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High Resolution Modeling of the Gulf of Mexico

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ABSTRACT

An advanced high-resolution numerical ocean model is employed to investigate the dynamics and physical characteristics of the deep and shallow circulation in the Gulf of Mexico. The resolution of the ocean model (~4 km) and revolutionary hybrid vertical coordinate makes it an excellent candidate to form the ocean model core of an ocean acoustic tomography program that can provide near real-time subsurface ocean data to augment satellite data that is routinely assimilated into ocean nowcast/forecast systems. Particular attention is paid to upwelling of relatively cold water near the Yucatan Peninsula, the dynamics of cold-core cyclones and their role in the separation of Loop Current Eddies, and shelf-break processes in the northeastern Gulf of Mexico.

PRÉCIS

The surface and deep circulation in the Gulf of Mexico are explored with the HYbrid Coordinate Ocean Model (HYCOM). HYCOM uses isopycnal coordinates in the deep-stratified ocean, pressure coordinates in unstratified regions including the mixed layer, and terrain-following (sigma) coordinates in shallow coastal regions. Bleck and Boudra (1981) discuss the fundamental aspects of the hybrid approach. To avoid discontinuities at the transition between vertical-coordinate surfaces, the generalized vertical-coordinate algorithm is dynamic in space and time via the layered continuity equation. The simulations have 20 layers in the vertical and 1/12° (~8 km) or 1/25° (~4 km) horizontal resolution and are forced with 6-hourly Navy Operational Global Atmospheric Prediction System (NOGAPS) surface winds and thermal fluxes over the period 2000-2001. Boundary conditions south of the Yucatan Channel and in the Florida Straits are provided by a 1/12° Atlantic HYCOM that spans 30°S to 70°N in latitude and is also forced by NOGAPS. Both the Atlantic and Gulf of Mexico models do not assimilate oceanic data, so model data comparisons are statistical in nature, but the dynamical interpretations are still valid.

The oceanic response to several different vertical-mixing schemes has been examined, including the K-profile parameterization (KPP), Mellor-Yamada 2.5, and a method developed by the Goddard Institute for Space Studies (GISS). These schemes are described in detail in Halliwell (2004). Overall the simulation that uses the GISS vertical mixing shows the most realistic RMS sea-surface height variability when compared to RMS sea-surface height from satellite altimetry. All simulations depict a realistic Loop Current and realistic Loop Current Eddy shedding. All also show upwelling of relatively cold water near the Yucatan Peninsula that may be associated with the southward Yucatan Undercurrent (Merino, 1997) or bottom friction associated with the strong Yucatan Current against the slope on the eastern edge of the Yucatan Shelf (Cochrane, 1968, 1969). The upwelling is typically most pronounced in June.

The 1/25° simulations generate a higher number of cyclones (relative to the 1/12° simulations) that tend to orbit around the anticyclonic Loop Current Eddies. The cyclones are believed to play an important role in the detachment of Loop Current Eddies, although the mechanisms are not well understood. Loop Current Eddies separate from the Loop Current Extension about every 10 months, consistent with observations. However, "near-separation" and reattachment of Loop Current Eddies is quite common. Separated Loop Current Eddies propagate towards the west south-west for about 1 to 3 months, where they eventually frictionally dissipate due to interaction with the bottom topography in the western Gulf.

Particular attention has been paid to shelf-break processes in the northern Gulf of Mexico, where the Naval Research Laboratory has an array of 14 ADCP's deployed in both shallow (<100m) and deep (~500m) water. The measurements from these instruments will be used to calculate cross-shelf fluxes of heat and momentum, and compared to similar measurements from the model experiments. Along the shelf break just east of the DeSoto Canyon, along shelf-break currents are geostrophically balanced and the depth changes in isopycnals across the current serve as a potential-energy source for baroclinic eddies. However, changes in the deep-ocean circulation can alter the along shelf-break current. Examples where reversals in the deep-ocean barotropic currents trigger a transition of the along shelf-break currents to flow onto the shelf will be shown.

Cyclones and anticyclones are prolific in the 1/25° simulations, including the northern Gulf. A snapshot of sea-surface height and surface currents is shown in Figure 1 (left panel). The interaction of the cyclone with the shelf break at this time is typical in that the cyclones (and anticyclones) seldom cross the shelf-break front, although filaments associated with these baroclinically unstable eddies do generate cross-shelf exchange and interact with the largely barotropic flows that tend to follow the shelf-break front discussed in the previous paragraph. A cross section of the v-component of velocity and salinity are shown in the right top and bottom panels, respectively, of Figure 1. The cross section of velocity reveals that the anticyclonic Loop Current Eddy has coherent vertical structure to at least 1000 m and that the maximum core velocity on the northward flowing (western) side of the eddy is shifted at depth (to the east) relative to the surface flow. The northward flow closest to the shelf-break (~85°W), i.e., the eastern side of the cyclone suggests that at this time, the cyclone is having little impact on cross-shelf circulation, but this is not always the case. There is a subsurface salinity maximum at about 200 m in the core of the anticyclone, consistent with observations reported by Nowlin (1972) and Elliott (1982).

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14. ABSTRACT

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15. SUBJECT TERMS

Hybrid Coordinate Ocean Model; Cold-core cyclones; Loop Current Eddies; Yucatan Peninsula; Gulf of Mexico

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