A BIOSPHERE MODEL (SiB) COUPLED TO AN ONE-DIMENSIONAL MODEL

H. R. Rocha and *J. P. Bonatti*

Instituto Nacional de Pesquisas Espaciais - INPE / CPTEC
Av. dos Astronautas, 1758 - CP 515
São José dos Campos - SP - Brasil

ABSTRACT

This paper evaluates two land surface and boundary layer parameterizations used in General Circulation Models (GCMs). A vertical one-dimensional model calculates the surface fluxes based on the Monin and Obukhov theory, and evaporation accordingly to the Penman-Monteith equation, coupled to a turbulent closure model of order zero. For one point in the central Amazon, one day simulations show the evaporation to be overestimated, while still showing numerical oscillations in the boundary layer profile. A new one-dimensional model is coupled to the Simple Biosphere model (SiB) and to a turbulent closure model of order *2,0*. The presented calculated fluxes are more realistic when compared to observed data, and numerical noises are now supressed.

1. INTRODUCTION

Numerical simulations in a vertical one-dimensional model is a practical viewpoint of analysing the atmosphere's physical processes represented in a GCM, mostly because of the control and simplicity in the the boundary conditions. Potential temperature, θ, and specific humidity, q, are in this case calculated by

$$\underset{}{\frac{\partial\theta}{\partial t}} = -\underset{\text{(I)}}{\frac{\partial}{\partial z}\left(\overline{w'\theta'}\right)} - \underset{\text{(II)}}{\frac{\partial}{\rho\partial z}\left(\rho K_T \frac{\partial\overline{\theta}}{\partial z}\right)} + \underset{\text{(III)}}{\frac{\lambda}{c_p}\left(\frac{\overline{C'}}{\pi}\right.} + \underset{\text{(IV)}}{\left.\delta C_{LS}\right)} - \underset{\text{(V)}}{\frac{1}{\rho c_p}\frac{\partial Q}{\partial z}} \qquad (1)$$

$$\frac{\partial q}{\partial t} = -\underset{\text{(I)}}{\frac{\partial}{\partial z}\left(\overline{w'q'}\right)} - \underset{\text{(II)}}{\frac{\partial}{\rho\partial z}\left(\rho K_Q \frac{\partial\overline{q}}{\partial z}\right)} - \underset{\text{(III)}}{(\ \overline{C'}} + \underset{\text{(IV)}}{\delta C_{LS}\ )} \qquad (2)$$

where (I) is the heat and humidity turbulent transport in the boundary layer; (II) is the heat and humidity transport by shallow cumulus; (III) is the latent heat release in deep cumulus convection; (IV) is the large scale precipitation by condensation in an approximated wet bulb process; and (V) is the diabatic heating by short and long wave radiation.

2. MODEL COUPLING

A control version of the one-dimensional model (Ctr1D) is used in this paper, having 18 sigma coordinated layers in the vertical direction, which was adapted from the National Meteorological Center (NMC - USA) medium range forecast GCM. The surface parameterization is based on the Monin and Obukhov's similarity theory, but calculates the evaporation accordingly to the Penman-Monteith concept. A turbulent closure model of order zero calculates the turbulent vertical diffusion, described in Kalnay (1988).

This paper presents the coupling of a simple biosphere model (SiB), Sellers et al. (1986), and a turbulent closure model of order *2,0* (Mellor and Yamada, 1982), to an one-dimensional vertical model, referenced to as SiB1D. The SiB model is a complex parameterization of the transfer of the surface momentum, heat and mass fluxes, which takes into account the physical, morphological and physiological parameters of the vegetation type.

Both Ctr1D and SiB1D models are integrated for 24 hours and time step of 20 min. The surface pressure and horizontal wind are kept constant in time. A rawinsounding nearby Manaus, in 03/May/87, at 00:00 UTC, provides the initial values.

3. RESULTS

The calculated terms of the energy balance are shown through the diurnal cycle (Figure 1) or daily values (Table 1). Solar radiation fluxes of both models compare very well with the review of Viswanadham et al. (1991), where observed data at Reserva Ducke, Manaus, are shown in a daily basis.

A comparison of the calculated net radiation is made with an fitted equation of *Rn x SW* shown by Shuttleworth et al. (1984b) (Table 1). Inputing the calculated *SW* values of both models in this equation, it is noticed that SiB1D's net radiation overestimates the resulting value by about *7%*, while Ctr1D does it by *14%* In fact, Figure 2 shows that SiB1D computes an higher albedo, and closer of observed data (*0,14* in average), than Ctr1D's one (*0,075*). Besides that, the lower net radiation of SiB1D is got upon calculating an higher peak of surface temperature, so that both short and long waves are balanced to diminish the net radiation.

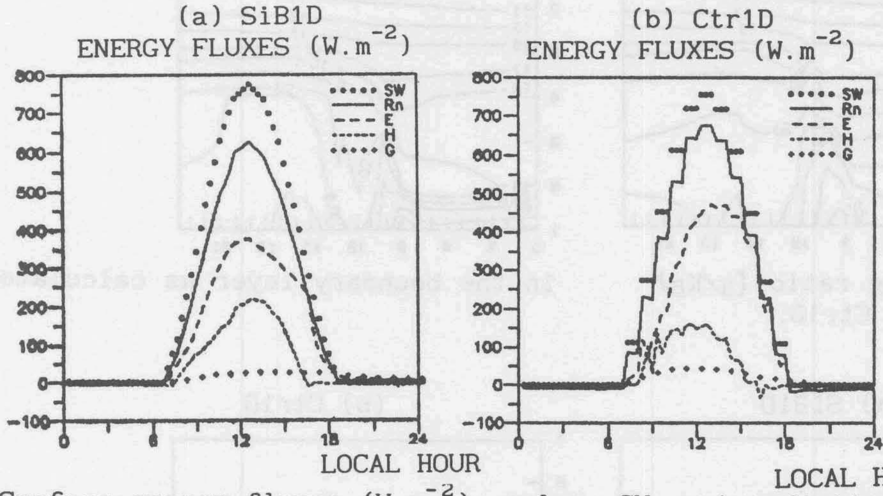
Table 1 - Daily values of calculated radiation fluxes by the models Ctr1D and SiB1D: solar, SW; net radiation, Rn; evaporation, λE; sensible heat, H, in MJ/m^2.

	SiB1D	*Ctr1D*	*Shuttleworth et al(1984b)**	*Shuttleworth et al(1984a)*
SW	*18.79*	*18.32*	-	-
Rn	*14.70*	*15.48*	(SiB1D) *13.05* (-7%) (Ctr1D) *12.65* (-14%)	*12.06*
E	*9.53* *(3.9 mm)*	*11.10* *(4.6 mm)*	-	*8.42* *(3.5 mm)*
H	*3.93*	*2.85*	-	*2.85*

* $Rn = (0.858 \pm 0.006)\, SW - (35 \pm 1.9)$, $(W.m^{-2})$

Shuttleworth et al. (1984a) estimates an average evaporation of *3,5 mm/day* for Amazon forest. That makes SiB1D's evaporation (*3,9 mm/day*) an more reliable value when compared to the Ctr1D result of *4,6 mm/day*, the later being nearer to results gotten by potencial evaporation relations (Shuttleworth et al., 1984a).

An optimization of numerical resolution is clearly gotten with the SiB1D version: the sensible heat flux (Figure 1) is better smoothed mainly in the first hours of the day. Another relevant improvement can be seen in the boundary layer profiles of potencial temperature (Figure 3) and mixing ratio (Figure 4). Altough there is an noticeable good description and reasonable similarity of the temperature profiles of both models, the humidity profile shows Ctr1D still to behave noisely on the period of mixing layer formation. This is better understood when analysing the calculated heating rates (Figure 5) and moistening rates (Figure 6) by turbulent difusion of both models: oscilations are more clearly evident in the Ctr1D's humidity difusion, while SiB1D supresses noises and calculates the process in a smoothing contour. Such as these bad numerical resolutions can even reach the effects of deep cumulus convection , where oscillations can be noticed in Ctr1D's result (Figure 7). The calculated convective precipitation by the two models are about the same: SiB1D computes *1.5 mm/day* against the Ctr1D's *1.6 mm/day*.


(a) SiB1D ENERGY FLUXES (W.m^{-2})

(b) Ctr1D ENERGY FLUXES (W.m^{-2})

Fig. 1. Surface energy fluxes (W.m^{-2}): solar, SW, net radiation, Rn, latent heat flux, λE, sensible heat flux, H, and soil heat flux, G, as calculated by (a) SiB1D and (b) Ctr1D.

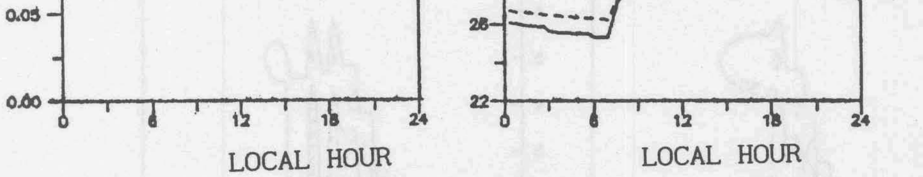


Fig. 2. (a) Surface albedo and (b) surface temperature (K) as calculated by SiB1D (solid) and Ctr1D (dashed).

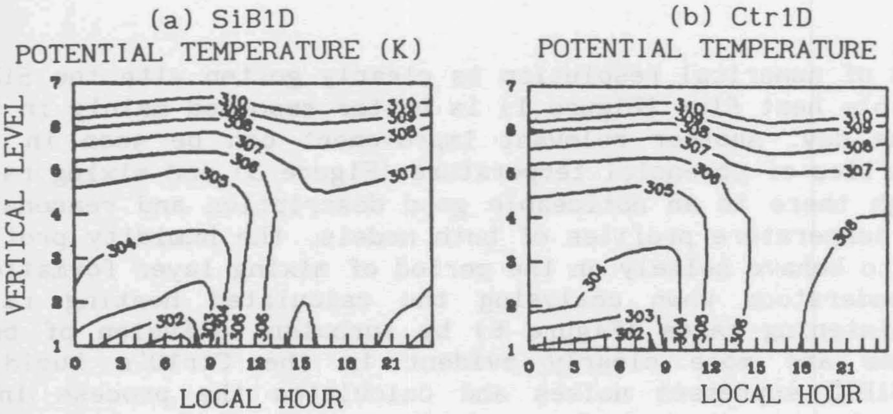


Fig. 3. Potential temperature in the boundary layer as calculated by (a) SiB1D and (b) Ctr1D.

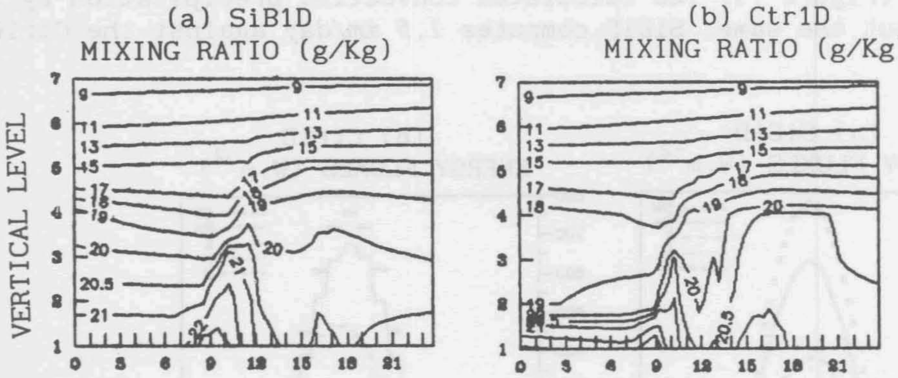


Fig. 4. Mixing ratio (g/Kg) in the boundary layer as calculated by (a) SiB1D and (b) Ctr1D.

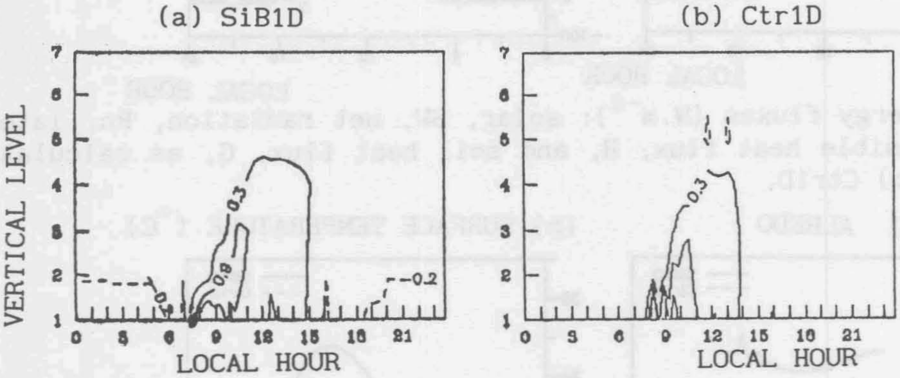


Fig. 5. Heating rates (K/hour) due to turbulent diffusion in the boundary layer as calculated by (a) SiB1D and (b) Ctr1D.

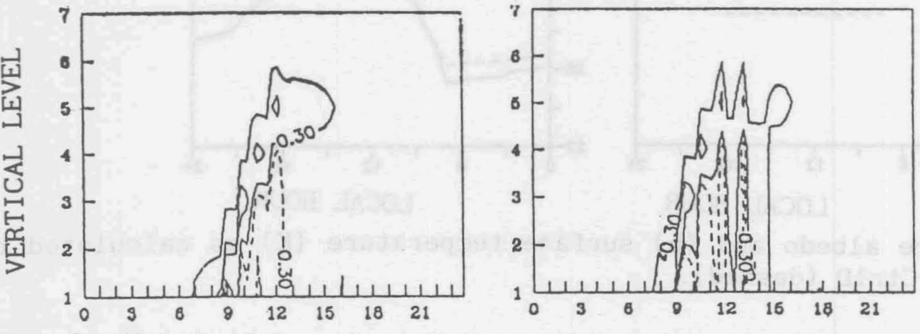


Fig. 6. Moistening rates (g/Kg/hour) due to turbulent diffusion in the boundary layer as calculated by (a) SiB1D and (b) Ctr1D.

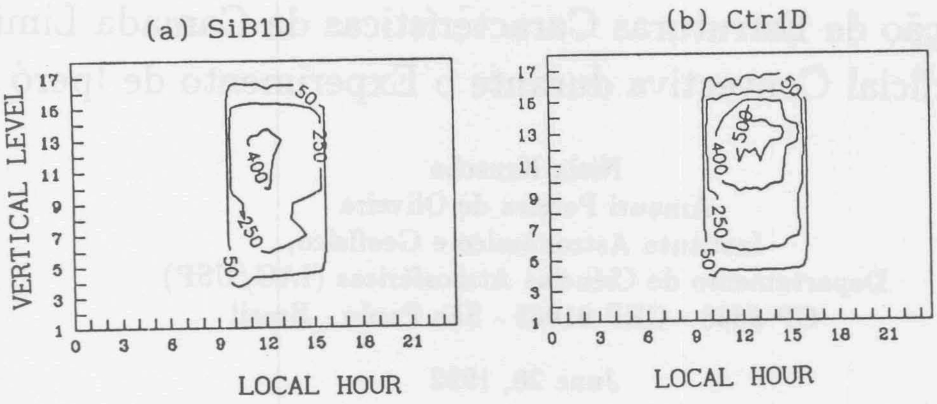


Fig. 7. Heating rate (K/hour) due to cumulus convection in the troposphere as calculated by (a) SiB1D and (b) Ctr1D.

4. CONCLUSIONS

The SiB1D one-dimensional model simulates realistically the surface physical processes (heat fluxes) and turbulent diffusion in the boundary layer, notably for the conditions of Amazon forest. Improvements were gotten if calculations are to be compared with an previous version (Ctr1D), which still does appear to overestimate evaporation, and still shows noises in the numerical resolution, particularly in the boundary layer and sensible heat flux description.

5. REFERENCES

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