CryoSat Processing Prototype,

LRM and SAR Processing on CNES Side

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Study Context

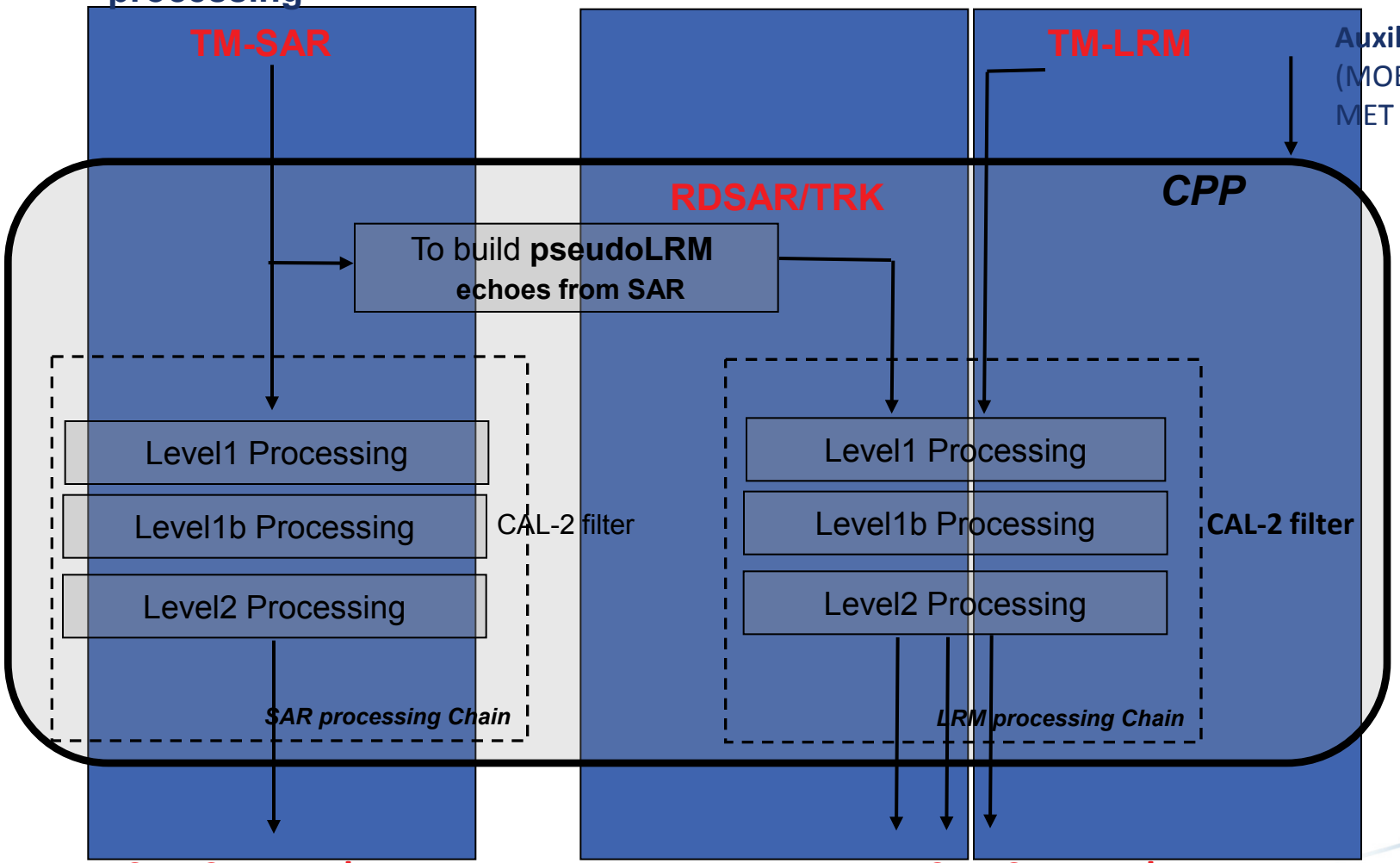
- To prepare the CNES proposed SAR retracking for Sentinel-3 mission, CNES decided **to take the opportunity of the availability of CRYOSAT/SIRAL data:**
  - To develop and test processing methods of SAR data over ocean,
  - To assess SAR processing performances,
  - To define how to ensure data quality continuity between SARM and LRM
  - To define how to provide a LRM reference during SAR mode to calibrate SAR results (so called RDSAR or pseudoLRM or TRK data).
- To achieve those goals,
  - CNES started the development of a processing module of CRYOSAT data **CPP (CRYOSAT Processing Prototype)** two years ago.
  - **Access to telemetry data has been kindly granted by CryoSat** project.

CPP Interfaces and Architecture

Core Objective :
To perform SAR processing

To provide a LRM reference during SAR mode (RDSAR)

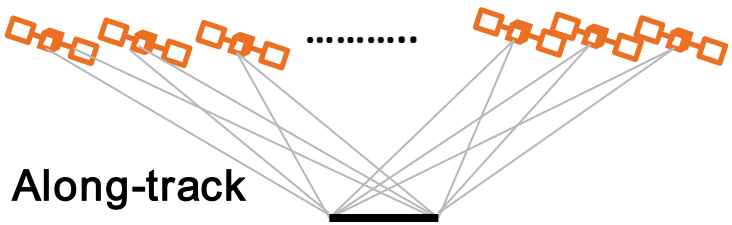
To analyze continuity between LRM <-> SAR



What are SAR and RDSAR 20Hz measurements?

From SAR BURST pulses

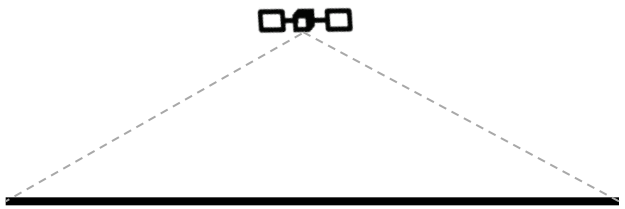
Delay/Doppler processing (multilook): SAR



Doppler resolution cell ~ 320m

Accumulation of 256 looks over the same doppler band → Doppler Echo

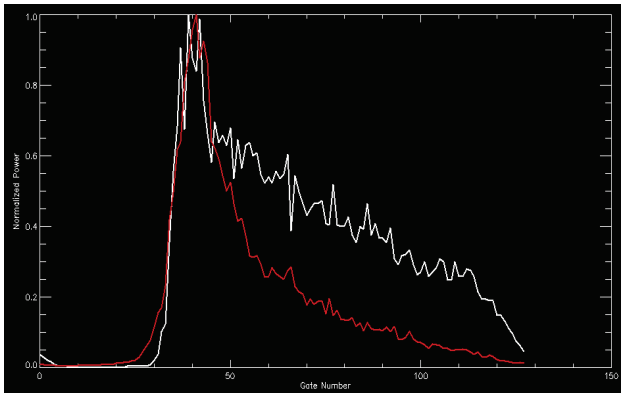
No SAR processing : ReducedSAR



LRM resolution cell ~ 7km

Power accumulation of radar echoes with « only » 32 uncorrelated conventionnal echoes

→ pseudoLRM echo



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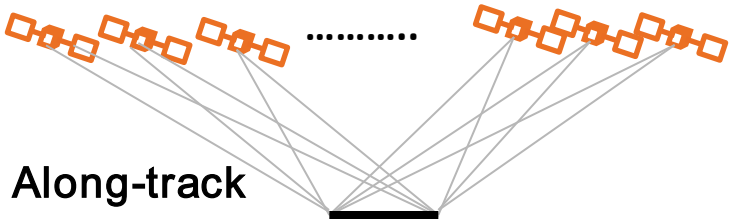

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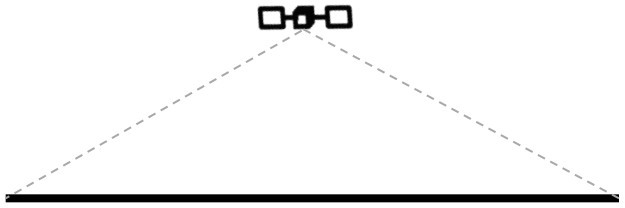

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Power accumulation of radar echoes with « only » 32 conventionnal echoes

udoLRM echo

The Reduced SAR is a LRM reference to validate the SAR results.

But, given that only 32 echoes are accumulated, this reference is more noisy than real LRM (sqrt(3) higher than real LRM).

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CNES SAR Retracking solution

❑ **Based on a full numerical Doppler model:** Numerical computation of the radar echo:

$$\text{Echo} = \text{FSSR} \otimes \text{IRs} \otimes \text{PDF}$$

Single Looks

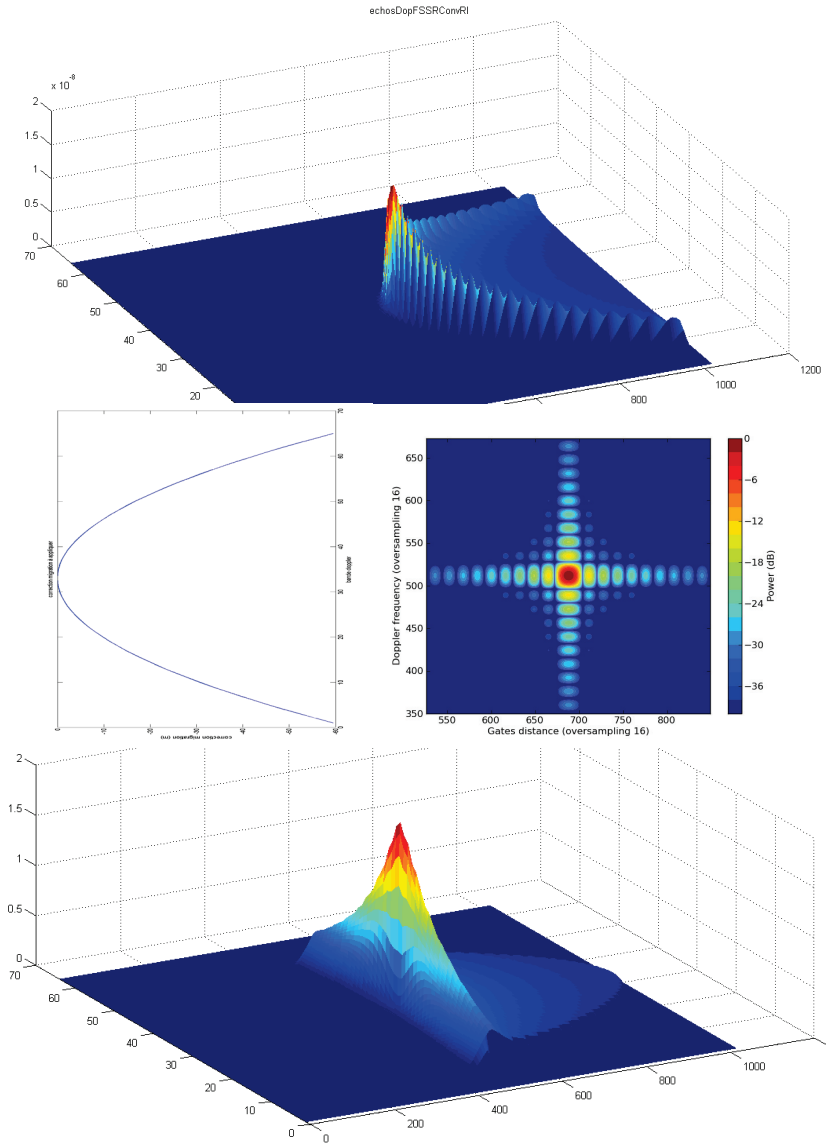
- ❑ Computation of the FSSR for each doppler band (64). A constant mispointing configuration can be taken into account.
- ❑ Convolution with Instrument and Azimuth Impulse Response
- ❑ Convolution with the PDF of SWH

Multi Look

- ❑ Then, range migration is performed to align each single looks
- ❑ Sum of each Singlelook migrated: multilook Doppler echo

❑ Retracking: **inheritage from Jason-2 MLE3** (mispointing is not estimated but constant) **Derivatives are numerically computed**.

Mispointing configuration: 0.1° x 0.1°
(based on W. Smith *et al* , OSTST San Diego, 2011)



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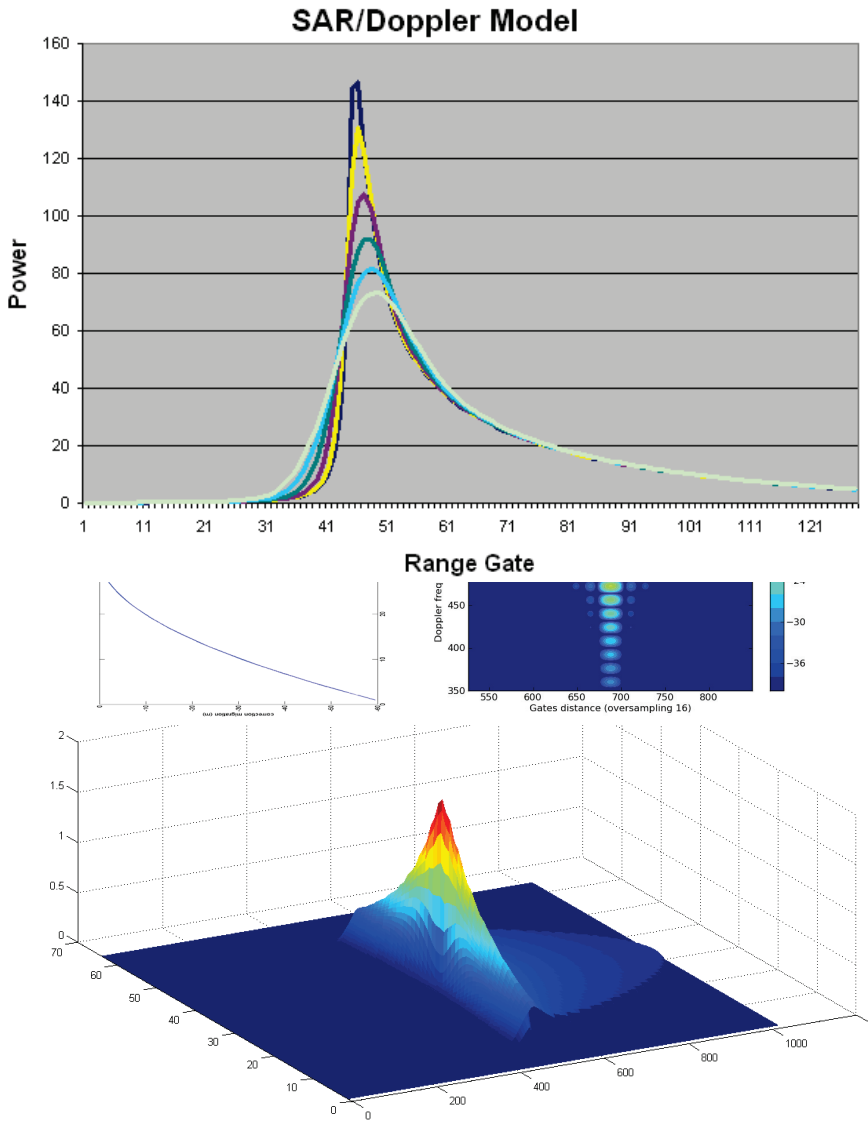

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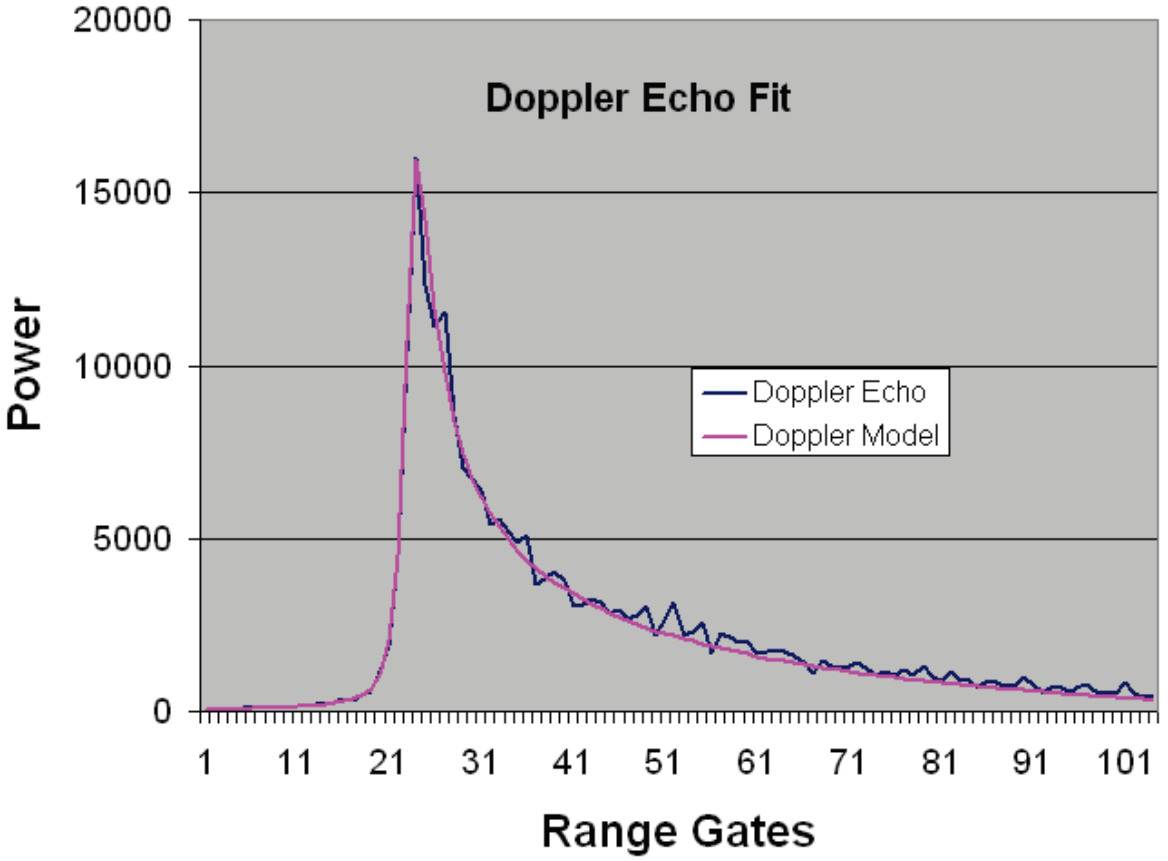

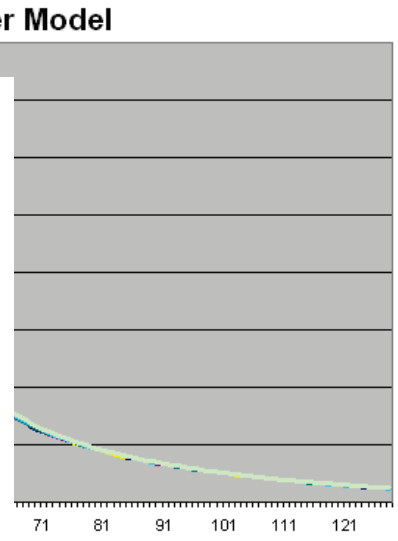

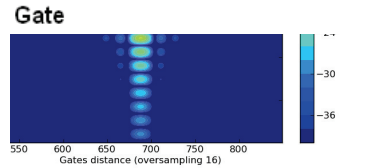

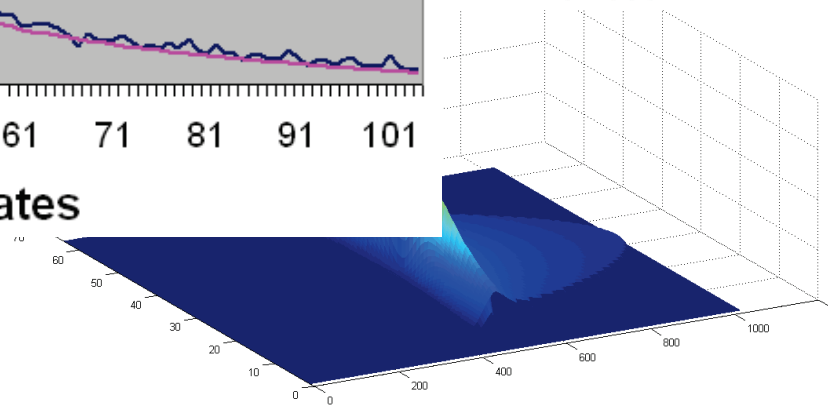

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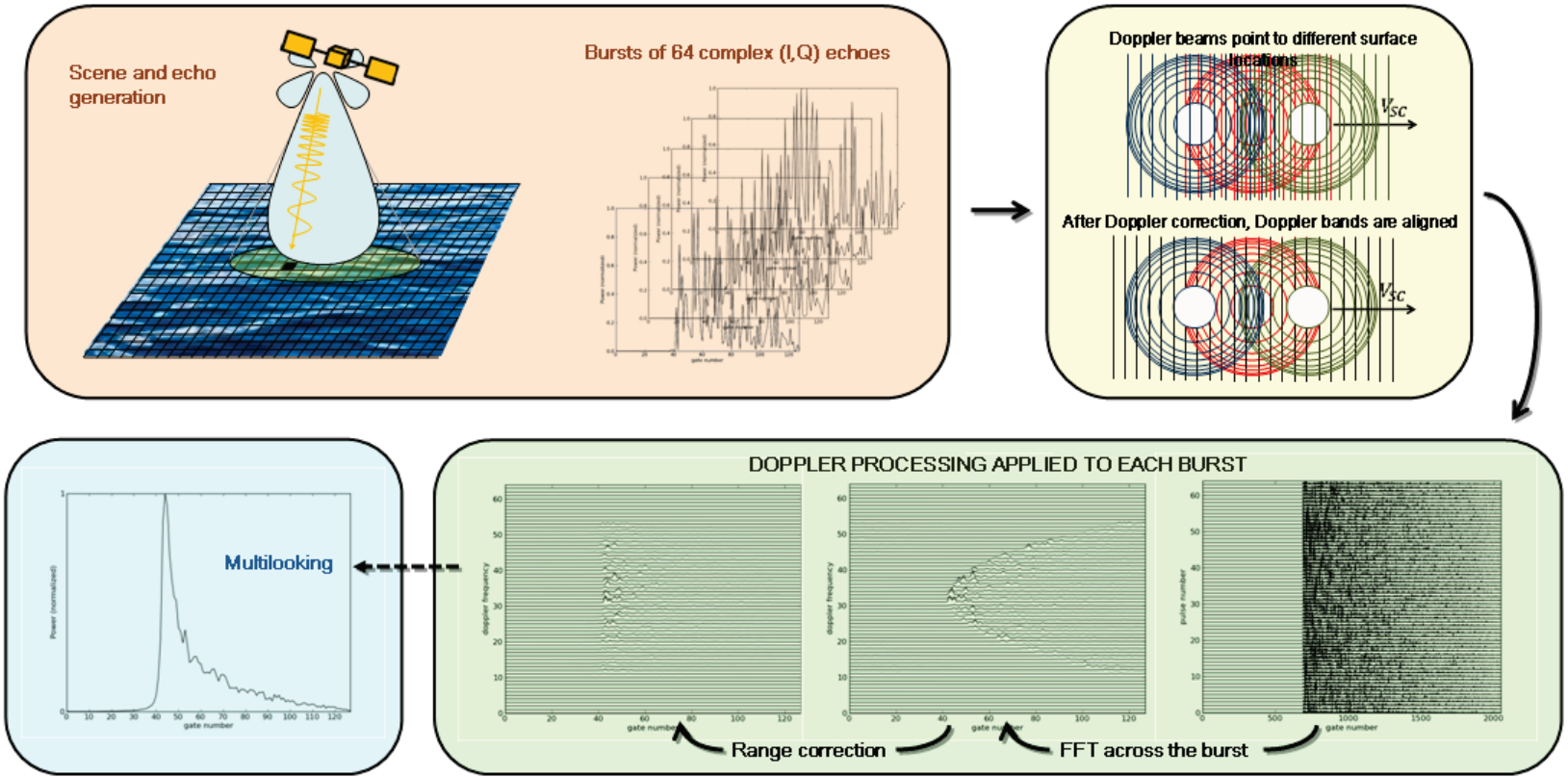
SAR Radar Simulator (CLS)

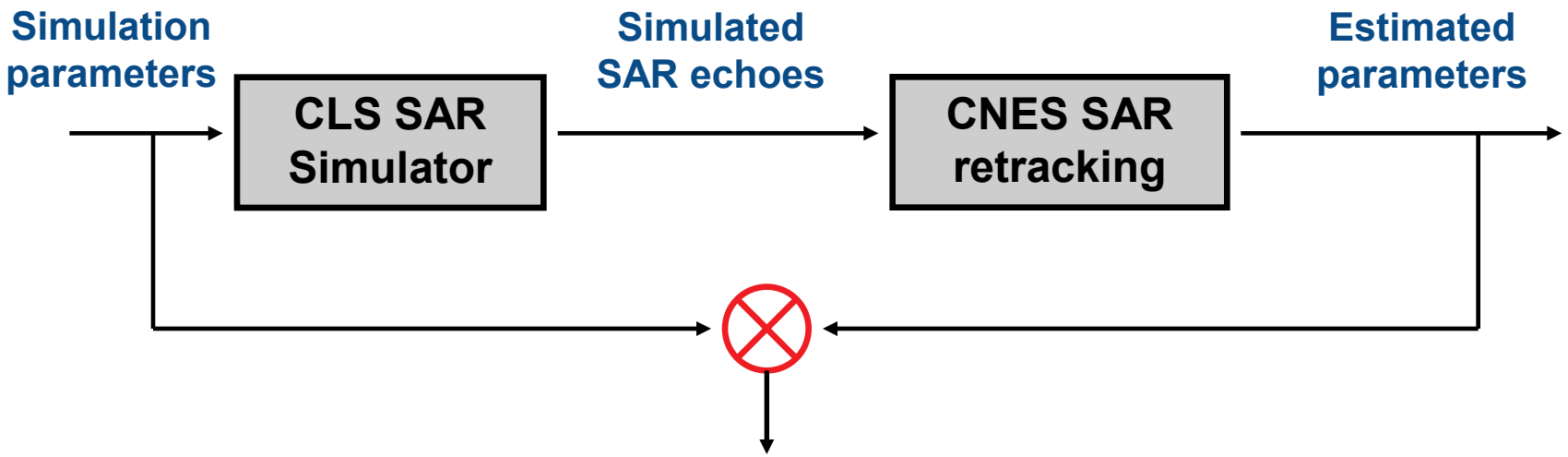
CLS (under CNES contract) has developed an end-to-end SAR radar altimeter simulator that mimics the Cryosat-2 altimeter in SAR mode:
This simulator consists of several components:

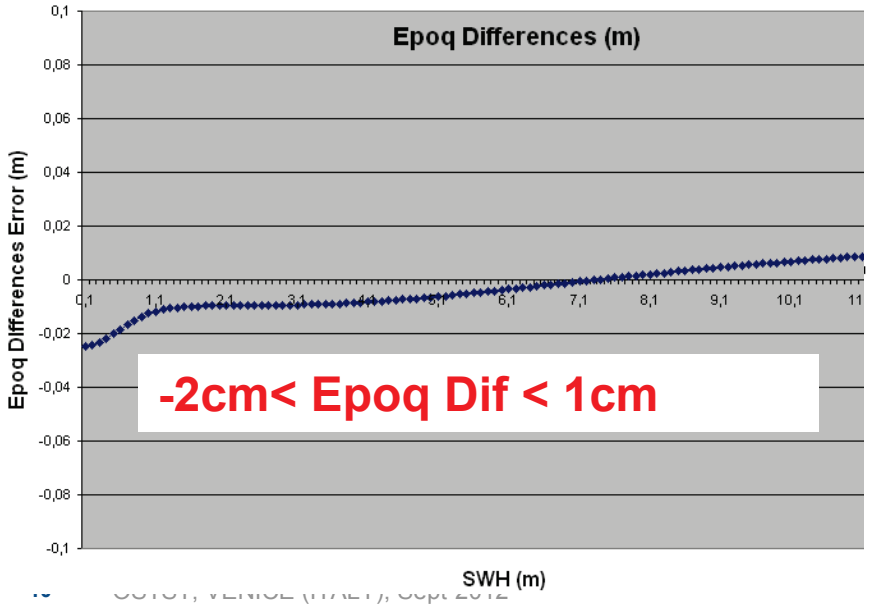
- ❑ A scene generator module:
- ❑ A power returns simulation → (I,Q) SAR Burst wvfs
- ❑ The Delay/Doppler processing scheme → Doppler echoes

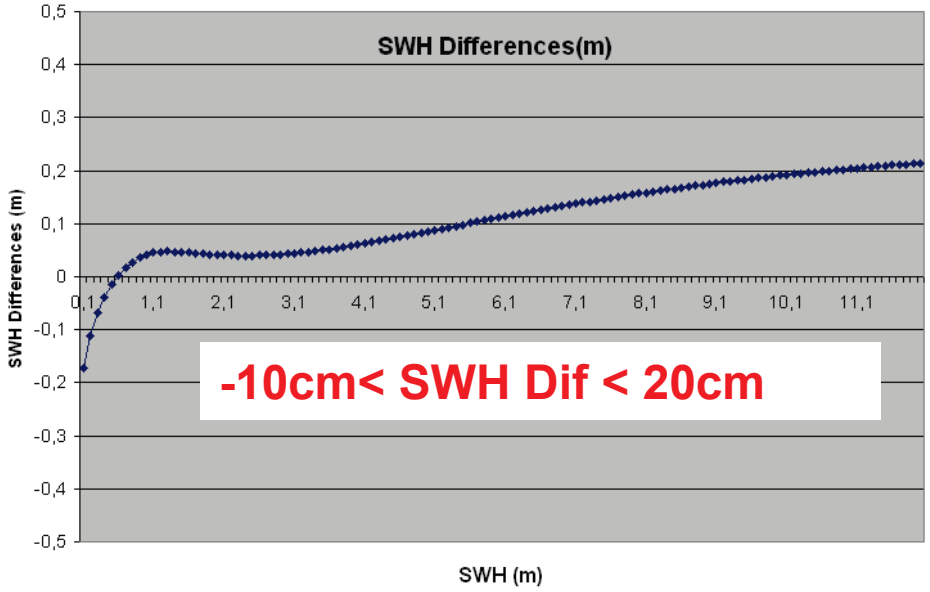
Credits: T. Moreau



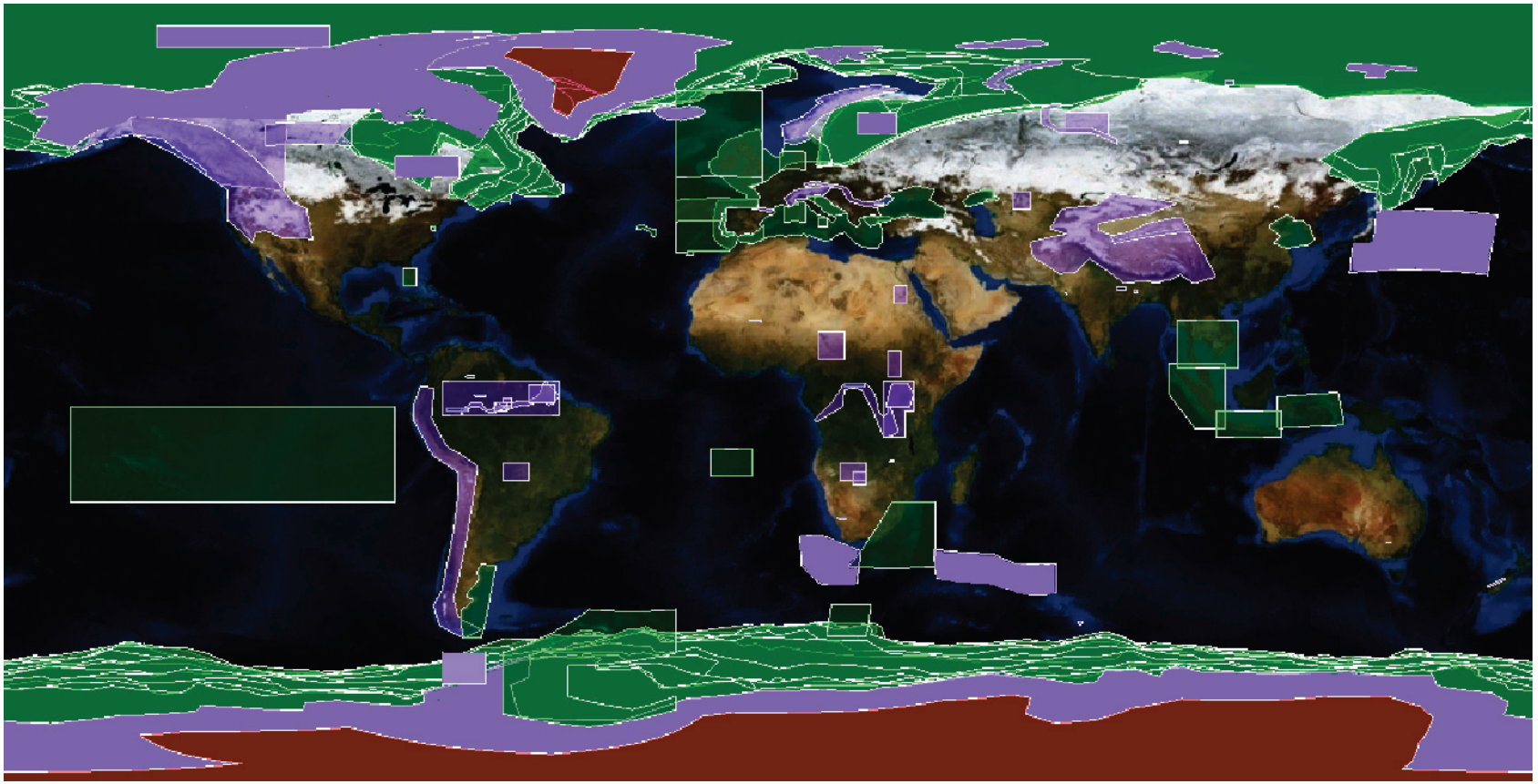
Comparison with CNES model





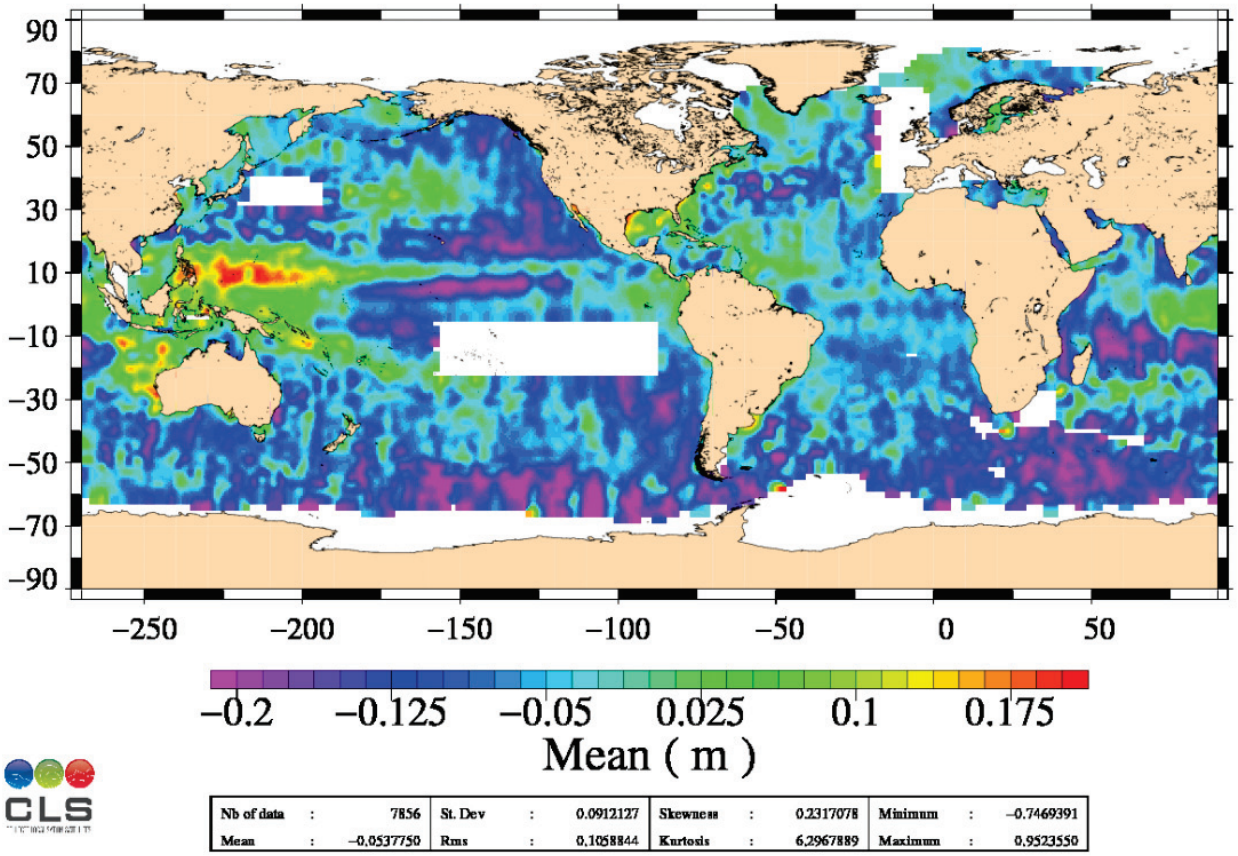


CRYOSAT mode Mask



CPP processing results on CRYOSAT-2 data

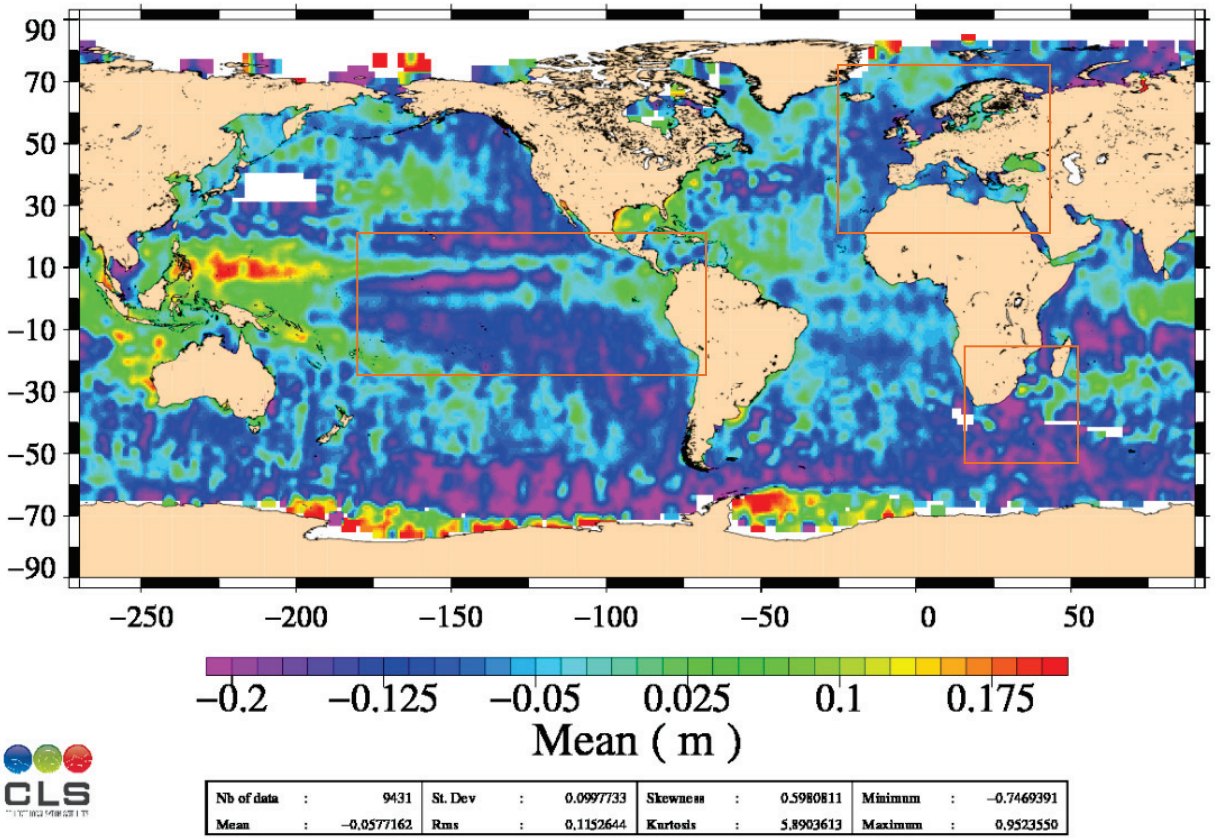
Cryosat LRM is at the same level of accuracy than Envisat and Jason-2.
(F.Boy, OSTST San Diego, 2011)



Nb of data	:	7856	St. Dev	:	0.0912127	Skewness	:	0.2317078	Minimum	:	−0.7469391
Mean	:	−0.0537750	Rms	:	0.1058844	Kurtosis	:	6.2967889	Maximum	:	0.9523550

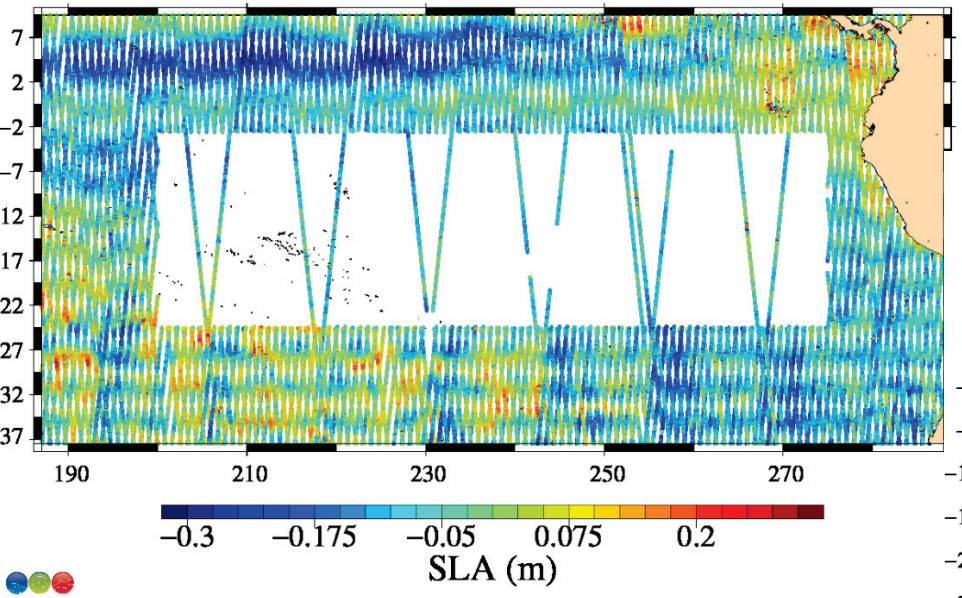
CPP processing results on CRYOSAT-2 data

Very good consistency between SARM and LRM Sea Level Anomalies



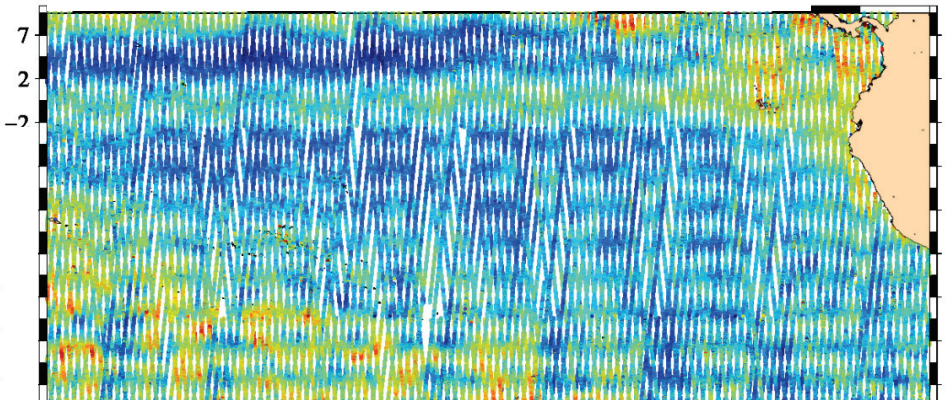
Focus on Pacific area

Cartography of CryoSat–2 SLA, LRM June 2012



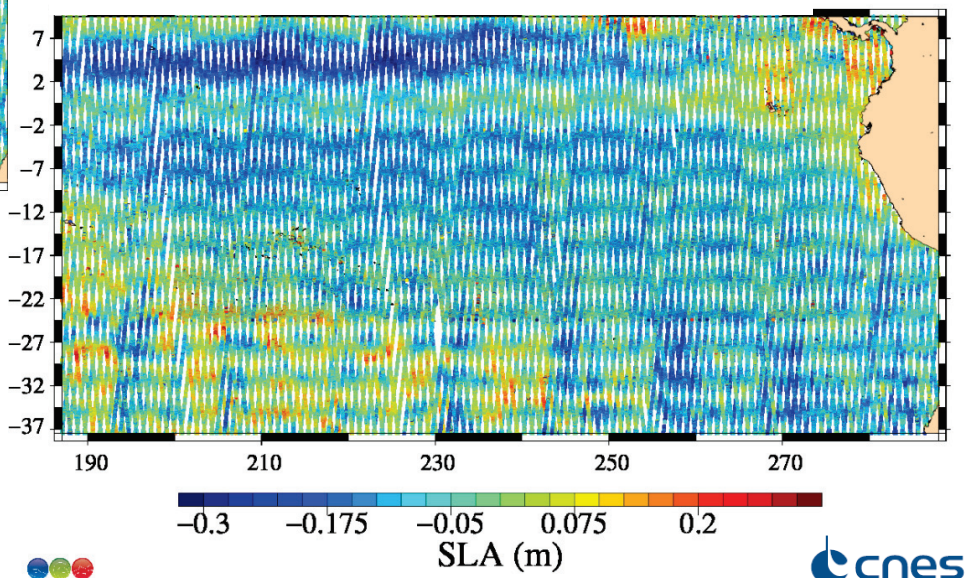
Cartography of CryoSat–2 SLA, LRM+SAR June 2012

LRM + SAR



Cartography of CryoSat–2 SLA, LRM+TRK June 2012

LRM + RDSAR



Focus on Atlantic Ocean

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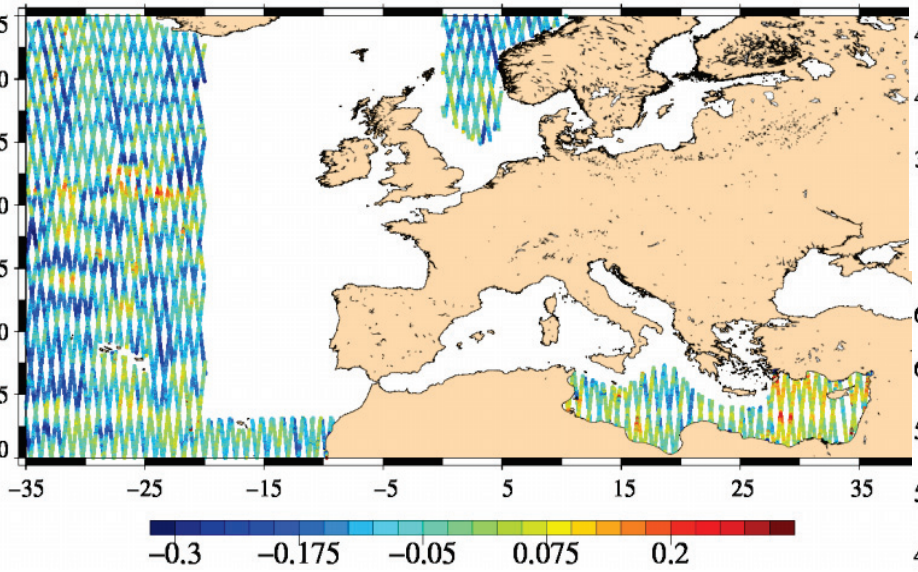

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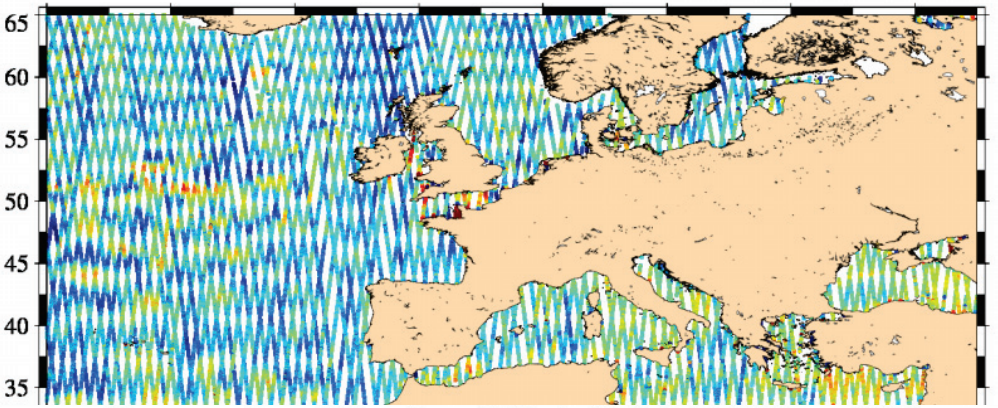

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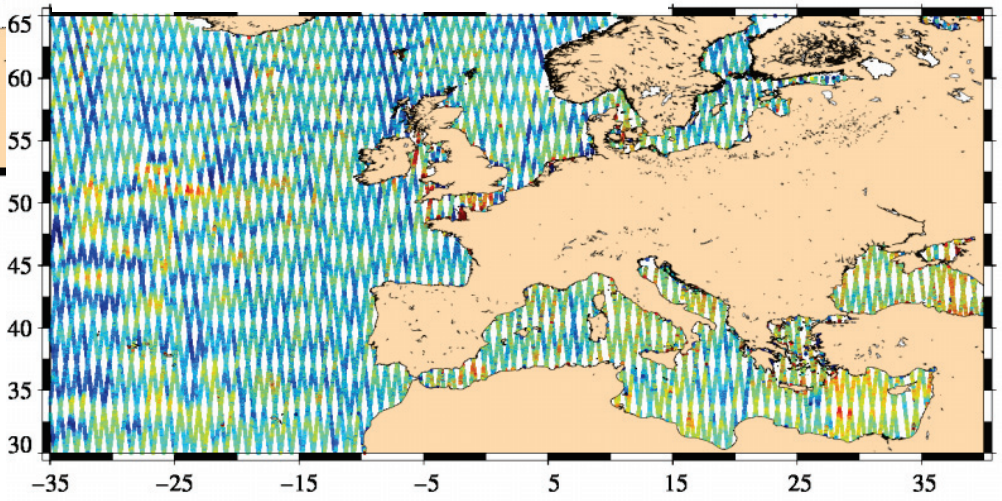
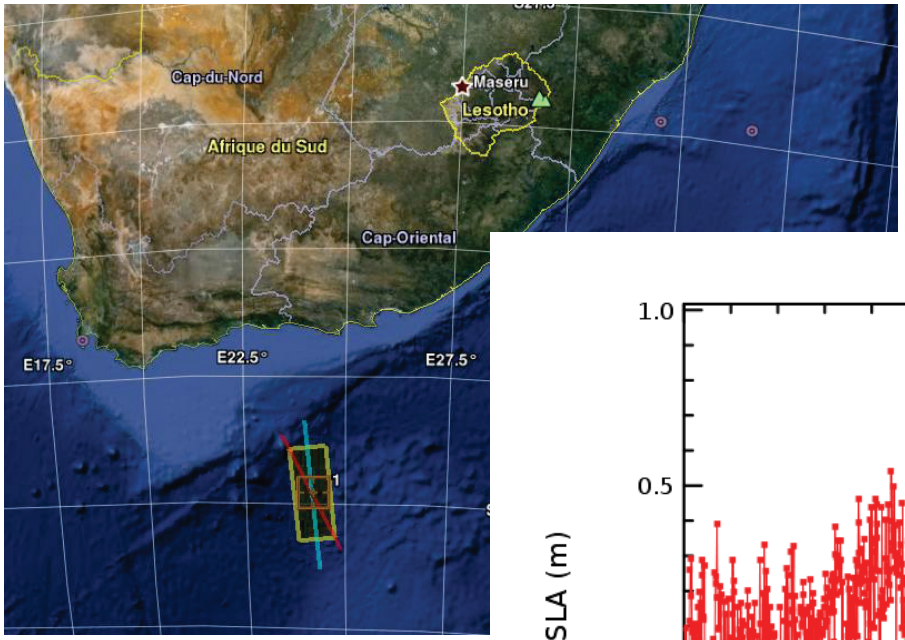
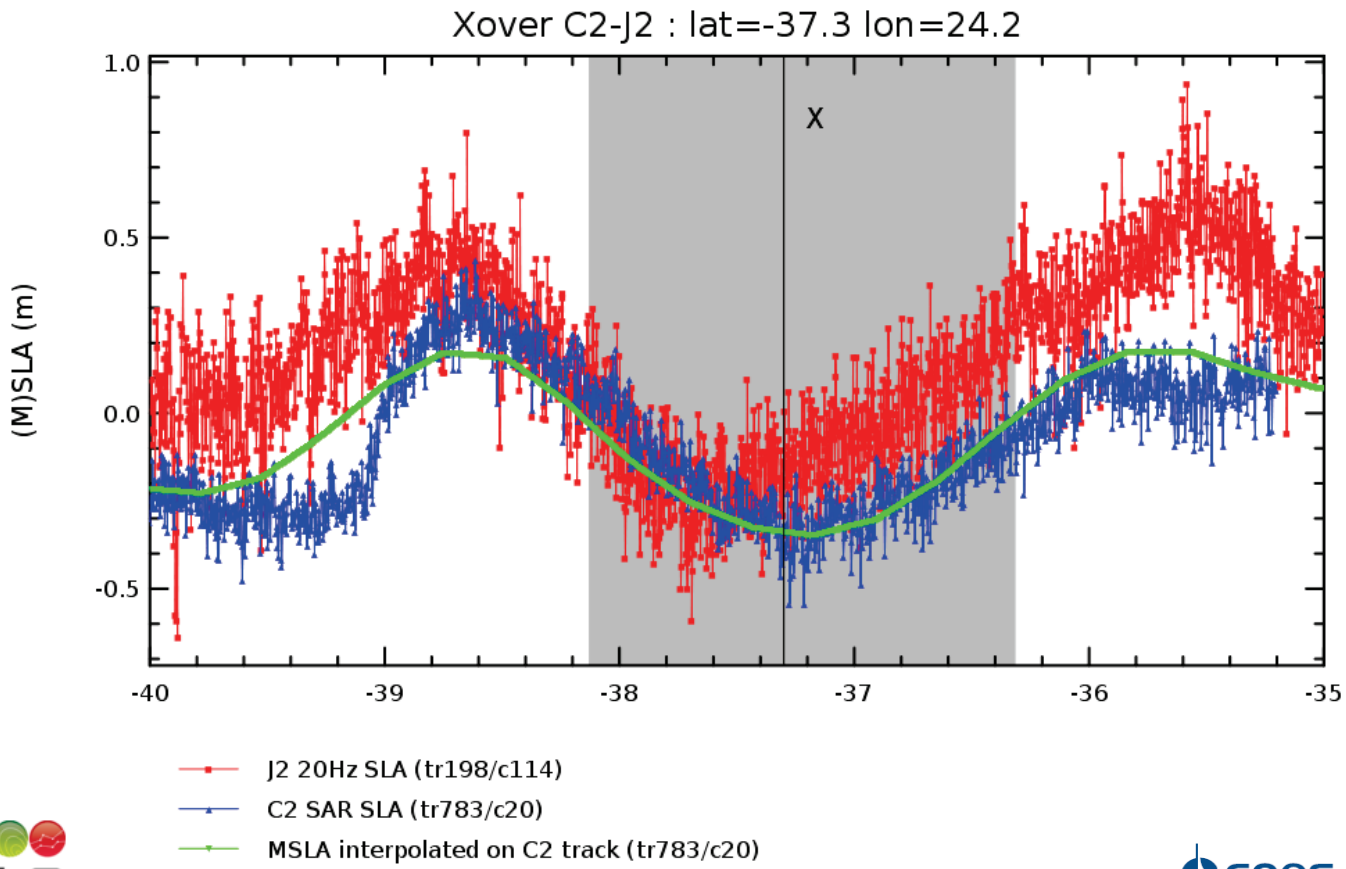


First along track example



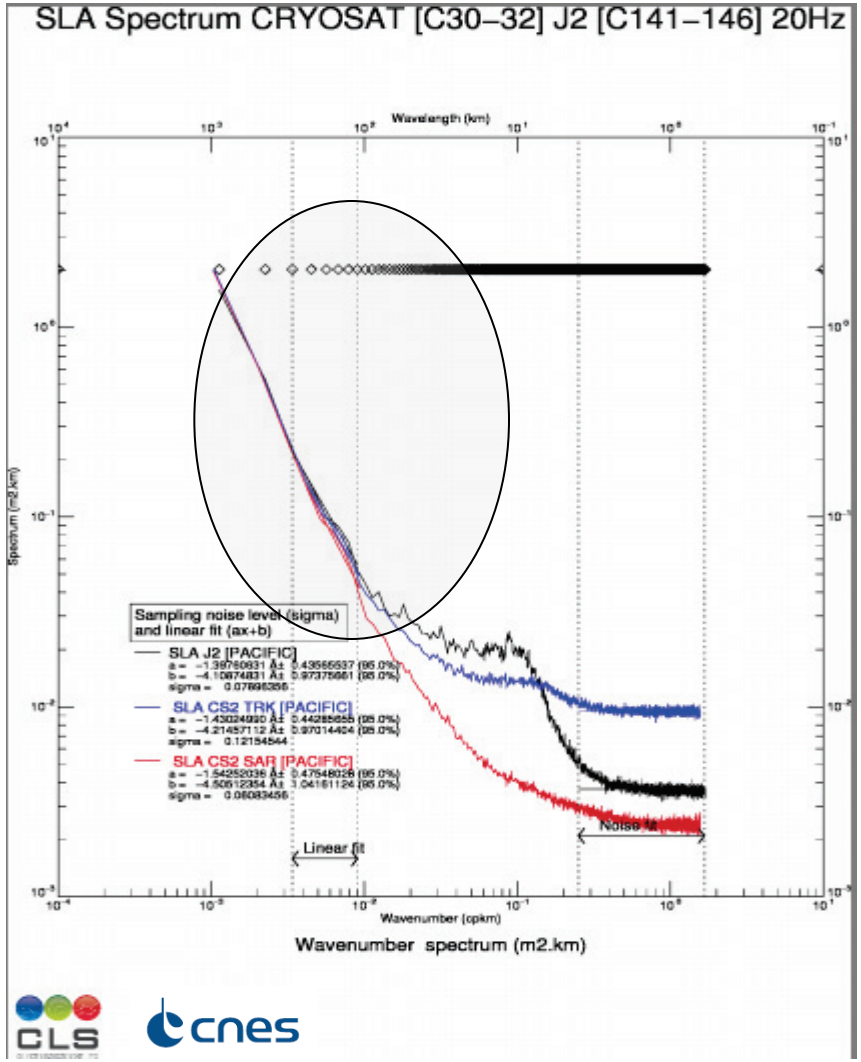
J2/C2 cross over points over Aghulas current



J2 trace 198 cycle 114 :
22505.242229
(2011-08-14 05:48:48)

C2 trace 783 cycle 20 :
22507.165698
(2011-08-16 03:58:36)

SAR SLA Spectrum (CRYOSAT-2)



Simulated SSH + Noise @ 20 Hz

- **All spectra are superimposed for wavelength larger than 100 km.** SARM processing is not affected by any error in the medium/large mesoscale band.

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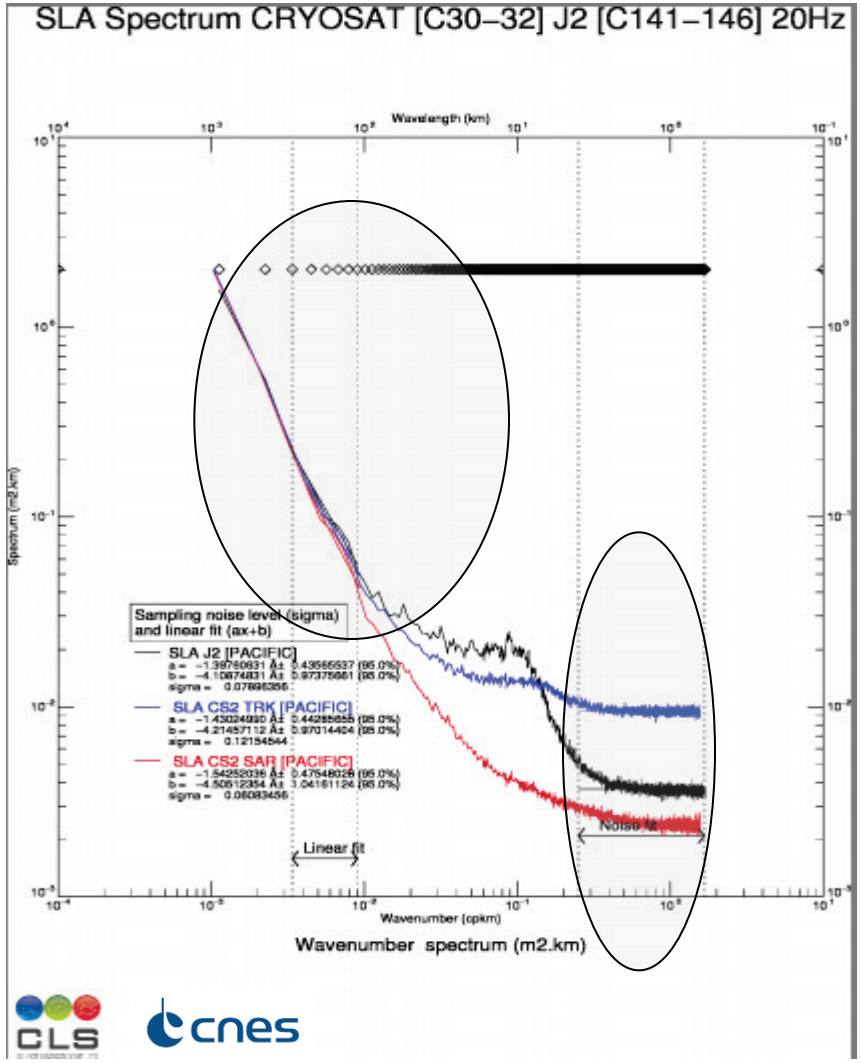

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- **A white noise plateau is visible on all spectra for wavelengths ranging from 600 m to approximately 3 km.** The blue spectrum (Cryosat, pseudo-LRM) is largely higher than Jason-2 (sqrt3 as expected) . **The SAR spectrum (red) exhibits a white noise plateau lower than Jason-2's (by approximately 30%).**

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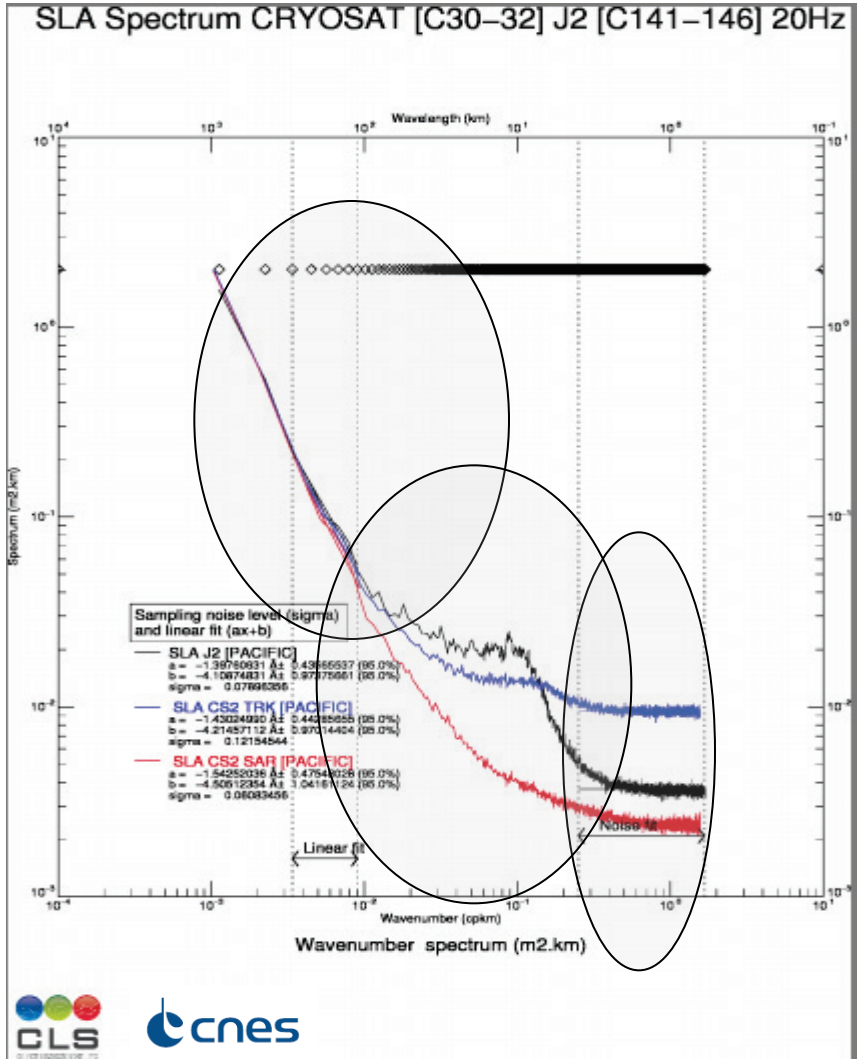

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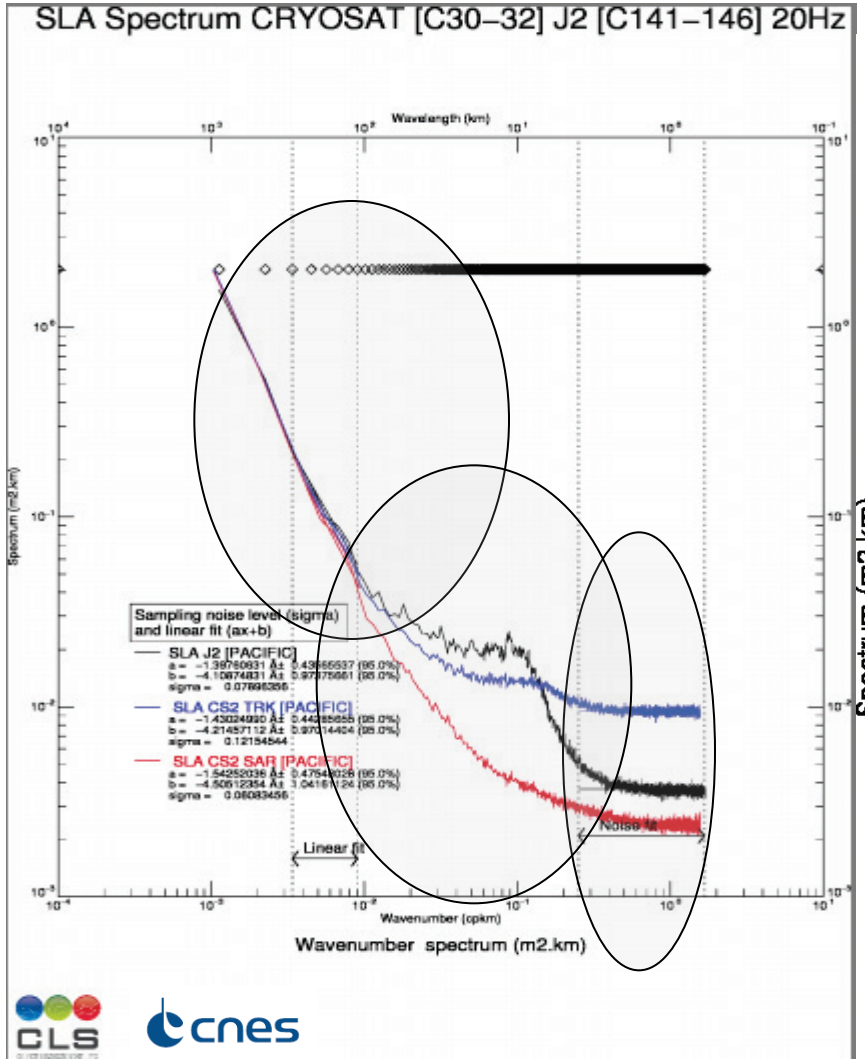
- **For wavelengths ranging from 7 to 100 km: although the black (LRM) and blue (pseudo-LRM) spectra exhibit a spectral "bump", the red spectrum (SARM) does not**

SAR SLA Spectrum (CRYOSAT-2)



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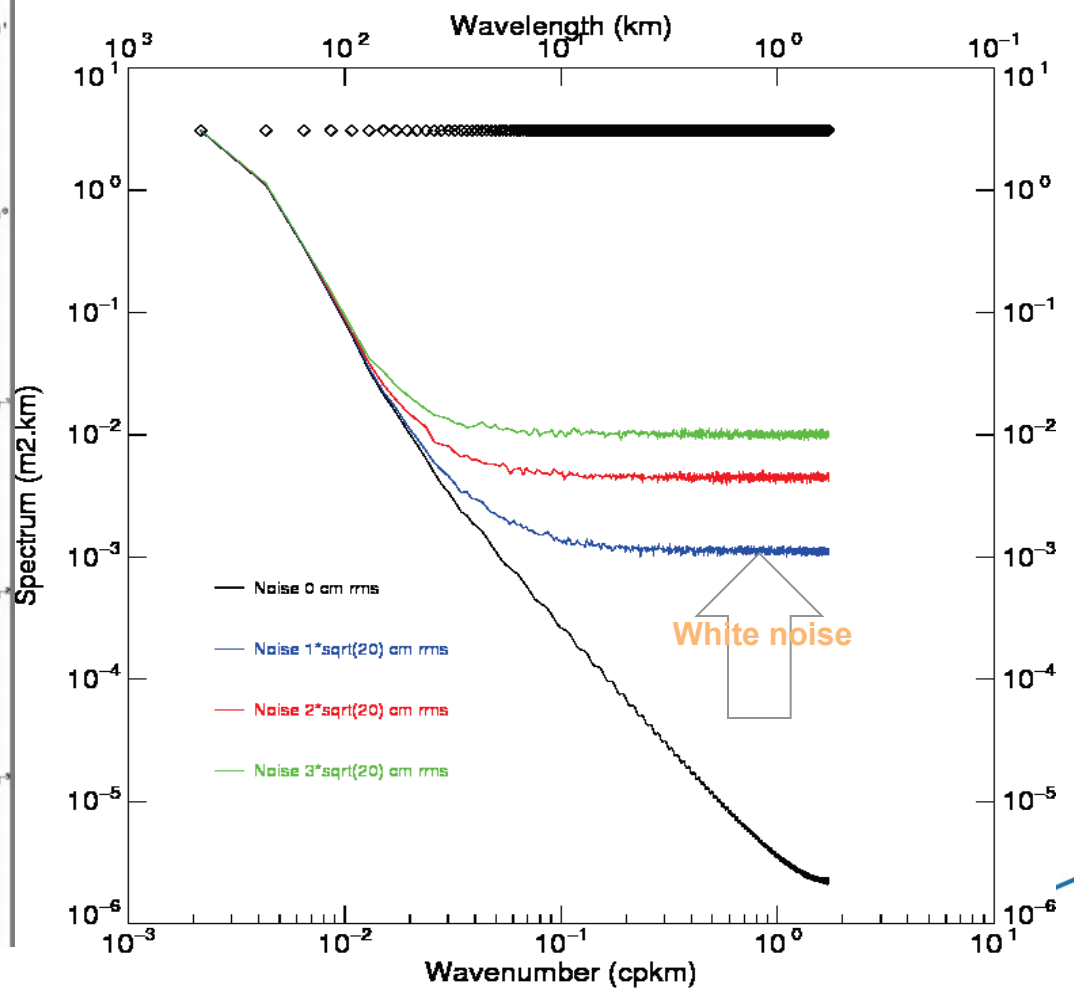
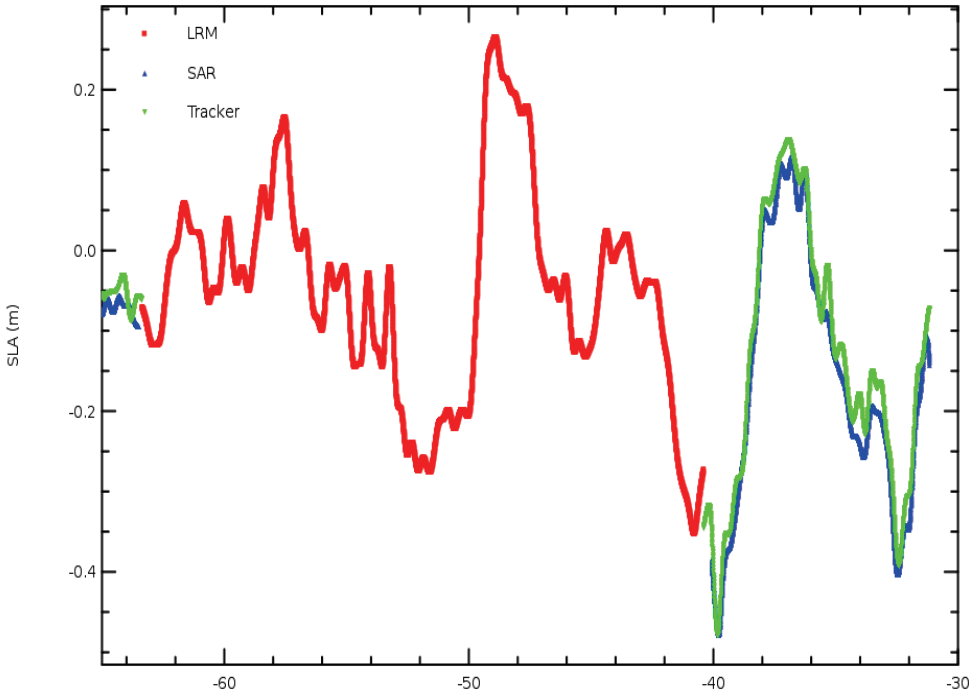


LRM<->SARM
Transition and Continuity

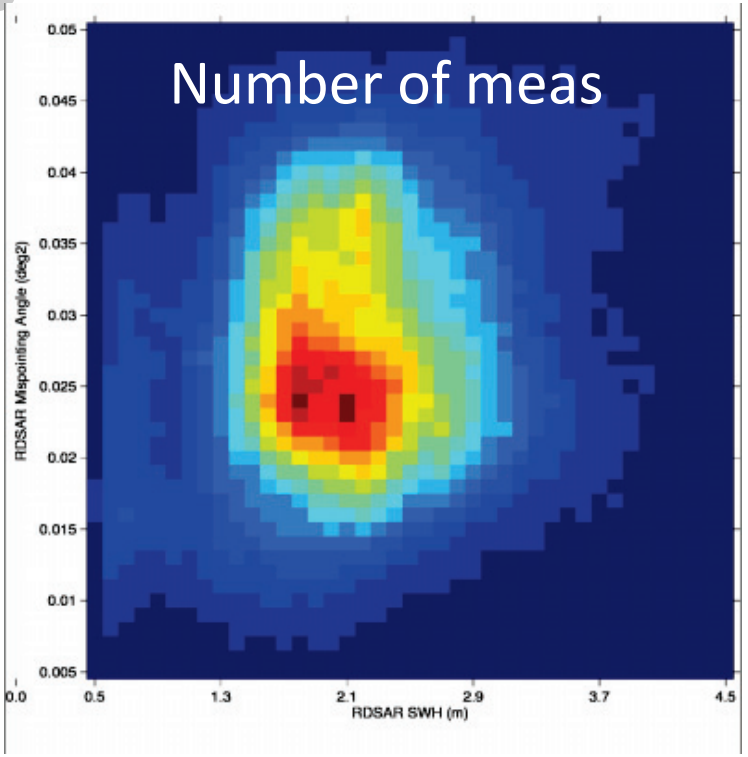
Track 130 over Aghulas current

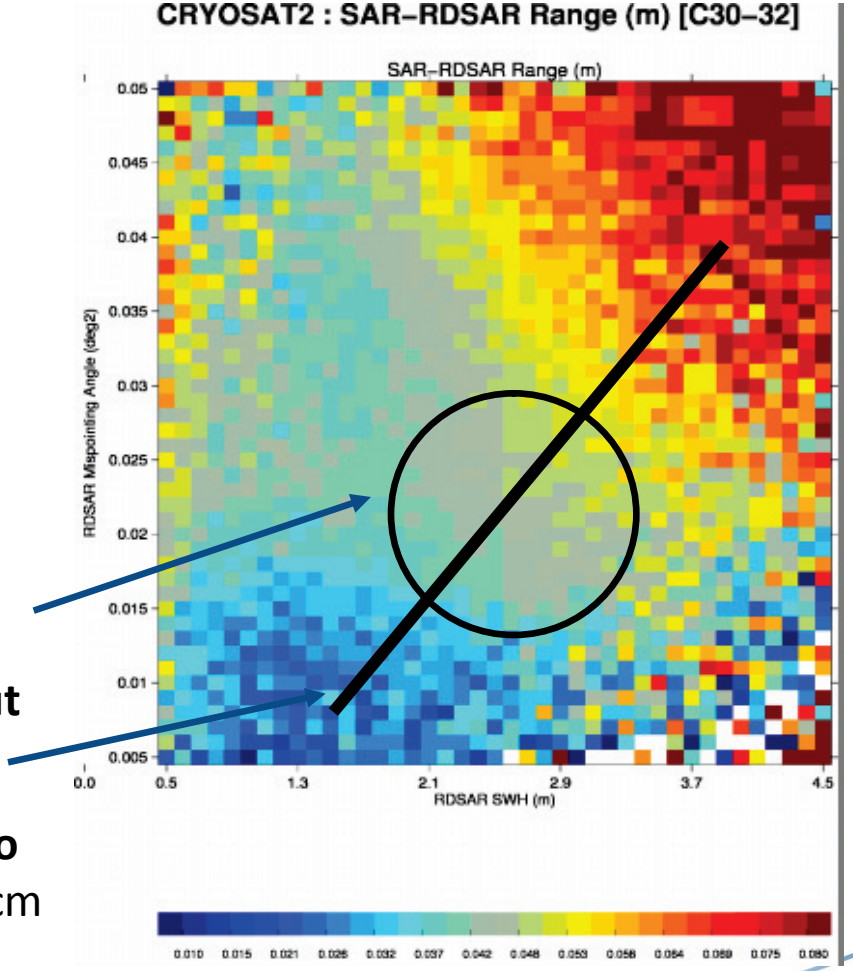
Red: LRM
Blue: SAR
Green: RDSAR



- Good transition between LRM (red) and SAR (blue) measurements.
- Analysis still on going to analyse precisely bias between LRM and SAR SLA. **Hard to do since SSB is applied on LRM results but none on SARM.**

SAR-RDSAR bias





- For the mispointing configuration used in the retracking (0.02deg^2), **SAR-RDSAR bias is about 4cm.**

- Bias between SAR and RDSAR are **correlated to SWH and mispointing values** (variation of +/-2cm depending on swh and ksi values)

Conclusion

Very promising results:

- ❑ SARM SLA noise is 30% lower than in LRM
- ❑ SARM provides with more trustworthy SLA dataset to observe scales ranging from 10 to 100km
- ❑ Thanks to the reduced azimuth resolution (320m vs 7km), SAR will improve the data coverage and quality approaching the coast.
- ❑ Low bias between LRM-SARM and SARM-RDSAR Sea Level Anomalies (few cm)

To optimize:

- ❑The SAR/Doppler retracking must be upgraded to:
  - Reduce bias dependencies in SWH and mispointing
  - Improve the SWH estimates: about 15cm bias between LRM/RDSAR and SAR SWH
- ❑The SAR/Doppler results must be more largely analyzed to:
  - Assess the continuity between LRM and SARM (SSB?, Doppler Model?)
  - Assess the SAR sensitivity to altitude, radial speed, …
  - Assess the SAR sensitivity to swell,
  - Assess the SAR retracking for very low SWH.

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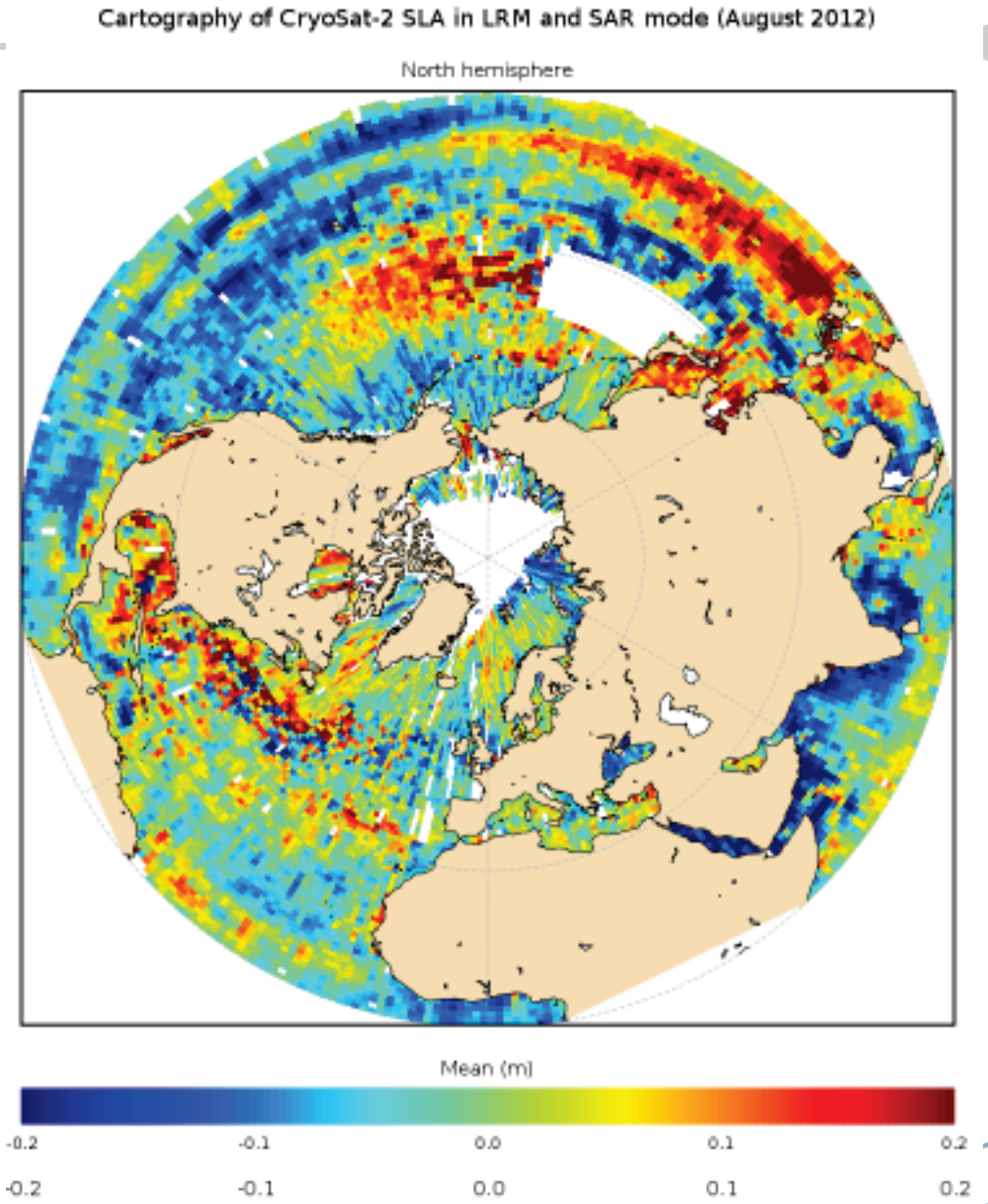
Thank you!


Cartography of CryoSat-2 SLA in LRM and SAR mode (August 2012)
North hemisphere
Mean (m)
-0.2
-0.1
0.0
0.1
0.2