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BLACK CARBON AEROSOLS DURING TRANSPORT AND CHEMICAL EVOLUTION OVER THE PACIFIC (TRACE-P) EXPERIMENT

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Introduction

Climate change poses potentially major challenges to social and economic development in all countries. As greenhouse gases, atmospheric aerosols affect climate but can play a more complex role in the heating and cooling of the atmosphere and surface because white aerosols reflect solar radiations and hence produce a cooling effect whereas black carbon aerosols absorb solar radiation (Koch and Hansen, 2005). Consequently it is reasonable to assume that the rapid increase in anthropogenic generated aerosols will contribute to climate change [Menon et al., 2002]. In order to improve estimates for the impact of aerosols on climate and refine global scale predictions, more efforts are needed to address the existing lacunae in information on the increasing effect of aerosols and their transport.

Aircraft measurements during TRACE-P (Transport and Chemical Evolution over the Pacific) promise a new insight into pollutant release, transformation, and transport. The measurements of black carbon (BC) aerosol over the NW Pacific during the TRACE-P Asia campaign reveal unexpectedly high concentrations in the free troposphere (FT). In this work, three-dimensional simulations of a BC plume originating from the South East Asia in the framework of the TRACE-P were performed using the GEOS-CHEM, to provide insight into the transport patterns of the pollutants, as well as to investigate the dynamical mechanisms of the plume and its evolution in the vicinity of the western pacific. The observations from aircraft mission conducted off the Asian Pacific Rim from bases in Hong Kong and Japan during February–April 2001 [Jacob et al., 2003] are used to assess the quality of the model simulations, as well as to understand the evolution, structure and transport of BC from the simulated plume. The current general circulation modeling exercise serves as a notion towards providing a realization on regional BC emissions and their implications to climate.

Numerical Experiments

We use the tropospheric chemistry global 3-D GEOS-CHEM model version 4.10 with a $2x2.5^{o}$ resolution to simulate BC concentrations for the month of March during Year 2001. We run a reference simulation which includes a climatological set of emissions with a sensitivity simulation consisting of only anthropogenic emissions from Asia and excluding emissions from rest of the World. The model results are evaluated for the March season with comparisons to the Asian outflow observations from the NASA TRACE-P aircraft emission over the northwest Pacific. The BC was measured onboard on DC-8 aircraft by the particle soot absorption photometer (PSAP). A mass absorption efficiency of 7 m^2 g^{-1} is assumed to convert the absorption coefficient to mass concentrations (micro grams per m^3) of BC (Park et al. 2005).

Results and Discussions

The model simulated zonal average concentration of BC (Fig. 1) for the period of interest shows maximum concentrations of BC at around 25-30^{o}N in the lower troposphere (0-3 km). The vertical observations from DC-8 aircraft also indicate that BC peaks in the lower free troposphere (1000-600 hPa) around these latitudes as shown in Fig. 2 and 3. Previous comparisons of GEOS-CHEM model fields to TRACE-P observations of ozone, CO, CO_2 and CH_4 indicate that GEOS-CHEM well describes the spatial variability of plumes from Asia but the magnitudes of these plumes can be underestimated by a factor of two or more [Liu et al., 2003; Heald et al., 2003]. The comparison between mean vertical profiles of simulated and observed BC concentrations for the ensemble of DC-8 flights is shown in Fig. 3 over the NW Pacific west of 177^{o}E and at 30^{o}–45^{o}N latitude. Monthly mean concentrations in the model were sampled along the flight tracks.

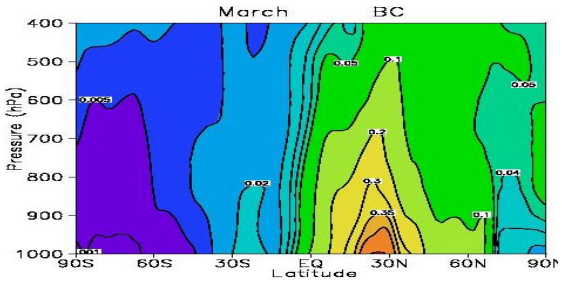

Fig. 1: Simulated zonal averaged distribution of BC for TRACE-P period.

The model reproduces well the spatial pattern and variability of BC observations along the flight tracks. BC aerosol concentrations in the model are highly correlated (Fig. 3) with observations (0.8-0.85) indicating that while the source strength may have significant uncertainties, the transport of black carbon form these sources to the observations is well understood.

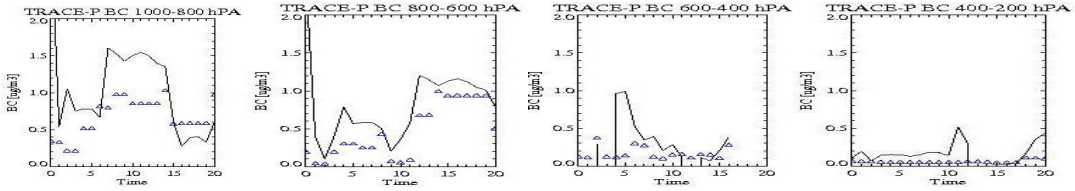

Fig. 2: Observations vs modeled Black Carbon for flight # 6 at different pressure levels. Dots represent modeled concentration while lines represent the aircraft measurements.

Figure 4 shows the global distribution of Asian pollution influence on BC aerosol concentrations in surface and free troposphere, as determined by simulating the difference between the standard simulation and the sensitivity simulation only with anthropogenic Asian emissions. Trans-Pacific transport from Asia to the United States mostly involves lifting of Asian air to the free troposphere by wet processes (convection, warm conveyor belts), followed by rapid advection in the westerlies and subsidence over the United States, generally behind cold fronts. The maximum outflow occurs (Fig. 4) in the free troposphere (3-6 km). During the simulated period this transport occurs throughout the column primarily between 20 -50^{o}N. BC aerosols are mostly transported in the lower free troposphere and subside over the NE Pacific; topography in western U.S. promotes contact with surface.

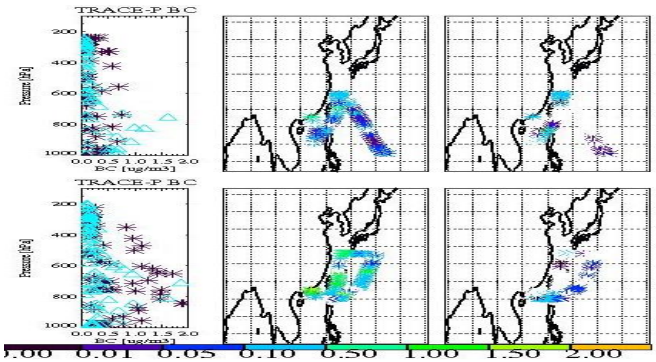

Fig. 3: Black Carbon vertical distribution averaged for March 2001 for TRACE-P domain along the ensemble of DC-8 flights (left panel) blue dots represent modeled concentration while black represents the observations (middle) BC observations along the flight track (right panel) observations minus modeled.

Conclusions

The model is able to reproduce the TRACE-P aircraft observations for BC in free troposphere and upper troposphere within a factor of two. Simulations for TRACE-P period with a global 3-D model (GEOS-CHEM) with Asian emission scenario suggest that despite their short lifetimes, BC aerosols can be transported across the Pacific. Like TRACE-P observations, the model simulation reproduces the fact that cold fronts sweeping across East Asia and the associated warm conveyor belts (WCBs) are the dominant pathway for Asian outflow to the Pacific in spring. The WCBs lift both anthropogenic and biomass burning (SE Asia) effluents to the free troposphere, resulting in complex chemical signatures. The GEOS-CHEM model predicts a significant transport of black carbon aerosols from Asian Regions to the western pacific and Arctic region during the spring season. As estimated by GEOS-CHEM, approximately 25% of the BC concentrations over the western pacific originate from SE Asia in the spring. These results document the significance and complexity of long-range aerosol transport and highlight the potential of global models to extend observational data and address related issues on global scales.

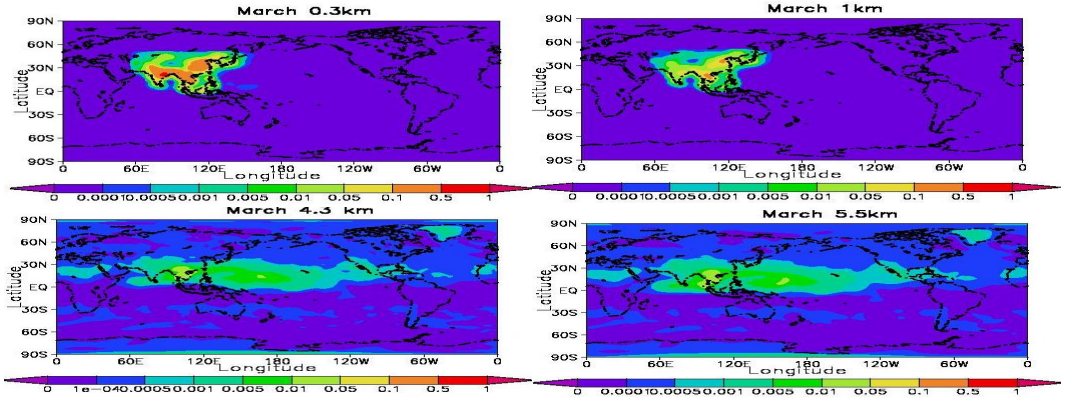

Fig. 4: Simulations for TRACE-P period with a global 3-D model (GEOS-CHEM) using Asian emission scenario.

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