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Road-Mapping the Way Forward for Sentinel-3 STM SAR-Mode Waveform Retracking over Water Surfaces

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In the framework of the preparation activities for the Sentinel-3 Topography Mission, ESA launched an R&D project on SAR Altimetry and Applications over Ocean, Coastal zones and Inland waters. The main objective was to design a novel processing algorithm over ocean surface that would run in the Sentinel-3 ground segment to provide unprecedented quality altimeter measurements over ocean surfaces when in SAR mode. Also coastal zones and inland waters were the targets of research to derive new models and re-trackers for these difficult measurements. Innovative physically based models have been developed for near-nadir ocean altimetric waveforms in SAR-Mode and subsequently implemented in prototype ocean SAR re-trackers to perform the validation. A Detailed Processing Model Document was delivered for implementation in the Sentinel-3 Topography Mission Ground Segment.

In this paper, we present the approach used to date within SAMOSA and the heritage behind the latest SAMOSA2 model. The SAMOSA2 model offers a complete description of SAR altimeter echoes from ocean surfaces, expressed in the form of maps of reflected power in delay and Doppler space. SAMOSA2 is able to account for an elliptical antenna pattern, mispointing errors in roll and yaw, errors in range cell migration correction, surface scattering pattern, non-linear ocean wave statistics and spherical Earth surface effects. SAMOSA2 addresses some of the known limitations of the earlier SAMOSA1 model, in particular with regards to sensitivity to mispointing. Due to its truly comprehensive character, the full SAMOSA2 model is a complicated semi-analytical formulation that still relies on some numerical integrations. The need for numerical integrations significantly impacts the computation time and raises problems of numerical stability once implemented operationally in a re-tracker scheme. This has potentially serious implications that could prevent the implementation of SAMOSA2 in operational re-tracker schemes.

However, since the ultimate goal of the SAMOSA project is to deliver to the Sentinel-3 Surface Topography Mission Product and Algorithm Development (S-3 STM PAD) a Detailed Processing Model of a SAR ocean waveform re-tracker based on the best SAMOSA model to operationally re-track Sentinel-3 STM SAR-Mode L1b waveforms, the need for the full mathematical complexity of the SAMOSA2 model was re-evaluated.

With this in mind, the SAMOSA team assessed a number of simplifications that can transform the SAMOSA2 model into a lighter, computationally more efficient, purely analytical formulation for input into the SAR re-tracker scheme for the Sentinel-3 STM PAD. The simplifications that have been considered involve the omission in the model of second order effects such as non-linear terms in the model, ocean surface skewness, and electromagnetic bias. Their impact has been evaluated. This SAMOSA3 model has the advantage to be a pure analytical solution, expressed by means of modified Bessel functions of first and second kind and returns no singularities for the full range of the gate bins.

An extensive validation was performed. First equivalence between SAMOSA3, SAMOSA2 & SAMOSA1 models was confirmed and then a a sensitivity study on the input parameters and the re-tracking approach was carried out. Finally, the SAMOSA3 Model and re-tracker was applied to Cryosat-2 L1B SAR waveforms and the performance was studied as well as the sensitivity to mispointing. Two areas were chosen as representative of the high and low ocean dynamics regions, respectively the South Norwegian Sea and the Caspian Sea. Finally the SAMOSA3 output was validated against in situ wave buoy measurements. An overview of these results will be shown here.