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Cloud Microphysics, Radiation and Dynamics in Two- and Three-Dimensional Simulations of Deep Convection

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Cloud-resolving models (CRMs) can be utilised instead of conventional cloud parametrisations to represent deep convection within global climate models. Such CRMs may be either two- or three- dimensional. This study investigates the importance of dimensionality for the accuracy of CRMs.\pa Cloud-resolving model simulations of five observed cases of deep convection are performed in both two and three dimensions (2D and 3D) with the aim of elucidating the impact of dimensionality on overall cloud statistics. Observed profiles of the large-scale average of advection of temperature and humidity are applied to initiate and maintain the convection. Two of the cases are from tropical oceanic regions: the Global Atlantic Tropical Experiment (GATE) over the eastern Atlantic, and the Tropical Ocean Global Atmosphere - Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) over the western Pacific. The other three cases are continental: Subcases A, B and C from the Intensive Operation Period (IOP) of the Atmospheric Radiation Measurement (ARM) Program over central Oklahoma.

The average ascent rate in deep convective updrafts is about 2 - 4 m/s lower at mid-levels of the troposphere in 2D than in 3D for all cases. Subsidence induced by deep convective updrafts tends to inhibit the formation of stratiform cloud at low levels. The subsidence rate is reduced in most 2D cases relative to 3D, especially for the oceanic cases (by about 20 - 50 \%). Consequently, there is a substantial sensitivity of the vertical profiles of cloud liquid and cloud ice, and of other microphysical species, to dimensionality. Corresponding changes in radiative transfer, especially in the shortwave band, result.