NOAA-GFDL’s new ocean model: MOM6

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What is MOM6?

- Unification of GFDL’s MOM5 & GOLD ocean models
  - Structured C-grid, Finite Volume Core
  - Focus on global climate modeling and process studies
  - Hydrostatic Primitive Equations
  - Conservative, including wetting & drying (ice shelves, estuaries)
- Arbitrary Lagrangian Eulerian Method (ALE)
  - General vertical coordinates (Bleck, 2002; White et al. 2009)
  - No vertical CFL limit on timesteps/resolution
  - Efficiencies for biogeochemistry & passive tracers
- Comprehensive set of physical process parameterizations
  - Required for climate model projections into unobserved states
- Many capabilities resulted from extensive collaborations
  - 4 NSF/NOAA sponsored Climate Process Teams
  - CVMix shared NCAR/GFDL/LANL vertical mixing code
  - CLIVAR CORE/OMIP ocean-climate model comparisons
  - Tidal simulations with B. Arbic & H. Simmons
Examples of Important MOM6 Applications

• Idealized process studies

• GFDL’s ESM4/CM4x coupled climate model

• CFS-v3 coupled S/I forecast system candidate

• Ice-sheet ocean interactions

Vorticity in study of resolution dependent eddy params. Hallberg (2013)

Surface Vorticity in CM4 prototype Adcroft et al., in prep.

Schematic illustration of dynamically coupled ice-sheet & ocean models. Goldberg et al. (2012)
Advanced dynamical core technical capabilities, including flexible vertical coordinates and resolution, advanced tracer advection schemes, natural boundary conditions on freshwater and tracers, and support for non-Boussinesq configurations;

Yes

Model infrastructure and a development environment that provides strong support for collaborative model development with the university-based CESM community. This includes both structured programs such as Climate Process Teams and small group entrepreneurial projects;

Open development paradigm, all code and configurations on GitHub; GFDL is involved in CPTs; multiple collaborations on MOM6 code and configurations.

Strong support for both regional and climate modeling applications;

In addition to GFDL’s OM4/CM4, MOM6 is being developed by collaborators for regional applications.
Support for a wide range of resolutions and grids, and accompanying scale aware parameterizations;
General curvilinear orthogonal grids, quadrilateral based. New scale-aware parameterizations published with MOM6 code (e.g. Hallberg, 2013, Jansen et al., 2014, ...)

Ability to configure and run simpler idealized configurations for process modeling and educational applications;
MOM6 routinely tested in dozens of idealized and realistic ocean-only, ice-ocean and fully coupled configurations.

Compatibility with the CESM sea-ice model;
Currently coupled to SIS2 via FMS coupler, and to CICE within NUOPC NEMS coupler.

Ability to interface with CESM coupled data assimilation system;
FMS infrastructure is ESMF compliant. MOM6 framework layer can be directed to use alternate hooks. ODA at GFDL/NCEP will migrate to MOM6 after forward model development.

Familiar post-processing and analysis capabilities (akin to CESM workflow tools).
FMS diagnostics are very flexible. MOM6 diagnostics in arbitrary vertical coordinates.
CMORization of output straight from model (for CMIP6) under way.
A strong partnership between the developers of the model and the CESM community;
This is of great interest to GFDL developers, scientists and management.

A strong commitment to sustained collaboration in model development from the model’s institutional home or consortium;

GFDL developers are committed to future development of MOM6 code and configurations, with backing and investment from management and other branches of NOAA.

Timely and unfettered access to new developments;
MOM6 code and configurations are shared unrestricted using an “open development” paradigm. Open access to latest developments.

Meet or have the potential to satisfy the technical requirements listed above;
Yes - modern code, very scalable, strict testing protocols, incl. dimensional units, valgrind.

State-of-the-science parameterizations (comparable to those in the present POP) suitable for use in coarse resolution climate models;

Comprehensive parameterizations necessary for GFDL’s configurations exist. Expansion and/or further development of param. is a primary interest of developers and collaborators.
Published solutions showing a model version that is comparable to POP in the context of Coordinated Ocean-ice Reference Experiments (CORE);

OM4 (1°, ½°, ¼°, ⅛°) is basis of GFDL’s CMIP6 contributions (in prep.)

A realistic expectation that a configuration of the model would satisfy CESM3 science requirements in a timely manner;

Start from an existing configuration and incrementally evolve towards goal.

A modern code base that adheres to software engineering best practices with scalability and computational performance on modern architectures comparable to, or better than, POP;

Fortran 90; routinely tested with multiple compilers; very scalable.

A commitment to comprehensive model documentation.

Documentation by papers is a given. User and developer level documentation:

• Installation and policies: Comprehensive and collaboratively maintained via wiki
• Input parameters: self-documenting with units, defaults, description.
• APIs (code): Inline documentation of all subroutines. Conversion to Doxygen ongoing.
• User guide: Mix of inline and wiki – needs development.
• GFDL’s ocean-model developers are excited by the possibility of directly collaborating with the CESM community.
• GFDL would commit resources to the collaboration.
• Management is excited by idea†.

†A direct collaboration on ocean modelling would also be consistent with recommendations of NRC 2012: A National Strategy to Advance Climate Modeling.