Implementation of a third-order turbulence closure in the cloud-resolving model component of a multiscale modeling framework

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This study presents preliminary results from a multiscale modeling framework (MMF) with an advanced third-order turbulence closure in its cloud-resolving model (CRM) component. In the original MMF, the Community Atmosphere Model (CAM3.5) is used as the host general circulation model (GCM), and the System for Atmospheric Modeling model with a first-order turbulence closure is used as the CRM for representing cloud physical processes in each grid box of the GCM. The results of annual and seasonal means and diurnal variability are compared between the modified and original MMFs and the CAM3.5. The global distributions of low-level cloud amounts and precipitation, the amounts of low-level clouds in the subtropics, and middle-level clouds in mid-latitude storm track regions in the modified MMF show substantial improvement relative to the original MMF when both are compared to observations. Some improvements can also be seen in the diurnal cycle of precipitation.

The improved simulation of low-level clouds is attributed not only to the representation of subgrid-scale condensation in the embedded CRM, but also to the cloud-climate feedback process. That is, the more realistic low-level clouds produced by the modified MMF may result in a more realistic Hadley cell and subtropical highs, which in turn enable more realistic subsidence and radiation cooling in the subtropics, leading to more realistic low-level clouds. The improved simulation of middle-level
clouds in the mid-latitude storm track regions is attributed to the enhanced large-scale ascent that is needed to balance additional condensate heating from higher amount of low clouds. The simulated storm track clouds thus extend deeper into the middle troposphere than those of the original MMF and CAM3.5, but those in CAM3.5 are produced from cumulus detrainment, instead of large-scale condensation.