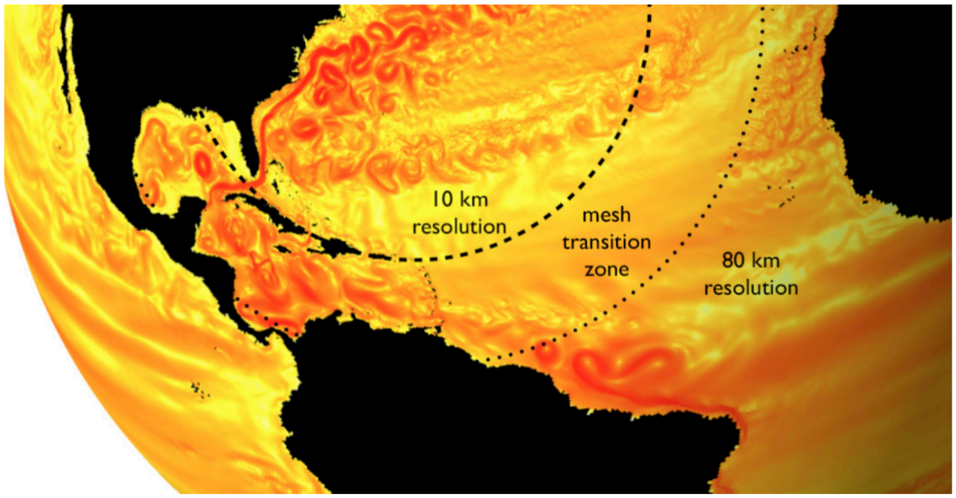
U.S. DEPARTMENT OF ENERGY | Office of Science

THE MODEL FOR PREDICTION ACROSS SCALES FRAMEWORK: A FLEXIBLE FOUNDATION FOR NEXT-GENERATION EARTH SYSTEM MODEL COMPONENTS

The Model Prediction Across Scales (MPAS) modeling framework is a multi-purpose computational code for simulating various parts of the earth system at variable resolution on irregular grids. MPAS enables scientists to improve the simulation of complex phenomena without having to contend with myriad routine computational details.



MPAS support of variable resolution grids focuses computing power for representing fine-scale processes.

An earth system model (ESM) includes individual components such as the atmosphere, ocean, land, and ice that each simulates unique and complex geophysical processes. All ESM components have certain common operational requirements, however. These include:

- Inputting and outputting of observational and computational data
- Configuring the ESM for different types of geophysical simulations (e.g. those involving prescribed versus calculated ocean properties)
- Selecting a computational grid for performing spatial calculations on component variables, such as atmospheric winds or ocean currents
- Tracking time evolution in the simulation
- Exploiting high-performance supercomputer capabilities.

Traditionally, ESM developers have tackled these operational requirements for each model component individually, resulting in much duplication of effort. However, MPAS (https://mpas-dev.github.io) eliminates such redundancies, supplying a platform on which to build any ESM component, so that its basic operational requirements are managed in a common framework.

PROMOTING GEOPHYSICAL SIMULATIONS

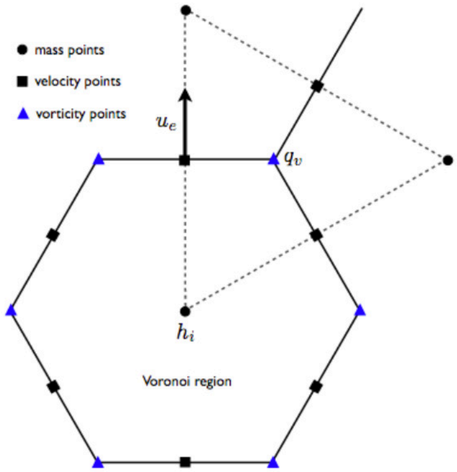
Key to the MPAS framework is promoting the deployment of model grid meshes having spatial resolution that can vary locally. For example, a tighter grid can be used on a selected ocean region, so that the ESM can more accurately simulate its fine-scale processes (see figure above).

MPAS also provides a foundation for generalized computation of geophysical processes by component models (“cores”) for simulating atmosphere, ocean, shallow water, sea ice, and land ice. The design philosophy aims to leverage the efforts of developers from various MPAS cores, in order to provide a common functionality with minimal effort. MPAS ocean, sea ice, and land ice cores are currently employed by the Energy Exascale Earth System Model (E3SM), and an MPAS atmospheric core by the Community Earth System Model (CESM).

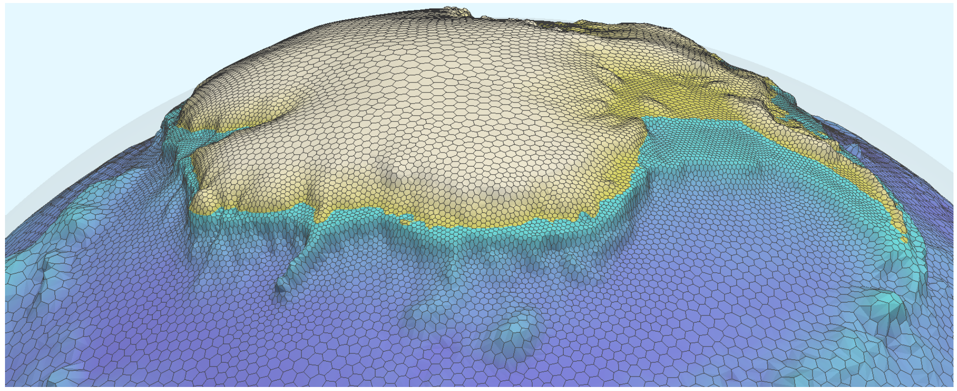
MPAS is built for unstructured, variable-resolution meshes that allow computing power to be focused where needed for particular research questions. The MPAS framework specification is general enough to describe unstructured meshes on most two-dimensional topological spaces. However, typical applications employ “centroidal Voronoi tesselation (CVT)” on a sphere or plane. CVT meshes allow the continuum equations of geophysical fluid dynamics

Get MPAS v5.2

The Model for Prediction Across Scales (MPAS) version 5.2 open-access software (https://doi.org/10.5281/zenodo.996549) is available for download at https://github.com/MPAS-Dev/MPAS-Release to be discretized with high accuracy, while also permitting the use of a variable-resolution grid.



MPAS supports Voronoi grids that implement highly accurate, discretized approximations of geophysical fluid dynamics.



Example of MPAS grids for the Southern Ocean and Antarctic Ice Sheet.

EXPEDITING ROUTINE OPERATIONS

The MPAS framework also includes shared modules for other common operational requirements (see bulleted list, above). MPAS performs parallel read/write operations to/from the disk via commonly used NetCDF and Parallel Input/Output libraries. These data libraries can be customized for different filesystems, and for a flexible run-time configuration of read/write files.

Model options are easily configurable at run-time. The MPAS framework supports flexible groupings of component model variables and enables easy registration of new variables. Timekeeping operations are handled by advanced MPAS operations that implement arithmetic operations on time intervals and alarm objects for handling specified events during a model run.

EXPLOITING A VARIETY OF HIGH-PERFORMANCE COMPUTING ARCHITECTURES

In addition, the MPAS framework supplies routines needed for exchanging information between processors in various parallel computing environments through a Message Passing Interface (MPI). Such routines include, for example, "global reductions and broadcasts" and "halo updates," which are techniques for synchronously sharing information across parallel processors. MPAS also supports the decomposition of multiple domain blocks on each processor, optimizing model performance by minimizing the transfer of data from disk to memory. Finally, shared memory parallelization is provided through the Open Multi-Processing (OpenMP) interface.

OCEAN-ICE SYSTEM EXAMPLE

MPAS capabilities are now being fully applied in simulating the interactions of the Antarctic Ice Sheet with the surrounding ocean and sea ice. Here, accurate prediction requires fine ocean resolution to resolve the currents flowing around or under ice shelves. Over the Antarctic continent also, extremely high resolution (1 km grid spacing) is needed to accurately represent the transition between the grounded ice sheet and the floating ice shelf (see figure above). The MPAS framework's support of variable-resolution Voronoi grids ensures the high accuracy of this difficult simulation.

For further reading on the MPAS modeling framework, see:

- Ringler et al. (2013), "*A Multi-Resolution Approach to Global Ocean Modeling*"
- Edwards et al. (2014), "*Effect of Uncertainty in Surface Mass Balance–Elevation Feedback on Projections of the Future Sea Level Contribution of the Greenland Ice Sheet*"
- Heinzeller et al. (2016), "*Towards Convection-Resolving, Global Atmospheric Simulations with the Model for Prediction Across Scales (MPAS) v3.1: An Extreme Scaling Experiment*."

SUPPORT

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CONTACTS

Matthew Hoffman, Ph.D.
Los Alamos National Laboratory
mhoffman@lanl.gov

Dorothy Koch, Ph.D.
DOE Program Manager
Earth System Modeling
dorothy.koch@science.doe.gov