A novel deep-atmosphere variant of the HOMME dynamical core for the E3SM climate model

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Abstract

The 'Higher Order Methods Modeling Environment' (HOMME) dynamical core for the 'Energy Exascale Earth System Model' (E3SM) of the Department of Energy (DoE), contains two approximations of the fluid dynamics equations called the Shallow-atmosphere and Traditional (SA+T) approximations. Recent theoretical work has called into question the suitability of the SA+T approximations for high-resolution and non-hydrostatic simulations. The biases induced by these approximations are expected to be most severe in tropical regions. It is hypothesized that these approximations may play a role in long-standing tropical biases within Earth System Models, such as the representation of the Intertropical Convergence Zone (ITCZ).

We present a novel version of the non-hydrostatic HOMME dynamical core that solves the so-called deep-atmosphere equations, which remove the SA+T approximations from the equations of motion. This modification restores the so-called Non-traditional Coriolis Terms (NCTs) to the dynamical core, which increases the realism of the circulation, even for moderate climate model grid spacings around 50-100 km. We present an overview of the modifications made to the HOMME dynamical core. This deep-atmosphere prototype is tested via a spectrum of idealized test cases that validate the correctness of the implementation and elucidate the dynamics of the deep atmosphere. We present results demonstrating the impacts of the SA+T approximations on Aquaplanet simulations, which offer preliminary insight into how these approximations impact large-scale equatorial dynamics.

Keywords: Deep atmosphere, High resolution modeling, Energy conservation, Idealized test cases, Equatorial dynamics

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