Intradiurnal variability of soil temperature, heat flux, and soil thermal diffusivity in different ecosystems in eastern Amazonian

Regina ALVALÁ[1], Júlia COHEN[2], Ralf GIELOW[1], J. Ricardo SOUZA[2], Leonardo SÁ[3], Paulo ARLINO[1], Adilson GANDU[4]

[1]Instituto Nacional de Pesquisas Espaciais – DMA/CPTEC/INPE, São José dos Campos, SP - Brasil
[2] Departamento de Meteorologia –Universidade Federal do Pará, Belém, PA - Brasil
[3] Museu Paraense Emílio Goeldi - MPEG, Belém, PA - Brasil
[4] Universidade de São Paulo – DCA/IAG/USP, São paulo, SP - Brasil

1 - INTRODUCTION

The deforestation and the subsequent land use change may result in significant alterations in the energy and water balances in the soil-vegetation-atmosphere continuum. The soil thermal properties, that is, the diffusivity, the conductivity and the volumetric heat capacity, especially as a function of the water content, are currently not readily available. Notwithstanding, the demand for these data is increasing due to requirements in, e.g., coupled models of heat and moisture transport in the soil near its surface, which are part of numerical weather and climate models. Thus, in this work, the measured soil temperature profiles at the 5, 20 and 50 cm depths were used to obtain thermal soil diffusivities at five different sites in the state of Pará, Eastern Amazonia. The measurements were collected within the Milênio-LBA program – Subproject UFPA, during the experiment CiMela ("Mesoscale Circulations in Amazonian East"), held during the dry period of 2003: (i) forest (Caxiuanã Reserve, Melgaço) (ii) pasture (Soure, Marajó Island); (iii) natural mangrove (Tracuateua Island, Bragança); (iv) degraded mangrove (Tracuateua Island, Bragança); and (v) agricultural area (Fazenda Escola da Universidade Federal Rural da Amazônia, Igarapé Açu). The thermal diffusivity was obtained through the numerical method described by Alvalá et al. (1996). The impact of changing moisture conditions on the thermal soil properties will be also investigated.

2- SOIL THERMAL PROPERTIES

Energy and moisture balance studies at the surface frequently require estimates of the soil heat flux and the temperature at the soil surface. Coupled models of heat and moisture transfer in bare soils (Novak and Black, 1985; Passerat de Silans et al, 1989), or in vegetated soils (Braud et al., 1995; Smirnova et al, 1997), require information about the soil thermal properties, such as the thermal conductivity, the thermal diffusivity, and the volumetric heat capacity. These properties may be deduced from the soil components (Van Wijk, 1963), and they are dependent on soil moisture content, soil composition and vegetation cover (shading, root influence on moisture content). Notwithstanding, they are currently not readily available. However, the demand for these data is increasing, due to more detailed requirements of the soil heat and water transport models.

3 - SITES

FOREST: Caxiianã Reserve (area = 33.000 km²), Melgaço, PA (01°42'30''S; 51°31'45''W), about 500 km from the Atlantic Ocean, with 85% of the terra firme forest and canopy height about 30-40 m.
Soil: Latossolo amarelo distrófico, Clay (53%), silt (10%) and sand (37%)

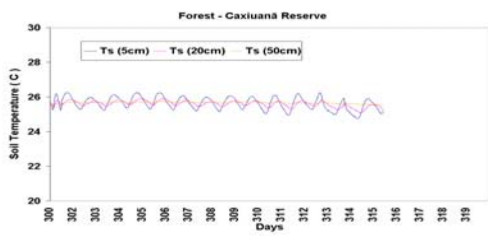
PASTURE: Fazenda Araruna, Soure, Marajó Island (00°43'25''S; 48°30'29''W), with natural grass (height of 0.30 m); shrubs about 500 m away from the site.
Soil : Sandy soil, not yet identified.

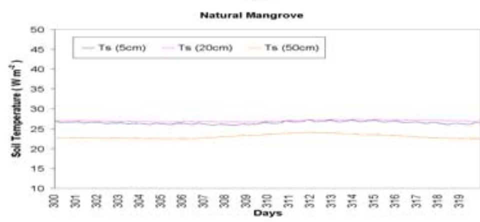
NATURAL MANGROVE: Tracuateua Island, Bragança, PA (0°50'31''S; 46°38'56''W), with a canopy height of 20 m, with periodic seawater invasion.
Soil: clay (65%), silt (27%) and fine sand (8%)

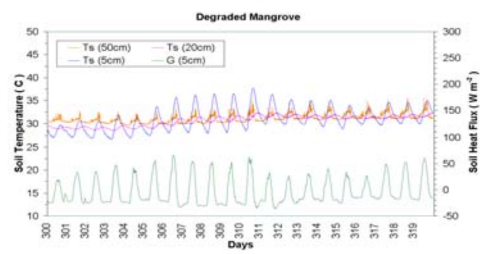
DEGRADED MANGROVE: Tracuateua Island, Bragança, PA, about 10 km from the coast (0°55'35,9''S; 46°42'18,1''W)
Soil: Bare soil, not yet identified

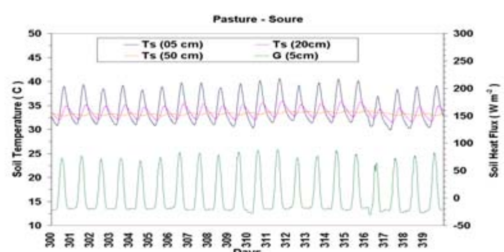
AGRICULTURAL : Fazenda Escola da Universidade Federal Rural da Amazônia, Município de Igarapé Açu, about 110 km away from Belém, (between 0° 55' - 01° 20' S and 47° 20' - 47° 50' W)
Soil: Grass soil, not yet identified

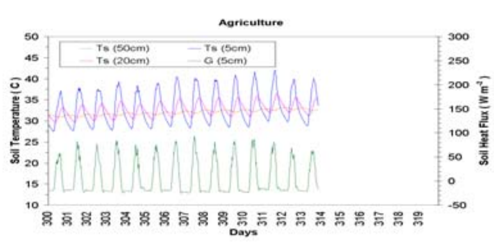
*Author email: _regina@cptec.inpe.br_











Heat Conduction Equation - $$C\frac{\partial T}{\partial t}=\frac{\partial}{\partial z}\left(\lambda\frac{\partial T}{\partial z}\right)$$

or, for an homogenous layer j:

$$\frac{\partial T}{\partial t}=\alpha_j\left(\frac{\partial^2 T}{\partial z^2}\right)$$

in finite differences:

$$\frac{\left(C_{j+\frac{1}{2}}K_{j+\frac{1}{2}}\left[\frac{T_{j+1}-T_j}{z_{j+1}-z_j}\right]-C_{j-\frac{1}{2}}K_{j-\frac{1}{2}}\left[\frac{T_j-T_{j-1}}{z_j-z_{j-1}}\right]\right)}{\left[\frac{z_{j+1}-z_{j-1}}{2}\right]}=C_j\left(\frac{T_j^{k+1}-T_j^k}{\Delta t}\right)$$

T is Temperature ©; t is time (s) ; z is the depth (m); C is the volumetric heat capacity of the soil (J m^{-3} K^{-1}) ; λ = K is the apparent thermal conductivity (W m^{-1} K^{-1}) and $\alpha = C \times \lambda$ is the thermal diffusivity (m^2 s^{-1})

The daily thermal diffusivity (αj) is obtained through the iterative solution of the last equation (Alvalá et al., 1996)

Daily Soil Thermal Diffusivity and Soil Moisture Content at the Sites During the Dry Period

Sites	Soil Thermal Diffusivity ($\times 10^{6}$ $m^2 s^{-1}$)	Soil Moisture ($m^3 m^{-3}$)
Forest	0.78-1.00	0.29-0.30
Natural Mangrove	-	Saturated
Degraded Mangrove	0.28-0.30	0.20-0.32
Pasture	0.51-0.55	0.09
Agricultural	0.39	0.145

References

Alvalá, R. C. S., Gielow, R., da Rocha, H. R., Freitas, H. C., Lopes, J. M., Manzi; A. O., von Randow, C.,. Dias;,M. A. F. S., Cabral, O. M. R., Waterloo, M. J. Intra diurnal and seasonal variability of soil temperature, heat flux, soil moisture content, and thermal properties under forest and pasture in Rondonia. Journal of the Geophysical Research, 2001, *In Press*.

Alvalá, R. C. S., R. Gielow, I. R. Wright, and M. G. Hodnett, Thermal diffusivity of Amazonian soils, in *Amazonian Deforestation and Climate*, edited by J. H. Gash, C. A. Nobre, J. M. Roberts, R. L. Vitoria, R. L, pp. 139-150, John Wiley, Chichester, 1996.

Braud, I., Dantas,-Antonino, A. C., Vauclin, M. Thony, J. L. and Ruelle, P. 1995. A simple soil plant atmosphere transfer model (SiSPAT): development and field verification. *J. Hydrol*., 166, 213-250.

de Vries, D. A., 1963. Thermal properties of soils. In: Van Wijk, W. R. (Ed.), Physics of Plant Environment. North Holland, Amsterdam, pp. 210-233.

Horton, P. Wierenga, P. J. and Nielsen, D. R., 1983. Evaluation of methods for determining the apparent thermal diffusivity of soil near the surface. *Soil Sci. Soc. Am. J*., 47, 25-32.

Novak, M. D. and Black, T. A., 1985. Theoretical determination of the surface energy balance and thermal regimes of bare soils. *Boundary-Layer Meteor*., 33, 313-333.

Passerat de Silans, A. M. B., Bruckler, L., Thony, J. L. and Vauclin, M., 1989. Numerical modeling of coupled heat and water flows during drying in a stratified bare soil. Comparison with field observations. *J. Hydrol*., 105, 109-138.

Smirnova, T. G., Brown, J. M and Benjamin, S. G., 1997. Performance of different soil model configuration in simulating ground surface temperature and surface fluxes. *Mon. Wea. Rev*., 125, 1870-1884.

Souza, J. R. S., Lopes, Z. F., Cohen, J. C. P., Costa, A. L., Variabilidade da temperatura e umidade em solos sob floresta, pastagem e manguezal no leste da Amazônia. Aceito no XII Congresso Brasileiro de Meteorologia, Foz do Iguaçu, 04 a 09 de agosto de 2002.

Souza, J. R. S., Cohen, J. C. P., Costa, A. L., Lopes, Z. F. Comportamento térmico e hídrico de solo sob pastagem na Ilha do Marajó. Aceito no XII Congresso Brasileiro de Meteorologia, Foz do Iguaçu, 04 a 09 de agosto de 2002.

Van Wijk, W, R. (Ed.), 1963. Physics of Plant Environment. First edition. North Holland, Amsterdam, 382p.

Acknowledgements - This work was supported by PPG7-FINEP/MCT (Project No. 64.99.0425.00) and Ministério da Ciência e Tecnologia/CNPq/PADCT (Projects No. 62.0056/01-0 and No. 620065/01-0 do Instituto do Milênio). Thanks are also due to Carlos César de Oliveira for data processing.