Terdiurnal tides in MLT region over Cachoeira Paulista (22.7º S; 45º W)

Aparecido S. Tokumoto, Paulo P. Batista, Barclay R. Clemesha INPE, Brazil

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Abstract

Five years of winds measurements obtained by a SkiYmet meteor radar at Cachoeira Paulista (22.7° S, 45.0° W) are used to investigate the terdiurnal This type of tide is frequently observed in the meteor region but the mechanisms responsible for its production are not yet completely explained. Among the possible causes are solar direct forcing and nonlinear interactions between the diurnal and semidiurnal tides. Nonlinear interaction between diurnal and semidiurnal tides can generate two secondary waves: a diurnal tide and a terdiurnal tide. The origin and distribution of the terdiurnal tide may indicate the presence of a secondary diurnal tide as a cause of variability in the primary diurnal tide. In this work we analyze the winds data in search of evidence for these mechanisms.

Introduction

The tidal climatology of atmospheric tides in the 70 to 110 km region has been studied for many years by observations and numerical simulations (Avery et al., 1989; Manson net al., 1989; Vial, 1986; Forbes and Hagan, 1988, Hagan et al., 1995). Tokumoto (2002) and Batista et al. (2004), studied the climatology of the atmospheric tides and mean winds in the 80 to 100 km over Cachoeira Paulista.

The terdiurnal tides have been less studied than the diurnal and semidiurnal ones, because, being the third harmonic in the wind decomposition, one could expect that its amplitude would be relatively small anywhere. But, Cevolani and Bonelli (1985) found that at middle latitude, its amplitude was comparable to the diurnal tide. Cevolani (1987) and Manson and Meek (1986) found a more irregular phase variation and wavelengths shorter in summer than in winter, and amplitude higher in winter than in summer.

A numerical study by Teitelbaum et al. (1989) looked at two possible mechanisms for the excitation of the terdiurnal tide: The direct thermal generation by the third harmonic of solar daily cycle and dynamical generation by nonlinear interaction between diurnal and semidiurnal tide. In this latter process, the terdiurnal tide (zonal wavenumber 3) is generated by the sum of diurnal and semidiurnal (wavenumbers 1 and 2, respectively) and the difference leads to the generation of another diurnal tidal component. They found that a superposition of two tides, a propagating tide forced by solar absorption in the lower to middle atmosphere and a tide generated locally by the nonlinear wave-wave interaction mechanism, is consistent with the observed terdiurnal tidal structure in the summer upper mesosphere. During winter the tidal structure is more consistent with direct solar forcing of the terdiurnal tide.

The model of Smith and Ortland (2001) indicates that the direct solar forcing of the terdiurnal tide is the dominant mechanism at middle and high latitudes and nonlinear interactions contribute to the low latitude tide.

Measurements and Data Analysis

Data used in this paper were collected by a SkiYmet meteor radar at Cachoeira Paulista (22.7^{o} S; 45^{o} W). This radar operates at the frequency of 35.24 MHz, and provides data since March, 1999.

The wave components were calculated using harmonic analysis. Lomb-Scargle periodogram and bispectral analysis were also applied to the winds data. In order to investigate the time distribution of wave components the harmonic analysis at time series in the interval April, 1999 to March, 2004 was used. Yearly meridional and zonal wind series were separated in amplitude and phase components at 48, 24, 12 and 8 hours periods, centered at heights 80, 84, 88, 92, 96 and 100km.

The Lomb-Scargle periodogram calculated the power spectrum density (PSD) using 15-day data window. This method permits investigate the periodic elements present in the wind. The Lomb-Scargle periodogram indicates the components present at spectrum, but not its origin.

In order to investigate the wave origin we use the bispectral analysis. The bispectral analysis is used to investigate the presence of nonlinear interaction between waves. The bispectrum is, by definition, the two-dimensional Fourier transform of a third-order cumulant. When three waves are present in a time series and there is a quadratic phase coupling (for example, there is a non-linear interaction between waves) the bispectrum will be non-zero, if there is not a quadratic phase coupling between the waves, the bispectrum will be zero. To evaluate the bispectrum, In this work we used the average of five intervals of seven days size with overlap of four days.

Results

We present in Figure 1 a time-height contour for the amplitudes of the meridional component of terdiurnal tide. In this figure, annual distribution of diurnal tide from April 1999 to March 2004 was plotted. The last panel refers to the five-year averaged data. This panel indicates that the terdiurnal tidal amplitudes have semiannual characteristics. Tidal amplitudes became maximum (between 20 and 40 m/s) at around 92 to 100 km, in April, July, August, September, February and March; in others months the amplitudes are weaker.

Figure 2 shows the periodogram of unfiltered winds for April and September of 1999 at 92 km. Figure 2, top and bottom, indicates that diurnal tide is the strongest wind component, but shows also weak semidiurnal and terdiurnal components in the spectrum.

The bispectrum (Figure 3) displays a strong peak around the bifrequencies (1.0, 1.0) cycles/day in April 1999. This peak can indicate the self-interaction between diurnal tidal components, however, it can indicate a difference triplet (2; 1; 1) cycles/day contribution. The figure displays weak sum triplet (2; 1; 3) cycles/day, too. These peaks may indicate a weak non-linear interaction between diurnal and semidiurnal tides.

Conclusions

The analysis of MLT region winds over Cachoeira Paulista reveals that terdiurnal tides have semiannual features with peaks at higher altitudes at equinoxes. Spectral analysis shows that semidiurnal and terdiurnal tides are present in these time intervals, but they are very weak if compared with diurnal tide. Bispectral analysis shows triplets (1.0, 2.0, 3.0). This fact indicates that, at least in this particular interval, there is a weak nonlinear interaction between diurnal and semidiurnal wind components generating a secondary diurnal and a terdiurnal component. However, the terdiurnal component is also weak, so that, the direct solar driving forcing contribution should also be weak. Thus, nonlinear interaction contribution can be a mechanism of generation of the terdiunal tide in our latitude. This feature explains also the semiannual variability of terdiunal components, observed above the altitude 90 km, because this distribution is the same of the diurnal and semidiurnal components (not shown in this work)

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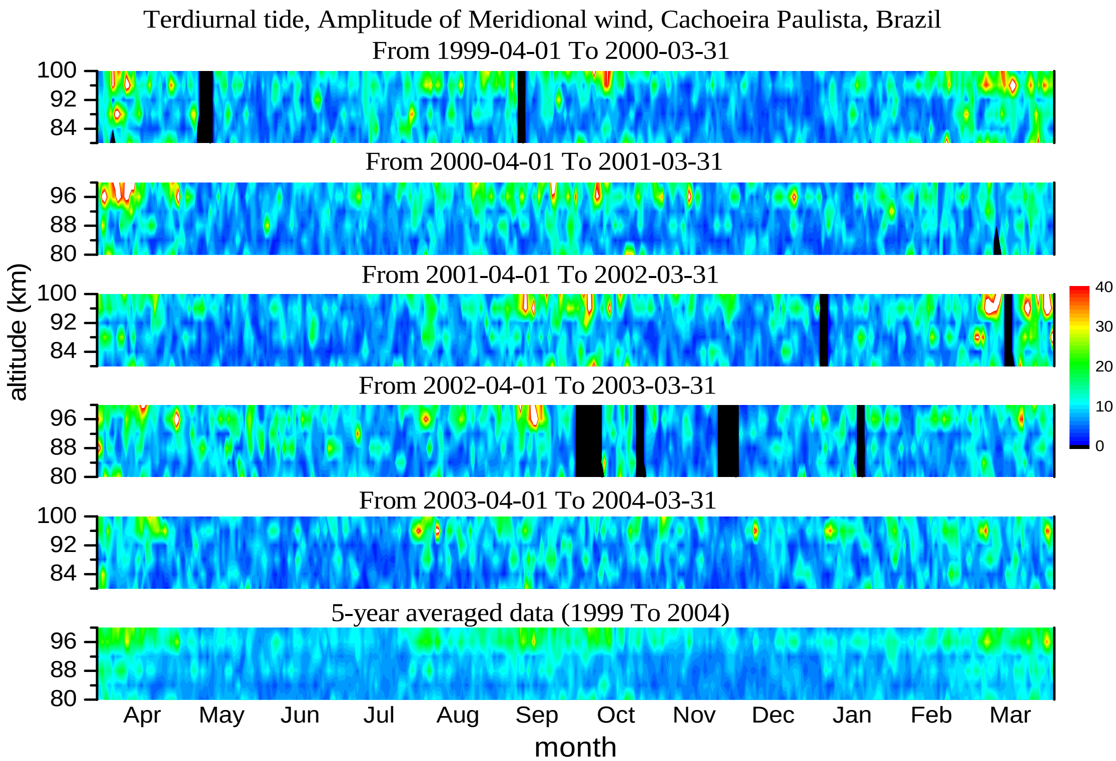
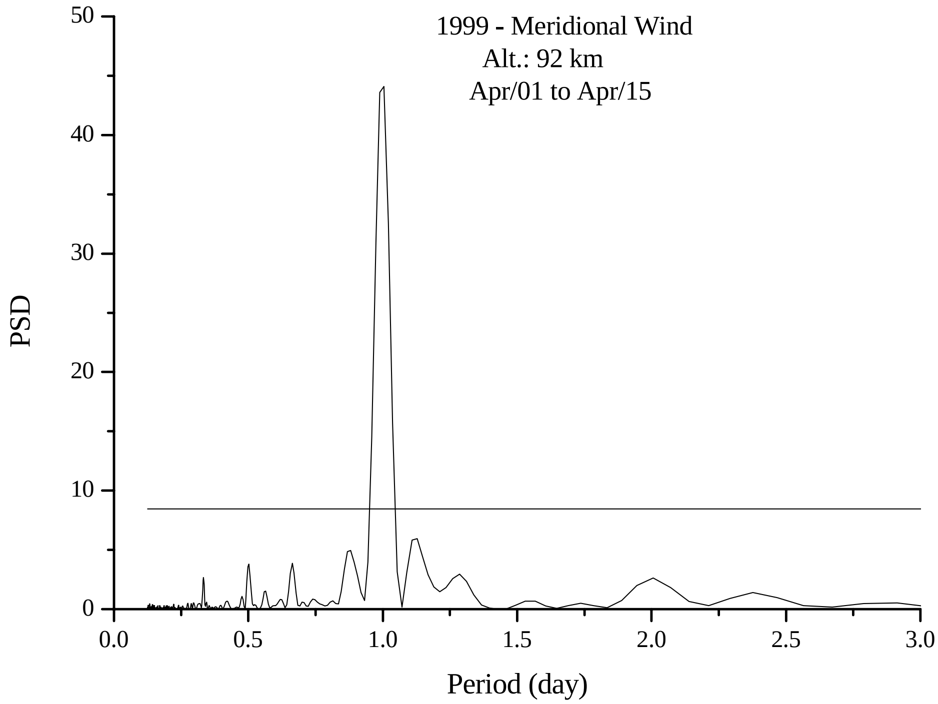


Fig. 1 Amplitudes of the terdiurnal component of the meridional wind, from April of 1999 to March of 2004. Panel 1 to 5 (top to bottom). Average of the 5 years: panel 6.



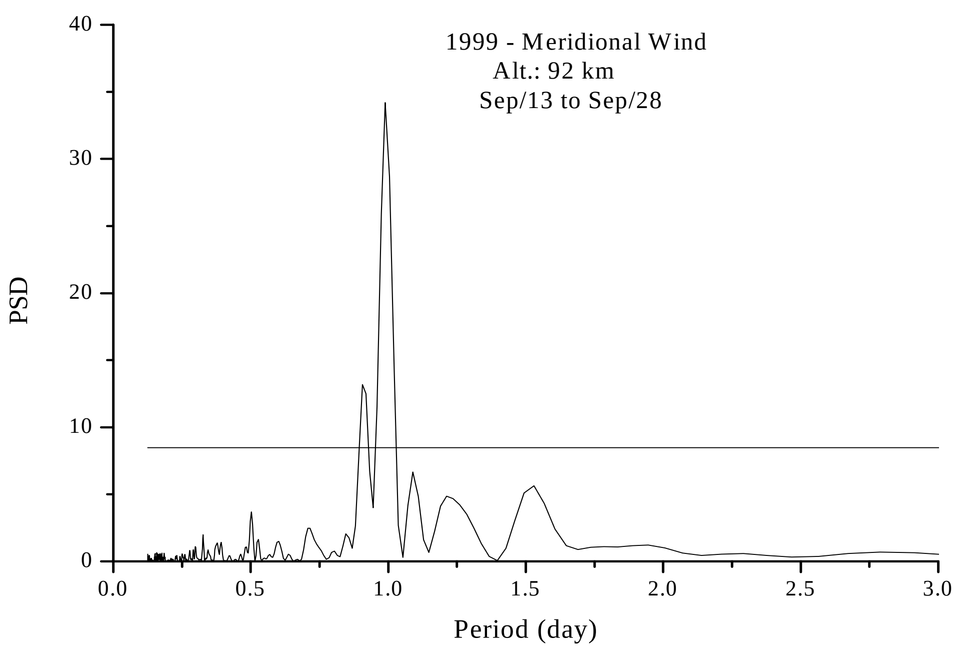


Fig. 2 Power spectrum density (PSD) of unfiltered meridional wind at 92 km for 1-15 April, 1999 (top),13-28 September, 1999 (bottom). Horizontal line indicates 90% confidence level.

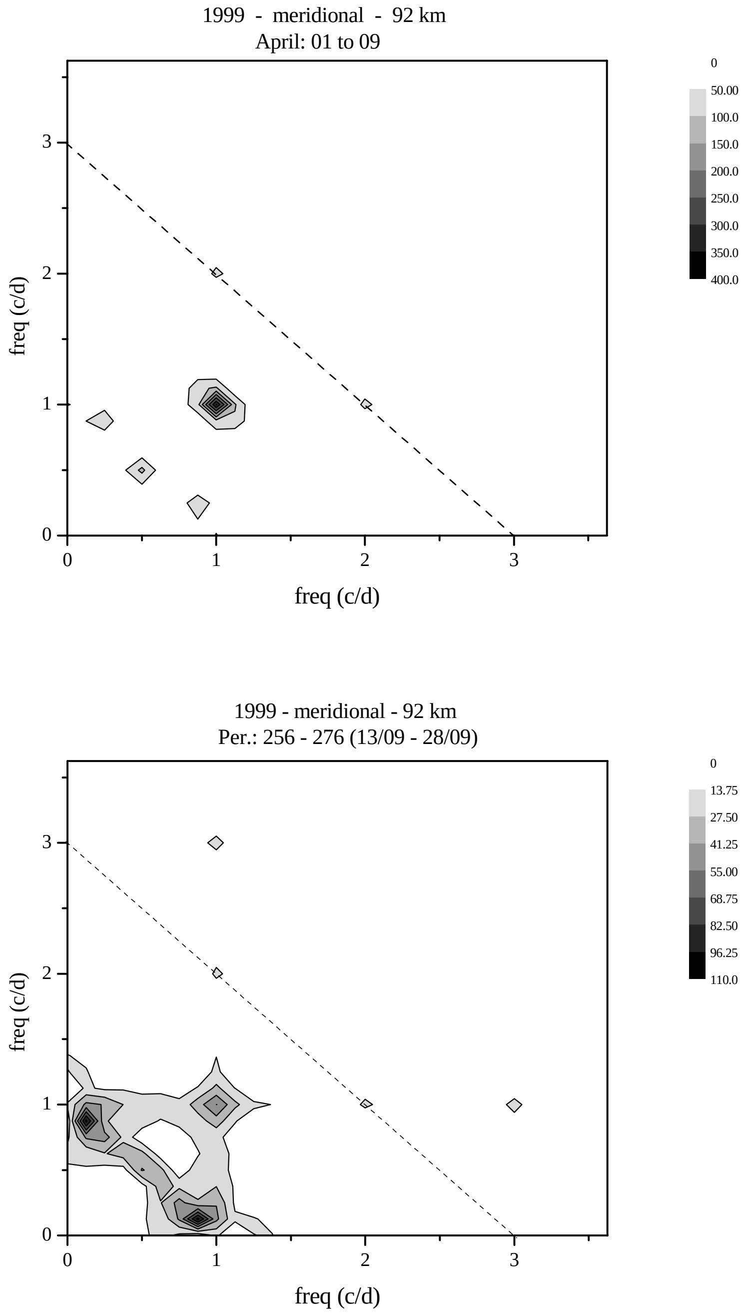


Fig. 3 Bispectra of unfiltered meridional wind at 92 km. (top) April of 1999, (bottom) September of 1999.