Circulation in the Gulf of Mexico from eddy resolving Hybrid Coordinate Ocean Models

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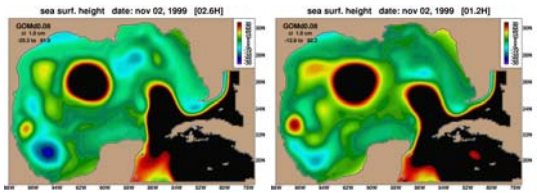
Abstract: The circulation in the Gulf of Mexico is examined with the HYbrid Coordinate Ocean Model (HYCOM). Two configurations include the Atlantic Ocean from 27°S to 70°N, thus eliminating the necessity of open boundary conditions in the region of interest. Both have horizontal grid resolution of 1/12° (about 8 km in the GoM) and 26 layers in the vertical. One is free running, the other assimilates sea surface height and temperature. A regional configuration (GoM only) accepts boundary information from the basin scale Atlantic model at the Yucatan and Channel and Florida Straits. All simulations show realistic Loop Current Eddy shedding with a period of about 10 months. The Loop Current Eddy shedding process is facilitated by cyclonic eddies that tend to ring the periphery of the Loop Current, increasing in amplitude as they migrate anticyclonically around the Loop Current.

Background: HYCOM is a generalized (hybrid isopycnal/sigma/z) vertical coordinate ocean circulation model. It is isopycnal in the open stratified ocean, but reverts to a terrain-following coordinate in shallow coastal regions, and to z level coordinates near the surface in the mixed layer. This generalized vertical coordinate approach is dynamic in space and time via the layered continuity equation, and permits the existence of zero thickness layers. Hence HYCOM allows for an accurate transition between deep and shallow water, historically a difficult problem for ocean models. It also allows high vertical resolution where it is most needed, over the shelf and in the mixed layer. The isopycnal coordinate reduces the need for high vertical resolution in deep water.

Atlantic/Gulf of Mexico HYCOM characteristics:

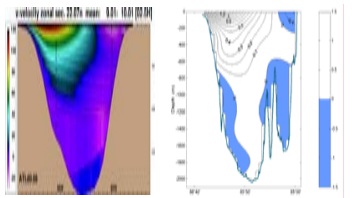
- Generalized vertical coordinate ocean model
- ~8 km horizontal grid resolution
- Includes realistic coastline geometry and bottom topography, including the shelf
- Forced by 6 hourly NOGAPS variability winds (1999-2002)
- K Profile Parameterization (KPP) mixed layer
- Vertical resolution: 26 layers (Atlantic); 22 layers (Gulf of Mexico)
- Bimonthly relaxation to GDEM SSS (instead of E-P)

Gulf of Mexico nested inside of 1/12° Atlantic HYCOM



Snapshot of SSH in the GoM from 1/12° Atlantic Model (plotted on nested domain).

Snapshot of SSH from 1/12° GoM model 3 months after restart from 1/12° ATL model

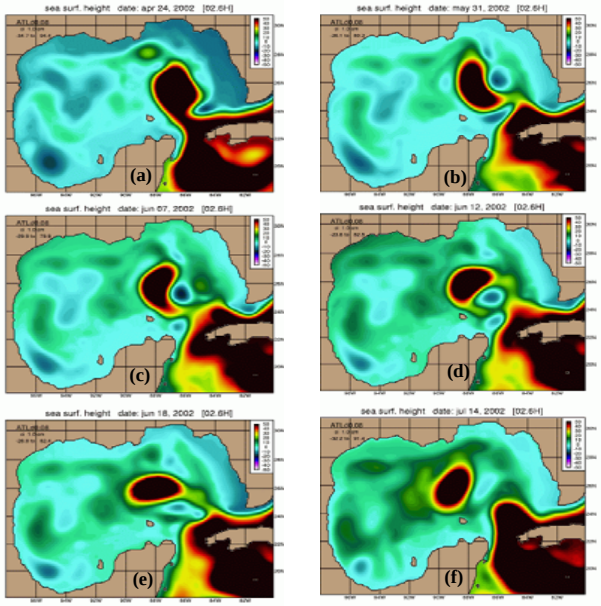


Comparison of simulated (left) and observed (right) mean flow through the Yucatan Channel. Both show surface intensified flow along the western boundary and return flow on the eastern boundary. Accurate flow through the Yucatan is critical for realistic Loop Current Eddy Shedding.

To date only 1/12° ATL to 1/12° GoM nesting has been done to test the sensitivity and accuracy of the boundary conditions. A 3x nest (2.7 km in the GoM) is planned in the near future.

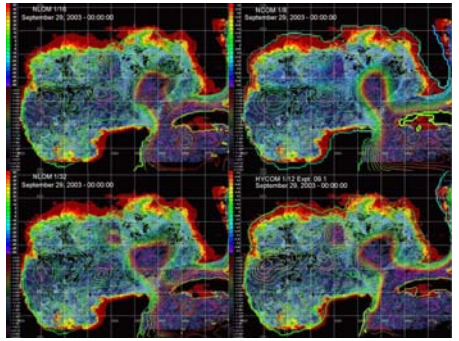
- Currently one way off line nesting
- Boundary info comes from coarse grid archive files
- Exact boundary condition for barotropic component
- Relaxation in buffer zone for T,S,P (optionally u,v) for baroclinic component

Evolution of Loop Current Eddy Shedding in the Gulf of Mexico

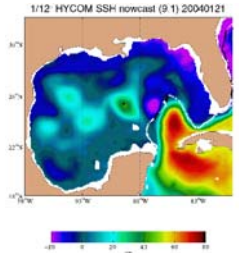


A sequence of SSH snapshots from non assimilative 1/12° Atlantic HYCOM showing the evolution of Loop Current Eddy shedding. (a) April 24, 2002, the Loop Current extends to 28°N and a cyclone has formed near the pinch-off point. (b) May 31, 2003, the cyclonic eddy has grown in size and migrated slightly to the north, and another cyclone has formed on the west side of the Loop Current. (c) June 07, 2003, the cyclone on the eastern side, accompanied by an anticyclone, has intensified and appears to be facilitating the eddy shedding process. Note the presence of cyclones around the periphery of the Loop Current. (d) July 12, 2003, the two cyclones have effectively pinched off the Loop Current eddy, (e) June 18, 2003, the Loop Current Eddy continues to interact with the cyclones, but does not completely detach. (f) July 14, 2003, the Loop Current Eddy is detached and begins to drift westward.

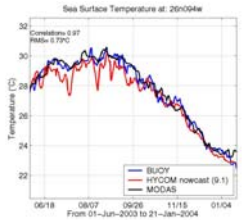
Comparison of Model Nowcasts and SeaWifs in the Gulf of Mexico



Comparison of SSH Nowcast for August 19, 2003 with SeaWifs from 1/16° global Navy Layered Ocean Model (NLOM) (upper left), 1/8° global Navy Coastal Ocean Model (NCOM) (upper right), 1/32° global NLOM (lower left), and 1/12° Atlantic HYCOM (lower right). NLOM, NCOM, and HYCOM differ primarily in the representation of the vertical coordinate and assimilation methodologies.

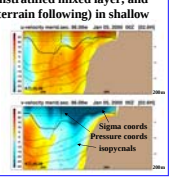


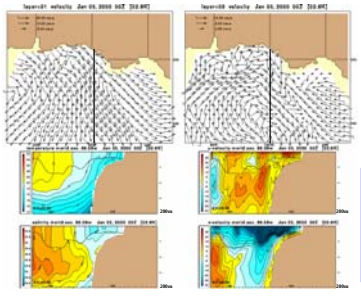
SSH nowcast (Jan. 21, 2004) in the GoM from 1/12° assimilative Atlantic model. White/black line is the frontal analysis of MCSST observations performed at the Naval Oceanographic Office. Black line represents data more than 4 days old.



SST time series from 1/12° Atlantic HYCOM compared to observed SST from NBDC buoy In the northern Gulf of Mexico (26°N, 94°W).

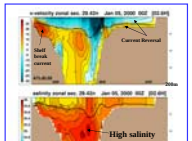
The section below is the same as the lower right hand panel in the figure to the right, except that the vertical coordinate surfaces are overlain. Note the vertical coordinate is isopycnal in the deep stratified ocean, z level in the unstratified mixed layer, and sigma (terrain following) in shallow water.





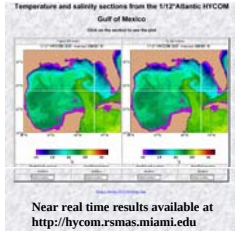
Snapshot of surface currents (upper left) and layer 9 currents (the 25.28 isopycnal surface) in the northern Gulf of Mexico on Jan. 5, 2002. The surface currents show brisk southward flow in response to northerly wind forcing but the layer 9 currents (variable depth, see figure to left) shows eastward flow along the shelf break.

Meridonal cross sections of temperature and salinity (left) and u and v velocity along 86°W. North is to the right. Outcropping of colder water is evident Towards the north, which may be facilitated by upwelling along the slope front as indicated by the northward vertical velocity (yellow) along the slope as shown in the bottom right panel.



Cross section of v velocity and salinity along 29.4°N. Note the current reversal with depth over the west Florida Shelf and the core of high salinity water at about 100m depth

Near Real Time Results Available!



Near real time results available at http://hycom.rsmas.miami.edu

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