Anthropogenic contribution to cloud condensation nuclei and the first aerosol indirect climate effect

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Atmospheric particles influence climate indirectly by acting as cloud condensation nuclei (CCN) that affect cloud properties (albedo, lifetime, etc.) and precipitation. The first aerosol indirect radiative forcing (FAIRF) (i.e., cloud albedo effect) constitutes the largest uncertainty among the various radiative forcings quantified by the latest IPCC assessment report (IPCC2007). Most previous and recent FAIRF studies are based on global models with simplified chemistry and aerosol microphysics, which may lead to large uncertainties in predicted aerosol properties and FAIRF values. Here, we investigate the anthropogenic contribution to CCN and associated FAIRF using a state-of-the-art global chemical transport model (CTM) GEOS-Chem with an advanced particle microphysics (APM) model incorporated. GEOS-Chem/APM contains a number of advanced features including size-resolved sectional particle microphysics, online comprehensive SOx-NOx-Ox-VOCs chemistry, consideration of nitrate and secondary organic aerosols, online aerosol-cloud-radiation calculation, and usage of more accurate assimilated meteorology. As far as we know, this is the first time that a CTM with full chemistry and size-resolved (sectional) particle microphysics is employed to study FAIRF.

Key aerosol properties predicted by GEOS-Chem/APM for the present-day case have been evaluated against a large set of land-, ship-, aircraft-, and satellite- based aerosol measurements including total particle number concentrations, CCN concentrations, aerosol optical depth (AOD), and vertical profiles of extinction coefficients. The GEOS-Chem/APM model, with its advanced features and ability to reproduce observed aerosol properties (including CCN) around the globe, is expected to provide a more robust assessment of first aerosol indirect climate effect. We show that anthropogenic emissions increase global mean CCN by ~60-80% and cloud droplet number concentration by ~40% in the lower troposphere. The global mean FAIRF based on GEOS-Chem/APM is ~0.75 W m⁻², close to the median values of both IPCC2007 and post-IPCC2007 studies. There still exists large diversity in FAIRF values among the post-IPCC2007 studies (range from ~1.76 to ~0.17 Wm⁻²) and one main source of the diversity is likely the difference in aerosol schemes employed by various models. Sensitivity studies looking into the impacts of various aerosol schemes (especially secondary particle formation and growth) on predicted aerosol properties and FAIRF values will be presented and implications will be discussed.

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Mona Campbell Building