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Improving coastal circulation analysis and prediction through refined altimeter data processing and variational data assimilation into a regional ocean model

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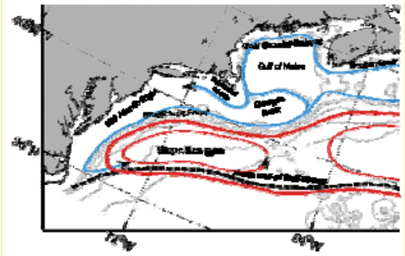
Motivation and Background

Data from multiple altimeters are routinely combined to chart mesoscale variability in boundary currents and the open ocean. Assimilation of these data in circulation models improves ocean state estimation and has moved us into an era of applied mesoscale ocean prediction. However, on continental shelves and in regions of steep bathymetry on the continental slope, there have been **relatively few applications of altimetry to analysis of coastal currents** and sub-mesoscale variability.

Limited adoption of altimetry in coastal studies stems from difficulties correcting for the high frequency ocean response to tidal and atmospheric forcing, and land contamination in the radar and radiometer footprints. Standard data validity checks, tailored to climate and mesoscale applications, reject much of the data acquired near the coast – even over wide continental shelves such as the **Middle Atlantic Bight (MAB)** and in the **Gulf of Maine (GoM).**

Compared to the deep ocean, sea level variability in coastal regions exhibits **shorter length and time scales**, and is more **anisotropic** due to flow-bathymetry interactions. These features challenge statistically-based multi-satellite analysis methods (e.g. optimal interpolation) typically used to produce spatial sea level anomaly (SLA) maps from along-track data.

To produce coherent regional analyses useful for coastal oceanographic applications, our approach is to ***reprocess along-track data for the coastal environment*** and ***assimilate the data into a high-resolution regional ocean model***, thereby combining data from multiple satellites while introducing dynamic and kinematic constraints into the analyzed circulation. Data-assimilative modeling for state estimation also allows validation of the integrated product by comparison of modeled now-cast and forecast fields to the in situ data sets available from the U.S. network of coastal observing systems.



Schematic circulation in the Gulf of Maine and Middle Atlantic Bight

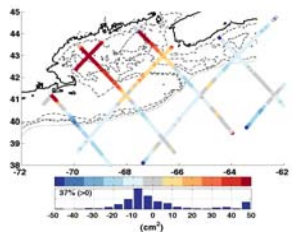
Blue lines on the shelf indicate southwestward flow from the Scotian Shelf to the MAB. Red lines depict currents that define the Slope Sea gyre. Dashed line is the mean position of the Gulf Stream.

Along-track data reprocessing

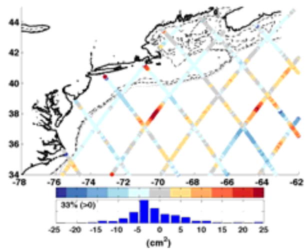
We work with along-track altimeter data and corrections stored in the RADS data base.

Data quality in the GoM has been assessed for frequency of dropouts due to correction failures and the veracity of the corrections (tides, water vapor, high frequency barotropic variability) by comparison to tide gauges, current-meters and wave buoy data. This indicates emphasis on tides and re-visiting GDR data flags will return data close to the coast without an immediate need for 10/20 Hz along-track data.

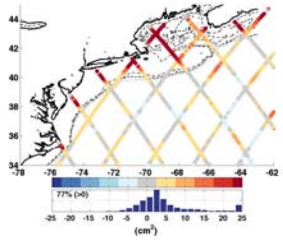
Range corrections: We show variance of sea surface height anomaly over long term mission. Reduced variance => improved correction.



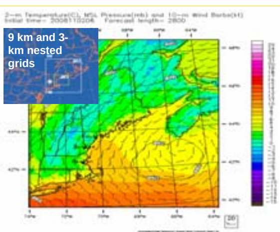
Tides: Local high-resolution tide models typically outperform OSTM global tide corrections. The red score indicates where the regional WebTide model *[Dupont et al. 2005]* lowers the variance compared to FES2004. 37% of locations improve.



Water vapor: Comparison of variance reduction using ECMWF vs. TMR radiometer. The global atmospheric model can degrade results.



High frequency barotropic correction: Using MOG2D in place of static Inverse Barometer improves signal in 77% of locations.



Surface met. analysis UNH WRF model
http://www.jcoot.unh.edu/forecasts/forecasts.html

Future work:

Water vapor: Mesoscale to submesoscale atmospheric variability near the coast leads to short length scales in tropospheric water vapor. We will evaluate using water vapor corrections from a local high-resolution weather forecast model (WRF) that assimilates QuikSCAT winds and data from NOAA's Meteorological Assimilation Data Ingest System (MADIS).

Tides: Other high-resolution regional models will be incorporated into RADS including NW Atlantic ADCIRC *[Mukai et al. 2002]* and our own regional ROMS model solution.

Other corrections: In collaboration European MARINA project we will investigate high-frequency barotropic corrections with high-resolution MOG2D, 10/20 Hz data (with X-Track) for resolving the MAB shelf/slope front, and waveform re-tracking.

Data Assimilation Modeling with ROMS

We use the Regional Ocean Modeling System (***www.myroms.org***) and the ***Incremental Strong constraint 4-Dimensional Variational*** data assimilation methodology. IS4DVAR *[Weaver et al. 2003]* seeks adjustments, ***or increments***, to initial conditions of each analysis period (we use 3 days for shelf/mesoscale dynamics) that minimize a weighted sum of model-data differences (or cost function) over the analysis interval.

The ROMS ***adjoint*** model gives the ***cost function gradient*** with respect to variations in initial conditions *[Moore et al. 2004]* and determines how these project from observed state variables (e.g. SLA and SST) on to others (e.g. unobserved velocity and sub-surface temperature/salinity). A descent algorithm minimizes model-data misfit by successively ***adjusting the analysis interval initial conditions***. Analysis initial conditions are the only ***control variables*** in our IS4DVAR implementation.

Upon convergence, the model solution is the "best" ocean reanalysis in the sense it acknowledges all ***observations*** and their ***expected errors***, and satisfies model ***physics*** including flow-bathymetry interaction on the continental shelf.

Preliminary results:

Along-track (from RADS) and AVISO gridded multi-satellite SLA differ significantly (~10 cm RMS) in the Slope Sea because of short time/space scale sub-mesoscale variability.

Figure at right shows ***increments*** to model initial conditions for assimilation of SST and a single Jason-1 SLA pass. IS4DVAR adjusts subsurface temperature, salinity and velocity.

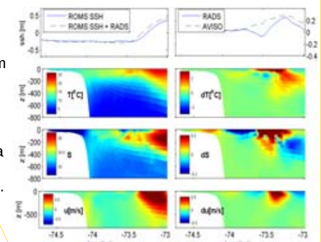
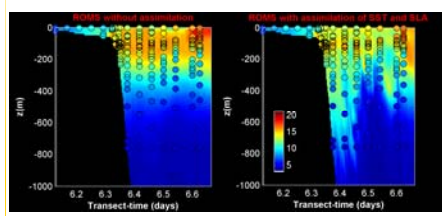
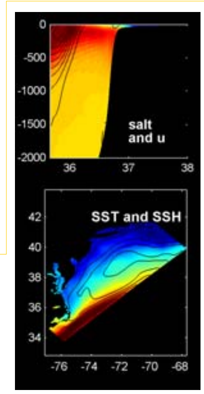
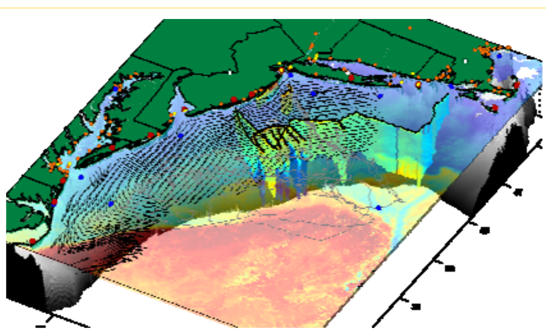


Figure below shows the ***improvement in fit*** to unassimilated XBT data along the NY-Bermuda *Oleander* section.



ROMS assimilation of corrected SLA requires the addition of a ***Mean Dynamic Topography*** (MDT) to the data. We compute MDT (shown at right) by IS4DVAR assimilation of 5-year mean surface currents from CODAR HF-radar and a local high-resolution 3-D temperature/salinity climatology computed from historical CTD data.

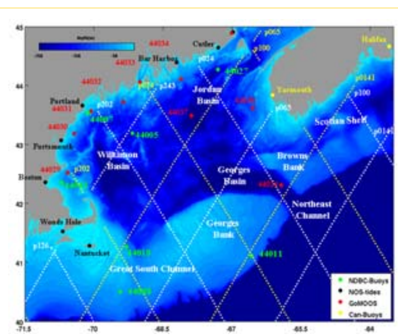




Data available for validation and assimilation in GoM-MAB region

Left: MARCOOS observing systems in MAB include bi-monthly autonomous Slocum glider CTD and optics (colored section), CODAR HF-radar surface currents (black arrows), *in situ* time series at LEO-15 and MVCO, repeat Volunteer Observing Ship XBT lines and ADCP on *Oleander*, NOS tide gauges and NDBC buoys.

Right: Diagonal dotted lines are ground-tracks of Topex/Jason/OSTM (white) and Topex-interlaced (white). Also shown: positions of NOS tide gauges, GoMOOS buoys and NDBC buoys.



Ocean Surface Topography Mission/Jason-2
Surveying Earth's Oceans
Science Team Meeting, Nice, France, 10-12 November, 2008

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