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11.1 RADIATIVE EFFFECTS OF AEROSOLS GENERATED FROM BIOMASS BURNING, DUST STORMS, AND FOREST FIRES

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1. INTRODUCTION

Atmospheric aerosol particles, both natural and anthropogenic, are important to the earth's radiative 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 (Twomey *et al.* 1984), 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 (Houghton *et al.* 1990).

Atmospheric aerosol particles generated from biomass burning, dust storms and forest fires are important regional climatic variables. A recent study by Penner *et al.* (1992) proposed that smoke particles from biomass burning may have a significant impact on the global radiation balance. They estimate that about 114 Tg of smoke is produced per year in the tropics through biomass burning. The direct and indirect effects of smoke aerosol due to biomass burning could add up globally to a cooling effect as large as $2 W/m^2$. Ackerman and Chung (1992) used model calculations and the Earth Radiation Budget Experiment (ERBE) data to show that in comparison to clear days, the heavy dust loading over the Saudi Arabian peninsula can change the top of the atmosphere (TOA) clear sky shortwave and longwave radiant exitance by 40-90 W/m^2 and 5-20 W/m^2, respectively. Large particle concentrations produced from these types of events often are found with optical thicknesses greater than one. These aerosol particles are transported across considerable distances from the source (Fraser *et al.* 1984). and they could perturb the radiative balance significantly.

In this study, the regional radiative effects of aerosols produced from biomass burning, dust storms and forest fires are examined using the Advanced Very High Resolution Radiometer (AVHRR) Local Area Coverage (LAC) data and the instantaneous scanner ERBE data from the NOAA-9 and NOAA-10 satellites.

2. DATA

In this study, the AVHRR LAC data is used to detect the aerosols by using a combination of spectral and textural measures from the NOAA-9 and NOAA-10 satellites. Collocated ERBE data from the same satellites then are used to examine the TOA radiative impact. The spatial resolution of the AVHRR LAC data is about 1.1 km at nadir, and the spatial resolution of the instantaneous scanner data from ERBE is about 35 km. The AVHRR has five channels which provide data in the visible, infrared and the infrared part of the electromagnetic spectrum. Channel 1 is between 0.58-0.68 μm, channel 2 between 0.725-1.1 μm, channel 3 between 3.55-3.93 μm, channel 4 between 10.3-11.3 μm and channel 5 between 11.5-12.5 μm. The ERBE scanner measures broadband SW radiances between 0.25-4 μm, longwave radiances between 4-50 μm and total radiances between 0.25-50 μm.

Selected images from August 13, 1986-September 20, 1986, from the NOAA-9 platform over the province of Rondonia in South America are used to study the radiative impact of aerosols generated from biomass burning. Selected images from June 4, 1985 - June 11, 1985 and from June 17, 1986 - June 26, 1986 from the NOAA-9 platform around the Mediterranean Sea are used to study the radiative impact of aerosols generated from dust storms. Selected images from the September 1988 Yellowstone fires are used to study

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the radiative impact of aerosols generated from forest fires using the NOAA-10 platform.

3. METHODOLOGY

In order to study the radiative impact of aerosols generated from biomass burning, dust storms and forest fires, they must first be identified in remote sensing imagery. Most detection schemes (e.g. Rao *et al* 1989) rely on a dark background such as the ocean to separate the aerosols from the underlying terrain. But a large contribution of aerosols are found over land with variable albedo values, making the detection of aerosols a difficult problem. However, a combination of spectral and textural measures are used to detect aerosols over land.

The fires from biomass burning are detected using the method of Kaufman *et al.* (1991), and the Yellowstone forest fires are detected using the method of Lee and Tag (1990).

Several combinations of spectral measures were examined which include AVHRR channels (3-4), (1-4)/(1+4), (1-2)/(1+2), (4-5) and (3-4)/(3+4). The spectral features that produced the best results then were used to compute several textural measures using the Gray Level Difference Vector (GLDV) method. The textural measures that were computed include mean, angular second moment, entropy and local homogeneity.

In order to examine the TOA radiative energy fluxes produced by these aerosols, the instantaneous scanner ERBE data was collocated with the AVHRR LAC data. Then the group of AVHRR pixels that corresponds to each ERBE pixel is identified. The correlation between 1) AVHRR channel 1 reflectance and ERBE SW flux and 2) the AVHRR channel 4 tempeature and the ERBE LW flux are checked for each image to ensure that the data have been properly calibrated, navigated and collocated.

4. RESULTS

The combination of spectral and textural measures appears to be a promising method for detecting aerosols over land. For the detection of biomass burning over South America the spectral and textural combinations that produced the best results were (1-4)/(1+4) and "mean" respectively. For the detection of dust storms over land, the best combinations were (3-4) and entropy. For the Yellowstone forest fires the combinations were (1-4)/(1+4) and both mean and entropy.

Figure 1 shows the results of the ERBE SW and LW fluxes for selected samples from one image over the Rondonia province in South America. Three categories are defined which are 1) Land, 2) Dense smoke and 3) Haze. The haze depicts the optically thin aerosols, which extend over most of the images that were studied. The land samples have average LW flux value of about 282 W/m^2 and average SW flux values between 150 W/m^2. The dense smoke and the haze have higher SW flux values than those of the background land and the LW flux values are larger than that of land. The shortwave forcing of aerosols for all images were computed by subtracting the albedo of aerosol pixels from clear sky pixels. The longwave aerosol forcing was computed by subtracting the LW flux of aerosol pixels from clear sky pixels. The net forcing was computed by adding the SW forcing and LW forcing values. Preliminary estimates show that the net forcing of aerosols produced from biomass burning is about -30 W/m^2, which indicates that the net effect of aerosols is one of cooling.

Figure 2 shows the relation between the SW and LW fluxes for selected samples from one image around the Mediteeranean Sea. Four classes are defined which are 1) Water, 2) Dust over Water , 3) Dust over land and 4) land. The SW fluxes of dust over water are larger than that of water by about 50-150 W/m^2. On the other hand, the SW flux values of dust over land are greater than that of land by about 50-75 W/m^2. The LW flux values of dust over water are smaller than that over land by about 15-20 W/m^2 because the radiating temperature is from a lower temperature. Depending upon the optical thickness of the aerosols and the height at which the aerosols emit radiation, there is wide variation of LW flux values of dust over land. Preliminary estimates show that the net radiative forcing of dust over land is about -39 W/m^2 and that of dust over water is about -78 W/m^2.

Figure 3 shows the relation between the SW and LW fluxes for selected samples from one image over Yellowstone National Park. Three classes are defined which are 1) Haze, which corresponds to the optically thin aerosols, 2) Land, and 3) Dense smoke. The separation between the three classes is not as obvious as compared to that of the dust storms and regions of biomass burning. Nevertheless, the dense smoke produced from forest fires have lower LW flux values as compared to haze and land and slightly larger SW fluxes as compared to land.

5. SUMMARY

The regional radiative impact of aerosols generated from biomass burning, dust storms, and forest fires are examined by using the AVHRR LAC and the ERBE data onboard NOAA-9 and NOAA-10 platforms. A new technique based on a combination of spectral and textural measures is used to detect the aerosols. Results indicate that it is possible to separate the aerosols from the underlying terrain even when the optical thickness of aerosols is relatively small. The combination of the mean textural measure along with AVHRR channel (1-4)/(1+4) is best suited for detecting aerosols generated from biomass burning. The entropy textural measure along with AVHRR channel (3-4) is best suited for detecting aerosols produced from dust storms. The mean/entropy textural measure along with the AVHRR channel (1-4)/1+4) appears to be the best combination for detecting aerosols produced from forest fires.

The net radiative forcing of aerosols produced from biomass burning is -39 W/m^2. The net radiative forcing of aerosols produced from dust storms transported over water is about -77 W/m^2 and the net radiative forcing of aerosols over land is about -55 W/m^2.

These results indicate that the net radiative impact of aerosols is one of cooling.

6. ACKNOWLEDGMENTS

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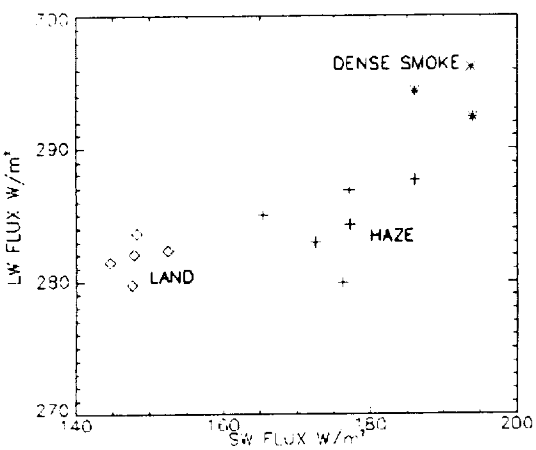

Fig 1. The relation between ERBE SW and LW fluxes for for selected samples from one image over Rondonia, South America (Biomass Burning)

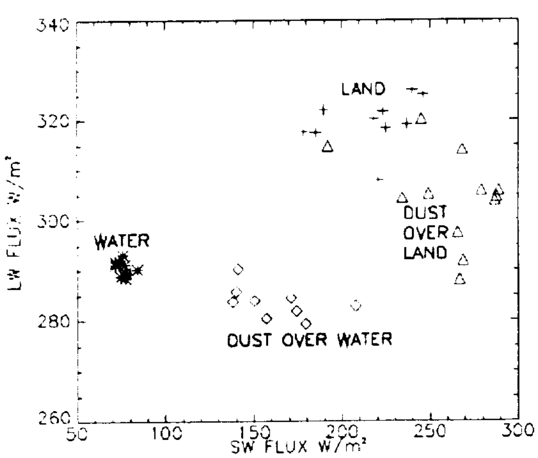

Fig. 2. The relation between ERBE SW and LW fluxes for selected samples from one image around the Mediterranean Sea (Dust storm)

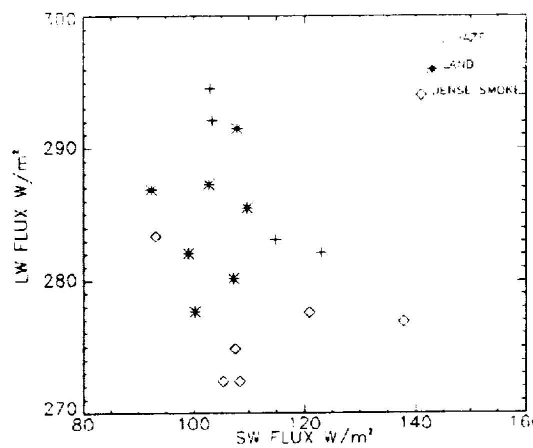

Fig. 3. The relation between SW and LW fluxes for selected samples from one image over Yellowstone (Forest fire)