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Diurnal and seasonal variation in surface wind at Sita Eliya, Sri Lanka

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With 8 Figures

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Summary

Hourly measurements of surface winds at Sita Eliya (6° 58′ N, 80° 46′ E, 1860 *m* a.s.l.) located atop the North-South mountain ridge in Sri Lanka were analyzed to investigate the diurnal and seasonal variation in the wind climate. Surface winds are dominated by the monsoon regimes, with Northeasterlies from November to January, Southwesterlies from February to May and Westerlies and Northwesterlies from June to October. Through most of the year, the average wind speed is around 6–8 m/s. However from June to August, it is around 10–14 m/s. Wind in June is gusty due the location of the low-level Easterly jet over Sri Lanka. The wind undergoes a reversal in both zonal and meridional directions in March and November coincident with the migration of the Inter-Tropical Convergence Zone. Notwithstanding the period from May to September being designated as the Southwest monsoon, the wind is from West, South-West-West and North-North-West. During the Southwest monsoon, wind speed during the night is nearly as high as that during the day. This anomalous diurnal variation in wind speeds may be related to orographic influences. The high wind speeds at Sita Eliya, in conjunction with the moderate diurnal and seasonal variability in wind speed, is suitable for wind-energy generation.

1. Introduction

Sri Lanka seasonal climate is modulated by the monsoonal regime and by the zonal migration of the Intertropical Convergence Zone. The seasonal variation is conventionally expressed by four climatic seasons, namely the First Inter-monsoon (March to April), Southwest monsoon (mid-May to September), Second Inter-monsoon (October to November) and Northeast monsoon (December to February) (Bamford, 1922; Domroes, 1974; Suppiah and Yoshino, 1984). Notwithstanding its importance in understanding the regional climate, studies of wind regimes in Sri Lanka have been limited in comparison with studies of rainfall.

Previous studies for Sri Lanka have been based primarily on measurements of the Department of Meteorology. Jameson (1941) reported on the dry and warm *foehn* wind phenomena known as ''kachchan'' on the east of Sri Lanka. Schweinfurth and Domroes (1974) provided detailed descriptions of the kachchan winds that develop in the eastern slopes of the hill country during the Southwest monsoon and its analogue during the North-East monsoon on the western slopes. Suppiah (1989) characterized the upper wind patterns at different altitudes over Sri Lanka. Yoshino (1982, 1983) developed a wind map of Sri Lanka for different seasons and studied the impact of *kachchan* winds on the climate system. Somasekeram et al. (1988) summarizes the surface wind measurements of the

Table 1. The duration of wind speeds occurring in given speed intervals in hours per day for Colombo (79.88E, 6.9N, 7 *m* a.s.l.), Nuwara Eliya (80.77E, 6.97N, 1895 *m* a.s.l.) and Batticaloa (81.7E, 7.7N, 3 *m* a.s.l.) for the months of January, April, July and October derived from measurements by the Department of Meteorology of Sri Lanka (Somasekeram et al., 1988). These months represent conditions during the North-East monsoon, First Inter-monsoon, South-West monsoon and Second Inter-monsoon

Month	January			April			July			October		
Speed(*m*/*s*)	< 2.7	3.05–4.16	4.4–5.5	< 2.7	3.05–4.16	4.4–5.5	< 2.7	3.05–4.16	4.4–5.5	< 2.7	3.05–4.16	4.4–5.5
Station												
Colombo	15	9	0	20	4	0	15	9	0	17	7	0
Nuwara Eliya	21	3	0	23	1	0	0	12	12	24	0	0
Batticaloa	0	19	5	13	9	2	14	4	6	14	7	3

Department of Meteorology (Table 1 provides an extract). All these studies highlight the need for further detailed characterization of the wind fields.

Recently, the Ceylon Electricity Board (CEB) carried out precise and detailed wind measurements at Sita Eliya, which is located atop the North-South mountain ridge that bisects the

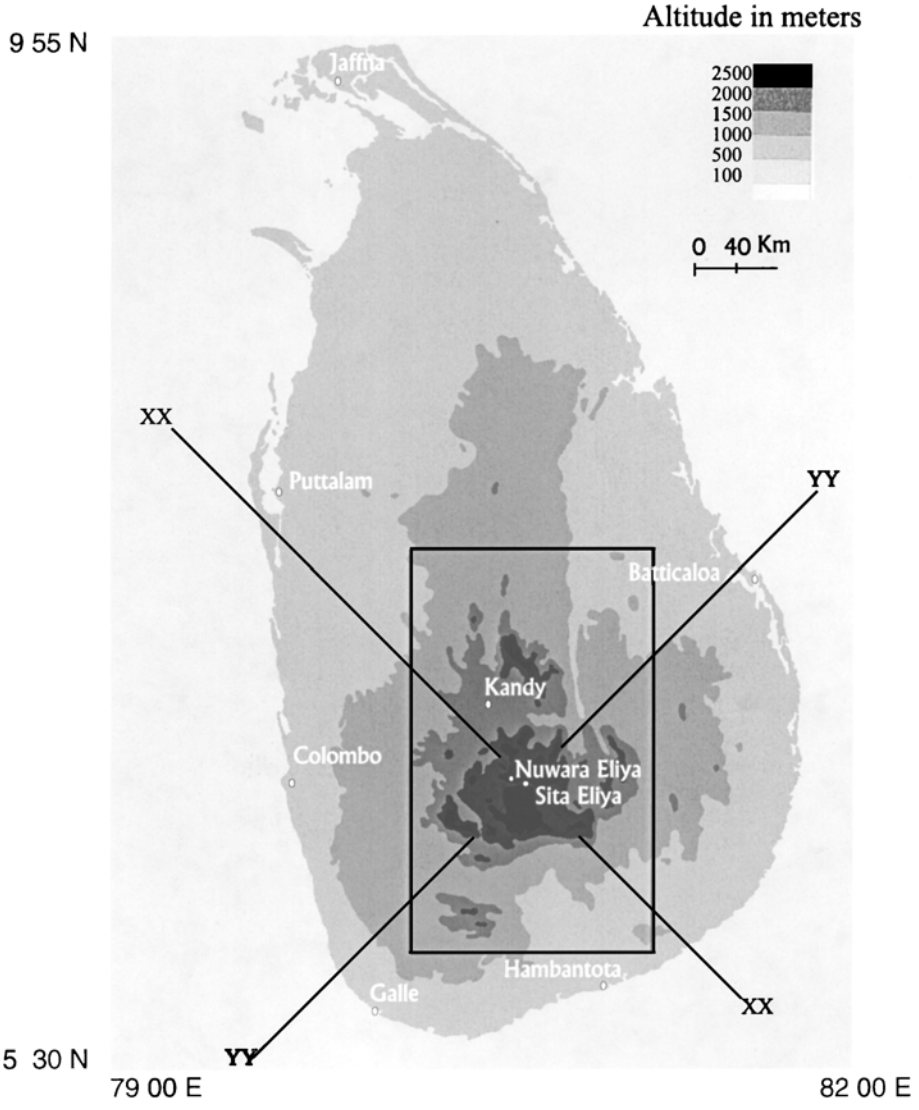

Fig. 1. The topographic map of Sri Lanka. Sita Eliya is located at the intersection of sections XX and YY

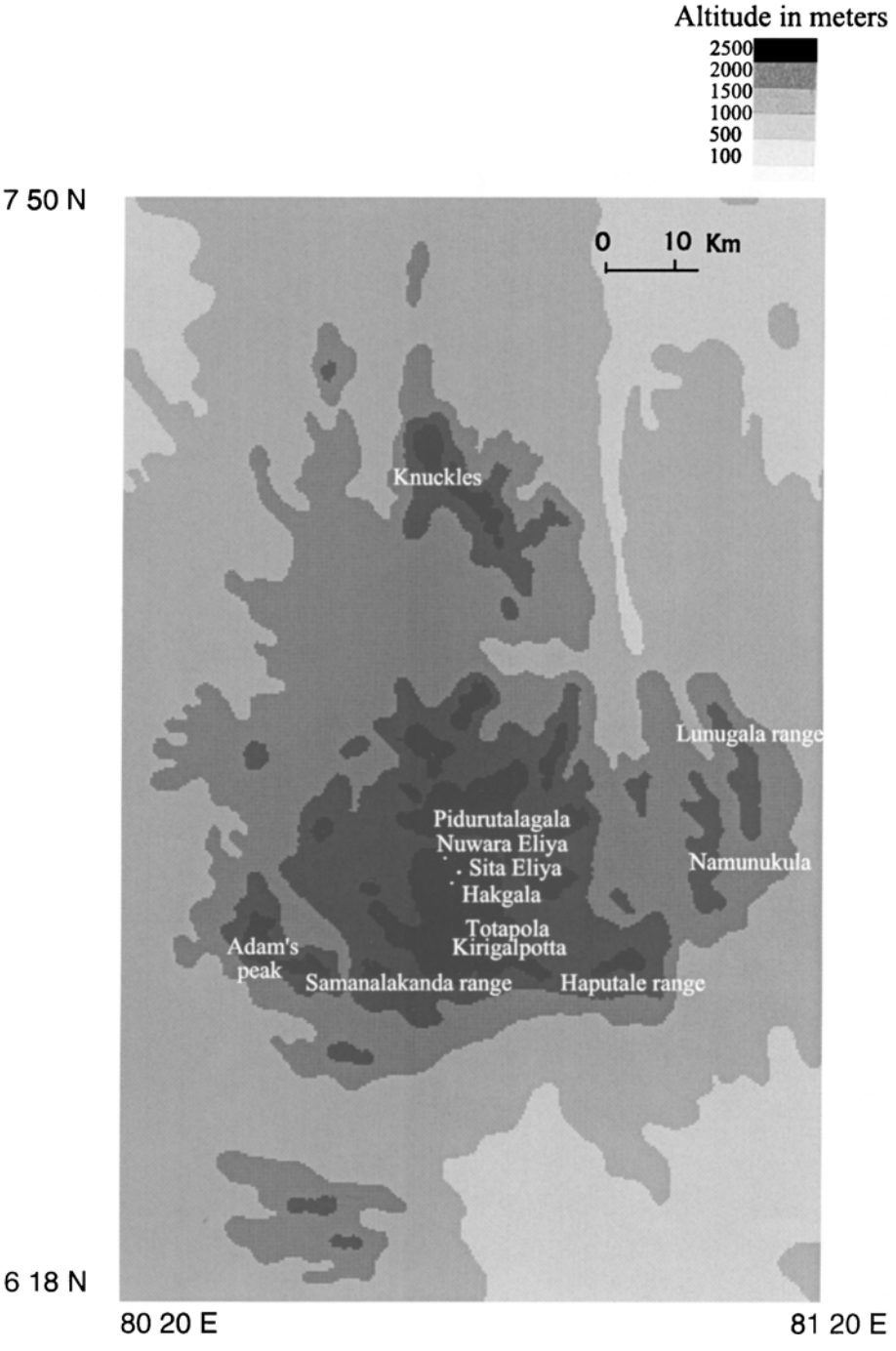

Fig. 2. The geography and topography of the hill country region within the rectangle marked in Fig. 1 is shown in detail

island. This mountain ridge rises to an altitude of 2,524 meters and plays an important role in modulating the climate of Sri Lanka. Sita Eliya (see Fig. 1) is located on top of the ridge at an altitude of 1,860 meters and at 6° 58′ N and 80° 46′ E. Its wind regime is affected by the neighbouring Pidurutalagala mountain rising to 2,524 meters to the Northwest and the Hakgala mountain range rising to 2,174 meters to the South-West (Fig. 2). These two mountain ranges create a funneling effect around Sita Eliya (Fig. 3).

The purpose of this paper is to establish the diurnal and seasonal wind characteristics at Sita Eliya and their implications for the climate of the region and potential for the generation

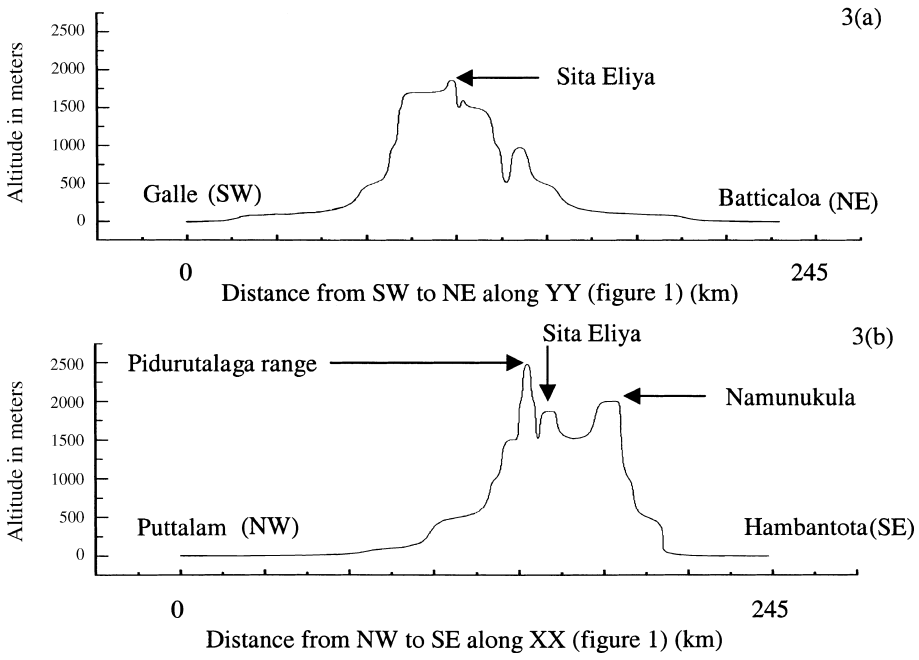

Fig. 3. The altitudes along the cross-section from the South-West to the North-East (marked as XX in Fig. 1) through Sita Eliya is shown in the top panel. The altitudes along the cross-section from the South-East to the North-West (marked as YY in Fig. 1) through Sita Eliya is shown in the bottom panel

of wind energy. This will highlight the orographic influence of the mountains on the wind field over Sri Lanka.

2. Data

The CEB data (CEB, 1992) at Sita Eliya were acquired using three anemometers mounted on a vertical tower. The average and maximum hourly wind speeds were measured at heights of 10, 15 and 20 meters. The wind direction was measured at a height of 20 meters. Wind measurements were made only from March 1991 to September 1992. Thereafter the tower was dismantled. A time series of the wind speeds and direction is provided in Fig. 4. A longer record of near-surface wind near

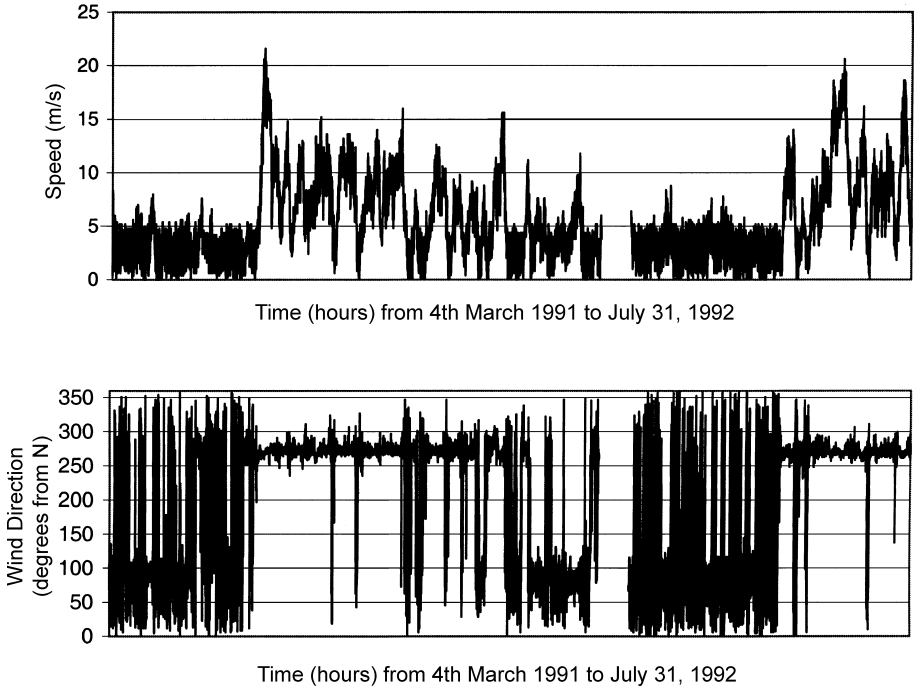

Fig. 4. The time series of the hourly wind speed and direction in Sita Eliya at a height of 20 m is shown from March 4, 1991 to July 31, 1992. Some data in February 1992 is not included due to measurement problems

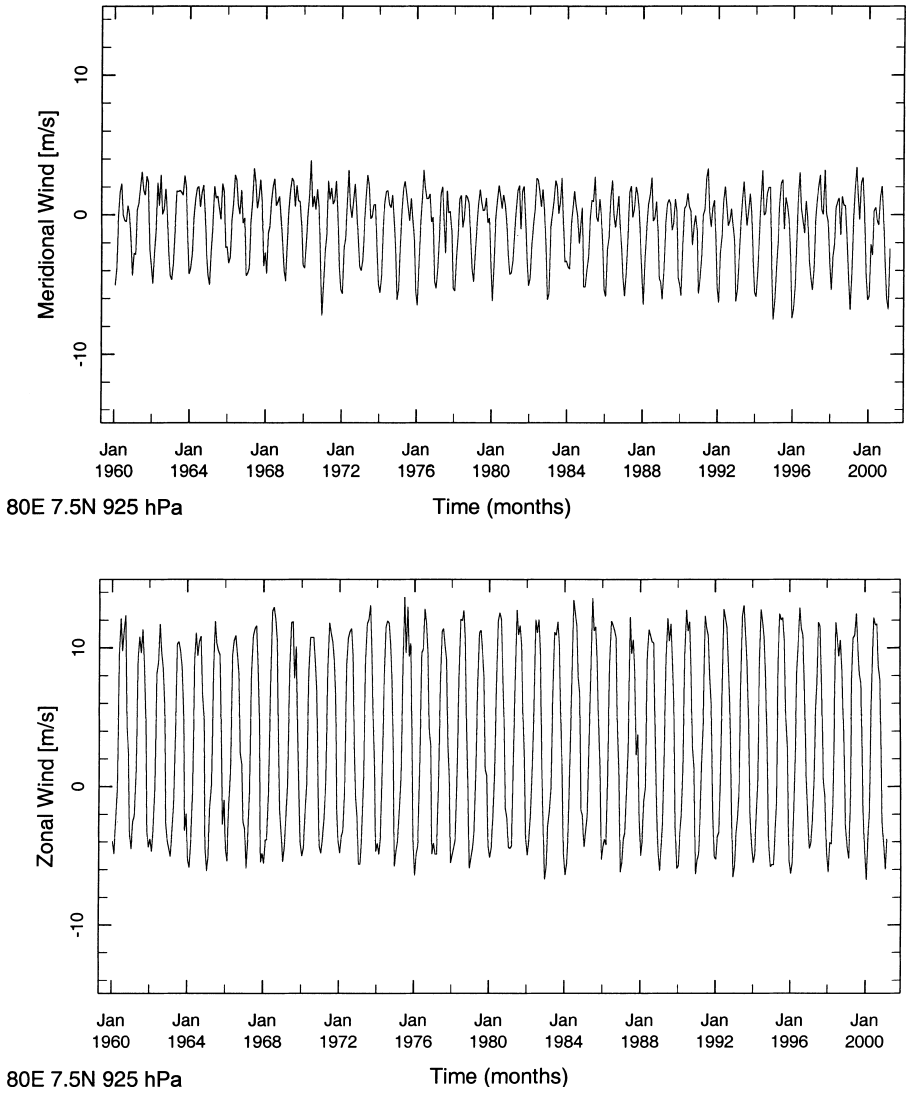

Fig. 5. The zonal and meridional wind speeds computed from the NOAA-NCEP reanalysis (Kalnay et al., 1996) for the grid location closest to Sita Eliya (80E, 7.5N and 925 *mb* pressure height) are shown. The wind speeds from 1991 to 1992 are approximately close to the wind climatology over Sri Lanka

Sita Eliya (Fig. 5), obtained from the NCEP reanalyses of global climatic data, (Kalnay et al., 1996) shows that the wind characteristics during the year 1991 and 1992 were not anomalous. The South-West monsoon in 1991 is seen to be stronger than that in 1992.

3. Analysis of wind measurements

The diurnal variation in mean and maximum wind speeds during April, July, October and December is shown in Fig. 6 and highlights several interesting features. Notwithstanding the hilly terrain, wind speeds at Sita Eliya are remarkably high in June, July and August, averaging around 10–14 m/s. These speeds are comparable to the highest wind speeds found on the island at Hambantota and Jaffna (Somasekeram et al., 1988). In September the wind is from the Southwest with a mean wind speed of 7–8 m/s. From November to March the wind is from the Northeast at a mean speed of 5–6 m/s. The predominant wind direction reverses from East to West and North to South in March and November, coincident with the zonal migration of the Inter-Tropical Convergence Zone.

The diurnal variation of the hourly mean and maximum wind speed shows one unusual feature (Fig. 6). As a result of the solar heating balance, wind speeds are usually reduced during the night and accelerate as the day unfolds. This is indeed the pattern in April in Sita Eliya and throughout the year in coastal areas (Zubair et al., 2001). However, this pattern is disrupted at Sita Eliya

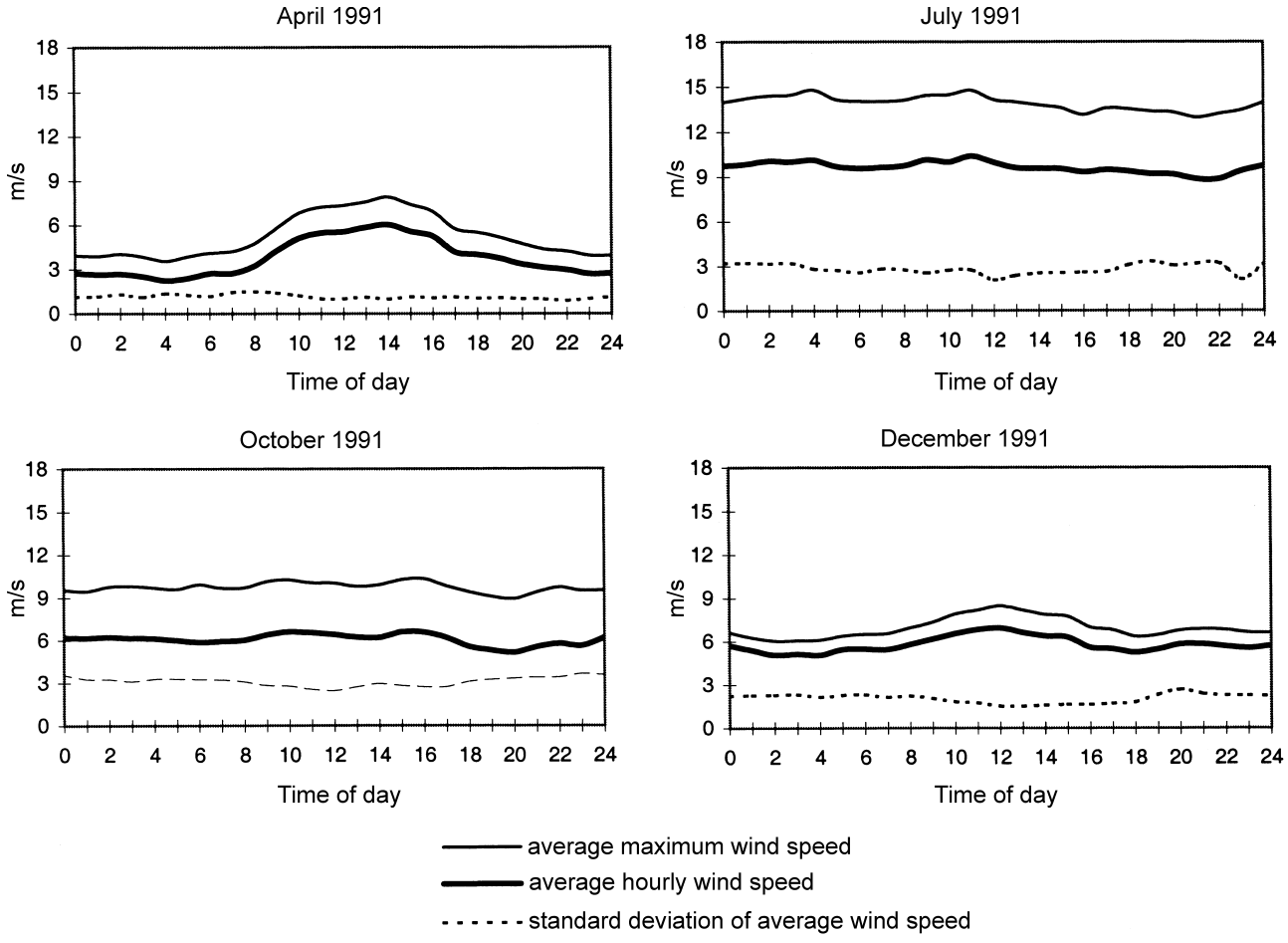

Fig. 6. The monthly average diurnal wind speeds at Sita Eliya for April, July October and December representing the four seasons (First Inter-monsoon, South-West monsoon, Second-Inter-monsoon and North-East monsoon) are shown

from June to October, and the night-time wind speeds are nearly as high as the day-time wind speeds.

The fraction of time during which wind speed was above 10 and 20 m/s was calculated for different months (Fig. 7). Wind speeds greater than 10 m/s are prevalent in the Southwest monsoon and Second Inter-monsoon periods. High speed gusts above 20 m/s are frequent in June and to a lesser extent in July, August and October. These high wind speeds may be attributed to the location of the low-level Easterly jet over Sri Lanka around June and July (Findlater, 1969).

The frequency of wind directions averaged to 8 points of the compass is shown in Fig. 8. In all four months considered, the wind direction is predominantly on the E-W axis. The wind direction during April was more variable. During July and October it was predominantly from W and WNW. During December the wind was predominantly from E and ENE.

4. Conclusions regarding the wind fields

The following conclusions may be reached regarding the seasonal and diurnal variations of the wind field in Sita Eliya.

- During the Southwest monsoon from May to September, the average wind speeds are high and approximately 10–14 m/s. The wind speed declines to 8 m/s in October.
- The wind during the Southwest monsoon is from the West, North-West-West and South-West-West. The wind direction during the

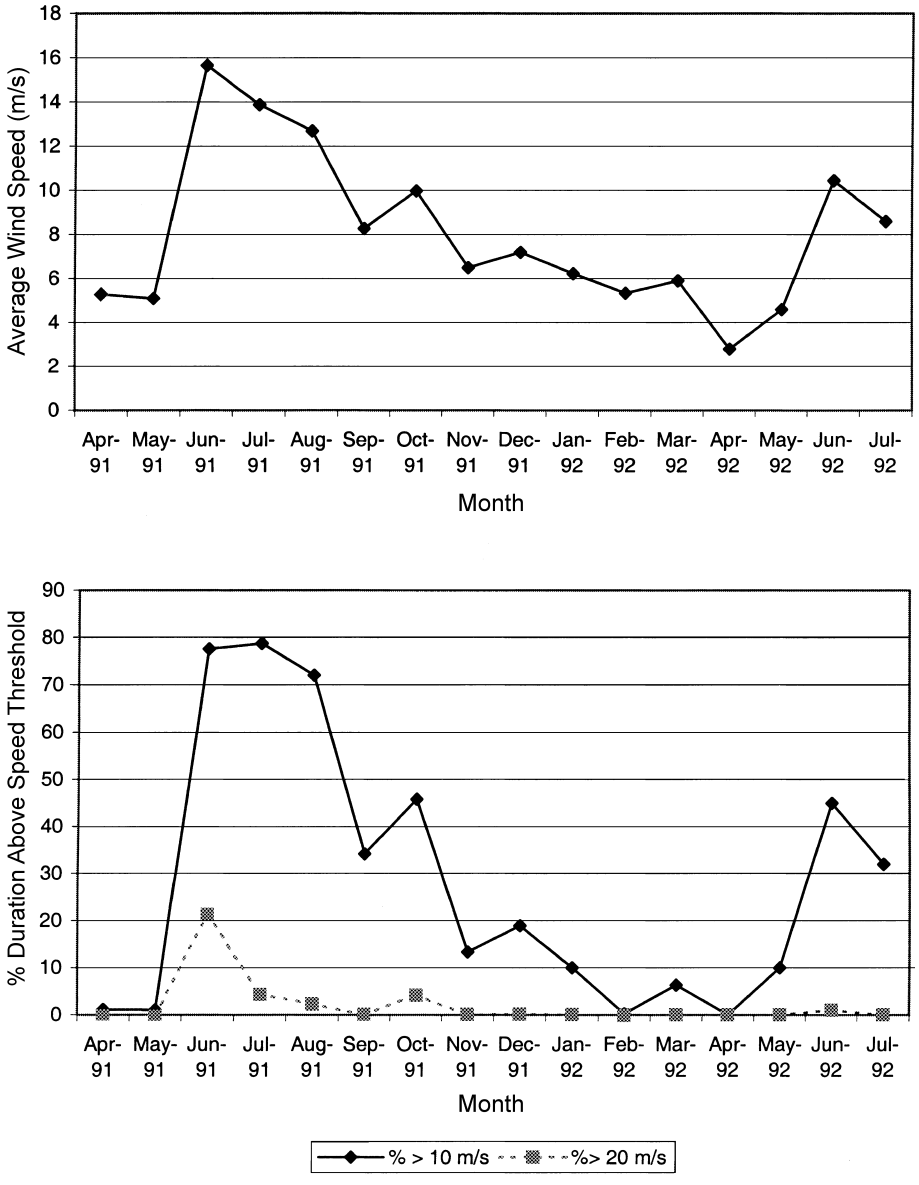

Fig. 7. The average monthly wind speeds from April 1991 to July 1992 are shown in the top panel. The percentage fraction of time during which the wind speed higher than 10 and 20 m/s respectively in each month is shown in the bottom panel

Northeast monsoon is from the North-East-East. The wind direction during the First Inter-Monsoon occurs from both Easterly and Westerly directions. However during the second Inter-Monsoon, the Westerlies dominate.

- Wind speeds do not drop at night by more than 50% of their day-time value during all months. In particular, during the Southwest monsoon, the night-time wind speeds are comparable to those during the day.
- Wind speeds are gusty during the Southwest monsoon. The wind is likely to be extreme (> 20 m/s) during June and July when the low-level Easterly jet is over Sri Lanka.

5. Interpretation of the results

The wind speeds in Sita Eliya are high in comparison with other locations in Sri Lanka and are only slightly lower than the highest wind speeds found at the Northern and Southern extremes of the island (Somasekeram et al., 1988). Wind energy generation would be highest in the Southwest monsoon period. The moderate diurnal and seasonal variability in wind speeds is an advantage for the generation of wind energy. Since the wind is primarily on an East-West axis, a wind turbine that does not follow the wind direction could be used. However, during the

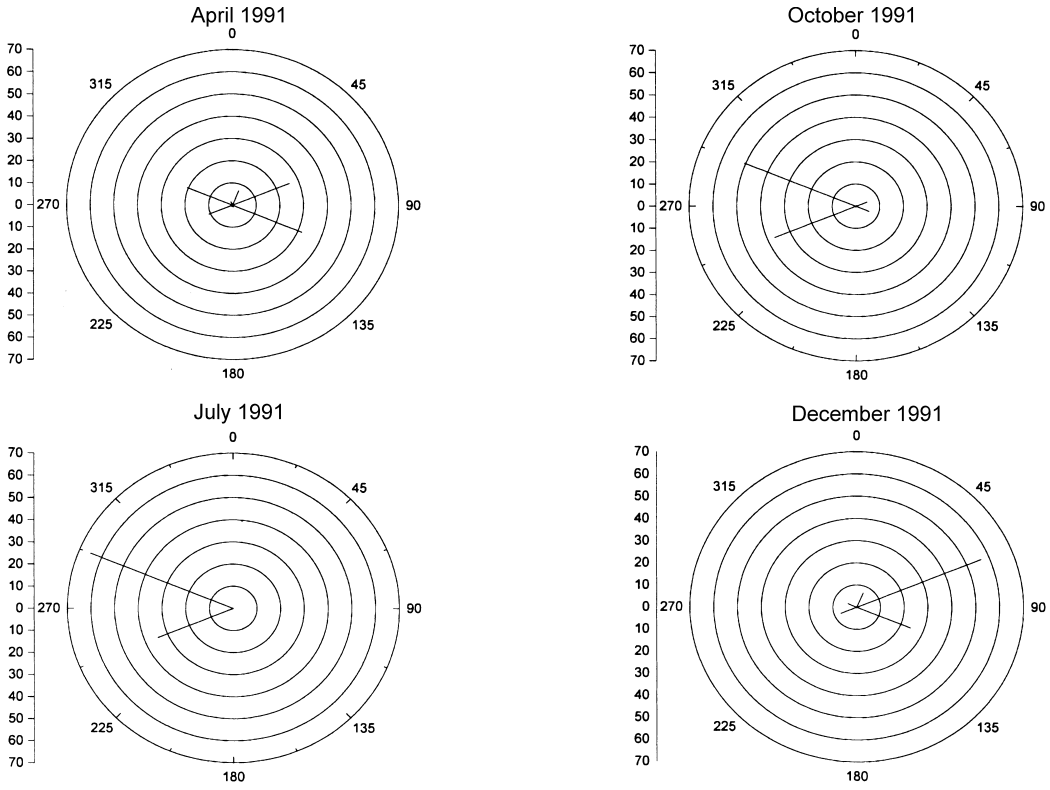

Fig. 8. The percentage frequency of wind directions at Sita Eliya occurring from eight points of the compass for months representative of the four seasons

Northeast monsoon, the turbine will have to be rotated 180°. The wind turbine will need protection from the wind gusts, particularly in June and July.

The two findings reported here that have implications for understanding regional climate are the disruption of the diurnal wind velocities during the Southwest monsoon months and the prevalence of W and WNW winds during the South-West monsoon period. These two issues are discussed further.

The first unusual feature of wind in Sita Eliya is its diurnal variation. The anomalous diurnal wind velocities may be related to the diurnal variability in orographic precipitation during the Southwest monsoon and the Kachchan winds in the leeward side of the mountains (Jameson, 1941; Yoshino, 1982, 1983). The precise mechanism for this phenomenon deserves further investigation.

Second, it is intriguing that during the so-called Southwest monsoon, the wind is predominately from the WNW rather than the SW. This poses the question as to whether these wind directions are a local feature. Hence an examination of the upper air winds is warranted. Somasekeram et al. (1988) present the synoptic circulation pattern at an altitude of 1,500 meters over the entire region surrounding Sri Lanka. Clearly the circulation pattern over Sri Lanka is from W in July and from WNW in October. The upper air wind direction measured using a radiosonde by the Department of Meteorology at Colombo consistently show that in July, the wind is from the W at an altitude of 1,500 *m* (Nakagawa et al., 1988). Thus the upper air measurements at Colombo also support the finding that the wind is from W to WNW in the Southwest monsoon period.

The prevalence of Westerly rather than South-Westerly wind direction during the so-called South-West monsoon is a feature found in Sri Lanka and the extreme South of India (Somasekeram et al., 1988). To the north along the Western coast of India, the wind is approximately South-Westerly. However, the nomenclature for monsoons used in India has always been applied indiscriminately to Sri Lanka as well (Bamford, 1922). Bamford, a Director of the Colombo

Meteorological Observatory in Ceylon (Sri Lanka), who produced the official meteorological reports wrote of this inappropriate nomenclature as follows; ''Our proximity to India has probably helped this idea, owing to the natural tendency to describe conditions in Ceylon in terms identical with those in India''.

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