O tipo de nuvem predominante é o Cumulus, tendo uma boa distribuição de céu claro, Stratus, Altocumulus e Cirrus principalmente à tarde.

As variações da umidade relativa diária chegam a 20 %, tendo uma umidade média de 72 % e umidades extremas de até 18 %.

As amplitudes térmicas são da ordem de 15 a 20 °C e as temperaturas médias compensadas são da ordem de 20 a 23 °C , as máximas predominantes estão entre 25 e 30°C e as mínimas entre 15 a 20°C.

Dos dias observados, 80 % não ocorre precipitação sendo que dos 20 % restantes com predominância (70%) de precipitações inferiores a 10 mm.

Bibliografia

NASCIMENTO, E.L.;PICANÇO,C.G.; MARQUES,V.S., 1994 - Distribuição de dias chuvosos no município do Rio de Janeiro- Im: Anais do VIII Congresso Brasileiro de Meteorologia, vol.1, pp.191-202

THOM,H.C.S., 1966 - Climatological series. Some methods of climatological analysis , Technical Note 81, WMO

SNADECOR, G.W. & COCHRAN,W.G., 1967 - Statistical Methods- The Iowa State University Press ames, Iowa, 593p.

Wavelet Analysis Optimized To The Time-Scale: Studying Gte-Able-2b Turbulent Data Above And Below The Canopy Of The Amazonian Rain Forest

Alexandre G. Nowosad
**Gannabathula S. S. D. Prasad*
Leonardo D. A. Sá
** CNPq Fellow Instituto Nacional de Pesquisas Espaciais-DCM*
Av. dos Astronautas 1758 12227-900 São José dos Campos, SP, Brasil
e-mail: alex@met.inpe.br

Abstract

In this work we study the turbulent signal measured above and below the Amazon Rain Forest (GTE-ABLE-2B Experiment) during daytime, in a dry day, in stable conditions, using wavelet transforms. Here there has been a systematic preoccupation with the scale optimization of the analysis. Such methodology results in better analysis results and can indicate important physical aspects of the turbulent exchange processes. In this we compare the data from above and below the canopy, with the objective of better understanding the role of the Rain Forest's canopy as physical barrier to the exchange processes of heat and momentum.

1 Introduction

For a long time the turbulent processes were studied as if they were stationary (Lumley et Panofsky, 1964). However, the technological innovations introduced in measuring and processing the turbulent signal have lead to the conclusion that this signal is essentially non-stationary and intermittent (Mahrt, 1989), even in flow above and below forests (Collineau and Brunet, 1993; Lu and Fitzjarrald, 1994). That requires the use of more powerful methods to analyze it. One of them, the Wavelet Transform (Farge, 1992), was used here to investigate the characteristics of the turbulence above and below the canopy of the "terra firme" amazon rain forest with a systematic time-scale emphasis. Intermittence detection and the possibility of statistical estimation of turbulent parameters were also examined.

2 Experimental Data

The data were obtained on a micrometeorologic tower in Ducke Forest Reserve (2° 57' S; 59° 57' W), 26 km from Manaus, AM, during Experiment GTE-ABLE/2B in April-May 1987. More information about the place, topography and climatologic characteristics of the region can be found in Sá et al. (1988) and in Fitzjarrald et al. (1990).

The turbulent quantities studied, the vertical wind velocity *(w)* and the temperature *(T)*, were measured at 10 Hz with Campbell fast response instruments. *w* was measured with sonic anemometer and *T* with thermocouple thermometer. The data were collected in May 5 1987 during the day, from 11 a.m. to nearly 2 p.m., at 45 m above the ground (above canopy) and 23 m above the ground (below canopy). The average height of the forest was 35 m.

The data collected had gaps. Therefore an interpolation was made on those series. The resulting time series had sampling time-interval of 0.4 s. These interpolated series were the actual inputs to the wavelet transformers.

3 Methodology

The method used to characterize the two data series involved two steps. The first was to calculate Discrete Wavelet Transforms of each time-series. According to Farge (1992), the WT is defined by:

$$T_{\psi}(a,\tau) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} \psi^{*}_{a\tau}\left(\frac{t\tau}{a}\right) s(t)\, dt$$

where $\mathbf{R}^*$ denotes the complex conjugate of $\mathbf{R}$. The wavelet $\mathbf{R}_{a_\tau}$ is defined from a base function $\mathbf{R}$, called the mother-wavelet. The values of $T\mathbf{R}(a,\tau)$ express, then, the decomposition of signal *s(t)* at a specific position τ and in a specific scale *a*.

The second step was to select at each scale the transform which best represented the physics of the scale according to the Matched Filter Principle (Skolnik, 1962). If *x(t)* is the mathematical model one chooses for *s(t)*, the matched filter is the filter :

$$H(j\omega) = G_a . X^{*}(j\omega).e^{j\omega.\Delta t},$$

where

$$X(j\omega) = \int_{\infty}^{\infty} x(t).e^{j\omega t}\, dt$$

is the input signal's spectrum (Fourier transform), Δt is the signal's duration and G_a is a constant equal to maximum filter gain (in our case unity). The error *E(t)* resulting from the difference between the signal under investigation and the model is assumed to be stationary and to have a uniform spectrum.This principle is widely used in radar engineering to detect pulses of known form.

The results are shown in the figures 1 and 2, where the Intermittency Factor is given by the formula

$$I(a,m) = \frac{|T(a,m)|^2}{\sum_k |T(a,k)|^2},$$

a being the time-scale in examination, m the instant of time and T(a,n) being the wavelet coefficient at coordinate (a, n) .

4 Conclusions

The authors have shown that, although every orthonormal wavelet transform is mathematically equally suited to execute a multiresolution analysis of this data series, the analysis can be systematically optimized to each scale.

Sharp structures were detected in the inertial subrange of turbulence, the high-frequency part of the spectrum, while smooth ones are detected in the low-frequency part of the spectrum of the data, where energy is produced.

We showed that the canopy appears to insulate the bottom of the forest from the atmosphere above. This agrees with the conclusions of Shuttleworth et al. (1985).

The smallest scale studied showed clearly a strongly non-stationary behaviour.

Finally, we were reluctant to make straightforward statistical analyses of the signals measured because of the impossibility of insuring ergodicity.

Acknowledgments

This research was partially supported by FAPESP under contract 93/2715-1 and CNPq under contract 300995/92-0 (NV). The authors thank also Dr. David Fitzjarrald, from SUNY at Albany, who kindly provided the data.

Figure 1 - Variability of vertical wind velocity above (w1) and under (w3) the canopy of the "terra firme" amazonian rain forest, shown through their Intermittency Factor.

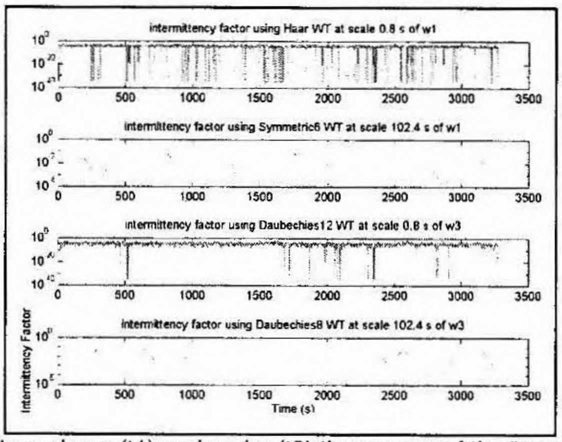
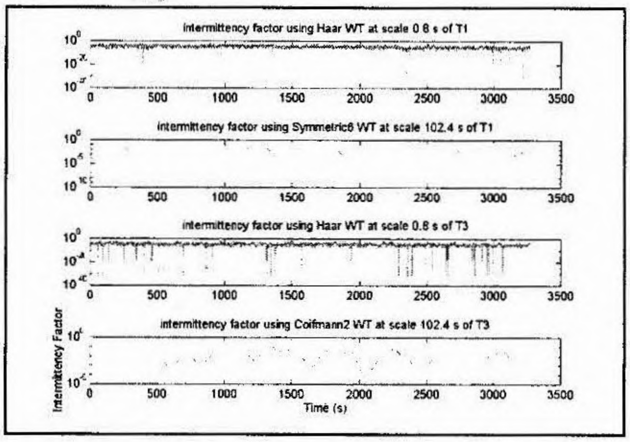


Figure 2 - Variability of temperature above (t1) and under (t3) the canopy of the "terra firme" amazonian rain forest, shown through their Intermittency Factor.



5 References

Collineau, S.; Brunet, Y., 1993a. "Detection of Turbulent Coherent Motions in a Forest Canopy. Part I: Wavelet Analysis". **Boundary-Layer Meteorol.**, 65(4): 357-379.

Farge, M. 1992. "Wavelet transforms and their applications to turbulence", **Annual Review of Fluid Mechanics**, 24, pp. 395-457.

Fitzjarrald, D.R.; Moore, K. E.; Cabral, O. M. R.; Scolar, J.; Manzi, A.O.; Sß, L.D.A., 1990. "Daytime Turbulent Exchange Between the Amazon Forest and the Atmosphere", **J. Geophys. Res.**, 95(D10): 16825-16838.

Lu, C.-H. and Fitzjarrald, D. R., 1994. "Seasonal and Diurnal Variations of Coherent Structures over a Deciduous Forest", **Boundary-Layer Meteorol.**, 69(1-2): 43-69.

Lumley, J.L.; Panofsky, H. A., 1964. **The structure of atmospheric turbulence**. Wiley, N. York, 239 p..

Mahrt, L., 1989. "Intermittency and Atmospheric Turbulence", **J. Atmos. Sci.**, 46(1): 79-95.

Sá, L. D. A.; Viswanadham, Y.; Manzi, A. O., 1988. "Energy Receipt Partitioning over the Amazon Forest", **Theoretical and Applied Climatology**, 39(1):1-16.

Shuttleworth, W. J.; Gash, J. H. C.; Lloyd, C. J.; Moore, C. J.; Roberts, J.; Marques Filho, A. D.; Fisch, G. F.; Silva Filho, V.P.; Ribeiro, M. N. G.; Molion, L. C. B.; Sá, L. D. A.; Nobre, C. A. ; Cabral, O. M. R.; Patel, S. R.; Moraes, J. C. 1985. "Daily variations of temperature and humidity within and above Amazon Forest", **Weather**, 40(4):101-108.

Skolnik, M. I., 1962. **Introduction to Radar Systems**, International Student Edition, McGraw-Hill Kogakusha Ltd., Tokyo.