Geophysical Research Abstracts
Vol. 14, EGU2012-13316-1, 2012
EGU General Assembly 2012

Cloud-Resolving Modeling Study of Aerosol Indirect Effects in Radiative Convective Equilibrium with Interactive and Fixed Sea Surface Temperature

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We estimate the sensitivity of the tropical climate to aerosol indirect effects (AIEs) on clouds using a three-dimensional cloud resolving model with bulk two-moment microphysics that responds to a prescribed concentrations of cloud condensation nuclei (CCN) as a proxy for aerosol burden. The CCN count at 1% supersaturation is varied from pristine maritime conditions (50 per cc) to polluted (1000 per cc). The Tropics are modeled using the Radiative Convective Equilibrium (RCE) framework when the interactions among radiation, turbulence, clouds, surface fluxes are explicitly represented while the effects of large-scale forcing are ignored. Despite the idealization, the RCE is considered to be a good framework for understanding the climate processes in Tropics which occupy about half the area of the Earth. Two sets of experiments have been performed: fixed (non-interactive) sea-surface temperature (SST), and interactive SST predicted by a simple slab-ocean model in response to changing radiation and precipitation fluxes. Arguably, the interactive SST framework represents a more realistic model of the climate system of Tropics. The CCN-sensitivity experiments have been complemented with a double-CO_2 experiment that represents the anthropogenic global warming by the end of this century. Both sets of experiments, interactive SST (ISST) and fixed SST (FSST), qualitatively agree with each other in tendency to decrease low-cloud fraction and enhance liquid-water path with increasing CCN count in accord with the current understanding of the so-called first indirect effect. In the ISST runs, for the highest CCN count, the cooling effect on the SST of increase in CCN cont was found to be as large as 1.5 K, which is quite comparable to about 2 K warming found in the double-CO_2 case with clean (100 per cc) maritime environment served as a control case. Interestingly, we found qualitative differences between the ISST and FSST cases in simulating changes in hydrological cycle; namely, in the FSST cases, the increase of CCN count tends to increase mean surface precipitation through the increase of snow production, while in the ISST experiments the effect of CCN increase tends to decrease surface precipitation.