Ocean Model Evaluation Project – Phase II: Geophysical Datasets

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LONG-TERM GOAL

Our long-term goal is to design, to implement and to maintain a World Wide Web site dedicated to the evaluation and comparison of numerical ocean circulation models and their component algorithms. Test problems included on the WWW site should offer verification against analytically tractable, idealized problems, as well as assessment with respect to datasets obtained in realistic geophysical settings.

OBJECTIVES

There are at present within the field of ocean general circulation modeling four classes of numerical models that 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/or vertical coordinate treatment (geopotential, isopycnic, sigma, hybrid). Although many of these models and model classes were originally intended for application to a narrow range of problems – *e.g.*, the study of coastal ocean circulation with terrain-following models – they are all by now less specialized in their usage.

Given the rapidly growing number of models, the algorithmic options within each of the various models, and the broad range of applications to which these models are now applied, it is important that we understand the behavior, properties and limitations of alternate ocean models and their component methods. Several alternative approaches to model comparison and validation are conceivable. An affordable and easily quantified means of contrasting model behavior is via a set of idealized, process-oriented test problems. Several types of idealized test problems exist, many of which are analytically tractable. Our goal is to make such test problems readily available to the ocean modeling community, as described further below.

Next in order of complexity and effort are quantitative comparisons between numerical and physical (*i.e.,* laboratory) models of simplified oceanic flow processes. Since many important geophysical processes are realizable in the laboratory, and are more readily measured there than in nature, comparisons made between physical and numerical models offer opportunities for quantification of "realistic" processes, particularly those involving non-linear and/or turbulent behavior. Comparative studies of this type have been performed -- *e.g.*, Perenne *et al.* (2000) -- and are presently being included in the test problem suite.

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Ultimately, ocean circulation models must be compared in fully realistic settings. Recent examples of this approach in the North Atlantic Basin -- including the CME, DYNAMO and DAMEE programs (see, *e.g.*, Haidvogel and Beckmann, 1999) -- have been successful in beginning to identify systematic differences in model formulation; however, their success has been limited by the relative scarcity of data for initial and boundary conditions, high-resolution surface forcing, and verification. A model validation exercise based upon an intensive coastal ocean dataset obtained at the LEO-15 National Littoral Laboratory in the New York Bight is being formulated to avoid some of these limitations.

APPROACHES

A web site featuring explicit examples of these test problems has been developed by the PI and his colleagues. Our approach is to take existing test problems and geophysical datasets, to define test problems based upon these, to provide solutions to these problems using more than one numerical ocean model, and finally to prepare the results thus obtained in a form appropriate to the World Wide Web. Each problem is described in detail, so as to allow replication by visitors to the WWW site. Sample results from one or more of the model classes mentioned above are included for illustration. Measures of accuracy ("metrics") are fully defined to allow cross-model comparison.

The accompanying numerical simulations have thus far utilized two different models -- the Spectral Element Ocean Model (SEOM) and the Regional Ocean Modeling System (ROMS). The two models differ primarily in their approaches to spatial discretization (high-order finite element and low-order finite difference, respectively), but are terrain-following so that in principle both should offer convergent solutions to flow problems featuring strong topographic variations and stratification. Haidvogel and Beckmann (1999) give a concise description of both model classes.

WORK COMPLETED

Figure 1 shows a schematic diagram of the web site contents, including test problems currently available on the WWW site and those scheduled for future installation. Idealized processes addressed in the first phase (FY99-00) of site development include:

- Equatorial Rossby solitons
- Gravitational adjustment of a vertical density front
- Trapped waves on curving coastlines
- Wind-driven western boundary currents
- Residual wind-driven currents over a coastal canyon

The results of these test problems follow closely the exposition in the monograph by Haidvogel and Beckmann (1999). Thus far, two other idealized tests have been added in FY01-02:

- Down-slope flow of a density current
- Supercritical flow in a constricted channel (due out in October 2002)

A test of static pressure gradient errors for non-geopotential coordinate system models will be added in FY03.

In addition to these web site enhancements, FY01-02 has seen the collection and synthesis of an intensive dataset at the LEO-15 National Littoral Laboratory during its annual coastal predictive skill experiment (CPSE) in July 2001. In contrast to prior years, the regional weather in summer 2001 was unusual, featuring several abrupt transitions from upwelling-favorable to downwelling-favorable winds. An integrated dataset -- based upon a subset of the data collected in July, and emphasizing the CTD, CODAR, AUV, and moored thermistor systems -- is being assembled to provide the basis for a quantitative hindcast/forecast test problem. Model metrics and sensitivity studies from the July 2001 CSPE are fully described in Wilkin *et al.* (2002).

RESULTS

FY02 saw the first concerted testing of ROMS (now in version 2.0) on many of the WWW test problems. With the addition of the supercritical flow problem (due out in October 2002), we will have evaluated ROMS on four test problems (supercritical flow, trapped waves in a circular basin, down-slope flow, and gravitational adjustment). As expected, ROMS displays considerable variety of behavior, depending on which of its algorithmic options for (*e.g.*) advection and baroclinic pressure gradient are selected. No single set of algorithmic options seems to work best across all problem classes. The test problem web site (http://marine.rutgers.edu/po/index.php) contains complete details of these behaviors.

IMPACT/APPLICATION

We have developed, for the first time, a centralized, integrated site containing documented test problems and metrics offering opportunities for systematic comparison across all classes of ocean models. The test problem web site is linked prominently to the IMCS Ocean Modeling web site (http://marine.rutgers.edu/po) and to Ocean-Modeling.org (http://www.ocean-modeling.org/). Both sites receive O(1000) visitors weekly.

TRANSITION

The developers of several new ocean models -- e.g., HyCOM -- are utilizing these test problems, and their results will be added to the web site when available.

RELATED PROJECTS

Our principal model "tools" for the illustration of these test problems continue to be the spectral finite element model SEOM and the generalized sigma coordinate model ROMS. Continued development of SEOM and ROMS benefits from support from several agencies including NSF, ONR and the NOPP program, and from the intellectual and technical contributions of colleagues at many institutions (*e.g.,* UCLA, JPL, SIO, USGS, etc.).

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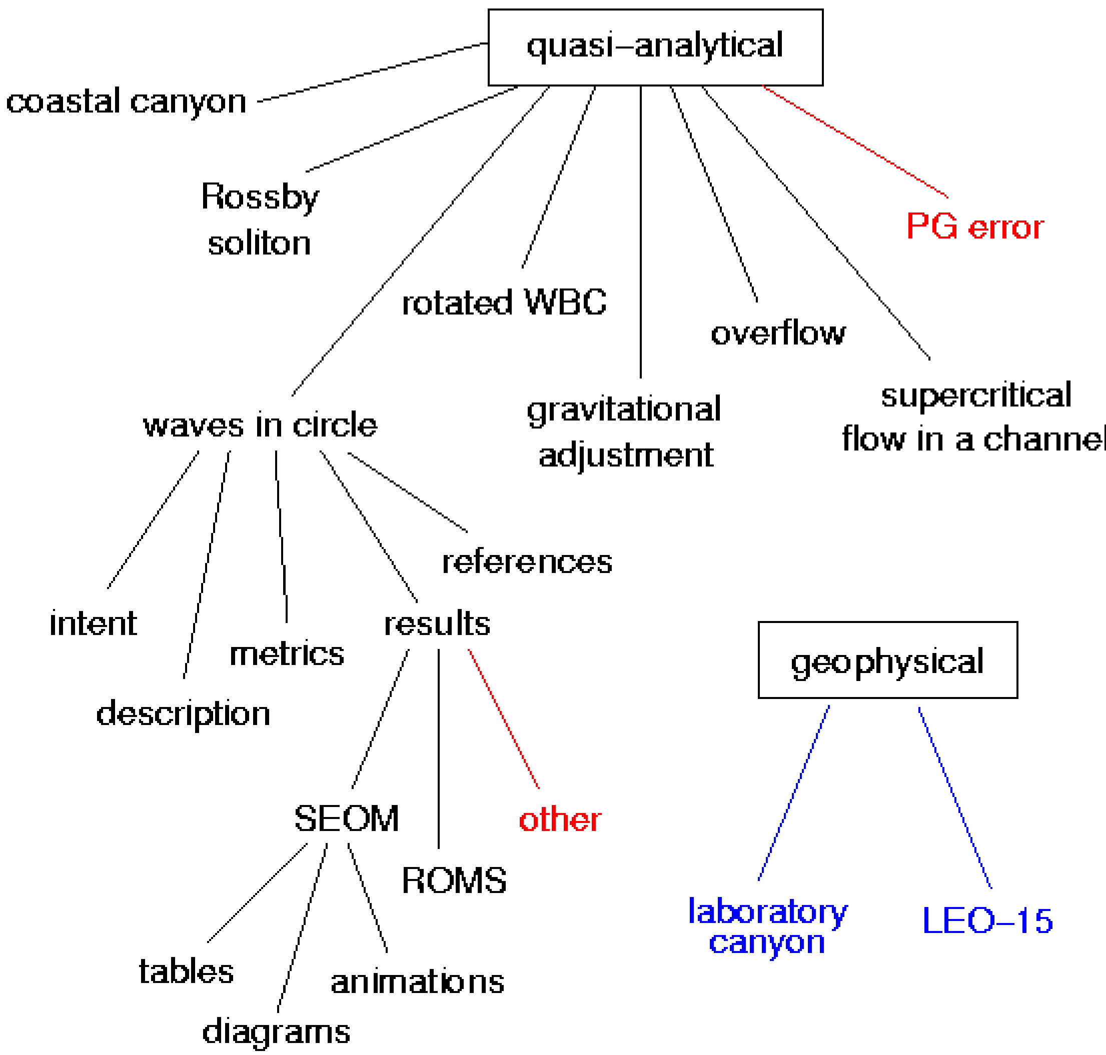

Figure 1: Hierarchy of model test problems on the web site. The existing components are shown in black. The test problems that will be available soon are shown in blue, while components which are planned for the future are shown in red.