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Effects of Grid Resolution on the Simulation of Internal Tides

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We simulate 2 cases to examine the effect of horizontal grid resolution on simulation of the semidiurnal internal tide in Monterey Bay: a coarse grid (∼2900-m resolution) and a fine grid (∼290-m resolution). All other inputs—barotropic M_2 tidal velocity boundary conditions, initial conditions, and other physical and numerical parameters—remain constant between the 2 runs. The results show that the choice of grid resolution and the associated interpolated bathymetry are crucial to properly simulate the internal tides. The coarse grid acts like a filter to remove critical locations where internal tides are generated, and this grid loses the ability to capture energetic small-scale motions. The fine grid yields results consistent with field measurements.

INTRODUCTION

Munk (1966) suggested that the ocean mixes largely at its boundaries. More recently, Müller and Briscoe (1999) refined that view by hypothesizing that internal tides and internal waves (non-tidal) propagating near coastal boundaries may be important players in the global energy budgets, mixing, and dissipation. Lien and Gregg (2001) and Carter et al. (2002) observe highly concentrated intermittent patches of turbulence coincident with computed linear internal wave characteristics over ridges and within canyons. Within the proximity of such bathymetric features, Petruncio et al. (1998) observe currents due to internal tides that are an order of magnitude larger than those in the surrounding area. This suggests a connection between enhanced mixing, elevated dissipation, and internal tides and internal waves in coastal locations.

Numerical simulations provide a tool to investigate this possible relationship. Results need to be accurate to assess this connection, and the accuracy of the results partly relies on the choice of grid resolution. A poor choice of grid resolution can lead to unrealistically low measures of velocities and scalar quantities, leading to inaccurate estimates of energy flux and conclusions about dissipation due to internal tides and waves. The grid resolution then needs to be selected carefully, depending on the ocean processes to be investigated.

The purpose of this paper is to demonstrate the effect of grid resolution on the numerical simulation of internal tide generation and propagation over complex coastal bathymetry. This is accomplished by applying the **S**tanford **U**nstructured **N**onhydrostatic **T**errain-following **A**daptive **N**avier-Stokes **S**imulator (SUNTANS) to various resolved grids and comparing the results to available field data. It is anticipated that techniques learned from this investigation will produce improved internal wave results for future studies without the need for overspecified boundary conditions, or atypical numerical parameters, thus providing better estimates for coastal-ocean mixing and dissipation.

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DESCRIPTION OF SUNTANS

SUNTANS is an unstructured, finite-volume, parallel coastal-ocean simulator that solves the incompressible 3-dimensional nonhydrostatic Navier-Stokes equations with the Boussinesq approximation in a rotating frame along with equations for the free-surface, scalar transport of salinity and temperature, and equation of state for density. Details of SUNTANS can be found in Fringer et al. (2006). Briefly, the solution is based on a predictor-corrector method in which the governing equations are advanced in time, first using only the pressure values at the current time. At this point in the calculation, mass conservation is not satisfied, so a nonhydrostatic pressure correction is computed to force the velocity field to satisfy continuity. This is accomplished by correcting the velocities with the nonhydrostatic pressure correction, which is the solution of a pressure-Poisson equation. Time advancement for the vertical diffusion terms and free surface is treated implicitly using the theta-method (Casulli, 1999), while the remaining terms are treated explicitly using the Adams-Bashforth method. The nonhydrostatic pressure is discretized at the half timestep to preserve 2nd-order accuracy (Armfield and Street, 2002). Time advancement for the scalar equation uses the theta-method for vertical advection and diffusion, along with the Adams-Bashforth method for horizontal advection and diffusion. Finite-volume prisms are used to spatially discretize the advection and diffusion terms within the unstructured grid. SUNTANS uses a prism grid with an unstructured (triangular) grid in the horizontal, and a structured grid in the vertical. The benefit of an unstructured grid is that it allows certain regions within the domain to be highly resolved, while others can be made coarse, which optimizes computer processing time while sacrificing little in resolution.

MODEL SETUP

Physical Setting

Monterey Bay, California, is located 150 km south of San Francisco in northern California (Fig. 1). Fig. 2 shows the bathymetry