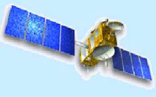
Investigating ocean altimeter data and applications in the Gulf of Maine



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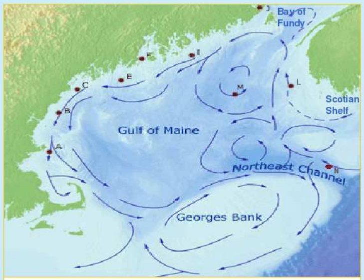
Motivation

The Gulf of Maine is a semi-enclosed marginal sea on the east coast of the United States encompassing a region with famously productive local and offshore fisheries and active ports, and one with extensive recreational usage and population along its shores. It is also home to large tidally driven sea level changes, complex bathymetry, and an ocean circulation and ecosystem that is strongly influenced by waters from the Labrador Sea and Scotian Shelf. At present, altimeter data are not routinely utilized in operational forecasting or science applications largely because satellite data quality in these coastal waters has not been sufficiently addressed.

The prevailing Gulf circulation pattern is a counterclockwise gyre. The unique bathymetric landscape leads to a self-contained oceanographic system, quite separate from the neighboring NW Atlantic shelf. Particularly, the extensive offshore shallow banks and shoals, including Georges and Browns Banks, Nantucket Shoals and Scotian Shelf, limit the water mass exchange locations between the Gulf and Atlantic. The main transport is thru deeper channels - the Northeast and mid-Scotian shelf channels (inflow) and the Great South channel (outflow). These transports vary significantly seasonally and inter-annually (Smith, 1983: Beardsley et al., 1985; Ramp et al., 1985;Brown and Irish, 1992; Pringle, 2006) and the biological implication of these variations is significant to numerous fisheries. Tides are a particularly dominant feature, varying significantly in space from near 1 m west near Cape Cod to record high 15 m in the Bay of Fundy. Finally, a buoyancy-dominated (freshwater) coastal current flows CCW along the Maine, NH, and MA coastline.

Recently, significant attention has been given to altimeter studies along the nearby Canadian Scotian Shelf region (Han et al., 2002a-b; 2006) but little work with has been done within the shallower Gulf. This coastal area has a maturing regional coastal observing system (**see map below**) containing National Oceanographic Service (NOS) coastal tide gauges and an impressive network of National Data Buoy Center (NDBC) and Gulf of Maine Observing System (GoMOOS) buoys providing oceanographic and meteorological measurements, including subsurface currents. The region is ideal for coastal altimeter data validation and application activities and this poster takes a first look at data quality and *in situ* comparisons using both TOPEX and Jason-1 data extracted from the DEOS RADS database and using the BIO WebTide model.



Schematic of ocean circulation in the Gulf of Maine
Key features: depth to 370m, CCW gyre, large tidal currents, incoming transport is through NE channel and along Scotian Shelf

Objectives

Study goals are

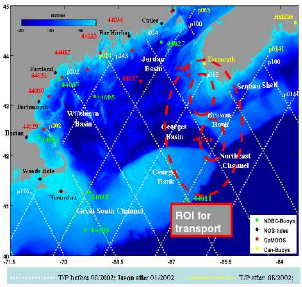
- altimeter data quality assessment in the coastal zone and
- to explore their potential in efforts to monitor seasonal-to-interannual variability in sea level, circulation and wave dynamics within the Gulf

Tasks performed in the initial effort:

- Assess overall sea level data quality including measurement precision against tide gauge measurements, frequency of dropouts due to correction failures, veracity of the corrections (tides, water vapor, barotropic)
- Assess derived geostrophic current in regions of high transport
- Validate altimeter-measured significant wave height and wind speed against the buoy measurements in deep and shallow water

Gulf of Maine map with various observational sites

Shown are NOS coastal tide gauges, NDBC, and GoMOOS buoy sites. Nominal ground tracks of the TOPEX and Jason-1 are indicated (odd and even pass #s represent the ascending and descending ground tracks, respectively).
NOTE: GoMOOS buoys provide real-time current measurements thru the water column.



Methods – geostrophic current@NE Channel

Altimeter geostrophic velocity estimates are calculated from the along altimeter track gradients of the corrected sea surface height following Strub et al. (1997):

- centered difference over 62 km (10 ground sampling points)
- 3-point running mean filter is applied
- resolves variability in the current field in the scale between 50 and 250km – may need tuning to gain resolution
- key tracks (#024 and #065) chosen for transport studies

Multi-year comparison of altimeter and buoy velocity estimates

Buoy velocity components (***u, v***) nearest altimeter crossover site (**Buoy 44024 at left**) are projected onto the altimeter tracks (i.e. the cross-track and along-track components (not orthogonal) by

V_crosstrack = *v**sin( )+*u**cos( );

V_alongtrack = *v**cos( )-*u**sin( );

where is the angle between the ground track and north meridian.

Jason-1 SSH anomaly data – 2002-2006
Multi-year Hovmuller display of Gulf of Maine passes
The dropout rate is 29% in various reasons (**Table 1**).

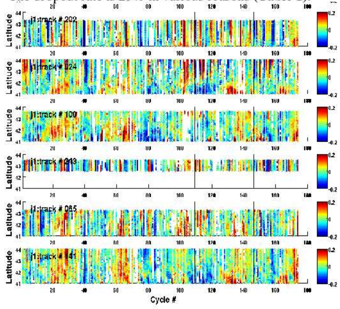
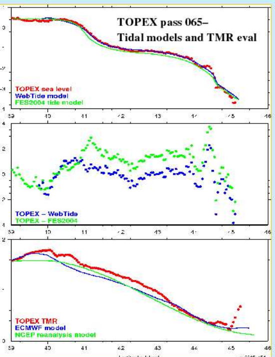


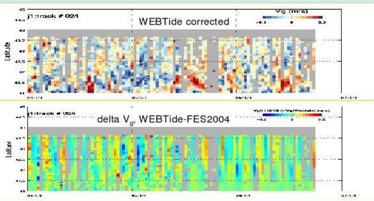
Table 1. Data dropout statistics of misson-long altimeter (TOPEX and Jason1) SSHA

	TOPEX	TOPEX (TDM)	Jason-1
Total SSH measurements	145948	42345	72270
Rejected SSH	29896(21%)	11137(26%)	20811(29%)
Orbital altitude, GCM02C(m)	161	0	91
TMR wet tropospheric corr (m)	8058(5.5%)	2823(6.7%)	
JMR wet tropospheric corr (m)			118 (<1%)
Dual-freq ionospheric correction	7950(5.5%)	2450(5.8%)	1000(1.4%)
Sea State Bias, Chambers,BM4	826(<1%)	102(<1%)	1619(2.2%)
Hs-Ku outside the range{0,8}[m]	7125(4.9%)	2161(5.1%)	374 (<1%)
Sigma-0 Ku outside {6,27} [db]	3125(2.1%)	690 (1.6%)	151(<1%)
Std of range(10HzKu) : {0,0.15}[m]	11504(7.9%)	3303(7.8%)	
Std of range(20HzKu) : {0,0.15}[m]			1204(1.7%)
# of 10Hz Ku range meas: {8.5, 10.5}	15898(11%)	4595(10.8%)	
# of 20Hz Ku range meas: {15.5, 20.5}			3664(5.1%)
Engineering flags	29339(20%)	10964(25.6%)	17647(24.4%)%
Std of Hs(10Hz-Ku) outside {0,0.09} [m]	7642(5.2%)	1996(4.7%)	
Std of Hs(20Hz-Ku) outside {0,0.09} [m]			1526(2.1%)

Altimeter data quality assessments

Tidal model and wet tropo. corrections: A regional tide model (WebTide) now resides in RADS for the altimeter tide corrections. The upper two panels compare it with FES2004 for the T/P pass 65 which heads into the Bay of Fundy and shows that the WebTide model is the better one. The bottom panel shows the wet tropo delay. The NCEP model is generally too smooth and the TMR is sometimes corrupted by land at the end of the track before hitting the coast.

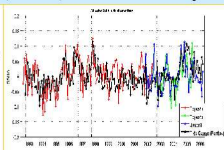


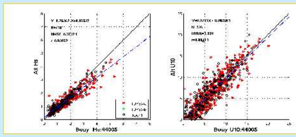


Top: Pass 24 Jason-1cross-track **geostrophic current (V_g)** for 2004-2006; **Bottom**: V_g difference using tide-corrected SSHA by FES2004 and regional WebTide model. An error of order 10-30% in derived current can be remedied using the regional tide model.

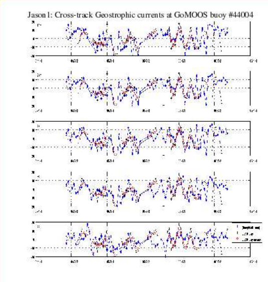
Data quality – sea level, SWH, U10 and velocity

SEA LEVEL - Monthly mean altimeter sea surface height anomalies (SSHA) versus the tide gauge sea level anomalies (SLA) at Portland, Maine. Altimeter SSHA is calculated within {42,44} in lat, and {-70,-66} in long. Tide gauge SLA is w/o tide and monthly averaged.





Surface waves and wind Scatter plots comparing TOPEX and Jason-1 Hs & U10 against NDBC # 44005 (matchup scale:(30min, 50km)



Cross-track geostroph. current Jason-1(pass 024) V_g (positive to the right of the track when looking northward) against 10-day cross-track LP filtered (48-hour half power) buoy currents from depth at the GoMOOS buoy #44024 in ROI on map above. Baroclinic flow will often compete with other components here.

Assessment Conclusions

- **A**ltimeter-measured wave heights match well with NDBC buoy measurements but ample opportunity to investigate nearer to coast
- **A**ltimeter-measured SSHA before tide correction is already comparable with tide gauge SLA in the Gulf of Maine coastal zone
- **A**ltimeter-derived across track geostrophic currents show promise for aiding in transport variability estimation
- **O**verall data filtering and tidal corrections need to be addressed but retracking, MWR corrections and high rate data are not 1[st] order issues

Future Work

The Gulf of Maine presents a complex coastal target for altimeter data usage, but this first look at the present-day altimeter data quality for the region is very encouraging. Collaboration with regional circulation modeling efforts is now being addressed to evaluate next steps in applying data to transport and circulation modeling efforts at seasonal-to-interannual time scales.

Some future steps:

- Full implementation of the WebTide model within the multi-altimeter mission RADS data base can be readily implemented and will provide a needed regional correction term.
- Dropouts in altimeter-measured sea level appear to be due to open ocean data filtering and correction failures. An immediate effort is needed to develop a regionally tailored flagging and correction approach to lower the present 20-30% drop out rate.
- Cross-track geostrophic velocities were estimated with a focus on resolving the variability at scales between 60 and 250km. A reassessment is needed to find an approach suitable for finer-scale Gulf circulation features.
- Explore to use multi-mission altimeter data is needed (GFO, Envisat, ERS, tandem phase)

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Acknowledgments

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Ocean Surface Topography Science Team Meeting

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