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

John Wilkin1, Doug Vandemark2, Remko Scharroo3, Javier Zavala-Garay1, Hui Feng2 and Guoqi Han4
1 Rutgers University; 2 University of New Hampshire; 3Altimetrics LLC; 4 Fisheries and Oceans, Canada

Motivation and Background

Data from multiple altimeters are routinely combined to chart mesoscale variability in the 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).

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.

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 errors on tides and re-visitting 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.

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

The GOCCP model gives the best unassimilated XBT data along the NY to model

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

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.

Future work:

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 errors on tides and re-visitting 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.

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

The GOCCP model gives the best unassimilated XBT data along the NY to model

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

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 gradients 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 surface-submarine 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 analysis in the sense it acknowledges all observations and their expected errors, and satisfies model physics including flow-barometric 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 improvements in fit to unassimilated XBT data along the NY-Bermuda Oleander section.

Future work:

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 5-7 mean surface currents from CODAR HF-radar and a local high-resolution 3-D temperature/salinity climatology computed from historical CTD data.

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.

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.

Acknowledgments: This work is sponsored by NASA’s Science Directorate. We thank the WebSide group at Bedford Institute of Oceanography, NOAA NOS/NHBS, and the GoMOoS, NEAOCODS and MARCOOS coastal observing efforts.

REFERENCES:


