J. Natn. Sci. Coun. Sri Lanka 1998 **26(3)**: *235-245*

SHORT COMMUNICATION

VARIATION OF SURFACE WINDS AT HAMBANTOTA FROM APRIL 1990 TO MARCH 1991

LAREEF ZUBAIR
Institute of Fundamental Studies, Kandy.

(Received: 10 September 1997; accepted: 04 September 1998)

Abstract: Hourly measurements of surface winds have recently become available through the Ceylon Electricity Board Wind Energy Project. These records were used to characterise the structure of the wind velocity of the atmospheric surface layer at Hambantota in different seasons. The surface winds at Hambantota are from the north-east from November to January. In the rest of the year, the winds are directed towards the south-west particularly intensely around July. The Von Karman log-law can approximate the velocity profile. The velocity at heights between 10 m and 20 m are highly correlated. There is a significant diurnal variation of wind velocity which averages 3-5 m/s from 2400 to 0800 h. Thereafter it peaks at 7-10 m/s around 1530 h. The "gustiness" of the wind as measured by the mean of the differences between maximum and average velocity is moderately greater during the monsoonal months. The average monthly wind velocity is correlated with precipitation. These seasonal variations of wind and precipitation in Sri Lanka are correlated with the latitude of the equatorial low pressure trough commonly called the Inter-Tropical Convergence Zone.

Key Words: Hambantota, velocity, wind

INTRODUCTION

The atmospheric flow field is a complex phenomenon governed by the Navier-Stokes equations which are known to have complex solutions.[1] The details of topography, solar radiation, landforms, cloud cover, adjacent water bodies, rainfall, atmospheric temperature and humidity fields affect the behaviour of the velocity flow field. Its modelling is complex. To manage with the available computer and data resources, it is necessary to compromise between the scale of the model and the details it considers.[2] The characterisation and modelling of atmospheric flow fields is advancing rapidly and it is now imperative to characterise the wind patterns over Sri Lanka to aid in modelling. The characterisation of wind velocity is not only useful for assessing the potential for wind energy schemes but also in the study of the structure of atmospheric turbulence, the dispersion of stack emissions, species migration, meteorology and a variety of environmental issues.[2] For many years, the Department of Meteorology has recorded wind velocity at nine stations in Sri Lanka. Their records are available at various heights albeit with significant gaps.[3] Several previous studies have described surface wind patterns in Sri Lanka based on the statistical analysis of wind data obtained from the Department of Meteorology and from field observations. Yoshino[4,5] has developed a wind map of Sri Lanka for different seasons. Schweinfurth & Domroes[6] have provided details regarding the kachchan (foehn) winds that develop in the eastern slopes of the hill country during the south-west monsoon and its analogue during the north-east monsoon. Suppiah[7] has characterised the wind patterns at different altitudes over Sri Lanka. Somasekeram *et al.*[3] provide a characterisation of the surface wind based upon the Department of Meteorology data. Detailed hourly measurements of surface winds have recently become available through the Ceylon Electricity Board Wind Energy Project[8] which studied the viability of harnessing wind energy. We take advantage of these records, which are far more detailed and precise than that of the Department of Meteorology, to characterise the surface winds at Hambantota in this study.

The wind at Hambantota is important because it is at the southern extreme of the island and indeed that of the South Asian subcontinent. The lay of the coastline at Hambantota is approximately parallel to the North-East - South-West axis. Thus, a predominant component of the winds reaching it blows over the sea during both monsoons. Winds blowing over the sea are much less affected by frictional drag than that blowing over land and as a result the wind speed is likely to be relatively high. The findings from this study can be used to deduce various details from the Department of Meteorology data which while less detailed and precise are available for several decades.

METHODS AND MATERIALS

The CEB data[1] were acquired using an anemometer mounted on a vertical tower at Hambantota Wave Trap (latitude 6 08' N, longitude 81 09' E, Altitude <30 m) (Fig. 1). Readings of the mean and maximum speed were acquired at heights of 10, 15 and 20 m every hour. The direction of the wind at a height of 20 m was recorded too. The records April 1990 to March 1991 were made available for this study.

The mean diurnal variation of the mean wind speed (Fig. 2), of the mean hourly maximum wind speed (Fig. 3) and the mean wind directions (Fig. 4) at a height of 20 m were computed for different months. The transport in a given direction was computed by totalling the wind speeds that occur from the direction of each sector (Fig. 5). The variation of the wind velocity with height was fitted with the Von Karman log law (Fig. 6). Finally in Fig. 7, the mean wind velocity in the northern and eastern directions are shown. The extent of correlations between velocity at different heights and "gustiness" were estimated based on one year's wind data . The correlation of wind velocity with rainfall and temperature were estimated. These correlations will help to understand the physical mechanisms that modulate the climate.

It will be useful to assess whether there is any clear correlation between wind speeds, rainfall and temperatures as these may give clues as to the dominant atmospheric mechanisms.

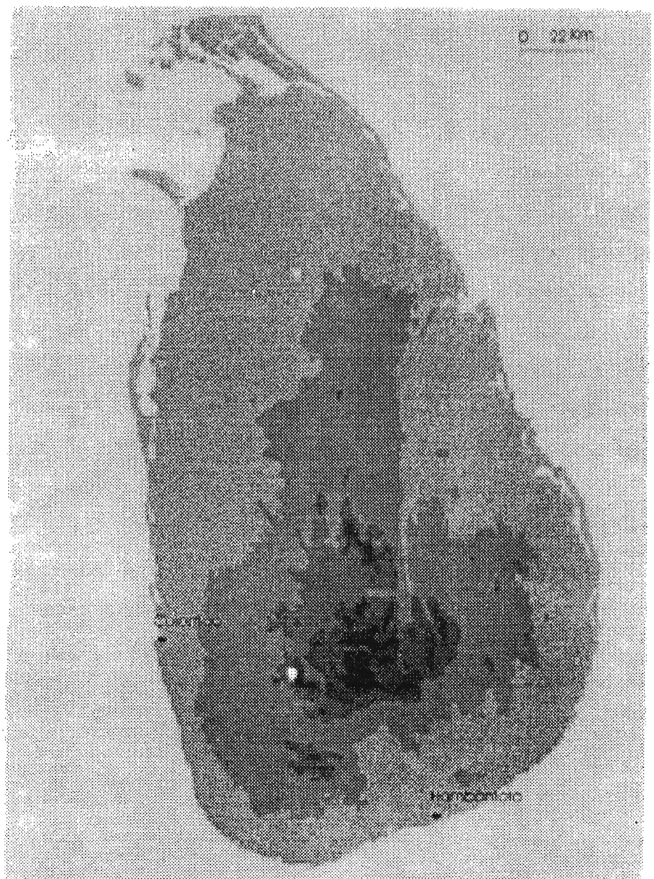

Figure 1: Location map of Hambantota.

One may anticipate correlation between wind and precipitation as the details of atmospheric circulation control the formation of clouds and condensation. Particularly, in monsoonal areas, one can anticipate high rainfall during times of high vertical wind velocities.[9] The monsoonal seasonal wind patterns are characteristically well established generally for the entire island.[3] Given the cellular structure of the Hadley cell[9] one can expect low surface wind speed when the vertical wind speed is high. Since there are no mountains around Hambantota, there will be no orographic rainfall arising from high surface winds. Thus, one expects an inverse correlation between surface wind speeds and rainfall and it will be insightful to estimate the extent of correlation.

Similarly, the temperature can be linked to wind velocity, either through the effects of bouyancy or rainfall. One may anticipate that at times of high rainfall the temperature will drop.

RESULTS

The mean diurnal variation of wind speeds for different months (Fig. 2) shows a consistent diurnal variation: the wind is twice as intense during the day as in the night. The wind speeds reach a peak of 7-8 m/s during the south-west monsoonal months of June, July, August and September. In other months, the peak wind velocity is between 4-6 m/s. The wind speed averages between 3 and 5 m/s depending on the month from 2400 to 0800 h. The diurnal hourly peak wind speeds (Fig. 3) have a similar profile to that of the mean wind speeds. The hourly peak is between 30-70% greater than the mean wind speed. The gustiness of the wind as measured by the mean of the absolute differences between maximum and average velocity is moderately greater during the peak monsoonal months of January and July. The average wind direction at a height of 20 m was calculated for different months (Fig. 4). The surface wind exhibits a clear transition from December to February (arriving at a north-eastern direction) and almost its opposite direction in the remaining months with the onset of the monsoon. The wind direction does not vary significantly between day and night and the lack of such variation shows that the influence of the sea-breeze on the wind velocity is low.

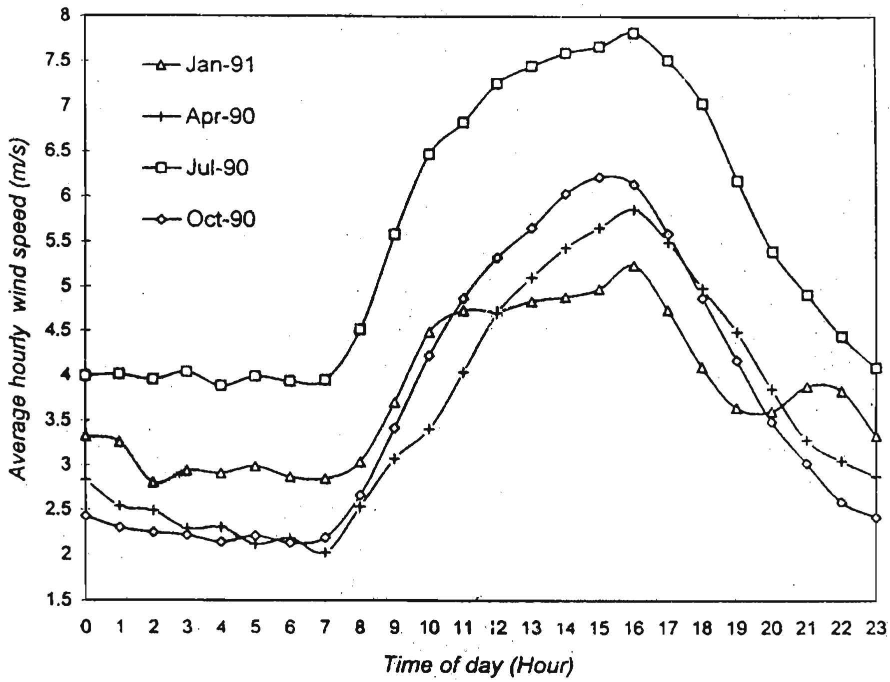

Figure 2: The seasonal diurnal variation of wind speeds.

The cumulative total of wind speeds occurring from a given direction for different months is shown in a polar plot in Fig. 5. We have computed the frequency of wind from various points of the compass and its distribution is close to the total of wind speeds occurring each month. This figure accounts for the speed of the wind as well as the duration in a given direction and it enables us to quantify the transport due to the wind.

The wind is strongly directed from the north-east from December to February. In the intermediate periods, the winds are directed from the south-west particularly intensely around July. While the predominant wind direction in April and October is from the south-west, in the peak monsoonal month of July it is from the south-south-west direction. The wind velocity at heights of 10m and 20m had a correlation coefficient of 0.98. Such high correlation requires that the wind directions at these heights are almost identical.

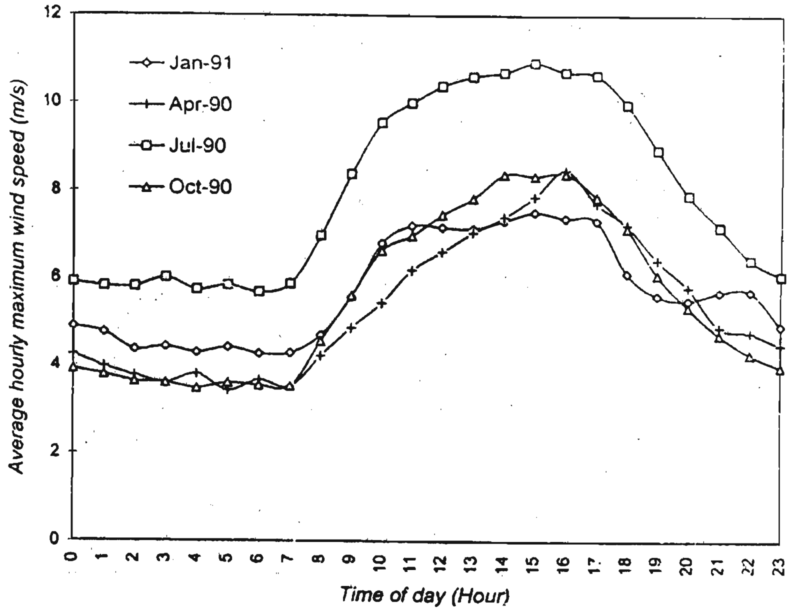

Figure 3: The seasonal diurnal variations of the hourly maximum wind speeds.

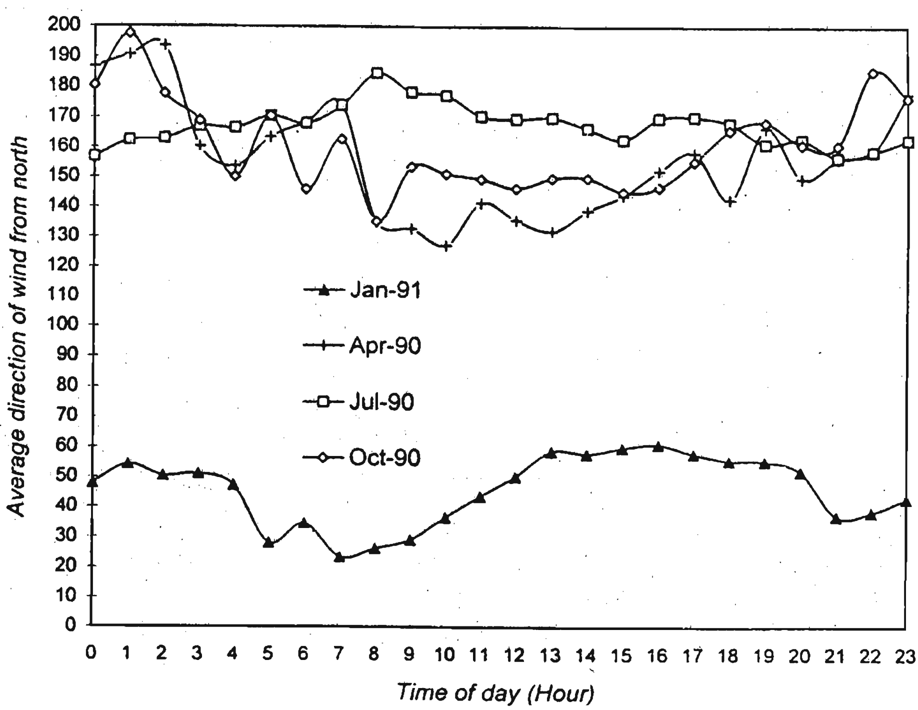

Figure 4: The seasonal diurnal variations of the wind directions.

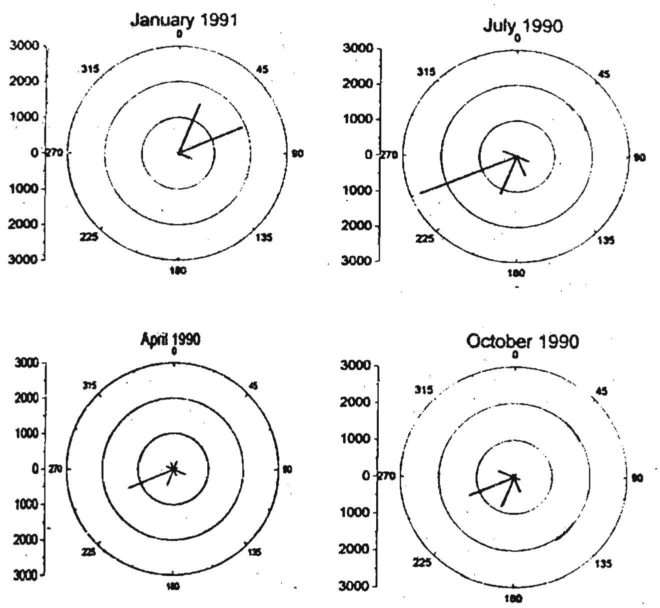

Figure 5: The cumulative of the wind speeds as broken up into eight points in the compass for Hambantota for different months. Note, that the frequency of winds from different directions has a similar distribution. The wind direction is indicated in the coming-from direction.

The Von Karman log law[10] can approximate the mean surface wind velocity profile for a boundary layer as :

$$\bar{u} = A \ln \frac{Z}{Z_0}$$

where u is the mean velocity at a height z from the surface and z_0 is the surface roughness. This profile assumes that bouyancy is negligible and that the flow is two dimensional. Both these conditions are not exactly met in an atmospheric surface layer. The bouyancy of the air changes with the time of day depending upon the terrestrial heating and the wind is rarely two-dimensional. Yet, the Von Karman law is an approximation, which can be used to obtain order of magnitude estimates for wind at different altitudes given the sparse measurements at just three heights of 10,15 and 20m.

The best fit obtained for the Hambantota data (Fig. 6) had a surface roughness z_0, which is approximately 0.13m when the wind arrives from the landside and several magnitudes smaller for the seaward direction. The analysis was based on wind speeds exceeding 4 ms^{-1} to ensure that shear rather than buoyancy dominates the flow. We also see that the wind is particularly intense in the south-west monsoonal months from April to September.

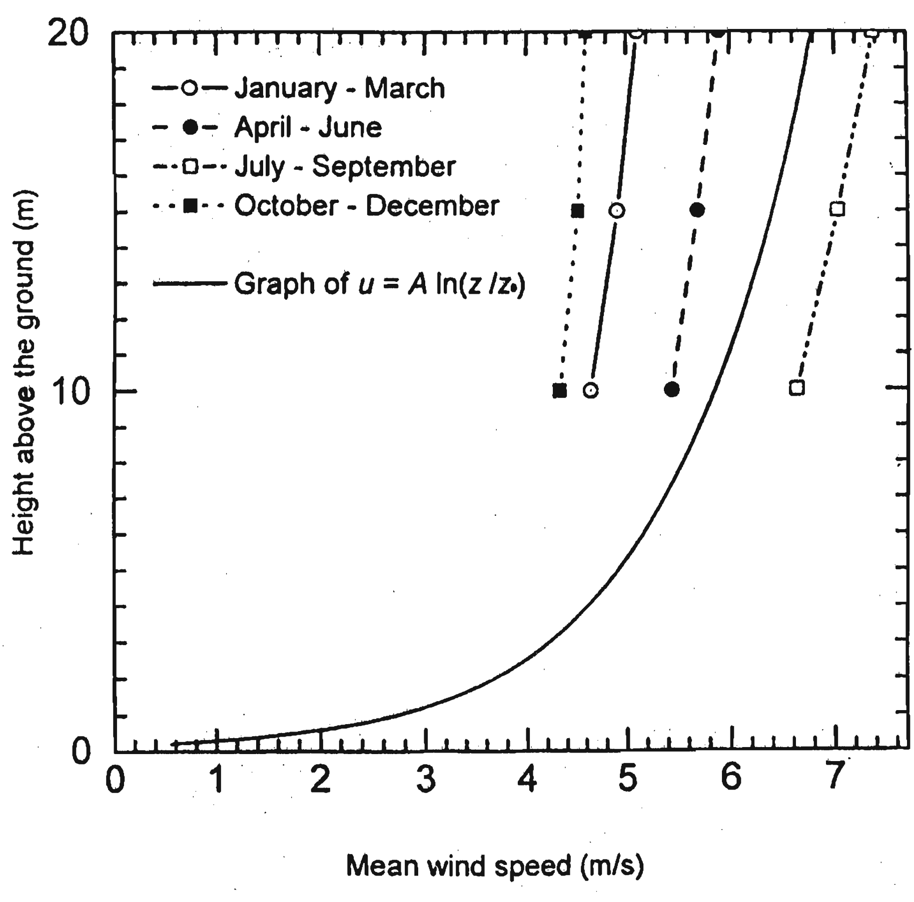

Figure 6: The profile of the wind velocity at different heights in different seasons.

Fig. 7 shows the mean meridional (northern) and zonal (eastern) components of the wind velocity at Hambantota in its top panel at a height of 20m. The wind velocity is directly correlated with precipitation but the correlation with temperature is not as clear.

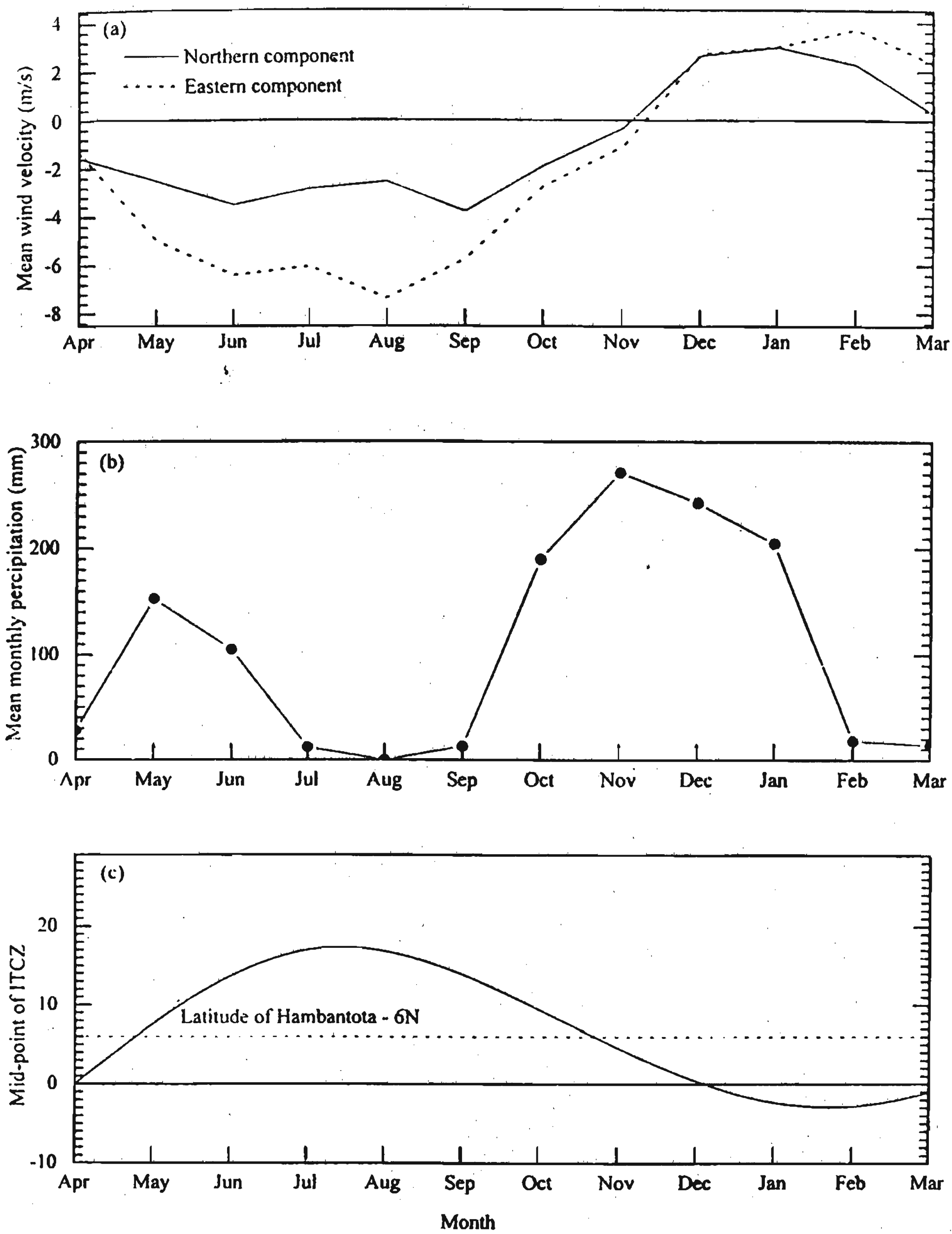

Figure 7. **Top: The northern and eastern component of the wind velocity by month.**
Middle: The precipitation for the same period starting in April 1990.
Bottom: The variation of the mid-point of the Inter-Tropical Convergence zone.

DISCUSSION

From May to November, the wind is dominated by the circulation arising from the monsoon cell which originates in the Southern hemisphere and is north of Sri Lanka from May to November.[9] This cell is advected northwards towards the low-pressure trough which is termed the Inter-Tropical Convergence Zone (ITCZ). This zone demarcates the regions for which the wind blows from the south-west and the north-east. The ITCZ is a clearly perceivable zone during certain months and is a broad indistinct region for other months. Its latitudinal variations are correlated with the solar radiation intensity in the region. From December to February, the ITCZ is centred around a latitude of 10° S. Thus Sri Lanka is North of the ITCZ and is thus affected by the tradewinds arriving from the north-east. From June to August, the ITCZ is centred around 23°N and the island is buffeted by the south-easterly tradewinds which turn south-westwards on crossing the equator due to the Coriolis component. It is clear from Fig. 7, that both northern and eastern components of the wind are strongly correlated (with a correlation coefficient of 0.9) with the location of the mid-point of the ITCZ. Thus, the location of the Hadley cell is a principal factor in wind behaviour in Sri Lanka.

The clear correlation of the seasonal variation of velocities and precipitation with the latitude of the ITCZ suggests that the dominant variations of the velocity can be accounted for by the relative location of the Hadley cell to Sri Lanka. These variations are modulated by the time of day and topography. The wind characteristics obtained at Hambantota are useful in making order-of-magnitude assessments for wind behaviour at other locations in the island.

Acknowledgement

We thank the General Manager of the Ceylon Electricity Board and Lalith Kariyawasam for providing data and W.L.S. Fernando, P.G.L. Kariyawasam and Dr. W.L. Sumathipala for useful discussions and A.U.K. Gunaratne for preparing the figures.

References

1. Lumley J.L. & Panofsky H.A. (1964). *The structure of the atmospheric boundary layer*. Interscience.

2. Lalas D.P. & Ratto G.F. (1996). *The modelling of atmospheric flow fields*. World Scientific, Singapore.

3. Somaskeram T. (1988). *National Atlas*. Survey Department.

4. Yoshino M.M. (1982). A climatological study on wind conditions in Sri Lanka. *Climatological Notes* **30** : 111-125.

5. Yoshino M.M. (1983). Wind and its effects on air temperature, humidityandrainfall in Sri Lanka. *Climatological Notes* **33**: 181-190.

6. Schweinfurth U. & Domroes M. (1974). Local wind phenomena in the Central Highlands of Ceylon. *Bonner Meteorologische Abhandlungen* **17**: 387-401.

7. Suppiah R. (1989). Atmospheric circulation variations and the rainfall of Sri Lanka. *Science Report.* Institute of Geoscience, University of Tsukuba, Section A, Vol 9.

8. Ceylon Electricity Board (1992). Wind resource assessment in the Southern Lowlands of Sri Lanka. Ceylon Electricity Board, 1992.

9. Gadgil S. (1982). Fluid dynamics of the monsoon. In: *Surveys influidmechanics.* (Eds. R. Narasimha & S.M. Deshpande). pp. 201-220. Indian Academy of Science, Bangalore.

10. Sutton O.G. (1989). *Atmospheric turbulence.* Metheun.