SAR Data over Ocean, Processing Strategy and Continuity with LRM Data

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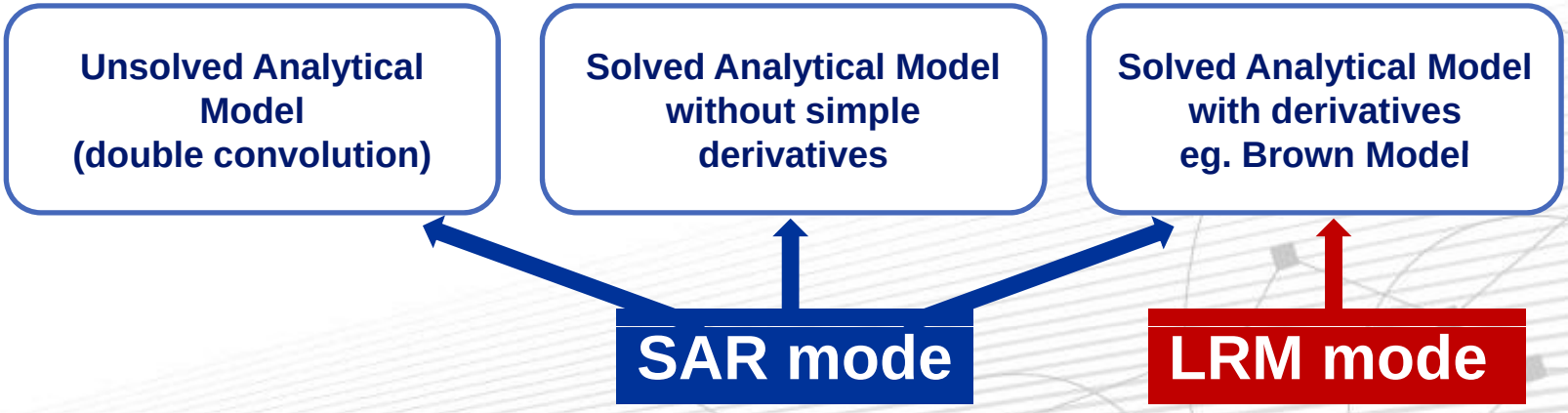
SAR retracking issue

- The objective of SAR echo processing is to determine the geophysical parameters (τ, SWH, Pu, …) by fitting the measured radar echo with a modeled echo
- As for the LRM mode, the SAR echo can be expressed as the convolution (on different geometry) between:
  - FSSR (Flat Sea Surface Response)
  - PDF(Probability Density Function of the heights)
  - PTR (Point Target Response)

$$S(t) = FSSR(t) \otimes PDF(t) \otimes PTR(t)$$

- There are mainly 3 possibilities regarding this model



- The aim of this talk is to describe how we (CNES + CLS people) deal with these different possibilities to retrack SAR data

Summary of CLS activities on SAR processing

- CNES R&T studies on Delay Doppler processing (Delay Doppler Simulation)

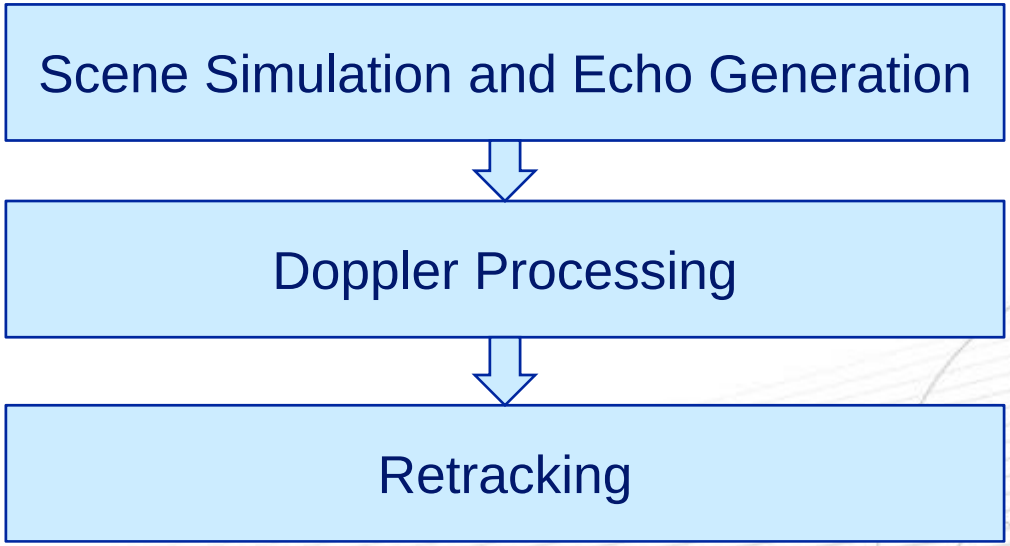
- PhD thesis on SAR echo modelisation funded by the french ministry of research, co-supervised by CNES, CLS and the University of Toulouse.

- Study on LRM numerical retracking as SAR processing validation (funded by CNES to propose a candidate retracking solution for Sentinel-3 mission)

- CLS is responsible for the definition and the development of a Sentinel 3 Topography Mission prototype, including SRAL, MWR and GNSS instrument simulation, scene generator, Level 0 and Level 1 processing (under ESA/TAS contract). CLS project manager is Laiba Amarouche.

Delay Doppler Altimetry Simulator

This DDA simulation tool is inherited from other tools developed in CLS for conventional altimetry



Scene simulator – Echo generator

• Scene generation

Regular gridded surface (configurable)

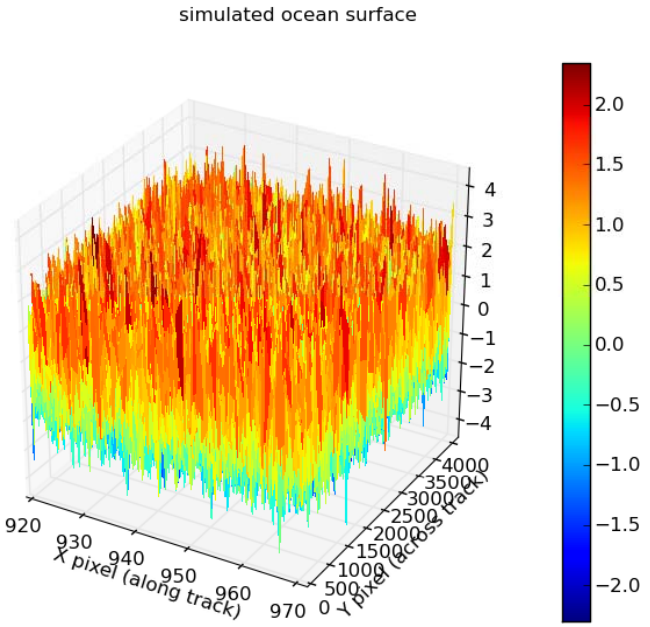
➔ scene size > footsprint radar size
+ distance traveled by the satellite

➔ resolution ~20m x 20m (1000*2000 array grid points)

Pixel scattering structure adjusting large/small scales

➔ large-scale waves: with amplitude and slope as defined by the selected surface (Gaussian roughness spectrum, sinusoidal surface, ocean wave spectra)

➔ small-scale waves : mss (mean square slopes)



• Echo generation

➔ apply radar equation to compute the backscatter power of each pixels

➔ accumulation of the signals in the range gates of the waveforms

Delay/Doppler Radar Altimeter Simulator (1)

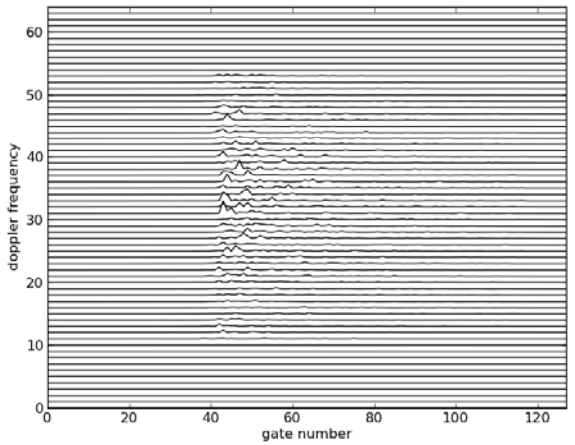
Range compressed real data

Scene simulation and Echos generation

Data Store : Burst of complex echoes (I,Q) in time domain

- Surface point locations
- Beam direction angles
- Phase shift + Along track FFT
- Slant range correction
- Applied PTR (optional)
- Range compression

Delay/Doppler processing scheme repeated burst by burst



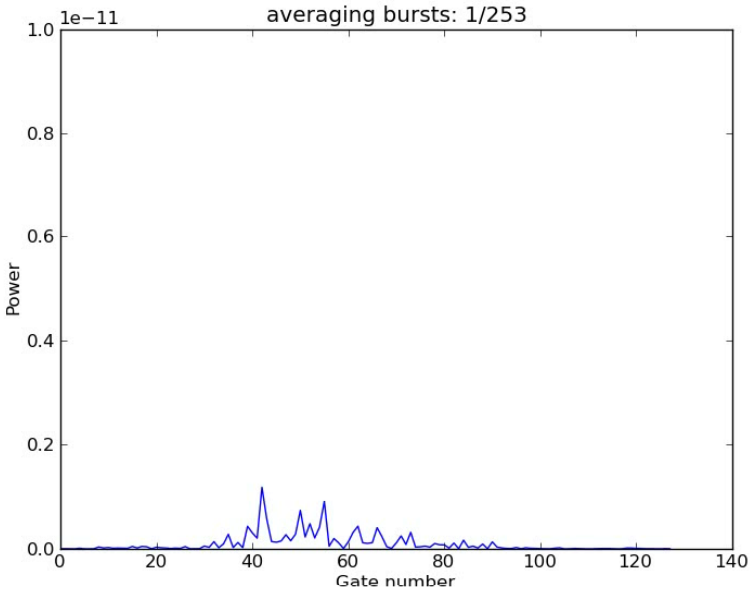
Single-Look images

Delay/Doppler Radar Altimeter Simulator (2)

Single-Look images

Incoherent look summation

Doppler echo obtained by accumulating contribution of multi looks within one band



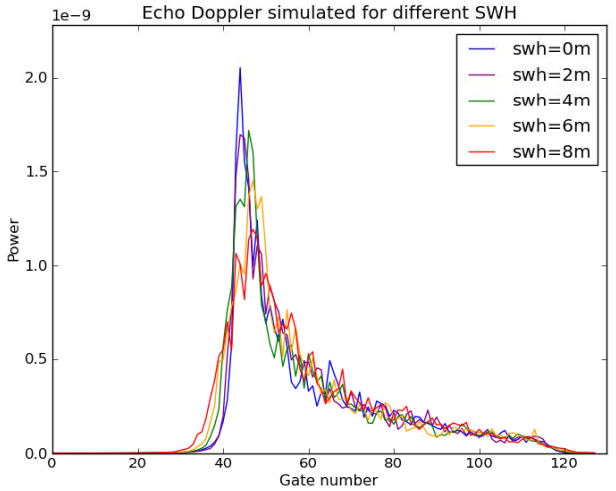
Delay/Doppler Radar Altimeter Simulator (2)

Single-Look images

Incoherent look summation

Echos processing for geophysical parameter estimation

Solved analytical Model	Unsolved Analytical Model
Classical Retracking Algorithms (MLE for example)	Retracking based on numerical derivatives computed in real time or using an echo database



PhD Thesis: *Modelisation of the SAR/Doppler echoes*

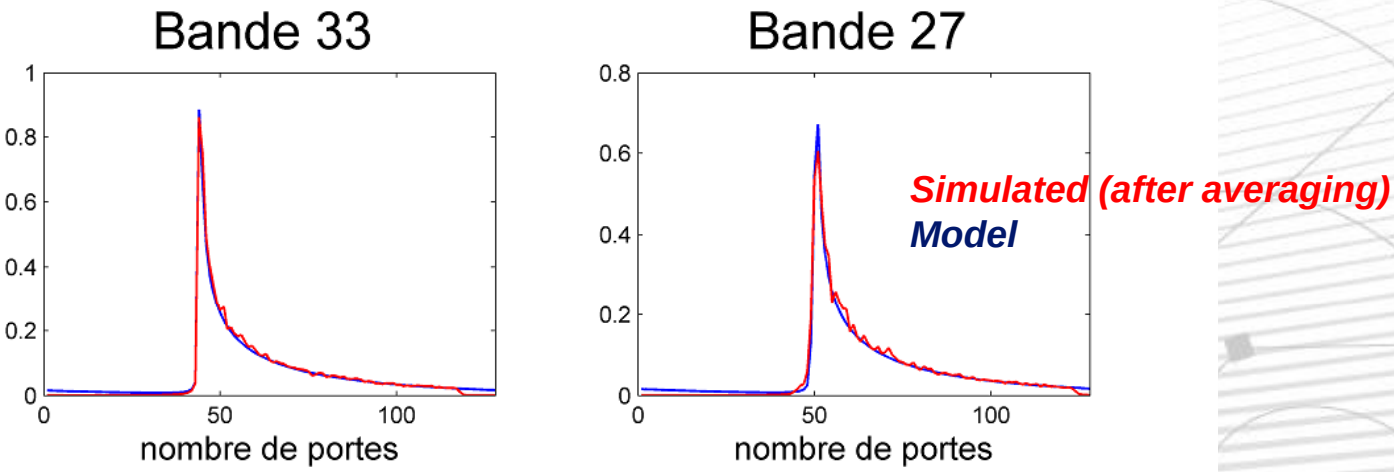
Abderrahim HALIMI

A PhD thesis, funded by the french ministry of research is taking place at the IRIT/INP-ENSEEIHT/TéSA, University of Toulouse (France). Co-supervised jointly by ENSEEIHT, CNES and CLS.

Objective: To determine a unsolved/solved analytical model for Doppler echoes and to derive related geophysical parameters

A model has been derived, based on geometrical considerations

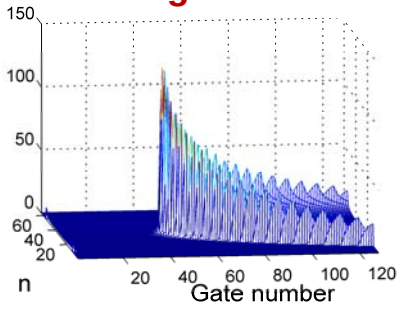
It provides very good results when comparing with simulated echoes



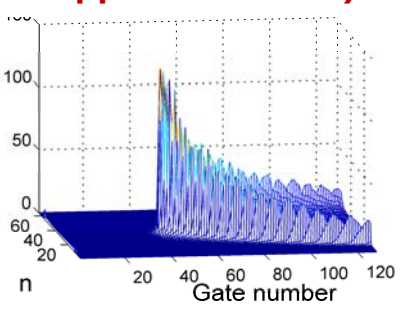
PhD Thesis: *Modelisation of the SAR/Doppler echoes*

Abderrahim HALIMI

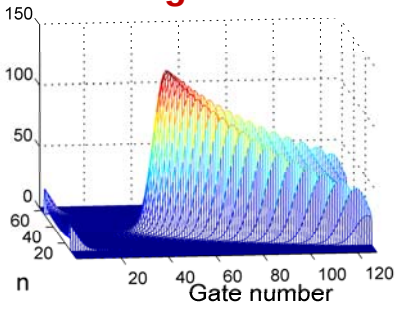
Analytical model Single Look



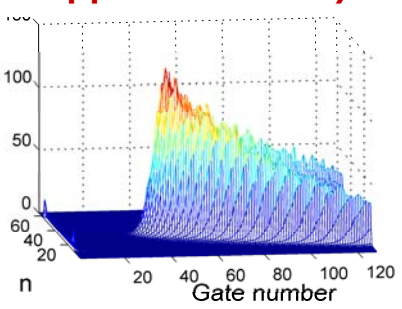
Averaged Single Look (output of the Doppler simulator)



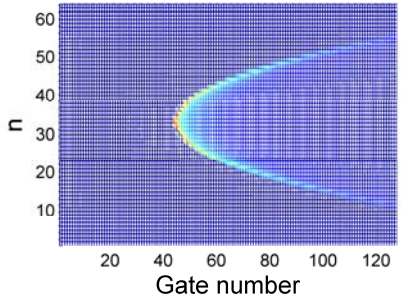
Analytical model Single Look

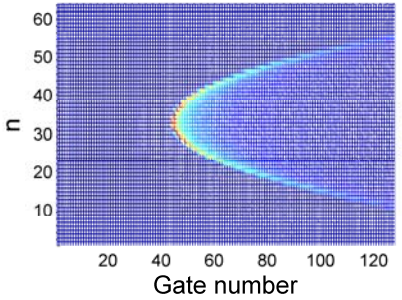


Averaged Single Look (output of the Doppler simulator)

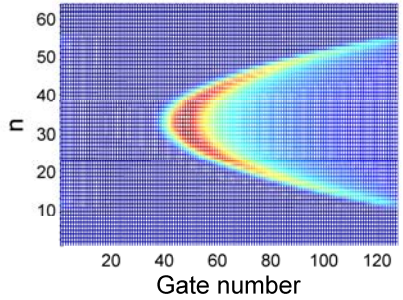


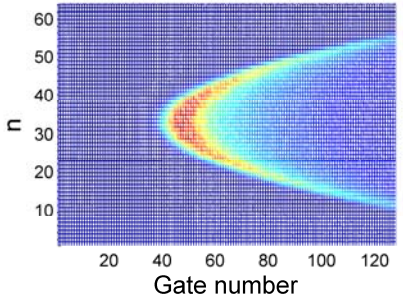
SWH = 0 m





SWH = 8 m





❑ Very good agreement between analytical model and simulations which allows us to be very confident on the estimation process using or not an echo data base

- ✓ Validation of the model that has been developed
- ✓Validation of the simulator

Numerical Retracking (1)

- The current LRM retracking algorithm (MLE) is based on a Newton-Raphson iterative method which uses the analytical derivatives of the Brown model (developed at the second order)

$$\theta_n = \theta_{n-1} - g\left(BB^T\right)^{-1}_{\theta_{n-1}} \left(BD\right)_{\theta_{n-1}}$$

B : derivatives matrix
D : residuals matrix

- We have anticipated that for Delay Doppler Altimetry, only an unsolved model can be derived (double convolution for example) without any formulated derivatives.

- Derivatives can be computed numerically from models differentiation

At each iteration n, models using the current estimation vector θ_{n-1} are directly computed using the analytical formulation or taken from a pre-computed model data base (generated off line by the simulator)

Numerical Retracking (2)

- Numerical Retracking is also an interesting and very promising method to account for corrupted Point Target Response (potential interest on Topex reprocessing)

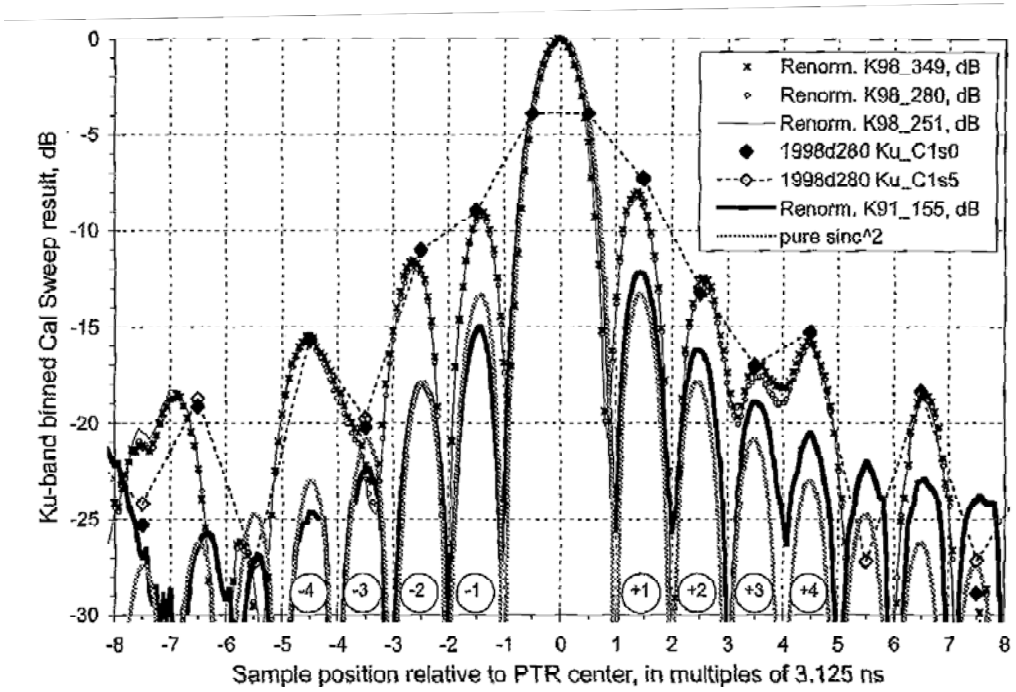
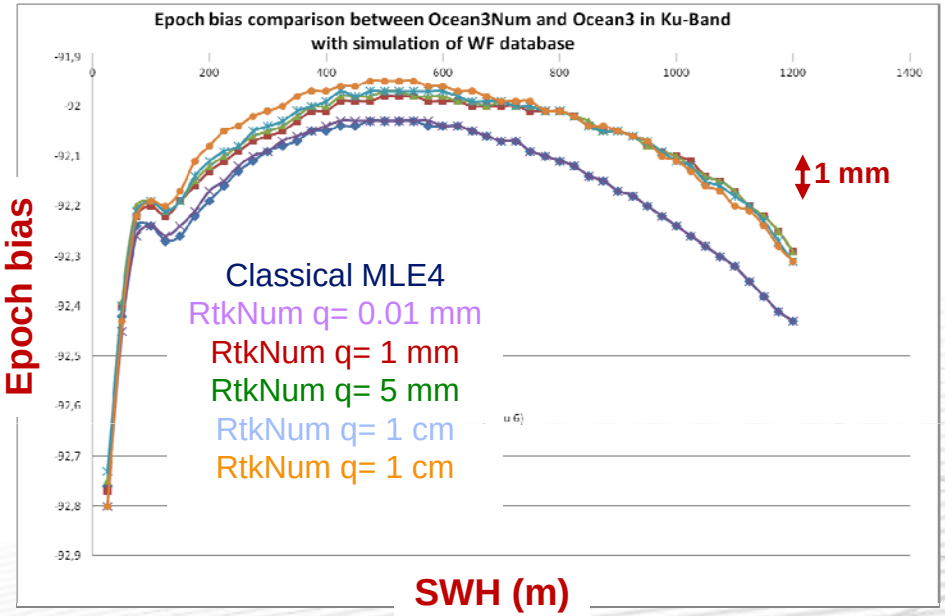


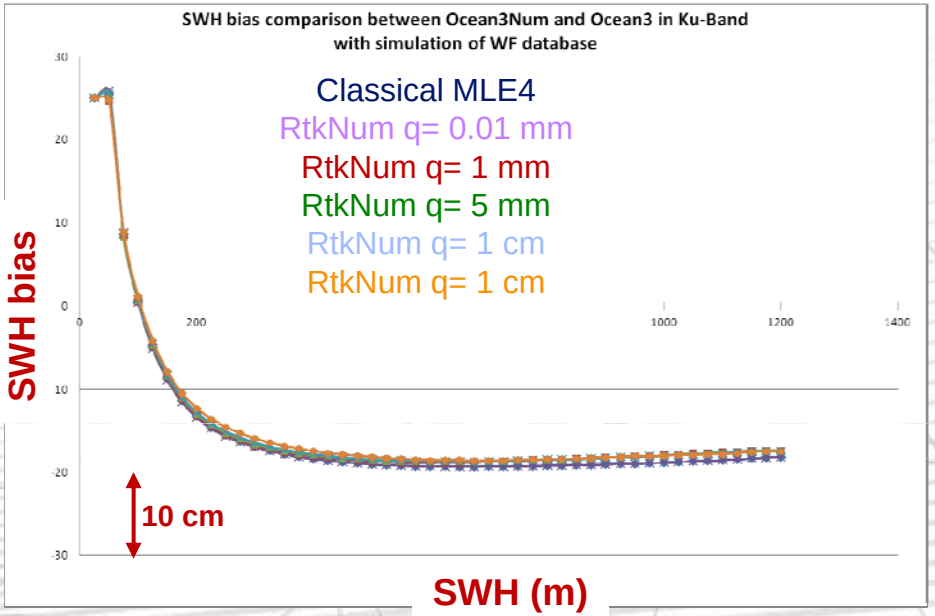
Figure 3-19 TOPEX Ku-Band Cal Sweep PTR Comparisons (labels shown for first four sidelobes each side of central peak)

Validation of SAR processing strategy on LRM mode (1)

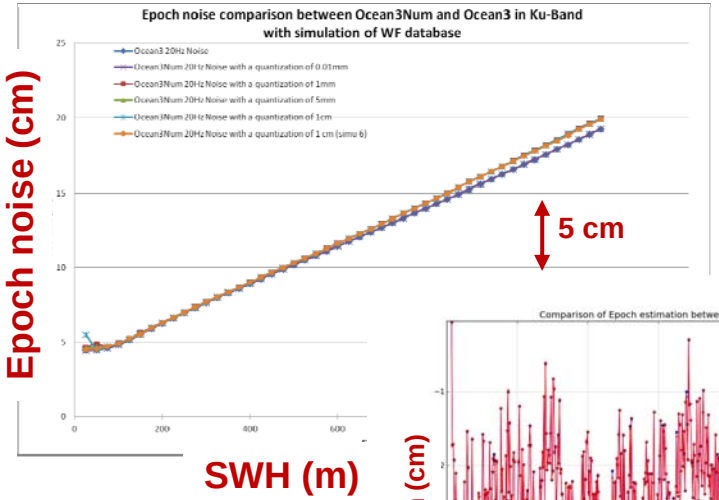
- A numerical retracking algorithm has been tested on LRM waveforms (simulated and real data)
- Performances have been calculated and compared to a classical MLE4 retracking
  - ✓in terms of biases wrt to SWH
  - ✓in terms of noises wrt to SWH

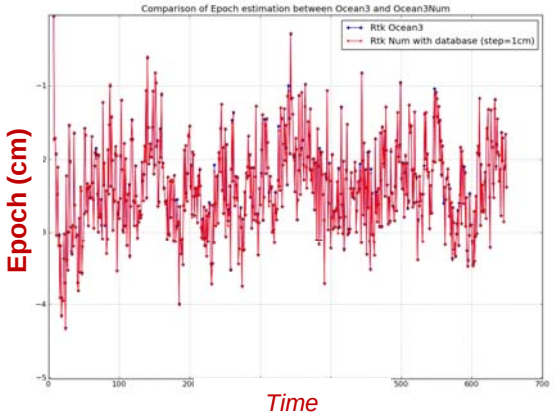
These performances have been obtained thanks to the LRM simulator of performances for different « gridding configurations » (spacing steps of the grid) and without any gridding scheme.

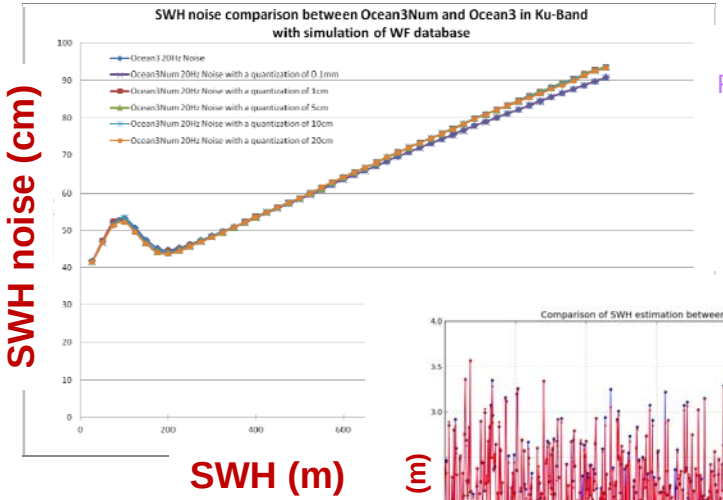




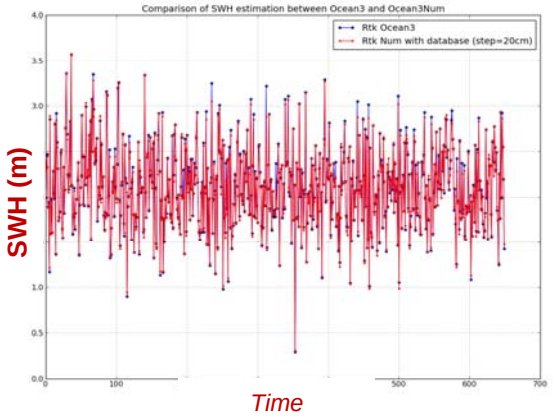
Validation of SAR processing strategy on LRM mode (2)





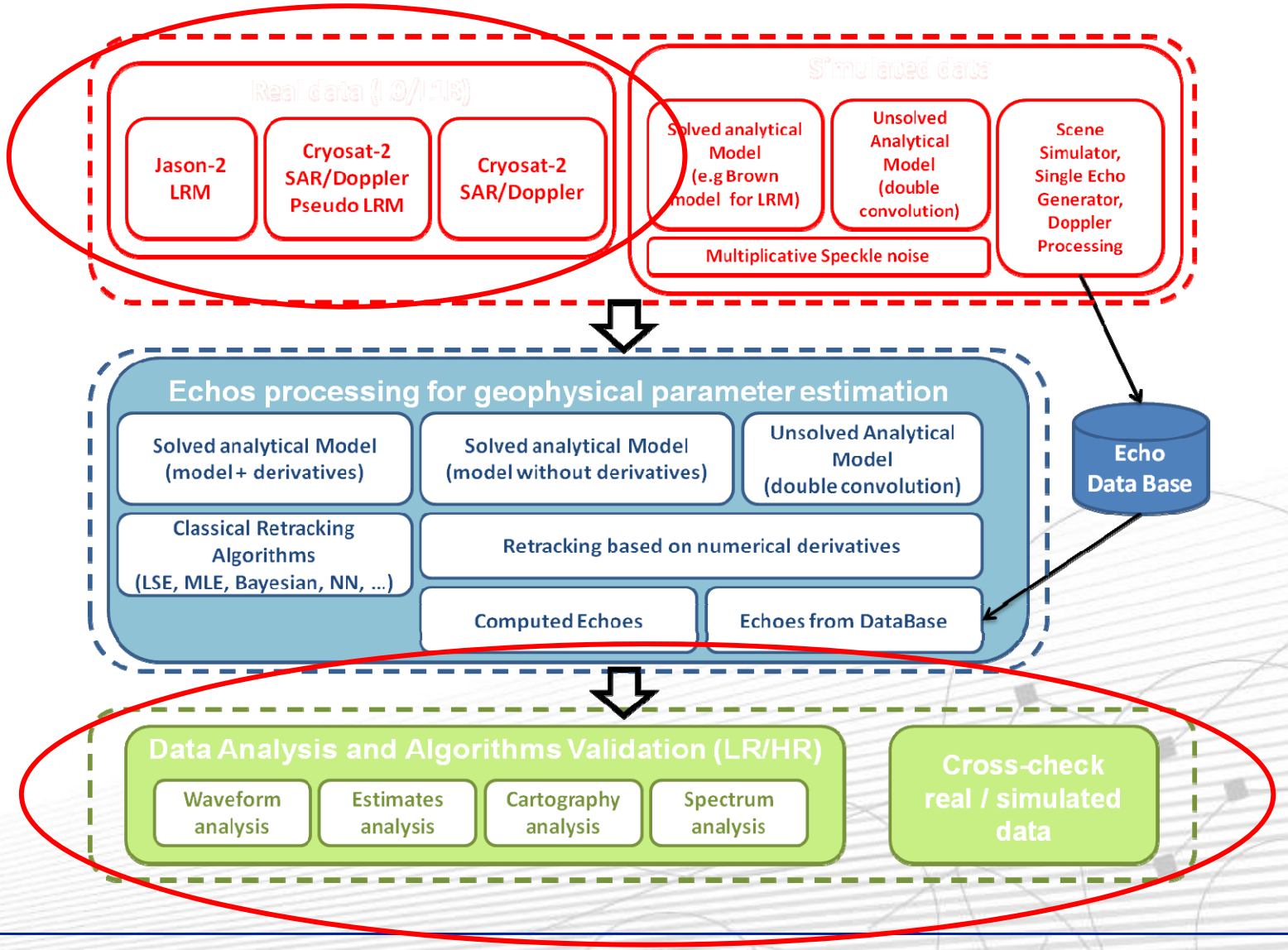


Classical MLE4
RtkNum q= 0.01 mm
RtkNum q= 1 mm
RtkNum q= 5 mm
RtkNum q= 1 cm
RtkNum q= 1 cm



- Performances are very consistent with current Jason processing ones
- A rough gridded echo database can be used without significant degradation of performances $\Delta\tau$ = 1 cm, ΔSWH=20 cm, ΔPu=5 FFT Pu
- A similar approach can be used to retrack SAR echoes

Summary of our approach



Thank you !