Development of Terrestrial Dynamical Core for the E3SM to Simulate Water Cycle

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Abstract

The inclusion of lateral subsurface transport of water and energy in Land Surface Models (LSMs) has been shown to impact surface energy fluxes, groundwater depth, and runoff in site-, watershed-, continental-, and global-scale simulations. However, most LSMs, including the land component of DOE's Energy Exascale Earth System Model (E3SM), exclude lateral subsurface processes. This Scientific Discovery through Advanced Computing (SciDAC) project aims to advance the state-of-the-art modeling of terrestrial hydrological and thermal processes in the E3SM by developing a next-generation multi-physics terrestrial dynamical core (TDycore) for the E3SM Land Model (ELM) that is rigorously verified, spatially adaptive, scalable and validated for a wide range of cases.

We have developed the open-source TDycore library using the Portable Extensible Toolkit for Scientific Computing (PETSc) to numerically solve the discretized equations. The terrain-following ELM meshes are non-orthogonal with O(10^6) differences in horizontal and vertical length scales, which render first-order spatial discretization methods inaccurate. The TDycore supports three second-order spatial discretization methods and four temporal discretization schemes. A code-agnostic verification and validation framework to benchmark the TDycore has been developed. The TDycore has been coupled to ELM, and idealized simulation with the coupled model has been performed. In collaboration with the Exascale Computing Project, TDycore has successfully used PETSc's support for heterogeneous computing architectures on DOE's Summit supercomputer.