Improvement and validation of the CARICOOS ROMS ocean model

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LONG-TERM GOALS

The CARICOOS ROMS ocean model will serve not only as a regional-scale ocean model for the primary purpose of predicting surface currents, but also to provide boundary conditions for the CARICOOS FVCOM coastal ocean model. In addition the CARICOOS ROMS surface currents will also be used for particle tracking, with an emphasis on giving guidance to the U.S. Coast Guard in matters related to search and rescue operations, as well as modeling of larval transport in the region. More generally and in a longer term the CARICOOS ROMS model can also serve as a tool for the modeling of the ocean vertical structure in Puerto Rico, the U.S. Virgin Islands and the Caribbean Sea, with validation provided by ocean gliders, CTDs, and ADCP measurements.

MILESTONES / OBJECTIVES

1. Include a two dimensional radiative boundary condition and determine the optimum values for the inflow and outflow nudging timescales.
2. Include eddy viscosity to account for momentum mixing and determine the optimum eddy viscosity coefficient for the operational CARICOOS ROMS domain.
3. Combine the optimum configurations of two dimensional radiative boundary condition and eddy viscosity and validate with HF-Radar in 10 locations West and South of Puerto Rico.
4. Conduct an extensive and thorough validation of the various ROMS configurations (see Table 1) for surface elevations and surface currents (time series, contours, scatter plots, difference statistics, low pass of surface elevation, spectral analysis of time series differences, daily means).

WORK COMPLETED

All milestones and objectives were accomplished. See Table 1 for a summary of the main ROMS configurations that were used during development and validation.

Table 1. Summary of ROMS configurations used for development and validation.

Case Name	2D Radiative Boundary	1D Radiative Boundary	Nudging Factor	OBCFAC	Eddy viscosity coefficient
ROMS3.2	-	x	2	20	NA
CASE1	-	x	0.5	20	NA
UPRM Case1.rad1	x	-	0.5166	10.33	NA
UPRM Case1.rad2	x	-	0.5166	60	NA
UPRM Case1.rad3	x	-	0.5166	20	NA
UPRM Case1.rad4	x	-	0.30	30	NA
UPRM_1	x	-	0.33	30	1000 m2/s
UPRM_2	x	-	0.33	30	5000 m2/s
UTexas_1	-	x	0.50	10	NA
UTexas_2	x	-	0.50	10	1000 m2/s
UTexas_3	x	-	0.50	10	5000 m2/s

MAJOR OUTCOMES

- An artificial oscillation that was prevalent throughout the entire domain was succesfully eliminated by the inclusion of both the two dimensional radiative boundary condition with a nudging factor on outflow of 0.33 days and inflow of 10 days and the eddy viscosity coefficient of 1000 and 5000 m2/s. It was found that the eddy viscosity of 1000 m2/s was enough to eliminate this oscillations at some locations in Mona Passage while at others 5000 m2/s was needed, indicating that a spatially-varying eddy viscosity coefficient would be the preferred configuration. Figure 1 shows the signature of this artificial oscillation, which was found to have a frequency of about 4 cycles per day (Figure 2).

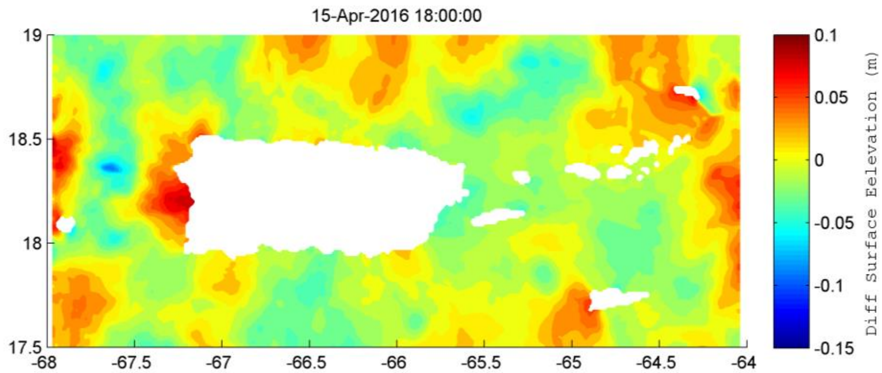

Figure 1. Difference in surface elevation between CASE1 and UPRM_1. Notice the signature of the oscillation that generates between the West boundary and Rincon (red, blue, and red progression) and how remnants of this oscillation move down the West boundary and then are reflected into the domain on the Southwestern corner of the grid.

- The University of Texas group implemented a larger and finer domain (Case UTexas_1) which initially had no two dimensional radiative boundary and no eddy viscosity. This larger and finer domain did not provided better results than configuration UPRM_1 or UPRM_2. Subsequently the University of Texas group included configurations UPRM_1 and UPRM_2 into this larger and finer domain (Cases UTexas_1 and UTexas_2) and the artificial oscillations dissapeared, proving that the two dimensional radiative boundary combined with eddy viscosity has more influence in the model performance than either extending the domain or increasing spatial resolution. Figure 3 shows the surface elevation difference and spectrum of the difference between UPRM_2 and UTexas_3, where the 4 cycles per day oscillation has been eliminated when the UPRM_2 configuration was used in the larger and finer domain.

- Both configurations UPRM_1 and UPRM_2 resulted in a root mean squared error improvement over AMSEAS in the Mona Passage and the Southwestern waters of Puerto Rico, while over the rest of the South waters both configurations generally followed the AMSEAS solution, with some exceptions. Figure 4 shows the velocity components at validation location C1, located Southwest of Faro de Cabo Rojo. This location is in the interface between the Mona Passage flow regime and the South of Puerto Rico flow regime. Here UPRM_1 improved over the AMSEAS solution, with AMSEAS overestimating the velocities in both components. In the v component the UPRM_1 velocities also had a better agreement with the observed phase. East of this location both UPRM configurations began to strongly follow AMSEAS, suggesting that the AMSEAS influence either through initial conditions or boundary conditions is still too strong and drives the errors. This is also an indication that different nudging timescales might be needed at each of the domain boundaries.

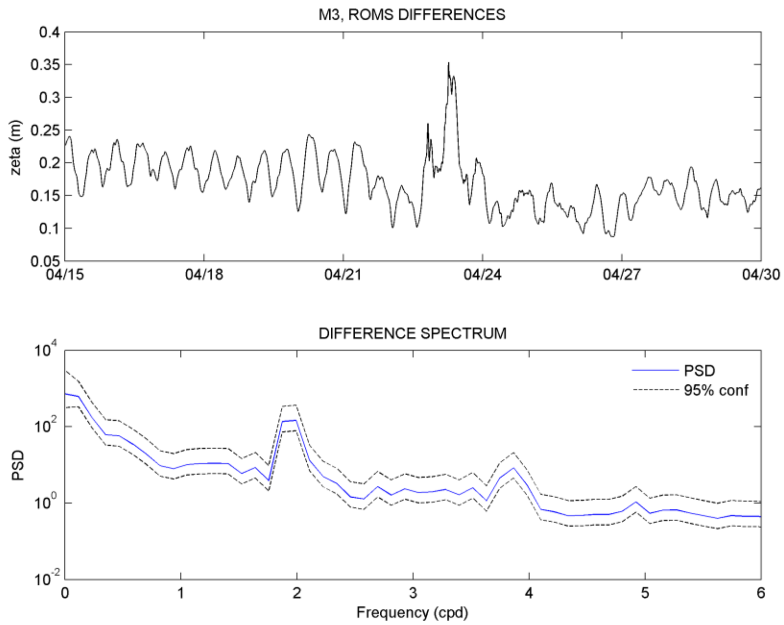

Figure 2. Top: Surface elevation difference between UPRM5000 and CASE1 configurations at location M3, located South of Desecheo Island. Bottom: Spectrum of the surface elevation difference, notice the dominant peaks at frequencies near two and four cycles per day.

- The inclusion of eddy viscosity does smoothes out or completely eliminates some flow features such as eddies, which are of great interest for CARICOOS and which are also sometimes observed in the HFRadar. Care must be taken so that important features are not eliminated by excessive momentum mixing. Results show that not all locations behave similarly for a given eddy viscosity coefficient, so spatially-varying coefficients should be assigned based on depths or flow regimes (ie. Mona Passage vs South of PR) after validation. Figure 5 shows such an example where an eddy viscosity of 5000 m2/s completely dissipated an eddy that was still evident with a coefficient of 1000 m2/s.

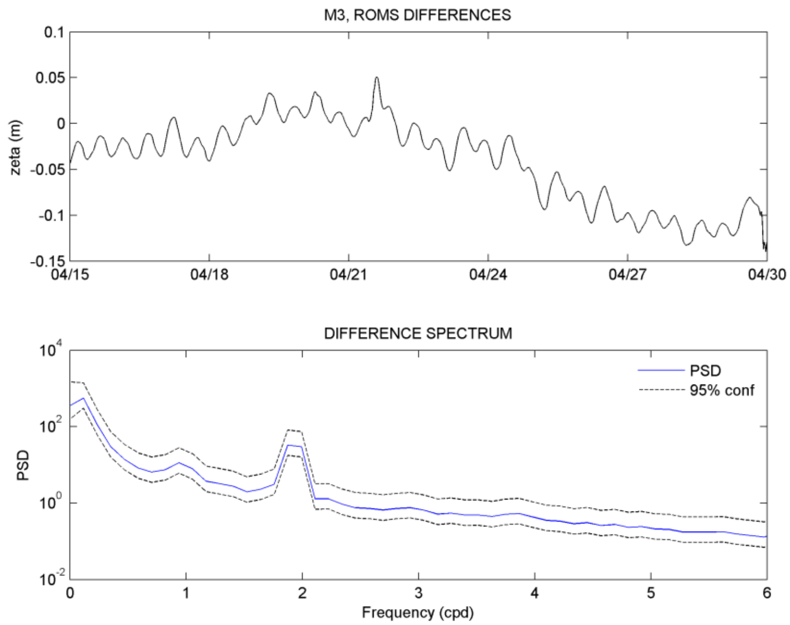

Figure 3. Top: Surface elevation difference between UPRM5000 and UTexas_3 configurations at location M3, located South of Desecheo Island. Bottom: Spectrum of the surface elevation difference, notice the dominant peak at frequency near two cycles per day, corresponding to differences in semidiurnal tide, and the elimination of the four cycles per day peak shown in Figure X. The UTexas_3 configuration had a difference spectrum similar to Figure 2.

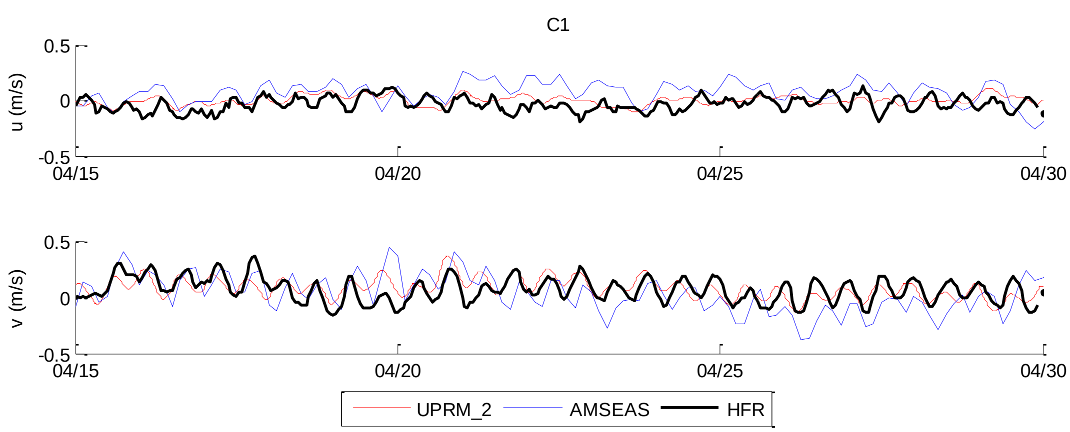

Figure 4. Surface velocity components of UPRM ROMS, AMSEAS, and HFR at validation location C1, Southwest of Faro de Cabo Rojo.

CARICOOS

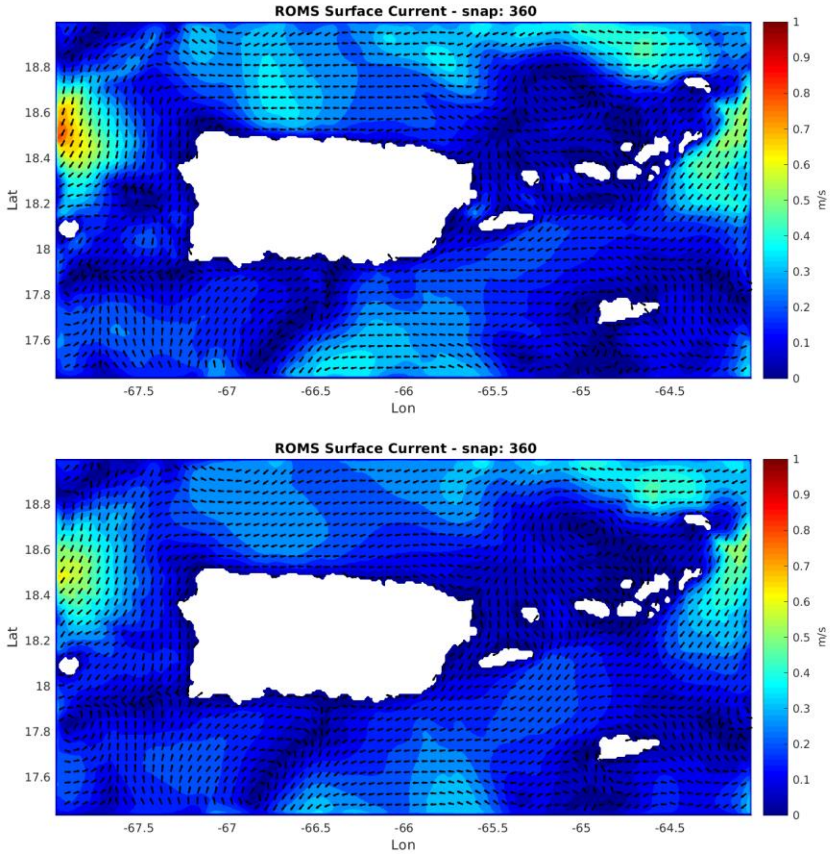

Figure 5. Top: Surface velocity of UPRM ROMS with eddy viscosity of 1000 m2/s. Bottom: Surface velocity of UPRM ROMS with eddy viscosity of 5000 m2/s. Notice how an eddy Southest of Rincon is entirely dissipated on the bottom panel.

RELATED PROJECTS

NSF XSEDE Allocation TG-OCE160002 (PI Juan Gonzalez-Lopez): The Stampede supercomputer located at University of Texas – Austin has been used extensively for the development and validation runs of the CARICOOS ROMS model.

WORK PLAN FOR UPCOMING PERFORMANCE PERIOD (Dec. 1 – May 31 2016)

1. Implement the two dimensional radiative boundary condition and eddy viscosity into the CARICOOS operational ROMS. Need to include spatially varying eddy viscosity coefficients and separate nudging timescales at each boundary.

2. Launch the operational CARICOOS ROMS validation framework and new visualization products.

3. A long ROMS simulation of at least one year of duration will be conducted on January 2017. This run will quantify how the ROMS solution decouples from the AMSEAS solution as time increases and determine if such a long run is necessary to obtain the initial conditions for the subsequent operational ROMS run. As the results show that: a) addition of a two dimensional radiative boundary and eddy viscosity increased the accuracy of the UPRM ROMS model, b) AMSEAS surface currents are significantly different from the HF-Radar observations along the South of Puerto Rico, and c) increase of domain size and spatial resolution did not resulted in an increase in the accuracy of the UTEXAS ROMS, this long simulation is warranted to determine if a decoupling of the UPRM ROMS from the AMSEAS initial solution is the necessary condition for properly predicting the surface currents in the South of Puerto Rico. So far no sensitivity test has been done to take into account the effect of the AMSEAS initial condition and this would be the final sensitivity test needed to quantify how the model performance improves along with boundary conditions and internal mometum mixing, which have now been shown to improve the ROMS performance, particularly on the West/Southwest coasts of Puerto Rico.

4. Following the long simulation and determining if it is the proper way to obtain the initial conditions for the operational ROMS run, assimilation of the CARICOOS HF-Radar surface currents into the operational ROMS will be implemented to take into account the observed surface current fields.

PUBLICATIONS & PRODUCTS

Accepted for Presentation and Proceedings Paper at American Metereological Society 97th Annual Meeting: “Incorporating HF-Radar and Lagrangian Drifters into a Coastal and Mesoscale Model Validation Framework in the Eastern Caribbean Sea”