On the use of GODAE products to improve coastal simulations in the northern Gulf of Mexico

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Summary

The coastal and shelf areas on the Northern Gulf of Mexico (NGoM) are subject to intense interactions with offshore flows, namely the Loop Current (LC), the Loop Current warm core eddies (LCEs) and the Loop Current frontal eddies (LCFEs). A nesting modeling approach is thus necessary to represent coastal to offshore interactions. Furthermore, the realistic representation of the extension of the Loop Current (and hence its proximity to the NGoM), as well as the position and size of the eddies approaching the shelfbreak require boundary conditions from a data assimilative regional model.

A high resolution (1/50°) model has been developed for the Northern Gulf of Mexico region, based on the Hybrid Coordinate Ocean Model (HYCOM) and hence called the NGoM-HYCOM model. It is nested within the regional, data assimilative Gulf of Mexico GoM-HYCOM model (1/25° resolution), which employs GODAE products for boundary conditions. The study objective is to simulate the NGoM coastal flows and in particular the coastal to offshore interactions. As this is a buoyancy dominated area, attention is given to the Mississippi River plume dynamics and the interactions with both the shelf circulation and offshore flows. The numerical simulations employ realistic atmospheric forcing from the Coupled/Ocean Atmosphere Mesoscale Prediction System (COAMPS 27km). The effects of wind on the development and evolution of the Mississippi River plume are studied in detail, together with purely wind-driven currents and changes in sea level. The effect of strong topographic features, such as the DeSoto canyon are also addressed. Process oriented simulations in the absence of wind forcing produce coherent shelfbreak flows eastward of the Mississippi River delta, which are able to transport the Mississippi River plume eastward onto the deep areas of the DeSoto Canyon, where the plume waters may interact with mesoscale eddies and be subject to offshore removal. Alongshore coastal flows are observed over the shelf in the presence of eastward/westward winds, which is followed by set-up and set-down of sea surface height and also alongshelf transport of Mississippi River waters.

Successful simulations of circulation in the Northern Gulf of Mexico require improvements in the outer, GoM-HYCOM model. Satellite products are employed to demonstrate improvements in the prediction of the Loop Current extension and the associated eddy field through data assimilation. These products include ocean color data, time series and maps of Sea Surface Temperature (SST), Sea Surface Temperature Residuals (SSTR), Sea Height Anomaly (SHA) and Sea Height Residuals (SHR) and spectrum and wavelet analyses of the SSTR and SHR time series. Model validation includes comparisons of the LC frontal location, based on the depth of the 20° C isotherm, derived by temperature profiles obtained from the GoM-HYCOM model and derived from satellite altimetry observations.

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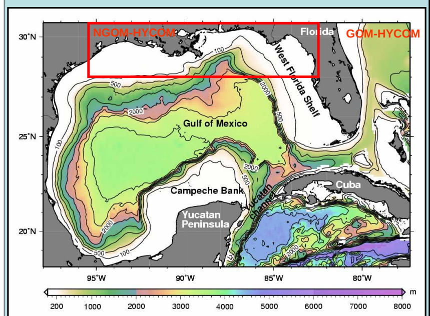
Downscaling GODAE products



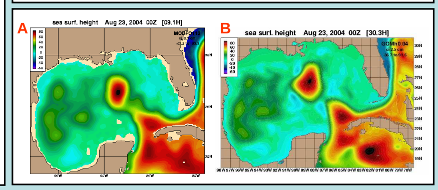
GOM-HYCOM (nested in ATL-HYCOM)

- 1/25˚ hor. resolution
- 20 vertical levels
- NCODA data assimilation (Cummings, 2005)

NGOM-HYCOM (nested in GOM-HYCOM)

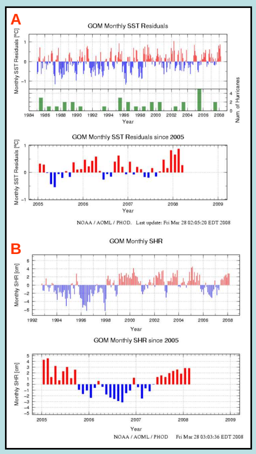
- 1/50° hor. resolution
- 20 vertical levels
- No data assimilation
- nDBDB2 bottom topography with 2m minimum water depth

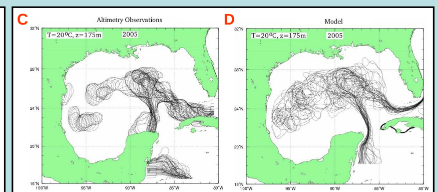
The 1/12° ATL-HYCOM (GODAE model, panel A) domain has a minimum water depth of 20m and assimilates gridded surface fields only. The 1/25° GOM-HYCOM model uses the GODAE boundary conditions (Kourafalou et al., 2008) and the Navy Code for Data Assimilation (Cummings, 2005) to improve the simulated Loop Current features (panel B). In this example, several LCFEs develop in the higher resolution GOM domain. Its higher coastal resolution also improves the impact of offshore circulation features over coastal dynamics, which is important for the nested NGoM-HYCOM simulations.



Satellite products

Different satellite derived products are used to investigate the variability in the upper layers in the GOM and to improve prediction of Loop Current dynamics. Time series of SSTR since 1984 indicates that during the last three years there have been warmer surface temperatures during the period October-March and cooler surface temperatures during the rest of the year with no significant changes during 2006 and 2007. In particular, from December 2007 until March 2008 we can see a mean SST in the GOM that is almost 1°C higher than usual (panel A). Preliminary results from a time series of SHR (sea height anomaly referenced to the monthly means) also reveals that the GOM experienced a constant cooling of its upper layer waters since mid 2005 until April 2007. Since then, the SHR exhibits an increase (panel B), a consequence of an increase in the heat storage and compatible with the positive SSTR observed for the same period.





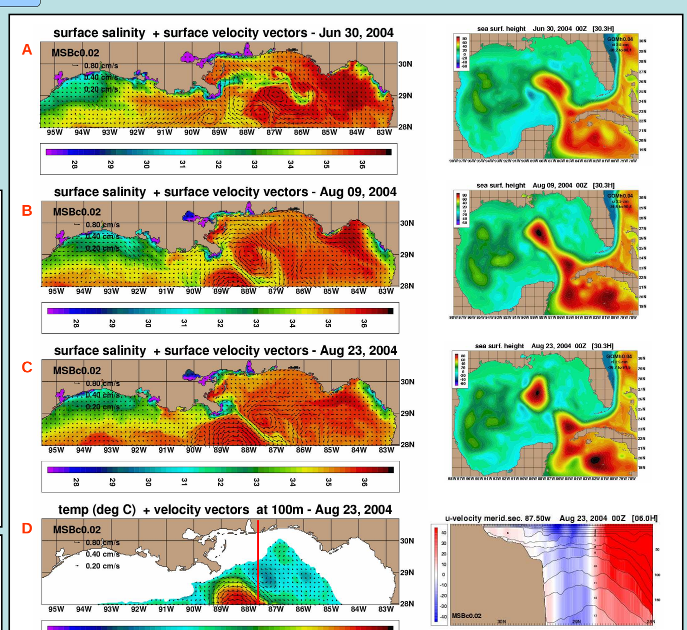
The variability of the Loop Current is also studied by implementing a methodology to determine the frontal location based on the depth of the 20°C isotherm, derived from synthetic temperature profiles obtained from satellite altimetry observations. Frontal locations were calculated from 1993 to 2007 and indicate large year-to-year variability. These results can be compared to the same frontal locations obtained from the HYCOM model. Panel C shows altimeter-derived contours of the 20°C isotherm at 175m, which are compared to the same parameter obtained with the GOM-HYCOM domain (panel D) during 2005. This type of analysis will allow to assess model outputs and study different factors controlling the dynamics of the region.

Northern Gulf of Mexico simulations

- ✓ 1 year realistic simulation (2004)
- ✓ High freq. 3-hourly COAMPS 27km atmospheric forcing
- ✓ Monthly river inflow, river plume dynamics (Schiller and Kourafalou, 2008)
- ✓ Daily lateral boundary conditions from the data assimilative GOM-HYCOM domain

Results from a realistic 1 year simulation demonstrate events of strong interaction between the Mississippi River (MR) plume and offshore circulation processes. In the absence of direct impact from an extended LC, LCEs or LCFEs (panel A), the MR plume may be transported eastward onto the shelfbreak by northward winds, where it can interact with smaller scale eddies and be entrained towards deeper regions (DeSoto Canyon). The proximity of a LCE and LCFEs to the MR delta may promote strong offshore removal of the buoyant plume. The combined circulation of a LCE and a LCFE can effectively entrain the buoyant plume. MR waters may be wrapped around a LCFE (panel B) or be directly transported to the open Gulf along the edge of a LCE (panel C).

The passage of LCFEs also promotes enhanced upwelling over the DeSoto Canyon region (panel D). Strong temperature contrast is observed between the warmer LCE and the upwelled colder waters. The shelfbreak flow structure is characterized by westward currents with little or no reversal with depth.



Vertical cross-section along the red line

References:

Cummings, J.A., 2005. Operational multivariate ocean data assimilation. *Quart. J. Royal Met. Soc.*, 131, 3583-3604.

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