Lecture 4, Monday, May 26, 15.30-16.30

ROMS vs POM: new tools for hydrodynamics simulations

Andrea Bergamasco

CNR - ISMAR

There are at present within the field of ocean general circulation modeling four classes of numerical models which have achieved a significant level of community management and involvement, including shared community development, regular user interaction, and ready availability of software and documentation via the World Wide Web. These four classes are loosely characterized by their respective approaches to spatial discretization (finite difference, finite element, finite volume) and vertical coordinate treatment (geopotential, isopycnic, sigma, hybrid).

The earliest class of ocean models, and still the most widely applied, was pioneered by Kirk Bryan and his colleagues at GFDL utilizing low-order finite difference techniques applied to the oceanic primitive equations written in geopotential (z-based) coordinates. At present, variations on this first OGCM are in place at Harvard (Harvard Ocean Prediction System), GFDL (Modular Ocean Model), the Los Alamos National Lab (Parallel Ocean Program), the National Center for Atmospheric Research (NCAR Community Ocean Model), and other institutions.

During the 1970's, two competing approaches to vertical discretization and coordinate treatment made their way into ocean modeling. These alternatives were based respectively on vertical discretization in immiscible layers ("layered" models) and on terrain-following vertical coordinates ("sigma" coordinate models). In keeping with 1970's-style thinking on algorithms, both these model classes used (and, by and large, continue to use) low-order finite difference schemes similar to those employed in the geopotential coordinate models.

Today, several examples of layered and sigma-coordinate models exist. The former category includes models designed and built at the Naval Research Lab (the Navy Layered Ocean Model), the University of Miami (the Miami Isopycnic Coordinate Ocean Model), GFDL (the Hallberg Isopycnic Model), and others. In the latter are models from Princeton (the Princeton Ocean Model), and Rutgers University and UCLA (the Regional Ocean Modeling System), to name the two most widely used in this class.

We will focus on the last two Princeton Ocean Model (POM) and the UCLA Regional Ocean Modeling System (ROMS). We will try to underline what the models want to capture and reproduce of our knowledge in physics, numerics and advanced data assimilation.

POM is the Princeton Ocean Model, a sigma coordinate, free surface, ocean model, which includes a turbulence sub-model. It was developed in the late 1970's by Blumberg and Mellor, with subsequent contributions from other people. During '80 - '83 the Gulf of Mexico (Blumberg, Herring), '86-'90 Artic ocean (Kantha, Hakkinen), '91-'93 the Mediterranean (Zavatarelli), from '90 to the present Gulf Stream, data assimilation (T. Ezer), actually he is focus on Atlantic Ocean Climate research. The model has been also used for modeling of estuaries, coastal regions, basin and global oceans. New versions with Wetting and Drying (WAD) and Surface Wave Coupling are under development, beta versions available to users.

ROMS is a free-surface, terrain-following, primitive equations ocean model widely used by the scientific community for a diverse range of applications. ROMS includes accurate and efficient physical and numerical algorithms and several coupled models for biogeochemical, bio-optical, sediment, and sea ice applications. It also includes several vertical mixing schemes, multiple levels of nesting and composed grids.

In the vertical, the primitive equations are discretized over variable topography using stretched terrain-following coordinates (Song and Haidvogel, 1994). In the horizontal, the primitive equations are evaluated using boundary-fitted, orthogonal curvilinear coordinates on a staggered Arakawa C-grid. The general formulation of curvilinear coordinates includes both Cartesian (constant metrics) and spherical (variable metrics) coordinates. Coastal boundaries can also be specified as a finite-discretized grid via land/sea masking. As in the vertical, the horizontal stencil utilizes a centered, second-order finite differences. However, the code is designed to make the implementation of higher order stencils easily.

ROMS has various options for advection schemes: second- and forth-order centered differences; and third-order, upstream biased. There are several subgrid-scale parameterizations in ROMS. The horizontal mixing of momentum and tracers can be along vertical levels, geopotential (constant depth) surfaces, or isopycnic (constant density) surfaces. The vertical mixing parameterization in ROMS can be either by local or nonlocal closure schemes. The local closure schemes are based on the level 2.5 turbulent kinetic energy equations by Mellor and Yamada (1982) and the Generic Length Scale (GLS) parameterization (Umlauf and Burchard, 2003).

ROMS is a very modern code and uses C-preprocessing to activate the various physical and numerical options. The code can be run in either serial or parallel computers. ROMS modular code is written in F90/F95. It uses C-preprocessing to activate the various physical and numerical options. Several coding standards have been established to facilitate model readability, maintenance, and portability. All the state model variables are dynamically allocated and passed as arguments to the computational routines via de-referenced pointer structures.