Estimate of Radiative Impact of Biomass Burning Aerosols during TRACE-P

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Abstract

This study is aimed to estimate the radiative impact of biomass burning aerosols in southern Asia during the experimental period of TRAnsport and Chemical Evolution over the Pacific (TRACE-P). The transport and dispersion of biomass burning aerosols was simulated by using the NOAA HYSPLIT model. A high-resolution solar radiative transfer model was further used to estimate the radiative impacts of biomass burning aerosols over the southern Asian region based on the spatial and temporal distribution of these aerosols. Results show the monthly mean clear sky shortwave TOA radiative forcing ranges from -0.9 to -3.5 Wm^{-2}, and surface radiative forcing ranges from -1 to -25 Wm^{-2}. Biomass burning aerosols in south Asian region present a cooling effect in the atmosphere.

1. Introduction

The radiative forcing due to the direct effect of aerosols from biomass burning remains a large uncertainty (IPCC, 2001)[1]. However, based on earlier studies Haywood et al. (2000)[2] estimated the radiative forcing due to biomass burning to be in the range of -0.14 ~ -0.74 Wm^{-2}. Most of previous studies applied global models to estimate the direct radiative impact of biomass burning aerosols. In this study, we use a regional transport model coupled with a high-resolution solar radiative transfer model to estimate monthly mean radiative impact of biomass burning aerosols on Asian region. We also compare our results with respect to various biomass burning sources, i.e. black carbon (BC), and organic carbon (OC) emission.

2. Methodology and Data Used

We combined the USA NOAA HYbrid Single-Particle Lagrangian Integrated Transport model (HYSPLIT) [3] and a solar radiative transfer model (CLIRAD-SW)[4] to estimate the radiative impact due to the aerosols from the southern Asia biomass burning. The model domain is between 70^o-140^{o}E, 0–50^{o}N, covering South and East Asian. The meteorological data adopted is NCEP's GDAS with a spatial resolution of 2.5^{o}x2.5^o and a time resolution of 6 hrs. The simulation period is between March 1–28, 2001.

2.1 HYSPLIT Model

HYSPLIT model was used for calculating the trajectories of air parcels and the transport, dispersion and deposition of pollutant particles (Draxler et al., 2001)[4]. Emissions of BC and OC from biomass burning sources were based on the work of Streets et al. (2003)[5]. In this study, we used the daily emission data in South Asian (10^o–30^{o}N, 90^o–110^{o}E) region during TRAnsport and Chemical Evolution over the Pacific (TRACE-P). For model simulation, the input hourly emission strength was simply by dividing above daily values over 24 hrs. The average biomass burning aerosol size distributions were based on the observations obtained by Anderson et al. (1996)[6]. Two mode radii were approximately 0.008 and 0.33 μm, respectively. Dry deposition and wet scavenge were also considered in model.

2.2 Aerosol optical properties and solar radiative transfer model

The monthly aerosol concentration was combined with tabulated information about the aerosol radiative properties. We used the software package OPAC (Optical Properties of Aerosols and Clouds; Hess et al., 1998)[7] to derive the optical properties (such as single scattering albedo and asymmetry parameter) and AOD (aerosol optical depth) of biomass burning aerosols.

The mean radiative forcing of aerosol was determined by its temporal and spatial distribution in the atmosphere together with its optical properties. We used the solar radiative transfer model (CLIRAD-SW) developed at the NASA Goddard Climate and Radiation Branch (Chou and Suarez 1999)[3] to compute the downward surface short wave flux. The model includes the absorption due to water vapor, O_3, O_2, CO_2, clouds, and aerosols. Interactions among the absorption and scattering by clouds, aerosols, molecules, and the surface are fully taken into account. Fluxes are integrated virtually over the entire spectrum, from 0.175 to 10 μm.

3. Results and discussion

Figure 1 shows the monthly mean concentration of biomass burning aerosols (BC+OC emission) on the surface. Most area in Indochina has the concentration of biomass burning aerosols more than 5 μg m^{-3}. The maximum value reaches to 200 μg m^{-3} in northern Myanmar. The vertical cross section of the aerosol mass concentration along 20°N shows it decreases 90% from 10 m to 1000 m near the source region (95-100°E).

We further consider three case runs with various emission sources. Table 1 lists the computed single scattering albedo (ω_0) and asymmetry parameter (g) at 0.55 μm and RH at 0%, 50% and 80%. These values are qualitatively in agreement with previous studies (Haywood et al., 2000)[3]. Figure 2 shows the aerosol optical depth (AOD) of Cases 1-3. The maximum AOD values in these cases are located in the northern Myanmar with the values of 0.03, 0.09 and 0.12, separately. The BC aerosol has relatively higher contribution to the aerosol optical depth, although the emission ratio of BC/OC (~ 0.14) is lower.

Figure 3 shows the monthly mean clear sky shortwave radiative forcing due to the aerosols from the southern Asia biomass burning. The pattern of the radiative impact is very similar to the monthly mean AOD. The TOA radiative forcing due to BC aerosol is generally positive (-0.5 ~ 4 Wm^{-2}), whereas, for OC (RH=50%) aerosol, it can reach to as low as -8 Wm^{-2}. In total, radiative forcing due to BC+OC (RH=50%) aerosol ranged from -0.9 ~ -3.5 Wm^{-2}. The BC and OC aerosols warms and cools the atmosphere, respectively. Generally, biomass burning presents a cooling effect in TOA. The clear sky surface radiative forcing is also shown in Fig. 3. All of the calculated results are negative in these three cases. The surface radiative forcing due to biomass burning aerosol (BC+OC) ranges from -1 to -25 Wm^{-2} in Indochina.

4. Conclusion

We have successfully coupled a three-dimensional Lagrangian model (HYSPLIT) with a solar radiative transfer model (CLIRAD-SW) to estimate the radiative impact due to the aerosols from the southern Asian biomass burning. The monthly mean clear sky shortwave TOA radiative forcing ranges from -0.9 to -3.5 Wm^{-2}, and surface radiative forcing ranges from -1 to -25 Wm^{-2}. Biomass burning aerosols in south Asian region present a cooling effect in the atmosphere.

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(a) Surface concentration (10m) (b) Vertical concentration profile

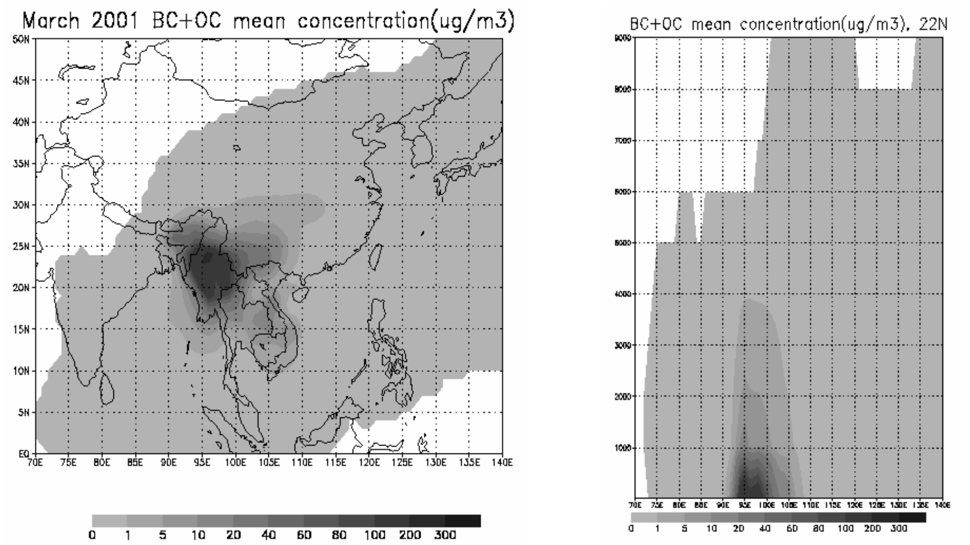

Fig. 1 Simulated monthly mean mass concentration of biomass burning aerosols in March 2001: (a) Surface concentration (10m) (b) Vertical cross section of aerosol mass concentration at 22°N in σ-coordinate. (Unit: μg m^{-3})

Table 1. The computed 2001/3 monthly mean single scattering albedo (ω_0) and asymmetry parameter (g) at 0.55 μm in three case studies.

Case	Emission species	ω_0 for corresponding RH			g for corresponding RH		
		0 %	50 %	80 %	0 %	50 %	80 %
Case 1	BC	0.21	-	-	0.34	-	-
Case 2	OC	0.96	0.98	0.98	0.61	0.67	0.70
Case 3	BC+OC	0.87	0.92	0.94	0.61	0.67	0.67

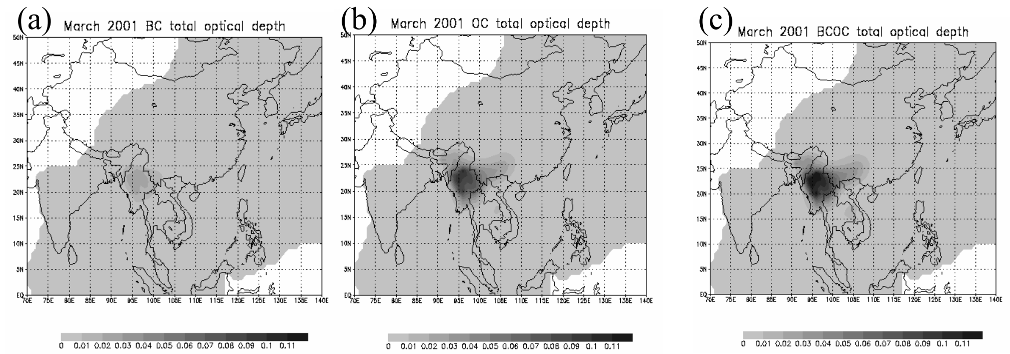

Fig. 2. The aerosol optical depth of (a)Case 1, (b)Case 2, and (c)Case 3.

(a)BC (b) OC (RH=50%) (c) BC+OC (RH=50%)

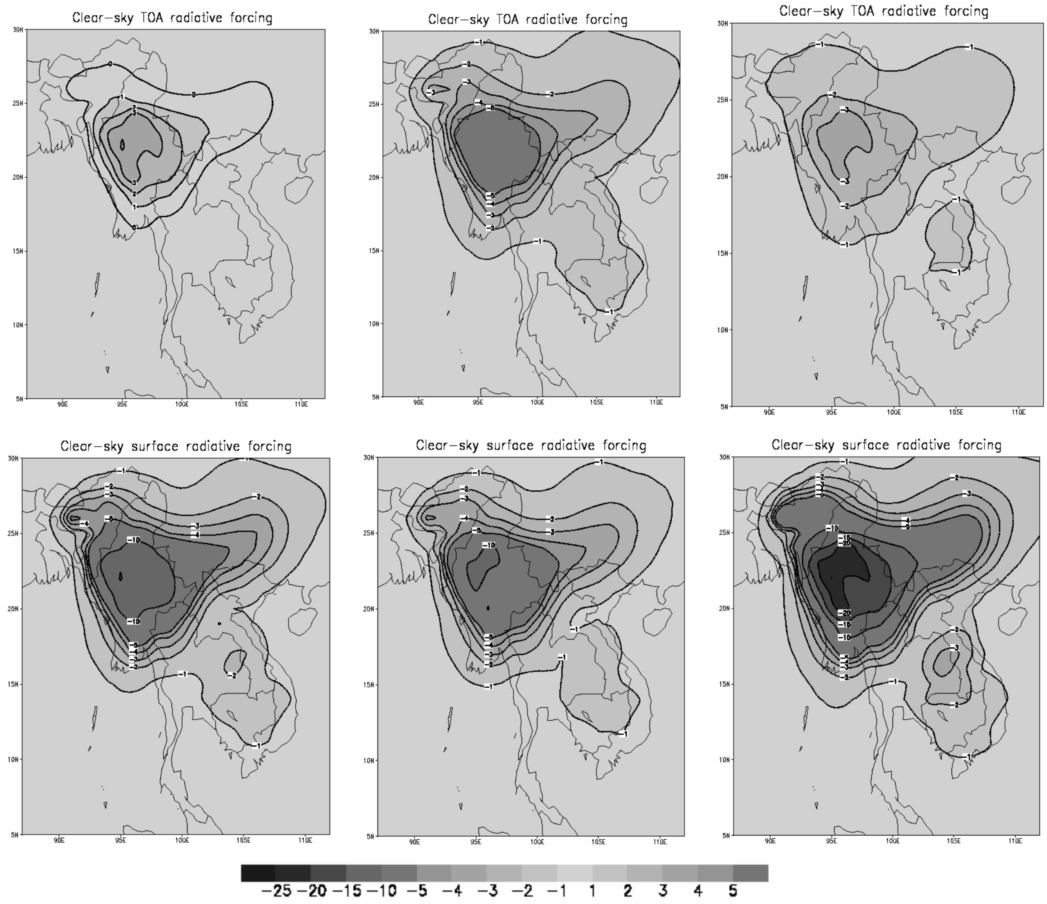

Fig. 3. The clear sky shortwave radiative forcing (W m^{-2}) due to the direct effect of (a) BC, (b) OC (RH=50%), and (c) BC+OC (RH=50%).