

Effects of High Resolution Wind Forcing on Ocean Circulation by Downscaling a Mesoscale Model into a Coastal Model in Puerto Rico and the Virgin Islands

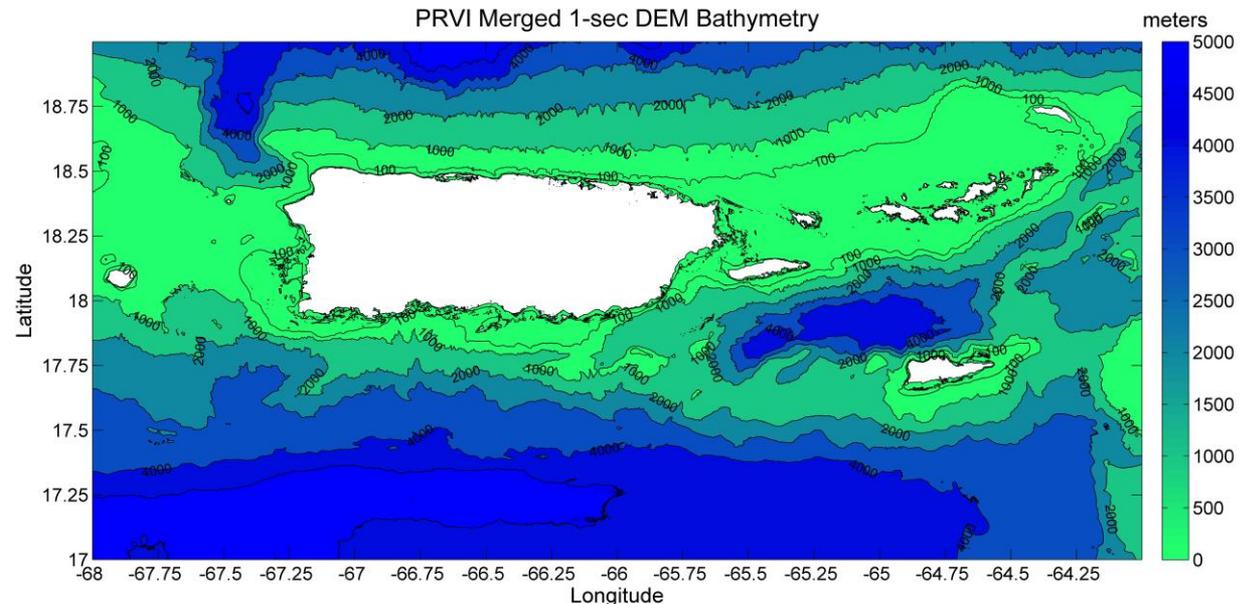


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- Introduction
 - Motivation and background
 - Numerical Setup
- Tide Validation
- Wind Forcing
- Ocean Currents/Temperature/Salinity distributions
- Upwelling
- Wind Effects on Ocean Currents
- Conclusions
- Future Work

- The purpose of the present work is to study the effects of high resolution **wind forcing** on **ocean currents**, sea surface **temperature** and **salinity** distribution.
- To observe and quantify the effects of wind forcing the Regional Ocean Modeling System, a free-surface, terrain following, primitive equation ocean model is used.
- The model uses an offline nesting approach to transmit boundary conditions from a mesoscale model (**AmSeas**) into a regional coastal model (**ROMS**). The mesoscale model is in turn nested in the global HYCOM model.

Domain Bathymetry from Digital Elevation Model (DEM).
Resolution: 1 arc-sec (~10m)
Source: National Geophysical Date Center



- Puerto Rico and the US Virgin islands are located in the continental shelf dividing the Caribbean Sea and the Atlantic Ocean. North of Puerto Rico we can find one of the deepest trenches in the world, with depths surpassing 7000 meters and extending about 800km.
- Puerto Rico and the US Virgin Islands have some of the busiest **ports** in the world, relying heavily in the ocean for **fisheries**, **tourism** and **importing** goods.
- Ocean circulation has a dramatic impact in marine **ecosystems**, wildlife and preservation of bio-luminescent bays.
- Aid in **weather** safety and preparedness, **oil spill** management and **search and rescue** missions.



Grid:

- Horizontal: 648 X 264 (1/162 degrees = 685m)
- Vertical: 32 sigma layers

Initial and Boundary Conditions:

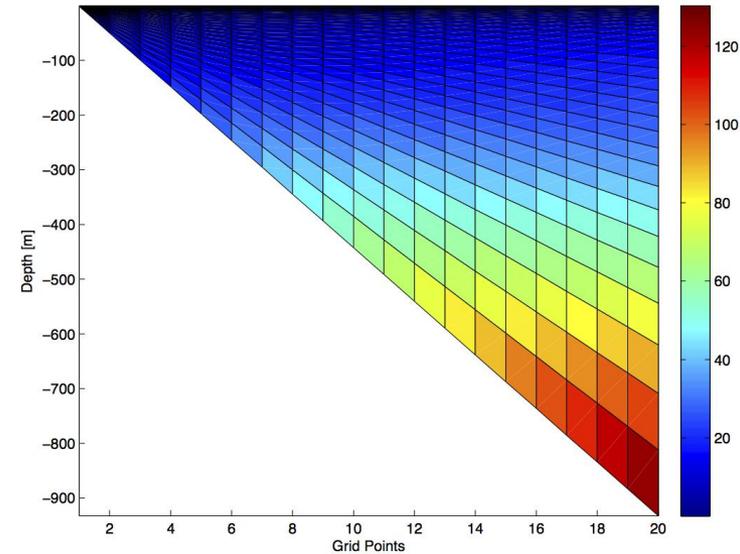
- Offline nesting: NCOM (~3.2km) -> ROMS (~685m)
- 3D velocity, temperature, salinity and SSH.
- Frequency: 3-hour interval.

Forcing:

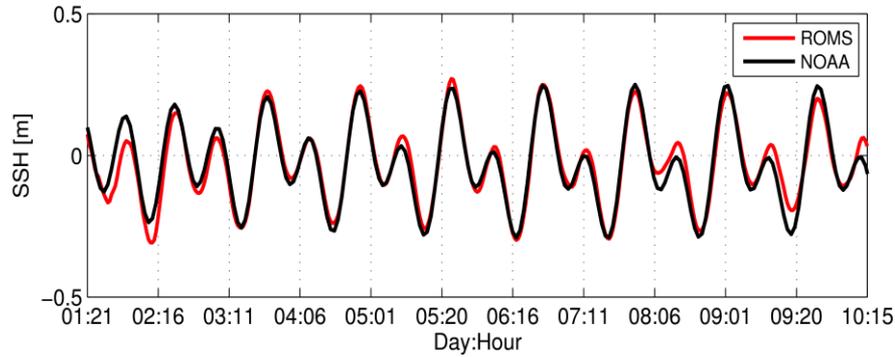
- Tide Forcing: OTPS (HARMONIC CONSTITUENTS)
- Surface: SST, heat flux, freshwater flux and shortwave radiation. (3-hour interval from AmSeas)

Wind Forcing:

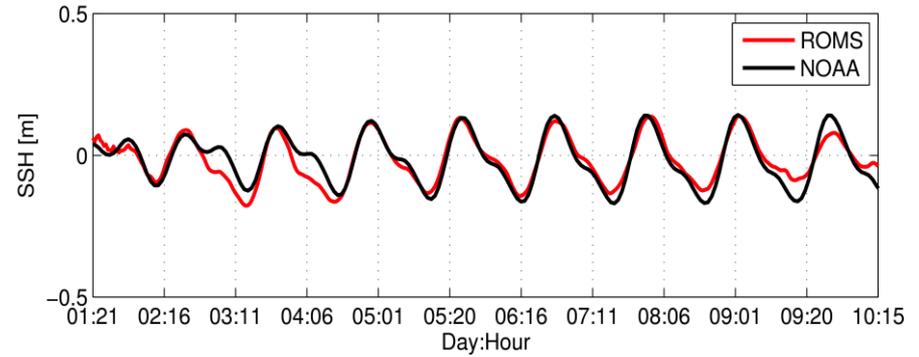
- Case 1: National Digital Forecast Database (NDFD) (~1.2km)
- Case 2: Coupled Ocean/Atmosphere Ocean Mesoscale Prediction System (COAMPS) (~3.2km)



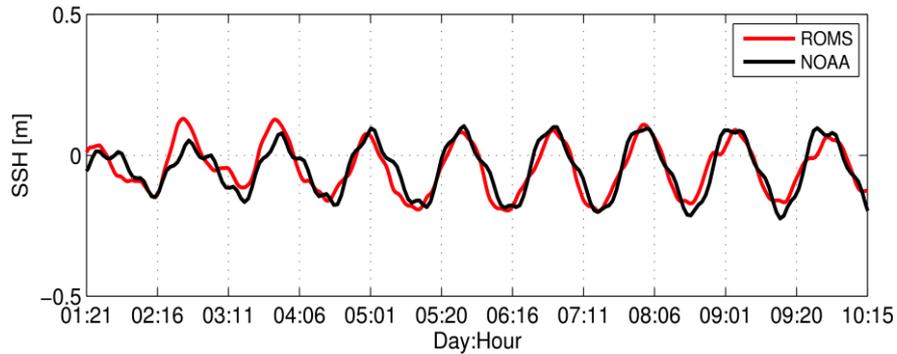
SSH San Juan Station Jun-2013



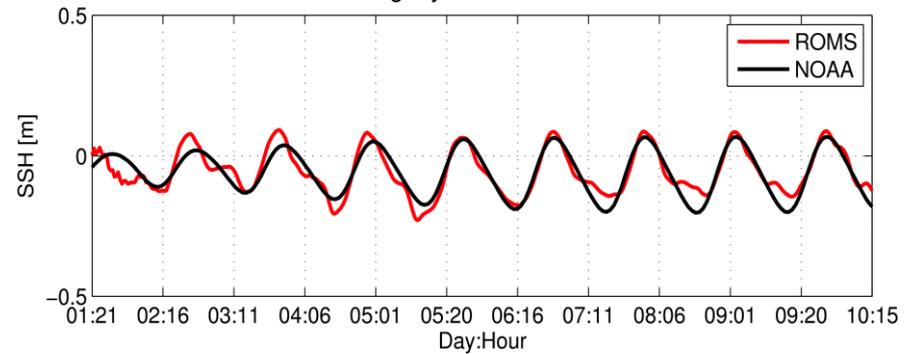
SSH Saint John Station Jun-2013



SSH Mona Station Jun-2013



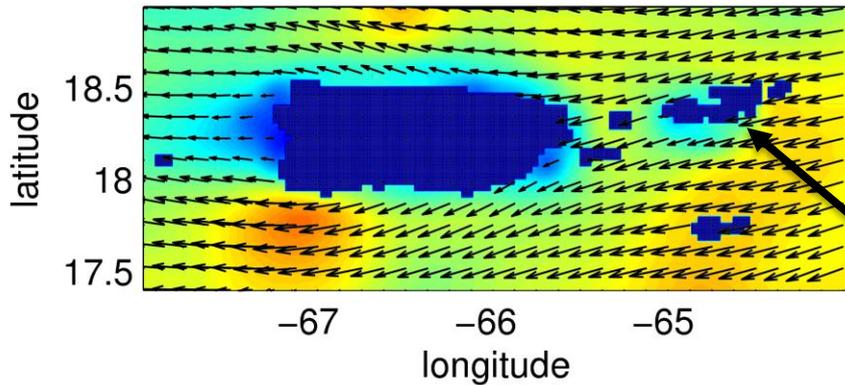
SSH Magueyes Station Jun-2013



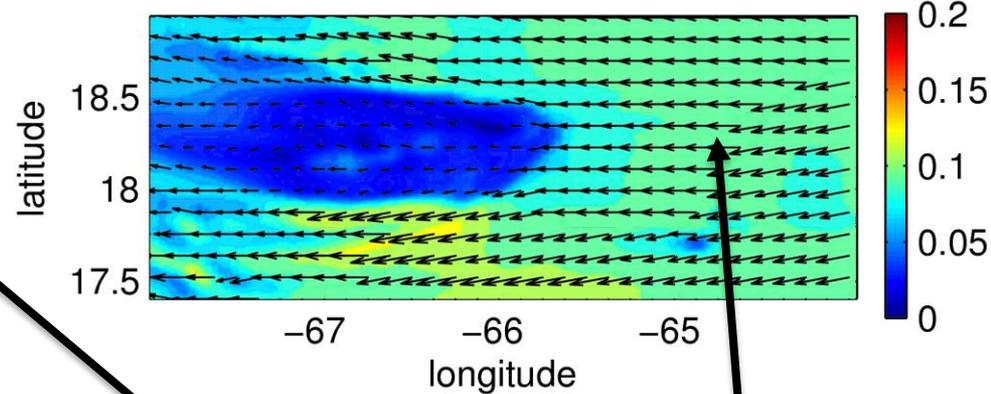
Wind Stress

- No nearshore wind data (3-8km) from COAMPS model
- Wake around the island better solved by the NDFD
- NDFD better captures wind divergence/convergence and drop-off caused by land

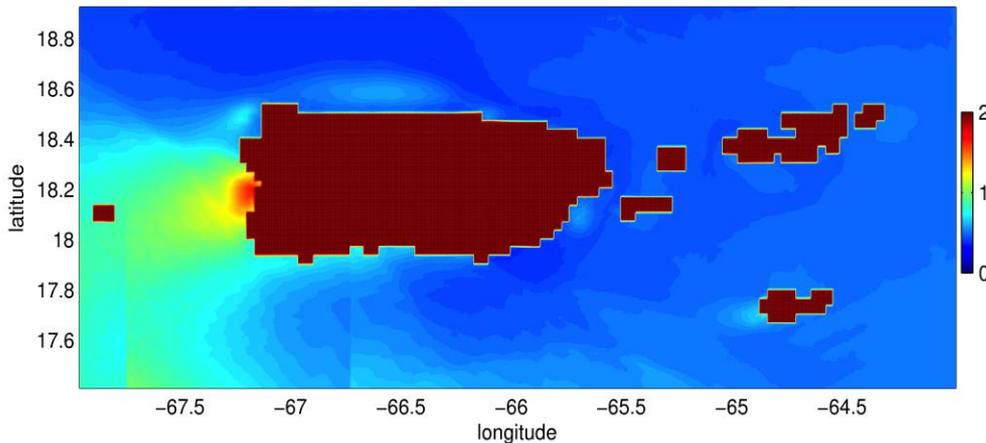
Stress Magnitude NCOM Jun-02 09[Hr]



Stress Magnitude NDFD Jun-02 09[Hr] [N/m²]



RMSE Stress Contours (NDFD,NCOM)

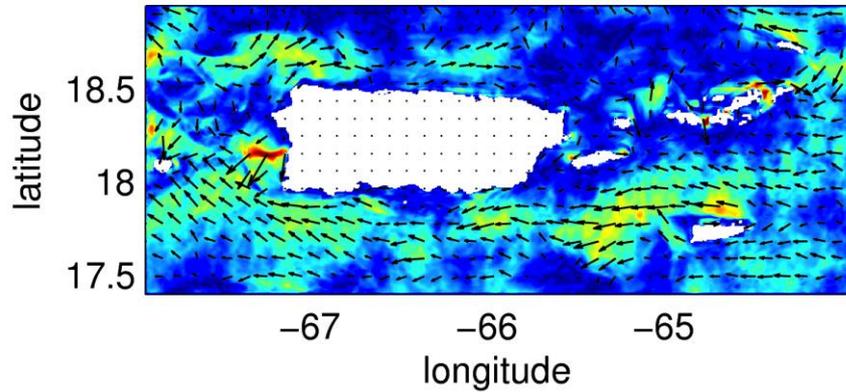


NDFD does not “see” USVI, Vieques or Culebra Island, even though land area and mountain height is considerable (~1500ft)

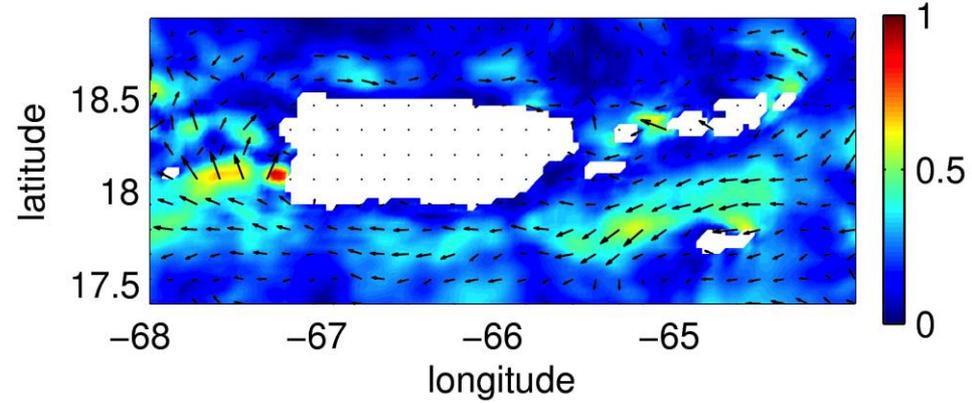
$$RMSE = \frac{1}{\tau_{ncom}} \sqrt{\sum_{i=1}^N \frac{(\tau_{ndfd_i} - \tau_{ncom_i})^2}{N}}$$

Ocean Currents

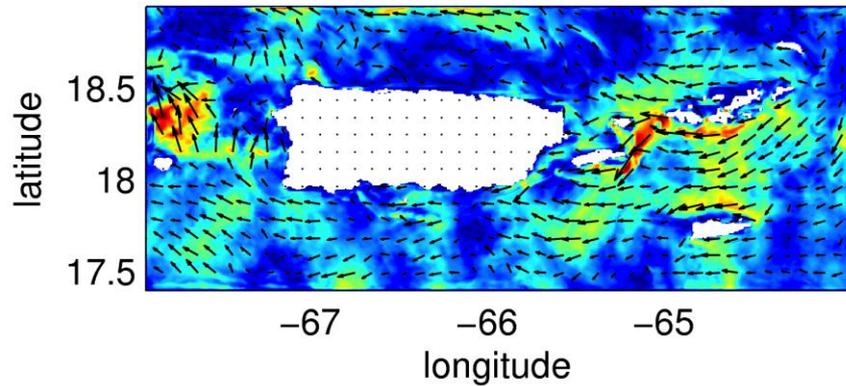
ROMS 02-Jun-2013 06:00:00



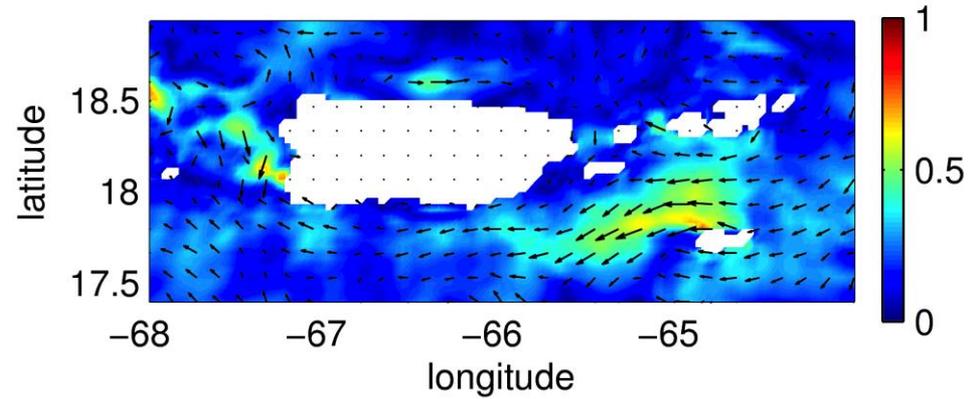
AmSeas NCOM 02-Jun-2013 06:00:00 [m/s]



ROMS 03-Jun-2013 12:00:00

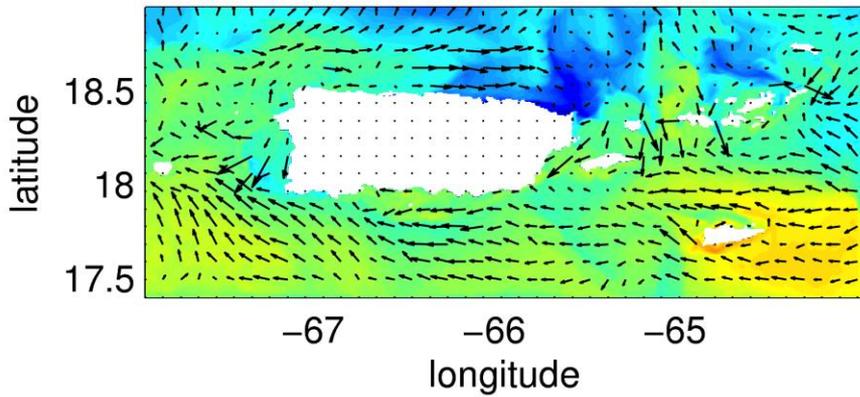


AmSeas NCOM 03-Jun-2013 12:00:00 [m/s]

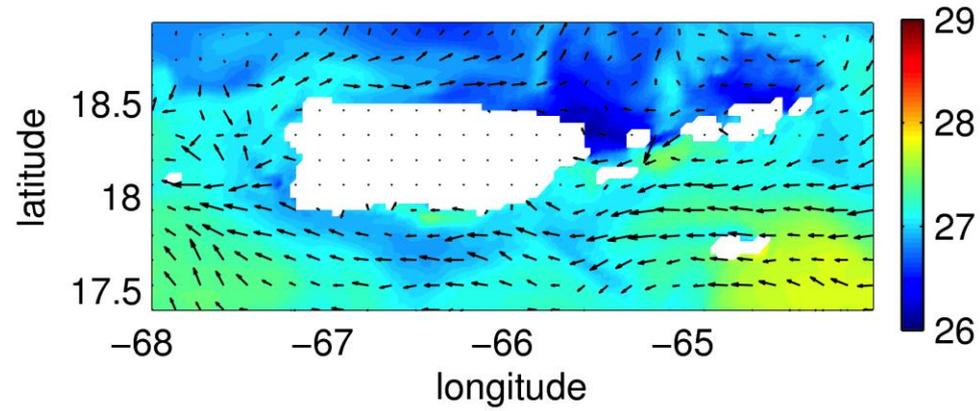


Temperature Distribution

ROMS 02-Jun-2013 15:00:00

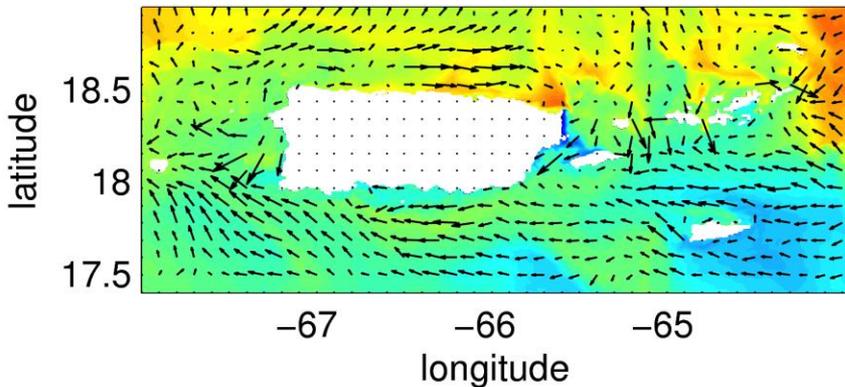


AmSeas NCOM 02-Jun-2013 15:00:00 [C]

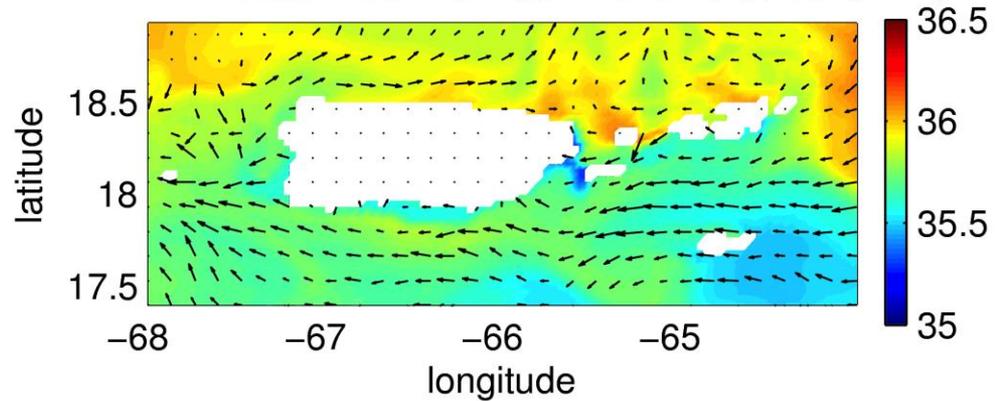


Salinity Distribution

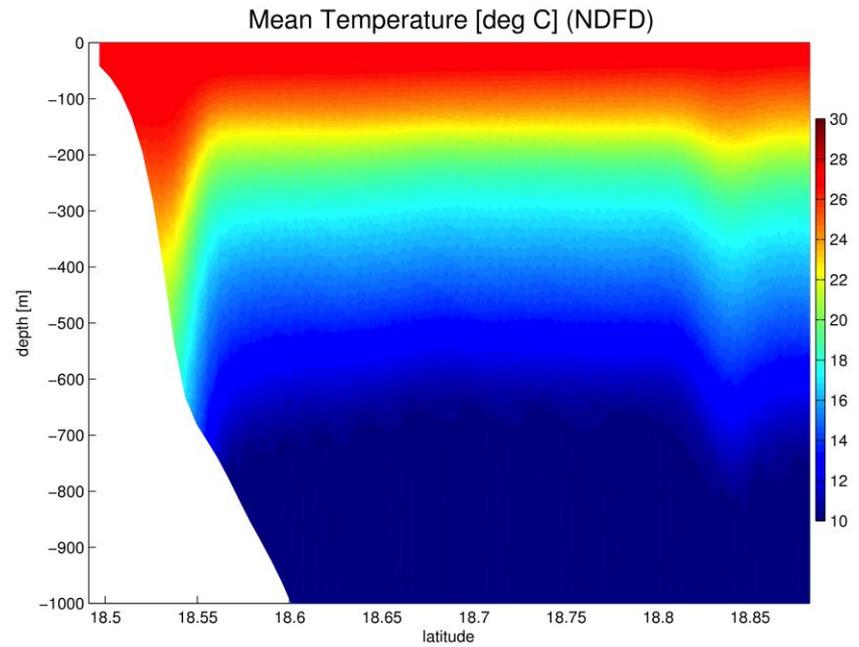
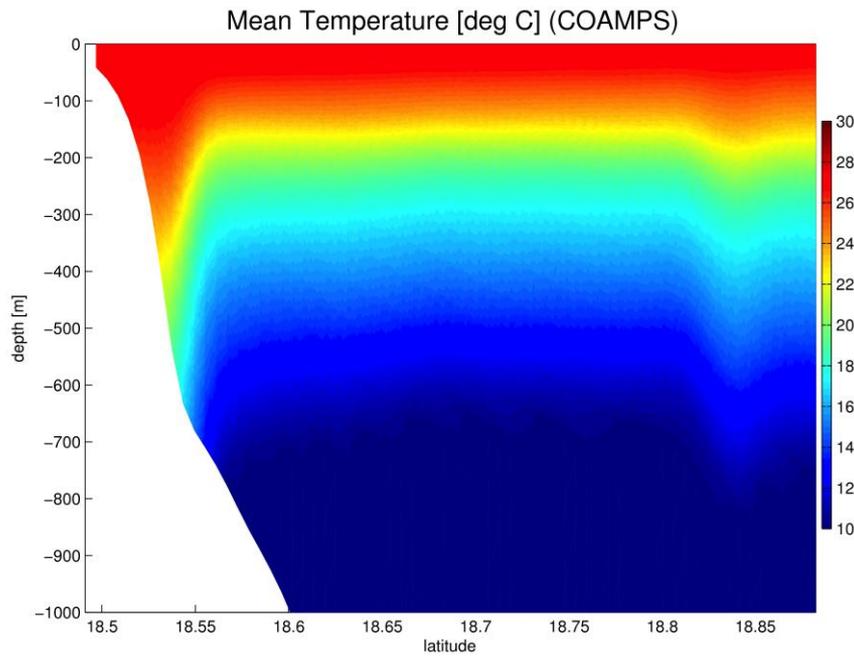
ROMS 02-Jun-2013 15:00:00



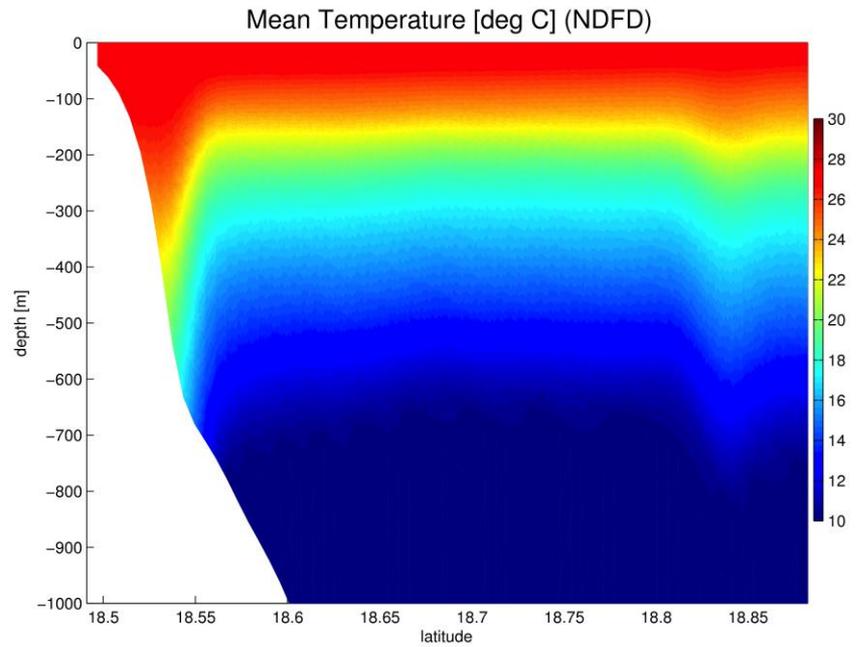
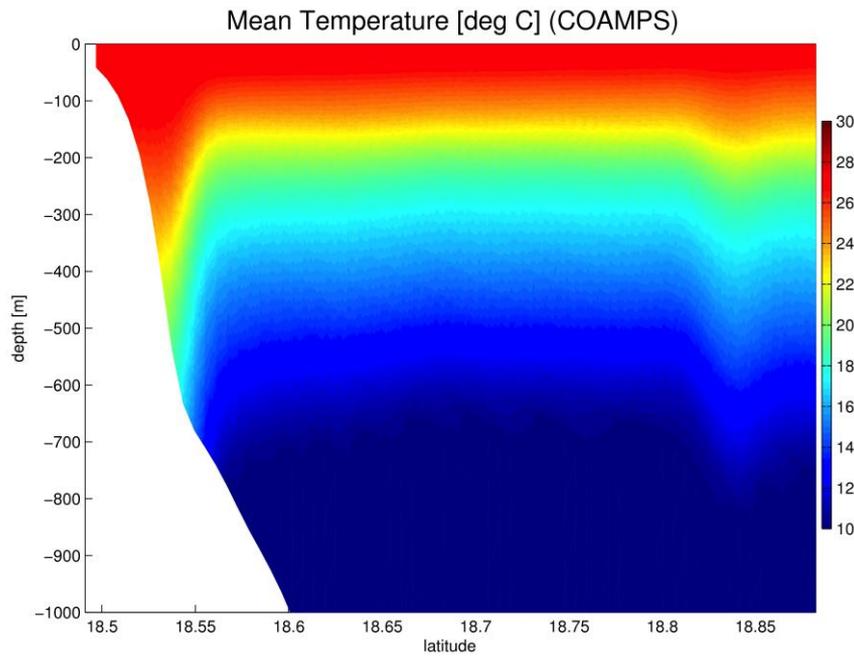
AmSeas NCOM 02-Jun-2013 15:00:00 [PSU]



Vertical Section



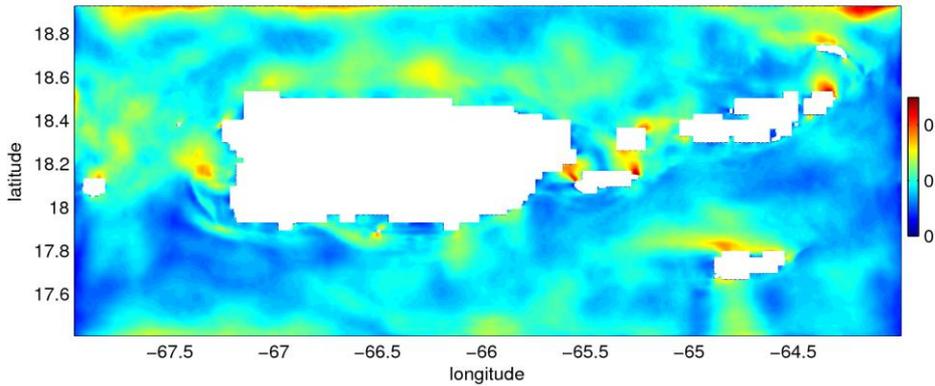
Vertical Section



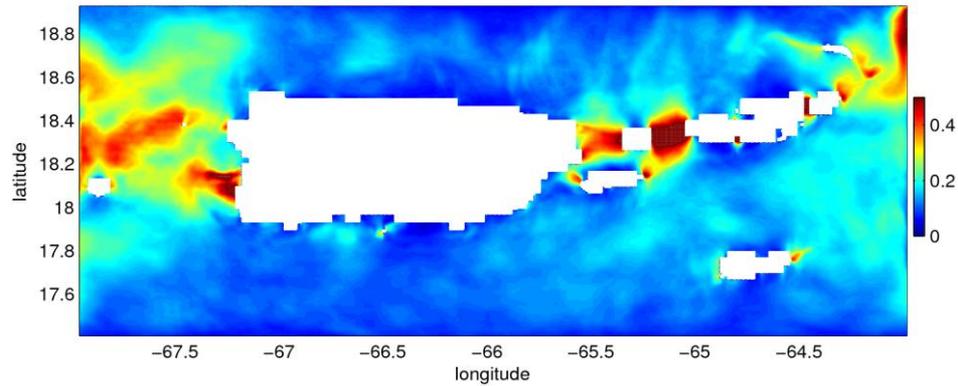
ROMS using high resolution wind forcing (NDFD) vs AmSeas NCOM model

- Right: Contours of root mean square error of U-component velocity [m/s]
- Left: Contours of root mean square of V-component velocity [m/s]

U RMSE ROMS(NDFD) vs AmSeas



V RMSE ROMS(NDFD) vs AmSeas



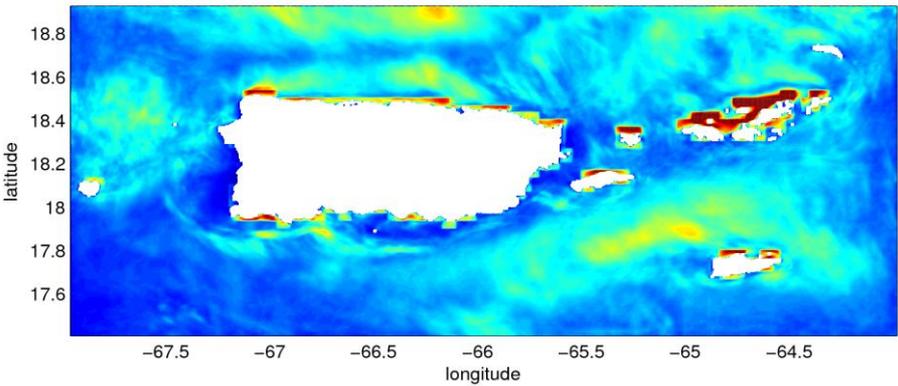
$$RMSE = \frac{1}{V_{ncom}} \sqrt{\sum_{i=1}^N \frac{(V_{ndfd_i} - V_{ncom_i})^2}{N}}$$

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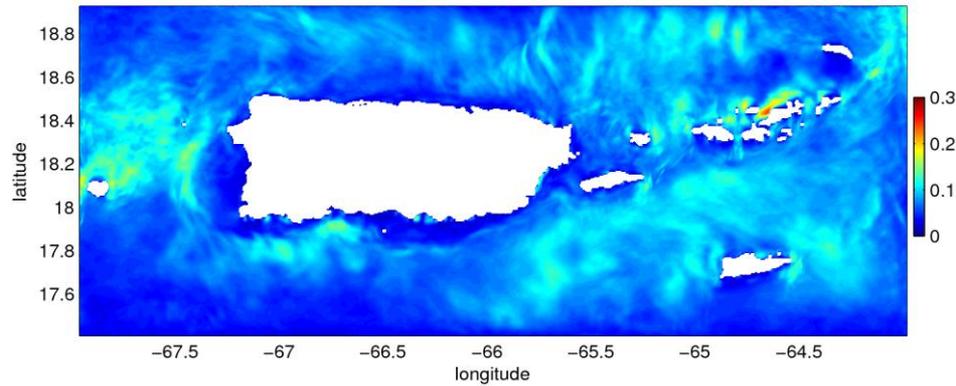
ROMS using high resolution wind forcing (NDFD) vs ROMS using medium resolution wind forcing (COAMPS)

- Right: Contours of root mean square error of U-component velocity [m/s]
- Left: Contours of root mean square error of V-component velocity [m/s]

U RMSE ROMS (NCOM) vs ROMS (NDFD)



V RMSE ROMS (NCOM) vs ROMS (NDFD)



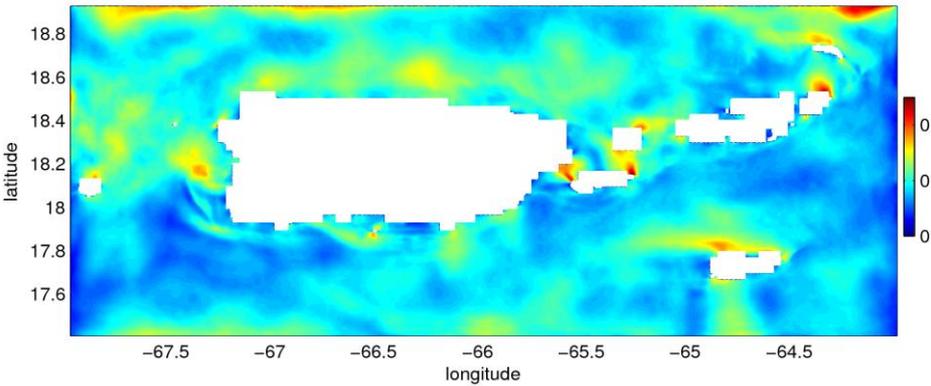
$$RMSE = \frac{1}{Vncom} \sqrt{\sum_{i=1}^N \frac{(Vndfd_i - Vncom_i)^2}{N}}$$

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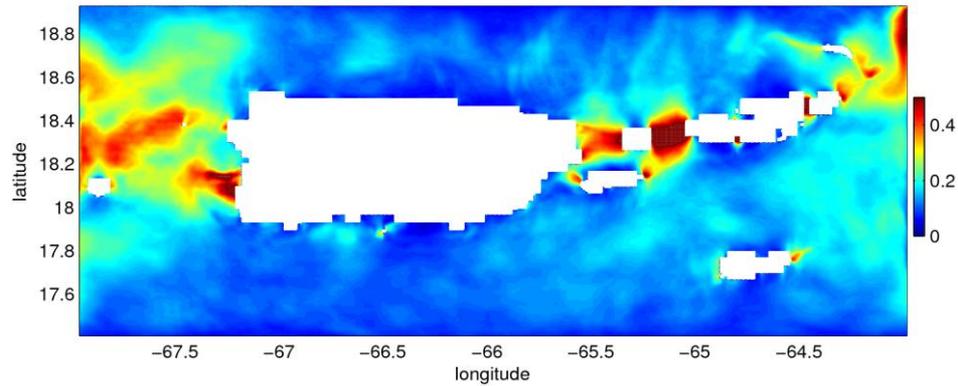
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U RMSE ROMS(NDFD) vs AmSeas



V RMSE ROMS(NDFD) vs AmSeas



$$RMSE = \frac{1}{V_{ncom}} \sqrt{\sum_{i=1}^N \frac{(V_{ndfd_i} - V_{ncom_i})^2}{N}}$$

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- High resolution wind forcing provides surface boundary conditions for the entire domain, including the near shore region where the mesoscale model fails to provide information.
- Wake west of PR is better solved by high resolution (NDFD) atmospheric model (WRF) as well as wind drop-off and convergence/divergence.
- UPWELLING CONCLUSION
- Root mean square error contours of (U) velocity with different wind forcing show large differences in surface ocean currents in the near-shore regions, suggesting that high resolution wind forcing greatly affects zonal currents. Furthermore, contours of RMSE (V) velocity suggest the Island's wake greatly affects ocean current direction west of the model domain.
- ROMS high resolution model successfully downscales the NCOM mesoscale model. Increase in resolution allows for better tide current modeling as observed by RMSE contours of (V) velocity. Additionally,

- Use grid refinement (on-line nesting) in order to bring the solution from coastal to harbor scales.
- Implement high resolution atmospheric model (WRF) and couple with ROMS model in order to quantify the effects of wind forcing in the coastal and harbor scales.
- Take field measurements in the area in order to validate high resolution model.