A Community Terrain-Following Ocean Modeling System

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LONG-TERM GOALS

The long-term technical goal is to design, to develop and to test the next generation primitive equation, Terrain-following Ocean Modeling System (TOMS) for high-resolution scientific and operational applications. This project will improve the ocean modeling capabilities of the U.S. Navy for relocatable, coastal, coupled atmosphere-ocean forecasting applications. It will also benefit the ocean modeling community at large by providing the current state-of-the-art knowledge in physics, numerical schemes, and computational technology.

OBJECTIVES

The main objective is to produce a tested expert Terrain-following Ocean Modeling System for scientific and operational applications over a wide range of spatial scales from coastal to global. The primary focus is to select the most robust set of options and algorithms for relocatable coastal forecasting systems for the Navy. The system will include state-of-the-art numerical algorithms and subgrid-scale parameterizations, nesting options, advanced data assimilation schemes, air-sea coupling, extensive web-based documentation and users-support software for model set-up, analysis and diagnostics. The system is intended for massive parallel shared- and distributed-memory architectures.

APPROACH

This project is collaborative effort involving Rutgers University (Arango) and Princeton University (Ezer) who support, respectively, two community terrain-following ocean models: the Regional Ocean Model System, ROMS (Haidvogel et al., 2000), and the Princeton Ocean Model, POM (Blumberg and Mellor, 1987). We also have close collaborations with developers at UCLA (A. Shchepetkin) and other groups around the country. We conduct three main functions: (i) a leaders role by coordinating the efforts of the different groups involved, (ii) a developers role by implementing, testing, and documenting the numerical algorithms of TOMS and its associated supporting software and datasets, and (iii) an ambassadors role by promoting TOMS usage throughout the scientific and operational ocean modeling communities.

In August 2001, we organized a workshop in Boulder to discuss TOMS structural design and kernel, user elements, data assimilation requirements, mixing processes and subgrid-scale parameterizations, and test problems with leading experts in the ocean modeling community. Detailed information about this workshop can be found at http://marine.rutgers.edu/po/models/roms/Workshops.html. The next biannual workshop will be hosted in the Summer 2003.

The framework for TOMS is based on ROMS because of its accurate and efficient numerical algorithms, tangent linear and adjoint model transformations, variational data assimilation, modular coding and explicit parallel structure conformal to modern computer architectures (both cache-coherent shared-memory and distributed cluster technologies).

WORK COMPLETED

A version of TOMS has been coded and it is currently being tested. The computational kernel is identical to that of ROMS**,** but it is writen in F90/F95 and allows multiple levels of nesting. All the state model variables are dynamically allocated and passed as arguments to the computational routines via dereferenced pointer structures. All the private or scratch arrays used in each subroutine are automatic; their size are determined when the procedure is entered. The resulting TOMS code is very compact and writen in the object programming style. It exploits the strong typing capabilities of F90/F95 modules. That is, mostly all routines are packaged inside module units so the number of passed arguments and their type are checked during the compilation stage. Several coding standards have been stablished to facilitate model readability, maintance, and portability. These standards are based on the guidelines for writing F90/F95 atmosphere-ocean models at several US and European centers.

The parallel framework of the model is a coarse-grained one, with both shared- and distributed-memory paradigms coexiting in the same code. The shared-memory option follows the OpenMP 2.0 standard. The distributed-memory follows the ROMS-SMS structure, developed in collaboration with NOAA's Forecast System Laboratory, Boulder. An MPI-2 version of the code is currently being derived from the SMS version. When completed, TOMS will have similar parallel framework as theWeather Research Forecast (WRF) model.

The NetCDF interface has been enhanced for nesting applications, tangent linear and adjoint data checkpointing, sampling of the state vector at the observations locations, and parallel computations. Although NetCDF only supports serial IO, it is possible in distributed-memory configurations for each node to process (read and write) individual NetCDF files. Then, pre- and post-processing software can be used to split into several files or concatenate into a single file.

TOMS is a modular code with diverse physical and numerical algorithms which can be activated via C-preprocessing options. The open boundary conditions has been re-designed to account for multiple levels of nesting. New algorithms have been added for tansport, erosion and deposition of cohesive and non-cohesive sediments and generic length scale turbulence parameterizations (GOTM, Burchard *et al*., 1999). This work is being carried out in collaboration with Warner and Sherwood (USGS, WHOI).

RESULTS

The building (Arango) of TOMS is largely a technical task. However, several intercomparison studies have been carried out (Ezer) between ROMS and POM to evaluate horizontal and vertical advection, pressure gradient and time-stepping algorithms using idealized, process-oriented test problems. These algorithms have been tested for their numerical errors, computational cost and numerical stability (Ezer *et al.,* 2002).

A web site for the expert system has been designed and builded, http://ocean-modeling.org. This web site provides links for several atmosphere and ocean models. Some of these models are well established and have a broad user community. Also information is provided about source code access, processing software, applications, bulletin boards, chat rooms, and other relevant resources. Currently, ROMS and TOMS have identical web site design. The TOMS code and related software will be made available, in the near future, through its web site to a selected number of beta testers from the scientific and operational communities.

IMPACT/APPLICATIONS

This project will provide the ocean modeling community with a freely accessible, well-documented, state-of-the-art dynamic and numeric algorithm that can be used as a tool for the study of various physical phenomena.

TRANSITIONS

The full transition of TOMS to the operational community is likely to occur in the future. However, the TOMS algorithms will available soon to the developers and scientific community via its web site.

RELATED PROJECTS

Moore, Arango, Miller and Cornuelle are currently being funded by ONR to build and test the tangent linear and adjoint models for ROMS/TOMS. The tangent linear and adjoint models are now working and being tested in various 2D and 3D applications. Both the tangent linear and adjoint models can be used for variational data assimilation, optimal perturbations, stochastic optimals, ensemble prediction, and sensitivity analysis. We also are funded by NSF (lead PI: A. Bennett, NPS/OSU) in a project entitled *Modular Ocean Data assimilation.* The goal is to use the infrastructure of the Inverse Ocean Modeling (IOM) system of Chua and Bennett (2001) in conjunction with ROMS/TOMS tangent linear and adjoint models for ocean data assimilation via the representer method.

This project benefits from the intellectual and technical contributions of colleagues at several institutions (UCLA, SIO, U. Colorado, Harvard, OSU, USGS, ODU, TAMU, JPL, NIWA, NOAA/FSL, and PMEL).

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