Fast and accurate Delay/Doppler processing: applying range walk compensation while preserving the computational complexity

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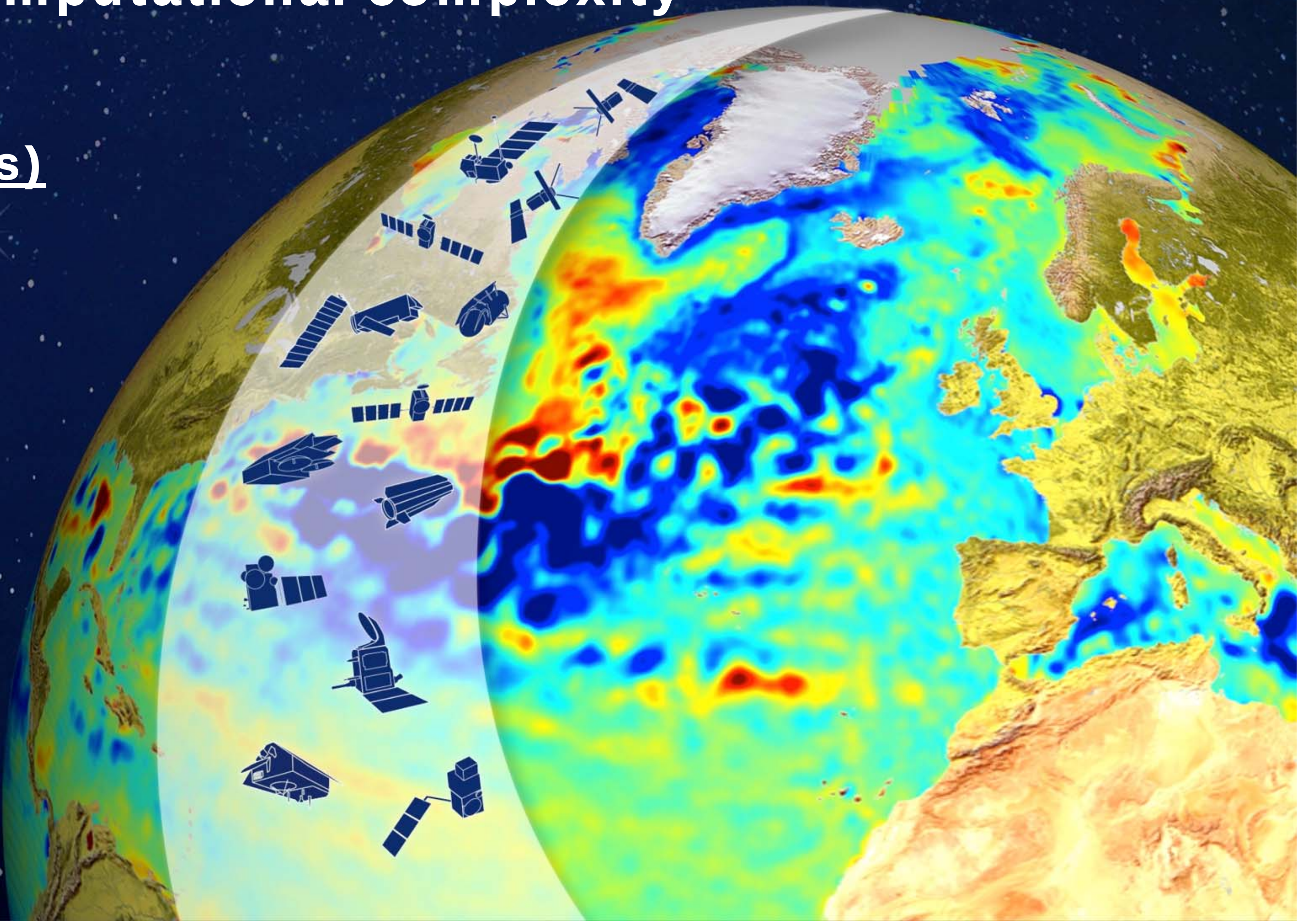


Outline

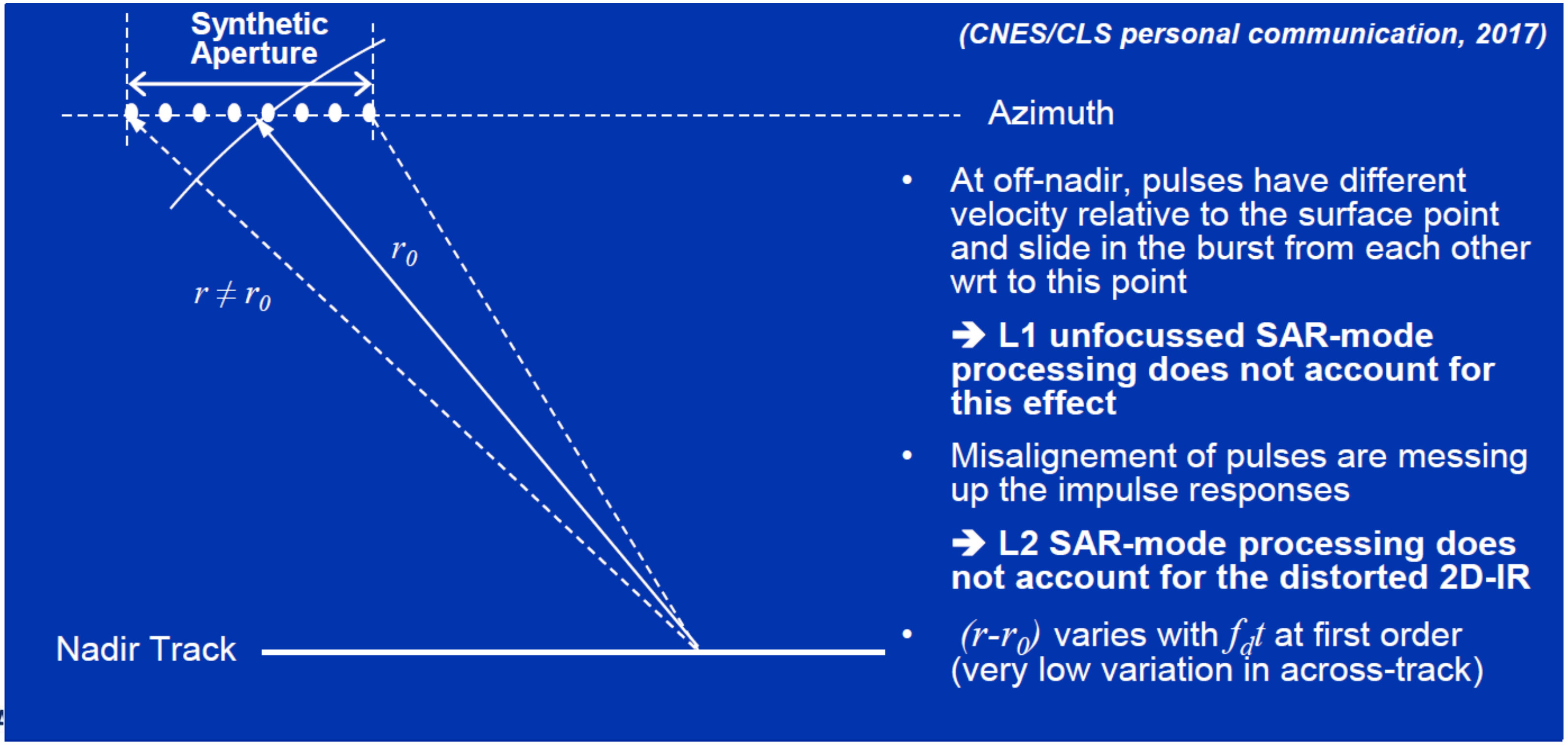
- Previous works
- Range walk in Delay/Doppler Processing
- DFT based beamforming
- Experimental framework and results
- Conclusions and next activities

From OSTST 2017:

"INVESTIGATION OF SWH BIAS IN SAR ALTIMETRY MODE"

T. Moreau, P. Rieu, J. Aublanc, L. Amarouche, P. Thibaut (CLS) F. Boy, A. Bohe, N. Picot (CNES) C. Mavrocordatos, F. Borde (ESA)

Objective of the study: to understand the >10cm discrepancy between LRM and SAR mode



The range walk

As already addressed in [1] the satellite-SS range distance $d_k(n,0)$ with k the index of pulses in a burst and n the burst index, can be disregarded in

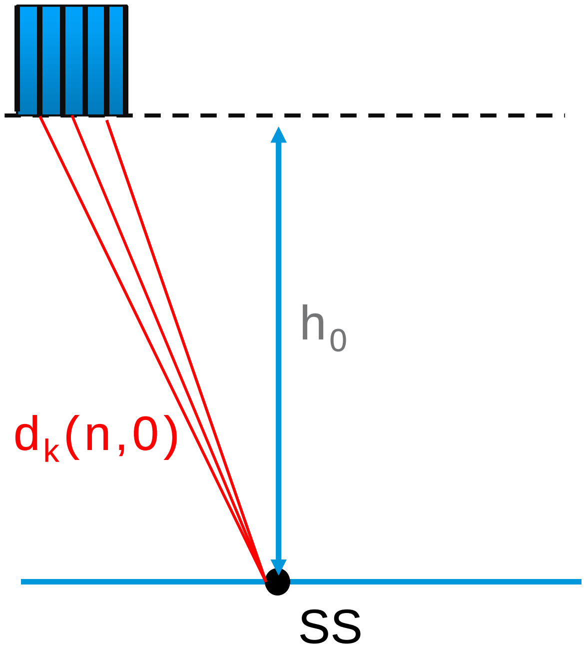
Range distance at burst center

$$d_0(n,0) = \sqrt{h_0^2 + y_n^2}$$

$$\Delta d_k(n,0) = \sqrt{h_0^2 + (y_n - (k+0.5)\Delta y)^2} - \sqrt{h_0^2 + y_n^2}$$

$$= d_k(n,0) - d_0(n,0).$$

Range walk, it represents the change in range distance during a burst acquisition



In Delay/Doppler processing the range walk is usually neglected achieving a great simplification in the processing but reducing the quality of the Impulse Response Function at high look angles

[1] P. Guccione, "Beam Sharpening of Delay/Doppler Altimeter Data Through Chirp Zeta Transform," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 46, no. 9, pp. 2517-2526, Sept. 2008.

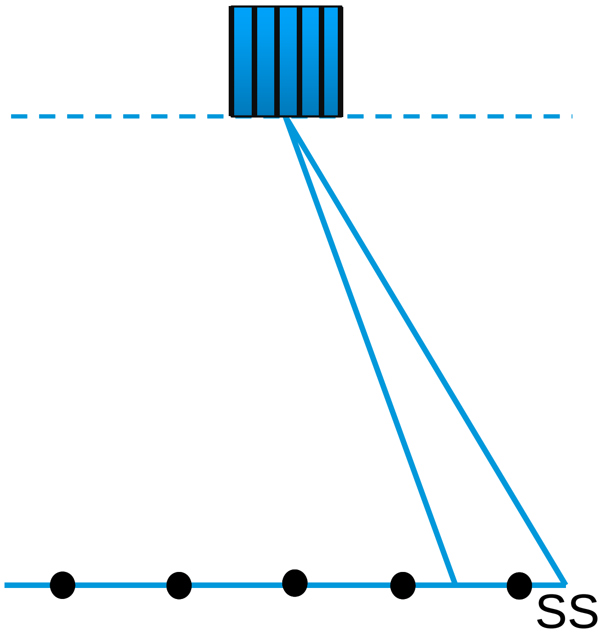
Range walk compensation in D/D

Being the range walk function of

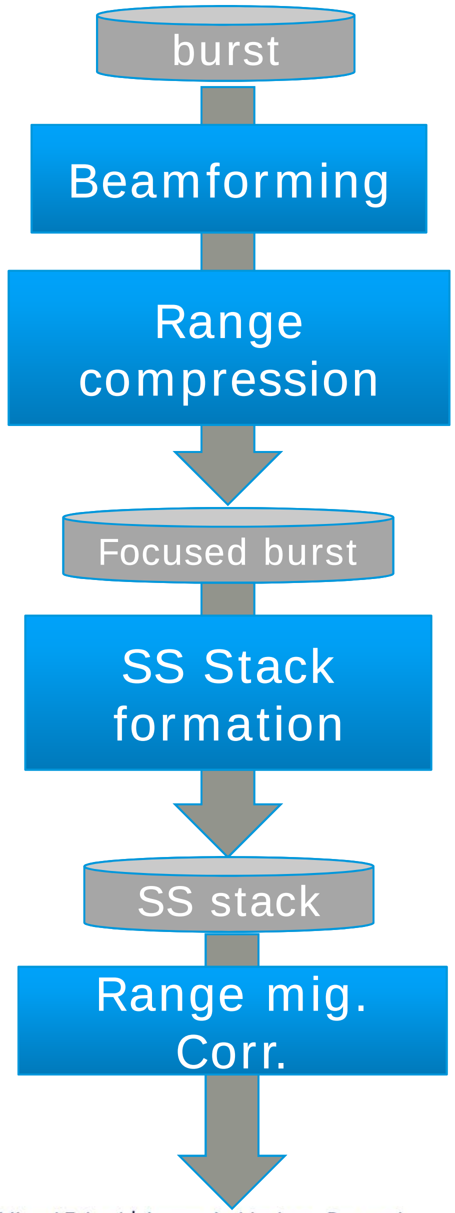
- The position of the satellite for the k-th pulse in a burst
- The surface point (i.e. surface sample) that is being focused

The range walk compensation is to be applied

- **together with the beamforming operation**
- **only in combination with exact beamforming**



Exact beamforming
It is computed one FFT for each SS in order to steer the beam exactly towards the current SS



DFT based beamforming

aresys esa

Approx. beamforming FFT-based

- **Approximate** beam steering towards SS
- Range walk compensation cannot be applied
- One FFT per burst

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i\frac{2\pi kn}{N}}$$

- Computational complexity

$$O(N\log(N)))$$

Exact beamforming FFT-based

- Exact beam steering towards SS
- Range walk compensation can be applied
- 64 FFT per burst

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i\frac{2\pi kn}{N}}$$

- Computational complexity:

$$N * O(N\log(N)))$$

Exact beamforming DFT-based

- Exact beam steering towards SS
- Range walk compensation can be applied
- 1 DFT per burst

$$X(\omega) = \sum_{n=0}^{N-1} x_n e^{-i\omega n}$$

- Computational complexity:

$$O(N^2)$$

Optimal tradeoff between accuracy and computational complexity

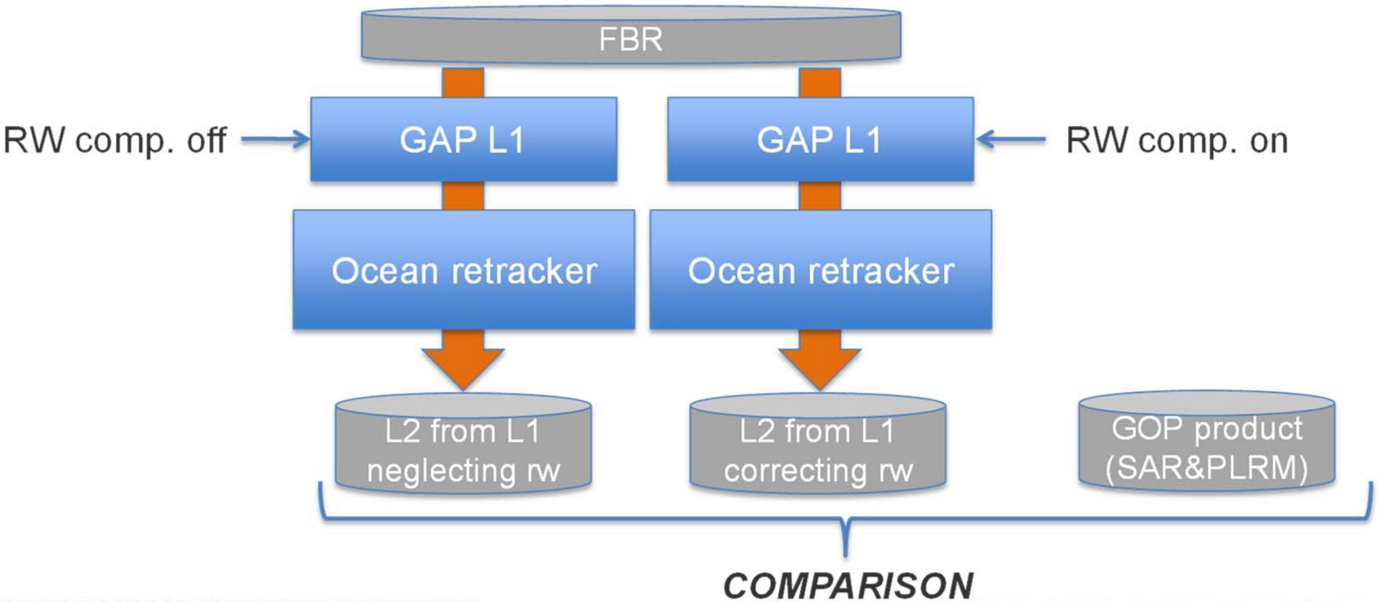
Experimental framework

Testing scenarios

- CryoSat Transponder acquisition (FBR product)
- CryoSat Ocean acquisitions (FBR and BaselineC GOP L2 products)

Testing tools

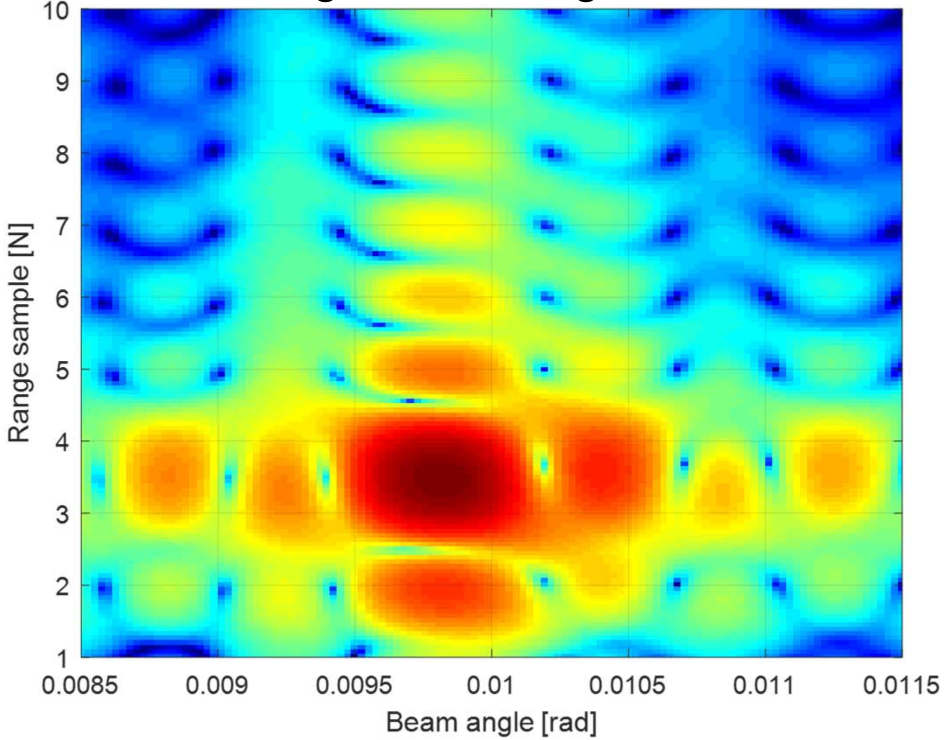
- Aresys Generic Altimetric Processor Level1
  - Beamforming DFT-based
  - Range walk compensation on/off by configuration
- Aresys Ocean retracker based on a semi-analytical implementation of Wingham's waveform model



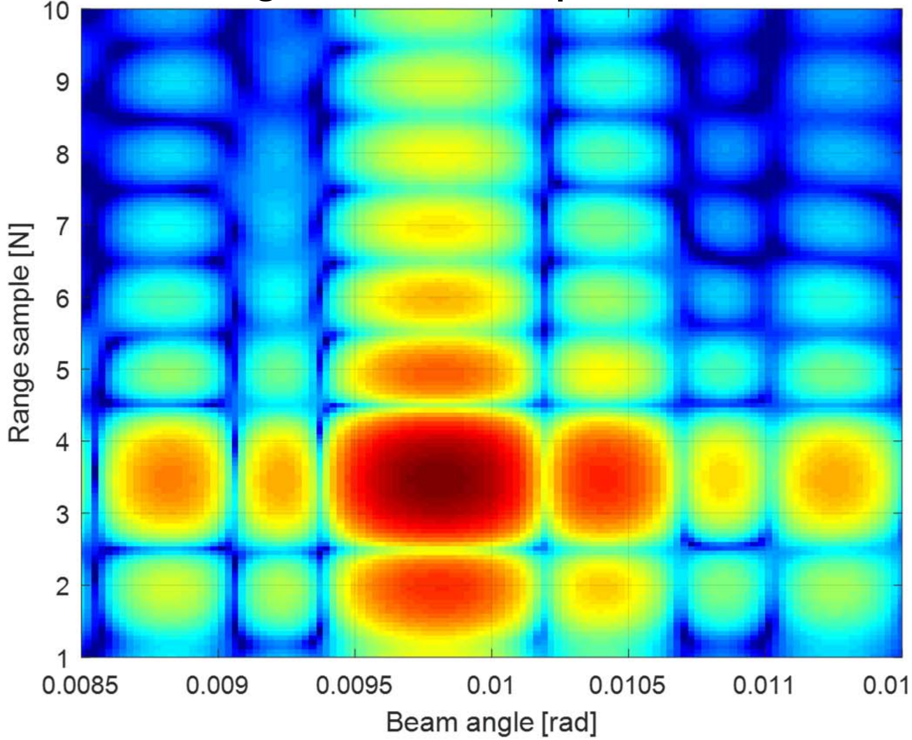
Transponder acquisition

Transponder IRF from focused burst at high look angle (burst far from the transponder)

Exact beamforming and range walk neglected



Exact beamforming and range walk compensated

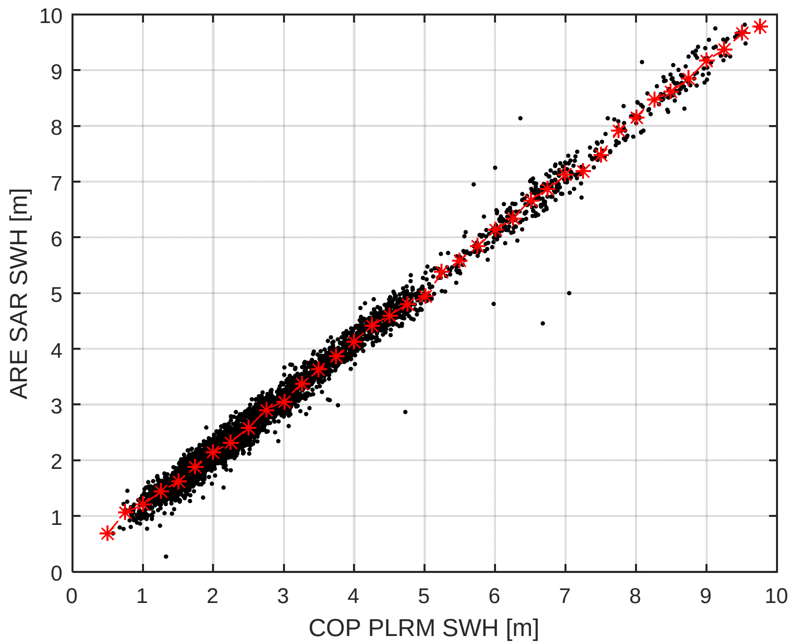


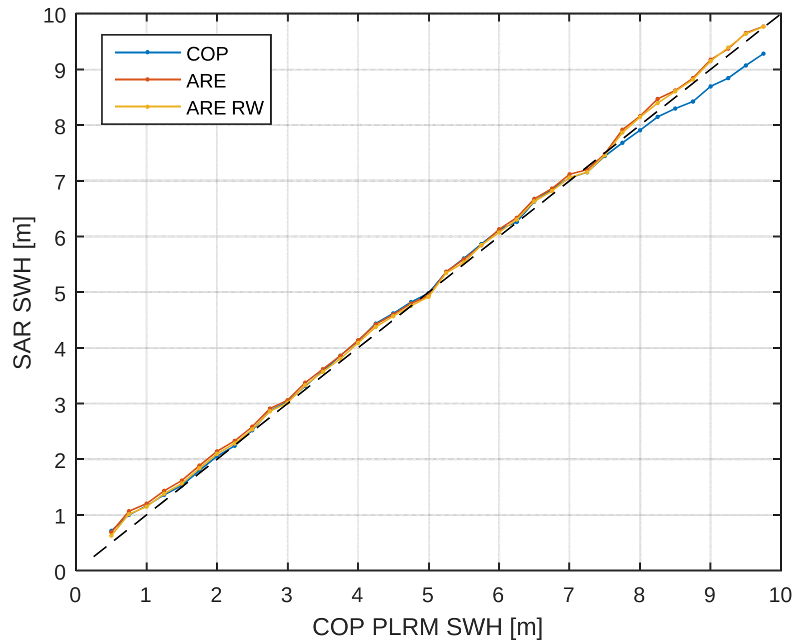
Neglecting the range walk, IRF is distorted as expected from previous works

Ocean acquisitions: comparison of SWH from different chains

As first we compared the PLRM SWH from GOP L2 products (COP PLRM) with

- SAR SWH from GOP L2 products (COP SAR)
- SAR SWH from Aresys chain and range walk compensation not applied (ARE SAR)
- SAR SWH from Aresys chain and range walk compensation applied (ARE SAR RW)



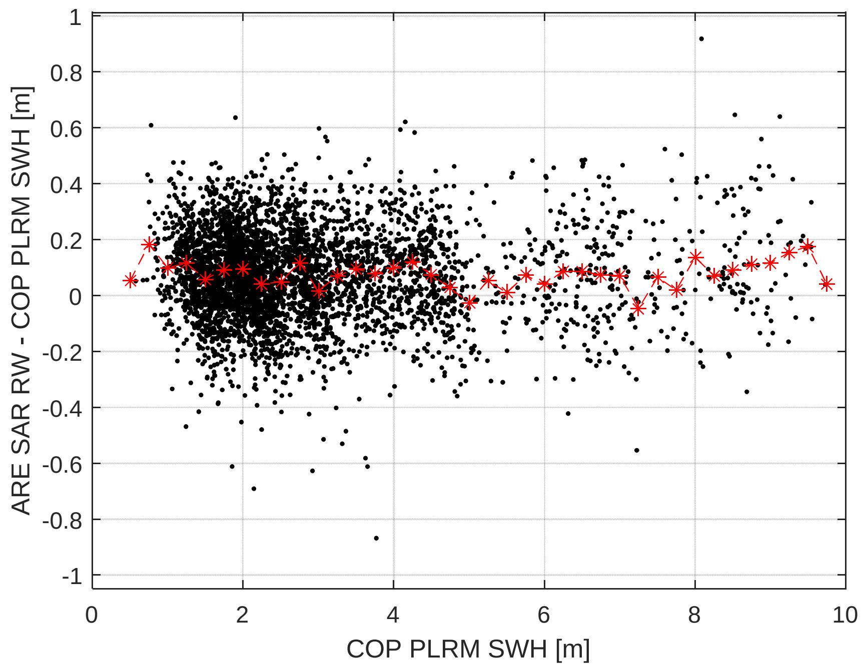


The SWH from Aresys chain is in good agreement with PLRM SWH from GOP L2 product independently of the range walk compensation

Ocean acquisitions: SWH bias due to range walk

Difference between

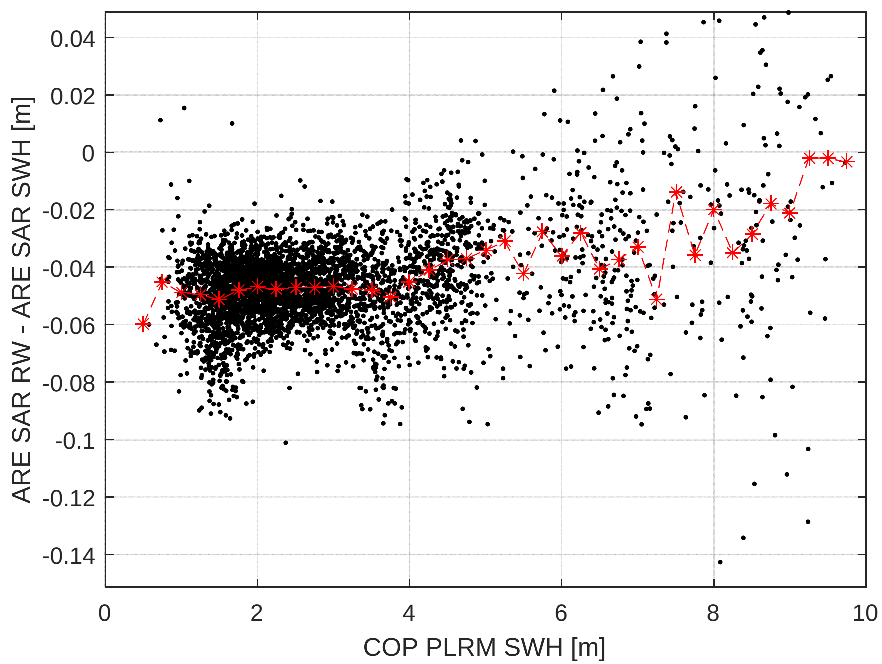
- SAR SWH from Aresys chain and range walk compensation applied
- PLRM SWH from GOP L2



The discrepancy between SAR and PLRM still exists

Difference between

- SAR SWH from Aresys chain and range walk compensation applied
- SAR SWH from Aresys chain and range walk compensation not applied



Applying the range walk correction the SWH is reduced by 5cm

Conclusions and Next activities

Conclusions

- The range walk compensation has been included in Delay/Doppler processing with exact beamforming
- DFT based exact beamforming has been used as a trade-off between accuracy and computational complexity
- Experimental results on a trasponder acquisition confirmed that compensating the range walk the IRF is accurately focused
- Experimental results on ocean acquisitions confirmed that a lower SWH (about 5 cm) is retracked when the range walk is compensated

Next activities

- The Aresys processing chain (L1 processor and Ocean retracker) will be integrated in GPOD to perform the analysis on a larger dataset of CryoSat Ocean acquisitions (activity ongoing)

For more information on the Aresys processing chain for SAR altimetry please refer to Poster

OTH_001	A SAR altimetry End-to-End simulation and processing chain
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