SATELLITE OBSERVATION AND RADIATIVE MODELING OF THE INFLUENCE OF AEROSOL PARTICLES FROM BIOMASS BURNING ON CLOUD MICROPHYSISCAL PROPERTIES

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1. INTRODUCTION

Various types of aerosols affect cloud microphysical properties and cloud lifetime through the so-called "indirect effect". The decrease of particles size when the cloud is polluted by small aerosol particles serving as additional cloud condensation nuclei and the reduction of the efficiency of the precipitation forming processes are phenomena described in numerous recent studies (Bréon et al. 2002; Rosenfeld 1999, 2000). Biomass burning aerosol is considered highly responsible of cloud property modifications, due to the high frequency of extended forest and cropland fires all over the planet.

In case of lack of wet scavenging biomass aerosol can reside in the atmosphere for time scales of days to weeks and may therefore be transported to considerable distances in an elevated (2-4 km) polluted layer (Keil and Haywood 2003). Cloudy scenarios are thus possible where the cloud layer is located below the aerosol layer and separated from it. The presence of the aerosol layer above the cloud deck can significantly affect the satellite retrieval of cloud properties (effective radius and optical thickness) and lead to an erroneous detection of the "indirect effect" (Haywood 2003).

Radiative transfer simulations in the VIS, NIR and IR for a scenario characterized by a stratocumulus cloud deck with and without an overlying biomass burning aerosol layer are carried out. The idea is to evaluate the variations of the radiance data within the satellite channels due to the aerosol presence, and understand the eventual effects on the retrieval of the cloud particle effective radius and optical thickness. The vertical structure of the atmosphere in terms of cloud and aerosol layer top and bottom heights and the optical properties of the aerosol and other parameters useful for the description of the simulated scenario are those of the Southern African Regional Science Initiative (SAFARI 2000) (Swap et al. 2003), a multi-national measurement campaign that took place in Southern Africa in August and September 2000 during the fire season.

2. THE RADIATIVE TRANSFER MODEL

The simulated radiances are computed by means of the RSTAR4b (Nakajima and Tanaka 1986, 1988; Stamnes et al. 1988) radiative transfer model (RTM). RSTAR4b is a 1D, plane-parallel model that is used in the present work to compute radiances at the VIS, NIR and IR wavelengths, in presence of water or ice clouds and aerosol. The RTM can simulate radiance data as measured by a satellite sensor using the response functions of the various channels, but monochromatic radiance simulations are allowed as well. The radiative transfer calculations are based on a combined discrete-ordinate / matrix-operator method, with the delta-M approach for the representation of the phase function and the corrections for the singly scattered radiation. The atmosphere is vertically divided in several homogeneous sublayers and limited at the ground by a Lambertian surface. The vertical profiles of temperature, pressure and gases are taken from the atmospheric models of the Air Force Geophysical Laboratory (AFGL) (Kneizys et al. 1988). The gas absorption is computed by means of a three term k-distribution. Finally, Mie theory is used to compute the scattering properties (extinction and absorption cross sections) and the phase function of aerosol and cloud particles.

3. RADIATIVE TRANSFER SIMULATIONS

The input parameters for RSTAR4b RTM are taken from the SAFARI experiment. Keil and Haywood (2003) describe the typical scenario observed off the Angolan and Namibian coasts during September 2000. According to this description the low-level stratiform clouds are confined between 400 and 700 m, whereas the majority of the biomass aerosol particles are located at variable altitudes between 1.8 and 3.7 km.

For the simulations clouds are considered as an homogeneous vertical layer, characterized by a unique size distribution, that is a monomodal log-normal distribution. Typical values for the cloud liquid water path (LWP) during the SAFARI field campaign range from about 70 to 10 g m^{-2}, with a cloud particle effective radius (R_e) of ~7 – 8 µm near the cloud top. Taking into account these values the radiative transfer computations are carried out for R_e values between 5 and 15 µm and cloud optical thickness at the reference 0.5 µm wavelength between 2 and 15.

The standard tropical atmospheric model is chosen for the simulations, where some modifications are brought in order to include the pronounced temperature inversion of ΔT =16 K (Keil and Haywood

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2003) that defines the top of the observed stratocumulus layer.

4. BIOMASS BURNING AEROSOL CHARACTERISTICS

A new aerosol type, more suitable to represent the radiative effects produced by the biomass burning aerosol observed during SAFARI 2000 was included among those already available with RSTAR4b. The built-in aerosol models of the RTM include the 'soot' aerosol (d'Almeida et al. 1991), but this latter aerosol type is representative only of more absorbing substances emitted into the atmosphere by combustion processes and results in scattering properties that don't match those reported by Haywood et al. (2003) as characteristic of this aerosol event. Thus the RSTAR4b data set of the Mie efficiency factors for the computation of the extinction and absorption cross sections and phase function was increased by including a new set of factors computed for proper refractive index values. The spectral aerosol refractive index values to be input into RSTAR4b are computed taking into account the Aerosol Robotic Network (AERONET; Holben et al. 1998) data and the refractive index spectral dependence shown by the RSTAR4b 'soot' aerosol. In particular, the refractive indexes relative to the AERONET Etosha-Pan site (Namibia) were chosen, concentrating on those retrieved on the 13th of September 2000 (see Tab. 1). They fairly agree with the refractive index value at 0.55 μm (1.54 – 0.018*i*), characteristic of the aged regional haze rich in biomass burning aerosol of the SAFARI 2000 campaign (Haywood et al. 2003).

A log-normal size distribution with two modes at 0.12 and 0.26 μm is used for the radiative transfer simulations.

The spectral single-scattering albedo computed by using this RSTAR4b set-up (Fig. 1) agrees quite well with the data reported by Haywood et al. (2003) and Dubovik et al. (2002).

Wavelength (μm)	0.441	0.673	0.873	1.02
Refractive index (real)	1.514	1.542	1.564	1.582
Refractive index (imaginary)	0.019	0.016	0.016	0.015

Table 1. AERONET refractive index values, 13 September, 2000, Etosha-Pan site.

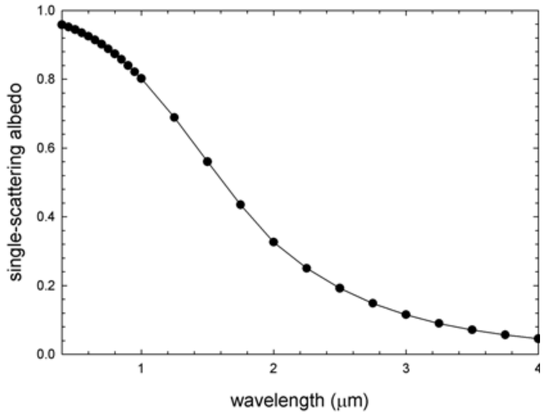

Fig. 1 Aerosol single-scattering albedo simulated with RSTAR4b.

5. CONCLUSIONS

To evaluate the radiative effect of the biomass burning aerosol on the retrieval of the cloud parameters it is necessary to reproduce correctly the spectral dependence of the aerosol scattering properties. This is especially true for the effective radius that can be retrieved using different wavelengths in the NIR portion of the electromagnetic spectrum (Rosenfeld et al., 2004). As demonstrated in Haywood et al. (2004) the R_e may be underestimated or overestimated, according to the wavelength used for the retrieval, i.e. 1.6 or 3.7 μm, respectively, due to the variations of the scattering properties of the aerosol in the NIR spectral interval. This effect should be accounted for when attempting to evaluate any potential aerosol "indirect effect". Nevertheless, it is very difficult to quantify it due to the limited availability of spectral aerosol scattering data.

The present work is in progress and many more cases are to examined to derive unambiguous results both on the effect of aerosol layers on the cloud property retrieval and on cloud-aerosol interactions. The reader is directed to first results by Cattani et al. (2003) and Costa et al. (2003).

6. ACKNOWLEDGEMENTS

The authors are grateful to the OpenCLASTR project for making available for use the RSTAR (system for transfer of atmospheric radiation) package. A special thank goes to the AERONET PI B. Holben for the effort in establishing and maintaining the Etosha-Pan site.

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