A METHOD TO DETERMINE THE HEIGHT OF THE MIXED LAYER FROM SPECTRAL PEAK FREQUENCY OF HORIZONTAL VELOCITY

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Resumo

Neste artigo é apresentado um novo método para determinar a altura da camada de mistura, estimada através do espectro da velocidade horizontal. O espectro da velocidade horizontal foi calculado com os dados obtidos durante o Experimento Interdisciplinar do Pantanal (IPE-1) para dois dias: um de céu claro e outro de céu nublado. A variação diurna da altura da camada de mistura apresentada para os dois dias, mostrou-se mais pronunciada no dia de céu claro se comparado ao dia de céu nublado.

Keywords

Micrometeorology, Mixed Layer, Spectra, Pantanal.

1 - Introduction

The mixed layer $\mathbf{z_i}$ is a scale height that characterizes the structure and development of the planetary boundary layer. It plays an important role in the parametrization of the boundary layer in macro-scale and meso-scale numerical simulations. The traditional methods of mixed layer determination are dependent on profiles of wind speed $\bar{\mathbf{u}}$, potential temperature $\bar{\theta}$, standard deviation of the vertical wind speed σ_w and sodar echo intensity and using tethered balloon as well as air craft. These were used in large scale field experiments but was not applied for small scale micro meteorological experiments with limited resources. However its should be mentioned here that the eddy correlation technique has become routine for determination of fluxes in the surface layer.

This paper works out the mixed layer height only from the peak frequency of the velocity spectra in the lines proposed by Liu and Ohtaki (1997).

2 - Methodology

The IPE-1 is a part of broad experimental programe to study the weather and climate of central region of Brazil. The data collection campaign was carried out in South Mato Grosso Pantanal in the experimental site in the farm São Bento (19^{o}33S and 53^{o}8W), 1.5km from the Pantanal studies base of UFMS in Passo do Lontra, Miranda, MS. A micro meteorological tower 21m height was installed and a fast response three dimentional sonic anemometer was installed at 25m.

Determination of ML (Mixed Layer) height from the peak frequency of horizontal velocity spectra. The spectrum of the vertical velocity component obeys Monin-Obukhov similarity theory quite well in the surface layer because of its distinct spread with stability. In contrast, the horizontal

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wind spectral are scaled with z_i, due to the effects of the low frequency convective eddies. Nevertheless the spectrum still obeys Monin-Obukhov and Kolmogorov scaling with high frequencies (Kaimal, 1978; Hojstrup, 1982; Panofsky and Dutton, 1984; Stull, 1988).

Hojstrup (1982) suggested that the spectral density can be split into low frequency and high frequency portians

$$S(f) = S_L(f) + S_H(f) \tag{1}$$

where for the horizontal velocity components u, and v the low frequency spectrum $S_L(f)$ depends on normalized frequency $n_i = fz_i/\bar{u}$ and (z_i/L) while high frequency spectrum $S_H(f)$ depends on reduced frequency $n = fz/\bar{u}$.Here $'f'$ is the natural frequency spectrum $\bar{u}$ mean wind speed and L is the Obukhov lenght. The resulting equations are adjusted to fit the conditions of inertial range and are expressed according to Panofsky and Dutton (1984)

$$\frac{fS_u(f)}{u_*^2} = \frac{0.5n_i}{1+2.2n_i^{5/3}}\left(-\frac{z_i}{L}\right)^{2/3} + \frac{105n}{(1+33n)^{5/3}} \tag{2}$$

$$\frac{fS_v(f)}{u_*^2} = \frac{0.95n_i}{(1+2n_i)^{5/3}}\left(-\frac{z_i}{L}\right)^{2/3} + \frac{17n}{(1+9.5n)^{5/3}} \tag{3}$$

The highest values of spectral density appear in low frequency range and is assisted with normalized frequency $n_i = fz_i/\bar{u}$. Mathematically the position of peak frequency can be obtained by taken differential of (2) or (3) and equating it to zero

$$\frac{d}{dz_i}\left\{\frac{[fS(f)]}{u_*^2}\right\} = 0$$

If we consider the longitudinal velocity spectrum, it reaches maximum at $n_{i\,max} = 0.7974$. This value corresponds to mixed layer height, z_i, as

$$z_i = 0.7974\frac{\bar{u}}{f_{u\,max}} = 0.7974\frac{z}{n_{u\,max}} \tag{4}$$

$\{$ since $n = fz/\bar{u}$ or $\bar{u}/f_{u\,max} = z/n\}$ with similar arguments it can also be shown as

$$z_i = 0.75\frac{z}{n_{v\,max}} \tag{5}$$

Thus z_i can be estimated from either Eq. (4) or Eq. (5), knowing the peak frequency of horizontal later or longitudinal velocity $(n_{u\,max}$ or $n_{vmax})$ respectively. Here z refers the level, where horizontal velocity is measured by fast response sonic anemometer.

3 - Results and discussion

The above theory has been applied to the Pantanal fast response data obtained by a sonic anemometer. The latitudinal and longitudinal velocity spectra were obtained for a cloudy day (julian day 136) and clear day (julian day 143) respectively. Only the spectra with distinct maxima are selected and z_i has been estimated.

The results were shown in Figs. 1 and 2. Fig. 1 shows the diurnal march of z_i for a cloudy day that is julian day 136. It is estimated from both u and v espectra. The depth of mixing layer slowly increased in the morning hours. It is around 800 meters in the evening hours from 18:00 hours and 21:00. Fig 2 represents the z_i variation an a clear day. Naturally be expected z_i is having more depth and the maximum is around 2000 meters. Better than the longitudinal spectra (u) the latitudinal spectra (v) reveals a gradual increase and decrease. It is interesting to note both u, v spectra confirmed an increase in the night time around 21:00 hours. This might be linked to synoptic or mesoscale phenomena.

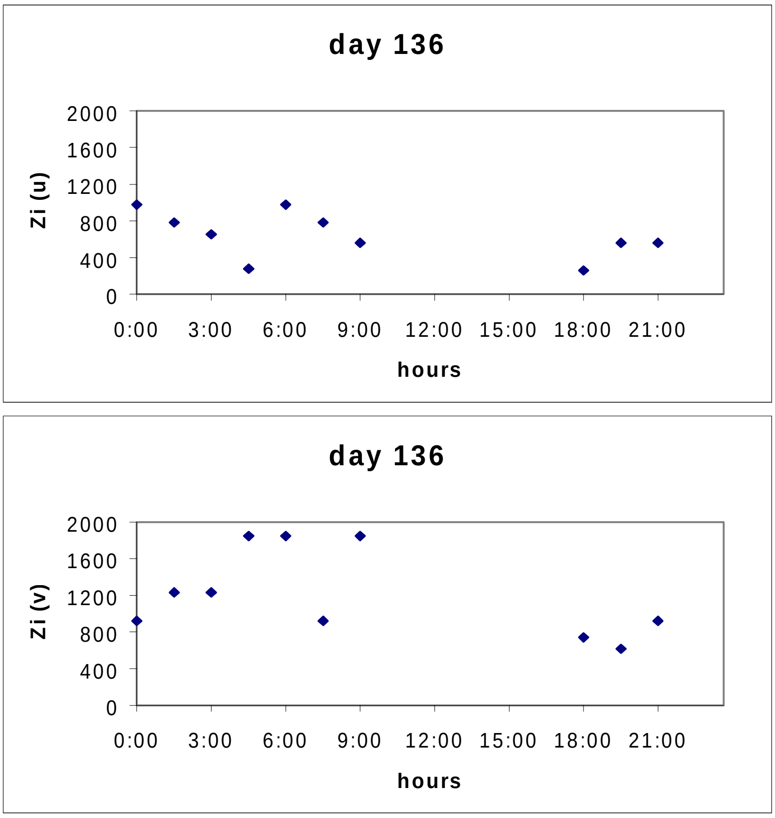

Fig. 1 - The diurnal march of mixing layer depth for a cloudy day.

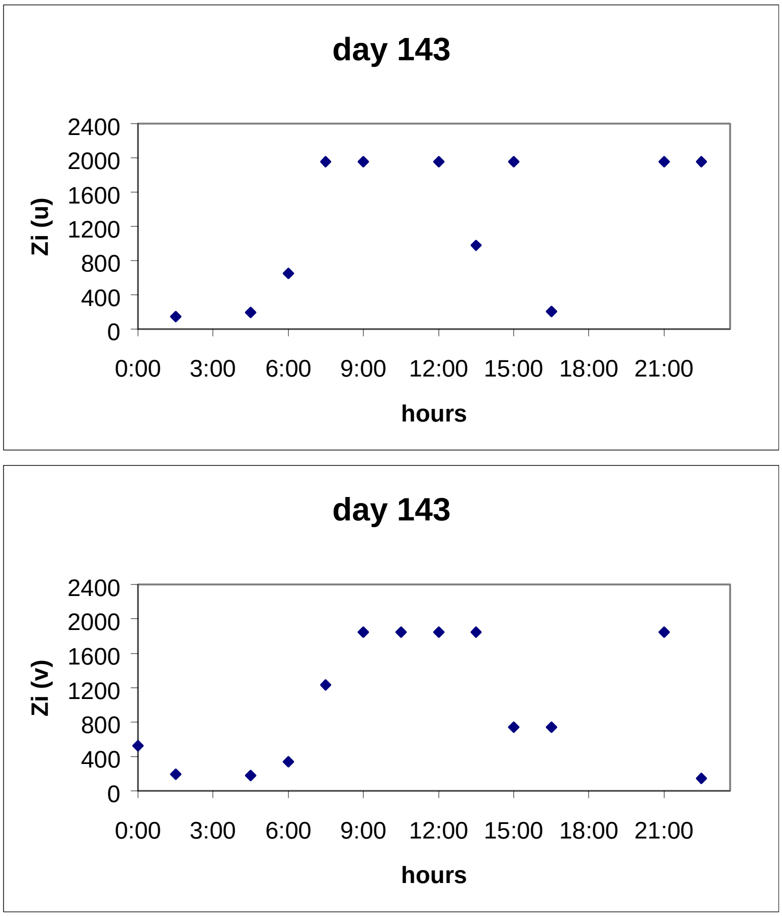

Fig. 2 - The diurnal march of mixing layer depth for a clear day.

4 - Conclusions

(1) The mixed layer depth can be estimated from the horizontal velocity spectra;
(2) The mixed layer depth on a cloudy day is less and around 800 meters;
(3) The mixed layer is extending upto 2 km. an a clear day in the afternoon hours.

5 - Acknowledgement

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6 - References

Hojstrup, J. . Velocity spectra in the unstable boundary layer. **J. Atmospheric Science**, v.39, p. 2239-2248, 1982.

Kaimal, J. C. . Horizontal velocity spectra in an unstable surface layer. **J. Atmospheric Science**, v.35, p. 18-24, 1978.

Liu, X.; Ohtaki, E. . An independent method to determine the height of the mixed layer. **Boundary-Layer Meteorology**, v.85, p. 497-504, 1997.

Panofsky, H. A.; Dutton, J. A. **Atmospheric turbulence. Models and methods for enginneering applications.** Wiley, New York, 397 p .,1984.

Stull, R. B. **An introduction to boundary layer meteorology**. Netherlands, Kluwer Academic Publishers, 1988, 666 p..