Ocean model development in Germany
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MPIOM (http://www.mpimet.mpg.de/en/wissenschaft/modelle.html)
The current Max Planck Institute for Meteorology (MPI-M) ocean model MPIOM (Marsland et al., 2003; Jungclaus et al., 2006) is maintained and has been improved in terms of performance. The ocean biogeochemical sub-model HAMOCC5 (Wetzel et al., 2006) has been implemented and coupled atmosphere-ocean integrations with interactive carbon cycle are presently carried out in the framework of simulations of the last Millennium. A tidal module option has been included where the tides are driven by the complete lunisolar tidal potential without decomposition into Fourier components (Thomas et al., 2001). To accommodate for higher resolution global set-ups, a tri-polar grid version (similar to GFDL, OPA) has been developed. Aiming at a resolution of 0.45 degree for the standard configuration for the upcoming IPCC AR5 and a high-resolution (0.1 degree) version, the model is presently configured and parameterizations are being reviewed.
MPI-M has established a new research group on sea ice processes and modeling. One focus of the group is the development of a new multi-category, multi-layer sea ice model.

ICON (Icosahedral non-hydrostatic General Circulation Model) (http://icon.enes.org/)
ICON is a joint project between MPI-M's atmosphere and ocean departments and the German Weather Service (DWD) with the goal to develop a new coupled Atmosphere-Ocean General Circulation Model (GCM) that is capable to operate on a variety of space-time scales: from weather prediction to climate studies in regional and global domains.
We aim to implement a non-hydrostatic GCM for both atmosphere and ocean (with a hydrostatic version as an intermediate step). In order to exploit structural similarities between the equations for atmosphere and ocean we have started to develop a 'joint dynamical core' that is shared by the atmosphere and ocean components and contains the dynamics, while the physics and the different initial/boundary conditions are encoded in the individual model components.
Additional features of the ICON-GCM are:

- conservative local grid refinement (non-adaptive) that allows e.g. regional modeling in both atmosphere and ocean or local refinement along lateral boundaries in the ocean
- use of a common model grid for atmosphere and ocean that facilitates their coupling by avoiding spatial interpolation

The ICON model grid is an icosahedral geodesic grid, which is obtained by a regular Delaunay triangulation or by direct construction of the great circles of the sphere. The result is an almost uniform covering of the sphere. The variables are arranged in a C-type staggering (scalar variables at triangle centers, velocities at midpoints of triangle sides). The grid generator has been implemented, including the option for local refinement of triangles and a domain decomposition for parallelization.
As a preliminary ocean model version in 3D, the basic structure of the ocean model MPIOM with trapezoidal grid cells has been transformed to the triangular system without refinement. The actual code allows for a transition from hydrostatic to non-hydrostatic by

a switch. In both cases the speed of surface waves implies the solution of large systems of linear equations; for the non-hydrostatic case this system links together all scalar points in three dimensions.

References:

Thomas, M., J. Sündermann, and E. Maier-Reimer, 2001: Consideration of ocean tides in an OGCM and impacts on subseasonal to decadal polar motion excitation. *Geophys. Res. Lett*., 28, 12, 2457-2460.

Marsland, S.J., H. Haak, J.H. Jungclaus, M. Latif, and F. Roeske, 2003: The Max-Planck- Institute global ocean/sea-ice model with orthogonal curvilinear coordinates. *Ocean Modelling,* 5, 91-127.

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Wetzel, P., E. Maier-Reimer, M. Botzet, J.H. Jungclaus, N. Keenlyside, and M. Latif, 2006: Effects of ocean biology on the penetrative radiation on a coupled climate model. *Journal of Climate,* 19, 3973-3987.

FEOM (Finite-Element Ocean circulation Model)

Many processes in the ocean depend on true representation of coastline and bottom topography which motivates current interest to models capable of working on unstructured grids. The Finite-Element Ocean circulation Model (FEOM) was developed at Alfred-Wegener-Institute for Polar and Marine Research (AWI) in Bremerhaven with recognition of the role played by true representation of geometry. It is designed to work on unstructured surface triangular grids and in addition to continuous ("smooth") representation of coastlines also allows for refinement in areas of interest thus providing nesting in a seamless way. We work with vertically aligned meshes to facilitate using the hydrostatic approximation.

FEOM in formulated in geopotential coordinates but supports generalized vertical grids including z, sigma and their combinations with variable numbers of levels. Partially and fully shaved cells with z coordinate vertical discretization are also supported. Two versions with prismatic or tetrahedral discretization are available.

FEOM solves the primitive equations based on pressure correction method (implicit linear free surface). It offers a choice of several advection schemes and supports typical parameterizations accepted in the oceanographic community i.e. Redi tensor, Gent-McWilliams, Smagorinsky, biharmonic viscosity, Pacanowsky-Philander mixed layer.

FEOM is coupled to a finite-element sea ice model that works on triangular surface meshes. For a technical description (pdf) please notify sergey.danilov@awi.de

Publications on FEOM:

Danilov, S., G. Kivman, J. Schroeter, 2004: A finite-element ocean model: principles and evaluation. *Ocean Modelling*, 6, 125-150.

Wang Q., S. Danilov, J. Schroeter, 2007: Comparison of overflow simulations on different vertical grids using the Finite Element Ocean circulation Model. *Ocean Modelling*, submitted.

Danilov, S., Q. Wang, J. Schroeter, 2007: Finite Element Ocean circulation Model based on prismatic elements. *Monthly Weather Review*, submitted.