A 2-dimensional Hadley circulation modeling for accelerated assessment of Framework for Improvement by Vertical Enhancement in a global cloud resolving model

*Takanobu Yamaguchi[1,2], Ryuji Yoshida[1,2], Graham Feingold[2]

1. Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, 2. NOAA Earth System Research Laboratory

For global cloud resolving models (GCRMs), low level clouds are unresolved and even though recent advances in microphysical and turbulence parameterizations are promising, there is much room for improvement. We first hypothesize that GCRMs likely represent low clouds better when high vertical resolution is used. This has recently been demonstrated in the U.S. Department of Energy (DOE) Energy Exascale Earth System Model (E3SM) with a 1-degree horizontal resolution. In this configuration, the Framework for Improvement by Vertical Enhancement (FIVE) circumvents the large increase in computational cost associated with high vertical resolution, while retaining the benefits of high vertical resolution. A future version of E3SM will be directed toward GCRM with 3 km horizontal resolution. The advantages and disadvantages of FIVE in GCRM should be assessed in a similar domain and a similar resolution to the target simulations. For this reason, the assessment is not straightforward because of the enormous cost of computations and volume of output data. This is a serious problem since numerous experiments are required to evaluate the performance of FIVE. This problem is also applicable to performance evaluation for new parameterizations. We approach this problem by applying 2-dimensional (2D) Hadley circulation modeling that simulates many types of clouds and scale interactions. In the 2D modeling framework, we can easily increase model resolution and the number of experiment cases. In a test experiment using 8 km horizontal grid spacing with 128 vertical levels (35 km domain top), a three year integration can be carried out with one week of CPU time with only 2 nodes (128 cores) on DOE’s supercomputer. The results show realistic features of the Hadley circulation and suggest that 2D Hadley circulation modeling can serve as a testbed for assessing, inter alia, FIVE, parameterizations, and their influence on the circulation. As a reference, 2D Hadley circulations have been simulated at LES resolution (250 m). We expect this 2D framework to rapidly accelerate the GCRM development.

