Can fully-focused altimeter range data provide enhanced detection of coastal currents in the Nova Scotia Shelf?: Preliminary diagnosis

Hui Feng[1], Alejandro Egido[2], Doug Vandemark[1] and Claire Dufau[3]

[1]Ocean Process Analysis Lab ,University of New Hampshire., NH, USA
[2] NOAA – Laboratory for Satellite Altimetry/GST Inc., MD, USA
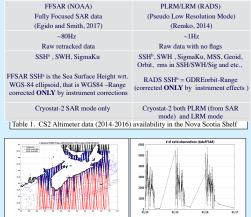[3]CLS Space Oceanography, Toulouse, France

I. Introduction

This study seeks to evaluate the potential of so-called Fully-Focused SAR (FFSAR) mode altimetry (Egido and Smith, 2017) to improve detection of nearshore currents that are critical advective pathways within narrow shelf-sea systems. The region of interest is the Nova Scotian Shelf and, in particular, the coastally trapped Nova Scotia current (NSC). The outer edge of this current resides between 10-60 km from the coast and previous efforts using conventional altimetry have failed to adequately capture expected resolutions of NSC dynamics.

Cryosat-2 (CS2) FFSAR data (Table 1) of sea surface height (SSH=Orbit ellipisoid– Range), significant wave height (SWH) and backscattering coefficient I Ku band (Sigma0) and SSH-derived cross-track (nearly alongshore) geostrophic current (Vg) will be assessed. One reference baseline is CS2 unfocused SAR processing, the pseudo-low resolution mode (PLRM) (Scharroo, 2014). The objectives seek to evaluate possible:
1) increased data recovery nearer to the coast,
2) reduced noise of SSH, SWH, Sigma0 and SSH-based Vg) at scales inside of 50km, and
3) identification of fine-scale signals like internal waves in the FF-SAR data, in comparison with other processing approaches

II. Data and Methods

FFSAR (NOAA) Fully Focused SAR data (Egido and Smith, 2017)	PLRM/LRM (RADS) (Pseudo Low Resolution Mode) (Remko, 2014)
~80Hz Raw retracked data	~1Hz Raw data with no flags
SSH[a] , SWH, SigmaKu	SSH[b], SWH , SigmaKu, MSS, Geoid, Orbit, rms in SSH/SWH/Sig and etc.,
FFSAR SSH[a] is the Sea Surface Height wrt. WGS-84 ellipsoid, that is WGS84 –Range corrected ONLY by instrument corrections	RADS SSH[b] = GDREorbit-Range (corrected ONLY by instrument effects)
Cryostat-2 SAR mode only	Cryostat-2 both PLRM (from SAR mode) and LRM mode

Table 1. CS2 Altimeter data (2014-2016) availability in the Nova Scotia Shelf

Noise (rms) calculations in 1Hz data

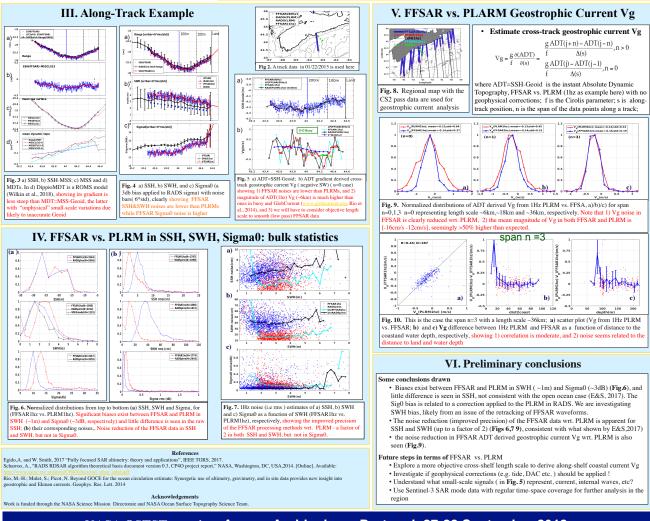• For PLRM:1Hz data from RADS, a set of rms parameters estimated from 20Hz measurements are available,
 "range_rms_ku", std dev of range-Ku
 "swh_rms_ku", std dev of SWH-Ku
 "sig0_rms_ku", std dev of Sigma- Ku

• For FFSAR:80Hz data, 1Hz FFSAR parameters and corresponding noises (i.e. rms) are estimated as the mean and the standard deviation of geophysical parameters within 1 second as follows:
 ▪ first, FFSAR:80Hz data is smoothed by a ¼ second(~20Hz) running-mean
 ▪ and then mean and rms are estimated within 1 second interval

In such a way, we want to objectively compare noise levels of FFSAR(1Hz) parameters with those from RADS PLRM(1Hz)

Figure 1 Regional map with Cryosat-2 (CS2) FFSAR and PLRM data availability in space (left) and time (right) for 3 years (2014-2016) near Nova Scotia. The isobars of 100m-, 200-m and 1000m are also shown.

III. Along-Track Example

Fig. 3 a) SSH, b) SSH-MSS; c) MSS and d) MDTs. In d) DippioMDT is a ROMS model (Wilkin et al., 2018), showing its gradient is less steep than MDT=MSS-Geoid, the latter with "unphysical" small-scale variations due likely to inaccurate Geoid

Fig. 4 a) SSH, b) SWH, and c) Sigma0 (a 3db bias applied to RADS sigma) with noise bars(6*std), clearly showing FFSAR SSH&SWH noises are lower than PLRMs while FFSAR Sigma0 noise is higher

Fig 2. A track data in 01/22/2015 is used here

Fig. 5 a) ADT=SSH-Geoid; b) ADT gradient derived cross-track geostrophic current (negative SW) (n=0 case) showing 1) FFSAR noises are lower than PLRMs, and 2) magnitude of ADT(1hz) Vg (~6km) is much higher than ones in buoy and GlobCurrent (www.globcurrent.org, Rio et al., 2014), and 3) we will have to consider objective length scale to smooth (low pass) FFSAR data

IV. FFSAR vs. PLRM in SSH, SWH, Sigma0: bulk statistics

Fig. 6. Normalized distributions from top to bottom a) SSH, SWH and Sigma, for (FFSAR1hz vs. PLRM1hz). Significant biases exist between FFSAR and PLRM in SWH (~1m) and Sigma0 (~3dB, respectively) and little difference is seen in the raw SSH; (b) their corresponding noises,. Noise reduction of the FFSAR data in SSH and SWH, but not in Sigma0.

Fig. 7. 1Hz noise (i.e rms) estimates of a) SSH, b) SWH and c) Sigma0 as a function of SWH (FFSAR1hz vs. PLRM1hz), respectively, showing the improved precision of the FFSAR processing methods wrt. PLRM - a factor of 2 in both SSH and SWH, but not in Sigma0.

V. FFSAR vs. PLARM Geostrophic Current Vg

Fig. 8. Regional map with the CS2 pass data are used for geostrophic current analysis

• Estimate cross-track geostrophic current Vg

$$Vg = \frac{g}{f}\frac{\partial(ADT)}{\partial(s)} = \begin{cases} \frac{g}{f}\frac{ADT(j+n) - ADT(j-n)}{\Delta(s)}, & n > 0 \\ \frac{g}{f}\frac{ADT(j) - ADT(j-1)}{\Delta(s)}, & n = 0 \end{cases}$$

where ADT=SSH-Geoid is the instant Absolute Dynamic Topography, FFSAR vs. PLRM (1hz as example here) with no geophysical corrections; f is the Cirolis parameter; s is along-track position, n is the span of the data points along a track;

Fig. 9. Normalized distributions of ADT derived Vg from 1Hz PLRM vs. FFSA, a)/b)/c) for span n=0,1,3 n=0 representing length scale ~6km,~18km and ~36km, respectively. Note that 1) Vg noise in FFSAR is clearly reduced wrt. PLRM, 2) the mean magnitude of Vg in both FFSAR and PLRM is [-16cm/s -12cm/s], seemingly >50% higher than expected.

span n =3

Fig. 10. This is the case the span n=3 with a length scale ~36km; a) scatter plot (Vg from 1Hz PLRM vs. FFSAR; b) and c) Vg difference between 1Hz PLRM and FFSAR as a function of distance to the coastand water depth, respectively, showing 1) correlation is moderate, and 2) noise seems related to the distance to land and water depth

VI. Preliminary conclusions

Some conclusions drawn
• Biases exist between FFSAR and PLRM in SWH (~1m) and Sigma0 (~3dB) (Fig.6), and little difference is seen in SSH, not consistent with the open ocean case (E&S, 2017). The Sig0 bias is related to a correction applied to the PLRM in RADS. We are investigating SWH bias, likely from an issue of the retracking of FFSAR waveforms.
• The noise reduction (improved precision) of the FFSAR data wrt. PLRM is apparent for SSH and SWH (up to a factor of 2) (Figs 6,7 9), consistent with what shown by E&S,2017
• the noise reduction in FFSAR ADT derived geostrophic current Vg wrt. PLRM is also seen (Fig.9).

Future steps in terms of FFSAR vs. PLRM
• Explore a more objective cross-shelf length scale to derive along-shelf coastal current Vg
• Investigate if geophysical corrections (e.g. tide, DAC etc.) should be applied !
• Understand what small-scale signals (in Fig. 5) represent, current, internal waves, etc?
• Use Sentinel-3 SAR mode data with regular time-space coverage for further analysis in the region

References
Egido,A. and W. Smith, 2017 "Fully focused SAR altimetry: theory and applications", IEEE TGRS, 2017.
Scharroo, A., "RADS RDSAR algorithm theoretical basis document version 0.3, CP4O project report," NASA, Washington, DC, USA,2014. [Online]. Available: http://www.satoc.eu/projects/CP4O/docs/rad_rdsar_atbd.pdf
Rio, M.-H.; Mulet, S.; Picot, N. Beyond GOCE for the ocean circulation estimate: Synergetic use of altimetry, gravimetry, and in situ data provides new insight into geostrophic and Ekman currents. Geophys. Res. Lett. 2014

NASA OSTST meeting ,Azores Archipelago, Portugal, 27-28 September 2018