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→ 8th COASTAL ALTIMETRY WORKSHOP

23—24 October 2014 | Lake Constance | Germany

Delay/Doppler waveform processing in coastal zones

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F.Boy, N.Picot : Centre National d'Etudes Spatiales, France

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Typical example of contaminated waveforms on coastal regions

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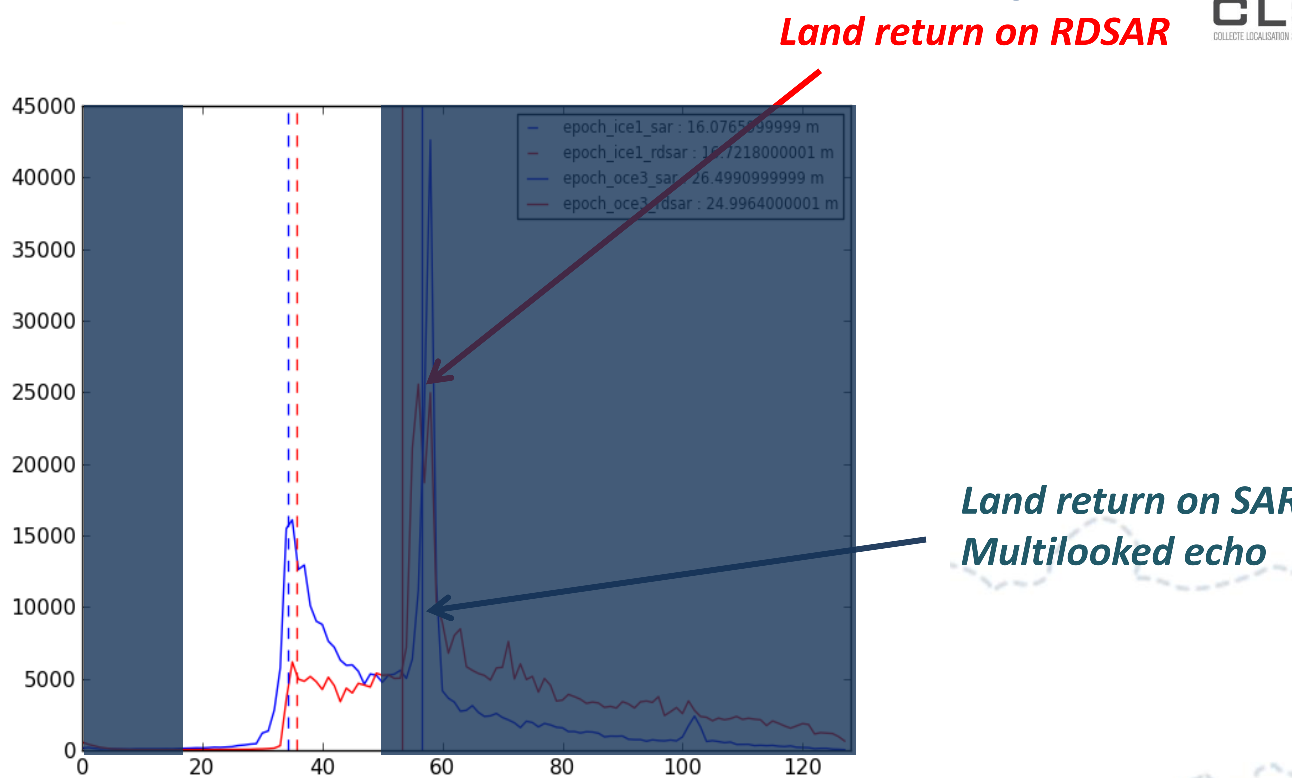
Cryosat-2

Cycle 36
Track 282
Lat = 9.84 deg
Lon = 104.86 deg
Dist_Coast = 3.6 km
α = 70 deg



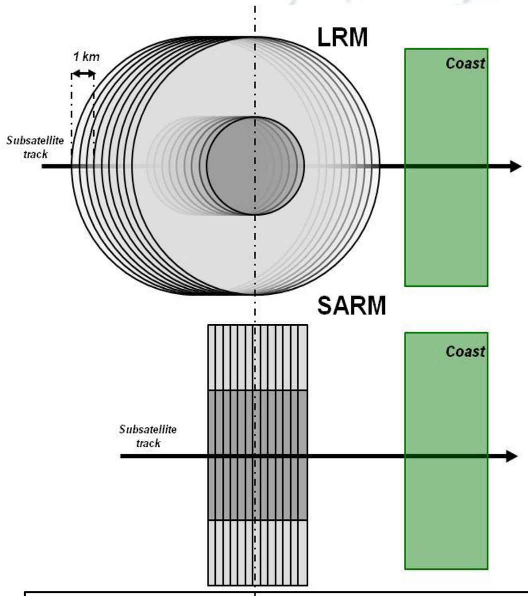
- Can we reduce the analysis window to avoid land (...) returns ?
- What are the associated performances for Delay/Doppler & for LRM/RDSAR in coastal regions but also over deep ocean ?

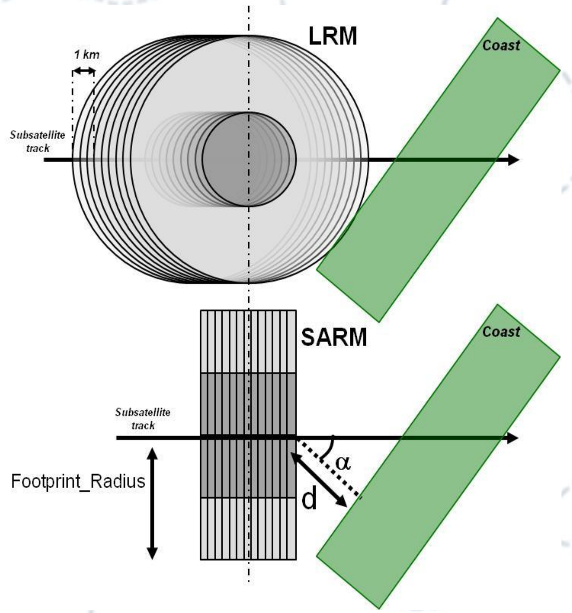
Summary

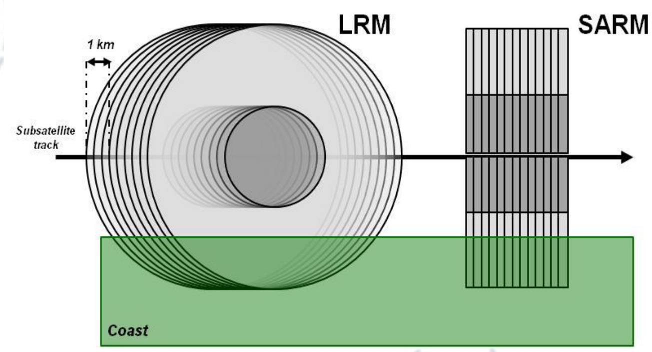
- Introduction : theoretical considerations for delay/doppler waveform processing
- Does window reduction improve SAR processing performances close to the coasts ?
- LRM & SAR comparison over deep ocean on reduced windows
- Conclusions

Impact of coast on LRM & SAR measurements

(reminder : Thibaut et al, 2013 CAW)







Tracks perpendicular to the shoreline

$\alpha=0°$

- ❑ LRM impacted as soon as its footprint reaches the coast (9.6 km for Jason, 7.7 km for CS-2)
- ❑ SARM impacted much later (320 m)

Attack angle α to the shoreline

α

- ❑ SARM impacted from distance

$$d = Footprint\_Radius*\sin(\alpha)$$

d : distance to the nearest coast
α : angle between track direction and nearest point of the coast

Tracks parallel to the shoreline

$\alpha=90°$

- ❑ LRM and SAR impacted as soon as their footprints touch the coast (9.6 km for Jason,7.7 km for CS-2)

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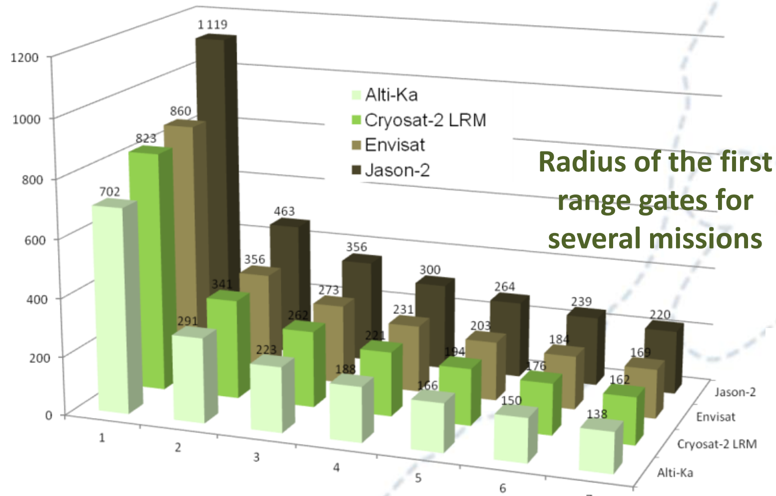
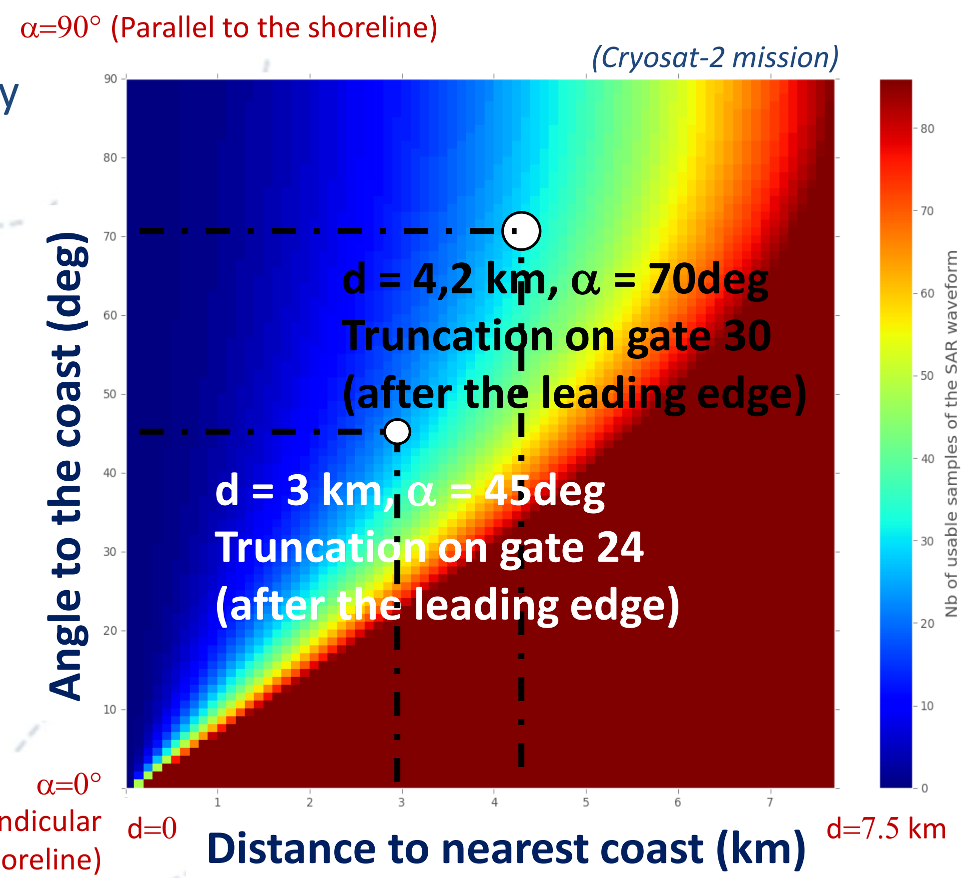
Uncontaminated range gates as a function of α and d

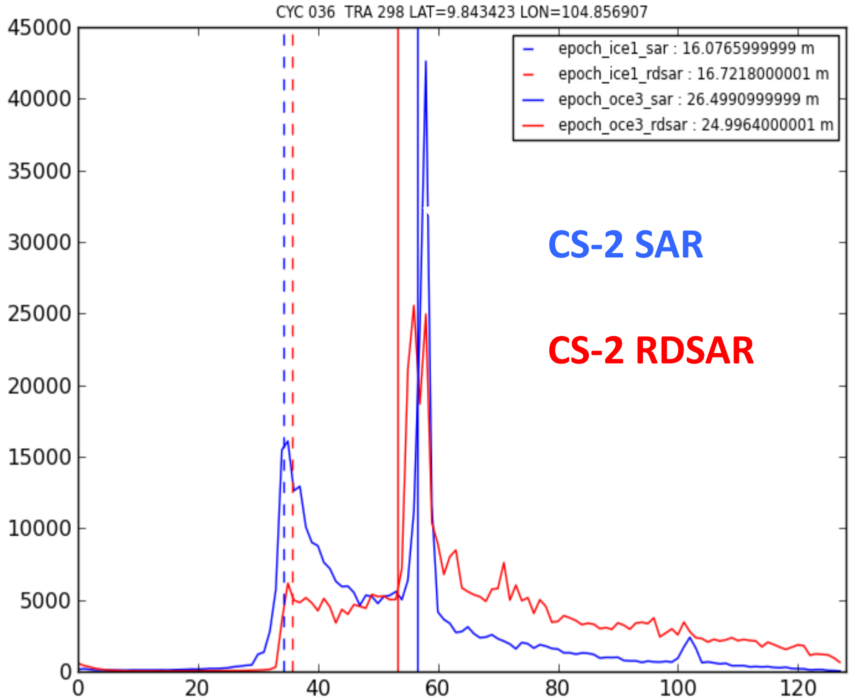
- Knowing the distance to the nearest coast and the angle with the track direction (geometrical determination), we can identify the number of uncontaminated samples to be retracked
- Not considering tide effects, shoreline relief, vegetation, sea state modification, …

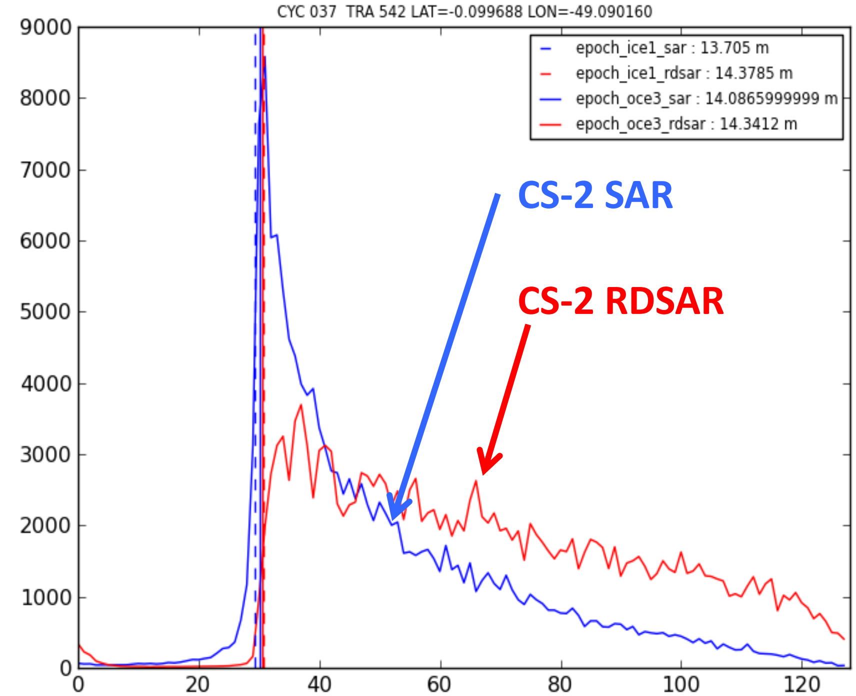




What are the impacts on performances :

- ❑ when the waveforms are corrupted (near the coast)
- ❑ when the waveforms are not corrupted (deep ocean conditions)





Comparison between LRM & SAR results when reducing the analysis window

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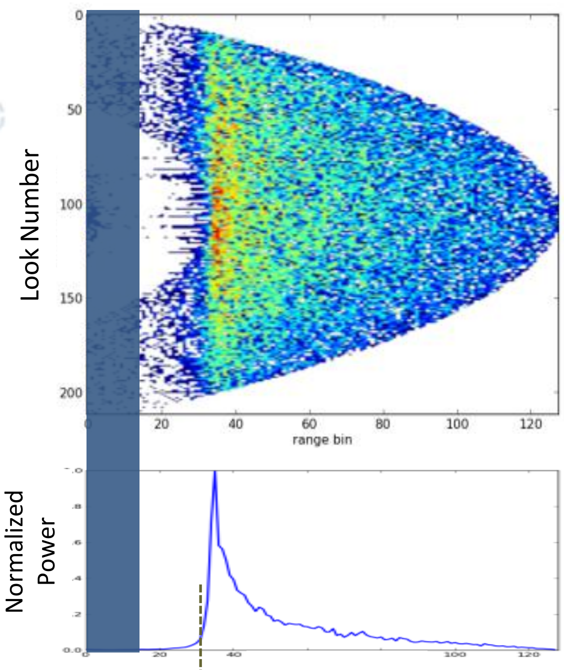
SAR Mode

Stack of echos (after migration)

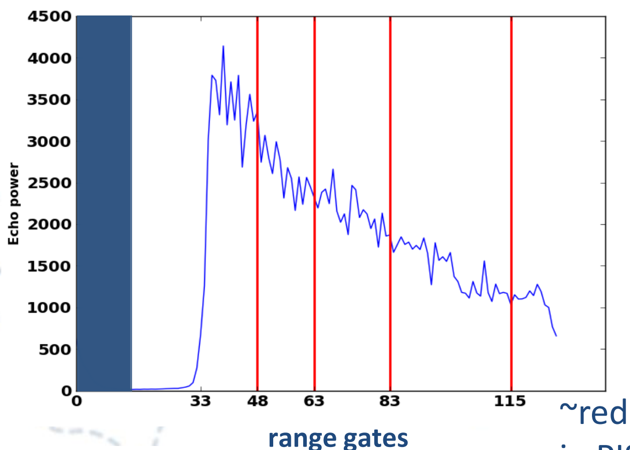
Multilooked echo



12 …33 … 63

➔ WFs have been retracked with 4 different window widths

LRM Mode



12 …33 … 63

~red3 algorithm in PISTACH products

Window Truncation	12-115	12-83	12-63	12-48
Radius of the WF footprint	7488 m	5848 m	4530 m	3203 m

Comparison between LRM & SAR results when reducing the analysis window

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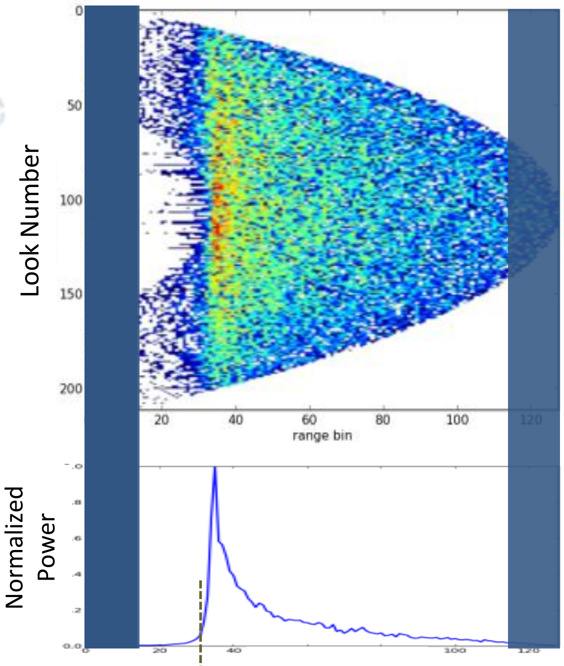
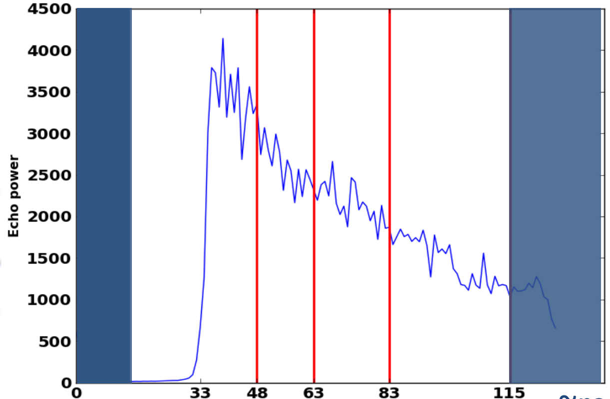


range gates

12 …33 ……………….. 115

➔ WFs have been retracked with 4 different window widths

LRM Mode



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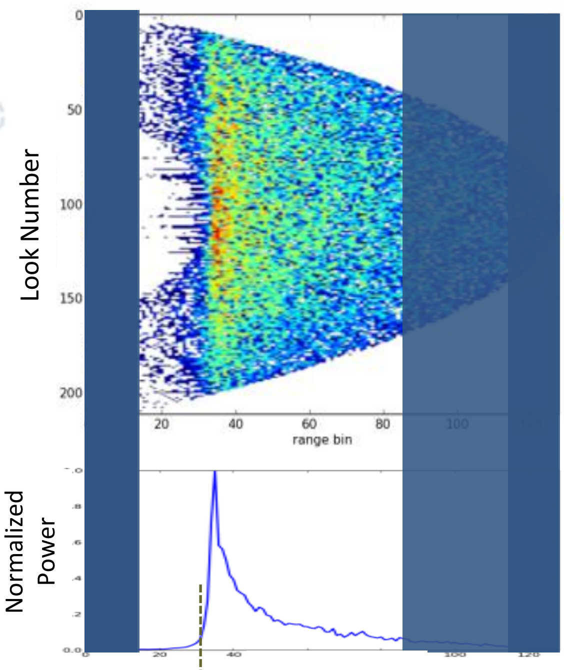

12 ...33 83

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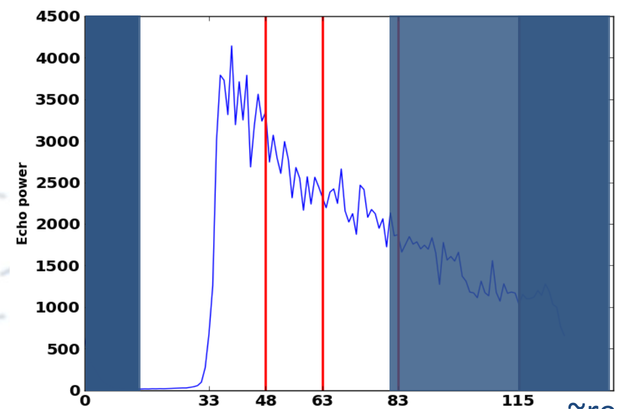

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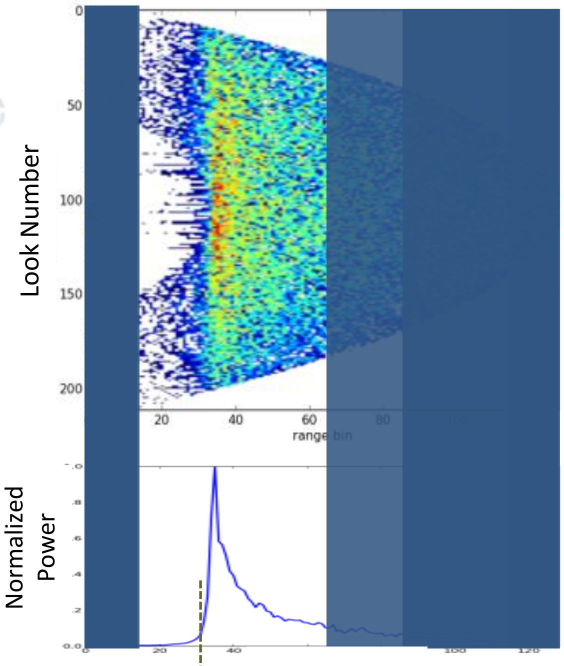

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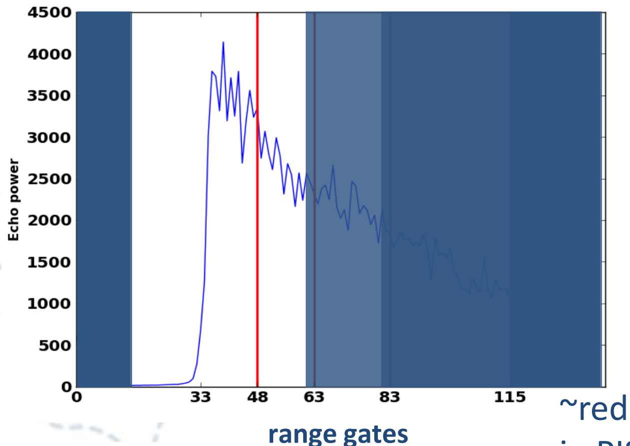

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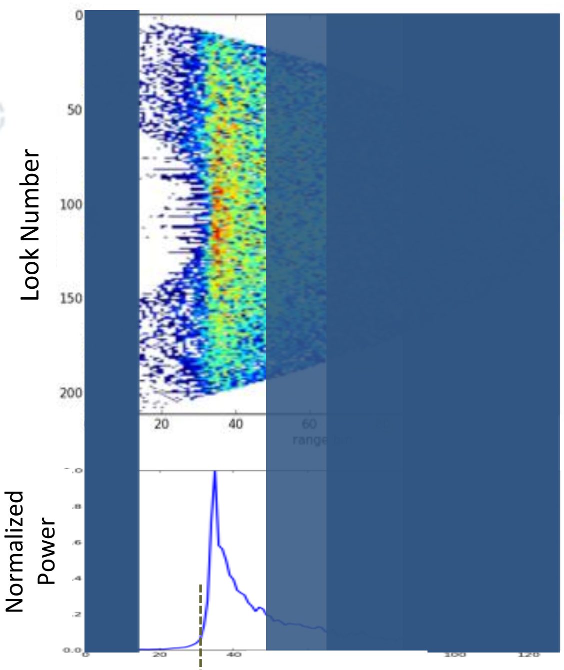
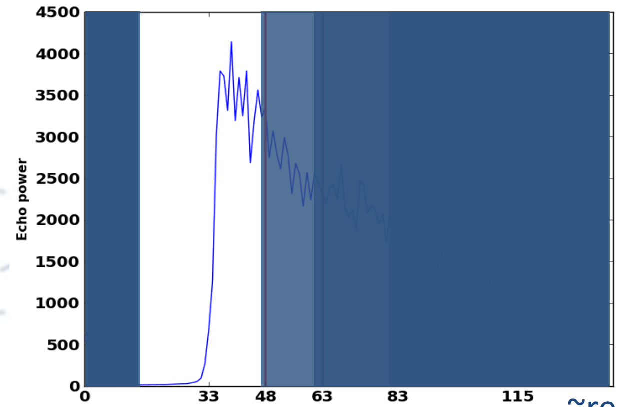


12 . 33 . 48

➔ WFs have been retracked with 4 different window widths

LRM Mode



12 . 33 . 48

~red3 algorithm in PISTACH products

Window Truncation	12-115	12-83	12-63	12-48
Radius of the WF footprint	7488 m	5848 m	4530 m	3203 m

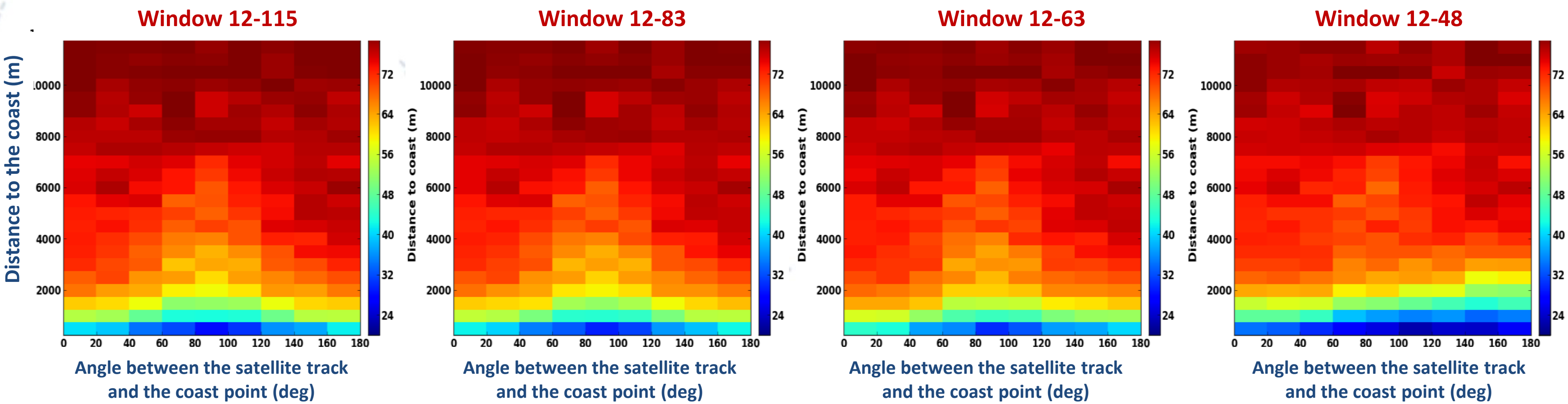
Coastal SAR results

For all CS-2 measurements, we computed :

- ❑ The distance to the nearest coast
- ❑ The angle to the nearest point (using Global Self-consistent, Hierarchical, High-resolution Shoreline Database, 40 m resolution)
- ❑ The transition flag (LandtoOcean or OceantoLand)

- ❑ then, we retracked with 4 different window widths (from July to October 2013, 45°S-60°N)

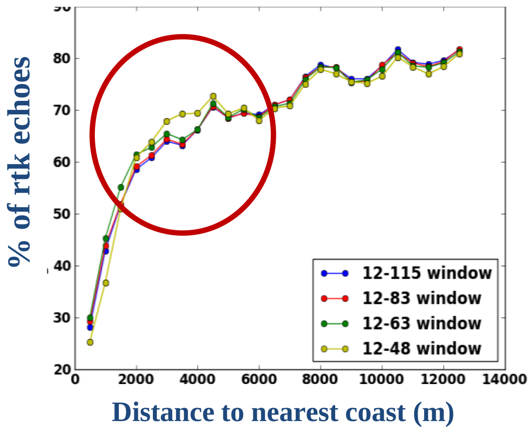
Percentage of successfully retracked SAR echoes

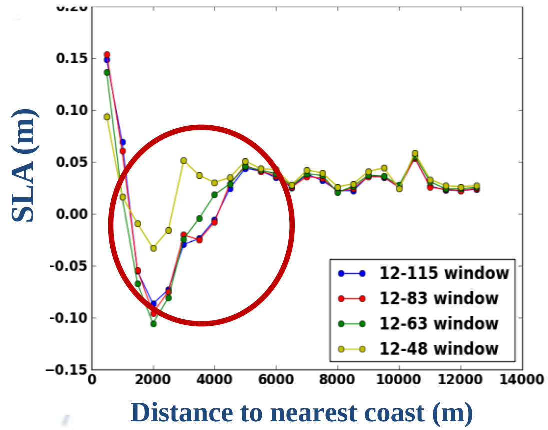


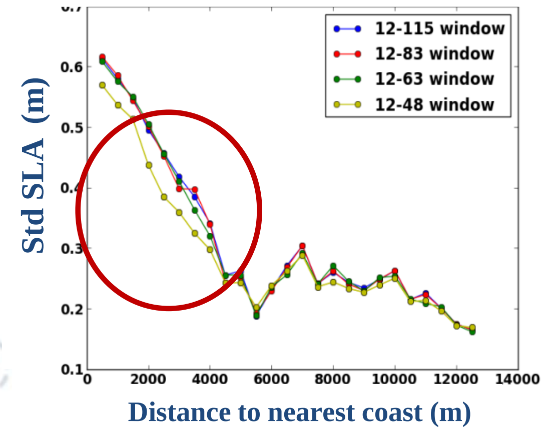
- For a given angle, clear improvement of this percentage when going off the coastline (for all windows)
- The percent. is higher when tracks are perpend. to the coast than when parall to the coast
- For a given distance to the coast (3 km for example), the percentage of retracked echos is higher when reducing the analysis window for tracks parallel to the coast
- Performances are not equivalent when going from Land to Ocean and from Ocean to land (higher percentage for Ocean to Land tracks) (➔ potential effect of the LRM tracker and potential advantage of the OLTC tracking mode or tracker based on SARM echoes)

α=90° (parallel to the coast)
α =0°, 180° (perpendicular to the coast)
α < 90° (from ocean to land)
α > 90° (from land to ocean)

Results for tracks parallel to the coast

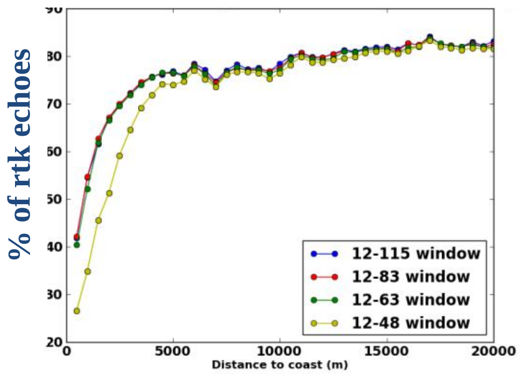


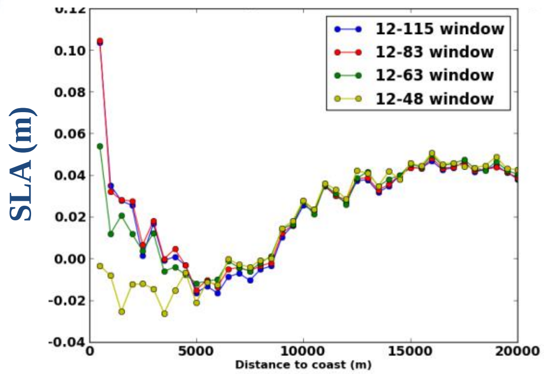


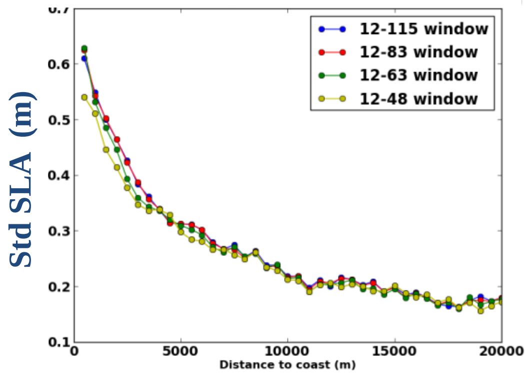


➔ For small analysis window (12-48), we observe an improvement of SLA performances close to the coast without loss of data (explained by the fact that land return are not considered in the analysis window)

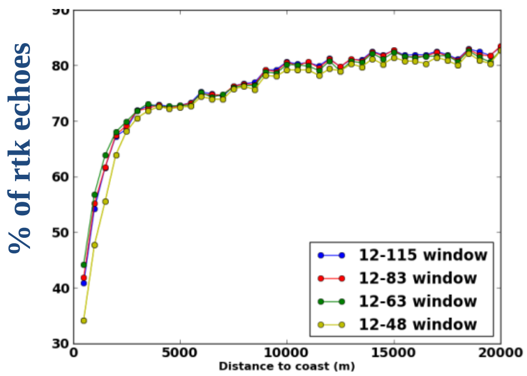
Results for tracks perpendicular to the coast (Land to Ocean)

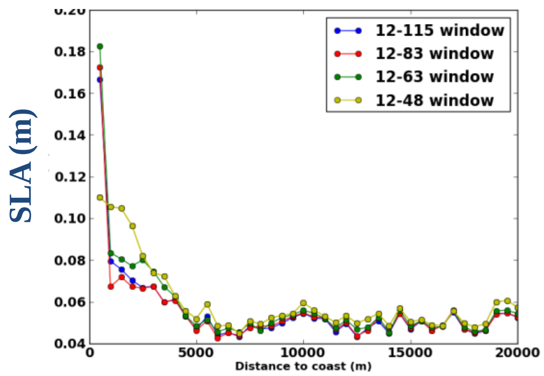


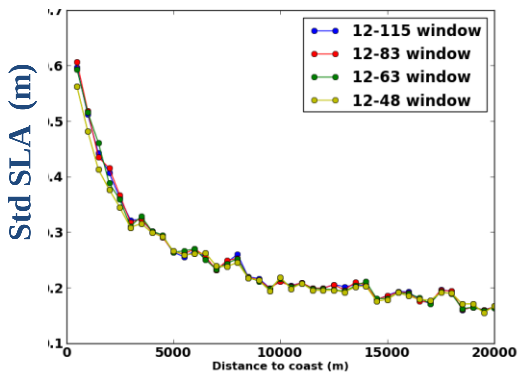




Results for tracks perpendicular to the coast (Ocean to Land)







Open ocean results

Analyses have been done with :

- Simulated data (gaussian PTR)
- Cryosat-2 measurements

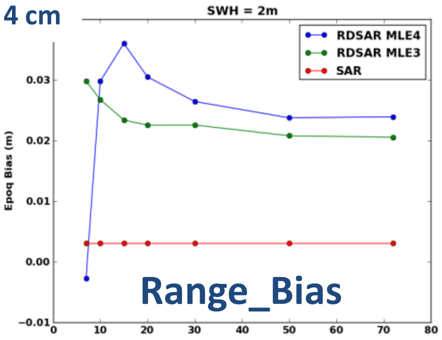
July 2012 for the pacific ocean patch.

- On SAR echos, we run the numerical retracker (CNES development for the Cryosat Processing Prototype), based on simulated numerical models.

- On RDSAR and LRM echos, we run MLE3 & MLE4 retrackers
(Note that STR unbiased mispointing angles are accounted for in the MLE3 version)

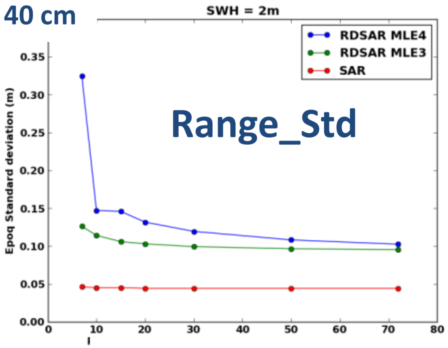
LRM & SAR comparisons on simulated data

4 cm



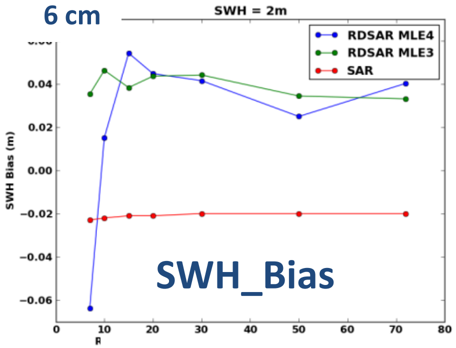
Window size

40 cm



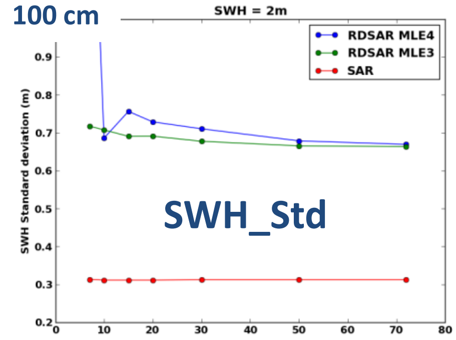
Window size

6 cm



Window size

100 cm

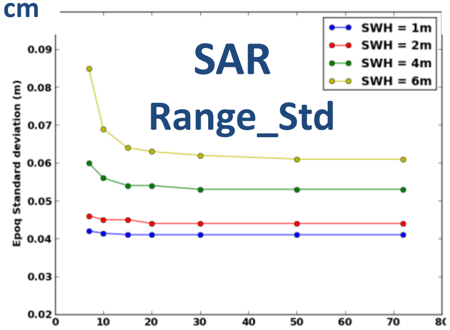


Window size

➔ SAR very stable (bias & Std), whatever the window reduction.

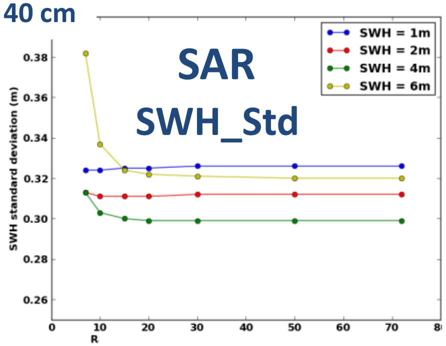
However, results depend on SWH

10 cm



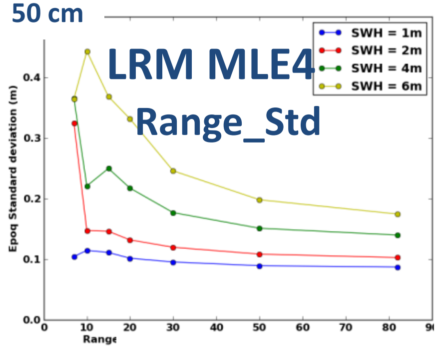
Window size

40 cm



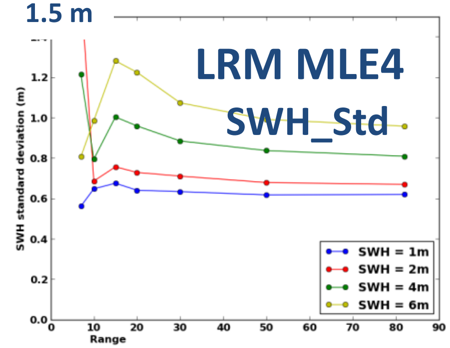
Window size

50 cm



Window size

1.5 m



Window size

➔ Equivalent results with MLE3

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LRM & SAR comparisons on Cryosat-2 data (ocean pacific patch)

Analysis Window	12-115	12-83	12-63	12-48
% of retracked RDSAR echoes (MLE3)	97.48	97.37	97.1	89.72
% of retracked RDSAR echoes (MLE4)	96.97	86.03	39.04	7.66
% of retracked SAR echoes	99.969	99.968	99.967	99.966

➔ The reduction of the analysis window doesn't degrade the percentage of retracked measurements in SAR

LRM & SAR comparisons on Cryosat-2 data : Range

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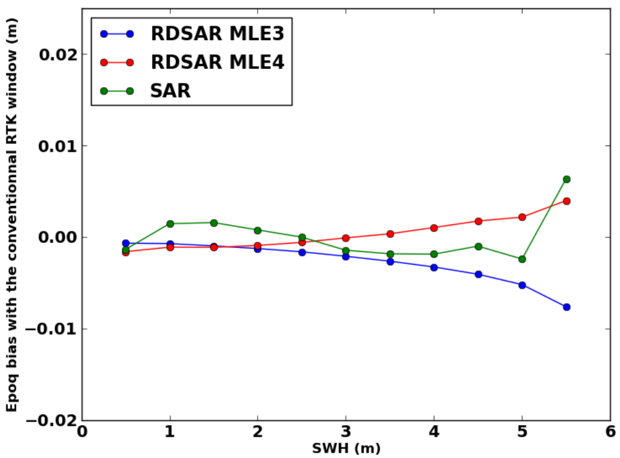
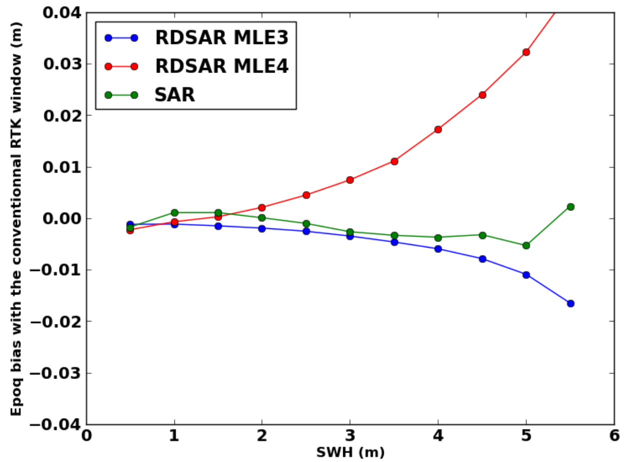
Bias obtained when processing with a reduced window wrt the full window (ocean echoes)

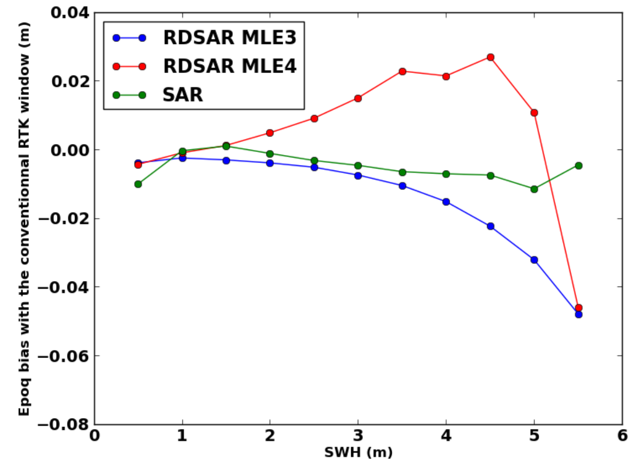
Window 12-83



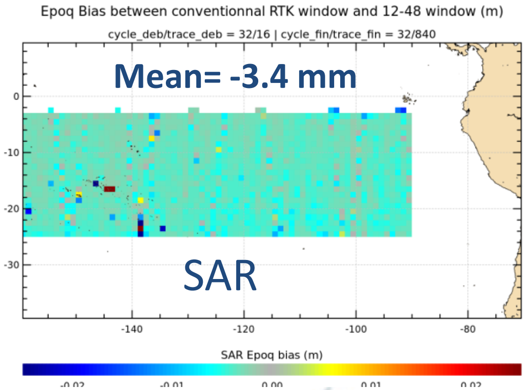
Window 12-63

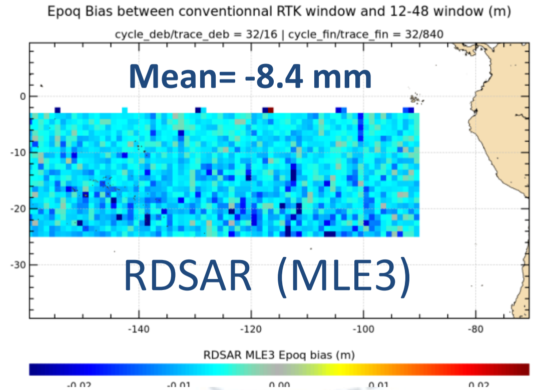


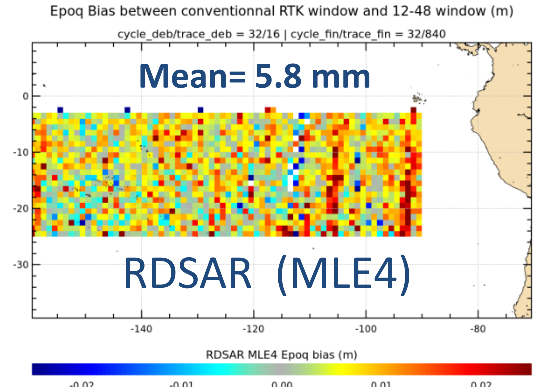
Window 12-48



Bias obtained when processing with a **reduced window (12-48)** wrt to the full window (12-115) (over the pacific patch)



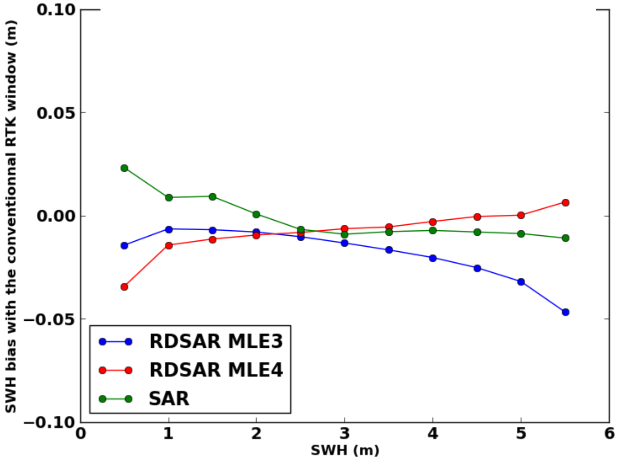




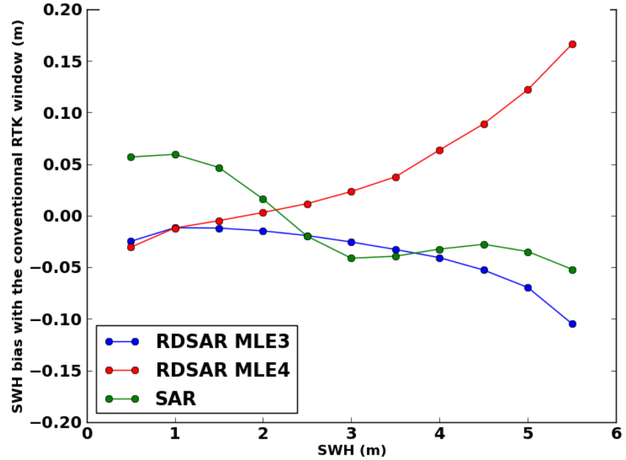
LRM & SAR comparisons on Cryosat-2 data : SWH

Bias obtained when processing with a reduced window wrt the full window (ocean echoes)

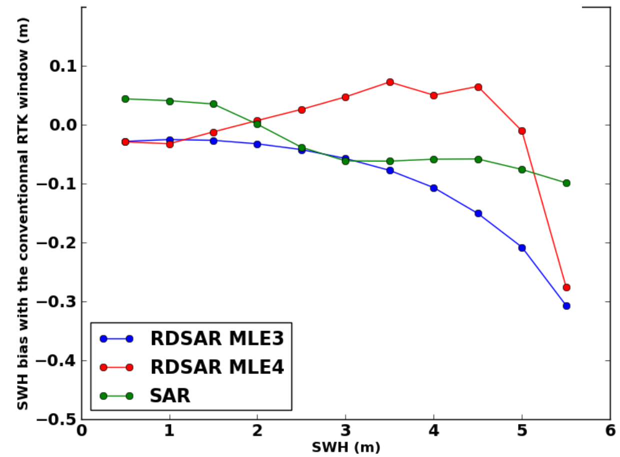
Window 12-83



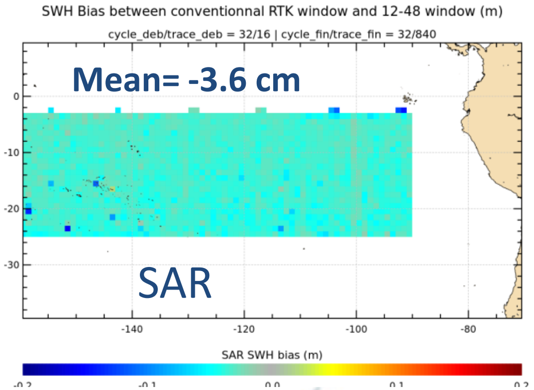
Window 12-63

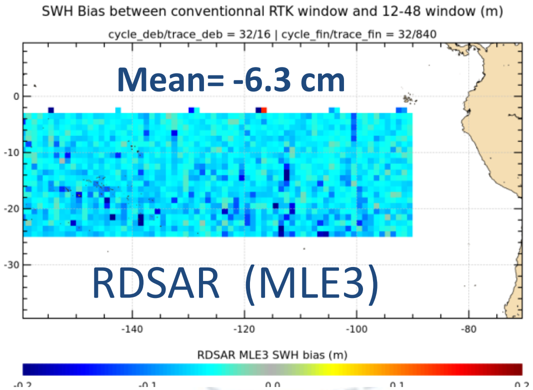


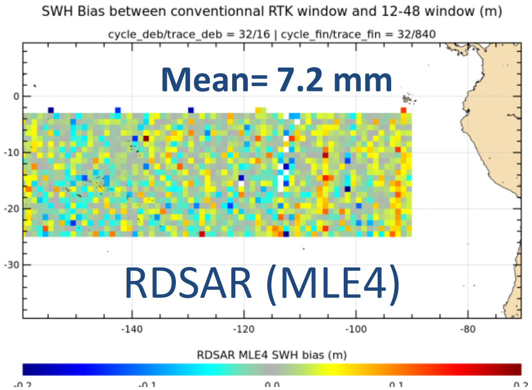
Window 12-48



Bias obtained when processing with **a reduced window (12-48)** wrt to the full window (12-115) (over the pacific patch)







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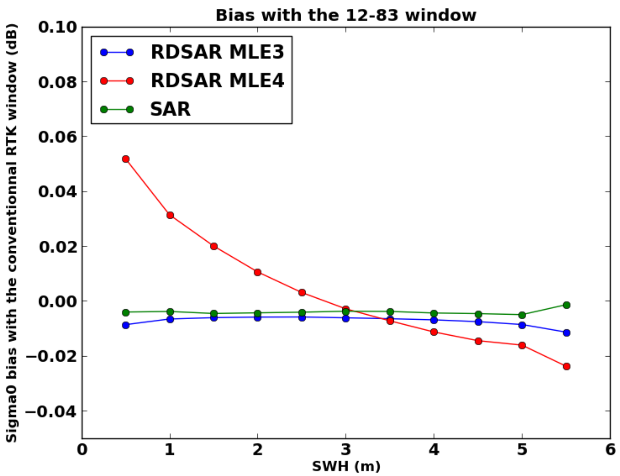
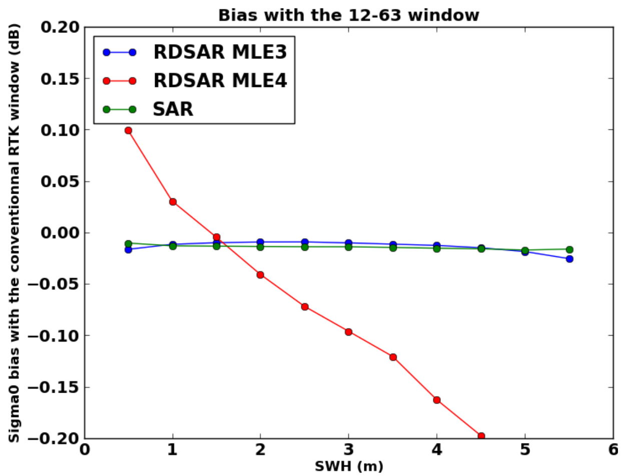
LRM & SAR comparisons on Cryosat-2 data : Sigma0

Bias obtained when processing with a reduced window wrt the full window (ocean echoes)

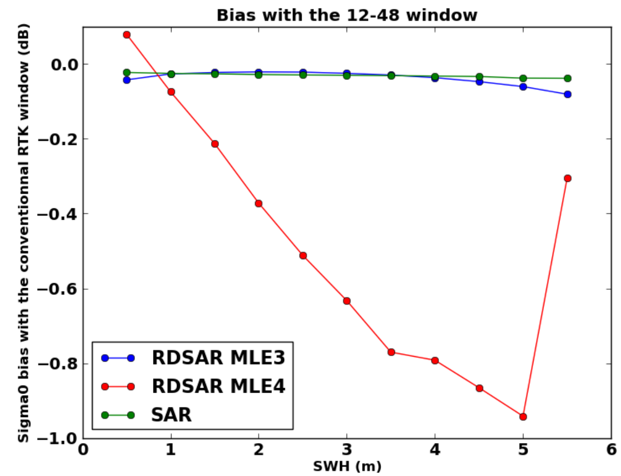
Window 12-83



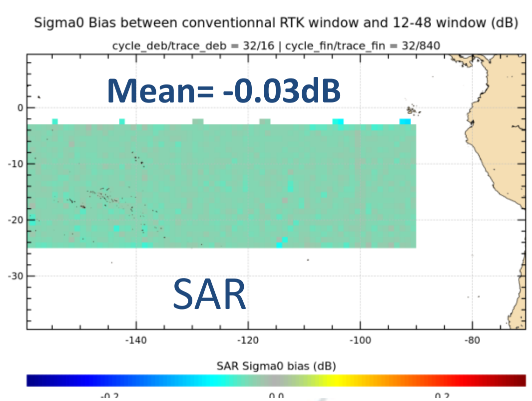
Window 12-63

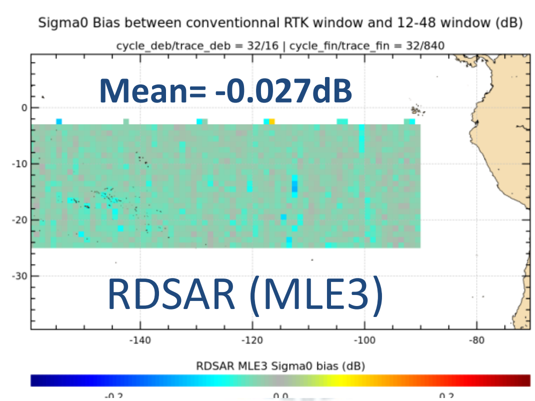


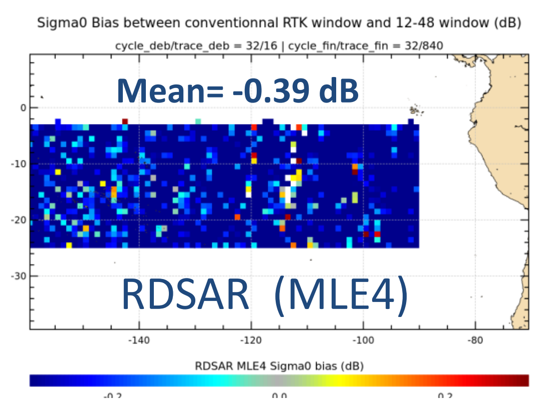
Window 12-48



Bias obtained when processing with **a reduced window (12-48)** wrt to the full window (12-115) (over the pacific patch)







Conclusions

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- For coastal SAR echoes, reducing the retracking window allows to better estimate closer to the coasts (especially when tracks are parallel to the coastline).
- For ocean SAR echoes, the analysis window can be reduced with very few damages on performances (not true for MLE3 and MLE4 on LRM/RDSAR echoes).
- The size of the window can be optimized. Very good results even with only few range gates.
- LRM tracker behavior (LandtoOcean or OceantoLand) could be solved on ground or on-board using OLTC or SAR tracker

- The advantage is that the processing is unchanged from deep ocean up to very close to the coast (LUT not required, no problem of discontinuity between retrackers, …)
- Along-Track improvements to be analysed as well (Hamming Window for example)
- Can allow to reduce the TM volume (if RMC performed on board) and to reduce CPU on ground.

General issues over coastal zones :

- waveforms are corrupted,
- ocean variability is higher than in deep ocean,
- corrections are not well defined (Tides, MSS, Wet Tropo, Iono filtering, SSB (link with SWH and $\sigma 0$)

➔ Hard to quantify the improvement of new processings, especially a retracker.