Calibration of the “Simplified Simple Biosphere Model—SSiB” for the Brazilian Northeast Caatinga

Article *in* AIP Conference Proceedings · March 2009

DOI: 10.1063/1.3117068 · Source: OAI

Calibration of the "Simplified Simple Biosphere Model – SSiB" for the Brazilian Northeast Caatinga

Ana Paula Martins do Amaral Cunha[a], Regina Célia dos Santos Alvalá[a], Francis Wagner Silva Correia[b], Paulo Yoshio Kubota[a]

[a] *CPTEC-INPE, São José dos Campos – SP, Bra. ana.paula@cptec.inpe.br, regina@cptec.inpe.br, pkubota@cptec.inpe.br.*
[b] *UEA, Manaus – AM, Bra. francisw@inpa.gov.br*

Abstract. The Brazilian Northeast region is covered largely by vegetation adapted to the arid conditions and with varied physiognomy, called *caatinga*. It occupies an extension of about 800.000 km^2 that corresponds to 70% of the region. In recent decades, considerable progress in understanding the micrometeorological processes has been reached, with results that were incorporated into soil-vegetation-atmosphere transfer schemes (SVATS) to study the momentum, energy, water vapor, carbon cycle and vegetation dynamics changes of different ecosystems. Notwithstanding, the knowledge of the parameters and physical or physiological characteristics of the vegetation and soil of the *caatinga* region is very scarce. So, the objective of this work was performing a calibration of the parameters of the SSiB model for the Brazilian Northeast Caatinga. Micrometeorological and hydrological data collected from July 2004 to June 2005, obtained in the Agricultural Research Center of the Semi-Arid Tropic (CPATSA), were used. Preceding the calibration process, a sensibility study of the SSiB model was performed in order to find the parameters that are sensible to the exchange processes between the surface and atmosphere. The results showed that the B parameter, soil moisture potential at saturation (ψs), hydraulic conductivity of saturated soil (ks) and the volumetric moisture at saturation (θs) present high variations on turbulent fluxes. With the initial parameters, the SSiB model showed best results for net radiation, and the latent heat (sensible heat) flux was over-estimated (under-estimated) for all simulation periods. Considering the calibrated parameters, better values of latent flux and sensible flux were obtained. The calibrated parameters were also used for a validation of the surface fluxes considering data from July 2005 to September 2005. The results showed that the model generated better estimations of latent heat and sensible heat fluxes, with low root mean square error. With better estimations of the turbulent fluxes, it was possible to obtain a more representative energy partitioning for the *caatinga*. Therefore, it is expected that from this calibrated SSiB model, coupled to the meteorological models, it will be possible to obtain more realistic climate and weather forecasts for the Brazilian Northeast region.

Keywords: SSiB model, land parameters, calibration, sensitivity testing.
PACS: 92.60.Kc, 92.70 Bc.

INTRODUCTION

The Simplified Simple Biosphere Model (SSiB, [1]) used in this study is a simplified version of the Simple Biosphere Model (SiB) [2], which is a biophysically based model of land-atmosphere interactions and is designed for global and regional studies.

The SSiB is more complex than other schemes of surface in the treatment of the albedo, energy surface and soil moisture, needing a set of morphological, physiological and physical parameters for the calculation of the turbulent exchanges between the surface and the atmosphere. Many of the parameters considered in the SSiB may present uncertainties concerning their specifications, or do not have field measurements associated with them, which may lead to a deficiency in the diagnosis of the turbulent fluxes on the surface. Therefore, it becomes necessary to calibrate or to adjust the parameters of the SSiB model for different types of biomes.

One of the biomes considered in the SSiB, for the Brazilian territory, is the *caatinga*, which is not well monitored in terms of micrometeorological variables; therefore, its role in the soil-vegetation-atmosphere interaction is still not much known. Thus, it is important to consider micrometeorological representative measurements of this biome for evaluation of the surface models and for subsequent verification of the impacts due to the improvements on its representation in the weather forecasting, climate and hydrological models. So, this work presents, to the best of our knowledge for the first time, the calibration of the SSiB parameters for the Brazilian Northeast region, using micrometeorological and hydrological data collected from July 2004 to June 2005, obtained at the Agricultural Research Center of the Semi-Arid Tropic (CPATSA).

EXPERIMENTAL SITE AND DATA

The *caatinga* experimental site is situated at the Agricultural Research Center of the Semi-Arid Tropic – CPATSA (9°03' 30.6" S; 40°19' 45.1" W; 350 m), Petrolina, Pernambuco, Brazil. It represents an area of 600 ha of native *caatinga*, which presents a thorny vegetation with small leaves, with trees of approximately 4,5 m of height, pertaining to the *Leguminosae family* (mostly *Mimosa tenuiflora*), but with some trees with heights up to 8 m. The data of the energy balance components necessary for the study were collected at the height of 11 m of a micrometeorological tower installed at the CPATSA.

METHODOLOGY AND RESULTS

Sensitivity Study of SSiB

For sensitivity tests, each selected SSiB parameter was modified for the integration, while the other ones were maintained constant. After that, the changes caused by the variation of each parameter considered on the radiation balance, latent heat flux, sensible heat flux and soil heat flux were analyzed, to determine their relative importance.

Although each parameter caused alterations in the results of the model, the tests showed that only a few had significant impacts. So, e.g., for a dry (July, 2004) and a wet (March, 2005) months, the changes in the vegetation parameters considered did not result in considerable variations in the radiation balance (R_n). But the partitioning of energy in sensible heat (H) and latent heat (LE) was more sensible to these. The seasonal vegetation parameters leaf area index (Lc), fractional area covered (Vc), green leaf fraction (Nc), displacement height (d) and ground roughness length (Z_0), when modified, did not cause significant alterations in the calculation of the surface fluxes; however, the non-seasonal soil hydraulic properties alterations have an important role in the simulation of H and LE. Finally, the B parameter, soil moisture potential at saturation (ψs), hydraulic conductivity of saturated soil (ks) and the volumetric moisture at saturation (θs) (all non-seasonal) caused high variations on turbulent flux (Figure 1).

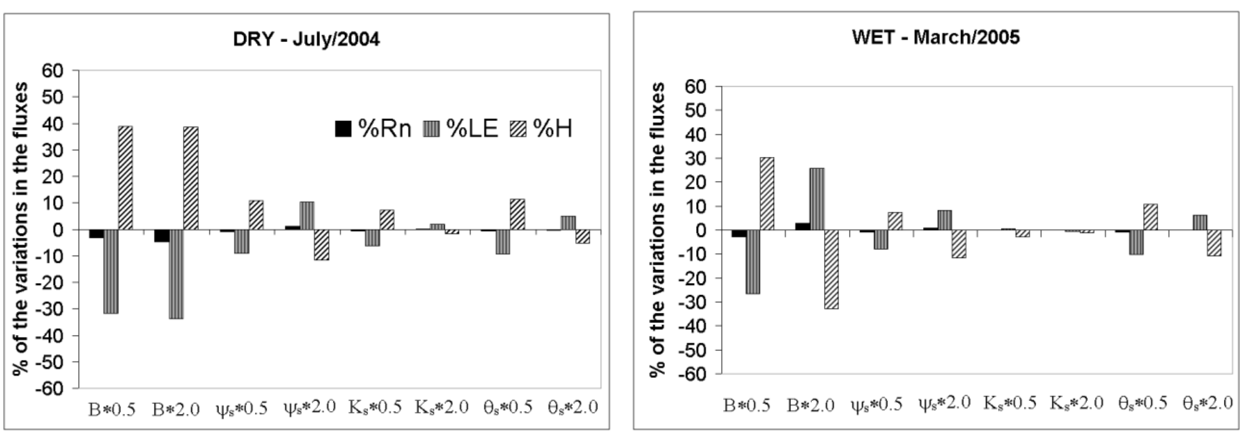

FIGURE 1. Results of the sensibility tests for soil parameters variation in (a) July/2004 (dry season) and (b) March/2005 (wet season) – NE Brazil Caatinga.

Calibration of the SSiB Model

For the calibration procedure, we used a method that considers the minimization of the root mean square errors of the ratio $\lambda E/(H+\lambda E)$, which was proposed by Sellers et al. (1989) [3], and later used by other authors [4, 5]. The off-line version of the SSiB model was used for the calibration process, to determine a set of parameters that represents well the processes of exchange between the surface and the atmosphere.

The new set of seasonal and non-seasonal parameters for the *caatinga* biome, obtained after the calibration process, is presented in Table 1. After calibration, on average, relative to their initial values, the stomatal resistance to photosynthetically active radiation (c) was reduced approximately 20%, the soil moisture potential at saturation (ψs) increased ten times; the hydraulic conductivity of saturated soil (ks) was reduced 18% and the volumetric moisture at saturation (θs) was reduced approximately 10%. No significant changes were observed for the other parameters.

For July 2004 (dry season), there was an increase of 20% for Lc; three fold increase for Vc and an increase of 14% for Z_0, when compared with their initial values. The root mean square error was reduced about 30%. For March 2005 (wet season), the same parameters did not present significant variations, except Vc, which had a four fold increase relative to its initial value. The root mean square error was reduced approximately 30%.

Also highlighted (Figure 2) is the super-estimation of LE using the initial parameters, especially during the day. With the calibrated parameters, specifically the reduced Ks and increased ψs, which in accordance with the sensitivity study causes a reduction of the evaporation, the difference between the simulated and observed LE was reduced. Despite the improvements in the LE simulation, an overestimation of H was observed, with the greatest differences occurring during the day. These results may be related with possible limitations of the algorithm used in the calibration process. Because observational data are subject to errors, the evaluation of the model performance should take into account these errors. One possible reason for the significant differences between the observed and simulated H, after the optimization procedure, may be associated with the eddy correlation method used to estimate LE and H, because it does not guarantee the closing of the energy balance.

TABLE (1) Results of the Calibration Process for Caatinga biome.

Non seasonal	**Initial (Sellers et al., 1989)**	**Calibrated**
Light dependent stomatal resistance coefficients for a green leaf:		
a ($J\ m^{-3}$)	93989.42	93992.74
b ($W\ m^{-2}$)	0.0100	0.0099
c ($s\ m^{-1}$)	855.00	672.35
Stomatal response of leaves to the atmospheric water vapor pressure - h_5 (hPa^{-1})	0.0275	0.0279
Parameters that specify leaf water potential dependency of stomatal functioning:		
ψ_1 *(m)*	1.9200	1.9232
ψ_2 *(m)*	5.6100	5.6110
B Parameter	4.0500	4.0216
Soil moisture potential at saturation - ψ_s (m)	-0.0350	-0.0029
Soil pore space - θ_s ($m^3\ m^{-3}$)	0.4352	0.3925
Satured soil hydraulic conductivity - K_s ($m\ s^{-1}$)	$2.0x10^{-4}$	$1.64x10^{-4}$

Seasonal	***July/ 2004***		***March/2005***	
	Initial	**Calibrated**	**Initial**	**Calibrated**
Canopy leaf area index – L_c ($m^2\ m^{-2}$)	0.5780	0.6921	1.5080	1.5078
Green leaf fraction - N_c	0.7979	0.826	0.6506	0.6504
Fractional area covered by the canopy - V_c	0.1000	0.2881	0.1000	0.4699
Ground roughness length - Z_0 (m)	0.2447	0.2786	0.2923	0.2921
Displacement height - d (m)	2.8126	2.8153	3.1377	3.1377
Root mean square errors ($W\ m^{-2}$)	121.7	86.5	171.0	117.3

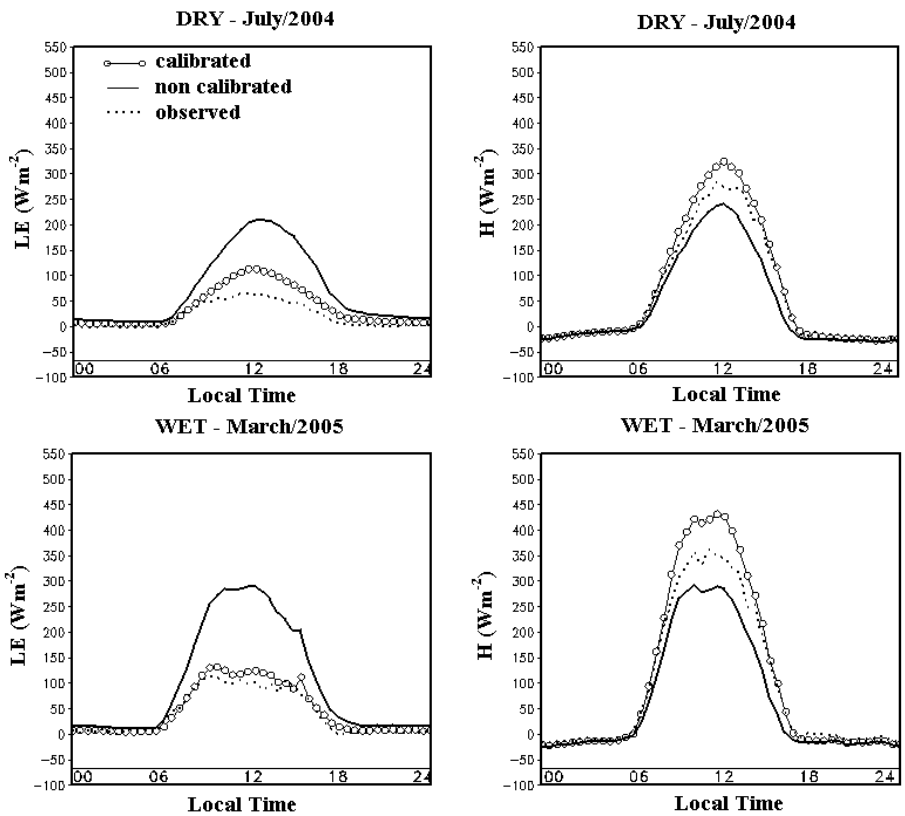

FIGURE 2. Diurnal Cycle of the Observed and Simulated Latent and Sensible Heat Fluxes – NE Brazilian Caatinga.

CONCLUSION

The new adjusted set of parameters of the SSiB model for the Brazilian *Caatinga* biome produced better results for the determination of the latent and sensible heat fluxes (especially LE), when compared with the performance of the initial parameters, thus representing better these surface processes, as may be seen by the reduction of the root mean square errors between observed and simulated fluxes. This will improve the reliability of numerical experiments using general circulation models, as well as regional models, that are basic for the climate forecast for threatened regions such as the Brazilian *Caatinga*, which presents a vegetation classified as type 8 of the SSiB model.

ACKNOWLEDGMENTS

This work is part of the first author master's dissertation under the guidance of the second author, and it was supported by CAPES, Brazil. The authors would like to thank Dr. Maria Betânia de Oliveira Leal for providing the field observation data.

REFERENCES

1. Y. Xue, P. J. Sellers, J. L. Kinter and J. Shukla, *Journal of Climate* **4**, 345-364 (1991).
2. P. J. Sellers, Y. Mintz, Y. C. Sud and A. Dalcher, *Journal of Atmospheric Sciences* **43**, 505-531 (1986).
3. P. J. Sellers, W. J. Shuttleworth and J. Dorman, *Journal of Applied Meteorology* **28**, 727-759 (1989).
4. H. R. Rocha, C. A. Nobre, J. P. Bonatti, I. R. Wright, and P. J. Sellers, *Quarterly Journal Royal Meteorological Society* **122**, 567-594 (1996).
5. F. W. S. Correia, R. C. S. Alvalá, A . O . Manzi, R. Gielow and P. Y. Kubota, *Acta Amazônica* **35**, 273-288 (2005).