Performance-Portability Results for the Non-Hydrostatic Atmosphere Dycore of E3SM at Cloud-Resolving Resolutions.

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Abstract

One of the largest sources of uncertainty in climate models comes from convective cloudssystems parametrizations, which are necessary at current horizontal resolutions, of about 25km.In order to fully resolve the effects of such systems, horizontal resolutions need to reach the 1-3km range, which entail a huge increase in computational costs. In recent years, the performance of the world largest supercomputers has steadilyimproved, to the point that we can now think of running a climate modelat cloud resolving resolution, with a Simulated Years Per Day (SYPD) throughputthat is suitable for decade or century long simulations.However, the architectures of the newest supercomputers are becoming more andmore heterogeneous, which makes the task of keeping a performant code base moreand more challenging. Here, we present our effort to upgrade the new non-hydrostatic atmosphere dycore ofE3SM to a version that is highly performant on a variety of architectures, includingGPUs, conventional CPUs, and many-core CPUs. When using GPUs, our implementation isone of the fastest, achieving 0.97 SYPD on the NGPPS benchmark, when running on the full Summit supercomputer.

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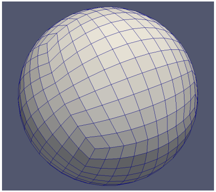
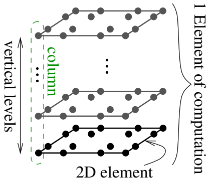
High-Order Methods Modeling Environment

- Component of E3SM for dynamics and transport in the atmosphere.
- Horizontal (2D) and vertical (1D) differential operators are decoupled.
- Spectral Element Method (SEM) in the horizontal direction.
- Eulerian or Lagrangian schemes for vertical operators.
- Hydrostatic and non-hydrostatic models available.





HOMMEXX

A performance portable implementation of Homme.

- Use C++ and Kokkos for on-node parallelism.
- Goals: expose parallelism/vectorization, minimize memory movement.
- Minimize of architecture-specific code.

2018: Hydrostatic dycore (preqx):

- Established viability of C++/Kokkos approach.
- Paper accepted in Geoscientific Model Development[1].

2020: Non-hydrostatic dycore (theta-l):

- Main challenges: nonlinear solver, larger memory footprint.
- Paper accepted at SC20[2].

[1] *HOMMEXX 1.0: a performance-portable atmospheric dynamical core for the Energy Exascale Earth System Model*, Geo. Model Dev., 2019

[2] *A Performance-Portable Nonhydrostatic Atmospheric Dycore for the Energy Exascale Earth System Model Running at Cloud-Resolving Resolutions*, SC20 Proceedings

Results: strong scaling

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- Solve for state and 10 tracers (NGPPS benchmark).
- Run at 3km and 1km horizontal resolution.
- Achieves 0.97 SYPD on GPU on full Summit system.
- Excellent scaling at 3km, perfect scaling at 1km.
- CPU performance comparable (or slightly better) to original F90.
- Approximately 10x speedup when using GPUs vs P9 on Summit.
- 1km resolution features approximately 1 trillion DOFs.

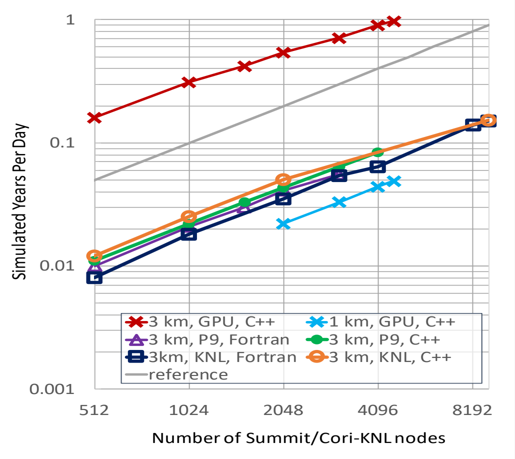

Figure: Achieved SYPD for different implementations and resolutions.

Conclusions

- Completed C++/Kokkos rewrite of HOMME non-hydrostatic dycore.
- New implementation faster than original on CPU.
- New implementation achieves 0.97 SYPD at 3km resolution on GPU on full Summit system.
- Performance-Portable dycore implementation crucial for Cloud-Resolving atmosphere model in E3SM.