Improved spatial resolution and range retrieval accuracy with SAR altimeters over the ocean and the coastal zone

Christine Gommenginger*(1), Cristina Martin-Puig(2), Salvatore Dinardo(3)
R. Keith Raney (4), Paolo Cipollini (1), P. David Cotton(5)
and JŽr me Benveniste(3)

(1) National Oceanography Centre (NOC), UK, (2) Starlab, Barcelona, Spain
(3) ESRIN, Frascati, Italy, (4) Johns Hopkins University, Applied Physics Laboratory, USA
(5) Satellite Oceanographic Consultants Ltd, UK

*Contact: cg1@noc.soton.ac.uk

OVERVIEW

We consider the performance of SAR altimeters (also known as Delay Doppler Altimeters; DDA) to measure sea level and significant wave height over the open ocean and coastal regions. This work was performed as part of the ESA-funded SAMOSA project led by SatOC Ltd.

This study aims to quantify the improvement in altimetric range and significant wave height retrieval accuracy compared to conventional pulse-limited altimeters. In order to retrack SAR altimeter waveforms over water surfaces, a new theoretical retracker for multi-looked SAR ocean waveforms was developed, implemented and tested by the SAMOSA team (Section 2). The SAMOSA SAR retracker forms the basis of the operational algorithm to be used to retrack SAR mode ocean waveforms on the GMES Sentinel-3 Surface Topograpphy Mission.

Prior to the launch of Cryosat-2, analyses were based on simulated ocean waveforms in SAR and LRM mode generated by the Cryosat Mission Performance Simulator (CRYMPS). The CRYMPS simulator was applied to 3D ocean surfaces featuring realistic ocean wave fields. Here, we examine the results of retracking CRYMPS SAR and LRM waveforms for one simulated scenario over idealised coastal conditions (Section 3).

Finally, following the launch of Cryosat-2, we now consider LRM and SAR mode waveforms from Cryosat-2 over water surfaces (Section 4). The Cryosat-2 waveforms in SAR and LRM mode are compared to the simulated CRYMPS data. First results of applying the SAMOSA SAR retracker to Cryosat-2 SAR mode waveforms over water are presented.

What is Delay Doppler Altimetry ?

Delay Doppler Altimetry was first proposed by K.R. Raney (1998). It consists of a nadir-looking altimeter with the capability for high PRF to ensure coherent pulse-to-pulse capability (SAR mode). Some expected benefits of DDA over water include finer along-track spatial resolution (~ 300m) and a two-fold improvement in range retrieval accuracy compared to conventional pulse-limited altimeters.

Based on the same hardware as conventional altimeters, DDA altimeter can operate in two modes (Figure 1):
(a) a Low Rate Mode (LRM) with continuous generation of pulses at a low pulse-repetition frequency (PRF) to ensure independent successive pulses and enable incoherent averaging;
(b) a SAR mode (SAR) characterised by bursts of pulses emitted at high PRF, to ensure pulse-to-pulse coherence and Doppler beam selection capability to increase the number of looks.

Both altimeters on Cryosat-2 and the Sentinel-3 Surface Topograpphy Mission feature Delay Doppler capability. In the case of S3-STM, SAR mode will be used over ocean regions of high spatial variability, such as the Western Boundary Currents and coastal regions.
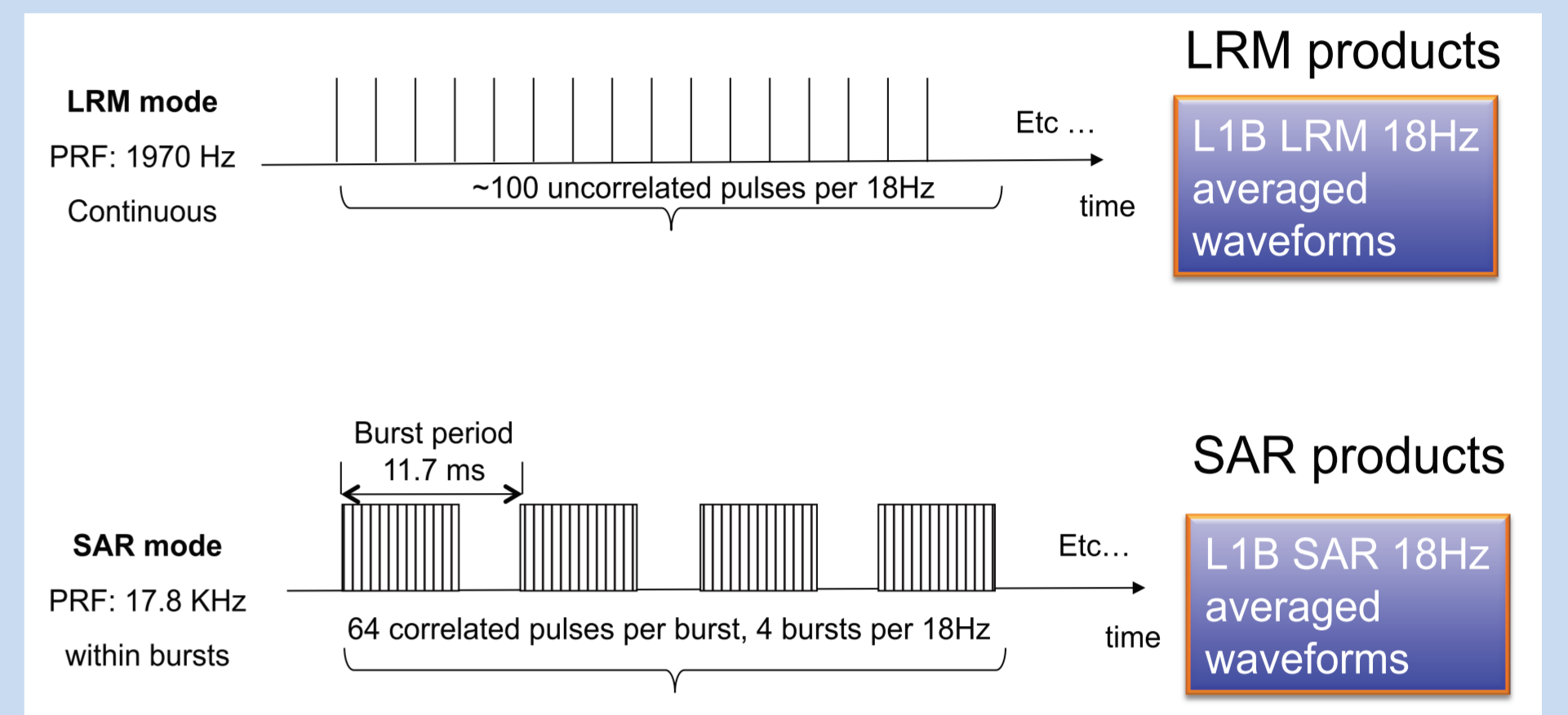

Figure 1 - Data acquisition mode in LRM (top) and SAR (bottom) mode for Cryosat-2 and Sentinel-3.

2 – The SAMOSA SAR Ocean retracker

SAR altimeter waveforms over water surfaces are much peakier than conventional LRM waveforms. A new theoretical model was developed from first principles within the SAMOSA project (Martin-Puig & Ruffini, 2009). In its analytical form, the model depends on geophysical parameters such as epoch, significant wave height, normalised radar cross section, mispointing angle and a parameter linked to the root mean square slope. Figure 2 shows the dependence on significant wave height of the single-look Delay Doppler Map at zero Doppler frequency.
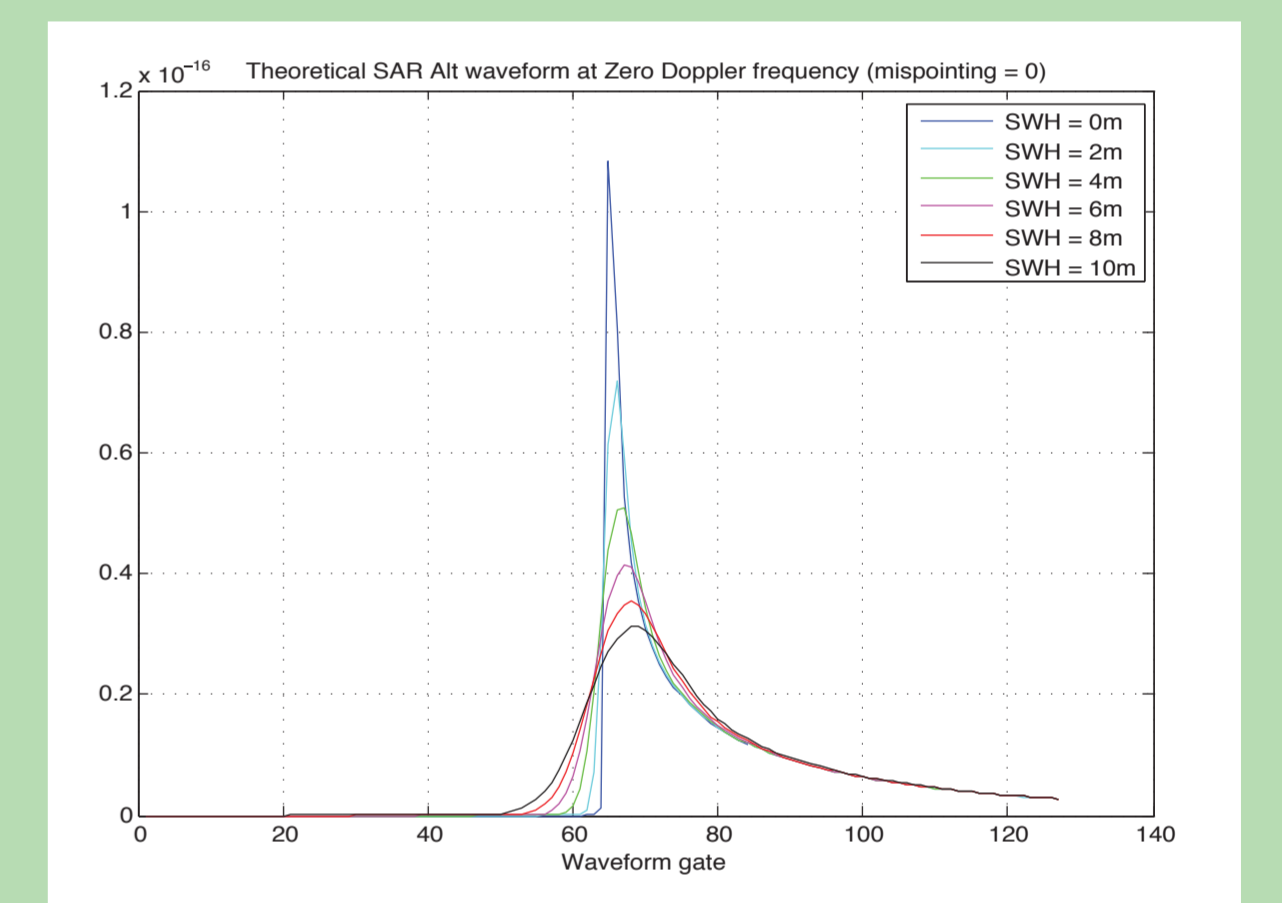
The single-look theoretical model was combined with multi-looking algortihm to form the prototype SAMOSA SAR ocean waveform retracker used here.

Figure 2 - Theoretical single-look Delay Doppler waveform at zero Doppler frequency for different values of significant wave height.

3 - CRYMPS Simulated waveforms: an idealised Coastal zone scenario

Figure 3 shows the surface DEM devised to represent a scenario over idealised coastal conditions, used as input into CRYMPS. Figure 4 shows a top view of the resulting CRYMPS L1B 20Hz waveforms in LRM and SAR mode in this 12 second scenario. The CRYMPS LRM and SAR waveforms were subsequently retracked with the Brown ocean retracker and the SAMOSA SAR retracker respectively (Figure 5). The retrieved epoch and significant wave height are shown in Figure 6.

Figure 3 - DEM and Input parameters for CRYMPS Idealised scenario over coastal zone.

Figure 4 - CRYMPS Idealised coastal scenario (top) Input parameters (middle) CRYMPS LRM wavforms (bottom) CRYMPS SAR waveforms. The x-axis represents time or distance along-track.
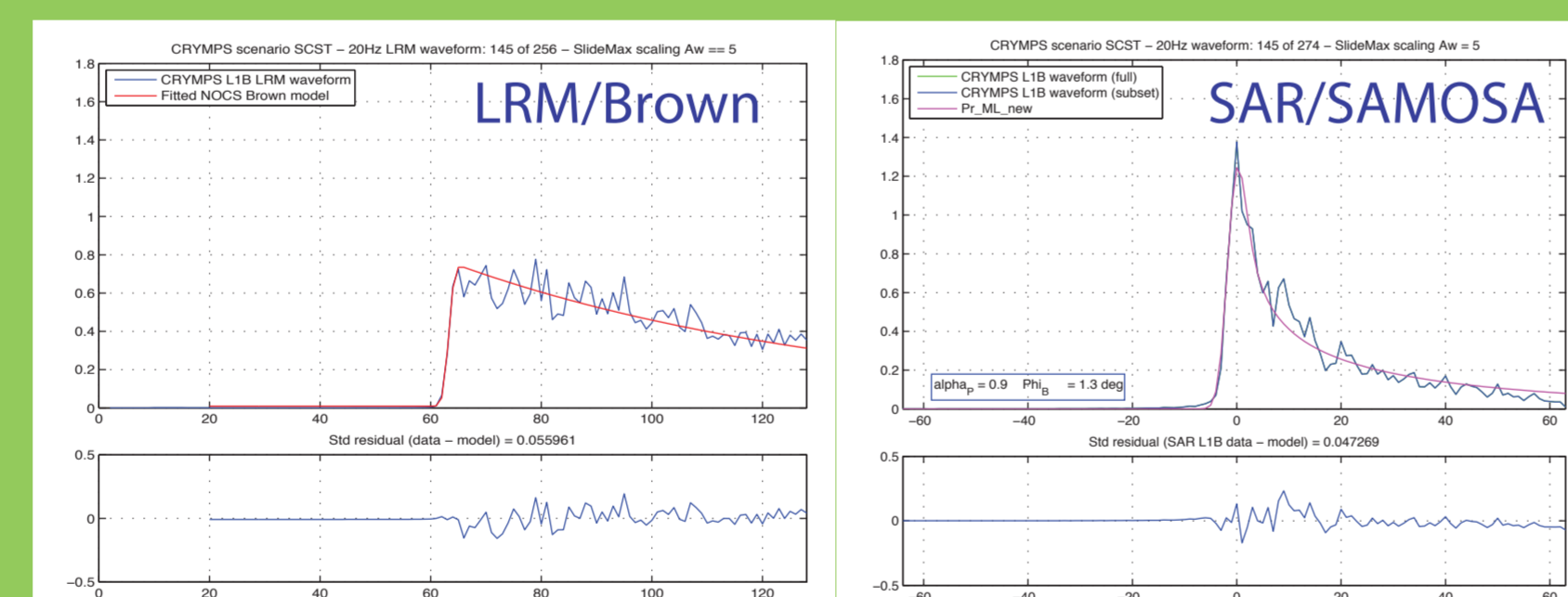

Figure 5 - Sample CRYMPS waveform from the coastal scenario in (left) LRM and (right) SAR mode, fitted respectively with the Brown Ocean retracker and the SAMOSA SAR Ocean retracker.
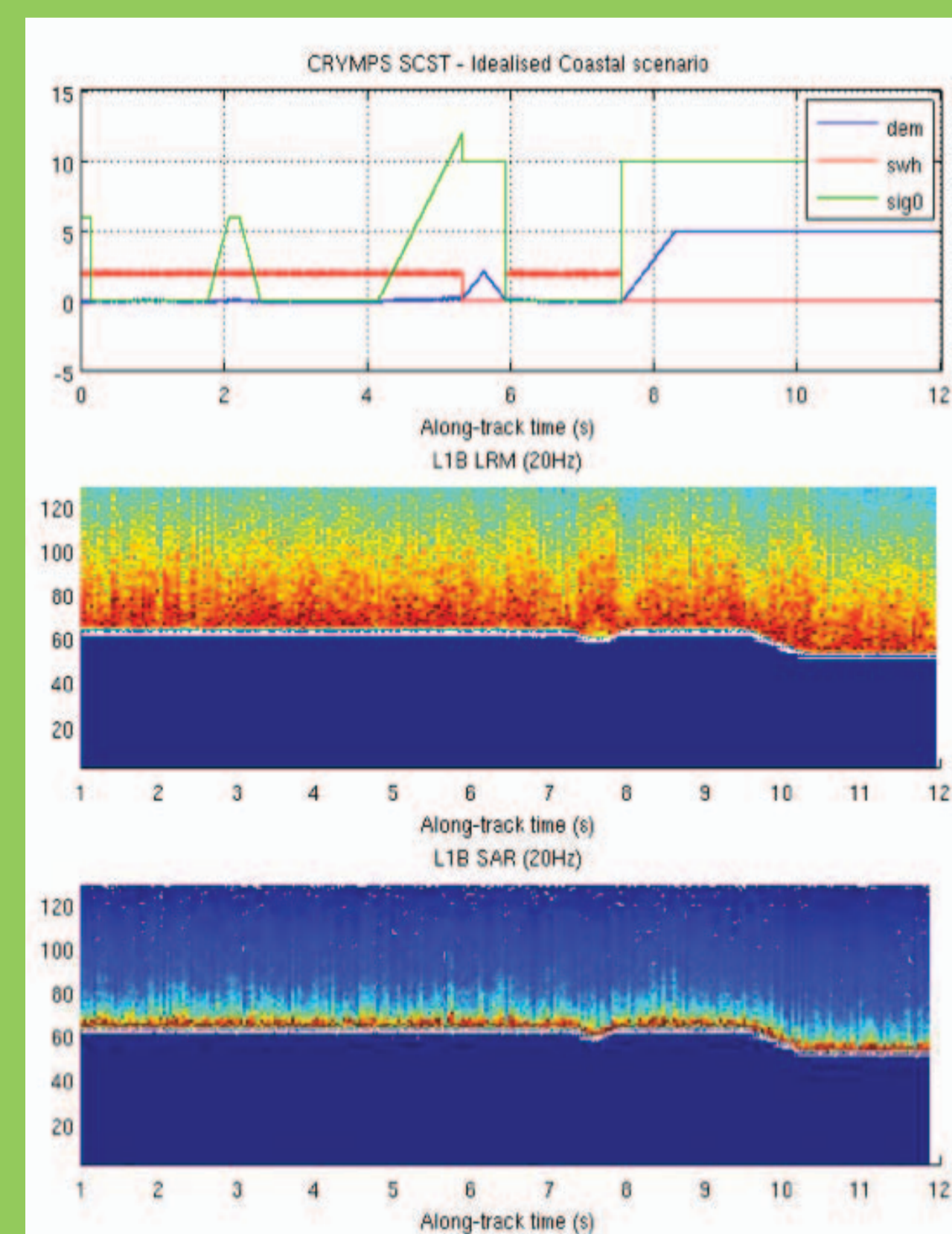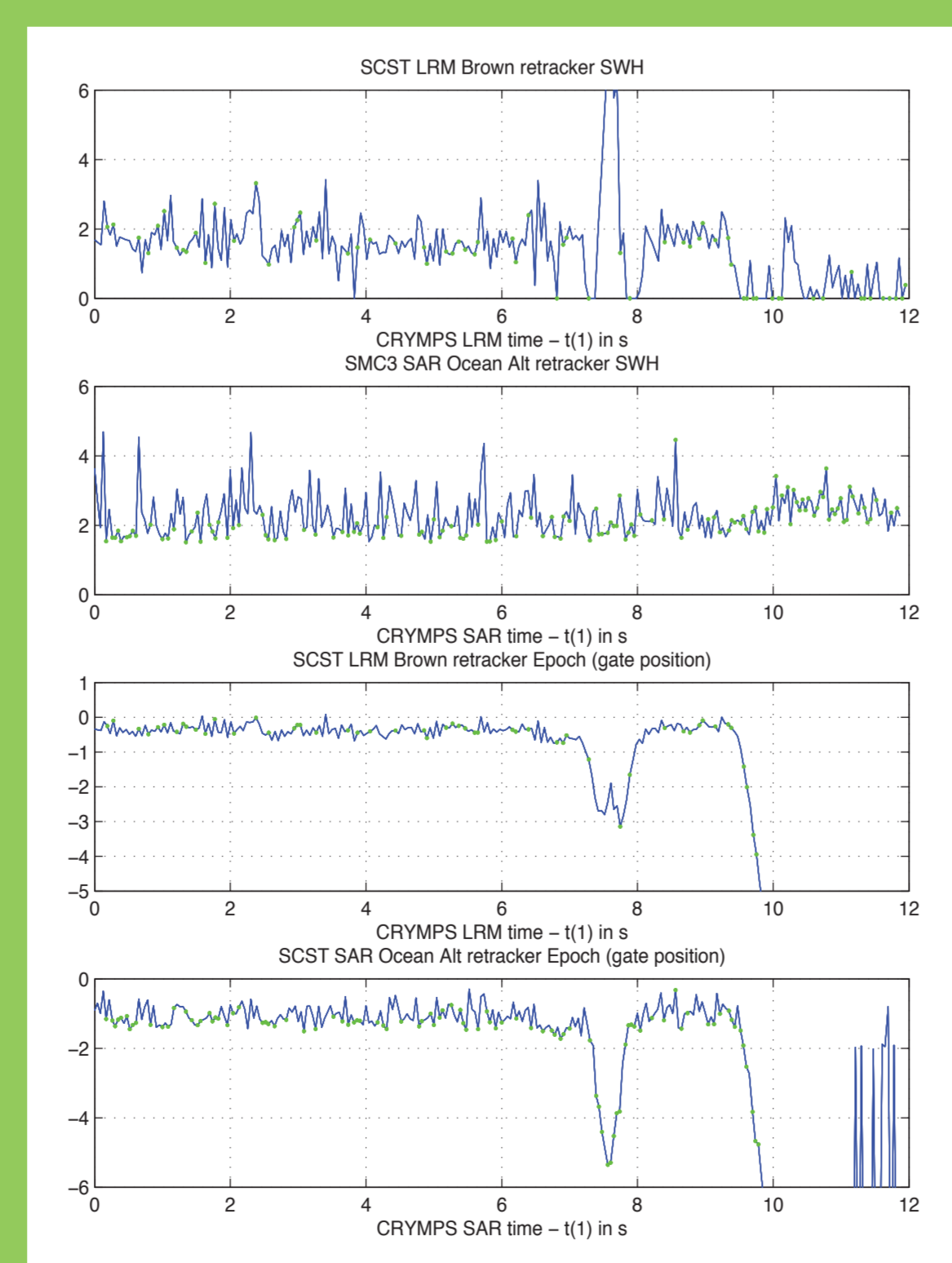

Figure 6 - Retracked significant wave height and Epoch for the CRYMPS LRM and SAR waveforms in the coastal scenario, using the Brown Ocean retracker and the SAMOSA SAR Ocean retracker.

Retracking CRYOSAT-2 SAR waveforms over water surfaces

Following the launch of Cryosat-2 in March 2010, we investigate Cryosat-2 L1B 20Hz waveforms over ocean and inshore waters in LRM and SAR mode. Figure 7 shows where the two types of products are typically found. Unfortunately, unlike CRYMPS, it is not possible to compare LRM and SAR mode directly over the same location. Figure 8 shows top-down views of the LRM and SAR waveforms for nearby tracks over the Gulf of Thailand. Figure 9 shows a SAR L1B waveform over water retracked with the SAMOSA SAR retracker, showing that the SAMOSA model offers a good fit to the Cryosat-2 SAR data over water.
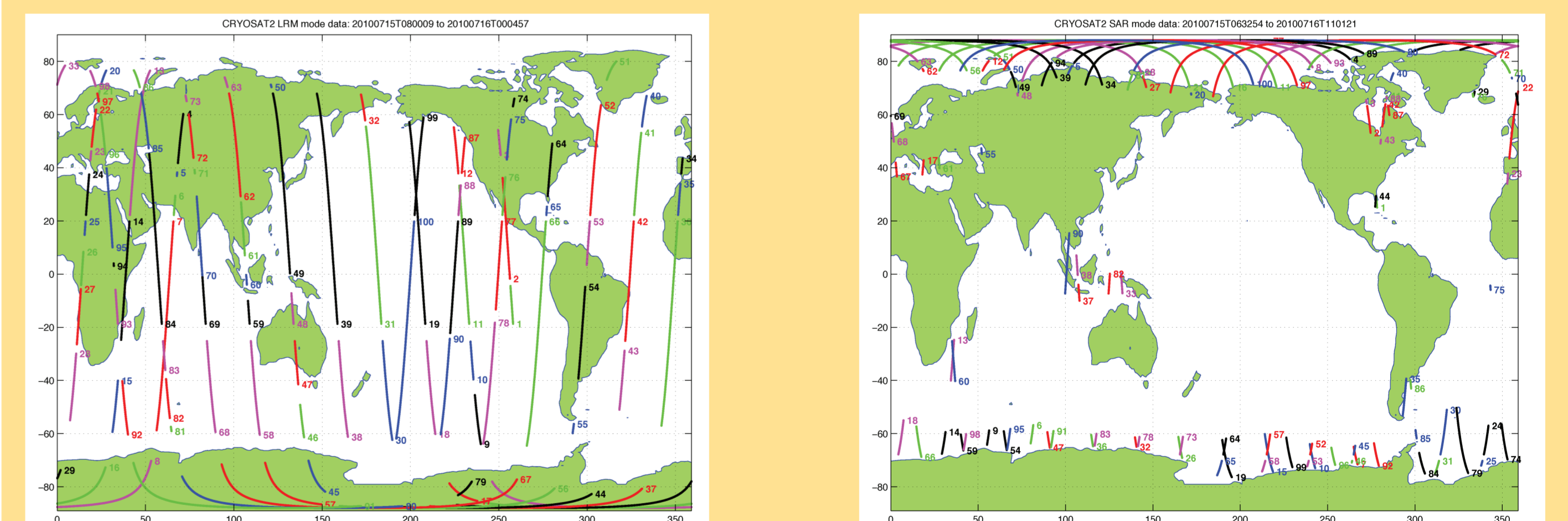

Figure 7 - Geographical location of Cryosat-2 LRM and SAR products. For Cryosat-2, LRM mode is typically used over open ocean, while SAR mode is typically reserved for sea ice.
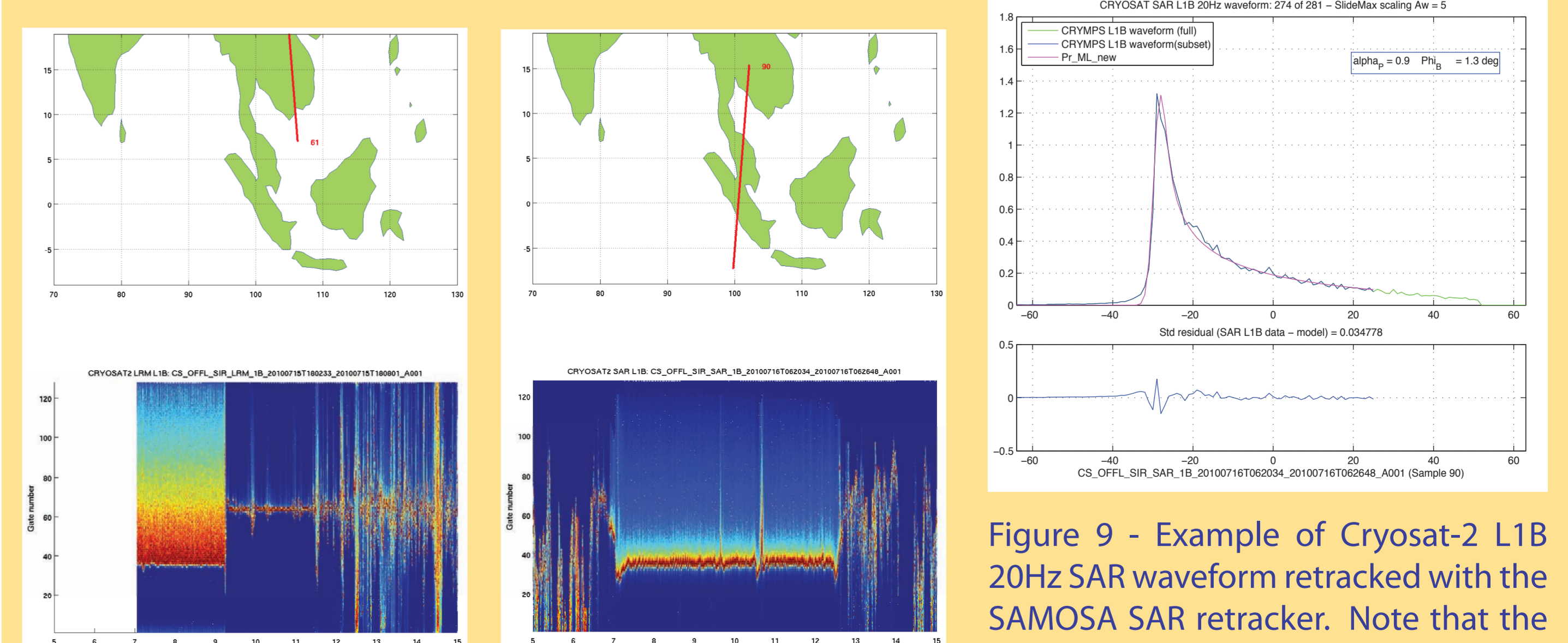

Figure 8 - Example of Cryosat-2 L1B 20Hz waveforms in (left) LRM and (right) SAR mode over the Gulf of Thailand.
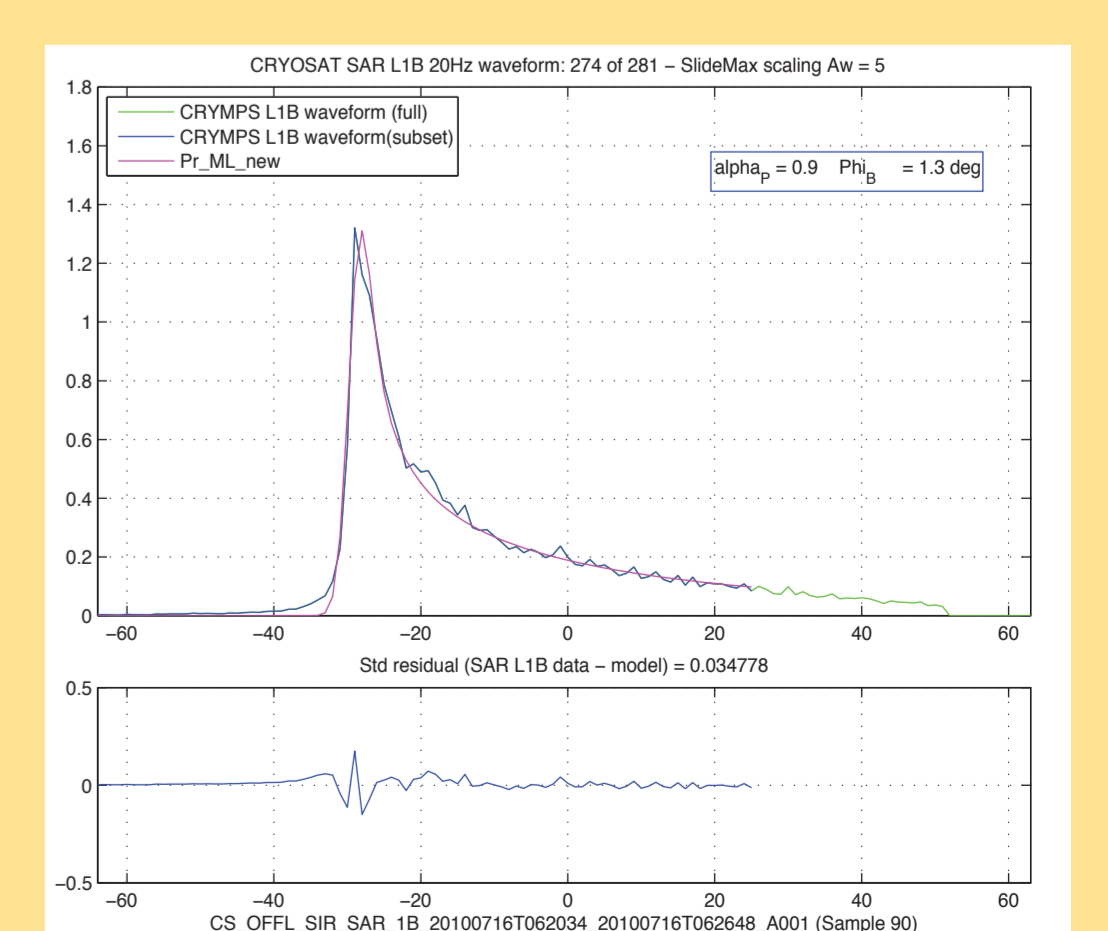

Figure 9 - Example of Cryosat-2 L1B 20Hz SAR waveform retracked with the SAMOSA SAR retracker. Note that the CRYOSAT waveforms seem to show less noise than the CRYMPS simulated data in Figure 5.

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

esa