P1.11 SOLAR RADIATIVE FORCING BY BIOMASS AEROSOL IN THE PRESENCE OF MARINE CLOUDS DURING SAFARI 2000

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1. INTRODUCTION

The latest IPCC report (*IPCC, 2001*) gives an estimate of the direct radiative forcing by biomass aerosol of -0.2 W/m^2 with an uncertainty of a factor of three as a global mean over the industrial period, and attributes a very low level of scientific understanding to it. Uncertainties regarding the forcing of biomass aerosol are largely due to a lack of information on the actual physical and optical properties of biomass aerosol as well as cloud characteristics around Africa (*Haywood and Boucher, 2000*). The international measurement campaign SAFARI 2000 (Southern AFricAn Regional science Initiative) was dedicated to investigate biomass aerosol from Africa during the main burning period in September 2000. This study focuses on the radiative effects - in particular the direct radiative forcing at the TOA (top of the atmosphere) - of biomass aerosol which is transported off the Namibian/Angolan coastline over the South Atlantic Ocean, a region with semi-permanent stratocumulus clouds sheets being present.

2. AIRBORNE MEASUREMENTS AND RADITIVE TRANSFER MODELLING

In this study we mainly used measurements carried out onboard the Met Office C-130 Hercules Aircraft on 07/09/00. These measurements are campaign-representative for (1) the aerosol properties (aerosol distribution and chemical composition and in turn single scattering albedo and asymmetry parameter are almost identical with the campaign average), and (2) the location of an elevated biomass aerosol layer above cloud level. Furthermore, the aerosol load (number concentration) was the highest measured in aged aerosol during the campaign (measurements in the center of the aerosol plume) and the cloud used for this case study, measured on 07/09/00, was the one with the highest albedo throughout the campaign. Figure 1 shows vertical profiles of the carbon monoxide (CO) concentrations and the particle number concentrations measured on that day. The CO concentration is an indicator for biomass burning. Fig. 1 shows the highest concentrations of aerosol particles in altitudes between 1.8 km and 3.7 km altitude, and therefore far above cloud level (clouds below 1 km altitude).

The average single scattering albedo of the biomass aerosol particles was 0.90, varying between 0.86 and 0.93 throughout the campaign (including different measurement techniques as well). *Haywood et al. (2002)* give a comprehensive summary of aerosol measurements during SAFARI 2000.

The cloud used for this study had an adiabatic liquid water content profile, a liquid water path (LWP) of around 85 g/m^2 and, in turn, a solar albedo of 0.68. So, this cloud's LWP is lower than the value of around 140 g/m^2, derived via *Wood et al. (2002)* for the same region [*R. Wood, personal communication, 2002*], which would give a somewhat higher cloud albedo (around 0.75).

Plane-parallel radiative transfer calculations were done using the measured aerosol and cloud parameter as described above as input (*Nakajima and Tanaka, 1986*). The definition of input parameters in the model, taken mainly from PCASP measurements, BC-Filter measurements and FSSP-measurements, is described in *Keil et al. (2001).*

3. RESULTS AND DISCUSSION

The radiative transfer calculations were performed for clear sky and overcast conditions. In clear skies the direct solar TOA aerosol forcing of the biomass aerosol layer amounted to -13.0 W/m^2. In cloudy skies, the biomass aerosol was above clouds, which act basically to enhance the reflection of the underlying atmospheric levels. The TOA forcing changed sign to +11.2 W/m^2 due to the presence of clouds. These forcings vary quantitatively, but not qualitatively, if lower aerosol loads or the whole span of measured aerosol scattering albedo values are used in the calculation. As we took extreme values as input parameters, i.e. maximum aerosol load and cloud albedo measured during SAFARI 2000, the given number represent (1) a maximum negative forcing estimate without clouds (due to highest aerosol load) and (2) a maximum positive forcing estimate with clouds (combination of highest aerosol load and highest cloud albedo).

Vertical profiling near the coast and far away from the coastline (near Ascension Island) has indicated that the biomass aerosol resides above cloud over large areas in the South Atlantic. These measurements tie in with TOMS satellite observations showing biomass aerosol moving thousands of kilometres off the southern African coastline, as such a long-range transport can only take place in the free troposphere, i.e. above stratocumulus cloud level.

Assuming our aerosol and cloud parameters as being representative for biomass aerosol over this region, we estimated the areas of positive and negative forcing due to biomass aerosol by weighting the calculated forcings with the fractional cloud cover. The fractional cloud cover was obtained using ISCCP data from 1983 to 1995 (International Cloud Climatology Project). Figure 2 shows climatology of the fractional cloud cover for the region of interest together with the zero-forcing line of the direct solar TOA forcing of the biomass aerosol particles. Over

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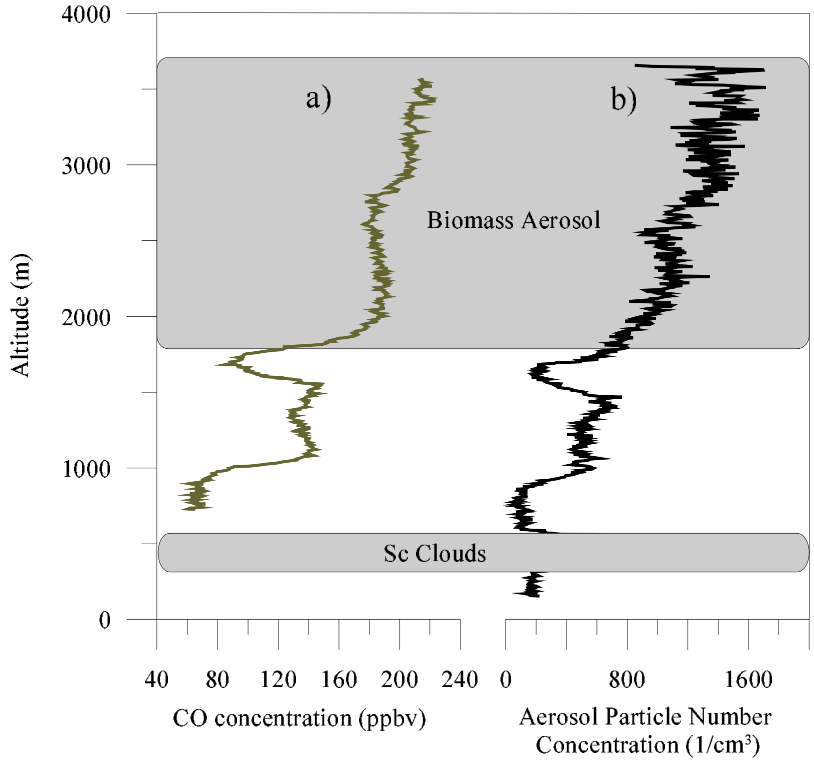

Figure 1. Typical vertical profiles of (a) CO concentration and (b) particle number concentration measured during SAFARI 2000. The main biomass aerosol layer is located far above cloud level.

large areas of the Namibian cloud sheet in the South Atlantic positive direct forcing due to biomass aerosol can be expected. This result is in agreement with *Myhre et al. (2002)*, who investigated the forcing of biomass aerosol based on dynamic modelling including burning sources. Defining clouds with higher albedo as representative (cp. section 2), would extend the region of positive forcing slightly, but not change the overall conclusion from this study qualitatively.

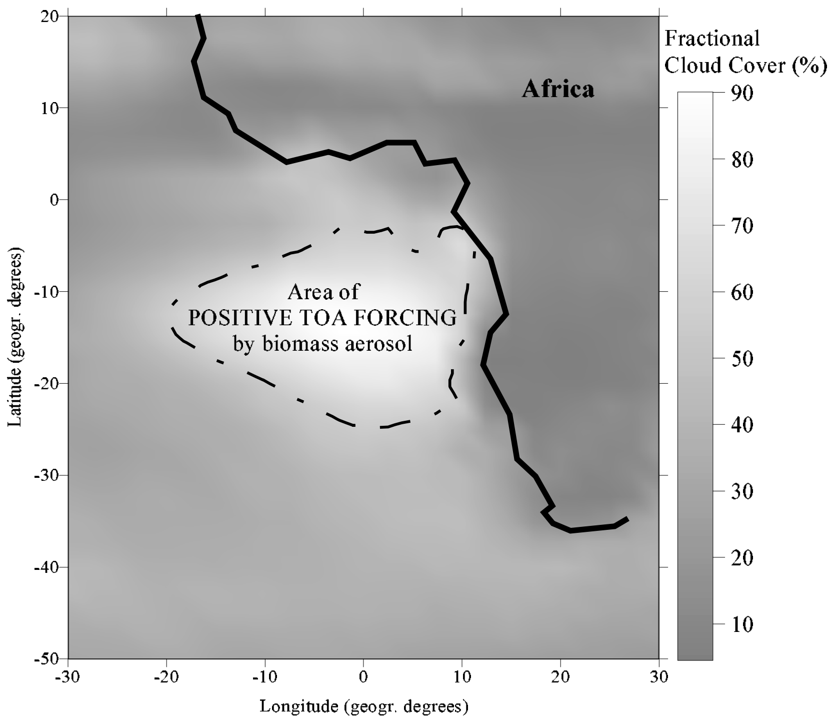

Figure 2. Climatology of the fractional cloud cover west of southern Africa and corresponding area of positive TOA direct radiative by biomass aerosol from Africa. The calculations use representative airborne measured aerosol and cloud properties during SAFARI 2000, mainly from 07/09/00. The aerosol is located above cloud and has a single scattering albedo of 0.90.

4. CONCLUSIONS

Based on airborne measurements of physical and optical aerosol and cloud properties off the southern African coastline during SAFARI 2000 we find that there is a strong negative TOA direct forcing of biomass aerosol to be expected in clear skies. In cloudy skies, however, this forcing will be converted into a strong positive one, mainly as the aerosol is located above the clouds.

Taking into account the cloud fraction climatology and the fact that there is a long-range transport of biomass aerosol above cloud level implies extended regions of *positive* TOA direct radiative forcing by biomass aerosol over the ocean regions west of southern Africa. This finding might have implications for global climate modelling studies, which suggested the globally strongest *negative* radiative forcing in this region (cp. *IPCC, 2001*).

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