Optical and radiative closure while deriving aerosol radiative effects in the vicinity of clouds

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Quantifying the direct aerosol radiative effect (DARE) with observations in various environments is a challenging task especially in the vicinity of clouds, where aerosol optical properties vary significantly due to cloud-induced processes on aerosols (e.g., entrainment, detrainment). Retrieving aerosol optical properties (AOPs) and isolating their radiative effects in the presence of clouds from observations are limited by instrument signal-to-noise ratio; aerosol radiative effects are small compared to those of clouds, and often comparable to spatial cloud inhomogeneity (3D) effects, which manifest as artifacts of radiation signal registered by aerosols [1]. The calculations based on Large Eddy Simulation (LES) enable the separation of DARE and cloud radiative effects under such conditions if there is radiative closure between spectral shortwave observation and simulated irradiance in the modeled atmosphere [2]. In addition, optical closure, i.e., consistency between size distributions and optical properties, is equally important when linking forecast model output to remote sensing derived DARE in cloudy environments. This study employs LES data designed to represent shallow cumulus cloud fields at the Atmospheric Radiation Measurement Southern Great Plains (ARM-SGP) atmospheric observatory over the summer in 2018 [3]. Based on the observed size distribution and chemical composition at ARM-SGP, AOPs for given humidity can be obtained using hygroscopic growth calculations and Lorenz-Mie theory. They were validated against surface observations of AOPs (optical closure), combined with aerosol concentration from the LES, and fed into the Education and Research 3D Radiative Transfer Toolbox (*EaR^{3}T*) [4] for spectrally resolved 3D radiative transfer simulations. The simulated multispectral surface irradiance was then compared against the irradiance measurements by the visible multifilter rotating shadowband radiometer (MFRSR [5]) for validation (radiative closure). These optically and radiatively consistent data were then used to quantify how DARE for a given aerosol field is modulated when it co-occurs with cloud fields of varying characteristics. This will be crucial to understand when developing algorithms for deriving DARE in presence of clouds from spaceborne active and passive remote sensing in the near future.

Keywords: aerosol radiative effects, shallow cumulus, three-dimensional radiative transfer

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