Shortwave versus longwave aerosol radiative forcing over an urban Environment.

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Abstract

Collocated observations of aerosol optical parameters, radiative fluxes in the longwave (0.4-50μm) and shortwave (0.3-3 μm) spectral regions were used to quantify aerosol radiative forcing in the longwave (LW) and shortwave (SW) spectral regions over an Indian urban site, Pune during October 2004 to May 2005. Aerosol optical parameters derived from a Prede Sun/Sky radiometer such as aerosol optical depth (AOD), single scattering albedo, asymmetry parameter, TOMS column ozone and MODIS water vapor were used in Santa Barbara Discrete ordinate Rdaitive Transfer model (SBDART) to derive short and long wave radiative fluxes. Short wave fluxes were found to be comparing well with the real time observed fluxes from a Short wave Pyranometer. The under estimation of modeled long wave fluxes got improved and found to be comparable with observed fluxes from a Precision infrared radiometer, on the inclusion of six hourly NCEP profiles of temperature and humidity in SBDART model. 'No aerosol' fluxes were also derived using SBDART in both the spectral region. The differences in fluxes with and without aerosol conditions were calculated to derive radiative forcing. The short wave radiative forcing during different seasons viz. Post monsoon (October, November), winter (Dec-Feb) and Pre-monsoon (March- May) respectively found to be -36, -33 and -44 Wm^{-2} at the surface and +0.5,-0.55, +0.4 Wm^{-2} at the Top of the Atmosphere (TOA) . The corresponding long wave enhancement found to be +8.5, +8, +10.5 Wm^{-2} at the surface and, +3.5, +3 and +4.7 Wm^{-2} at TOA. The study suggests that around 23-25% of aerosol cooling in the short wave region is being compensated by long wave enhancement at the surface.

1. Introduction

Aerosols, which are microscopic particles suspended in the atmosphere are key components of the climate system. Apart from their crucial role in air pollution, aerosols influence the climate directly and indirectly through radiative forcing. Direct radiative forcing includes the scattering and absorption of the incoming solar radiation by aerosols, which in turn cools the earth's surface (Badrinath and latha, 2006; Takamura et al., 2007; Panicker et al., 2008). Aerosols influence the climate indirectly by altering cloud microphysical properties and hence increasing albedo and cloud life time (Twomey, 1977). Several studies report aerosol radiative forcing in the shortwave spectral region (Conant, 2000; Jayaraman et al., 1998). But it is shown that aerosol long-wave forcing is of comparable magnitude as that of greenhouse gases in heating the earth's surface and in modifying earth's energy balance (Vogelmann et al. 2003). Direct observations of aerosol IR forcing are rare either at the surface (e.g., Lubin and Simpson, 1994; Spankuch et al. 2000), in the atmosphere (Highwood et al., 2003), or at the top of the atmosphere (Ackerman and Chung, 1992; Hsu et al., 2000). Thus, our understanding of IR aerosol forcing is largely model-based with few direct observations available for validations (Vogelmann et al., 2003). In this scenario, we are trying to estimate aerosol radiative forcing in short and long wave spectral regions, to find the exact modulation of short wave cooling by longwave enhancement at the surface.

2. Instrumentation and Data

The instruments used in this study are (i) Prede sun/sky radiometer; (ii) Pyranometer and (iii) an Infrared radiometer (Pyrgeometer) are installed in the roof of Indian Institute of Tropical Meteorology [IITM], Pune [18°32' N ,73°51' E, 559 m AMSL]. The Prede sky radiometer is an automatic sun tracking instrument, which is capable of measuring direct solar and diffuse sky radiance at five spectral channels. The filters are centered at wavelengths 400, 500, 675, 870 and 1020 nm and a detailed description of calibration methodology and data reduction procedures of this instrument are presented in Nakajima et al. (1996). Once a month, sky radiometer is operated to collect disc sans to estimate solid view angles at different wavelengths as part of the calibration and used in data processing. Absolute calibration is done by PREDE, Japan at the factory and the last such calibration was done in December 2003. Also, on very clear sky days, absolute calibration constant $V_0(\lambda)$ is estimated using the modified Langley plot technique and found to be consistent with the manufacturer calibration (Pandithurai et al. 2004). A Kipp and Zonen ventilated Pyranometer [Model CM21] and a Pyrgeometer [Eppley Model PIR] are used to measure down-welling short- and long-wave radiative fluxes respectively. Both sensors are ventilated, inspected and cleaned daily to avoid data contamination.

3. Methodology

Aerosol optical parameters derived from a Prede Sun/Sky radiometer such as aerosol optical depth (AOD), single scattering albedo, asymmetry parameter, TOMS column ozone and MODIS water vapor were used in Santa Barbara Discrete ordinate Rdaitive Transfer model (SBDART) to derive short and long wave radiative fluxes. The derived short-long wave fluxes were compared with the observed fluxes from A Pyranometer and Pyrgeometer respectively. ‘No aerosol’ fluxes were also derived using SBDART in both the spectral region. The differences in fluxes with and without aerosol conditions were calculated to derive radiative forcing.

4. Results and Discussions

4.1. Comparison of Observed and Modeled fluxes

On comparing, modeled Short wave fluxes were found to be matching well with the real time observed fluxes from a Short wave Pyranometer. Longwave fluxes have been estimated for 21 clear sky days during winter 2004-05 at half hourly intervals with SBDART and were compared with Pyrgeometer (PIR) observed fluxes. The fluxes derived with default tropical profile were compared with a mean bias of -4.6 Wm^{-2}. The underestimation of fluxes may be due to fixed tropical model profiles of temperature and humidity used for the entire day. In the longwave, aerosol volume extinction depends more strongly on relative humidity than in most of the shortwave, implying that realistic relative humidity profiles must be taken in to account while modeling the longwave fluxes (Lubin et al., 2002). It is also shown that simultaneous measurements of vertical distribution of aerosols, surface temperature and water vapor are critical to the understanding of LWARF (Zhang and Christopher, 2003). Hence, it is proposed to use temporal variation of realistic vertical profiles of atmospheric temperature and humidity. As such observations on vertical profiles of temperature and humidity were not available over the site, we incorporated six hourly NCEP profiles from surface to 300 mb level in SBDART and diurnal LW fluxes were simulated for all the 21 selected days. The introduction of NCEP profiles reduced the mean bias from -4.6 to -2.2 Wm^{-2}. A scatter plot between observed and modeled LW fluxes with tropical model and realistic six hourly NCEP profiles are shown in figure 1.

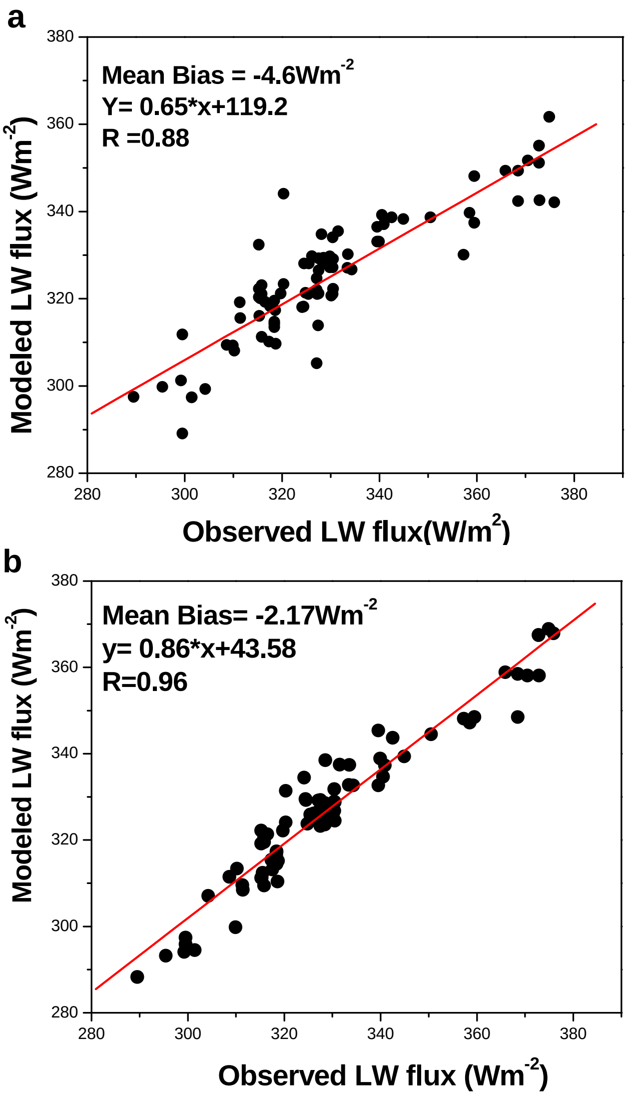

Figure 1: Comparison of Observed fluxes with Modeled LW fluxes (a) with Default model profile (b) with NCEP 6-hr profiles during winter 2004-05.

4.2. Estimation of Aerosol short- Long wave radiative forcing

Aerosol Short- long wave radiative forcing has been estimated as described in section 3.

The short wave radiative forcing during different seasons viz. Post monsoon (October, November), winter (Dec-Feb) and Pre-monsoon (March- May) respectively found to be -36, -33 and -44 Wm^{-2} at the surface and +0.5,-0.55, +0.4

Wm^{-2} at the Top of the Atmosphere (TOA), which are directly correlated with the aerosol loading during respective periods. The positive TOA forcing is attributed to the high absorbing type aerosols present over the experimental station. Aerosol longwave radiative forcing has been estimated using realistic NCEP profiles instead of model profile, along with other inputs specified in section 3. The long wave enhancement found to be +8.5, +8, +10.5 Wm^{-2} at the surface and, +3.5, +3 and +4.7 Wm^{-2} at TOA. The study suggests that around 23-25% of aerosol cooling in the short wave region is being compensated by long wave enhancement at the surface.

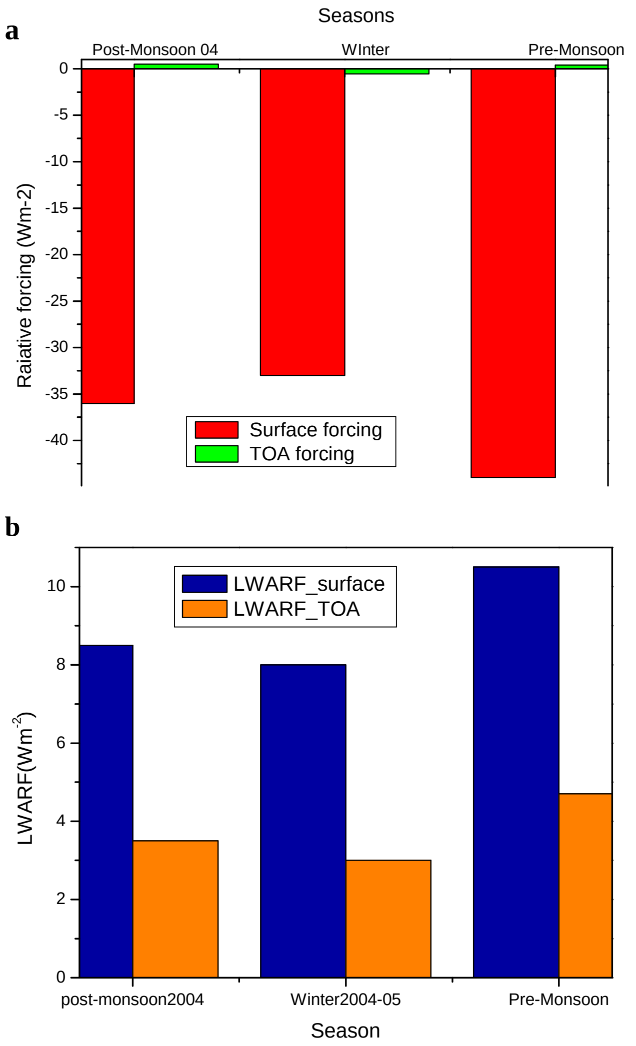

Figure 2: Estimated radiative forcing at surface and TOA (a) for shortwave fluxes, (b) For Longwave fluxes

5. Summary and Conclusions

Collocated observations of aerosol optical parameters, radiative fluxes in the longwave (0.4-50μm) and shortwave (0.3-3 μm) spectral regions were used to quantify aerosol radiative forcing in the longwave (LW) and shortwave (SW) spectral regions over an Indian urban site, Pune during October 2004 to May 2005. The short wave radiative forcing during different seasons viz. Post monsoon (October, November), winter (Dec-Feb) and Pre-monsoon (March-May) respectively found to be -36, -33 and -44 Wm^{-2} at the surface and +0.5,-0.55, +0.4 Wm^{-2} at the Top of the Atmosphere (TOA). The corresponding long wave enhancement found to be +8.5, +8, +10.5 Wm^{-2} at the surface and, +3.5, +3 and +4.7 Wm^{-2} at TOA. The study suggests that around 23-25% of aerosol cooling in the short wave region is being compensated by long wave enhancement at the surface.

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