High Resolution Parallel Coastal Ocean Modeling: a Large Eddy Simulation Tool

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LONG-TERM GOALS

Our goal is to create a robust and highly efficient nonhydrostatic code that can be applied in a predictive manner to littoral zones and bays on a spatial scale of the order of 100 km and time scales of the order of days to weeks. The product will be a user-oriented production code for the coastal environment.

OBJECTIVES

This project aims to synthesize a number of computational and numerical tools to produce an innovative and powerful coastal ocean simulation tool to generate accurate predictions of motions and transport in coastal oceans under conditions when a nonhydrostatic and terrain-following representation is essential. Another primary objective is to apply the best algorithms available to create a simulation code that is capable of representing the physical processes at high resolution and capable of very high speed on multiple-processor parallel computers.

APPROACH

This proposal is complementary to one funded by the NSF ITR program [Start date January 2002]. That project is focused on creation of a new generation computer code and application of it to internal waves in Monterey and Mamala Bays. Four faculty are involved. Robert Street is the PI. Margot Gerritsen is an expert on numerical methods and composite grids. Mark Merrifield is a member of the HOME project and will provide the data for Mamala Bay and assist in its interpretation. The main code development is supported by the NSF ITR project and Oliver Fringer is carrying out the development work.

The ONR funding is supporting a doctoral student to take responsibility for applications; he is working with Profs. Street, Gerritsen and Fringer. This entails the crucial task of generation of grids and initial data and boundary forcing. The student has just joined the ONR project, has a background in ocean and marine science, and will carry out and analyze production runs. As planned, the student has begun his tenure at the beginning of the second ONR grant year.

We will employ numerical large-eddy simulation to generate accurate predictions of motions and transport in coastal oceans under conditions when a nonhydrostatic and terrain-following representation is essential. The simulation should be able to handle all processes from the free surface to the bed so that the whole range from surface waves through internal waves to sediment motions could be simulated. Two specific applications of the completed code are planned. Both involve nonhydrostatic evolution of internal tides. The first is in Monterey Bay, California, where solitons are expected to form and the internal tide signal is intensified in the bottom of the Monterey Canyon. The second is in Mamala Bay, Hawaii, where high-amplitude and nonlinear internal tides are observed and there are key questions to be answered about the nature of these waves and their behavior in the Bay.

From a numerical point of view our approaches include:

1. Parallel processing: We are using MPI, the message passing interface.
2. Poisson-equation solvers: We are exploring the use of *PETSc* [see below].
3. Accurate advection: We are developing a procedure based on Kriging.
4. Large Eddy Simulation: We have developed and tested a mixed subfilter-scale model for turbulence.
5. State of the art gridding: We use the *Triangle* code of Shewchuk.
6. Representing topography: We plan to employ the IBM [Immersed boundary method].

WORK COMPLETED

For Fiscal Year 2002, the primary tasks under this ONR grant were the recruitment of a student whose support began in FY2003 [accomplished] and support of the code development plans by the faculty, namely, Gerritsen and Street [accomplished]. At this juncture, we are using a shallow-water equation version of our unstructured-grid code to test (1) the free-surface behavior in a shallow version of Monterey Bay and (2) the wetting and drying ability at its coastlines. The unstructured grid is generated by the *Triangle* software package. We use the *ParMetis* parallel graph partitioning and sparse matrix ordering library to produce optimum grid cell and face ordering. The ordering library produces a grid structure that yields a 38% faster code execution than a grid that has not been so processed. A particular task being undertaken by Prof. Gerritsen is exploration of the use of *PETSc [Portable Extensible Toolkit for Scientific Computing]* to parallelize and optimize our free surface and pressure solvers.

Because this project has just begun, we list now a brief description of some of the planned tasks:

Task List: * indicates tasks that are specifically supported by ONR.

FY 2003

Complete first version of parallel and improved code.
*New student assists primary code writer.
*New student prepares high-resolution grid for Monterey Bay. Test it with the current non-parallel UnTRIM code being developed under an ONR PO grant.
*New student begins production runs of parallel code for internal waves in Monterey Bay.
*New student assists in analysis of code performance and comparisons between simulations and field data.

Future FYs

*Complete production runs of parallel code for internal waves in Monterey Bay.

*Prepare high-resolution grid for Mamala Bay.
*Verify Mamala Bay grid and inputs with preliminary tests.
Complete code development and publish users' manual.
*Carry out production runs for Mamala Bay.
*Complete data analysis from production runs.

RESULTS

None; project is just underway.

IMPACT/APPLICATIONS

There will be a contribution to understanding of coastal ocean dynamics. A key goal is to produce a production-style code, i.e., one that can be used by others, is fully documented and tested, and in the public domain. Thus, a result will be a robust tool for use by the coastal oceanographic community to study coastal processes.

Previous studies have documented the importance of gaining an understanding of the generation, propagation, and fate of internal tidal waves on the continental shelf and coastal bays. Definitive answers about the role of these waves would materially increase our understanding of the mixing and transport on the shelves and in the bays and their influence on sediment transport. Hence a predictive capability has broad coastal oceanographic applications, including for example, to the modeling phase of the HOME project. It is also the case that the successful simulation of the Mamala Bay wave motions will have important impacts on public health and tourist-related issues in the Bay.

RELATED PROJECTS

NSF OCE-0113111 High Resolution Coastal Ocean Modeling. The numerical code for this ONR project is being created under the NSF grant.