ON THE TEMPERATURE AEROSOL EFFECT MEASURED IN BRAZIL'S AMAZONIA DURING THE DRY SEASON IN SMOKE AEROSOL CONDITIONS

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ABSTRACT

The data of the daily minimum and maximum near surface air temperatures obtained at the observational site Reserva Jaru in Brazil's Amazonia in August-September 1995 are analyzed in conjunction with the data of the incident solar irradiance and net thermal irradiance at the surface. The solar irradiance incoming at the surface decreases from the beginning of August to mid-September in accordance with the increase of the aerosol optical depth at the mid-visible wavelength from 0.3 to 1-3. The aerosol optical depth elevation is related to the emission of smoke by the biomass burning. But the calculations show that the daily average net (downward minus upward) solar radiative flux at the top of the aerosol layer, 2 km, does not change with the aerosol optical depth elevation because both downward and upward fluxes increase simultaneously. Thus the absence of the trend in the daily maximum temperature from the beginning of August to mid-September is explained by the constant absorption of the solar radiation in both aerosol and surface layers while the positive trend in the daily minimum temperature can be explained by increasing in the night of the downward longwave radiative flux from the heated aerosol layer to the surface.

1. INTRODUCTION

The smoke aerosol impact on the surface solar irradiance has been estimated in the previous study (Tarasova et al.,1999). It was shown that the negative trend in the surface solar irradiance from the beginning of August to mid-September is related to the aerosol optical depth elevation while the cloudiness effect is small and presented mainly by the daily variations of the irradiance. But the decrease of the near surface air temperature has not been recorded. On the contrary, the increase of the daily minimum temperature by +3°C and the lack of the trend in the maximum temperature were revealed. Note that advection was weak during the observed period except the two events of the cold front penetration from the south, characterized by the drop of both minimum and maximum temperatures for 2-3 days. In this study we calculate the net solar radiative flux at the different atmospheric levels in order to estimate the solar radiation absorption in the troposphere-surface system and to analyse its relation with the near surface air temperature.

2. IRRADIANCE MEASUREMENTS

Measurements of the surface solar irradiance were taken at the observational site Reserva Jaru (10°05'S, 61°55'W) located near Ji-Paraná town in the Rondônia region of Brazil's Amazonia. The detailed description of the Reserva Jaru site (ABRACOS project) and the instruments is given in (Gash et al., 1996). The CM-5 solarimeter (Kipp and Zonen, Delft, Netherlands) measured total downward solar irradiance (300-3000 nm) at a 5 minute sampling interval, which was recorded as hourly average data. The error in measured solar flux is estimated to be about $\pm(3-4)\%$ due mainly to a combination of cosine response, calibration, non-linearity, leveling, and thermal offset errors. The near surface air temperature and dew point temperature were measured by wet and dry bulb platinum resistance thermometers (Didcot Instrument Company, Abington, England) every 10 min with the recorded data averaged over 1 hour. These thermometers are accurate to $\pm 0.1°C$. The direct beam solar radiation was measured at the Ji-Paraná site of the AERONET Sun photometer network every 15 min by a Cimel Sun photometer at the wavelengths 340, 380, 440, 500, 670, 870, 940, and 1020 nm (Holben et al.,1996). The derivation of the aerosol optical thickness at 500 nm was accurate to 0.02.

3. RADIATIVE TRANSFER MODEL

The radiative transfer model employed in the calculations is described in (Tarasova et al.,1999). It is based on the vertically inhomogeneous Delta-Eddington technique. Computations are carried out for 14 intervals in the visible and ultraviolet solar spectrum and for three bands in the near infrared region. The molecular scattering, absorption, and scattering by aerosol particles, as well as the absorption

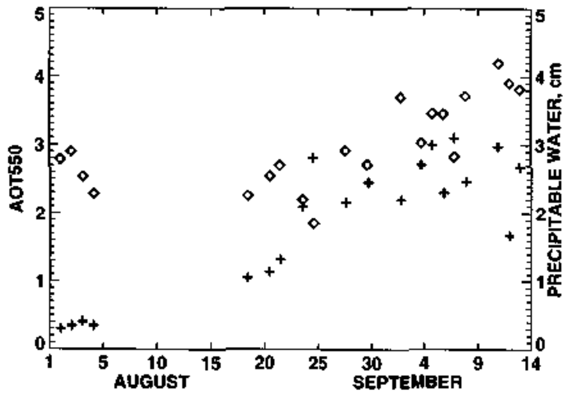

Figure 1: Daily average aerosol optical thickness at 550 nm (AOT550) (pluses), and precipitable water in centimeters (diamonds). Data were retrieved from Sun photometer measurements taken at the Ji-Paraná site during the first days of August 1994 and from mid-August to mid-September 1995.

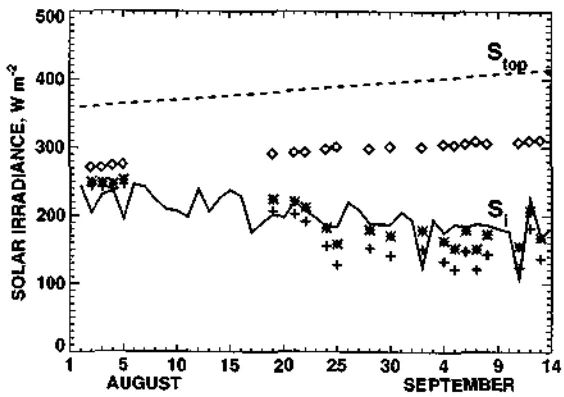

Figure 2: Daily average incident solar irradiance S_i measured at the Reserva Jaru site in August and September 1995 (solid), and the computed irradiance at the top of the atmosphere S_{top} (dashed) and at the surface for a gaseous cloudless atmosphere (diamonds) and for a gaseous cloudless atmosphere with the aerosol loading (models 1: pluses and model 2: asterisks).

by water vapor, ozone, O_2, and CO_2 are taken into account. In order to calculate the solar radiation absorption by water vapor, the k-distribution method is used with k-distribution functions from (Tarasova and Fomin, 2000). The new version of the radiative transfer code also incorporates the effective parameterizations of Chou (1990) for the absorption due to O_2, and CO_2.

The aerosol optical parameters, single-scattering albedo and asymmetry factor, also required as inputs by the radiative transfer model, are given in (Tarasova et al., 1999) for the smoke aerosol composition consisted of 4 aerosol components (World Meteorological Organization (WMO),1986). The external mixing of the components is assumed with the following percentages by particle volume: 71% of water-soluble fine mode, 17% of dust-like coarse mode, 7% of oceanic coarse mode, and 5% of soot (black carbon) fine mode. The percentages were determined from the aerosol mass concentration measurements taken in Amazonia during Smoke, Clouds and Radiation - Brazil (SCAR-B) experiment (Artaxo et al.,1998). In the present study, we change the percentage of the soot component in order to prepare the new model of the aerosol composition: 75% of water-soluble fine mode, 17% of dust-like coarse mode, 7% of oceanic coarse mode, and 1% of soot (black carbon) fine mode. The calculations of the surface solar irradiance with the less absorptive aerosol composition model are in a better agreement with measurements taken under the conditions with the aerosol optical depth larger than 2 (Tarasova et al., 1999). The single-scattering albedo and asymmetry factor for the aerosol model 1 (5% of the soot mode) are equal to 0.866 and 0.623, respectively. For the model 2 (1% of the soot mode) these parameters are equal to 0.937 and 0.630, respectively.

4. RESULTS AND CONCLUSIONS

The calculations of the surface solar irradiance and net radiative fluxes at 5 levels in the atmosphere were performed with the broadband radiative transfer model for the days with available data of aerosol optical depth and precipitable water derived from the Sun photometer measurements. The radiative transfer model adopts as inputs the daily average values of these parameters shown in Figure 1. The daily average aerosol optical depth increases from mid-August to mid-September 1995 due to the smoke aerosols emitted to the troposphere by the biomass burning. In 1995 the measurements were not taken in the beginning of August. Thus we utilizes the data obtained in 1994. The increase of the precipitable water is in accordance with its seasonal cycle related to the change of the dry (June-September) and wet (December-March) seasons.

Figure 2 presents the results of the calculations of solar irradiance incoming at the top of the atmosphere, S_{top}, and at the surface , S_i. The values of S_i were computed for the gaseous atmosphere (diamonds), and for the gaseous atmosphere with aerosols (models 1:plusses and model 2:asterisks). The surface solar irradiance measured on the ground in the all-sky conditions is denoted by solid curve. Note that the effect of cloudiness on the irradiance is weak because of the small cloud amount values observed during this

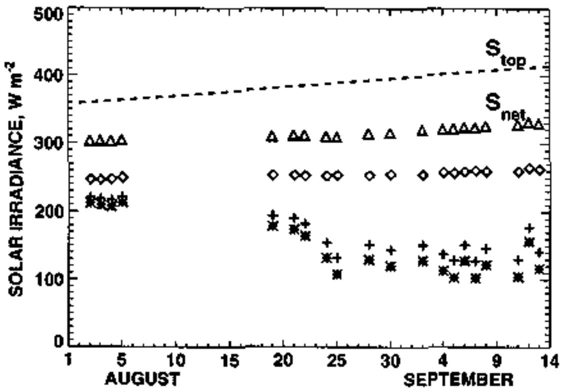

Figure 3: Daily average incident solar irradiance at the top of the atmosphere S_{top} (dashed) and the net solar radiative flux at the top of the atmosphere (triangles), at the height 2 km (diamonds), at the height 0.5 km (pluses), and at the surface (asterisks), all computed for a gaseous cloudless atmosphere with the aerosol loading (aerosol models 1).

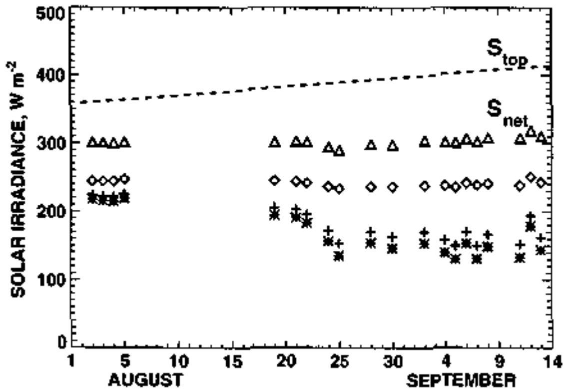

Figure 4: The same as in Figure 3 but for the aerosol model 2.

period. Figure 2 shows that the increase of the precipitable water does not lead to the decrease of S_i while the elevation of the aerosol optical depth causes the decrease of the irradiance. The use of the aerosol model 2 with 1% of the soot mode leads to the better agreement between the calculations and measurements.

In order to estimate solar radiation absorption in the atmosphere-surface systems, we computed the net solar radiative fluxes, S_{net}, at the 5 atmospheric levels. Figures 3 and 4 show the magnitude of the net flux at the top of the atmosphere (triangles), at the top of the main smoke layer, 2 km, (diamonds), at the 0.5 km level (plusses), and at the surface (asterisks). From mid-August to mid-September the net fluxes at the surface and at the 0.5 km level decrease. The net fluxes at the 2 km level and at the top of the atmosphere do not change (model 2) or even increase a little (model 1). Thus the aerosol radiative forcing at the top of the aerosol layer and at the top of the atmosphere is balanced by the increase of the extraterrestrial solar irradiance related to the change of the astronomical position of Sun. Therefore the absorption of the solar radiation in the atmosphere-surface system does not change.

The daily average values of the maximum amd minimum near surface air temperatures, T_{max} and T_{min}, are shown in Figure 5. Note that advection was weak from the beginning of August to mid-September except the two events of the cold air penetration from South (I and II) whith the drop of both maximum and minimum temperatures during 2-3 days. The maximum temperature demonstrate no trend from mid-August to mid-September. This can be explained by the constant solar radiation absorption in both aerosol layer and surface. The increase of minimum temperature by ~ 3°C can be explained by the increase of the longwave radiative flux emitted in the night by the aerosol layer heated by solar radiation in the day. The corresponding decrease of the net longwave radiative flux (LW) measured on the ground and then averaged over night is also shown in Figure 5.

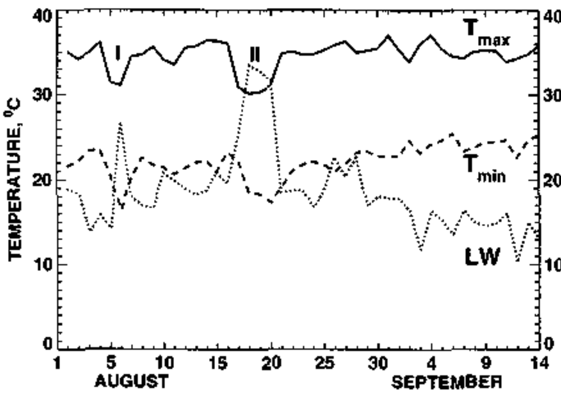

Figure 5: Daily maximum and daily minimum near surface air temperatures, T_{max} and T_{min}, and the net longwave radiative flux averaged over the night, LW, (upward direction is positive).

The smoke aerosols emitted into the troposphere by the biomass burning in Brazil's Amazonia in August and September cause the stabilization of the maximum temperature and increasing of the minimum temperature. Without smoke both T_{max} and T_{min} should increase during this period in accordance with the increase of the extraterrestrial solar irradiance. We also demonstrate that the magnitude of the near surface air temperature in the smoke aerosol conditions is related more to the solar radiation absorption in both aerosol and surface layers than to the absorption at the surface only.

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