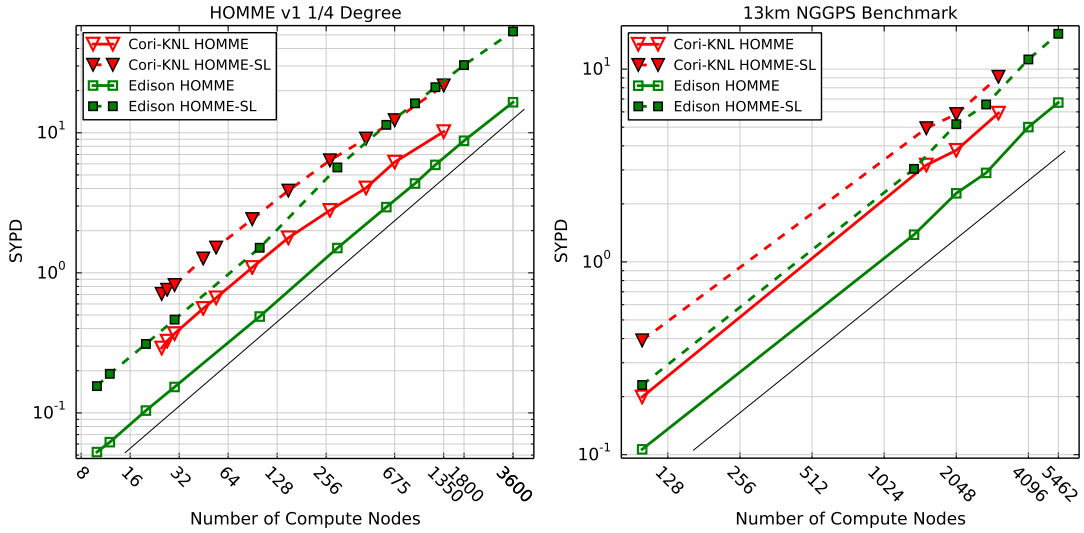
Semi-Lagrangian tracer transport in the E3SM atmospheric dycore

O. Guba*, P. Bosler*, A. Bradley*, M. Taylor*, J.-C. Golaz†

We develop and integrate a semi-Lagrangian transport scheme for the HOMME atmospheric dynamical core. The implementation is based on a classical interpolation-based semi-Lagrangian scheme and achieves CFL numbers as high as 3. It reduces computational time of the standalone dycore by 50% or more, depending on architecture and number of tracers. For shape preservation, conservation and consistency, we apply a new algorithm, QLT. QLT uses one round of communication equivalent to all-to-all reduction. A tree over the mesh organizes mass redistribution. Mass redistribution to preserve shape and tracer consistency is quasi-local; it occurs as close to the tree leaves as possible. The mass adjustment to conserve global mass must still be global.

For performance, we verify the new transport scheme in standalone idealized HOMME with benchmark simulations for 110 km and 13 km resolutions at scale on NERSC clusters. The simulations include 5462-node runs on Edison (Ivy Bridge architecture) and 3072-node runs on Cori (KNL architecture). The standalone dycore achieves performance gains of up to a factor 3 for 40 tracers.

As a part of a larger effort to develop a climate model suitable for exascale arcitectures, the semi-Lagrangian transport scheme is integrated into Energy Exascale Earth System Model (E3SM). To exploit computational efficiencies of the method and to verify it for climate simulations, we run E3SM simulations with active atmosphere, land and ice components with prescribed SSTs and sea ice extent. Comparisons of the default (Eulerian) transport scheme and the semi-Lagrangian transport scheme show significantly improved performance and nearly equivalent 5-year climatologies.



(a) (b)

Figure 1: Strong scaling at large scale on NERSC platforms for benchmarks for (a) 110 km resolution and (b) 13 km resolution. Data are plotted in terms of Simulated Years Per wall-clock Day of compute time (SYPD). Runs with Eulerian transport are marked as HOMME, runs with semi-Lagrangian transport are marked as HOMME-SL.

*Affiliation: Sandia Natl. Laboratories. Sandia National Laboratories is a multimission laboratory managed and operated by the National Technology and Engineering Solutions of Sandia, L.L.C., a wholly owned subsidiary of Honeywell International, Inc., for the DOE's National Nuclear Security Administration under contract DE-NA-0003525. This research used resources of the National Energy Research Scientific Computing Center, a User Facility supported by the Office of Science of DOE under Contract No. DE-AC02-05CH11231. SAND2019-1102 A

†Affiliation: Lawrence Livermore Natl. Laboratory