The SAMOSA project

Development of SAR Altimetry studies over Oceans, coastal zones and inland Water

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SAMOSA

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The Motivation of SAMOSA

CryoSat-2 is the first satellite with a SAR Altimeter on board: SIRAL (name of the instrument)

SIRAL has three operating modes the:

•The Low Resolution Mode or LRM

•The SAR Mode or SARM

•The interferemotric SAR mode or inSARM

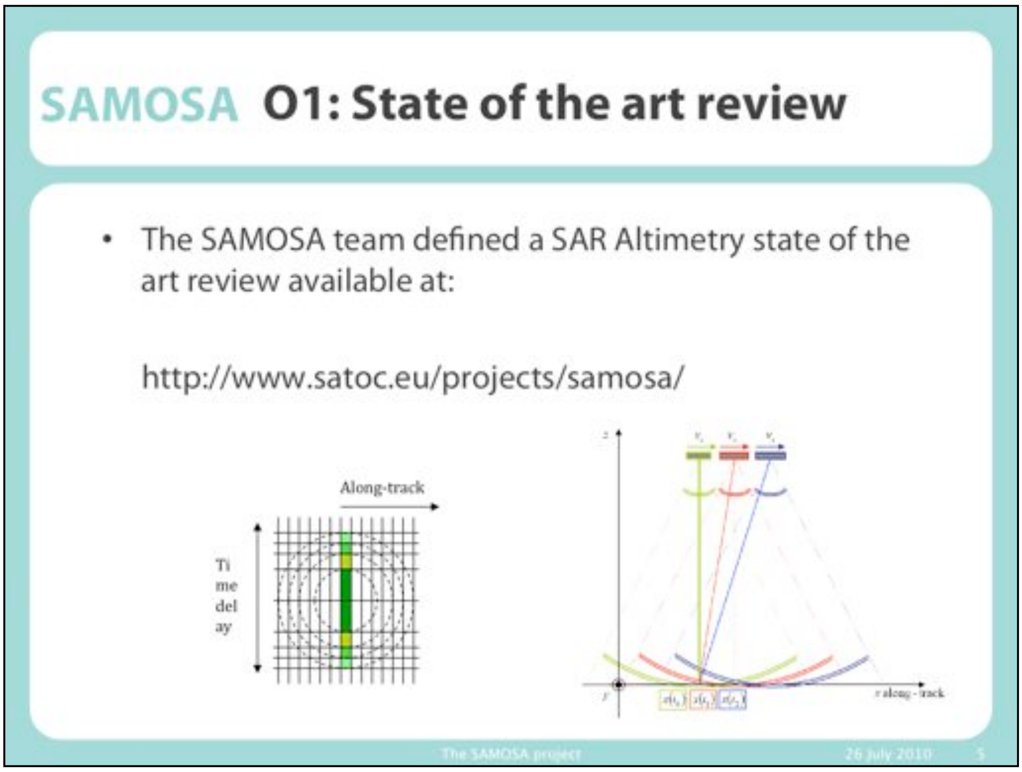
The first two only of the interest of these activities and will be explained in slide 7

The Mission of SAMOSA is clearly described in the paragraph in the slide, thus there are no additional comments

SAMOSA OBJECTIVES

1. To establish a **state of the art review for SAR altimetry** capabilities to observe water surfaces
2. To reduce SARM data into LRM data and perform a scientific study of the **potential improved capability of SAR** data **compared to conventional altimetry** over water surfaces
3. To develop a **theoretical model** for the SAR altimetry mode echoes over water surfaces
4. To define a **new re-tracking method** for the SAR altimetry mode
5. To perform a **scientific study** of the potential capabilities of SAR altimetry data to characterise coastal zones, estuaries, rivers and lakes
6. To evaluate the SAMOSA re-tracker with **ASIRAS** data

Keith is a great support in the understanding of the SAR Altimeter and in the interpretation of our scientific investigations and the other two are a great support in the understanding of
CRYMPS, which stands for CryoSat Mission Performance Symulator

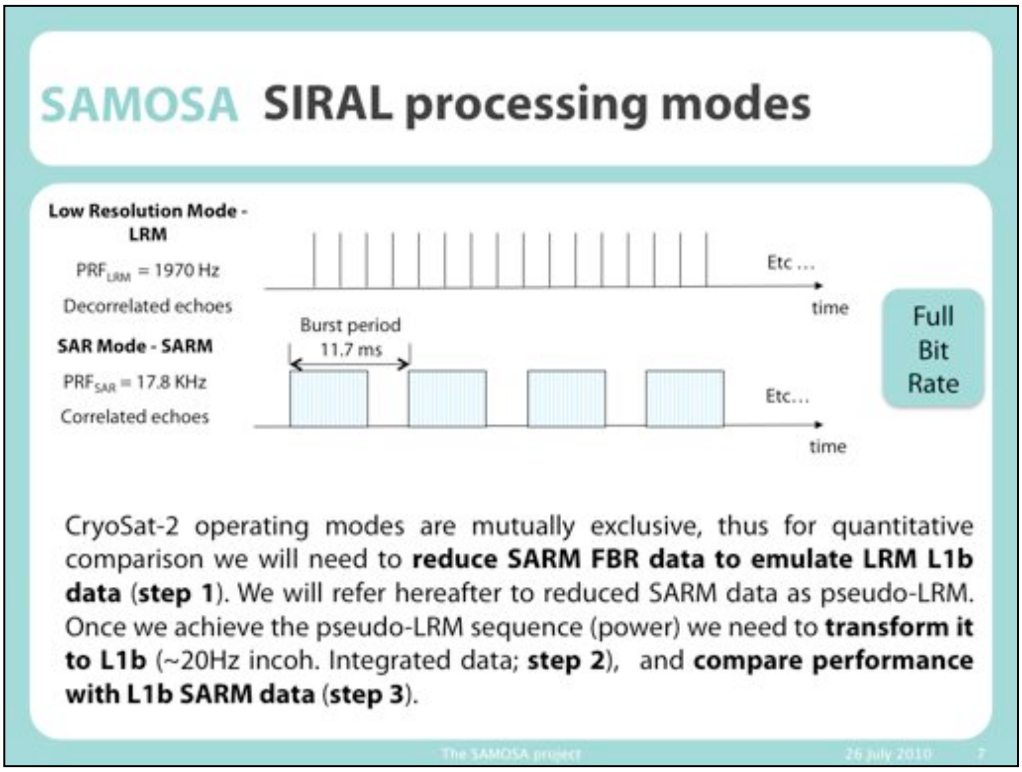


In this state of the art review we describe the main differences of conventional altimetry and SAR Altimetry in the form of a tutorial.

SAMOSA O2: RDSAR

- The SIRAL modes are mutually exclusive
- For the quantitative comparison of SARM and LRM data the SAMOSA team is working on the reduction of SAR data such that it emulates conventional altimetry data
- Achieving this objective would allow to retrieve LRM data and SARM data from a single operating mode

In addition to the previous, achieving this objective would also allow for the simplification of hardware/mission planning and risks estimation of offset/gaps between modes



The main objective of this slide is to describe the SIRAL operating modes.

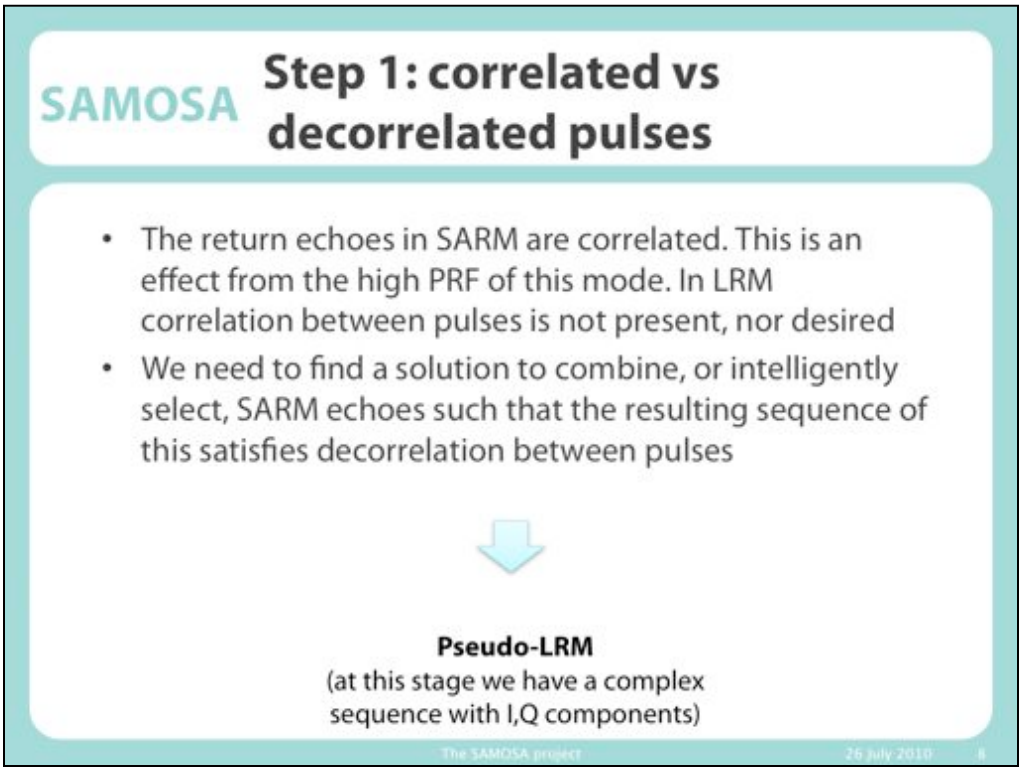
• When operating in LRM or conventional altimetry mode, the SIRAL sensor emits pulses at a frequency of 1970Hz. These echoes are independent to each other, thus we can perform incoherent integration between them to reduce the effect of Speckle noise.

• When operating in SARM the SIRAL sensor emits the echoes grouped in the form of bursts. 64 pulses are emitted per burst at a PRF of 17,8KHz. This high PRF ensures the correlation between echoes which is needed for the Delay Doppler Processing to be applied to the return echoes. After emission, there is a reception time window to gather all returns and a new burst is emitted again.

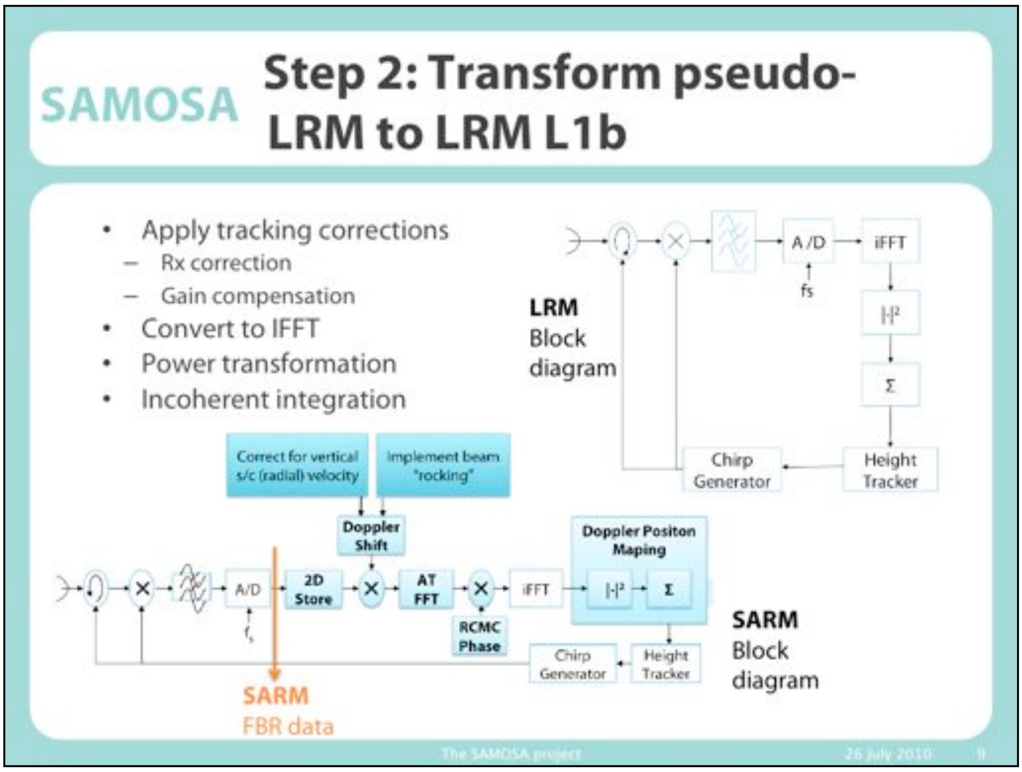
IT IS VERY IMPORTANT THAT IN THIS SLIDE YOU SPECIFY THAT

• SIRAL data of interest for our work is the Full Bit Rate (FBR) Data , which for each mode corresponds to:

- • LRM: incoherently integrated echoes at a rate approximately 20Hz
- • SARM: consists of the individual complex (I and Q) echoes → equivalent to the individual echoes of RA-2



We prefer not to explain yet how this is done until we achieve a final methodology

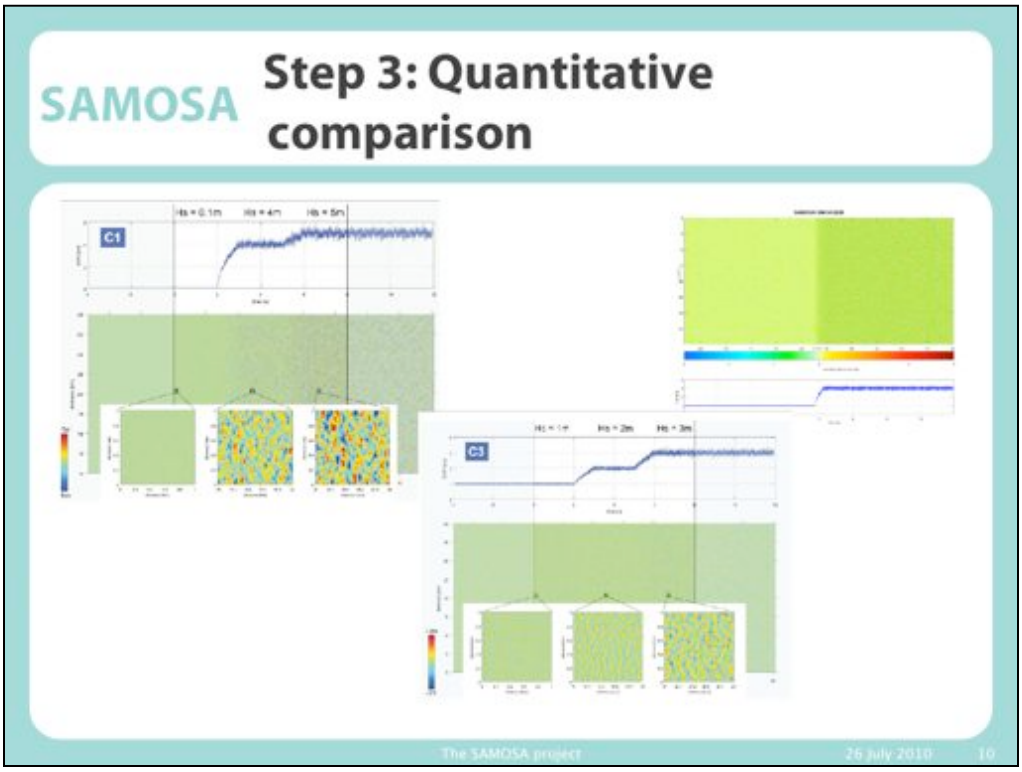


In this slide first we show the LRM block diagram and after the SARM block diagram

The main different blocks from one to the other are highlighted in blue

The SARM FBR data corresponds to the data previous to the Doppler shift block. Therefore in order to process it as in LRM we need to apply the same blocks as in the first diagram. Which are mainly:

-IFFT
-Transform to power
-Incoherent integration

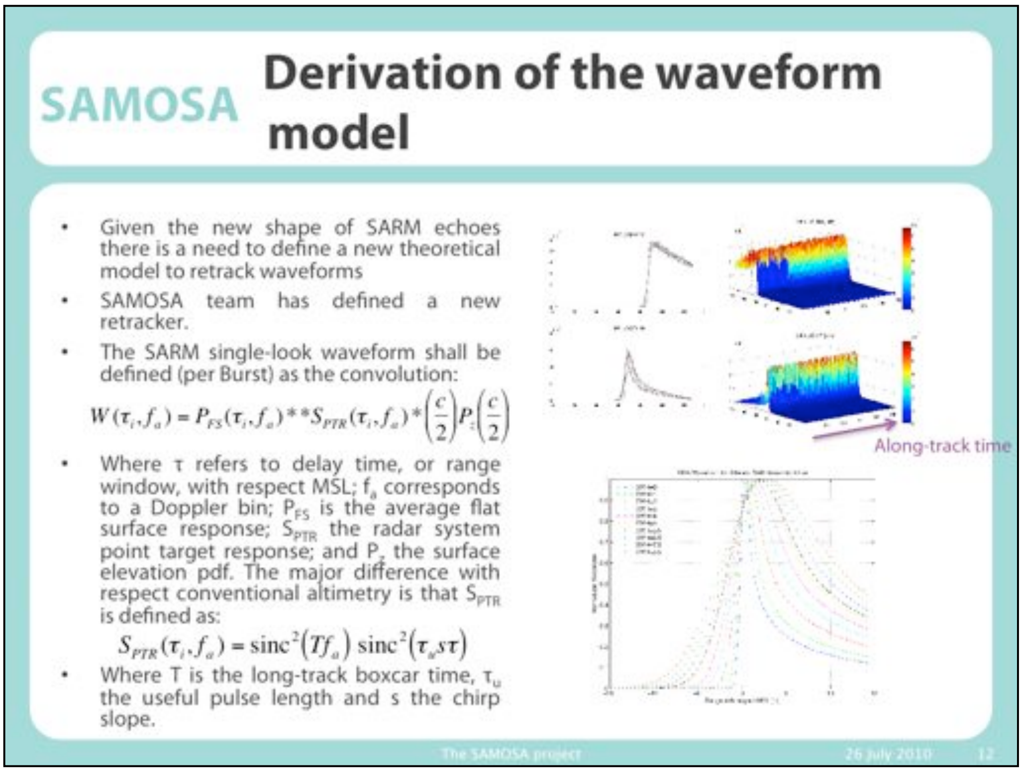


For the Quantitative comparison of modes we are using the CRYMPS simulator. And we have derived a wide variety of DEMs to do the scientific study.

SAMOSA

O3: SAR altimeter theoretical model

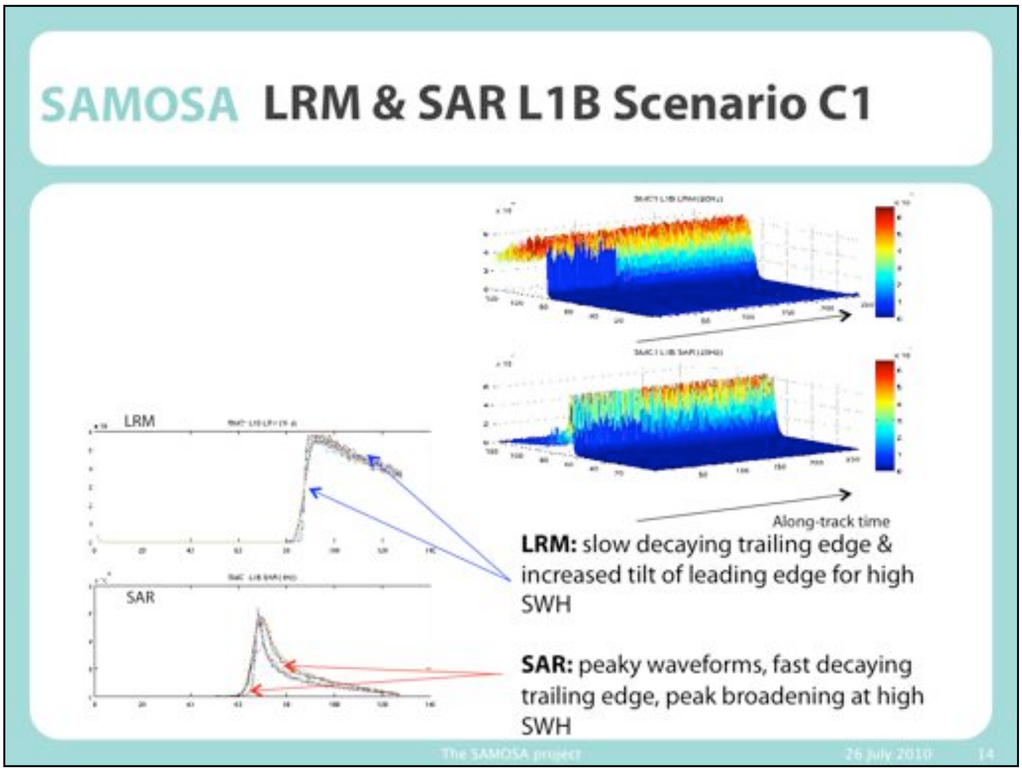
- An analytical waveform model has been defined for:
  - Circular Antenna Pattern
  - No curvature effects across track
  - No radial velocity effects
  - Gaussian sea surface statistics
  - Absence of across-track miss-pointing effects
- Currently the team is improving this model:
  - Introduce Elliptical antenna pattern
  - Consider Earth curvature effects across track
  - Study radial velocity effects
  - Use of non-Gaussian sea surface geometry



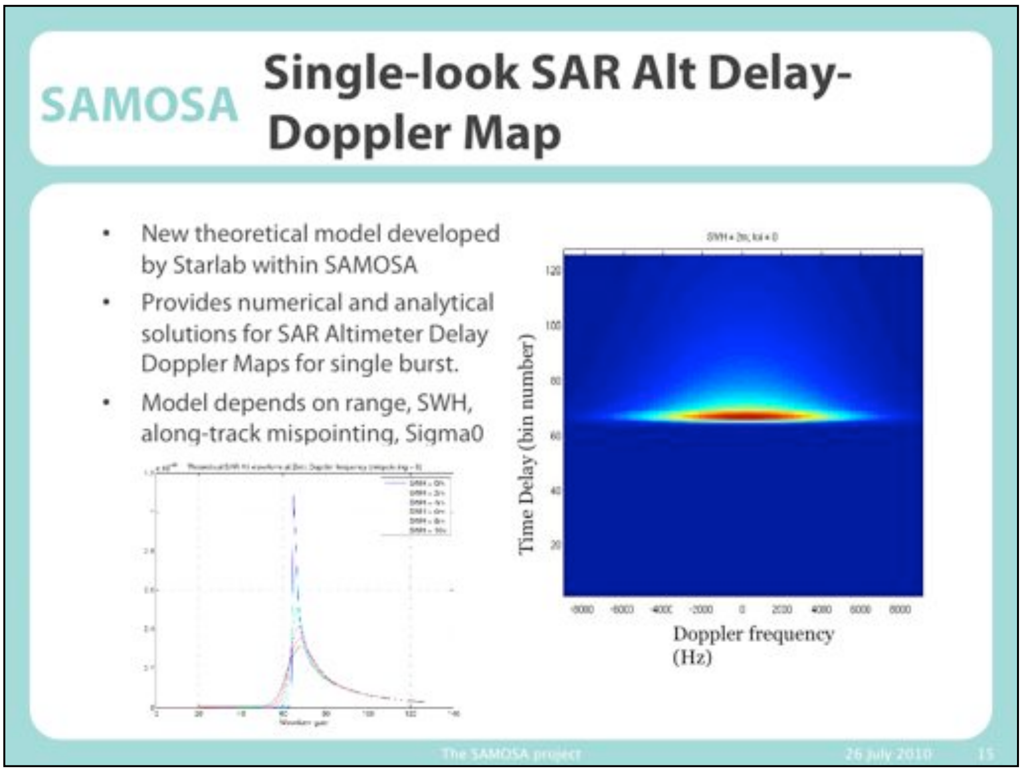
You can use this slide to eplain which is the origin of the analytical expression. For IPR issues we prefer not to include the expression in this presentation until the scientific paper is published.

SAMOSA O4: SAR Altimeter re-tracker

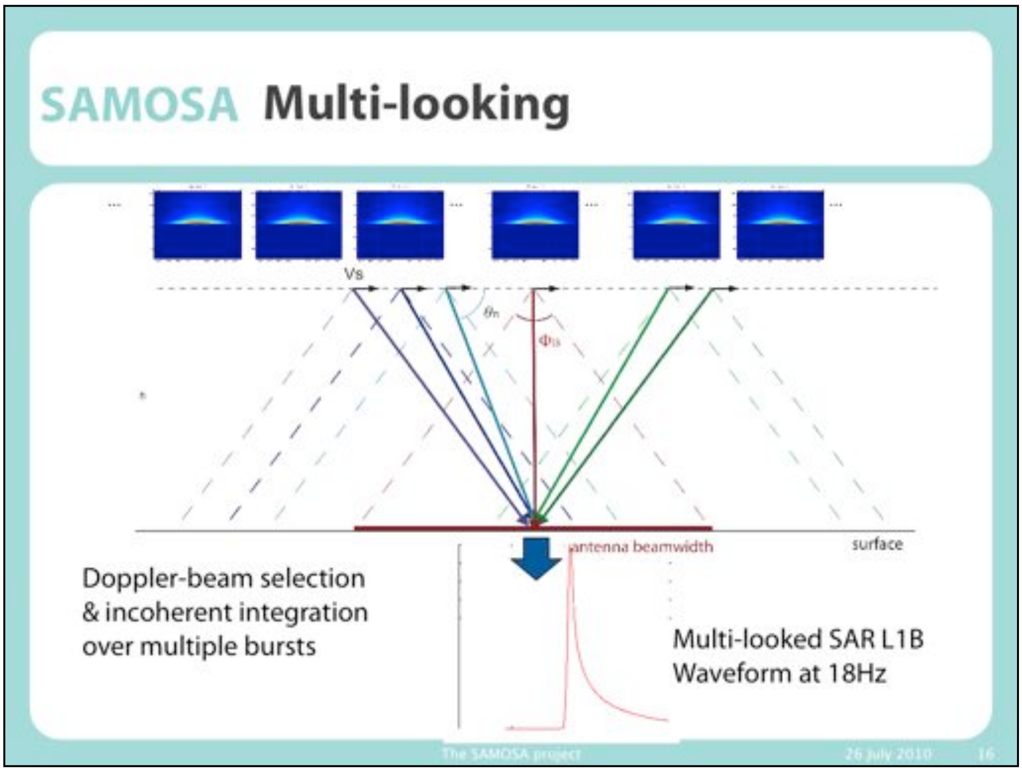
- A SAR altimeter re-tracker has been developed based on the analytical expression derived in the previous objective
- Good agreement was found between theoretical & numerical SAR waveforms
- A DPM for the Sentinel-3 SRAL retracker has been delivered.



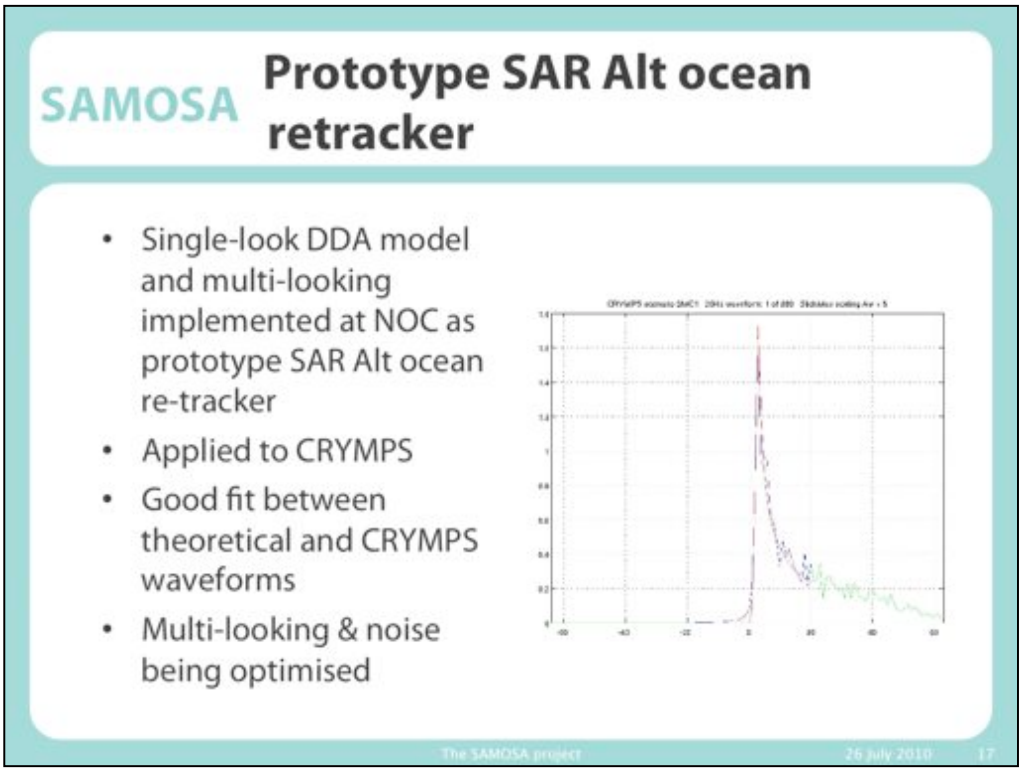
First, let's compare the shapes of LRM and SAR 18Hz waveforms for the same CRYMPS ocean scenario (C1). On the right, we show 3D views of the (top) LRM and (bottom) SAR waveforms, where along-track time is directed into the page. Note how the SAR waveforms are a lot peakier than LRM (The waveforms were scaled so the along-track changes in power levels cannot be observed). The figure on the left shows the waveforms averaged over 1 second along-track to illustrate clear differences in the leading edge and trailing edge between LRM and SAR.



Since peaky SAR waveforms cannot easily be fitted with Brown-type ocean retrackers, a new theoretical model was developed in SAMOSA by Starlab for SAR Altimeter waveforms over water surfaces. The model gives analytical and numerical solutions to compute the distribution of power in Delay Doppler space for single burst (as shown in the figure). The model depends on geophysical parameters such as range, SWH, along-track mispointing and Sigma0. Click once to reveal another figure showing the theoretical SAR waveform in the zero Doppler bin for different values of SWH. Note the peaky waveform shape and the broadening of the peak, similar to what is seen in the CRYMPS SAR data.



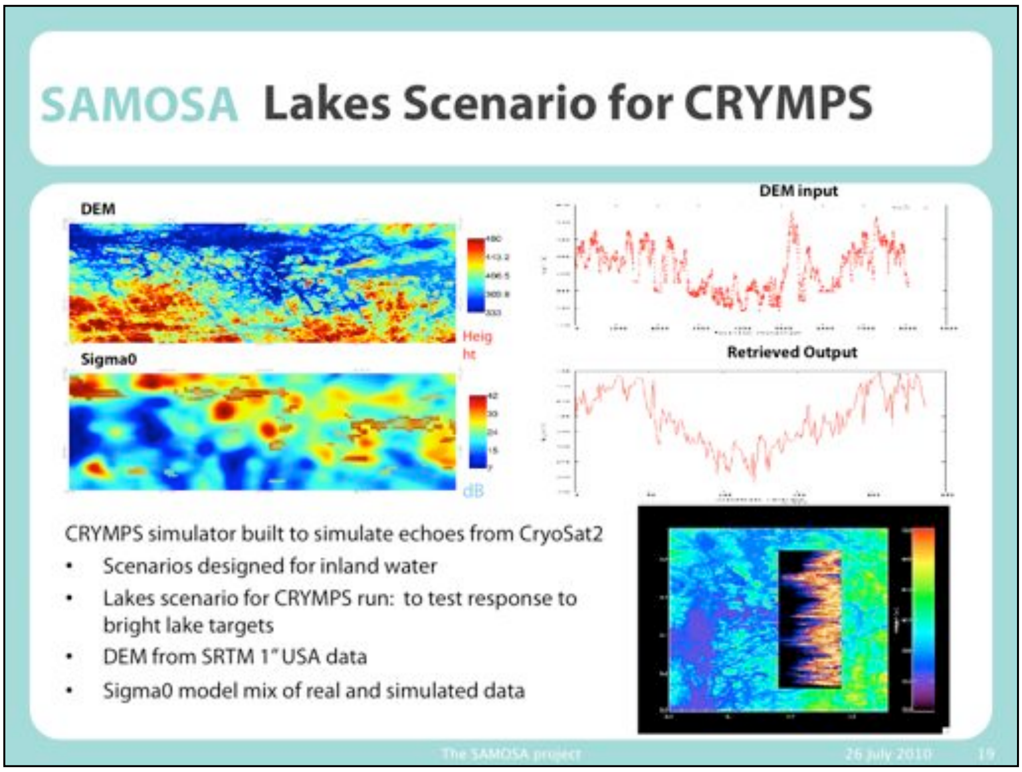
To obtain theoretical waveforms comparable to the SAR L1B 18Hz waveforms, you need to select the relevant Doppler beam in each burst and incoherent integration over multiple bursts. This is known as multi-looking.



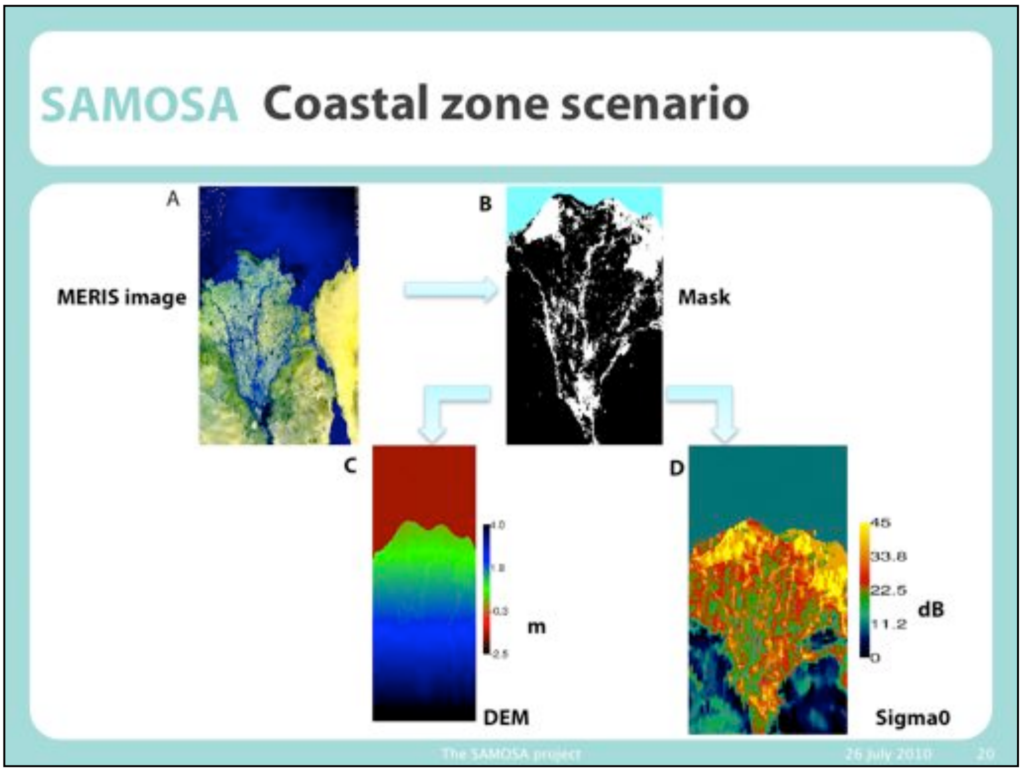
The theoretical single-look DDA model and multi-looking integration procedure was implemented at NOCS as a prototype SAR altimeter ocean retracker. The SAR ocean retracker was applied to CRYMPS SAR waveforms for the CRYMPS scenarios over ocean. The movie shows the 18Hz L1B SAR waveforms for scenario C1 with CRYMPS in blue/green and the fitted theoretical model in red. We find good agreement between CRYMPS SAR waveforms and the multi-looked theoretical waveforms in different SWH conditions. The multi-llooking is now being optimised before we can proceed with comparing the retrieval capability of SAR mode with LRM.

SAMOSA O5: Coastal & Inland Waters

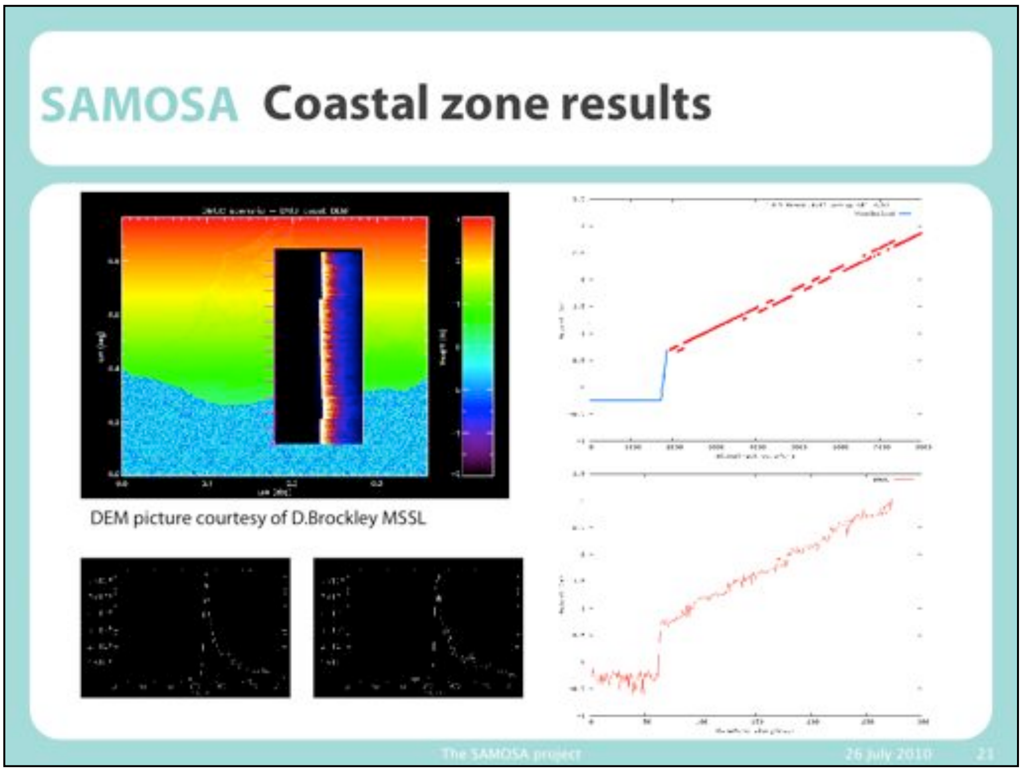
- What improvements does SARM altimetry offer for coastal and inland waters? Two types of scenario have been modelled:
  - Lakes
  - Coastal Zones



In order to examine how Cryosat2 will capture echoes over complex water targets, several scenarios were developed, including the lakes and coastal zone scenarios presented here. This scenario was designed to simulate inland water targets, with a number of lakes present within complex terrain. In order to ensure the DEM was as accurate as possible the highest resolution DEM available, the SRTM 1 arc second dataset over the continental USA, was supersampled to the CRYMPS resolution. SAR Level1B echoes were processed using an expert system method and the vast majority of terrain features were successfully retrieved.



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 a sloping DEM augmented by river channeling 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 (upper left) 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.

Two examples of SAR processed Level1B echoes are shown lower left.

The SAR echoes were then retracked using a version of the Berry Expert System (Berry et al. 2005) configured for SAR mode echoes; the recovered height profile is shown in the lower right profile plot, with the input heights (showing mean ocean height from input scenario) in the upper right plot. 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

SAMOSA O6: ASIRAS and SAMOSA

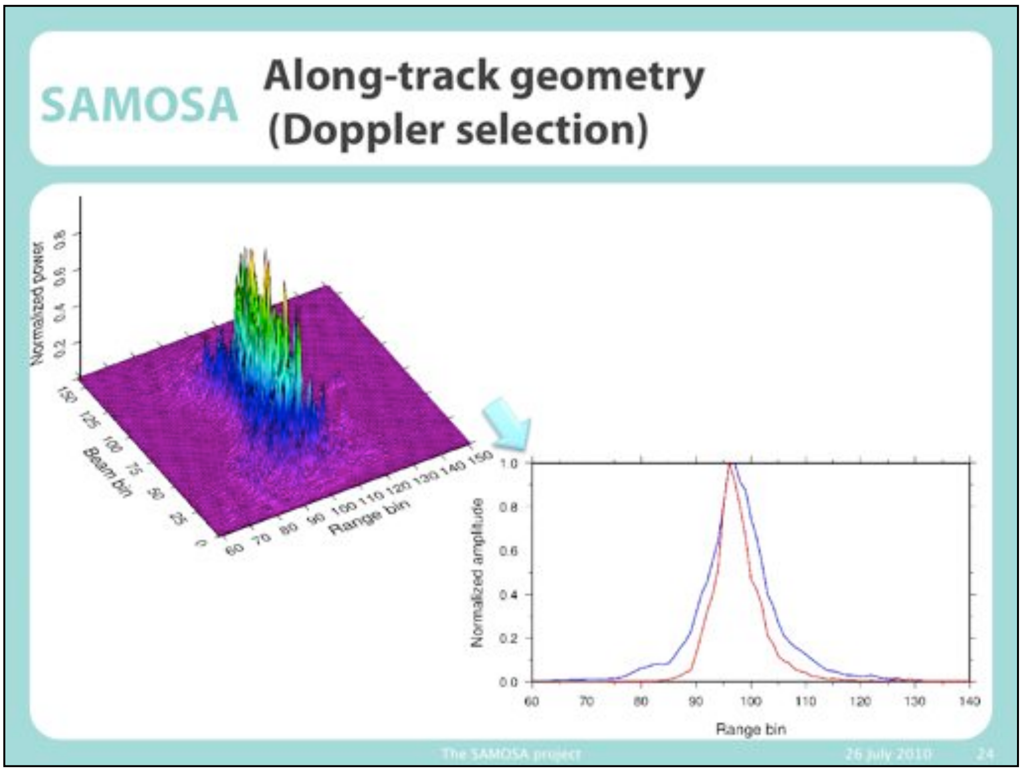
- Evaluate the SAMOSA re-tracker against real SAR altimetry data
- Gain information on the differences between space- and airborne data
- Processing scheme for airborne data to allow comparison with space-borne data

SAMOSA SIRAL vs. ASIRAS

	SIRAL	ASIRAS
Along-track beam width	1.0766°	10°
Cross-track beam width	1.2016°	2.5°
Transmitted power	25 W	5 W
Center frequency	13.575 GHz	13.5 GHz
Transmitted bandwidth	350 MHz	1,000 MHz (100-1,000MHz)
Transmitted pulse length	49 ms	4 μs (4-80 μs)
Pulse repetition frequency	18.182 kHz	2.5 kHz (2-15 kHz)
Approximate footprint size	15 km x 250 m	120 m x 10 m

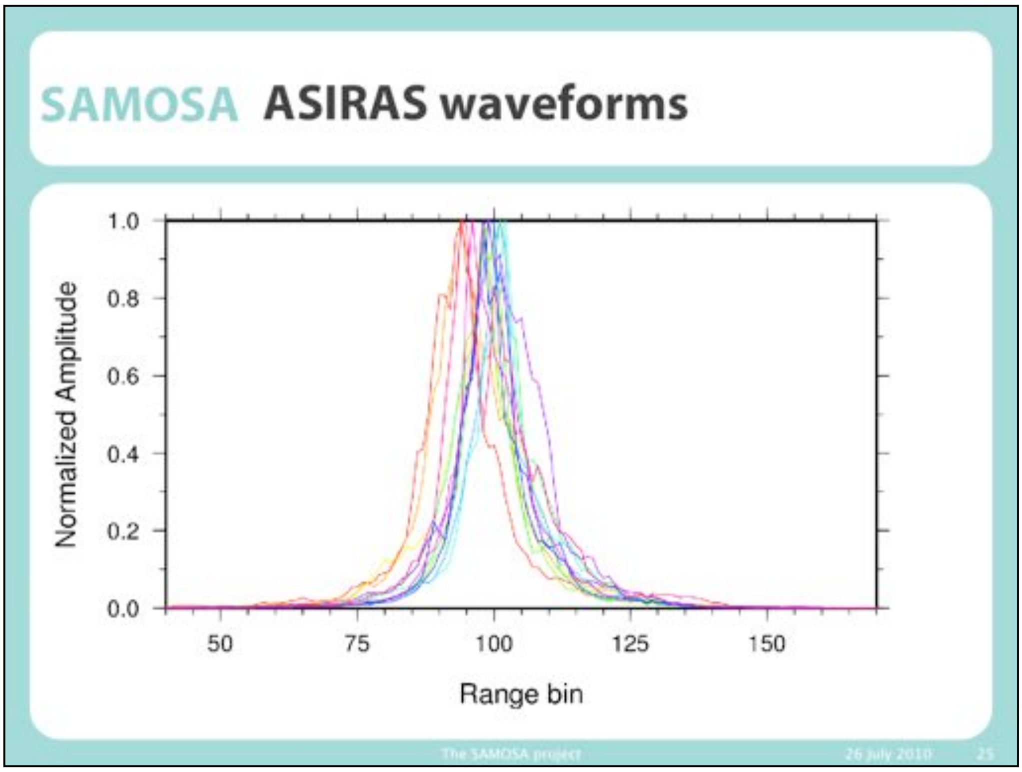
Comparison of key figures for SIRAL (in SAR mode) and ASIRAS (in HAM (High Altitude mode = SARIn)).
ASIRAS figures represents the dataset used by SAMOSA and in brackets the optional values for ASIRAS.
Due to the short travel time it is not necessary to fix the number of pulses in a burst to 64 (as for SIRAL) instead the number of pulses can be chosen during processing.
ASIRAS can also operate in LAM (Low Altitude Mode = SAR). When in LAM ASIRAS operates in CW (Continuous Wave) mode due to the short travel time.

The ASIRAS footprint can vary a lot; cross-track from 10 to 500 m (due to range) along-track from 2 to 15 m (aircraft speed, instrument settings, etc.)



Example of Doppler selection applied to a L1 stack, the burst length is 128 pulses.
Top left: entire stack with 160 beams illuminating the same area of the sea.
Lower right: In blue: multilook/sum of all 160 beams. In red: multilook/sum of 37 beams ~ 1.4° angular cutoff.

To reduce noise sufficiently it might be necessary to average several L1b multilooked echoes.



To reduce noise sufficiently and to remove local effects (footprint only over ocean wavetop) it might be necessary to average several L1b multilooked echoes.
The plot shows a number of L1b waveforms (without Doppler selection).

SAMOSA SAMOSA main progress

- Investigations to reduce SAR mode to LRM
- Definition of SAR Altimetry waveform model
- Development of SAR retracker
- CRYMPS investigations
- Analysis of performance of SAR retracker with ASIRAS data

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