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Impact of aerosols on cloud system-resolving model simulations of tropical deep convection

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The indirect impact of atmospheric aerosols (i.e. the impact through cloud processes) is one of the most uncertain aspects of the clouds-in-climate problem. This paper will summarize results of aerosol indirect effects simulations using a two-dimensional cloud system-resolving model with a sophisticated two-moment liquid and ice microphysics scheme, focusing on tropical deep convection and associated outflow cirrus clouds. Simulations are performed with different aerosol loadings representing either pristine or polluted conditions. Simulations of a 16-day period of monsoon conditions during the 2006 Tropical Warm Pool - International Cloud Experiment (TWP-ICE) using observed large-scale forcing and initial conditions are discussed. Aerosols have little impact on tropospheric destabilization and therefore surface precipitation is insensitive to aerosols given the fixed sea surface temperature. This lack of sensitivity illustrates differences between aerosol effects on precipitation using a system-dynamics approach for an ensemble of clouds versus the effects on a single cloud or cloud system using a process-oriented approach. The spread of the TOA radiative fluxes among different model realizations (generated from applying small random perturbations to lower tropospheric potential temperature) with either pristine or polluted aerosols is large, exceeding 30 W/m2 even when averaged over the entire the 16-day period. This "internal" variability overwhelms any signal from the aerosol indirect effects for a given set of pristine and polluted realizations. Thus, large member ensembles were run to determine statistical significance of the aerosol impacts. Aerosol loading produces a statistically-significant increase in the outgoing shortwave radiative flux and decrease in outgoing longwave flux at the top-of-atmosphere (TOA) for the ensemble mean. These impacts are mostly a direct result of larger droplet and ice number concentrations in polluted conditions that increase cloud optical thickness and emissivity and also reduce the sedimentation of ice leading to greater ice mass aloft in anvils. On average there is a slight weakening of convection in the polluted simulations compared to pristine, in contrast to the hypothesis of convective invigoration as a result of aerosol loading. Sensitivities of aerosol impacts to cloud microphysics parameter settings, model resolution, and domain size usingthe ensemble approach are also described.