An Overview of Nested Regions Using HYCOM

Patrick Hogan
Alan Wallcraft
Luis Zamudio
Sergio DeRada
Prasad Thoppil

Naval Research Laboratory
Stennis Space Center, MS

10th HYCOM Consortium Meeting

COAPS, Florida State University, 7-9 November 2006
Outline

• Motivation

• Open boundary nesting techniques

• Different nested regions
  
  East Asian Seas region – shallow isopycnals
  Japan/East Sea – Intrathermocline Eddies
  Gulf of California – sensitivity to BC params
  Gulf of Mexico – cross-shelf exchange
  California Current System – HYCOM-NCOM coupling
  Norwegian Coastal Current – buoyancy driven current
  Persian Gulf – contaminant dispersion

• Need generic and accurate horizontal and vertical interpolation

• Need to cover wide range of flow regimes
Navy Ocean Circulation Prediction

Expected Evolution

OPERATIONAL

1/32°NLOM, 1/8°NCOM

Through FY07

HYCOM
(Hybrid Coordinate Ocean Model)

NCOM

FY 08 & Beyond

Boundary Conditions

Note: Coastal component does not include nearshore environment
Current Status of Nesting

HYCOM NESTING in HYCOM

- Currently off-line
- Boundary info comes from archive files
- Exact boundary condition for depth averaged (barotropic) component
- Relaxation in buffer zone for T,S,P,u,v

Off-line:
- Boundary information comes from archive files
- Updating frequency limited by archive file frequency
- Don’t need to know nest area in advance

3.5 km East Asian Seas HYCOM Nested inside 16 km North Pacific HYCOM

open boundary conditions from 1/6° North Pacific HYCOM

Same vertical structure as Pacific Ocean model (20 layers)
1/25° HYCOM East Asian Seas Model
(nested inside 1/6° North Pacific Model)
North-south cross-section along 124.5°E

Yellow Sea flow reversal with depth

Isopycnals over shelf region

Snapshot on Oct. 14

Density front associated with sharp topo feature (can’t resolve with sigma coordinates)

Snapshot on April 12

z-levels and sigmas over shelf and in mixed layer
**RMS error map (wrt Pacific model over GoC domain)**

- **Time series of domain-wide RMS error**

- Barotropic BCS are updated every 1-day
- Baroclinic BCS are updated every 6-day
- 10 grid-point wide relaxation zone
- 1-10 day relaxation e-folding time

**Starting Point**

- Same geometry
- Same horz. res.
- Same vert. res.
Sensitivity to:

E-folding time in BZ

- 1-10, 1-5, \textbf{1-1}, .1-.5, .1-.2
- 10 grid-points
- 3 hours
- Barotropic + baroclinic

Updating frequency

- \textbf{3 hours}, 1, 2, 4, 6 days
- 10 grid-points
- 1-10 e-folding
- Barotropic + baroclinic
Sensitivity to:

**Barotropic/baroclinic mode**

- Barotropic or baroclinic only
  - 10 gridpoints
  - 0.1-1.0 e-folding
  - 3 hourly

**Width of buffer zone**

- 1,2,3,4,5,10 grid-point
  - 3 hourly
  - 0.1-1.0 e-folding
  - Barotropic + baroclinic
Lowest Error Nesting Parameters

RMS error map

Time series of domain-wide RMS error

10 grid points
.1-1 day e-folding
3 hour updating
Baroclinic+barotropic
15 layer 1/25° Japan/East Sea HYCOM

Mean Sea Surface Height

2 Sverdrup barotropic straits forcing
Relaxation to climatology for baroclinic part
Observed JES Intrathermocline Eddies (Gordon et al., 2002)

May 1999

January 2000
Location of JES Intrathermocline Eddies (Gordon et al., 2002)

Layer thickness between the 8°-11° isotherm
Layer 6 salinity (color) and layer 7 thickness
Secondary JES ITE Formation Mechanism: Frontal subduction along the subpolar front

From Gordon et al. (2002)

Hogan and Hurlburt (2006)
20 layer 1/25° Gulf of Mexico Model (~4 km)

Method of Characteristics used
To update the barotropic mode
Bathy from NRL-DBDB2

20 gridpoint buffer zone for baroclinic mode with e-folding time .1 to 10 days

Atlantic boundary data provided daily
Sensitivity of boundary forcing updating

Climatological forcing

Monthly climatology formed from 1-day archives

1-day forcing

Climatological forcing
$1/25^\circ$ (~4 km) Nested Gulf of Mexico

Snapshot of SSH and SST on June, 13 2000

Lots of cyclonic cold core eddies (impact of 2x res.)

Local upwelling
Vertical Remapping and Nesting Different Ocean Models

Global NCOM to CCS NCOM
\((\sigma-z)\) to \((\sigma-z)\)
1/8°-1/12°

PAC HYCOM to CCS NCOM
\((\sigma-z-\rho)\) to \((\sigma-z)\)
1/12°-1/12°

PAC HYCOM to CCS HYCOM
\((\sigma-z-\rho)\) to \((\sigma-z-\rho)\)
1/12°-1/12°
Triple nesting in the California Current System

NCOM CCS 9 km
NCOM-NCOM 1-4 km
NCOM-NCOM 0.5-1.5 km
1 km Persian Gulf HYCOM

- Boundary conditions from 1/12° Global HYCOM
- Includes rivers, bottom boundary layer
- Requires remapping from $\sigma_{2000}$ to $\sigma_\theta$

*unclassified*
1 km Persian Gulf HYCOM

Surface Temperature

Surface Tracer

Forced with 0.5° NOGAPS and lateral boundary conditions from 1/12° Global HYCOM

unclassified
Summary and Future Plans

- A Robust capability exists for nesting HYCOM within HYCOM and HYCOM within NCOM
- Sensitivity studies reveal the most accurate nesting params
- HYCOM successfully simulates JES Intrathermocline eddies
- HYCOM successfully simulates Loop Current eddy shedding

Future Plans

- Add wetting and drying (inudation) capability to HYCOM
- Add tidal forcing to standard version
- Improve river plume dynamics
- More quantitative HYCOM-NCOM-Observations comparisons
- Evaluation of nested boundary placement (on or off-shelf)
- Implementation and evaluation of other boundary conditions
- Additional evaluation of coastal HYCOM
Supplemental Slides Follow
1/25° Nested Gulf of Mexico HYCOM

July 27, 2000

red = east  blue = west  red = north  blue = south

Barotropic u-velocity  Barotropic v-velocity

Initial eastward along-shelf break current in geostrophic balance
A reversal in the barotropic currents triggers a transition of the along-shelf break currents to flow onto the shelf.
Significant cross-shelf flow exists after the reversal.