Ocean Model Evaluation Web Site

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LONG-TERM GOALS

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

SCIENTIFIC/TECHNICAL OBJECTIVES

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, HOPS), GFDL (Modular Ocean Model, MOM), Los Alamos National Lab (Parallel Ocean Program, POP), the National Center for Atmospheric Research (NCAR Community Ocean Model, NCOM), 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 continue to use) low-order finite difference schemes similar to those employed in the GFDL-based codes. 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, NLOM), the University of Miami (the Miami Isopycnic Coordinate Ocean Model, MICOM), GFDL (the Hallberg Isopycnic Model, HIM), and others. In the latter are models from Princeton (the Princeton Ocean Model, POM), and Rutgers University and UCLA (the Regional Ocean Modeling

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE
3. DATES COVERED	**00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE	**Ocean Model Evaluation Web Site**
5a. CONTRACT NUMBER	
5b. GRANT NUMBER	
5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)	
5d. PROJECT NUMBER	
5e. TASK NUMBER	
5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**Rutgers University,Institute of Marine and Coastal Sciences,71 Dudley Road,New Brunswick,NJ,08901**
8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	
10. SPONSOR/MONITOR'S ACRONYM(S)	
11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT	**Approved for public release; distribution unlimited**
13. SUPPLEMENTARY NOTES	
14. ABSTRACT	
15. SUBJECT TERMS	

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

System, ROMS), to name the two most widely used in this class. More recently, OGCM's have been constructed which make use of more advanced, and less traditional, algorithmic approaches. Most importantly, models have been developed based upon Galerkin finite element schemes - *e.g.*, the triangular finite element code QUODDY (Dartmouth University) and the spectral finite element code SEOM (Rutgers). These differ most fundamentally from earlier models in the numerical algorithms used to solve the equations of motion, and their use of unstructured (as opposed to structured) horizontal grids.

Given the rapidly growing number of models (and algorithmic options within each of the various models), it is imperative 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 interpreted means of contrasting model behavior is via an inexpensive set of process-oriented test problems. Several types of dynamically distinct, process-oriented test problems are available; our goal is to include the set discussed further below.

Next in order of complexity - following idealized, analytically tractable test problems - are quantitative comparisons between numerical and physical (*i.e.*, laboratory) models of simplified oceanic flow processes. Since many important geophysical processes are amenable to laboratory simulation, and are more easily measured there than in nature, comparisons made between physical with numerical models offer more ready opportunities for quantification of “realistic” processes, particularly those involving non-linear and/or turbulent behavior. Comparative studies of this type are presently underway - *e.g.*, Perenne *et al.* (1999) - and are scheduled for inclusion in future.

Ultimately, ocean circulation models must be intercompared 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 dataset obtained at the LEO-15 National Littoral Laboratory in the New York Bight is also scheduled for addition.

APPROACH

An ONR-based web site containing explicit examples of these test problems is presently under development by the PI's. Idealized processes addressed in the first phase of site development include Rossby solitons, wind-driven western boundary currents, coastal-trapped waves on curving coastlines, and gravitational adjustment of a vertical density front. The results of these test problems follow closely the exposition in the recent monograph by Haidvogel and Beckmann (1999). Figure 1 shows a schematic diagram of the web site contents as envisioned here, including test problems currently available on the WWW site and those scheduled for future installation.

Our approach is to take existing test problems and geophysical datasets, to define test problems based upon these, to verify the usefulness of the test problems by solving the problems with one or more different models, and finally to prepare the results thus obtained in a form appropriate to the world wide web. Each problem is described in complete detail, so as to allow replication by viewers of 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.

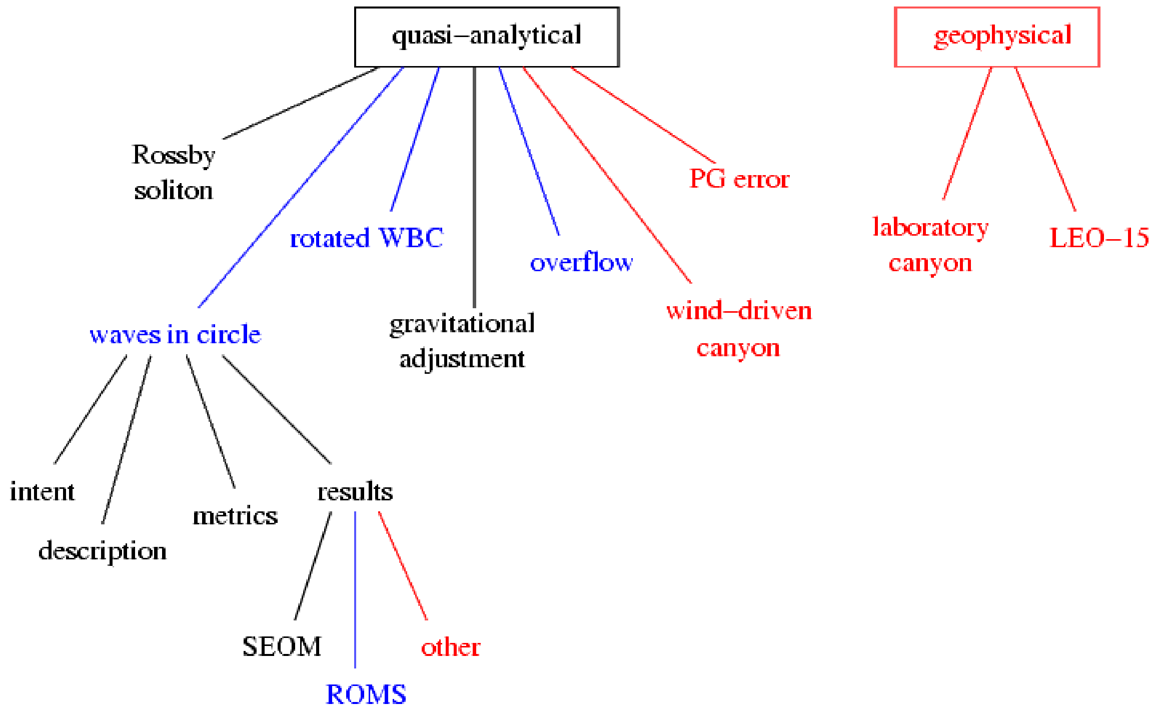

Figure 1: Hierarchy of model test problems for the web site. The currently existing components are shown in black. The test problems which will be available soon are shown in blue, while components which are planned for the future are shown in red.

WORK COMPLETED

Two of the test problems described in Haidvogel and Beckmann (1999) have been placed on our web site with sample results from the SEOM model. (Additional results from finite-difference-based models - *e.g.*, ROMS - are being developed.) These two problems include the propagation of an equatorial Rossby soliton (an asymptotic solution to the inviscid, nonlinear shallow water equations emphasizing wave propagation and numerical damping) and the adjustment under gravity of an initially vertical, two-density-layer system (inviscid, stratified frontal adjustment). The effects of resolution on the solution are shown for the Rossby soliton in Fig. 2. Animations of the results are included as part of the web contents. Two other idealized tests should be ready shortly: a frictional western boundary current test problem (frictional boundary layer flow against a tilted boundary) and the propagation of trapped waves in a circle (Curchitser, 1999).

RESULTS

We have gained experience with some software tools available for building web pages. Some of the material that we are moving to the web is already available in the form of a LaTeX document. Therefore, it made sense to become more familiar with the latex2html package. It has numerous options and also allows you to insert WWW links. latex2html uses cascading style sheets (CSS) to control the layout of a group of documents at once. This seems like the best way to go for a collection of related documents; we have therefore been making adjustments to the style sheets with advice from

Siegel (1997). The web pages also need pictures and movies. We have considered how to create animations of our model results using a suite of tools including NCAR graphics, ImageMagick, and gifsicle. Still images can be created by a number of means, but the Gimp is very useful for converting them to web images with anti-aliasing.

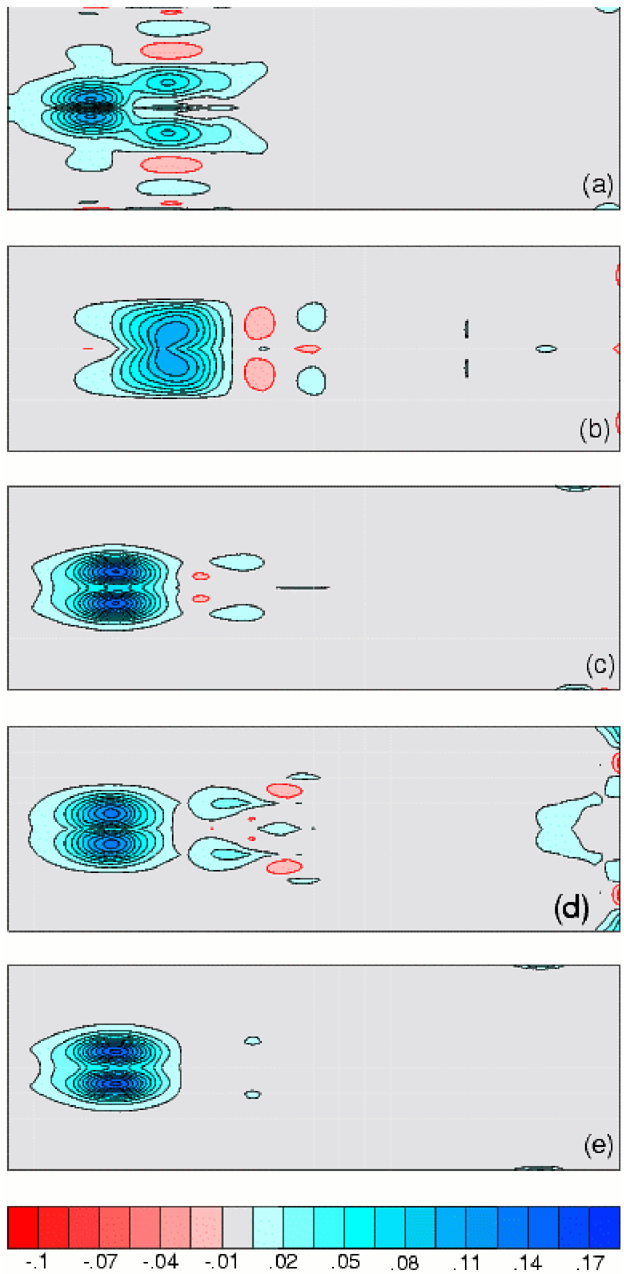

Figure 2: ***Rossby soliton solutions: Surface displacement at time 40 for the Rossby soliton problem obtained with (a)*** **16 x 48** ***points, ninth-order accuracy, (b)*** **16 x 48** ***points, fifth-order accuracy, (c)*** **32 x 96** ***points, ninth-order accuracy, (d)*** **32 x 96** ***points, fifth-order accuracy, (e)*** **64 x 192** ***points, ninth-order accuracy.***

IMPACTS/APPLICATIONS

We will soon have, 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.

TRANSITIONS

None.

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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