Vertical resolution impacts on modeled Gulf of Mexico Loop Current Eddies

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1. Introduction

This study examines the role vertical resolution plays in simulating the Loop Current Eddie (LCE) formation, propagation, and decay in an ocean model. It is quite possible that even the highest vertical resolution models published to date are not adequately resolving the large vertical gradients associated with the energetic Loop Current (LC) and LCEs, nor are adequately resolving near-bottom processes that may affect the upper ocean circulation. The impacts of vertical resolution are studied with the Navy Coastal Ocean Model (NCOM) configured to realistically simulate the GoM. Experiments are run with differing vertical resolutions and the eddy behavior in the solutions is examined.

Results suggest that higher vertical resolution simulations produce a more variable eddy field, and stronger LCEs. The propagation pathways appear more realistic compared to Topex/Poseidon satellite altimeter observations. In the lower vertical resolution simulation, LCEs tend to decay more preferentially in the northwestern corner of the GoM resulting in an unrealistically permanent anticyclone. This anticylonic feature is much weaker in the higher vertical resolution simulation.

2. The Model

The NCOM is a three-dimensional primitive equation hydrostatic ocean model developed at the Navy Research Laboratory [*Martin*, 2000]. The model's hybrid sigma (terrain following) and z (geopotential) level vertical coordinate is useful for simulating upper ocean processes in domains encompassing both deep ocean basins and very shallow shelves. The NCOM is set up to simulate the entire GoM and Caribbean north of Honduras (15.55°N) to 80.6°W with 1/20° between like variables on the C-grid, 20 sigma levels above 100 m and either 20 or 40 z-levels below 100 m to a maximum depth of 4000 m [*Morey et al.*, 2003]. The model is forced by discharge from 30 rivers, transport through the open boundary (with monthly climatology temperature and salinity) yielding a mean transport through the Yucatan Strait of approximately 27 Sv ($10^6 m^3 s^{-1}$), and monthly climatology surface heat and momentum flux. A surface salinity flux has the effect of uniformly evaporating an amount of water at a rate equal to the sum of the annual average discharge rates of the 30 rivers. The model is run for 10 years for each experiment, with the last seven years used for analysis.

3. Results

The variance of the model sea surface height (SSH) shows highest values in the region of the LC retroflection and LCE separation (Fig. 1). A region of high SSH values stretch westward from the LC across the GoM near the latitude band of 23°N to 28°N, showing the preferred westward propagation pathways of the shed LCEs. The 60 level experiment shows much larger values of the SSH variance, with a more pronounced maximum near the LC retroflection, and a less pronounced secondary maximum in the northwestern corner of the GoM than the 40 level experiment.

The mean SSH (surface deviation from a resting level) maps from the two GoM experiments both show a high in the northwestern corner of the GoM, indicating a preferred location for the anticyclonic LCEs to reside. The 40 level experiment has relative maxima here of over 30 cm, compared to less than 20 cm for the higher vertical resolution 60 layer experiment. The mean SSH scaled by the standard deviation is less than 1.0 in the 60 level experiment, indicating that the anticyclone is not a permanent feature at this location. However, in the 40 level experiment, the SSH mean scaled by the standard deviation is greater than 3.0 in the northwestern GoM suggesting a nearly permanent anticylonic feature exists here. Although an anticyclone is evident in the mean dynamic topography from historical data, observations do not support that this is a permanent feature. Thus, the higher vertical resolution experiment seems to simulate a more realistic eddy field in the western GoM.

The sea level variability across a line coincident with a Topex/Poseidon satellite altimeter (T/P) ground track is compared between NCOM GoM simulations and T/P data (Fig. 3). LCEs cross this track as they propagate westward from the Loop Current. The sea surface height variance versus latitude plot gives some indication of the eddy strength and preferred propagation path. The results show weaker than expected sea level variability across this track in the 40 level experiment, and much better agreement in the near-twin experiment with 60 vertical levels.

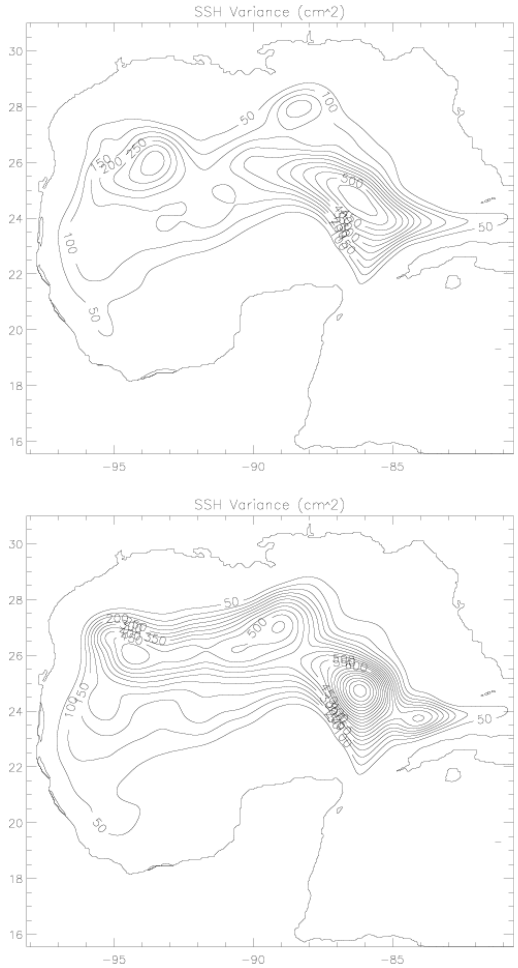

Fig. 1. Variance (cm^2) of the model SSH from the 40 level experiment (top) and the 60 level experiment (bottom). The contour interval is 50 cm^2.

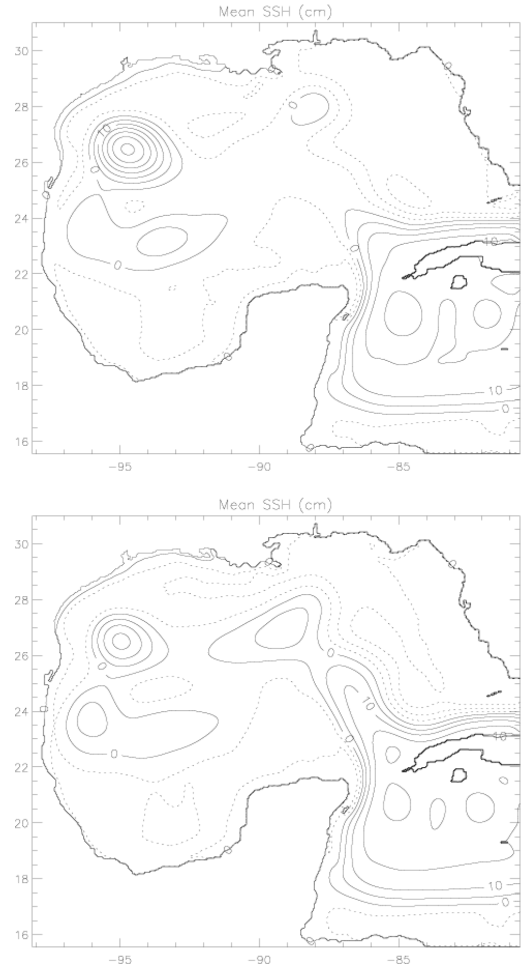

Fig. 2. Model mean SSH (cm) from the 40 level experiment (top) and the 60 level experiment (bottom). The contour interval is 5 cm and negative values are indicated by dotted contour lines.

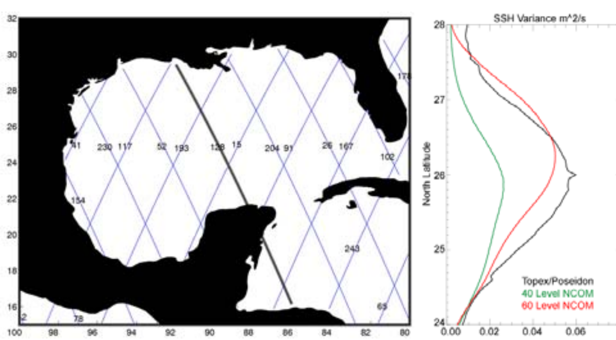

Fig. 3. Right: Variance of the sea surface height versus latitude for seven years of data across T/P ground track 128 shown highlighted at left. Black curve: Topex/Poseidon altimeter. Green curve: 40 level simulation. Red curve: 60 level simulation.

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