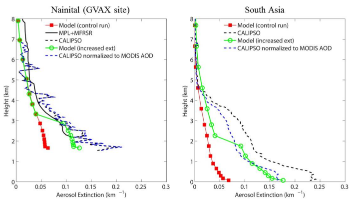
Radiative and Thermodynamic Responses to Uncertainty in Aerosol Extinction Profiles

Research Highlight

Aerosol radiative effects are of great importance for climate simulations over South Asia. For quantifying aerosol direct radiative effect, aerosol optical depth (AOD) and single scattering albedo (SSA) are often compared with observations. These comparisons have revealed large AOD underestimation and SSA overestimation in models over this region. Aerosol vertical distributions have received less scrutiny due to a lack of observational data. Moreover, while previous studies identified the deficiencies in simulated aerosol extinction or concentration profiles, the effect of corrected profiles on atmospheric heating, dynamics, and cloud adjustments (the so-called aerosol semi-direct effects) have yet to be quantified.

In this study, aerosol radiative effects and thermodynamic responses over South Asia are examined with the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) for March 2012. Model results of AOD and extinction profiles are analyzed and compared to two ground-based lidars located in northern India including deployment of the first Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF1) and micropulse lidar at Nainital, India, during the DOE Ganges Valley Aerosol Experiment (GVAX). The WRF-Chem model is found to heavily underestimate the AOD during the simulated pre-monsoon month, and about 83% of the model's low bias is due to aerosol extinctions below 2 km, consistent with other studies. Doubling the calculated aerosol extinctions below 850 hPa in model sensitivity studies generates better agreement with the observed regional mean AOD (percent difference decreased from -66% to -11%) and extinction profile (percent difference decreased from -75% to -16%). On a regional mean basis, if we fill the missing profile with primarily light-absorptive aerosols, the model generates 48% more heating in the atmosphere and 21% more dimming at the surface than the simulation with all the adjusted profile assigned to scattering aerosols. Consequently, boundary layer heights, meridional circulation, atmospheric water vapor, and cloudiness are shown to respond differently.

Our study reveals the altitude dependence of the model underestimation in AOD over South Asia, and highlights the importance of accurate representation of aerosol extinction and absorption profiles in regional climate simulations. Furthermore, we demonstrate that aerosol semi-direct effects, including rapid adjustments in the land surface and atmospheric dynamics, modulate the lower atmosphere heating rates with a comparable force to the direct aerosol radiative effect.



WRF-Chem (red) underpredicts aerosol extinctions in the lower atmosphere compared with ground (solid black) and satellite remote sensing (dashed blue and black). Doubling the modeled aerosol extinctions below 850 hPa (green) leads to better agreement with observed profiles

Reference(s)

Feng Y, R Kotamarthi, R Coulter, C Zhao, and M Cadeddu. 2016. "Radiative and Thermodynamic Responses to Aerosol Extinction Profiles during the Pre-monsoon Month over South Asia." Atmospheric Chemistry and Physics, 16(1), 247-264.

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Working Group(s)

Aerosol Life Cycle