SAR Altimetry Over Water Surfaces

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Abstract : This poster aims to present an overview of the main results achieved by the ESA SAMOSA project. The poster will concentration in advanced processing techniques and retracking techniques to assess the performance of SAR altimetry over water surfaces.

Keywords: SAR Altimeter, Delay Doppler Altimeter, Oceanography, CryoSat-2, Sentinel-3.

INTRODUCTION

The use of Synthetic Aperture Radar (SAR) techniques in conventional altimetry—i.e., Delay Doppler Altimetry (DDA)—was first introduced by R.K. Raney in 1998 [1]. This technique provides an improved solution for water surface observations due to two major innovations: the addition of along track processing for increased resolution, and multi-look processing for improved SNR. Cryosat-2 is the first satellite to operate in SAR altimetry mode (a.k.a DDA mode). Although its main focus will be the cryosphere, this instrument will also be sporadically operative over water surfaces, thus provide an opportunity to test and refine the improved capabilities of DDA.

This poster will present an overview of the main results achieved by the ESA SAMOSA project. **SAMOSA stands for "Development of SAR Altimetry Studies and Applications over Ocean, coastal zone and inland waters"**. For this study the SAMOSA consortium has developed new theoretical models and analyzed new processing techniques to assess the performance of DDA over water surfaces. These include the development of a new re-tracker.

The work presented here is of interest to the ESA's Sentinel-3 mission. This mission will be devoted to the provision of operational oceanographic services within Global Monitoring for the Environment and Security (GMES), and will include a DDA altimeter on board.

Quantitative comparison of LRM and SAR mode over water surfaces

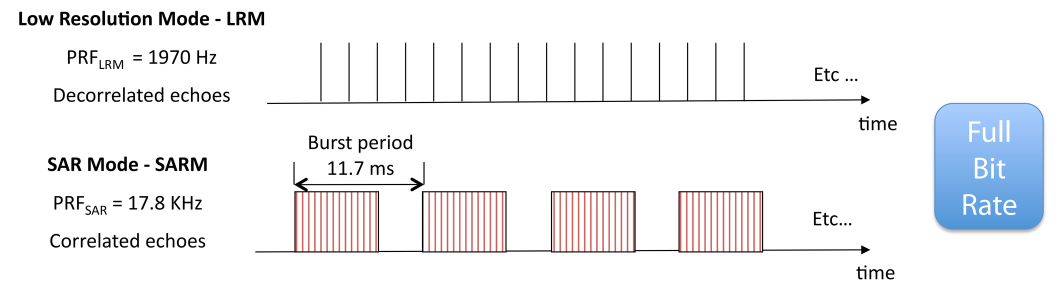


Figure 1: CryoSat-2 operating MODES of interest for SAMOSA

CryoSat-2 operating modes are exclusive, thus for quantitative comparison we will need to **reduce SARM FBR data to emulate LRM FBR data** (**step 1**). We will refer hereafter to reduced SARM data as pseudo-LRM. Once we achieve the pseudo-LRM sequence we need to **transform it to L1b** (**step 2**), and **compare performance with L1b SAR data** (**step 3**).

Step 1: Reduce SARM FBR data to pseudo-LRM

Reduction based on PRF comparison between modes:

$$m = \frac{\mathrm{PRF}_{SARM}}{\mathrm{PRF}_{LRM}}$$

We use one every 9 (value of m) SARM echoes for the generation of pseudo-LRM. Provided that the acquisition modes are different, and SARM does not continuously emit pulses, to acquire equivalent number of pseudo-LRM echoes to emulate a LRM sequence we will need a SARM FBR data sequence larger in time than LRM FBR sequence.

Step 2: Transform pseudo-LRM to L1b

For all CryoSat-2 modes L1b data corresponds to L1 data, or FBR data, incoherently added at a rate of approx. 20Hz

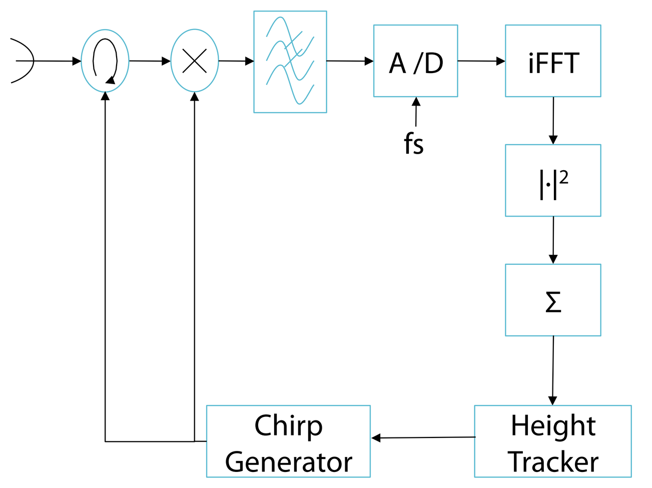


Figure 2: LRM block diagram

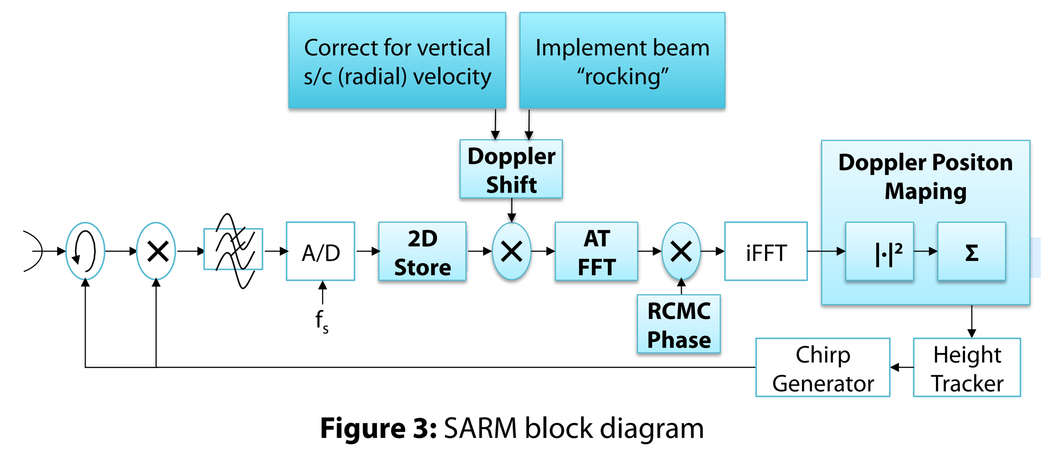


Figure 3: SARM block diagram

Step 3: Quantitative comparison

Pseudo-LRM L1b data ⟷ SARM L1b data

For an equal length time sequence both modes will be compare

SAR Altimeter Retracker

CRYMPS: CryoSat-2 Mission Performance Simulator

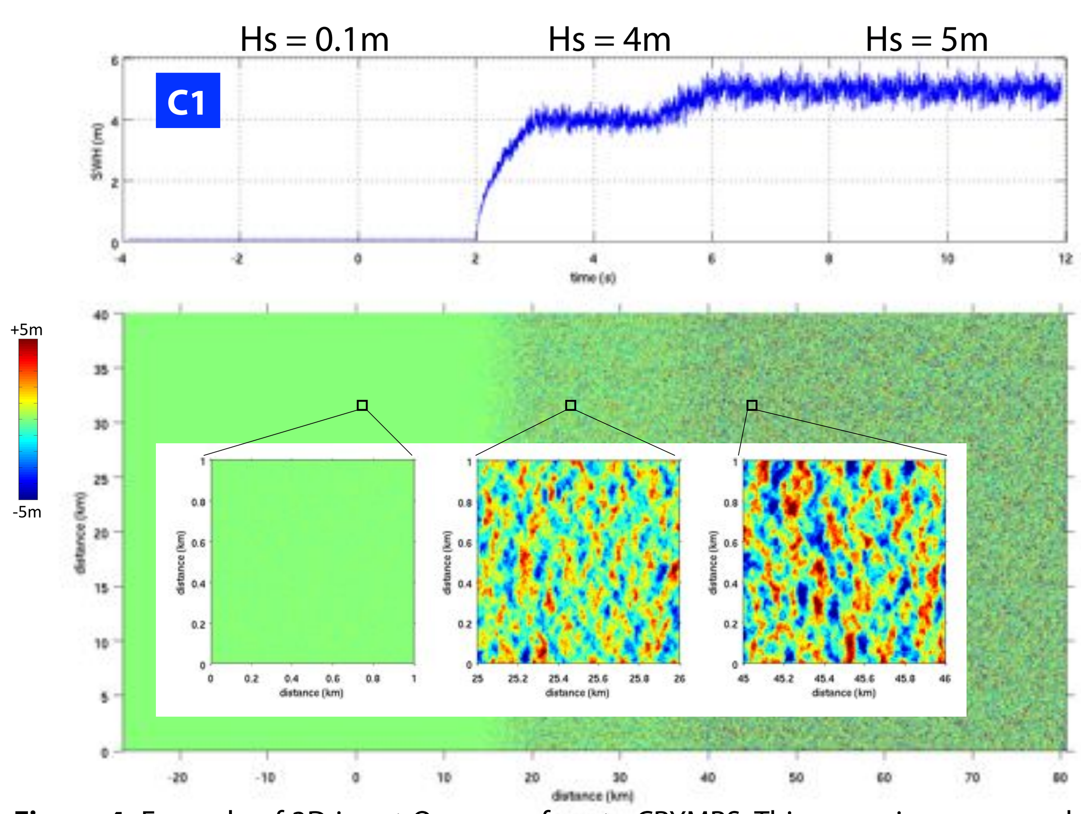


Figure 4: Example of 3D input Ocean surface to CRYMPS. This scenario corresponds to a surface about 120 km x 40 km, equivalent to about 12 seconds of data. Surface waves are generated by inverting wave spectra generated with **the Elfouhaily et al. (1997)** theoretical model for a given SWH values.

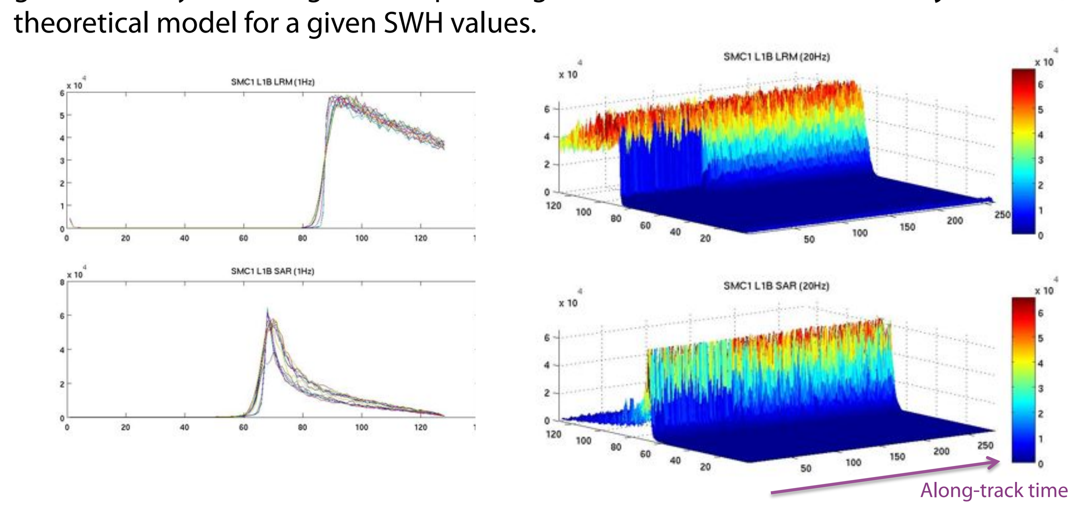


Figure 5: Example of comparison of L1b data shapes for LRM (top) and SARM (bottom).

Given the new shape of SARM echoes there is a need to define a new theoretical model to retrack waveforms in the same spirit as set by [2] and [3].

SAMOSA team has defined a new retracker

Analytical expression achieved. To be published soon

The SARM single-look waveform shall be defined as the convolution [4]:

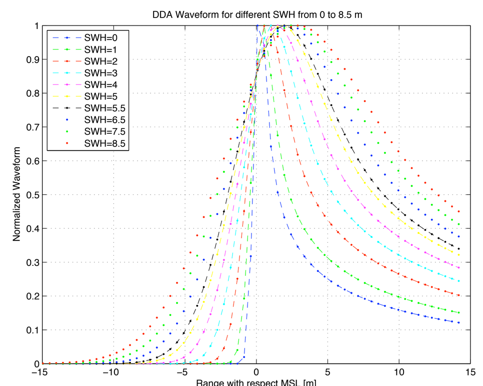
$$W(\tau_i, f_a) = P_{FS}(\tau_i, f_a) ** S_{PTR}(\tau_i, f_a) * \left(\frac{c}{2}\right) P_z\left(\frac{c}{2}\right)$$

Where τ refers to delay time, or range window, with respect MSL; f_a corresponds to a Doppler bin within the burst; P_{FS} is the average flat surface response; S_{PTR} the radar system point target response; and P_z the surface elevation pdf. The major difference with respect conventional altimetry is that S_{PTR} is defined as:

$$S_{PTR}(\tau_i, f_a) = \mathrm{sinc}^2(Tf_a)\, \mathrm{sinc}^2(\tau_u s \tau)$$

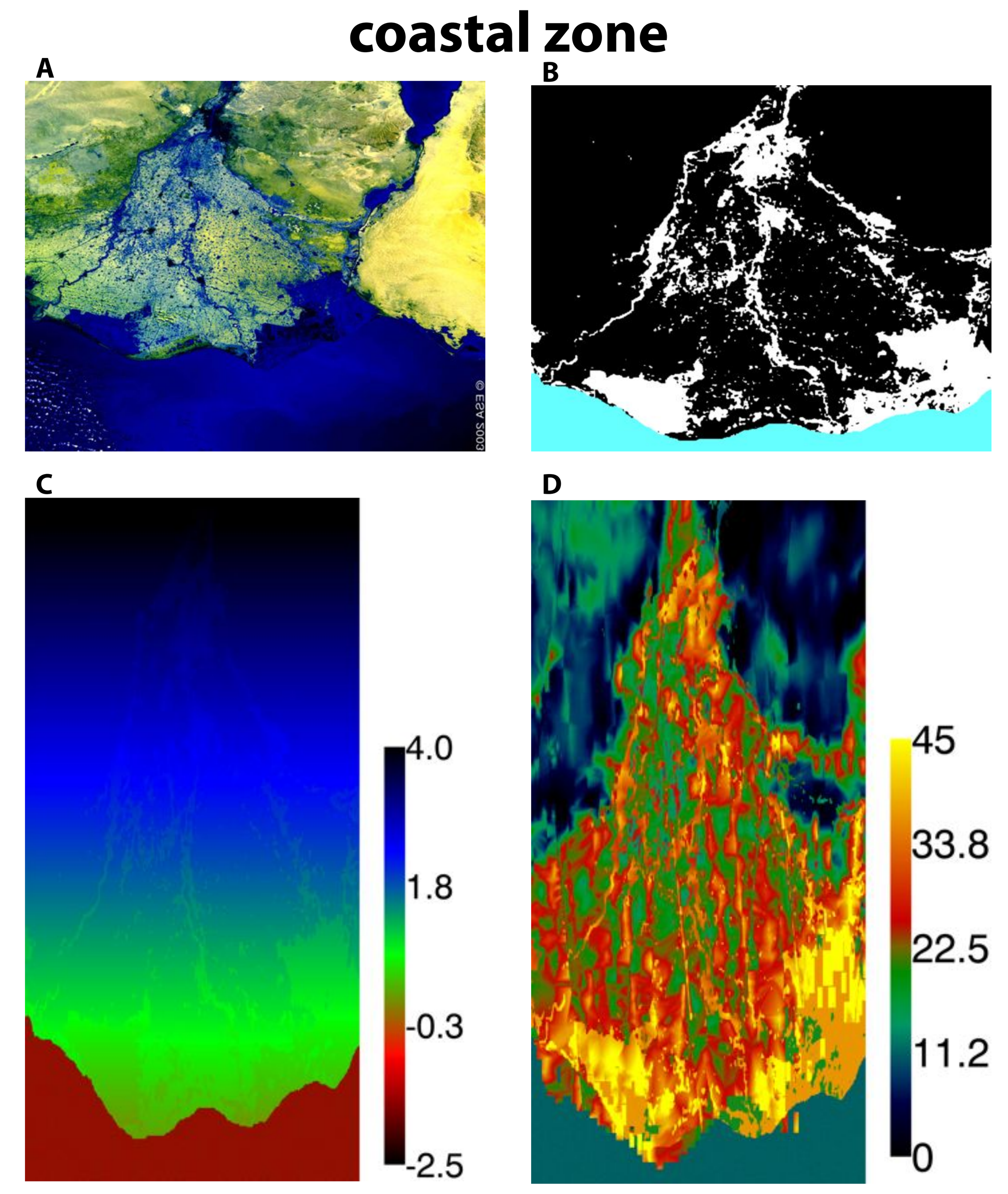
Where T is the long-track boxcar time, τ_u the useful pulse length and s the chirp slope.

Figure 6: Single-look model examples for different SWH

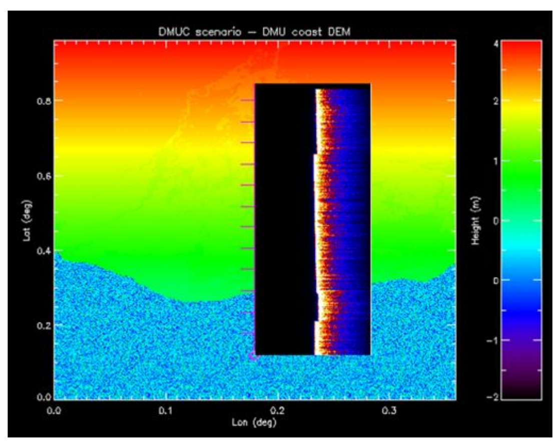


The multi-looked waveform shall be achieved by adding all available looks (single-look contributions) per Doppler cells.

SAR Altimetry over Inland waters / coastal zone

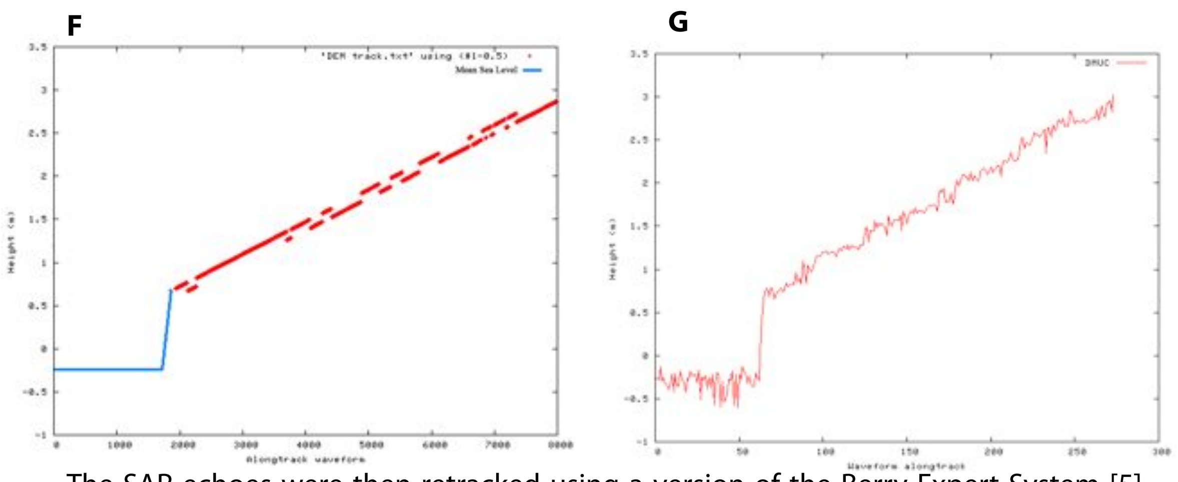


In order to examine how CryoSat-2 will capture echoes over complex water targets, several scenarios were developed, including the coastal zone scenario presented here. The Nile delta was used as the basis for this scenario, utilising a MERIS image (A) to produce a mask (B) of the complex dispersion of water over this estuary. A detailed DEM was prepared (C) using the ACE2 GDEM augmented by river channelling from the MERIS mask and including an ocean model with SWH of 2m. The ERS-1 Geodetic Mission dataset was used to create longer wavelength components of the sigma0 model which was again augmented by brighter pixels following the water distribution (D).



The CRYMPS simulator SAR output waveforms are shown (E) over the input DEM including the wave climate; the track location is along the left edge of the waveform plot (DEM picture courtesy of D.Brockley MSSL).

Note the discontinuities in the leading edge position are due to the simulated tracker performance.



The SAR echoes were then retracked using a version of the Berry Expert System [5] configured for SAR mode echoes; the recovered height profile is shown in (G), with the input heights (showing mean ocean height from input scenario) in (F). Excellent recovery of is seen of the input DEM. The SAR FBR echoes when multi-looked also produced good results.

The conclusion from this analysis is that the SAR L1B and SAR FBR echoes can be successfully retracked over complex coastal/inland water scenarios.

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