Radiative Impact of Aerosols Generated From Biomass Burning

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Abstract -- Atmospheric aerosol particles play a vital role in the earth's radiative energy budget. They exert a net cooling influence on climate by directly reflecting the solar radiation to space and by modifying the shortwave reflective properties of clouds. Each year, increasing amounts of aerosol particles are released into the atmosphere due to biomass burning, dust storms, forest fires and volcanic activity. These particles significantly perturb the radiative balance on local, regional, and global scales. While the detection of aerosols over water is a well established procedure, the detection of aerosols over land is often difficult due to the poor contrast between the aerosols and the underlying terrain. In this study, we use textural measures in order to detect aerosols generated from biomass burning over South America, using AVHRR data. The regional radiative effects are then examined using ERBE data. Preliminary results show that the net radiative forcing of aerosols is about -36 W/m^2.

INTRODUCTION

Atmospheric aerosol particles, both natural and anthropogenic, are important to the earth's radiative energy balance. They scatter the incoming solar radiation and modify the shortwave reflective properties of clouds by acting as cloud condensation nuclei (CCN). Although it has been recognized that aerosols exert a net cooling influence on climate [1], this effect has received much less attention than the radiative forcings due to clouds and greenhouse gases. The radiative forcing due to aerosols is comparable in magnitude to current anthropogenic greenhouse gas forcing but opposite in sign [2]. One contributing factor for the inability of current climate models to accurately estimate surface temperatures may be due to the inaccurate characterization of aerosol effects. In order to obtain accurate estimates of aerosol perturbations on the earth's radiation balance, it is imperative to include the influence of aerosols in climate models. This will enable us to predict potential future climate changes more confidently. However, first we must obtain realistic global estimates of aerosol radiative effects before reliable parameterizations can be made.

Biomass burning, which is widely prevalent in the tropics [3], serves to clear land for shifting cultivation and the expanding population. It produces large amounts of trace gases and aerosol particles which play a pivotal role in tropospheric chemistry and climate [4]. The aerosol particles emitted from biomass burning are a major source of cloud condensation nuclei, affecting the microphysics of boundary layer clouds and altering the radiation budget of the earth by increasing the albedo [5]. Recently, Penner *et al.* [6] proposed that smoke from biomass burning may have a significant impact on the global radiation balance. They estimate that 114 Tg of smoke is produced per year in the tropics through biomass burning. From their analysis, they conclude that the effects of smoke aerosol due to biomass burning may exert a net cooling effect as large as 2 W/m^2.

In this study, 32 selected satellite images of South America are analyzed during the biomass burning season by using a new aerosol detection scheme based on textural measures.

DATA

In this project, the Advanced Very High Resolution Radiometer (AVHRR), Local Area Coverage (LAC) data is used to detect aerosols generated from biomass burning. The nominal resolution of the AVHRR LAC data is about 1.1 km and it has five spectral channels. In order to study the radiative properties of the aerosol particles, the ERBE instantaneous scanner data is used. The nominal resolution of the ERBE data is about 40 km and the radiances are converted to TOA fluxes using a scene dependent bidirectional reflection model [7].

METHODOLOGY

In this study, we use spectral and textural measures to identify aerosols. Texture is often interpreted in the literature as a set of statistical measures of the spatial distribution of gray levels in the images. The Gray Level Difference Vector (GLDV) method is used to compute several textural features [8]. The GLDV method assumes that the textural

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information in an image is contained in the overall spatial relationship the gray levels in the image have to one another. GLDV is based upon the absolute difference between pairs of gray levels i and j found at a distance d apart at angle ϕ with a fixed direction. Several textural measures were computed, including contrast, local homogeneity, angular second moment, entropy, mean difference cluster shade, and difference cluster prominence. An example of the mean textural feature calculated for one of the analyzed images is shown in Fig. 1.

The ERBE scanner data used in this study has a nominal spatial resolution of about 40 km, and the AVHRR data has a nominal spatial resolution of about 1.1 km in the LAC form. Both radiometers scan the earth in a cross-track direction which allows for simultaneous and coincident measurements. In this study, we use a collocation procedure similar to that of Li and Leighton [9]. First the center of the ERBE pixel that is closest to the center of the AVHRR pixel is identified. Once the center pixel has been identified, a group of 37 x 37 AVHRR pixels centered on the closest pixel is assumed to correspond with an ERBE pixel.

In this study, the ERBE SW fluxes versus the AVHRR channel 1 reflectance are correlated. Figure 2 shows a typical plot between ERBE and AVHRR measurements in the Amazon area, with a correlation coefficient of 97%.

Fig. 1: AVHRR LAC image over South America, Rondonia Province (Sept 3, 1985). Overlay: red - ch1; green - ratio14; blue - MEAN (ratio14).

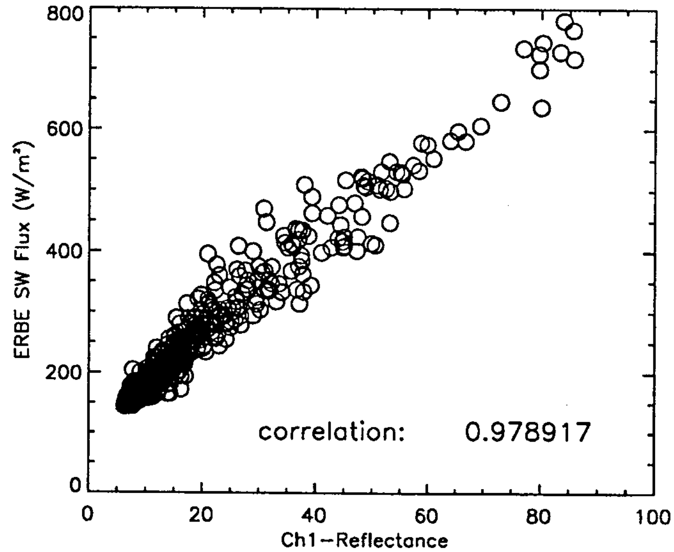

Fig. 2: Collocation between AVHRR and ERBE: AVHRR channel 1 reflectance vs. ERBE SW flux.

RESULTS

The selected satelltite images of South America during the burning seasons of 1985, 1986, and 1987 have been examined in order to identify the aerosols generated from biomass burning, as well as to study their effect on the top of the atmosphere fluxes.

The collocation analysis was performed only for the 1985 and 1986 data, since ERBE data is not available for 1987. Figure 1 shows our preliminary results. This image is about 700 km^2. The three-band overlay has channel 1 in red, the ratio of channel 1 and channel 4 in green, and in blue the MEAN of the ratio. The detection of aerosols over land gave the best results when combining spectral measures with textural features such as mean and angular second moment. The fire detection was done using the same criteria as Kaufman *et al.* [10]. A total of 9,034 fires were detected in this scene.

Understanding the influence of clouds on the earth radiation budget is important for understanding the earth's climate. The difference in the radiative heating between a column of clear and cloudy air is called cloud radiative forcing [11]. Similarly we calculated the aerosol radiative forcing by subtracting the "smoky" air from the column of clear air. Figure 3 shows preliminary results obtained in this study. The TOA flux for the clear air varied from 93 to 166.6 W/m^2; cloud air had a minimum of 240.6 W/m^2 and a maximum of 780.6 W/m^2; and the smoke covered areas had a corresponding TOA flux varying from 133.2 to 221.6 W/m^2. The net radiative forcing for aerosols was determined to be -36.15 ± 14.20 W/m^2.

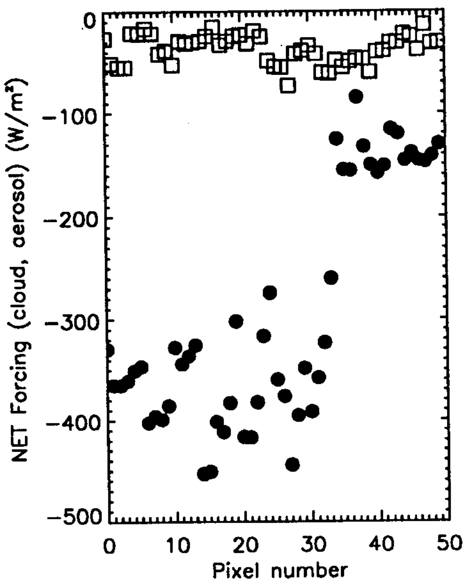

Fig. 3: Net radiative forcing (squares for smoke, filled circles for cloud). Each sample covered 37 x 37 km^2 area.

SUMMARY

Aerosols play a crucial role in the radiative balance of the earth-atmosphere system. While the detection of aerosols over water is relatively straight forward, the detection of aerosols over land is often difficult due to the high albedo of the background. In this study, we use the spatial information of AVHRR LAC imagery to accurately detect aerosols produced from biomass burning. Several textural measures were computed and the best results were obtained using mean and angular second moment. The selected images were analyzed in order to determine the regional radiative impact of aerosols generated by biomass burning. Our preliminary results show that the net radiative forcing of aerosols is about -36 W/m^2.

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