# A baroclinic, regional West Florida Shelf model nested in a 1/12° North Atlantic HYCOM model, inclusive of tides

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## 1 Introduction

The West Florida Shelf (WFS) is characterized by a wide shelf extending about 300 km followed by a steep shelf slope. The dynamics on the shelf are mainly driven by winds and atmospheric heat fluxes. Northerlies and north-westerlies winds produce an upwelling along the Florida west coast. Since the surface heat flux controls the stratification, the Ekman dynamics are also influenced by the atmospheric heat input. Accurate local forcings are therefore believed to be a crucial ingredient for modeling the WFS.

Beyond the shelf break, the variability is dominated by the Loop Current. Baroclinic instabilities modulate the path of this current. Occasionally the Loop Current hits shallow isobaths near Dry Tortugas generating topographic Rossby waves moving northward along the shelf break. Through this mechanism, deep water can be advected onto the shelf (He and Weisberg, 2003b, Weisberg and He, 2003).

To study these combined effects of local and deep-ocean forcing we constructed a baroclinic WFS ROMS model nested in the North Atlantic HYCOM (Barth et at., 2006). Here we include tides, assess the accuracy against coastal tide gages, and study the impact of tides on the subtidal flow.

## 2 WFS ROMS model

| | |
|---|---|
| Physics | hydrostatic 3D primitive equations, free surface |
| Model | ROMS 2.0 (e.g. Shchepetkin and McWilliams, 2005) |
| Topography | modified ETOPO5 merged with HYCOM |
| horizontal grid | curvilinear grid with 4 km resolution near the coast and 10 km resolution at the open boundary |
| vertical grid | 32 s-coordinates |
| Atmospheric forcings | • NCEP EDAS wind merged with *in situ* wind buoys (Alvera-Azcárate, 2006, poster OS15C-06).<br>• NOGAPS thermodynamic forcing (air temperature, relative humidity, cloud fraction and short wave radiation)<br>• Heat flux correction by optimal interpolated SST (AVHRR, GOES, MODIS and TMI). |
| Open boundary conditions | • temperature, salinity and velocity from operational 1/12 degree North Atlantic HYCOM<br>• tidal elevation and currents |
| Initialization | from HYCOM |
| River | Climatological river runoff (Mississipi River, Mobile River, Apalachicola River, Suwannee River, Hillsborough River, Caloosahatchee River , Shark River) |

## 3 Open boundary

### 3.1 Tidal boundary conditions

Different tidal models are tested in this study:

- Global Oregon State University (OSU) TPXO 6.2, Egbert et al, 1994. The components used are M2, S2, N2, K2, K1, O1, P1 and Q1.
- Regional OSU Gulf of Mexico. This tidal solution contains only M2, S2, K1 and O1.
- ADCIRC, 2001 2v1 (Mukai et al, 2001). The components used are M2, S2, N2, K2, K1, O1 and Q1.

For the barotropic boundary conditions the information from the ocean general circulation model and the tidal model are simply added.
The elevation:

$$\zeta_b = \zeta_{\mathrm{OGCM}} + \zeta_{\mathrm{tides}} \qquad (1)$$

The barotropic velocity:

$$\mathbf{V}_b = \mathbf{V}_{\mathrm{OGCM}} + \mathbf{V}_{\mathrm{tides}} \qquad (2)$$

The boundary elevation is included as a Chapman boundary condition:

$$\zeta_b^{n+1} = \frac{\zeta_b^n + \mu_e \zeta_{b+1}^{n+1}}{1+\mu_e} \qquad (3)$$

where $\mu_e = \sqrt{gH}\frac{\Delta t_e}{\Delta y}$ and the barotropic velocity is imposed as a Flather boundary condition:

$$\mathbf{V}_b + \sqrt{\frac{g}{H}}\zeta_b = \mathbf{V}_e + \sqrt{\frac{g}{H}}\zeta_e \qquad (4)$$

### 3.2 Large scale boundary conditions

NAT HYCOM provides large scale boundary conditions of sea surface height, temperature, salinity and velocity.

Temperature, salinity and velocity are nudged towards the NAT HYCOM (Bleck, 2002) fields over a transition zone (flow relaxation scheme).

$$\frac{\partial T}{\partial t} = .... + \alpha(\boldsymbol{x})(T - T_{OGCM}) \qquad (5)$$

Where $T$ is the temperature, salinity or one component of the internal horizontal velocity. $T_{OGCM}$ is the corresponding variable of the large scale model, here the 1/12° North Atlantic HYCOM model. The flow relaxation coefficient $\alpha(\boldsymbol{x})$ depends on the distance to the open boundary. It decreases smoothly from its maximum value at the boundary (0.1 days) towards zero over a distance of 100 km.

## 4 Results of a 3-month run

### 4.1 Sea level

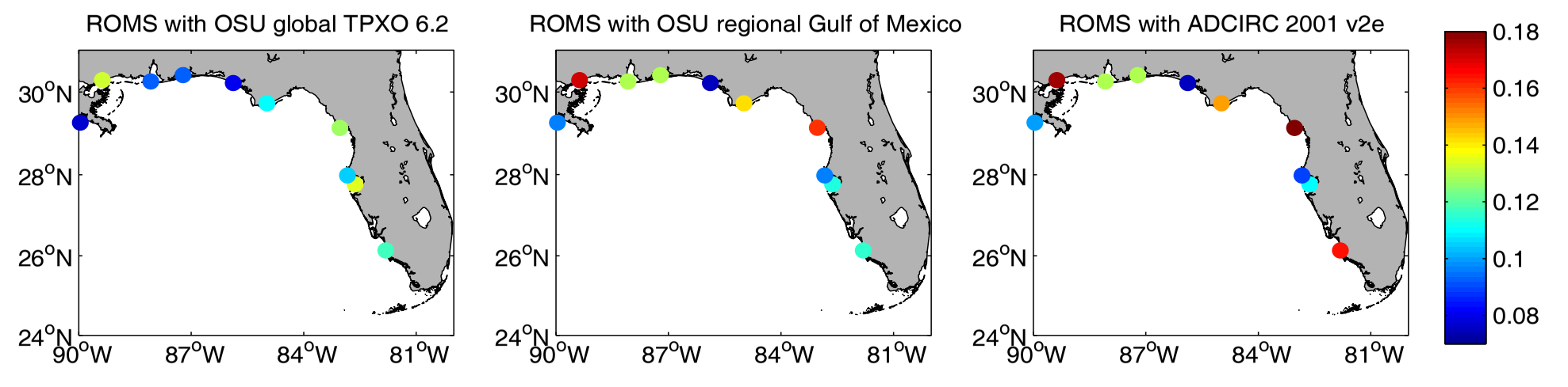
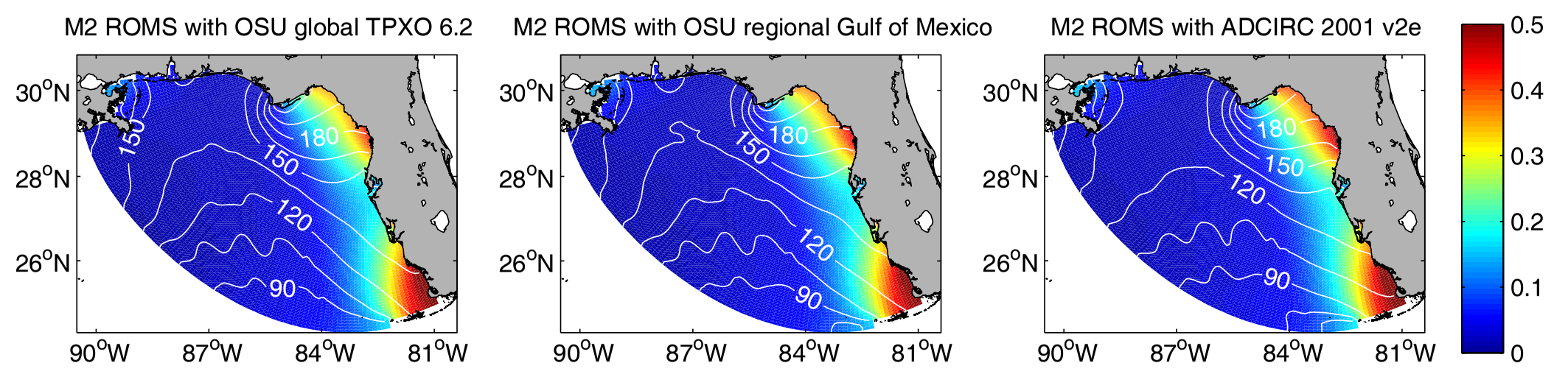


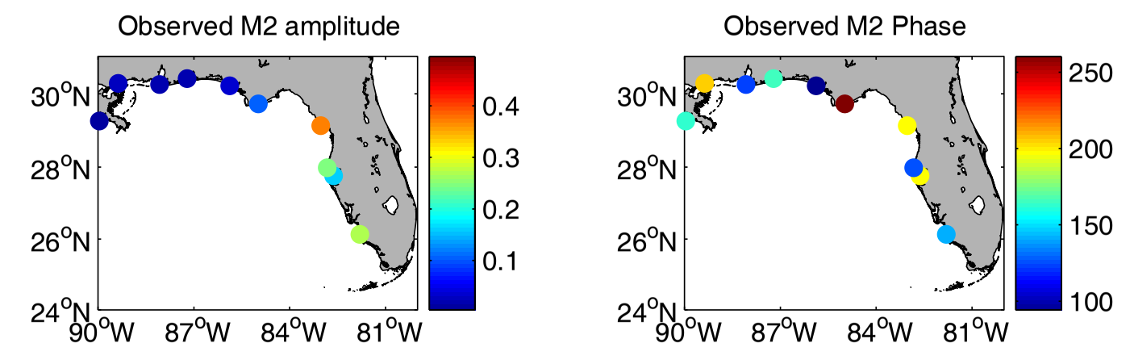
Figure 1. The sea level of WFS ROMS forced by the three tidal models, plus local and deep-ocean fluxes, is compared to observed sea level at various stations. The color represents the RMS error in meters. The following table shows the spatially averaged RMS error and mean correlation. The best results were obtained with the global TPXO 6.2 forcings.

| Tidal Model | Mean CRMS (m) | Mean Corr. |
|---|---|---|
| ROMS with TPXO 6.2 | 0.107 | 0.89 |
| ROMS with GoM | 0.129 | 0.84 |
| ROMS with ADCIRC | 0.130 | 0.84 |

### 4.2 Amplitude and phase

#### 4.2.1 Constituent M2

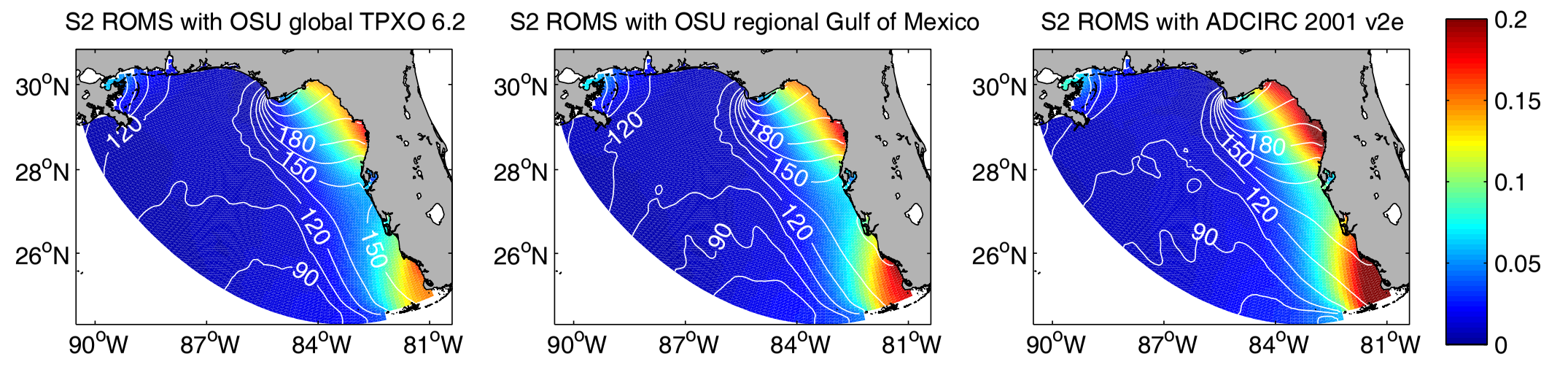


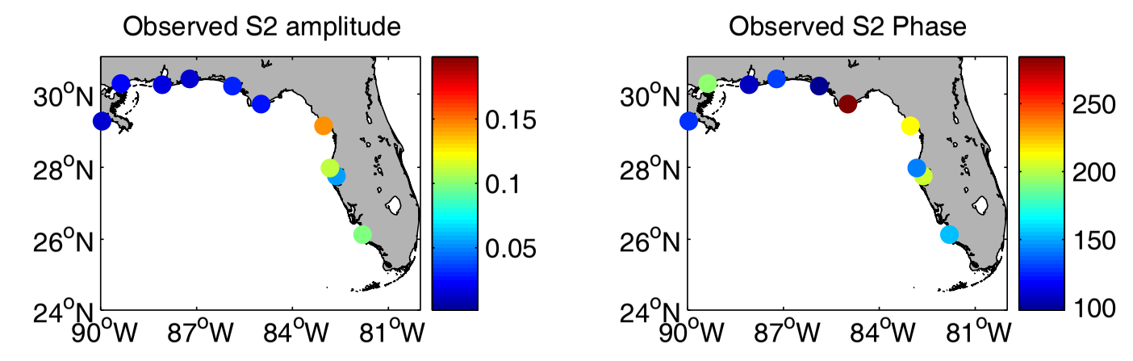


The ROMS forced by TPXO and GoM tidal solution correctly predicts the M2 amplitude in Florida's Big Bend while the amplitude of ROMS forced by ADCIRC is slightly larger than observed.

The phase of the three model simulations is very similar. The difference between the observed phase and the modeled phase is probably mainly due to the local topography and coastline not resolved by the model.

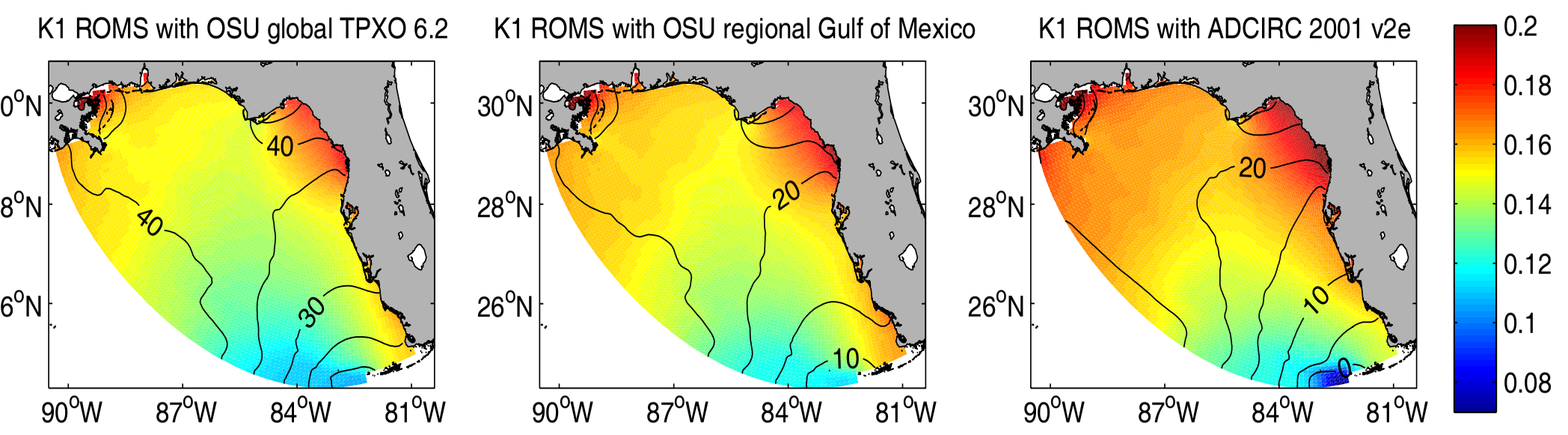
#### 4.2.2 Constituent S2

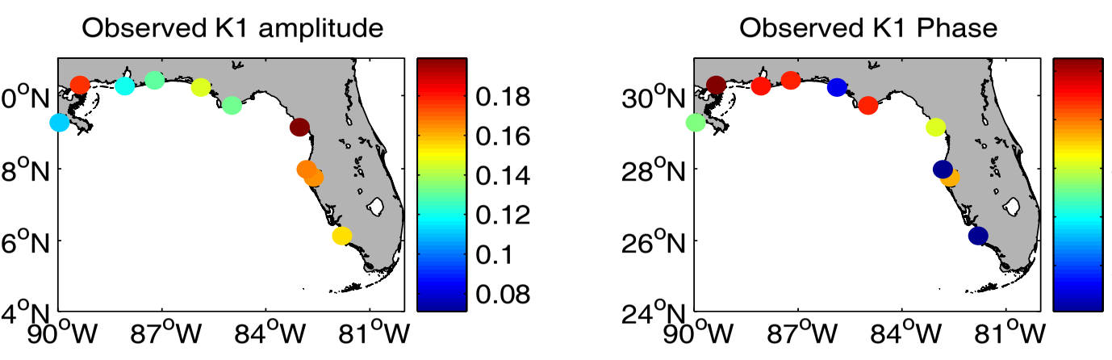




The amplitude and phase pattern of the S2 tide is similar to the M2 tide. Again, ROMS with ADCIRC slightly overestimates the amplitude in Florida's Big Bend and ROMS with TPXO 6.2 gives the best results. In this region the S2 and M2 cophases are almost perpendicular to the coast and the amplitudes are rapidly decaying far from the coast. This indicates that refractive effects lead to local Kelvin wave propagation in this region.

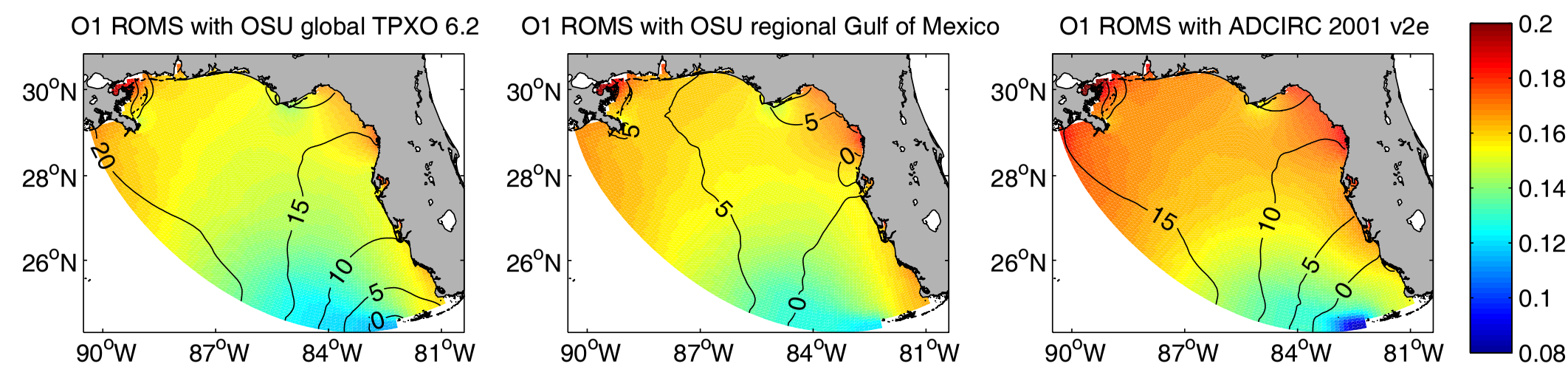
#### 4.2.3 Constituent K1

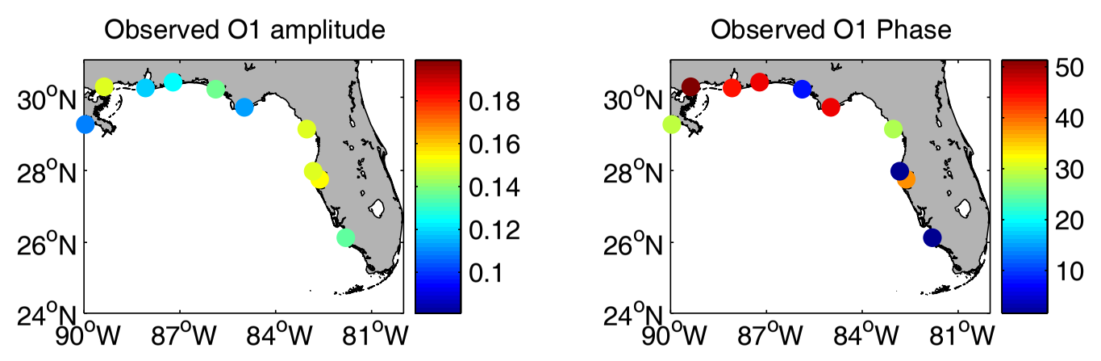




ROMS forced by the ADCIRC tidal solution is now closer to the observed amplitudes in Cedar Key and Clearwater while the global TPXO and regional GoM tidal solution underestimates the amplitude. The situation is different in the Florida Panhandle where all model simulations produce higher amplitudes than the observed but ROMS with global TPXO is the closest to the observed amplitude in this zone. In all model simulations, the phase is close to the observations in Florida's West coast but in Florida's Panhandle the modeled phases lag behind the observed ones.

#### 4.2.4 Constituent O1

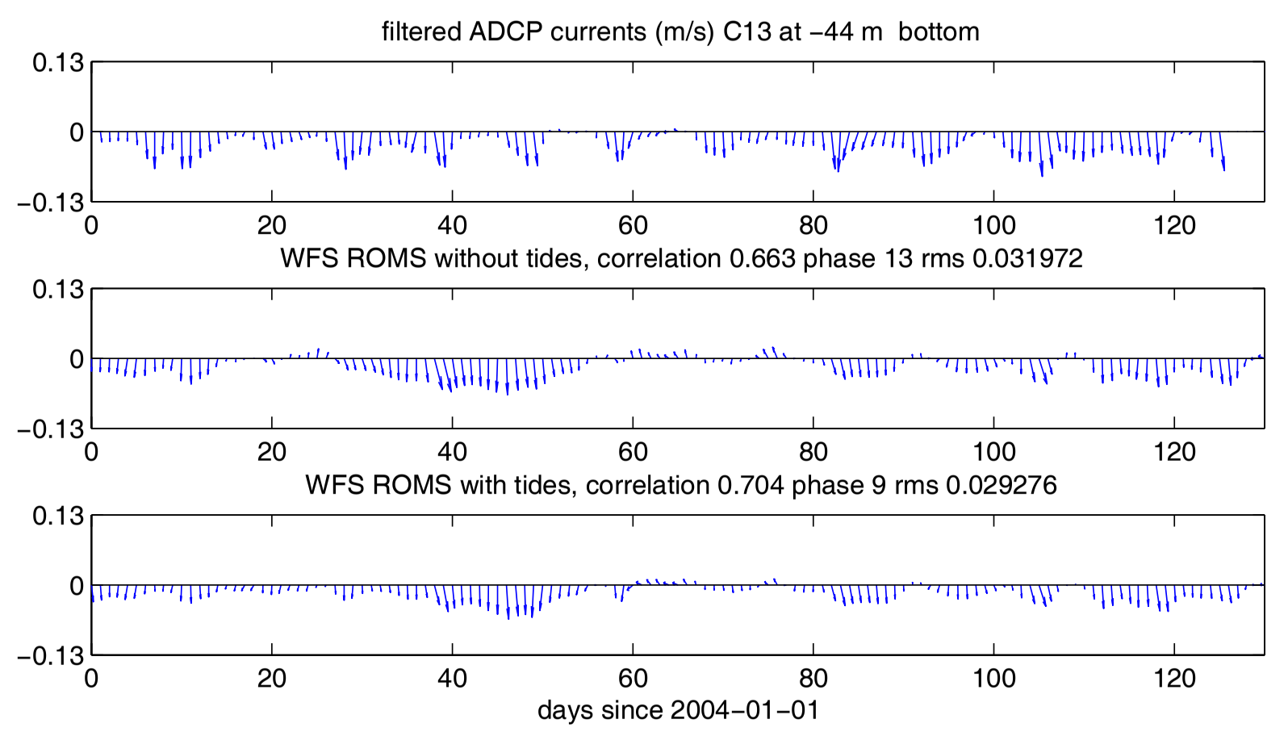




ROMS forced by ADCIRC overestimates the amplitude of O1. As previously, ROMS driven by global TPXO give the best results. These tidal constituents are comparable to the solution of He and Weisberg, 2002.

## 5 Annual simulation

### 5.1 Effects on subtidal currents



In the following simulation, only the solution forced with OSU TPXO 6.2 tides is presented. The subtidal currents were compared to various in-situ ADCP stations. We found an improvement of the subtidal currents compared to the simulation without tides.

- During winter months, the velocity is constantly directed to the south at bottom station C13.
- In the model without tides currents occasionally inverse.
- With tides, these inversions are much more weaker (possibly due to an increased bottom friction)
- Better RMS error and correlation at most stations.
- Improvement is weak (0.45 cm/s or 7%) but statistically significant.

| Bottom drag coefficient | mean RMS with tides (m/s) | mean RMS without tides (m/s) |
|---|---|---|
| 25 | 0.0646 | 0.0708 |
| 30 | 0.0648 | 0.0706 |
| 35 | 0.0623 | 0.0688 |
| 40 | 0.0628 | 0.0721 |

### 5.2 SST and surface velocity

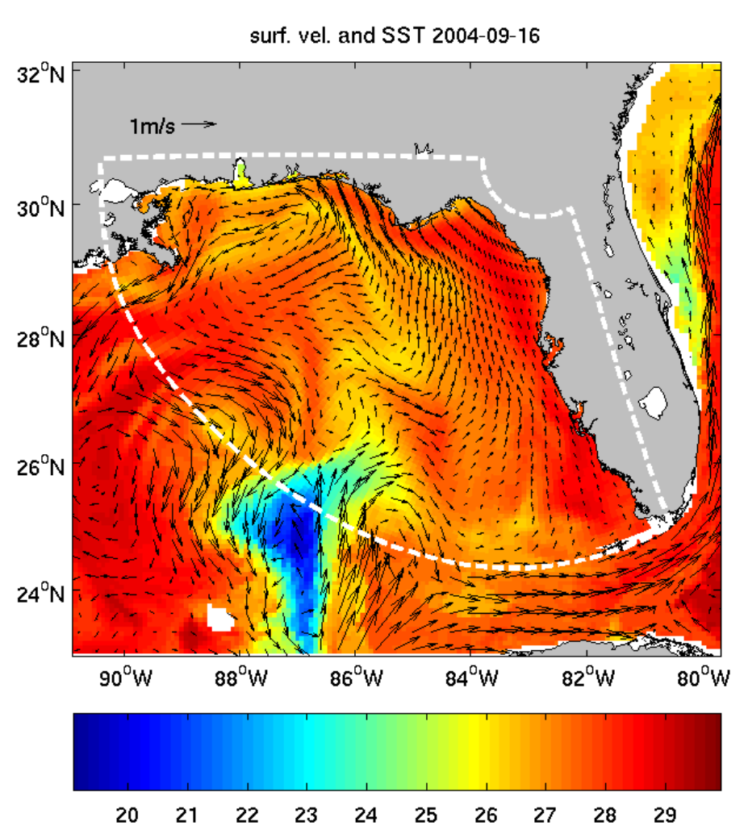


Figure 2. This image shows the SST and surface velocity of the 16 September 2004.

Inside the dashed white line, the results of the WFS ROMS are shown, outside the results of NAT HYCOM.

At the boundary, there is a smooth transition of temperature and velocity between both models .

The cold temperature patch located at 25°N and 87° W is due to Hurricane Ivan operating on a cold core eddy region embedded between the Loop Current and a detached warm core eddy. The presence of this structure has been confirmed by satellite SST from a later date.

## 6 Daily forecasts

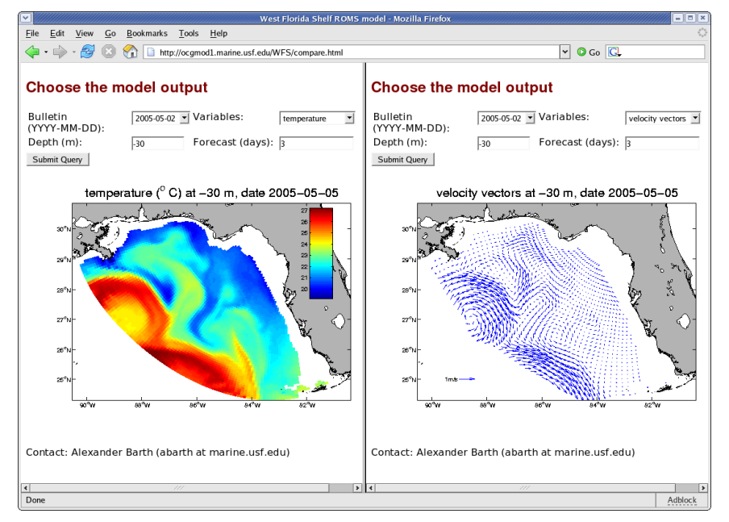


Figure 3. This model runs on a daily basis and performs a one-day hindcast followed by a 3.5-day forecast. Model results can be interactively plotted at http://ocgmod1.marine.usf.edu/WFS.

The daily forecasts do not presently include tides.

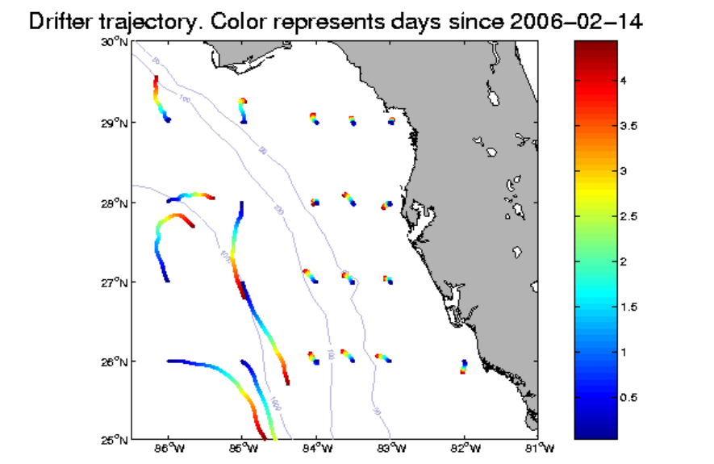


Figure 4. The computation of simulated drifter trajectories has recently be added to the other forecast fields (elevation, velocity, temperature, salinity)

## Conclusions

- The forcing functions of three tidal models have been tested for driving a regional WFS model. The global OSU TPXO 6.2 provide the most accurate results. However, by comparing the three tidal models directly to tide gage stations, the ADCIRC model is more accurate. It appears that, on one hand, the OSU TPXO model provides better tidal information for the deep ocean (at the location of WFS model open boundary). On the other hand, the ADCIRC model (using an unstructured grid) resolves better the coastline and thus represents more accurately the tides near shore.
- The inclusion of tides improve the subtidal velocity at most stations. This improvement is statistically significant and cannot be obtained by parameterizing the tides with an increased bottom drag.
- The model is able to reproduce qualitatively the surface mixing produced by Hurricane Ivan.

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