1. Project Overview

Thin clouds, i.e., stratocumulus and cirrus clouds, are poorly represented even in state-of-the-art global models like E3SM. This SciDAC project aims to evolve FIVE into E3SM, not only to implement FIVE into E3SM, but also to dynamically adapt vertical resolution depending on the atmospheric state. The goal is to improve representation of cirrus clouds and mixed phase stratocumulus. One notable advantage of FIVE is its flexibility, so that it can be used with any choice of turbulence parameterization.

2. Framework for Improvement by Vertical Enhancement

FIVE is summarized in Figs. 1, 2, and 3. In Yamaguchi et al. (2017), a prototype version of FIVE implemented into a regional model, the System for Atmospheric Modeling (SAM; Kharoloudov and Randall 2001) coupled with the Cloud Layer by-Parameter (CLUBB) turbulence parameterization (Larson and Golaz 2005), shows moderate improvement when doubling vertical resolution. The first version of E3SM-FIVE will use a stationary VEP level so that the resolution for the VEP level is not only to implement FIVE into E3SM, but also to evolve FIVE into a computationally efficient version by adding a capability of dynamically adapting vertical resolution depending on the atmospheric state (Adaptive Vertical Grid: AVG).

3. Adaptive Vertical Grid for VEP

The first version of E3SM-FIVE will use a stationary VEP vertical level, which will be computationally expensive for the regions where the current parameterization can reasonably represent atmospheric state. For multi-core processors available when FIVE is used on the fly (i.e., E3SM as well as VEP information). We will test a number of ideas ranging from lower tropospheric stability and boundary layer classification schemes to machine learning and a statistical emulator to develop these criteria.

4. Resolution Criteria for AVG

AVG requires decision criteria to adjust VEP resolution based on the current and very near future atmospheric state. Development of an AVG for VEP will use information that would be available when FIVE is used on the fly (i.e., E3SM as well as VEP information). We will test a number of ideas ranging from lower tropospheric stability and boundary layer classification schemes to machine learning and a statistical emulator to develop these criteria.

5. Path to E3SM-FIVE

This project consists of 4 tasks:

- Task 1 implements FIVE into the E3SM single column model, followed by E3SM-SCH and E3SM-SCH-FIVE.
- Task 2 refines the existing FIVE with E3SM.
- Task 3 works on computational aspects of AVG.
- Task 4 develops resolution criteria for AVG.

6. Preparation for a Benchmark High Resolution Hindcast Simulation

Fig. 6a shows bias in shortwave radiative forcing for a 2-year simulation of the current E3SM with its standard 72 levels and 1 degree mesh. The stratocumulus regions are too dark and the trade cumulus regions are too bright. Fig. 6c shows improvement in these regions by simulating with doubled and quadrupled vertical resolution below 700 hPa. Increasing vertical resolution in the boundary layer generally results in more reflective marine stratocumulus and less reflective trade cumulus. We are confident that E3SM-FIVE can replicate these results, at reduced cost. An experiment with octupled resolution as well as the same experiment for high clouds at levels 400 hPa to 50 hPa are currently running.

All simulations were run using 1024 processors. The runs with quadrupled and octupled cases required changes in the host and CLUBB timestep for a stable run. A sensitivity test to timestep for the standard configuration will be carried out in order to elucidate any potential differences. A summary for this experiment will be available in the future.

References


Fig. 6

Results from 2-year simulation with various vertical resolutions below 700 hPa.

Fig. 5

Flowchart for proposed tasks.

Fig. 3

Details of FIVE. Upper (lower) case label identifies the E3SM (VEP) variables.

Fig. 2

Flowchart for process calculations over one time step for FIVE. In FIVE, selected processes, in this example process B, C, and E, are computed on VEP. Synchronization proceeds either E3SM or VEP to the appropriate partial timestep by adding tendency.

Fig. 1

In addition to the E3SM vertical grid, FIVE additionally constructs partially high resolution vertical level and allocates prognostic variables separately from E3SM. Selected processes are computed on this high resolution grid, termed the Vertically Enhanced Physics (VEP).

Fig. 4

Schematic for AVG for VEP.

Fig. 4

Schematic for proposed tasks.

Fig. 3

Details of FIVE. Upper (lower) case label identifies the E3SM (VEP) variables.

Fig. 1

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Fig. 4

Schematic for AVG for VEP.

Fig. 6

Results from 2-year simulation with various vertical resolutions below 700 hPa.