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Nucleation Processes in Tropical Deep Convection Simulated by a Cloud-System Resolving Model with Double-Moment Bulk Microphysics and Interactive Radiation

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A novel type of limited double-moment scheme for bulk microphysics is presented here for cloud-system resolving models (CSRMs). It predicts the size of cloud droplets and crystals, which is important for representing the radiative impact of clouds on the climate system. In this new scheme, there are interactive aerosol components for ice nuclei and cloud condensation nuclei. For cloud ice, the processes of primary ice nucleation, Hallett-Mossop (H-M) multiplication of ice particles ('secondary ice production') and homogeneous freezing of aerosols and droplets provide the source of ice number. Primary and secondary (ie. 'in-cloud') droplet nucleation are also represented, by predicting the supersaturation as a function of the vertical velocity and local cloud liquid properties. A power-law activity spectrum is assumed for the aerosol, which is assumed to be ammonium sulphate. A linearised scheme predicts the supersaturation, explicitly predicting rates of condensation and vapour deposition onto liquid (cloud liquid, rain) and ice (cloud ice, snow, graupel) species. The predicted supersaturation becomes the input for most nucleation processes, including homogeneous aerosol freezing and secondary droplet activation.

Comparison of the scheme with available aircraft and satellite data is performed for a case of deep convection over the tropical west Pacific ocean. Sensitivity tests are performed with respect to a range of nucleation processes. Concerning heterogeneous ice nucleation, it appears that contact nucleation produces little impact for such a case. The H-M process of ice particle multiplication has an important impact on the

domain-wide ice concentration in the lower half of the mixed-phase region. Finally, homogeneous freezing of droplets and aerosols is found to be the key control on number and sizes of cloud particles in the simulated cloud ensemble. Aerosols originating from the remote free troposphere become activated in deep convective updrafts and produce most of the supercooled cloud droplets that freeze homogeneously aloft. Qualitative impacts on the glaciation of the cloud ensemble from inclusion of exotic forms of ice initiation, such as inside-out contact nucleation, are also described.