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Simulation of aerosol-cloud interactions in spring over East Asia using WRF-chem model : Comparison with aircraft obs.

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1. Introduction

Aerosols act as cloud condensation nuclei and increase/decrease cloud droplet number concentrations. They play an important role for cloud microphysics, dynamics, and radiative forcing. Recently, various observational and modeling studies have been conducted to understand aerosol-cloud interactions in the lower stratus over the Eastern Pacific (e.g., California, Chile) However, there are still few studies focused on aerosol-cloud interactions over East Asia, although aerosol concentrations are considerably high and large aerosol-cloud interactions are expected over the regions.

In this study, we calculated aerosol and cloud droplet number concentrations using a regional three-dimensional model, WRF-Chem, which explicitly expresses the impact of aerosols on cloud microphysics processes. The purpose of this study is to validate model-calculated aerosol and cloud droplet concentrations with the observation during the A-FORCE aircraft campaign.

2. A-FORCE aircraft observation

Our target is low-level stratus/stratocumulus clouds ($<$ 2km in altitude) without precipitation. During the A-FORCE campaign, aerosol number concentrations below the cloud base and cloud droplet number concentrations just above the cloud base were observed 9 times over the Yellow Sea and the East China Sea in March and April 2009 [Koike et al., 2012].

3. WRF-Chem model calculation

Model simulations were conducted over East Asia using the WRF-Chem v3.4. The simulation periods are from 21 March to 26 April 2009. We used 3 domains with the horizontal grid resolutions of 108km, 36km, and 12km, respectively. Vertical resolutions are 46 layers from the surface to 100 hPa (the lowest layer is about 30m). Both anthropogenic and biomass burning emissions are considered in the simulation. Chemical and microphysical processes of aerosols were calculated by the MOSAIC module with 8 size bins. The Morrison double moment scheme was used for cloud microphysics.

4. Results

Mean observed and calculated aerosol number concentrations ($>$130 nm in diameter) have good agreement within 30% (underestimation by 27% by model). They also have a positive correlation (r2=0.32), suggesting that spatial and temporal variations of aerosol number concentrations (the transport of anthropogenic aerosols from the Asian continent) were generally reproduced by the model. On the other hand, cloud droplet number concentrations were overestimated by 90%, while a good correlation (r2=0.83) was found between measurements and model simulations.

To quantify the impact of aerosols on cloud microphysics, we compared the relationship between aerosol ($>$130nm in diameter) and cloud droplet number concentrations. Positive correlations are found for both measurements and simulations. However, the ratio of cloud/aerosol number concentrations is by overestimated by 170% by the model. The potential reasons of this overestimation are 1) the underestimation of entrainment and 2) the overestimation of aerosol activation to cloud droplets in the model.

Keywords: aerosol, cloud, indirect effect, numerical simulation