Hydrostatic and Nonhydrostatic Nested Modeling of Straits in the Philippines Archipelago

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LONG-TERM GOALS

This study utilizes nested nonhydrostatic models embedded in hydrostatic models to simulate and predict the submesoscale dynamics of straits at high spatial and temporal resolutions. The goal of this work is to understand the submesoscale dynamics of straits and the impact of these dynamics on the throughflow in the straits. The Navy requires the ability to forecast features and circulations forced by these dynamics on scales that impact naval operations, i.e. kilometers to meters.

OBJECTIVES

The primary objective is to understand the submesoscale dynamics in straits using nested nonhydrostatic models embedded in hydrostatic models. Specifically we will work

- To understand the effects and interactions of the primary forcing components:
  - Tides, especially the spring-neap tidal cycle and remotely versus locally generated tides,
  - Large scale circulation, particularly the Pacific to Indian ocean throughflow and it's seasonal variability,
  - Winds, especially the Southeast Asian monsoon cycle,
- To establish the resolution (dx and dz) and the aspect ratio (dx/dz) required to accurately simulate submesoscale physics and structures,
- To determine the importance of accurate and detailed representation of topography and forcing, especially at open boundaries,
- To understand the impact of rotation on the flow in straits, this is particularly important to nonhydrostatic physics,
- To explore the impact of data assimilation in a nonhydrostatic model, especially for sparse and irregular data,
- To compare model and field observations both for planning and for assessment.

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APPROACH

We use a system of multiply nested nonhydrostatic model (NRL-MIT) domains which utilize hydrostatic models (NCOM and/or HYCOM) to provide open boundary conditions for the coarsest NRL-MIT domain. The NRL-MIT domains consist of the nonhydrostatic version of the MITgcm model wrapped in a suite of scripts that provide initial/restart fields, open boundary values and handle output in a series of segmented, parallel integrations that maximize cpu usage and the ratio of system to wall clock time. The forcing consists of surface fluxes from the NOGAPS and COAMPS operational nowcast/forecast systems and open boundary conditions from the NCOM and/or HYCOM nowcast/forecast systems. HYCOM forecasts with resolutions of up to 4 km may be available in the region in the next year or two (Harley Hurlburt, personal communication). The basic bathymetry will be the NRL DBDB2 (2 minute) bathymetry which we hope will be enhanced and improved with several additional bathymetry databases obtained during the DRI.

WORK COMPLETED

Work has been severely hampered by the inconsistencies between the available numerical bathymetry databases and the bathymetry reported by the cruises. We continue to work to improve the bathymetry and to verify and analyze results in the rotated coordinate system.

Implemented, Tested and Published NEW Open Boundary Conditions for nesting a Nonhydrostatic model in a Hydrostatic model.

- Formulated a combined open boundary condition consisting of
    - A Transport Correction Scheme (TCS) for incoming fluxes to conserve volume
    - A Flow Relaxation Scheme (FRS) to match outgoing and incoming fluxes
- Developed and tested methods using hindcasts of the Mindoro straits (Gallacher *et al.* 2011)

Exploring Next Generation Visualization and Analysis for Very Large Datasets.

- Visualization and data management for very large datasets constitutes one of the next big challenges for HP Computing.
- We have conducted a very large experiment which generated 3.5 TB of data.
    - The domain for this experiment uses 2,000 processors and 3500x2400x40 = 336 Million grid points, more than 3 times the number of grid points used by Global NCOM.
- Under the auspice of ONR 321US we have partnered with Makai Engineering to determine the feasibility of visualizing such a large dataset.
    - To that end we have downloaded the data onto an external disk provided by ONR and sent it to Makai engineering for preliminary processing and visualization
- Collaborating with Dr. Sean Ziegler of PETT, we are devising and testing new methods for data mining and visualization of large data sets.
    - Developing new nondimensional parameters to locate important areas or significant features in the data sets.

- Utilizing and improving scaling methods such as WKB to normalize widely varying data values.

RESULTS

Hindcasts of the 3D nonhydrostatic flow through the Mindoro straits at 500m resolution are forced with data from NRL-MTRY's RELO COAMPS. The model data are compared with mooring data in the Mindoro straits and the Panay Straits. The results are in good agreement in the Mindoro straits (Figure 3). However, in the Panay straits differences in model and in situ bathymetries caused significant discrepancies in the comparisons (Figure 4). Work is ongoing to improve the bathymetry and the open boundary conditions and to verify the rotated values.

IMPACT/APPLICATIONS

Tactical scale or submesoscale forecasting in domains of 100 to 200 km will require nonhydrostatic modeling systems with resolutions of 100s of meters or less to correctly predict the NLIWs, turbulent regions, fronts, boils and small scale eddies. This project studies the dynamics of NLIWs, their interactions and their impact on the tactical environment. This work furthers the basic understanding of NLIWs and lays the foundation for fututre nonhydrostatic forecast systems.

RELATED PROJECTS

This project is synergistic with the following projects:
Internal Waves in Straits (IWISE) ONR DRI,
Effects of Non-Acoustic Noise on Multi-Sensor USW Networks, NRL 6.2 core

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Nonhydrostatic Modeling of Nonlinear Internal Waves and Turbulence

PUBLICATIONS

Gallacher, P. C., D. A. Hebert, M. R. Schaferkotter, Nesting a Nonhydrostatic Model in a Hydrostatic Model: The Boundary Interface , Ocean Modelling, **40**, 2, 190-198, 2011.