Eddy Variability Along the Florida Keys

Cesar R. Bulhões de Morais[1], V. Kourafalou and H. Kang
Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL
[1]cmorais@rsmas.miami.edu

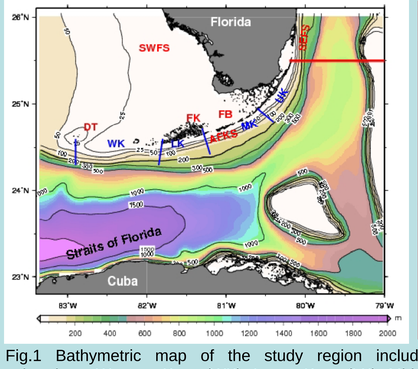
Summary

The Florida Keys Coastal Zone is a narrow, curving shelf with complex topography, especially because of its shallow coral reef tract. This region is affected by the Florida Current (FC) with its meanders and eddies. The FC is part of a complex ocean circulation that includes the Loop Current (LC) at the Gulf of Mexico. Understanding the physical mechanisms that drive water exchanges is this area is an important tool to marine resource managers' strategies. These tools include providing model predictions of currents to support management tactics in response to ecological disasters. A recent example involves the Deepwater Horizon oil spill that may affect the Florida Keys fragile ecosystem.

This study employs hydrodynamic parameters from three-dimensional fields generated by numerical simulations using a multi-nested, high resolution (~900m) regional application of the Hybrid Coordinate Ocean Model (HYCOM). The eddy identification method consists of analysis of velocity, temperature, Sea Surface Height maps, in tandem with the Okubo-Weiss parameter to identify and characterize the cyclonic eddies. The domain was divided in four subregions according to flow properties, physical characteristics and species composition to facilitate this analysis. Using this approach it is possible to identify if there is a preferred location for eddy formation along the Florida Keys.

A total of 394 eddies were identified and tracked in the domain. Estimating the baroclinic Rossby radius of deformation at ~30 km in this region, 205 mesoscale (diameter larger than 30 km) and 210 submesoscale (diameter less than 30km) cyclonic eddies were identified in the Florida Keys (FKEYS) domain throughout the five years (2004-2008). A histogram showing eddy activity on each subarea reveals that the mesoscale eddy activity is dominant in the Western Keys, while submesoscale activity is dominant in the Upper Keys. Wavelet analysis of surface currents in the Western Keys and Upper Keys give similar results. It was also observed that the Florida Current location and the topographic constraints affect eddy evolution.

Florida Keys Hybrid Coordinate Ocean Model (FKEYS-HYCOM)



FKEYS-HYCOM:
Resolution ~ 900 m
- **nested in the real time, data assimilative, lower resolution (~3.5 km) Gulf of Mexico GoM-HYCOM**
- **Topographic details in shallow Florida Keys areas; tides included**
- **Atm. Forcing: COAMPS 27km**
- **Now extended to provide real time forecasts (South Florida and Florida Keys SFFS-HYCOM)**

Fig.1 Bathymetric map of the study region including Florida Keys subregions: Western Keys (WK), Lower Keys (LK), Middle Keys (MK) and Upper Keys (UK).

Modelling in high resolution

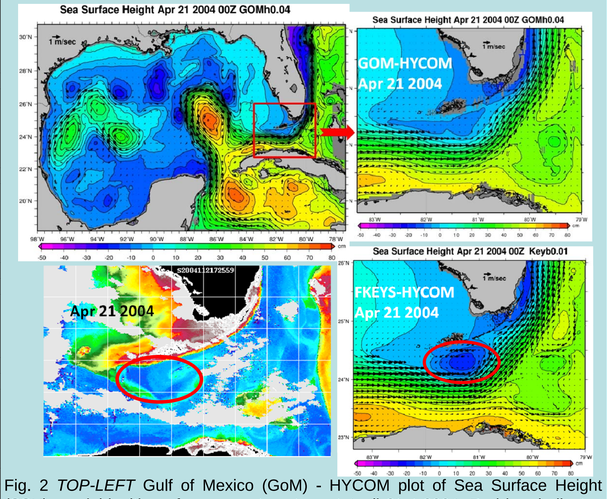


Fig. 2 *TOP-LEFT* Gulf of Mexico (GoM) - HYCOM plot of Sea Surface Height (SSH) overlaid with surface current vectors at April 21st 2004. Red box indicates the area covered by the FKEYS-HYCOM domain.
TOP-RIGHT SSH overlaid with surface current vector map from GoM-HYCOM simulation zoomed in the area covered by the FKEYS-HYCOM domain.
BOTTOM-LEFT Chlorophyll-A satellite image from SeaWiFS *(provided by C. Hu, IMARS/USF)* showing a cyclonic eddy (red circle).
BOTTOM-RIGHT FKEYS-HYCOM plot of SSH overlaid with surface current vectors map. Red circle highlights the cyclonic eddy, in good agreement with the ocean color data.

➢The FKEYS-HYCOM much finer grid, more detailed topography and high-resolution forcing enables reproducing observed features observed (which are missing in regional and global models).

Eddy characteristics

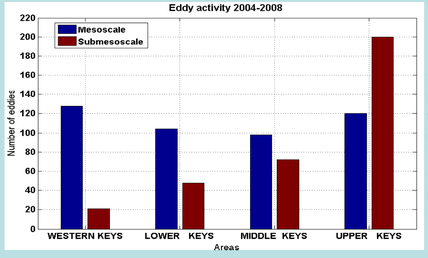


Fig. 3 Histogram showing the presence of eddies sorted by size in each subarea of the Florida Keys (FKEYS-HYCOM domain) from 2004 to 2008.

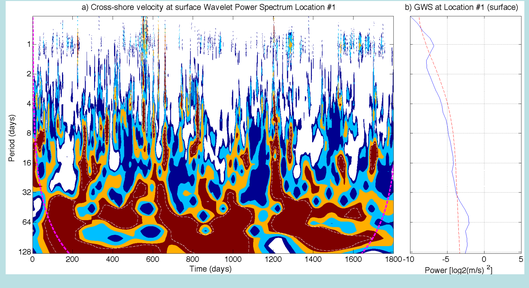


Fig. 4 (a) Local Wavelet Power Spectrum of cross-shore velocity at the surface using Morlet wavelet, normalized by $1/\sigma^2$ (σ^2=0.0111m^2/s^2). The left axis is the Fourier period (in days) corresponding to the wavelet scale on the right axis. The bottom axis is time (days). The shaded contours are at normalized variances of 1, 2, 5 and 10. The white dashed contours enclose regions of greater than 95% confidence for a red-noise process with a lag-1 coefficient of 0.6821. Magenta line indicates the "cone of influence", where edge effects become important.

(b) Global Wavelet Spectra (GWS) is the time average of the wavelet power spectrum. The dashed red line is the 95% confidence level, equal to (95%) times the mean spectrum.

➢The energy associated with cross-shore current fluctuations in the western Keys is primarily grouped in the 32-100 days period with peak energy centered around the 64 day period.

Eddy merging

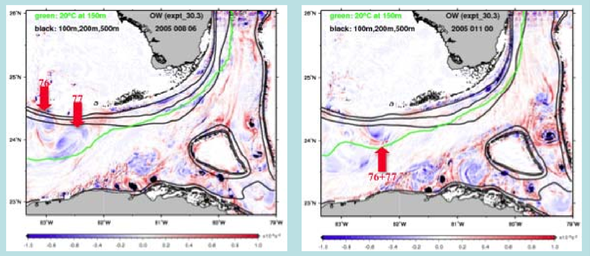


Fig. 5 LEFT Okubo-Weiss parameter plot showing eddies #76 and #77 before merging. Green solid line indicates the location of the Florida Current front. Black solid lines are 100m, 200m and 500m isobaths.
RIGHT Okubo-Weiss parameter plot showing eddy #76+77 after merging.

➢Eddy evolution along the Florida Keys is influenced by eddy-to-eddy interactions like merging.

Eddy splitting

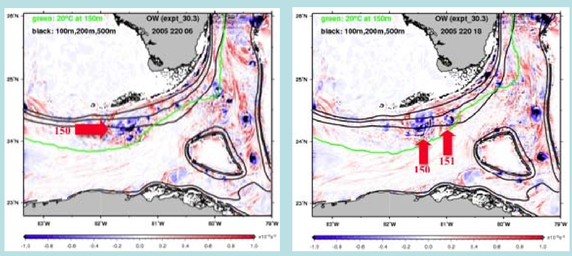


Fig. 6 *LEFT* Okubo-Weiss parameter plot showing eddy #150 before splitting. Green solid line indicates the location of the Florida Current front. Black solid lines are 100m, 200m and 500m isobaths.
RIGHT Okubo-Weiss parameter plot showing eddy #151 formed by splitting of eddy #150.

➢Another process influencing eddy evolution along the Florida Keys is eddy splitting.

Eddy interaction with topography and the Florida Current

Eddy moving along isobaths

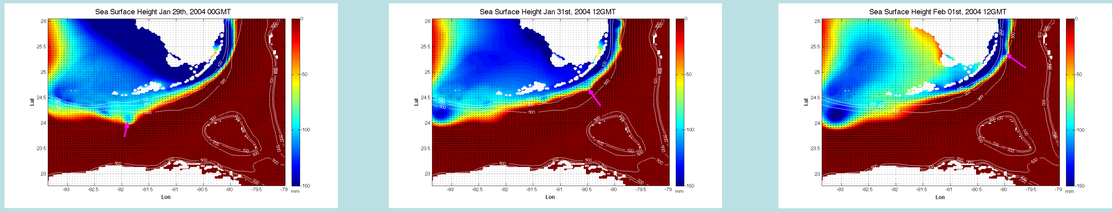


Fig. 7 FKEYS-HYCOM SSH and surface current vector maps showing a cyclonic eddy moving along the shallow isobath lines without significant changes in characteristics (100m, 200m and 500m isobaths are marked with white lines). Eddy #8 location is indicated by the magenta arrow.

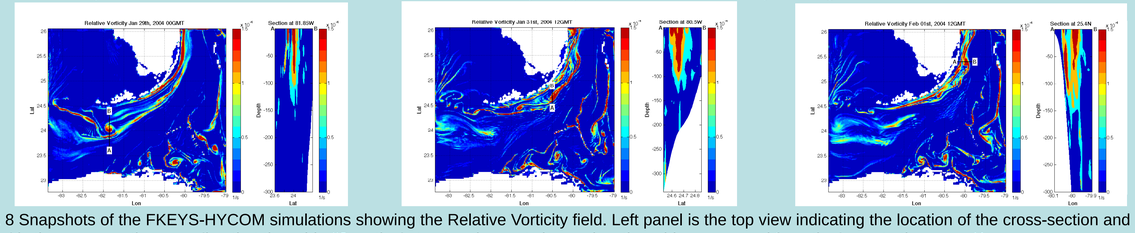


Fig. 8 Snapshots of the FKEYS-HYCOM simulations showing the Relative Vorticity field. Left panel is the top view indicating the location of the cross-section and right panel is the cross-section revealing that the eddy #8 vertical structure has not changed as the eddy progressed from the lower to the upper Keys.

Eddy moving across isobaths

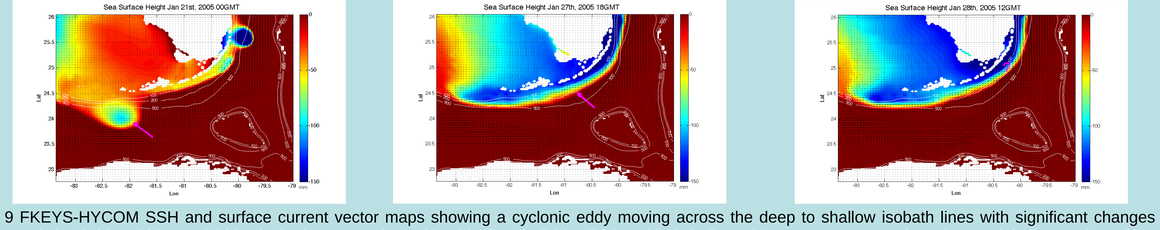


Fig. 9 FKEYS-HYCOM SSH and surface current vector maps showing a cyclonic eddy moving across the deep to shallow isobath lines with significant changes in characteristics (100m, 200m and 500m isobaths are marked with white lines). Eddy #78 location is indicated by magenta arrow. Question mark indicates that #78 was sheared apart.

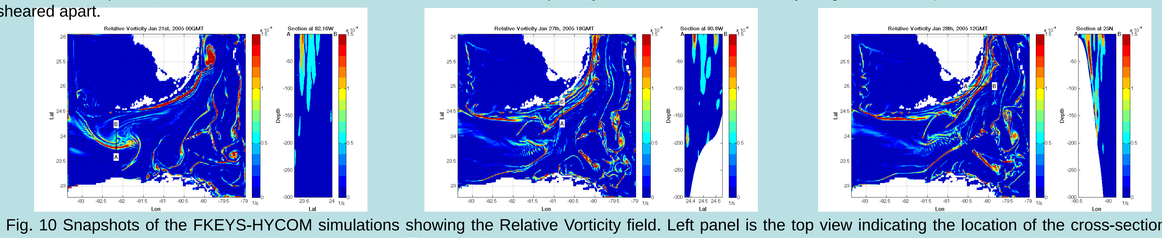


Fig. 10 Snapshots of the FKEYS-HYCOM simulations showing the Relative Vorticity field. Left panel is the top view indicating the location of the cross-section and right panel is the cross-section revealing that the eddy #78 vertical structure changed significantly as the eddy progressed downstream – apparently due to interaction with the shallow topography in the middle Keys (where the shallow isobaths extend offshore, see Fig. 1), under the conservation of potential vorticity principle.

➢When cyclonic eddies enter the Florida Straits at shallow depths (or are small in size), topographic effects are minimal; when they enter through the deep areas, they are subject to changes in their characteristics, as they are forced to cross isobaths, in close synergy with the meandering Florida Current.