High-Resolution Ocean Modeling of the Gulf of Mexico

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The Gulf of Mexico (GoM) is a dynamically unique region of the ocean. The energetic loop current and its associated large anticyclonic eddies dominate the circulation in the Gulf. In addition, the waters of the wide continental shelves are dynamically isolated from the deep ocean circulation by the shelf break. Occasional interaction and exchange of mass and water properties between the shelf water and the deep ocean are critical for the redistribution of nutrients. Typically, ocean models have specialized in simulating either the circulation offshore of the shelf break, or regionally on the continental shelf. The reason for this is the inability of vertical grids to perform well everywhere. Sigma (terrain following) coordinates perform well on the shelf where increased vertical resolution is desired in shallow water, but introduce errors in the calculation of horizontal gradients near steeply sloping bottom topography. Z-level (geopotential) coordinates eliminate this problem, but are not useful for simulating shallow water dynamics in a domain with deep water as well. This dilemma is resolved by simulating the GoM to the coastline using the Navy Coastal Ocean Model (NCOM), employing a hybrid vertical grid in which z-levels are used below a specified depth (typically the depth of the shelf break) and sigma coordinates are used above this depth (*Martin*, 2000).

The NCOM is a spatially three-dimensional time-dependent numerical physical ocean model based on the primitive equations of motion. Temperature, salinity, and three-dimensional velocity fields are predicted by the thermodynamic model, which includes a free surface and realistic bottom topography and coastline geometry. The model is forced by surface fluxes of momentum, heat and freshwater, and by rivers and flow through the open boundaries in the Caribbean Sea and Florida Strait. The third-order upwind advection scheme permits sharper fronts than those simulated with typical second order calculations.

In its current configuration, the model domain has a horizontal resolution of 1/20° between like variables on the C-grid. It encompasses the entire GoM and the Caribbean north of the Honduras bank and east to 81°W (Figure 1). The ocean's natural coastline is used as the model coastline with a 4 m minimum depth. The model has 40 vertical grid points, 20 sigma coordinates above 100 m or on the continental shelf and 20 z-levels below 100 m with stretched grid spacing.

The model is being used to simulate and study processes on the scale of a few tens of kilometers, including loop current frontal eddies, cyclonic eddies on the Bank of Campeche shelf break, frontal instabilities on the West Florida Shelf, and fronts and cross-shelf mass exchange in the western GoM (Figure 2). During the winter in the western GoM, a southward flow of cold low salinity water is evident near the coast with a sharp front near the shelf break. Pairs of cyclonic and anticyclonic eddies spinning along the continental margin set up eastward jets with depths to 1000 m and near-surface core velocities in excess of 50 cm/s. These jets transport the shelf water offshore for distances of greater than 300 km. The cold low salinity buoyant shelf water overrides the deeper more saline water resulting in a temperature inversion. These features have been observed in hydrographic measurements, satellite pigment measurements (*Biggs and Muller-Karger*, 1994), and in satellite sea surface temperature images (Figure 3).

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References

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Martin, P.J., "A description of the Navy Coastal Ocean Model Version 1.0", NRL Report: NRL/FR/7322-009962, Naval Research Laboratory, Stennis Space Center, MS, 39 pp., 2000.

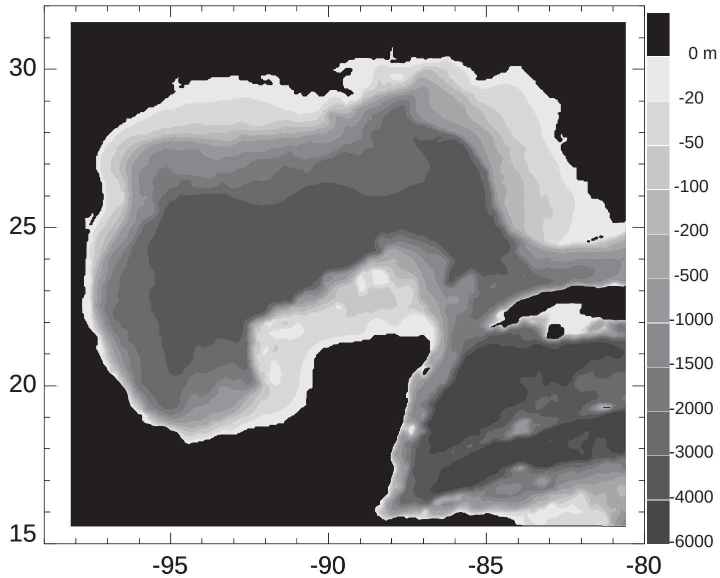

Figure 1. Bathymetry of the NCOM Gulf of Mexico simulation.

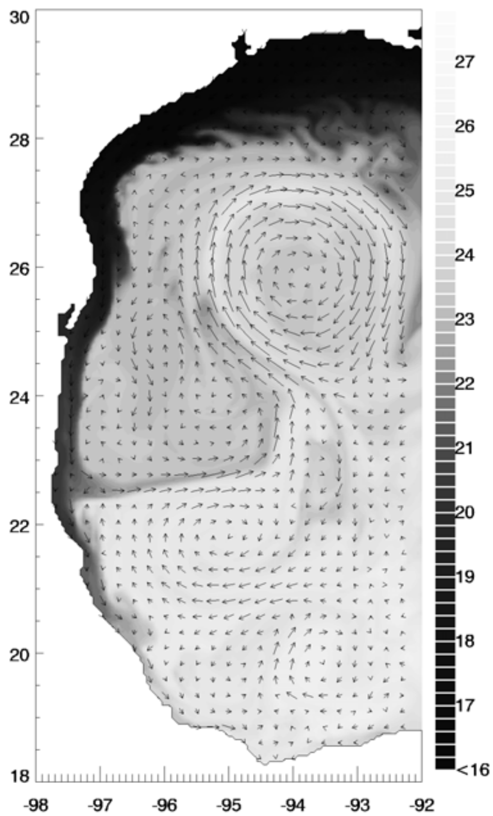

Figure 2. Modeled currents and temperature (C) of the topmost grid cell on January 9 of a year foced by climatological surface fluxes and river input.

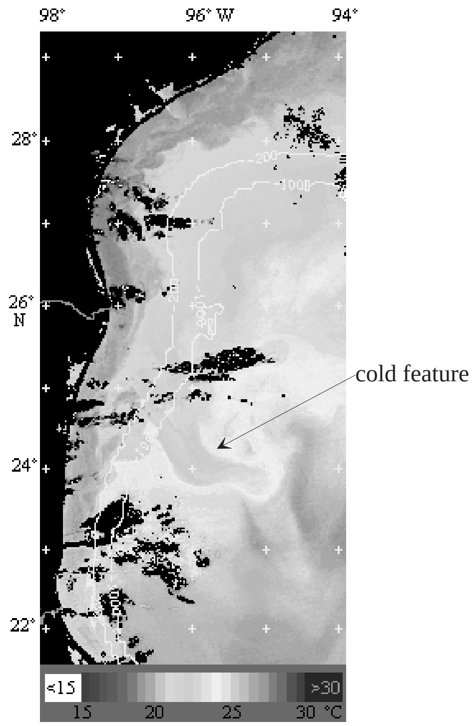

Figure 2. Sea surface temperature image from NOAA-AVHRR on 3/21/97. Image produced by Agustin Fernandez of UNAM, Instituto do Geografia. Lab. de Observacion de la Tierra.