

FLUX-VARIANCE METHOD ESTIMATION OF SENSIBLE HEAT FLUXES ABOVE PANTANAL WETLAND

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ABSTRACT

IPE-1 is part of a wide experimental programme to study the weather and climate of the central region of Brazil. The data collection campaign was carried out in the South Mato Grosso Pantanal in the experimental site in the farm São Bento (19°33'S and 53°8'W), 1.5 km far from the Pantanal studies base of UFMS in Passo do Lontra, Corumbá, MS. One of the goals of the project is to study the turbulent exchanges above Pantanal in both seasons, wet and dry, particularly the turbulent fluxes and its variability. In this work, the feasibility of the Flux-variance (FV) estimating flux method is investigated. To perform this, eddy-correlation (EC) and FV flux calculations are compared. The data were obtained in a 21 m height micrometeorological tower, in which fast response sampling instruments were installed to measure wind velocity and temperature turbulent fluctuations. It is shown that FV method appears to be a very good alternative to estimate sensible heat fluxes under unstable conditions, when the flow is stationary and there is no advection.

RESUMO

O IPE-1 é parte de um amplo programa de estudos do tempo e do clima da região central do Brasil. A campanha intensiva de coleta de dados foi realizada no Pantanal Sul Matogrossense no sítio experimental da Fazenda São Bento (19°33'S and 53°8'W), distante 1,5 km da Base de Estudos do Pantanal da UFMS em Passo do Lontra, Corumbá, MS. Um dos objetivos do projeto é o de estudar as trocas turbulentas acima do Pantanal, tanto na estação úmida quanto na estação seca, particularmente os fluxos turbulentos e sua variabilidade. Neste trabalho é investigada a possibilidade de se estimarem fluxos pelo método do Fluxo-Variância (FV). Para isto são efetuadas comparações entre os resultados obtidos pelos Métodos das Covariâncias e pelo FV. Os dados foram obtidos em uma torre micrometeorológica de 21 m de altura, na qual foram instalados instrumentos de resposta rápida para medir a velocidade do vento e temperatura. Os resultados demonstram que o método FV é perfeitamente válido para estimar fluxos de calor sensível, sob condições instáveis, estacionárias e com pouca advecção horizontal.

Key-words: Flux-variance, turbulent fluxes, Pantanal

1 - INTRODUCTION

Among the various techniques employed to measure the turbulent energy and mass fluxes, the eddy-correlation technique (EC) is the most favoured by experimenters, as it is constituted by direct measurement of fluxes. This technique, however, requires fast response wind velocity, air temperature and concentration fluctuation measurements, which still require a considerable investment in equipment, and may be subject to a large amount of errors (Moore, 1986).

One measurement technique which is simple and inexpensive, and allows the sensible heat flux to be estimated from only the standard deviation of temperature fluctuations, is the flux-variance method (FV). Lloyd *et al.* (1991) showed that this method reproduces well the sensible heat fluxes

measured by the eddy-correlation technique for four different surface types. Katul *et al.* (1995) made a long bibliographic review of the usefulness of the FV method above uniform and non-uniform terrain. Other previous works have highlighted the potential of this technique, and good results were obtained for a number of land surface types (Tillman, 1972; Weaver, 1990). In this work, we compare EC sensible heat flux measurements with FV estimations obtained above Pantanal wetland, during IPE-1 campaign, in the Brazilian state of Mato Grosso do Sul.

2 - THEORY

The standard deviation of the temperature under unstable conditions can be described by the atmospheric surface layer similarity theory (Monin and Yaglom, 1971):

$$\frac{\sigma_\theta}{\theta_*} = \psi\left(\frac{z}{L}\right) \quad (1)$$

where σ_θ is the standard deviation of potential temperature; $\psi(z/L)$ is a dimensionless function of stability; z is the height above the ground; L the Obukhov length scale and θ_* is the temperature turbulent scale given by:

$$\theta_* = -\frac{1}{\rho c_p} \frac{H}{u_*} \quad (2)$$

where H is the sensible heat flux; u_* is the friction velocity; c_p is the specific heat and ρ is the air density. The general form of $\psi(z/L)$ must satisfy two limiting cases: the limit next to neutrality, where $-z/L$ approaches to zero, and the case of free convection, where $-z/L$ approaches infinity. For free convection, $\psi(z/L)$ should be a linear function of $(-z/L)^{-1/3}$. Monin and Yaglom (1971) suggest the use of:

$$\psi\left(\frac{z}{L}\right) = C_1 \left(\frac{z}{L}\right)^{-1/3} \quad (3)$$

where C_1 is a constant value. For neutral conditions, $\psi(z/L)$ appears approach a constant value, C_3 . Tillman (1972), basing his analysis on a work by Wyngaard *et al.* (1971), obtained the values of $C_1 = 0.95$ and $C_3 = 2.5$.

Rearranging the above equations, H , the sensible heat flux, becomes independent of u_* and it depends only on σ_θ and θ (potential temperature), in the case of free convection:

$$H = \rho c_p \left(\frac{\sigma_\theta}{C_1}\right)^{3/2} \left(\frac{k g z}{\theta}\right)^{1/2} \quad (4)$$

where k is the von Kármán's constant and g is the acceleration due to gravity.

Where vegetation and measurement heights are of the same order, Lloyd *et al.* (1991) highlighted the need of replacing z by $z_m = z - d$ in equation (4), where d is the zero plane displacement height

3 - MEASUREMENTS

The measurements were carried out using a 21 m micrometeorological tower located at Corumbá city (19° 6'S; 57° W) in a selected site which is representative of the Pantanal wetland micrometeorological conditions, at 100 m above sea level.

The fast response turbulence data, sampled at 21 Hz, were measured at a height of 25 m above the ground, which is located above the transition sublayer, as shown by Marques Filho (1999). A Gill 3-D sonic anemometer provided measurements of three components of wind velocity and a Lycor fast response thermometer provided temperature measurements, which were recorded in a CR10X-2M Campbell Datalogger.

These measurements were part of the IPE (Interdisciplinary Pantanal Experiment) Project and were carried out during a transition period (from wet to dry conditions), which was held in May 1998. More information can be found in Santos Alvalá et al. (1998) and in Marques Filho (1999).

4 - RESULTS

To validate the calculations of the sensible heat fluxes H , obtained by the flux-variance method, they were compared with the fluxes measured by the eddy-correlation method. The zero-plane displacement was $d = 4.28$ m, as calculated by Marques Filho (1999).

Before calculations, the temperature (T) and the vertical wind (w) signals, sampled at a frequency of 21 Hz, were high-pass filtered at a cutoff frequency of 0.00083 Hz, to remove some possible low frequency mesoscale effects on the results, as discussed by Marques Filho (1999).

Figure 1 shows, on the horizontal axis, the values of sensible heat flux calculated by the EC method, and on the vertical axis, the ones estimated by the FV method. Least squares linear fitting and correlation coefficients are presented and the 1:1 lines are also shown, for two situations: (a) for all available data under unstable conditions (47 data); (b) only for data measured between 10:00 and 16:00 Hs (local time), when the flow was stationary and there were less horizontal advection (31 data).

Table 1 shows information of linear least square fitting between the estimated flux (FV) and the measured one (EC) presented by Katul *et al.* (1995) in their review for FV calculations over complex surfaces, and the results obtained for amazonian forest Rebio-Jaru Stand (Von Randow et al., 2000) and for Pantanal IPE-1 data. So, the quality level of the linear regression for Pantanal data is one of the best, comparatively to that obtained by Katul *et al.* for uniform and non-uniform surfaces: $R^2 = 0.89$; slope 0.93 and intercept 12.4. When only the data for the time interval from 10:00 Hs to 16:00 Hs are retained, the statistical parameters of the linear regression fitting are improved to $R^2 = 0.99$; slope 0.99 and intercept 6.03.

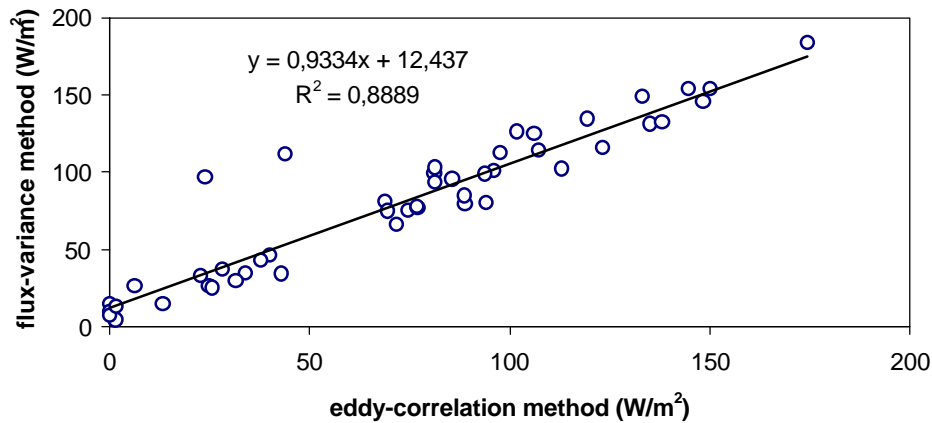
These results show that it is possible to estimate sensible heat fluxes by the flux-variance method in Pantanal under adequate unstable conditions: stationarity and no advection. These are also some of the conditions in which surface layer Monin-Obukhov Similarity Theory holds.

Location	Slope	Intercept	R^2	n. of data points
Maine Forest (non-uniform terrain)	0.89	29.5	0.68	119
Davis (dry, uniform terrain)	0.89	19.3	0.92	55
Davis (wet, non-uniform terrain)	0.71	-7.5	0.66	16
Duke (favorable winds, uniform terrain)	1.06	-14.7	0.79	45
Duke (unfavorable winds, non-uniform terrain)	0.68	14.6	0.64	59
All (sites above)	0.94	8.2	0.76	294
Rebio-Jaru	1.28	15.2	0.83	188
Pantanal Wetland	0,93	12,4	0,89	47

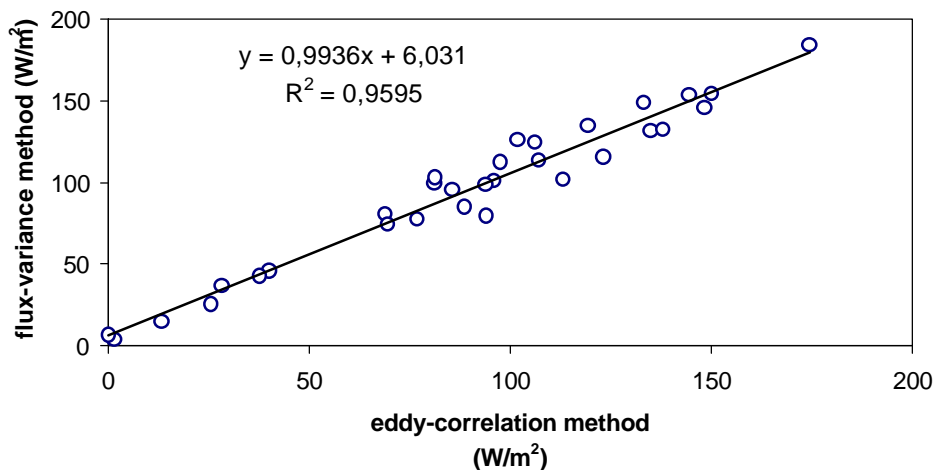
Table 1. Linear least square regression of H estimated by flux-variance method on measured H , obtained by Katul *et al.* (1995) for uniform and non-uniform terrain, as well as for Rebio-Jaru site and Pantanal Wetland.

**Fig1 - Sensible Heat Fluxes under unstable conditions
measured in Pantanal Wetland**

a) with all available data



b) only with data obtained between 10 and 16 hours (local time)



5 - CONCLUSIONS

These results show that the flux-variance method can be used to provide sensible heat flux information when fast response wind velocity fluctuations are not available, even when the measurements were taken over a complex terrain as Pantanal one. This seems to agree with the results presented by Katul *et al.* (1995) and by Von Randow *et al.* (2000).

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