SURFACE ENERGY BUDGET: OBSERVATION AND MODELING

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ABSTRACT

A simple model of soil-atmosphere interaction, including an one-layer foliage parameterization proposed by Deardorff (1978), is utilized to estimate turbulent fluxes over a surface covered by corn field (summer) and short grass (winter). The results indicate good agreement between modeled and observed turbulent fluxes and net radiation, and large discrepancy between observed and modeled soil surface heat fluxes. These discrepancies are attributed to the lack of representativity of the observed soil heat fluxes. The model was also able to reproduce the linear relationship found between the observed turbulent fluxes and the observed net radiation(|regression coefficient| $\cong$ 0.90). Regression lines obtained from modeled results are proposed to estimate turbulent fluxes from observed net radiation values.

Key words: Surface Energy Balance, Turbulent Fluxes and Net Radiation.

INTRODUCTION

In order to investigate the surface-atmosphere interaction the model proposed of Deardorff (1978) is used in this work. This model involves, basically, solution of an abbreviated energy budget equation to obtain the temperature of a representative foliage element and diagnosis of mean air temperature and humidity within the vegetation layer. The surface temperature and moisture are determined solving a prognostic equation, dependent upon forcing by the sum of the energy fluxes. It contains a mechanism by which a deeper soil layer can influence both surface temperature and humidity. The turbulent vertical fluxes are estimated from bulk formulae.

In the present work Micrometeorological measurements, obtained in Iperó, SP, during the field campaign of July-August, 1992 and March, 1993, are used to validate and calibrate the Deardorff's model. Observed and modeled energy fluxes are compared and theirs results are discussed.

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A practical approach to estimate turbulent fluxes as a function of observed net radiation, based on modeled regression curves is proposed here that requires information about the soil temperature (below 10 cm), soil water content (below 10 cm), radiation shield factor, roughness length, albedo and soil thermal diffusitivty.

MATERIAL AND METHODS

The measurements reported here were performed at the Brazilian Navy's Industrial Installation "Centro Experimental ARAMAR", during winter and summer campaigns. This site is located in Iperó, in a country region of the State of São Paulo, Brazil (23° 25' S and 47° 35'W), approximately 120 km from the Atlantic Ocean coastline and 550 m above the mean sea level. The winter campaign took place in July and August 1992 and the summer one in March 1993, each one lasting two weeks. In both campaigns three sets of turbulent sensors were used to measure turbulence on a 12 m tower (3.0, 5.0 and 9.4 m). These turbulence sensors measured fluctuations of vertical velocity, air temperature and water vapor density with sampling frequency that varied from 1-10 Hz. The sensible and latent heat fluxes correspond to the 3-level average covariance, each one based on 20 minutes period data. Net radiation was measured at 2 m high and soil heat flux at 1 cm below the surface (Oliveira et al, 1998). These two parameters were also average using 20 minutes period data. In winter and summer campaigns the surface was covered, respectively, by short grass 10 cm high and by corn field 0.5 m tall.

Deardorff's model: A single layer of vegetation which has negligible heat capacity is assumed to be present in the problem. Its density is characterized by the single quantity σ_f, which is an area average shielding factor associated with the degree to which the foliage prevents shortwave radiation from reaching the ground. The limits of σ_f are $0 \leq \sigma_f \leq 1$; $\sigma_f = 0$ signifying no foliage and $\sigma_f = 1$ signifying complete radiative blocking. The air in close proximity to the foliage is assumed to take on properties intermediate between above-canopy air properties, foliage surface properties, and ground surface properties. A gross energy budget for the foliage layer is established in order to estimate foliage surface temperature. The soil properties are parameterized in function of soil moisture.

The force-restore method is used to estimate the ground surface temperature (T_g). It includes a restoring term that contains the deep soil temperature T_2:

$$\partial T_g / \partial t = -c_1 H_A / (\rho_s c_s d_1) - c_2 (T_g - T_2) / \tau_1 \qquad (1)$$

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$$\partial T_2 / \partial t = -H_A / (\rho_s c_s d_2) \quad (2)$$

where, T_2 is the mean soil temperature over layer of depth d_2; H_A is the sum of fluxes to atmosphere; c_1, c_2 are dimensionless constants; r_s is the density of soil; c_s is the specific heat of the soil; d_1, d_2 are the soil depths influenced by the diurnal and annual temperature cycles, respectively and t_1 is the diurnal period.

A method, analogous to the force-restore method of predicting surface temperature, is used to predict the ground surface moisture. The specific humidity at the surface is then related to the ground surface moisture content. This permits evaporation to dry out the ground surface and so reduce the evaporation rate from bare soil in comparison with evapotranspiration.

Assuming that most of the vertical movement of the volumetric concentration of ground soil moisture (w) within the soil can be described by a diffusion process, the equation for the volumetric concentration of soil moisture can be written as:

$$\partial w_g / \partial t = -C_1 (E_g + 0.1 E_{tr} - P_g) / (\rho_w d_1') - C_2 (w_g - w_2) / \tau_1 \quad (3)$$

$$\partial w_2 / \partial t = -(E_g + E_{tr} - P_g) / (\rho_w d_2') \quad (4)$$

where, w_g is the ground surface value of w; ρ_w is the density of liquid water; C_1 and C_2 are constants analogous to c_1 and c_2; d_1' is a depth to which the diurnal soil moisture cycle extends; w_2 is the vertically averaged value of w over a ticker layer d_2' below which the moisture flux is negligible; E_g is the evaporation rate at the ground surface; E_{tr} is the foliage transpiration rate and P_g is precipitation rate felt at the ground surface.

RESULTS AND DISCUSSION

This model requires as external parameters only air temperature, specific humidity and wind speed measured at one level above the surface.

The most important internal parameters necessary to simulate the fluxes in Iperó are indicated in the Table 1. The others are kept similar to Deardorff (1978).

Table 1: Model Internal Parameters.

Parameter	For Winter (Short grass)	For Summer (Corn Field)
T_2	291.2 K	301.6 K
w_2	0.10	0.30
σ_f	0.20	0.25
Roughness length	0.05 m	0.010 m
Albedo	0.21	0.16
Soil thermal diffusivity	$0.33x10^{-7}\ m^2s^{-1}$	$0.24x10^{-7}\ m^2s^{-1}$

The numerical simulations were carried out for two periods: winter, from July 30 – August 8, (Julian Day 211-220) and summer, from March 9-19 (Julian Day 68-78). The model time step was 20 minutes.

The model was able to reproduce the observed seasonal patterns of net radiation, sensible and latent heat fluxes (Fig. 1). The large discrepancy found in the soil heat fluxes, in both seasons, are comparable to the large residue resulting of observed energy budget (see Fig. 1, bottom). Meanwhile, the energy balance is always satisfied in the model, it is seldom verified observationally. This may be the reason why the comparison between simulated and observed fluxes are rarely found in the literature.

Even though the residues are proportional to the observed net radiation amplitude, the comparison with other independent observations of Rn indicates that the net radiation used here is reliable. Moreover, there is no indication of important horizontal advection in the studied area, once that the area where measurements were performed can be considered homogeneous within a radius of 500 m and the turbulent fluxes measured did not show significant vertical variation (within 10%). It is important to mention that the observed turbulent fluxes used here correspond to the average of observed turbulent fluxes in three different heights (3.0 ,5.0 and 9.4 m). Therefore the observed residues can only be explained in terms of lack of representativity of soil heat flux measurements.

The observations indicated a linear relationship between the net radiation and the other components of the energy budget (Figs. 2-4). The linear correlation coefficient values varied from 0.89 (LE in summer) to 0.94 (G in summer and H in winter). The linear relationship between the net radiation and the observed soil heat flux was an expected result given the fact that the later was measured near to the surface, 1cm (Idso, et al. 1975).

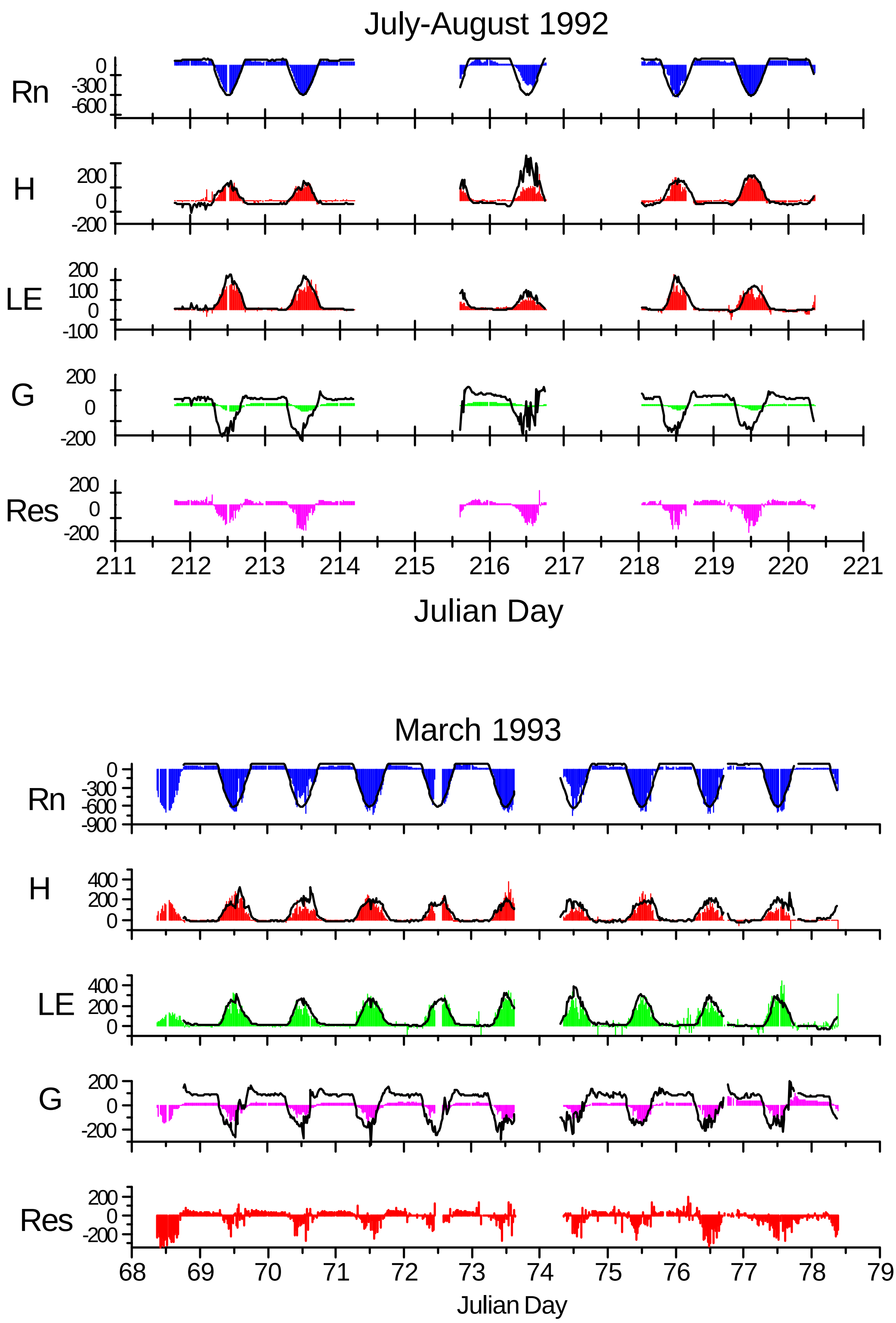

Figure 1: Modeled (continuous line) and observed: time evolution of net radiation (Rn); sensible heat flux (H); latent heat flux (LE) and soil energy flux at the surface (G). The observed residues are indicated at the bottom. Energy fluxes are in W/m^2 and positive when directed upward.

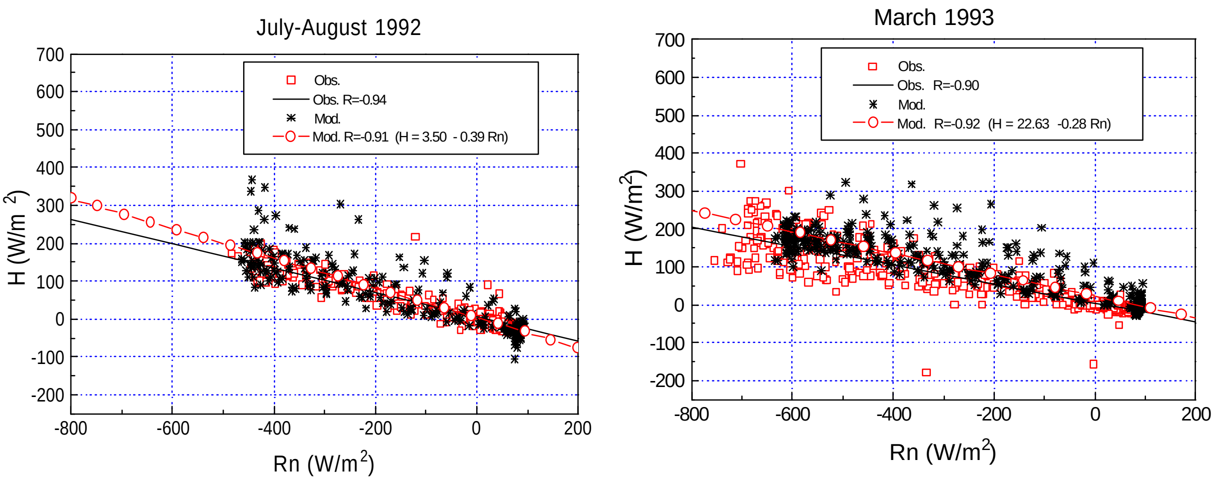

Figure 2: Dispersion diagram of net radiation (**Rn**) versus sensible heat flux (**H**). Observed and modeled values are indicated by open square and star, respectively. The fitted regression lines through the observed and modeled displayed by continuous and open circle lines, respectively. The linear regression coefficients **R** and the regression equation for the modeled results are also indicated above.

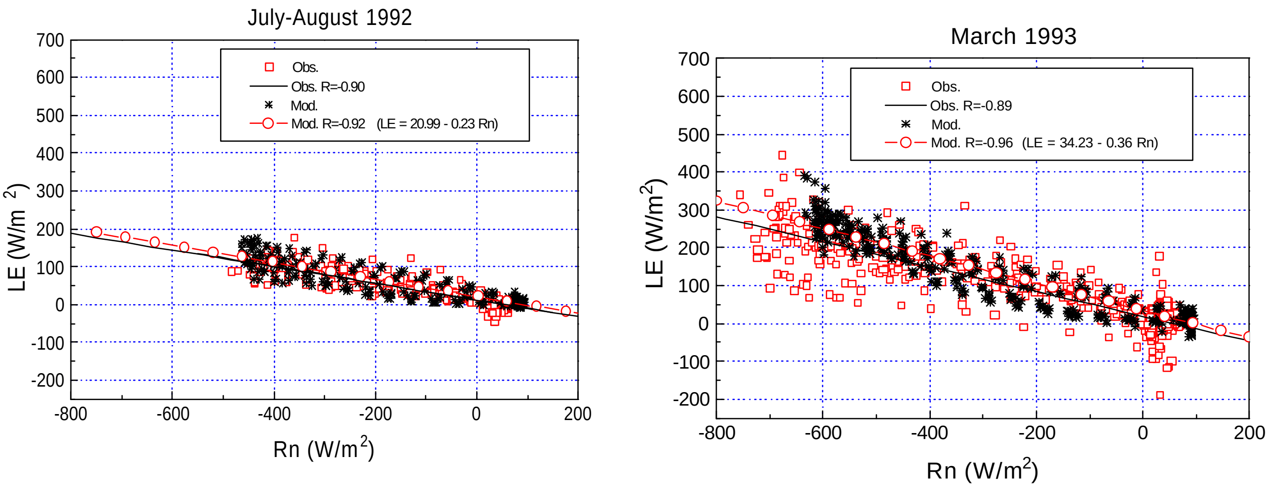

Figure 3: The same of Figure 2 for latent heat flux (**LE**).

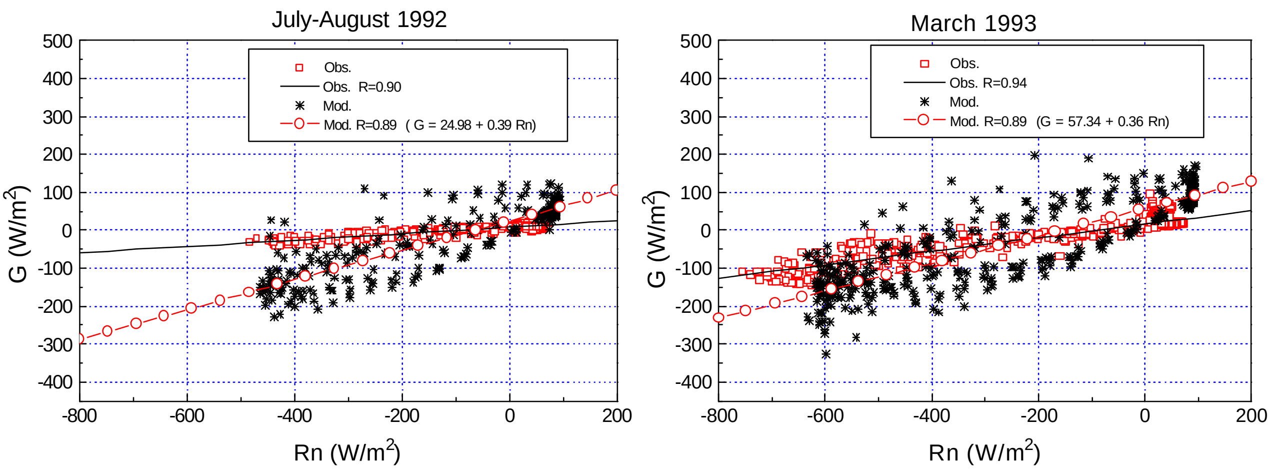

Figure 4: The same of Figure 2 for soil heat flux (**G**).

The modeled results have also shown large values of linear correlation between the modeled net radiation and the other modeled components of the energy budget (Figs. 2-4). The linear correlation coefficient values varied from 0.89 (G both seasons) to 0.96 (LE in summer). The time lag between the modeled net radiation and the modeled soil heat flux, despite the large correlation coefficient values, positioned the points in the dispersion diagram around an elliptical pattern.

The high degree of linear correlation between Rn and the energy budget components allow to estimate these components from Rn. The regression lines displayed in Figs. 2-4, were obtained from modeled values once that they are more suitable to estimate the energy balance components because in the model there is no residue.

CONCLUSIONS

Despite the uncertainties in the experimental conditions, the Deardorff's model was able to reproduce the observed seasonal patterns of sensible heat flux, latent heat flux and the net radiation in Iperó. The large discrepancy found between the modeled and observed soil heat flux are attributed to the lack representativity of soil heat flux measurements.

The model was also able to reproduce the linear relationship found between the observed turbulent fluxes and the observed net radiation ($|$regression coefficient$| \cong$ 0.90). Regression lines obtained from model results are proposed to estimate turbulent fluxes from observed net radiation values.

This procedure can be extent to other sites and climate conditions in order to estimate the turbulent fluxes as a function of observed net radiation, based on modeled regression curves. The required information are soil temperature (below 10 cm), soil water content (below 10 cm), radiation shield factor, roughness length, albedo and soil thermal diffusitivty.

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