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Ocean forecasting in terrain-following coordinates: Formulation and skill assessment of the Regional Ocean Modeling System

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Abstract

Systematic improvements in algorithmic design of regional ocean circulation models have led to significant enhancement in simulation ability across a wide range of space/time scales and marine system types. As an example, we briefly review the Regional Ocean Modeling System, a member of a general class of three-dimensional, free-surface, terrain-following numerical models. Noteworthy characteristics of the ROMS computational kernel include: consistent temporal averaging of the barotropic mode to guarantee both exact conservation and constancy preservation properties for tracers; redefined barotropic pressure-gradient terms to account for local variations in the density field; vertical interpolation performed using conservative parabolic splines; and higher-order, quasi-monotone advection algorithms. Examples of quantitative skill assessment are shown for a tidally driven estuary, an ice-covered high-latitude sea, a wind- and buoyancy-forced continental shelf, and a mid-latitude ocean basin. The combination of moderate-order spatial approximations, enhanced conservation properties, and quasi-monotone advection produces both more robust and accurate, and less diffusive, solutions than those produced in earlier terrain-following ocean models. Together with advanced methods of data assimilation and novel observing system technologies, these capabilities constitute the necessary ingredients for multi-purpose regional ocean prediction systems.

Introduction

The modeling of variability within the marine environment is essential for societal concerns that span the entire space/time spectrum. Examples include the prediction of estuarine and coastal ocean processes (circulation, turbulent mixing, and the transport of sediment) on time scales of minutes to days, studies of the oceanic response to global climate change (sea ice growth/retreat, sea level rise, carbon cycling) on interannual to decadal time scales, as well as numerous associated issues related to navigation, fisheries, security and health. Although modeling systems designed to deal with these problems will inevitably take a variety of forms, the development and demonstration of ocean modeling systems capable of broad geographic application is desirable.

Any broadly portable marine modeling system will require significant dynamical complexity, however. In addition to the underlying hydro-dynamical engine – responsible for determining sea level height, and the three-dimensional circulation and transport of momentum, temperature and salt – application-specific sub-models are required for, *e.g.*, turbulent mixing; sediment resuspension, transport and deposition; sea ice thermo/dynamics; and *in situ* biogeochemical responses. These requirements in turn constrain the numerical solution procedures to be highly flexible, robust and computationally efficient.

Historically, ocean circulation models were developed for particular classes of applications (climate modeling, coastal prediction, *etc.*) and made specific choices as deemed best (at that time) for such considerations as vertical coordinate treatment and horizontal grid representation [1]. Recently, several of these classes of ocean models have been enriched with more general algorithmic options to allow a broader range of effective application. We review one such model here.

References (60)

D.B. Haidvogel *et al.*
A semi-spectral primitive equation ocean circulation model using vertical sigma and orthogonal curvilinear horizontal coordinates
Journal of Computational Physics (1991)

Y. Song *et al.*
A semi-implicit ocean circulation model using a generalized topography-following coordinate system
Journal of Computational Physics (1994)

D.B. Haidvogel *et al.*
Model evaluation experiments in the North Atlantic Basin simulations in nonlinear terrain-following coordinates
Dynamics of Atmospheres and Oceans (2000)

A.F. Shchepetkin *et al.*
The regional oceanic modeling system (ROMS) a split-explicit, free-surface, topography-following-coordinate oceanic model
Ocean Modelling (2005)

J.C. Warner *et al.*
Performance of four turbulence closure models implemented using a generic length scale method
Ocean Modelling (2005)

P. Nielsen
Suspended sediment concentrations under waves
Coastal Engineering (1986)

M.Z. Li *et al.*
SEDTRANS96: the upgraded and better calibrated sediment-transport model for continental shelves
Computers & Geosciences (2001)

W.P. Bissett *et al.*
Carbon cycling in the upper waters of the Sargasso Sea: I. Numerical simulation of differential carbon and nitrogen fluxes
Deep-Sea Research I (1999)

H.P. Batchelder *et al.*
Individual-based models of copepod populations in coastal upwelling regions: implications of physiologically and environmentally influenced diel vertical migration on demographic success and nearshore retention
Progress in Oceanography (2002)

Hunke
Viscous-plastic sea ice dynamics with the EVP model: linearization issues
Journal of Computational Physics (2001)

Cited by (1098)