and evening winds respectively. Very shallow variations in v component during afternoon and late night implies v component geostrophic wind will have sharp changes within a short span of time during morning and evening hours.

The feasibility of getting elliptical path with time for wind hodographs during the course of a day is very dominating feature in the months having meso-scale forcing on boundary layer. This plays high role to have local weather phenomenon like sea breeze and thunderstorms to the station. Generally this tropical station is having highest degree incidence for diurnal wind variability which is the necessary and sufficient condition for any meso-scale modelling studies.

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