Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 283-289.

NUMERICAL MODELLING OF THE BIOMASS-BURNING AEROSOL DIRECT RADIATIVE EFFECTS ON THE THERMODYNAMICS STRUCTURE OF THE ATMOSPHERE AND PRECIPITATION

Karla M. Longo*, Saulo R. Freitas, Maria A. Silva Dias,
Pedro L. Silva Dias and Luiz Flavio Rodrigues
Center for Weather Forecasting and Climate Studies - CPTEC/INPE

1. ABSTRACT

The biomass burning aerosol direct radiative effect is studied through a numerical simulation using the CATT-BRAMS (Coupled Aerosol and Tracer Transport model to the Brazilian developments on the Regional Atmospheric Modeling System) model system. CATT-BRAMS is an on-line transport model fully consistent with the simulated atmospheric dynamics. The sources emission from biomass burning and technological activities for several gases and aerosol may be defined from several published dataset and remote sensing. The mass concentration prognoses accounts also for convective transport by shallow and deep cumulus, wet and dry deposition and plume rise. Also, an additional radiation parameterization, which takes the interaction between aerosol particles and short and long wave radiation into account, was implemented. The model is applied to simulate carbon monoxide (CO) and particulate material PM2.5 transport during the SMOCC/RACCI campaign during the 2002 dry season. We present preliminaries results of the direct effect of aerosol on the atmosphere thermodynamic structure, surface energy budget and precipitation.

2. INTRODUCTION

The high concentration of aerosol particles and trace gases observed in the Amazon and Central Brazilian atmosphere during the dry season is associated with intense anthropogenic biomass burning activity (vegetation fires, Andreae, **Erro! A origem da referência não foi encontrada.**). Most of the particles are in the fine particle fraction of the size distribution, which can remain in the atmosphere for approximately a week (Kaufman, **Erro! A origem da referência não foi encontrada.**).

In GOES-8 visible imagery Prins *et al.* **Erro! A origem da referência não foi encontrada.** have observed immense regional smoke plumes in South America covering an area of approximately 4 to 5 million km^2 during the biomass-burning season. Inhalable aerosol particles (d_p<10 μm) with concentrations as high as 400 μg m^{-3} have been measured near the surface level and the vertically integrated smoke aerosol optical thickness column rises as high as 4.0 (440 nm channel) in Central Brazil (Artaxo *et al.* **Erro! A origem da referência não foi encontrada.**, **Erro! A origem da referência não foi encontrada.**; Echalar *et al.* **Erro! A origem da referência não foi encontrada.**).

On a regional and global scale, a persistent and heavy smoke layer over an extensive tropical region may alter the radiation balance and hydrologic cycling. Modeling efforts of Jacobson **Erro! A origem da referência não foi encontrada.** and Sato *et al.* **Erro! A origem da referência não foi encontrada.** have suggested that black-carbon radiative forcing could balance the cooling effects of the global anthropogenic sulfate emissions. The direct global radiative forcing of black-carbon is estimated to be 0.55 Wm^{-2}, corresponding to 1/3 of the CO_2 forcing. In terms of direct radiative forcing, this would elevate black-carbon to one of the most important elements in global warming, second only to CO_2 (Andreae **Erro! A origem da referência não foi encontrada.**).

The presence of biomass burning particles in the atmosphere may also modify the solar radiative balance by changing cloud microphysics. These particles act as cloud condensation and ice nuclei, promoting changes in the cloud drops spectrum and so altering the cloud albedo and precipitation (Cotton and Pielke **Erro! A origem da referência não foi encontrada.**; Rosenfeld **Erro! A origem da referência não foi encontrada.**). This suggests that biomass burning effects may extrapolate from the local scale and be determinant in the pattern of planetary redistribution of energy from the tropics to medium and high latitudes via convective transport processes. Koren et al. **Erro! A origem da referência não foi encontrada.** using satellite images of the Amazon rainforest suggested that smoke and cumulus clouds rarely occur together. Figure 1 shows an example of this situation for 2005.

In this paper the direct effect of biomass burning aerosols is investigated using the CATT-

Corresponding author address: Karla M. Longo, Centro de Previsão de Tempo e Estudos Climáticos (INPE), Cachoeira Paulista, São Paulo, Brazil. E-mail: longo@cptec.inpe.br.

BRAMS model (Freitas et al., **Erro! A origem da referência não foi encontrada.**), a system designed to simulate and study the transport and processes associated to biomass burning emissions. CATT is an Eulerian transport model fully coupled to the Regional Atmospheric Modeling System – RAMS (Walko *et al.* **Erro! A origem da referência não foi encontrada.**). Also, an additional radiation parameterization, which takes the interaction between aerosol particles and short and long wave radiation into account, was account, was implemented. The short and long wave radiative code used is the rapid two-stream approximation (Toon, et al., **Erro! A origem da referência não foi encontrada.**). For the smoke aerosol, climatological properties derived from a three years of optical properties retrieval obtained for an Amazonian observational site of the AERONET sun photometer network are used (Procópio et al., **Erro! A origem da referência não foi encontrada.**). Basically, the radiative code access a pre calculated optical parameters table (single scattering albedo ϖ_0, asymmetry parameter of the phase function *g* and extinction coefficient Q_e*)* as functions of the aerosol optical thickness at 500 nm channel calculated for each model column.

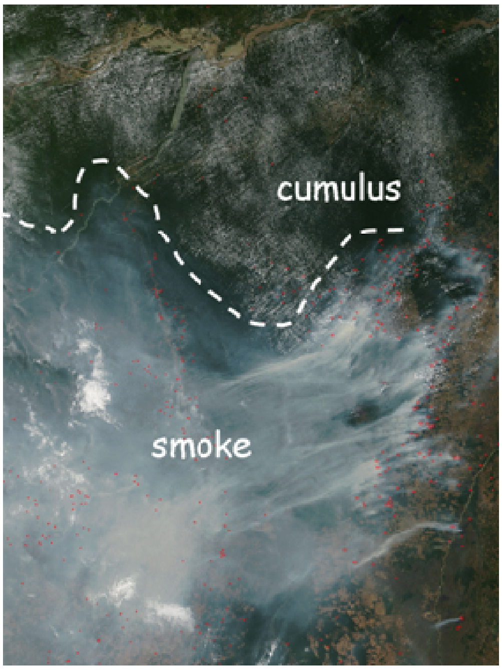

Figure 1: MODIS Rapid Response System Image on 24/Aug/2005. This picture shows the clearly cloud inhibition due a haze layer over Brazilian Amazon.

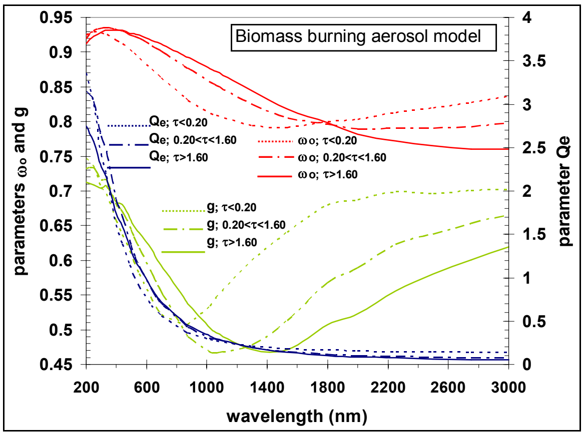

Figure 2: Spectral smoke aerosol optical properties (single scattering albedo ϖ_0, asymmetry parameter of the phase function *g* and extinction coefficient Q_e) as functions of the aerosol optical thickness at 500 nm derived from three years of AERONET data collected during the dry season in Amazonia (Procopio et al., 2003) implemented at CATT-BRAMS model.

3. MODEL SIMULATION FOR 2002 DRY SEASON

Simulation for 2002 dry season was performed to compare model results with observed data and study the direct effect of biomass burning aerosol. The model configuration had 2 grids. The coarse grid had a horizontal resolution of 140 km covering the South American and African continents. Its main purpose was to simulate approximately the intermittent smoke inflow from the African fires to South America and to coordinate with and compare to the long-range transport of smoke from fires in South America to the Atlantic compare to the long-range transport of smoke from fires in South America to the Atlantic Ocean. The nested grid had a horizontal resolution of 35 km and covering only South America. The vertical resolution for both grids was between 150 to 850 m, with the top of the model at 23 km (42 vertical levels). The time integration was 135 days, starting on 00Z 15 July 2002. For atmospheric initial and boundary condition the 6 hourly CPTEC T126 analysis fields were used through 4DDA technique. Two tracers were simulated, CO and particulate material with diameter less than 2.5 μm (PM2.5). Figure 3 shows the aerosol optical thickness (AOT) at 550 nm channel from MODIS (Moderate Resolution Imaging Spectroradiometer), combining TERRA and AQUA satellites observations on 25 August 2002. Values of AOT of order 2 ~ 3 were observed over the Brazilian Amazonia. Also is evident the large extension of the plume and its long range transport reaching North Argentina and South Atlantic Ocean. White color depicts

places not covered by the sensor or contaminated by clouds (see Figure 5).
The simulated AOT is showed at Figure 4. Model agreement with MODIS retrieval is quite good and reveals how the South Atlantic anticyclonic circulation and the cold front approach control the dispersion and advection of smoke over South America. The model results depicted in red box is from 35 km resolution grid and show finer plumes that are possible to compare with MODIS retrieval.

Figure 6 shows several surface properties associated to the biomass burning aerosols simulated for ABRACOS site. Figure 6 (a) shows AOT at 550 nm from 00Z20 to 00Z23 September 2002 where values up to 2.8 can be envisioned. Figure 6 (b) shows the surface temperature simulated considering (blue) or not (green) the aerosols in the radiative transfer calculations. The maximum temperature is about 1 C warmer when aerosols are not taken into account. However, there are not significant differences for the minimum. The relative

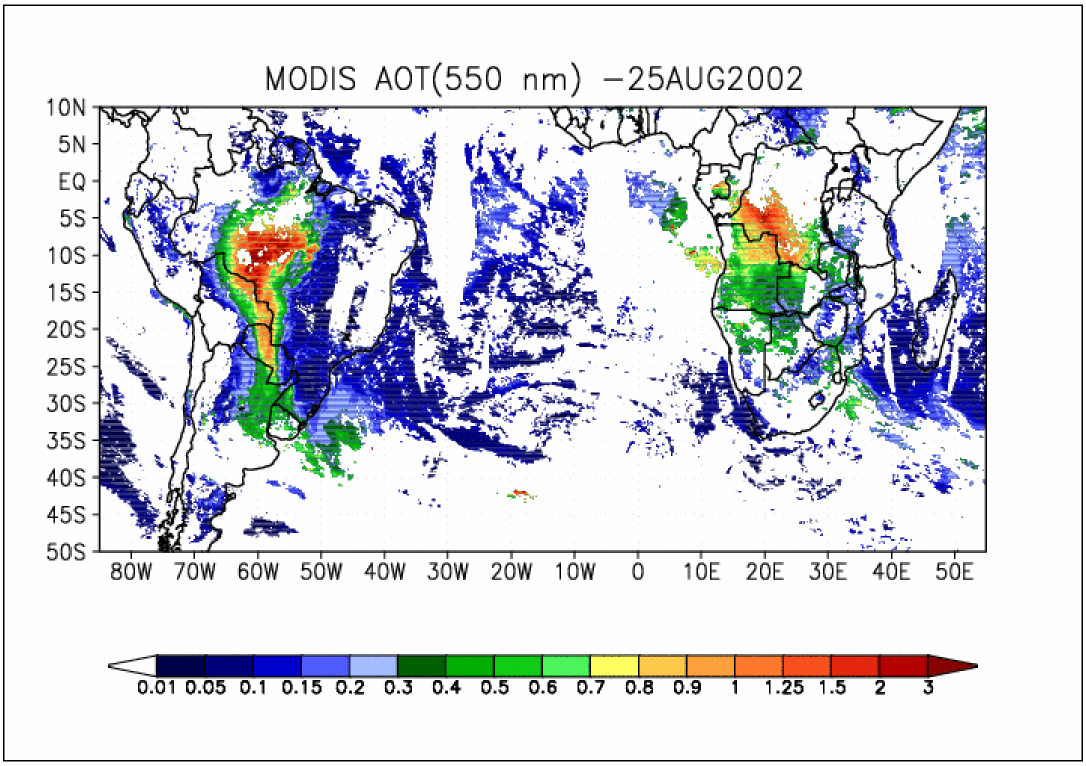

Figure 3: Aerosol optical thickness (AOT) at 550 nm channel from MODIS, combining TERRA and AQUA satellites observations on 25AUG2002.

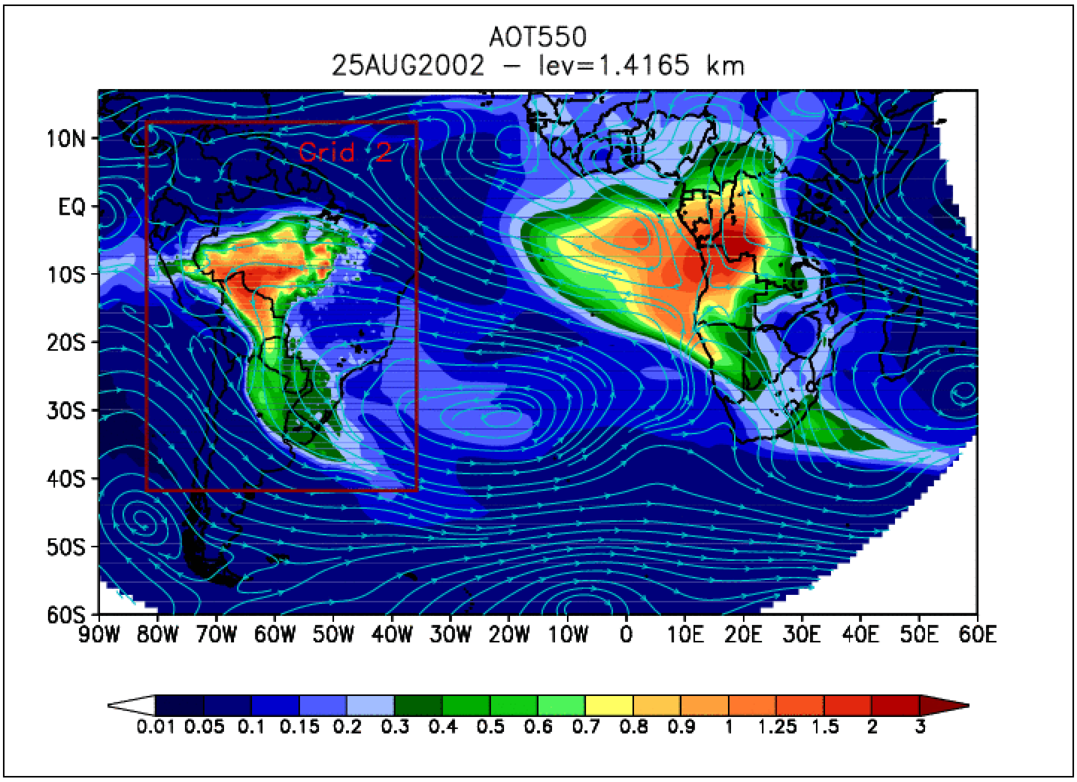

Figure 4. Aerosol optical thickness (AOT) at 550 nm from CATT model on 25AUG2002. In grid 2 finer plumes are possible to visualize and compare with MODIS retrieval.

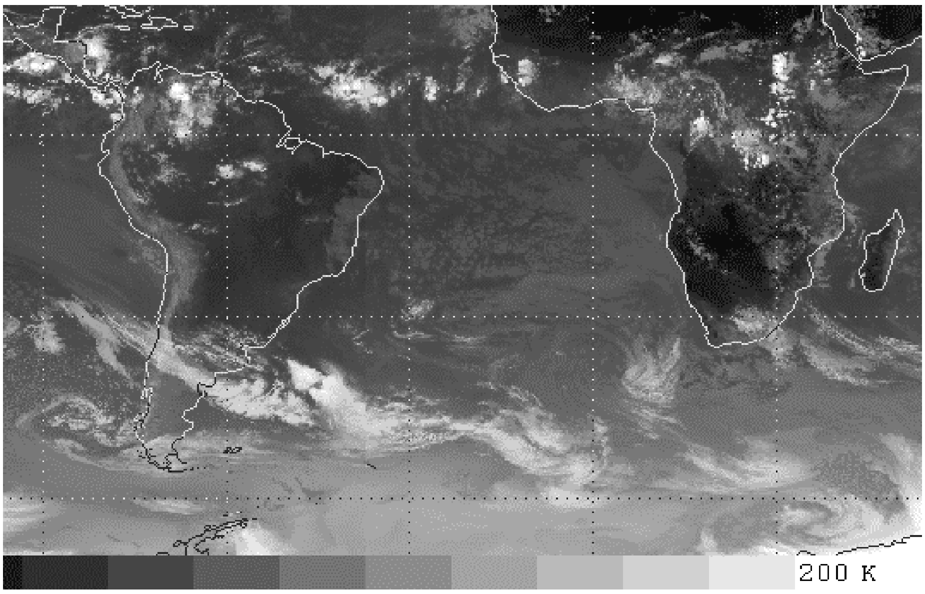

Figure 5. GOES and METEOSAT IR image on 12Z 25AUG2002. This Image shows some cloud systems which contaminated MODIS AOT retrieval.

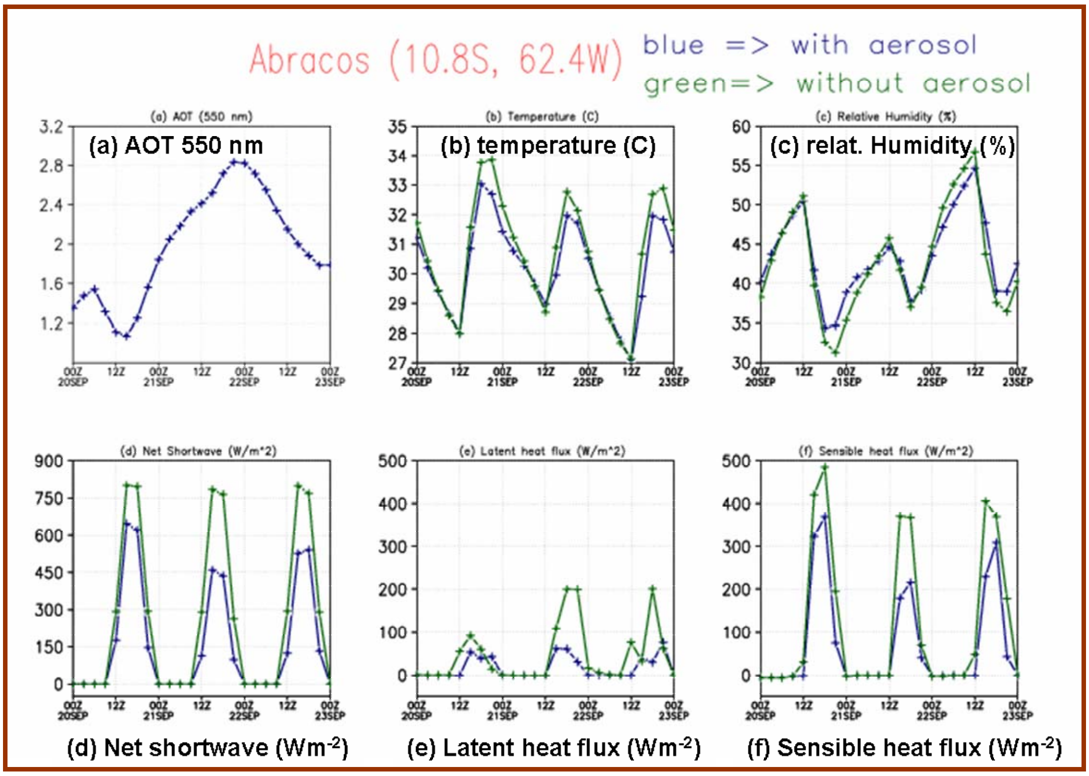

Figure 6. The aerosol direct effect on surface thermodynamic properties and energy budget on ABRACOS pasture site from 00Z20 to 00Z23 September 2002. Blue colors depict results considering the aerosol in radiative transfer calculations, for green results it is not considered.

humidity (Figure 6 (c)) in the end of the day (around 21Z) is slightly higher when the aerosols are considered. This can be explained due to the fact that surface is colder and moister. The surface net shortwave radiation reduction is presented at Figure 6 (d). For the period of the maximum AOT, the reduction is about 40%, which impact directly the latent (Figure (e)) and sensible (Figure (f)) heat fluxes. The Figure 7 presents time series of 3-hourly rainfall simulated by model considering the aerosol on radiative transfer calculation and not for the same site from 00Z16JUL to12Z30NOV 2002. Comparing figures (a) and (b) is evident the effect of aerosol on reducing the amount of rainfall. However, the onset of the wet season is not clearly demonstrated. This suggests that the large scale aerosol distribution is not enough to delay it.

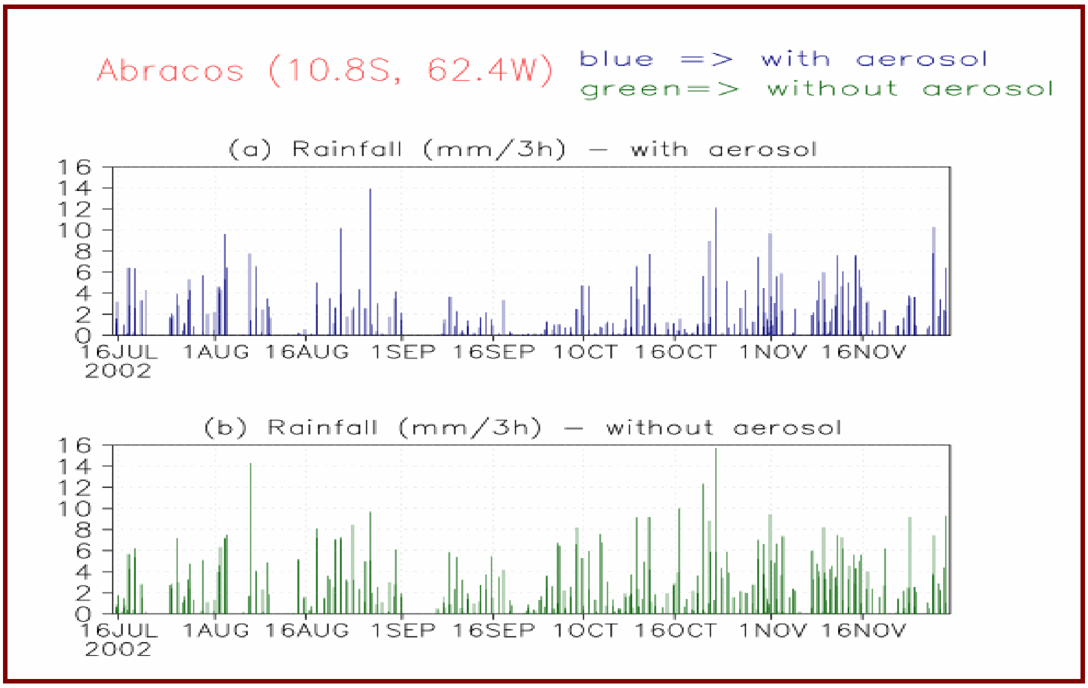

Figure 7. Time series of 3-houly rainfall simulated by model considering the aerosol on radiative transfer calculation (blue) and not (green) for ABRACOS site from 00Z16JUL to 12Z30NOV 2002.

4. CONCLUSIONS

Preliminary results of direct effects of biomass burning aerosols simulated by CATT-BRAMS system were showed. Model could represent quite well the large scale aerosols distribution and associated AOT for 2002 dry season. The expected trends in surface thermodynamical properties, energy budget and rainfall were simulated. Comparisons with surface observed data is under work to model validation and will appear in future papers.

ACKNOWLEDGEMENTS

We acknowledge partial support of this work by NASA Headquarters (NRA-03-OES-02 and NRA-02-OES-06). This work was carried out within the framework of the project “Monitoramento de emissões de queimadas e avaliação das observações de qualidade do ar em Três Lagoas – MS” in collaboration with CENPES/Petrobrás; Smoke, Aerosols, Clouds, Rainfall, and Climate (SMOCC) project and Radiation, Cloud, and Climate Interactions in the Amazon during the DRY-TO-WET Transition Season (RACCI) project.

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