Geophysical Research Abstracts
Vol. 16, EGU2014-9031, 2014
EGU General Assembly 2014

Climate Simulations from Super-parameterized and Conventional General Circulation Models with a Third-order Turbulence Closure

Kuan-Man Xu (1) and Anning Cheng (1,2)

(1) NASA Langley Research Center, Hampton, VA, United States (Kuan-Man.Xu@nasa.gov), (2) Science Systems and Applications, Inc., Hampton, VA, United States

A high-resolution cloud-resolving model (CRM) embedded in a general circulation model (GCM) is an attractive alternative for climate modeling because it replaces all traditional cloud parameterizations and explicitly simulates cloud physical processes in each grid column of the GCM. Such an approach is called "Multiscale Modeling Framework." MMF still needs to parameterize the subgrid-scale (SGS) processes associated with clouds and large turbulent eddies because circulations associated with planetary boundary layer (PBL) and in-cloud turbulence are unresolved by CRMs with horizontal grid sizes on the order of a few kilometers. A third-order turbulence closure (IPHOC) has been implemented in the CRM component of the super-parameterized Community Atmosphere Model (SPCAM). IPHOC is used to predict (or diagnose) fractional cloudiness and the variability of temperature and water vapor at scales that are not resolved on the CRM's grid. This model has produced promised results, especially for low-level cloud climatology, seasonal variations and diurnal variations (Cheng and Xu 2011, 2013a, b; Xu and Cheng 2013a, b). Because of the enormous computational cost of SPCAM-IPHOC, which is 400 times of a conventional CAM, we decided to bypass the CRM and implement the IPHOC directly to CAM version 5 (CAM5). IPHOC replaces the PBL/stratocumulus, shallow convection, and cloud macrophysics parameterizations in CAM5. Since there are large discrepancies in the spatial and temporal scales between CRM and CAM5, IPHOC used in CAM5 has to be modified from that used in SPCAM. In particular, we diagnose all second- and third-order moments except for the fluxes. These prognostic and diagnostic moments are used to select a double-Gaussian probability density function to describe the SGS variability. We also incorporate a diagnostic PBL height parameterization to represent the strong inversion above PBL.

The goal of this study is to compare the simulation of the climatology from these three models (CAM5, CAM5-IPHOC and SPCAM-IPHOC), with emphasis on low-level clouds and precipitation. Detailed comparisons of scatter diagrams among the monthly-mean low-level cloudiness, PBL height, surface relative humidity and lower tropospheric stability (LTS) reveal the relative strengths and weaknesses for five coastal low-cloud regions among the three models. Observations from CloudSat and CALIPSO and ECMWF Interim reanalysis are used as the truths for the comparisons. We found that the standard CAM5 underestimates cloudiness and produces small cloud fractions at low PBL heights that contradict with observations. CAM5-IPHOC tends to overestimate low clouds but the ranges of LTS and PBL height variations are most realistic. SPCAM-IPHOC seems to produce most realistic results with relatively consistent results from one region to another. Further comparisons with other atmospheric environmental variables will be helpful to reveal the causes of model deficiencies so that SPCAM-IPHOC results will provide guidance to the other two models.