Final Technical Report

Award Number: DE-SC0006690

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1. Summary

Originally, the main role of the P.I. (Sungsu Park) in this project was to improve the treatment of cloud microphysics in the CAM5 shallow and deep convection scheme. During the progress of the project, however, the main research theme was changed to develop a new unified convection scheme (so called, UNICON) with the permission of the program manager.

UNICON simulates all dry–moist, forced–free, and shallow–deep convection within a single framework in a seamless, consistent, and unified way. It diagnoses the vertical profiles of the macrophysics (fractional area, plume radius, and number density) as well as the microphysics (production and evaporation rates of convective precipitation) and the dynamics (mass flux and vertical velocity) of multiple convective updraft and downdraft plumes. UNICON also prognoses subgrid cold pool and mesoscale organized flow within the planetary boundary layer (PBL) that is forced by evaporation of convective precipitation and accompanying convective downdrafts but damped by surface flux and entrainment at the PBL top. The combined subgrid parameterization of diagnostic convective updraft and downdraft plumes, prognostic subgrid mesoscale organized flow, and the feedback among them remedies the weakness of conventional quasi-steady diagnostic plume models—the lack of plume memory across the time step—allowing UNICON to successfully simulate various transitional phenomena associated with convection (e.g., the diurnal cycle of precipitation and the Madden–Julian oscillation).

A unified convection scheme (UNICON) is implemented into the Community Atmosphere Model, version 5 (CAM5), and tested in single-column and global simulations forced by observed sea surface temperature. Compared to CAM5, UNICON substantially improves the single-column simulations of stratocumulus-tocumulus transition and shallow and deep convection cases. The global performance of UNICON is similar to CAM5 with a relative spatiotemporal root-mean-square error (RMSE) of 0.777 (0.755 in CAM5) against the earlier version of the model (CCSM3.5). The notable improvements in the UNICON-simulated climatologies over CAM5 are seasonal precipitation patterns (i.e., monsoon) over the western Pacific and South Asia, reduced biases of cloud radiative forcing in the tropical deep convection regions, aerosol optical depth in the tropical and subtropical regions, and cumulus fraction and in-cumulus condensate. One notable degradation is that UNICON simulates warmer near-surface air temperature over the United States during summer. In addition to the climatology, UNICON significantly improves the simulation of the diurnal

cycle of precipitation and the Madden–Julian oscillation (MJO). The surface precipitation simulated by UNICON is a maximum in the late afternoon (early afternoon in CAM5) over the summer continents and in the early morning (predawn in CAM5) over the ocean with a fairly realistic amplitude of the diurnal cycle. Sensitivity simulations indicate that the key for successful MJO simulation in UNICON is a seamless parameterization of the updraft plume dilution rate as convection evolves from shallow to deep convection. The mesoscale perturbation of the vertical velocity and the thermodynamic scalars of convective updrafts is an additional requirement for simulating the observed diurnal cycle of precipitation.

The development of UNICON is successfully completed and the resulting scheme was provided both to NCAR and DOE. The final results are described in the two papers listed below. The contribution of this award to developing UNICON is acknowledged in the two papers.

2. Publications

A Unified Convection Scheme (UNICON). Part I: Formulation
Sungsu Park
Journal of the Atmospheric Sciences
Volume 71, Issue 11 (November 2014) pp. 3902-3930

A Unified Convection Scheme (UNICON). Part II: Simulation
Sungsu Park
Journal of the Atmospheric Sciences
Volume 71, Issue 11 (November 2014) pp. 3931-3973

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