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INVERSE THEORY APPLIED TO SURFACE LAYER RADIATION BUDGET IN SÃO JOÃO DO CARIRI-PB N-E BRAZIL

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1.INTRODUCTION

Generally, knowledge of the radiation budget at the earth's surface is very important in the investigation of the surface energetics. Net all wave radiation provides the energy that is responsible for turbulent sensible- and latent-heat exchange processes between the earth's surface and the lower troposphere, i.e. within the Planetary Boundary Layer (PBL), as well as determining soil heat flux.

Recently the inverse theory has received much attention in micrometeorological studies and several successful applications have been presented within the last decade (Siquira et al., 2003, 2000; Raupach, 1988; 1989a,b; Denmead and Roupach 1993; Denmead, 2000, Denmead et al., 2000; Katul et al., 1997, 2001; Massman and Weil 1999; Leuning 2000; Leuning et al., Simon, et al., 2002; Hsich, et al., 2003; Paz, 2002; Paz et al., 2004; among others). In short the inverse modeling technique uses a measured data set of an atmospheric quantity and an assumed model relationship that describes the physical processes of the quantity to produce the measured data set as a set of parameters (Wolff and Bange, 2000). In other words the technique uses appropriate model assumptions that are based on theoretical assumptions to fit measured data (Zittel, et al., 2002). The technique is based on the assumption of a relationship (operator **D**) between the model parameter **M** and the measured parameter **C,** i.e., $\mathbf{C}_{obs} = \mathbf{D}\ \mathbf{M}_{mod}$, where, **D** is also called as dispersion matrix (ixj terms), $\mathbf{C}_{obs}$ is a vector (with i rows) and $\mathbf{M}_{\mathbf{obs}}$ is a vector with j rows. In this study the inverse theory is applied for the estimation of the net radiation at the earth's surface in São João do Carri-PB, N-E Brazil.

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2. EXPERIMENTAL SITE DESCRIPTION

The experimental site is located in the semi-arid region of the institute-basin of Federal University of Campina Grande-UFCG, in the city of São João do Cariri (latitude $07^0 22'44''$S and longitude $36^0 32'00''$W) and altitude approximately 465 m, covered with sparse vegetation of the type caatinga and pasture. The region is considered to be semi-arid with less abundant rainfall from the month of February to April. The soil is rocky type and the vegetation is sparse and gives the appearance of strips alternatively between the rocky soil and the sparse vegetation.

3. EXPERIMENTAL METHOD

A micrometeorological tower of ten m height is located in the middle of the sparsely vegetated surface of the experimental site described above. The net radiometer and radiometer (both Campbell Scientific Inc., Q-7) were installed at the canopy top at the height of 6 meter. The soil temperature were measured by the temperature sensor (Campbell Scientific Inc., model 108) of precision of $0{,}001^0$ C, installed one at the surface (to measure surface temperature) and the other three in the depths of 2, 5 and 15 cms. The air temperatures were measured by, two Cromel Constantin thermocouple of 25 μm and 74 μm diameters, one located at the surface of the vegetation and the other at 10 m height. The temperature and specific humidity were also measured by a HMP 45C (Campbell Scientific Inc.) thermo hygrometer located at the top of the bush. The wind velocity, temperature and specific humidity were measured at 1,5 and 10 m heights. The precipitation and the humidity of the soil were also measured. The observations for this work were made during the period from 28-02-2001 to 09-03-2001 and from 07-11-2001 to 16-11-2001, the rainy and the dry seasons respectively. The measurements were taken during the interval of 20 minutes by the data acquisition system CR23X of Campbell Scientific Inc., continuously connected to the battery of 12 volts and 55 AH, accompanied to a solar panel of potential of 50 W. The datalogger is programmed to control all the experiment and to unload the data to the microcomputer.

4. METHODOLOGY AND DISCUSSION

A radiation balance at the earth's surface may be written in the form (Paz, 2002)

$$R_n = (1 - alb)\, R_g + \varepsilon_g\, f\, \sigma_B\, T^4{}_{ar} - \varepsilon_g\, \sigma_B\, T^4{}_g \qquad (1)$$

where R_n is net radiation, R_g is short wave radiation at the earth's surface, T_a is temperature at the first height of the model (K), T_g is surface temperature, alb is albedo, σ_g is soil's emissivity, σ_B is Stefqan-Boltzman constant ($W/m^2\,K^4$) and f is given by

$$f = \left\{1 - \left[0{,}49 - 0{,}66(e_a)^{1/2}\right](1 - CA)\right\} \qquad (2)$$

C and A are the parameters for short wave radiation correction for the presence of clouds. The net radiation R_n may be estimated from eq. (1), but the inverse problem is to estimate the radiative properties of the soil and the air. For this a FORTRAN code is developed using the method of Levenberg-Marquardt (Press et al., 1992). This method is based on the adjustment of the merit function S^2 which is capable of resolving nonlinear models and is given by

$$S^2(\beta, t) = \sum_{i=1}^{N} \left[\frac{R^i{}_{n(obs)}(\beta, t) - R^i{}_{n(mod)}(\beta, t)}{d_i} \right]$$

where d_i represents standard deviation at time i.

Initially, the values of the measured variable (net radiation - R_n) submitted to the processes of the minimization for each period are shown in the figures 1 and 2, considering the parametric values adopted in Regional Circulation Meteorological Model –MAL. The objective is to see visually the efficiency of the model before the process of identification. The figures 1 and 2 show the existence of a significant dispersion between the measured and modeled values. This characteristics, may be caused by the following reasons:

1) The measurements errors associated with the instruments
2) The deficiency of the model caused by the radiative properties for calculating the radiation exchange to or from the vegetated surface.

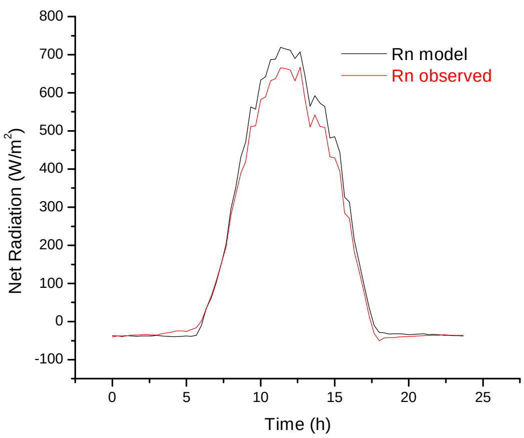

Fig. 1 Observed and modeled values of Net Radiation before the identification for dry period.

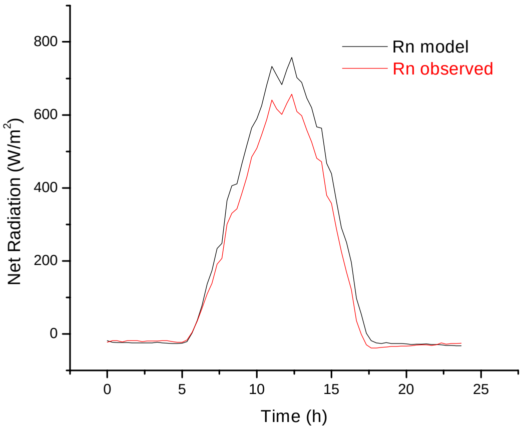

Fig. 2 Observed and modeled values of Net Radiation before the identification for humid period

To examine in detail the influence of various parameters, which interfere, in estimation of the net radiation to or from the vegetated surface must be performed by using the method of the sensibility to the parameters. This method permits to find out the effect of small variation in parameter in the model. It can be seen that the net radiation depends on the following:

$$R_n = F(alb, \varepsilon_g, f, \sigma_B, T_g, T_{ar}, R_g, z, t)$$

Of these parameters, the micrometeorological station furnishes the measurements of the air temperature at height z, soil surface temperature and the total solar radiation. So the estimation of the net radiation in terms of the properties of air and soil may be written in functional mathematical form as:

$$R_n = F(alb, \varepsilon_g, f, z, t)$$

and the function f is therefore calculated from the radiation balance at the vegetated surface. The evolution of the coefficients of sensibility to albedo (alb) and the emissivity of air ε_{ar} for both periods are shown in figures (5) and (6). It can be seen from the figures (5) and (6) that the sensivity to albedo is obviously nil during night and during day varies, reaching maximum at midday and minimum at sun rise and sun set. This indicates that the variation of albedo has an important role on the net radiation. The evolution of the sensibility to emissivity shows that this parameter has much influence on the net radiation since it´s value is much more significant during all periods of measurements. Finally, these two parameters are linearly independent in view of the estimation of parameters, so one may estimate simultaneously these two parameters from the measurements of the radiation exchange at the vegetated surface. These identifications of albedo and f were obtained using the method of Levenberg-Marquardt (Press et al., 1992). The measurements errors of the data acquisition systems were furnished by manufacturer and the standard deviation of each point of measurement are also considered. The figures (3) and (4) show that the curves of net radiation measured and calculated using the values estimated by inverse problem for each period are in good agreements.

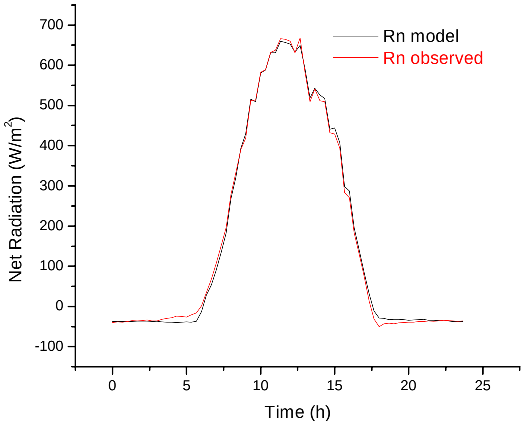

Fig. 3 Observed and modeled values of Net Radiation after the identification for dry period

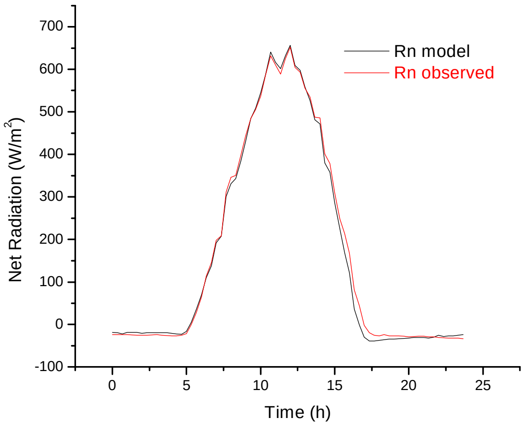

Fig. 4. Observed and modeled values of Net Radiation after the identification for humid period

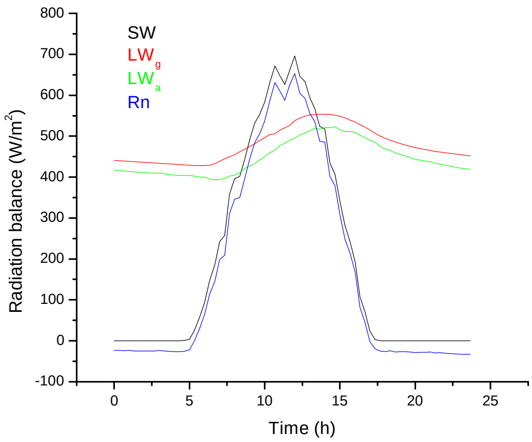

Fig. 5 Radiation balance before the identification before the identification for dry period

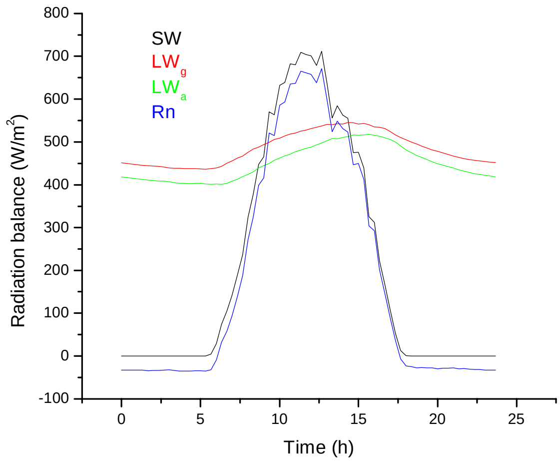

Fig. 6 Radiation balance after the identification for humid period

Further from the figures (5) and (6) one may see that radiation balance for both the periods are in good agreement. The further details of this study will be reported in a future paper.

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