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Aerosol Indirect Forcing of the Trimodal Distribution of Convection and the Water Vapor Budget of the Tropics

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Tropical convection is important to many of the interactions and feedback mechanisms of the climate system, playing a crucial role in the production of precipitation and in the maintenance of the Earth's energy and hydrological budgets. Tropical convection tends to be distributed in a trimodal manner, being made up of a shallow cloud mode, a congestus mode and a deep convective mode. Much is still not understood about how these three convective modes interact, the roles that they serve in the global water and energy balances, and how these modes and interactions may change when perturbed by aerosol indirect forcing. The goals of the research to be presented here are twofold: (1) to investigate the role played by each of the three convective modes in the precipitable water (PW) budget of the Tropics; and (2) to investigate the impacts of aerosol indirect forcing on the contributions of each of the convective modes to the tropical PW budget.

As the tropical atmosphere is never far from a state of radiative convective equilibrium (RCE), previous cloud resolving modeling (CRM) studies using such a framework have proven highly successful in experiments focusing on the feedbacks between radiation, clouds, water vapor and convection in the tropics. For the research presented here, numerous CRM simulations have been conducted using the Regional Atmospheric Modeling System (RAMS) under such a RCE framework. RAMS is a sophisticated CRM that allows for the prognosis of aerosol concentrations. The model grid used for these experiments spans $\sim$10,000 km in the zonal direction, and utilizes a horizontal grid spacing of 1km, variable grid spacing in the vertical, and periodic lateral boundary conditions. The lower boundary is an oceanic boundary with a fixed sea surface temperature. The CRM is first run until RCE is reached, a process that takes approximately 50 simulation days. Numerous sensitivity tests are then conducted in which the model is restarted at day 50 and aerosols that can potentially serve as cloud condensation nuclei (CCN) are introduced. The amount of aerosol available for activation is progressively increased from one sensitivity experiment to the next, thus representing a range of aerosol conditions from pristine to polluted. The sensitivity tests are then run for a further 50 days. The use of such large-domain, high-resolution and temporally long simulations allows for the investigation of aerosol indirect forcing on the wide range of cloud types and systems that develop under the variety of environments that evolve.

The precipitable water budget is made up of a number of terms including the local time rate of change of PW (which can be thought of as the PW storage term), an evaporation term, a precipitation term, and a water vapor flux divergence term. In the analysis conducted here, these PW budget terms are binned over precipitable water itself, thus allowing for an examination of their relative contributions in the dry and moist regions that develop within the model output. The contributions made by each of the three modes of tropical convection to each of the PW budget terms are examined. Also, the impacts of enhanced aerosol concentrations on the contributions of each of the PW budget terms are assessed, both for the entire domain and then for each of the three convective cloud modes independently. Preliminary results from this analysis indicate that enhanced aerosol concentrations result in making the dry regions drier and the moist regions moister. A mechanism to explain these findings that includes the role of storm dynamics, convective mass flux and cold pool dynamics will be presented.