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The influence of the complexity of ground surface in the flow through a spectral analysis of turbulent quantities in the stable boundary layer

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Abstract

Two micrometeorological towers located in the experimental site of Pedras Altas in the region of Pampa Gaúcho were separated by a distance of about 500 m from each other, enabling a small scale horizontal variability, due to the complexity of the terrain. Such variability favors distinct contributions in the modes of flow. This work points out a relation between classes of maximum wind measured in the station of the top of the hill with obstructions provoked by the heterogeneity of the terrain. Through a spectral analysis it was possible to find encouraging results for future work, as the study shows a pertinent relation between non-turbulent low frequency motions with surface heterogeneity and how this implies in the horizontal and vertical turbulent velocity.

Keywords: *Obstructions. Low-frequency motions. Velocity spectra*

1 Introdction

In very stable conditions the turbulent activity decreases until a minimum condition so as to be subject to intermittent turbulence. Intermittence is a large variability in the time and space of the turbulence so that events occur sporadically (ACEVEDO et al., 2006). On well-stable, clean nights, but with weak winds, the turbulent mixture is reduced and the thermal stratification is controlled by the radiative processes (VAN DE WIEL; MOENE; JONKER, 2012). These small turbulent activities in the stable boundary layer are controlled by the horizontal variability of the surface, and temperature, wind and Turbulent Kinetic Energy (TKE), for small distances, may differ as a consequence of local heterogeneity.

Non turbulent low-frequency motions, also known as submeso (MAHRT, 2009; MAHRT; MILLS, 2009) are highly variable and locally dependent, influenced by surface characteristics such as terrain and vegetation (MAHRT, 2009; VICKERS; MAHRT, 2007).). These low-frequency motions may influence turbulent processes, especially in the stable boundary layer, where much of the turbulence occurs due to windshear induced by such non-turbulent motions (MAHRT, 2010).

For analysis of the local interference of obstructions in the flow, a relationship between wind speed classes and turbulent quantities was made in two distinct micrometeorological towers located at the Pedras Altas experimental site.

2 Datas and Methods

The Pedras Altas site is located in the Pampa Gaúcho region at 400 m above sea level (31 ° 44 'S, 53 ° 35' W). The data were collected during a micrometeorological campaign from August to September 2013. The site presents characteristics typical of the Pampa, with small trees, underbrush and some terrain elevations, known with coxilhas. From these particularities of the site, two stations were arranged so as to contemplate these irregularities. Station 1 was placed in the depression region of the ground with the presence of small shrubs and 500 m above it, Station 2, in a region of the top of the coxilla (Figure 1). Turbulence and flow observations were obtained through the fast response measurements of wind and temperature components (CSAT3, Campbel Scientific Inc.) performed at 10 Hz from 2000 to 0600 LST.

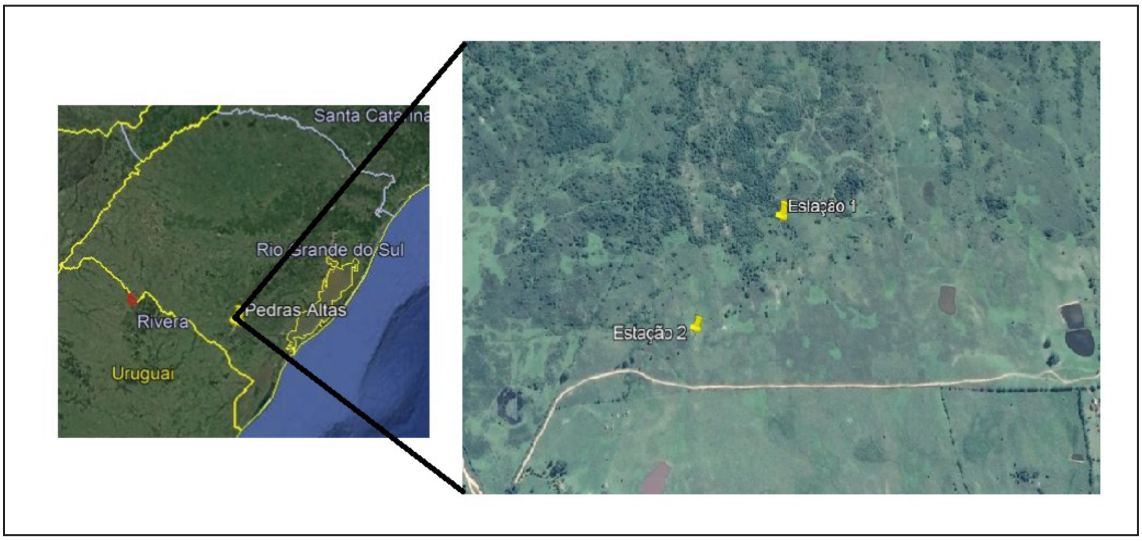


Figure 1 – Map of the Pedras Altas experimental site with the arrangement of the two micrometeorological stations used in the study.

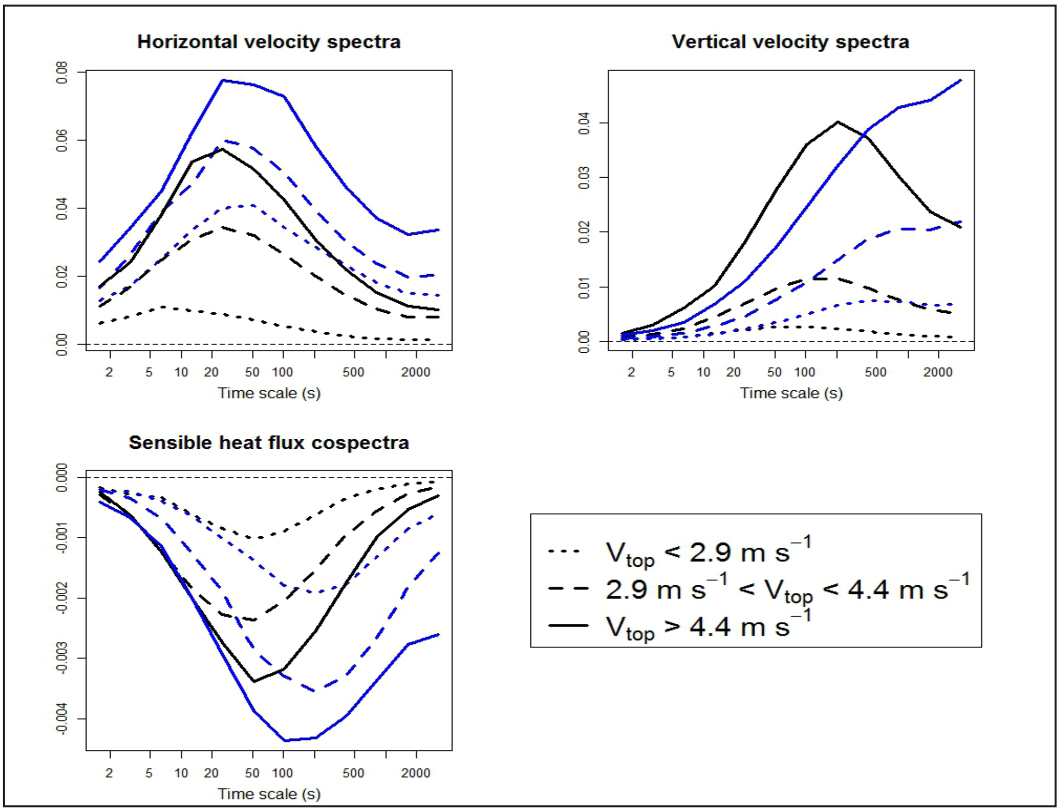
The spectral analyzes of the horizontal and vertical velocity and sensible heat flux cospetra were made through the Decomposition in Multiresolution, DM (HOWELL; MAHRT, 1997; MALLAT, 1989), in which it decomposes the time series into its scale and defines which time scale most of the more intense fluctuations occur. For the present work a time series of 2^{16} was used corresponding to a time window of 109 min. The dependence of the spectrum and cospectrum in relation to the maximum speed in the network were related to 3 classes of maximum velocity (V_{max}) of wind with equal number of cases for each class measured at the top. Weak with top speed of less than 2.9 ms^{-1}, moderate with top velocity above 2.9 and below 4.4 ms^{-1} and strong with top velocity above 4.4 ms^{-1}.

3 Results and Discussion

To estimate how much the spectra and cospectra depend on V_{max}, they were divided into three classes of V_{max}, each with an equal number of cases between them. From all spectra and cospectra considered, the amount with a clearer dependence of V_{max} is the spectra of vertical turbulent fluctuations as show Figure 2b.

The average spectral peak of the horizontal velocity fluctuations S_v occurs at time scales similar to each other at the lower and upper place, between 20 and 50 s (Figure 2a). Differently it happens with the average spectra of vertical velocity fluctuations S_w (Figure 2b) at time scales greater than those observed for the horizontal component and differ much more between the lower and upper place. At station 1, the average spectral peak in the S_w reaches about 200 s, while at station 2 there is indication of a peak associated with turbulent fluctuations at time scales between 500 and 1000 s. However, the most notable feature of the average S_w in the station is the fact that it has significant energy at time scales over 2000 s. This is probably associated with a non-turbulent low-frequency motion, but it is notable that this movement affects vertical velocity spectra more than horizontal, and also influence on the scalar flow coefficient (Figure 2c) in contrast to observed by Acevedo et al., (2014) in more homogeneous places

Furthermore, S_w also shows a variability in the role of the non-turbulent maximum over the more long time-scale limit. While for class V of S_w it is possible to discern a turbulent peak at scales around 500 s, for the other two classes this peak becomes very subtle, with the maximum energy happening at the longest limit.


Horizontal velocity spectra

Vertical velocity spectra

Sensible heat flux cospectra

Figure 2 – Spectrum and average Coespectro determined by the wind speed class at the top. Station 1 represented by the black color (located in the lower part of the site) and Station 2 (located in the highest part of the site) represented by blue color.

4 Conclusions

The results showed a dependence of vertical and horizontal turbulent velocity with different wind classes found at the site. Such wind classes, measured at the top station, allowed to verify how much a station located in the depression of the terrain suffers interference from the heterogeneity of the surface.

The peaks of the spectros for the horizontal velocities pointed small differences in the time scale for both wind classes. Differently in the vertical velocities, the peaks for the top station happen at the more turbulent scales, whereas in the lower, more obstructed station, there is an increase of energy in the limit of the upper scales of lower frequency. The results indicated that the obstructions present in station 2 cause a reduction in the smaller scale motions. Most of the total energy is associated with low-frequency motions, mainly in vertical ones and almost none in horizontal motions and scalar flows.

The purpose of this study was to provide an attempt to guide future works in what concerns the importance of identifying in which scale of motion the obstructions can modulate the velocity of the flow.

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