Mònica Roca

Cristina Martin-Puig

isardSAT®

SAR altimetry from L0 to L2:

L1 processing impact on L2 performance and accuracy

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ToC

1. isardSAT projects and capabilities

- isardSAT is a research SME with highly qualified and specialised personnel in altimetry not only L1, but L2 for SAR mode now, and L3 as well.

- **isardSAT** is located in a technological park in Barcelona

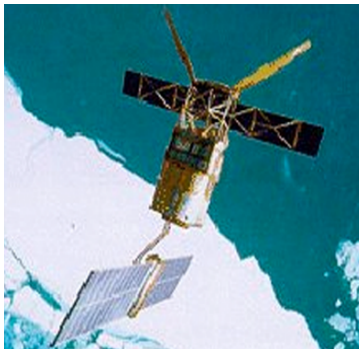
- with subsidiaries in:
  - UK (since spring 2013)
  - Poland (since summer 2013)

1. isardSAT Altimetry Projects

isardSAT employees expertise and *background* in LRM altimetry:

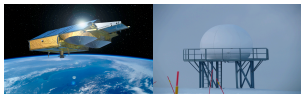
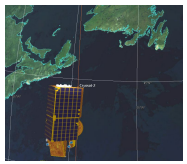
- EnviSat RA-2 Level 1b ESL

- ERS Level 1b processor development within REAPER project



1. isardSAT Altimetry Projects

isardSAT employees expertise and *background* in SAR altimetry:

- SAR mode L1 processing
  - CryoSat cal/val using tranponders 
  - Sentinel-3 from L0 and L1b GPP implementation 
  - **Jason-CS Poseidon-4 GPP definition and implementation**
- SAR mode L2 processing
  - SAMOSA
    - SAR mode waveform modelling (e,g, SAMOSA model)
    - SAR mode Retracking
  - CP4O
    - Analysis of the SARin mode for Coastal 
- SAR mode L3 processing
  - isardSAT is building collaborative partnerships with scientific institutes of relevance (Europe and China) for the derivation of **ocean** and **in land** products from SAR mode

2. isardSAT L1 Altimeter SAR processing

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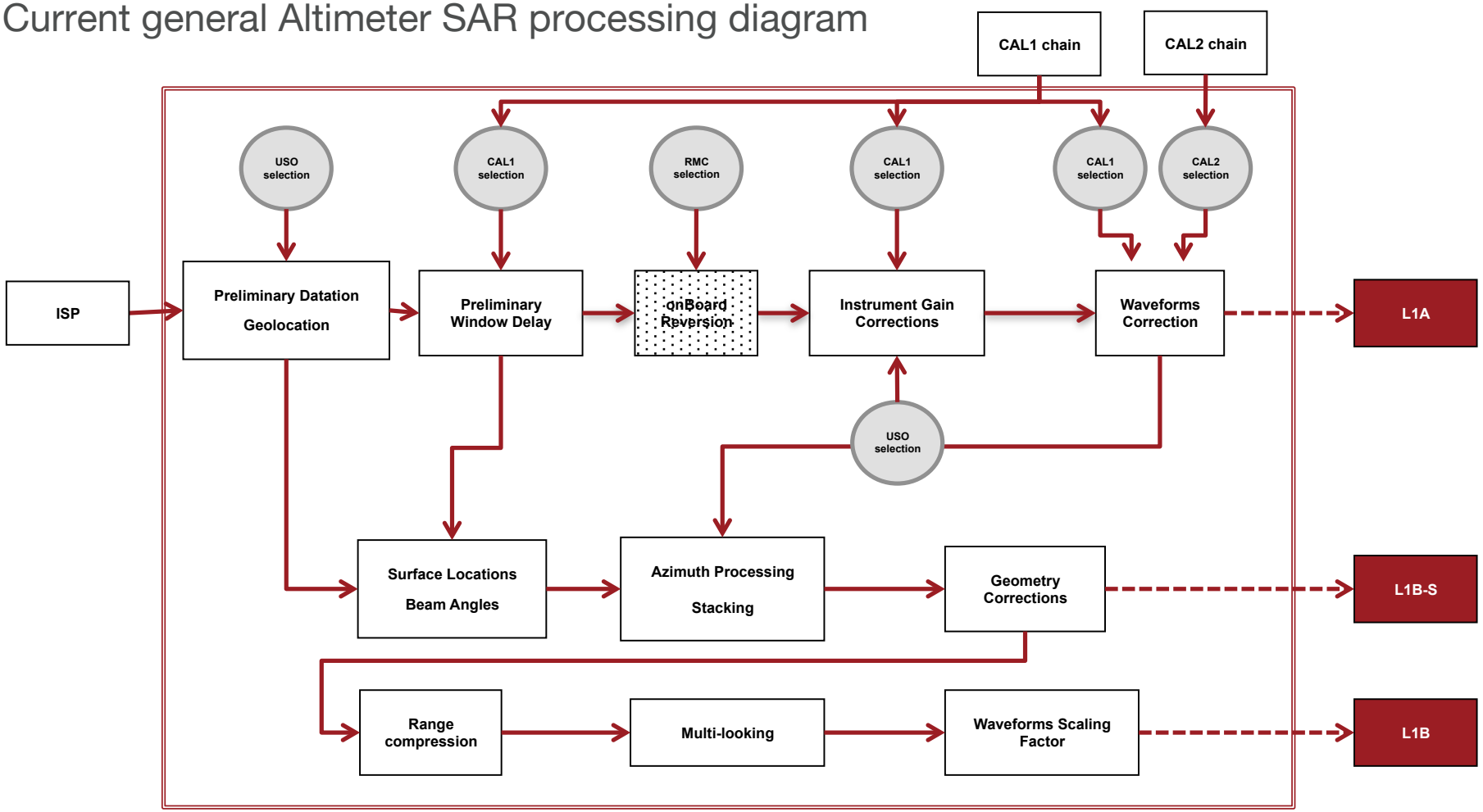
Current general Altimeter SAR processing diagram

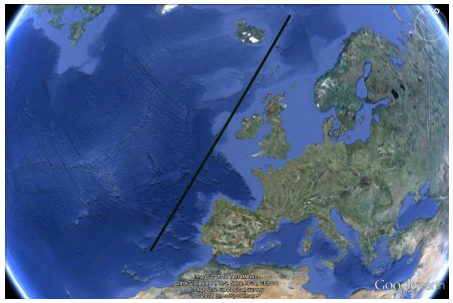


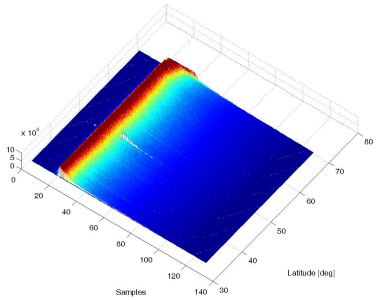
Verification

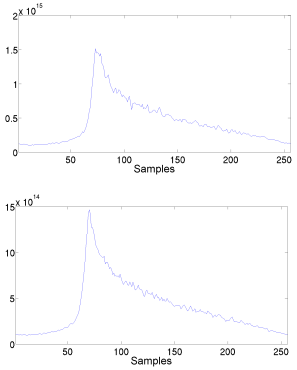
- Verification using:
  - Adapted CRYMPS simulated data: with Jason-CS characteristics (e.g. orbit)
  - CryoSat adapted FBR data: with CryoSat characteristics
- Several scenarios have been tested:
  - Point Targets
  - Ocean Surfaces
  - Other surfaces (specular)
- Using different geometries:
  - Simplified: circular orbit, spherical Earth
  - Real: real orbit, real Earth, with mispointing, etc.
- All modes (LRM, SAR and CALs)

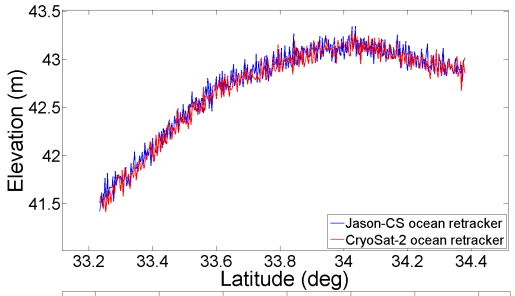
2. isardSAT L1 Altimeter SAR processing

Jason-CS P4 GPP Verification using CryoSat data adapted to Jason-CS

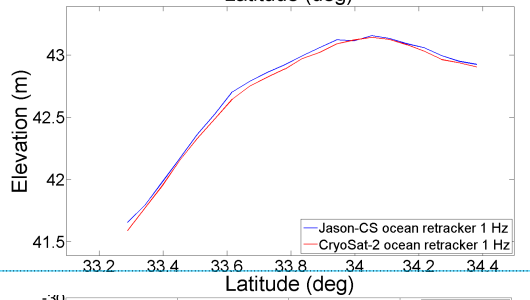




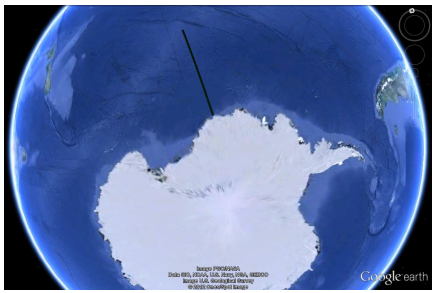


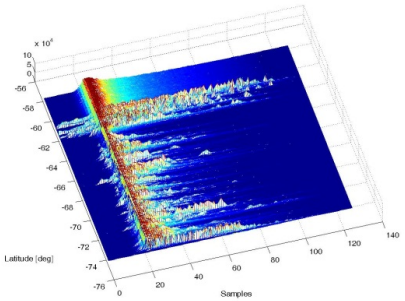


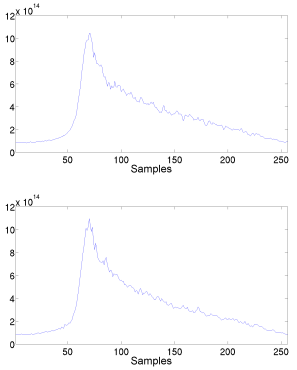
20 Hz

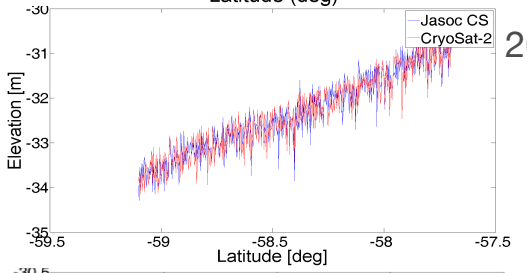


1 Hz

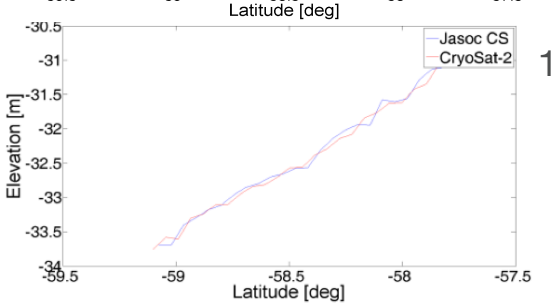








20 Hz



1 Hz

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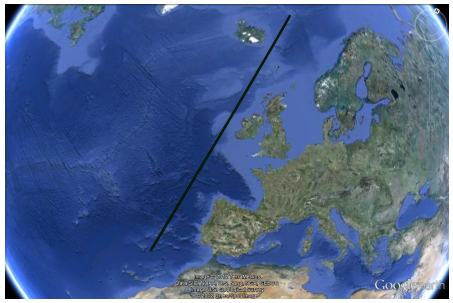
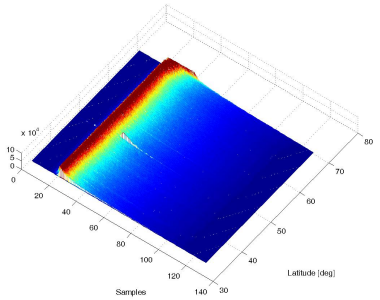
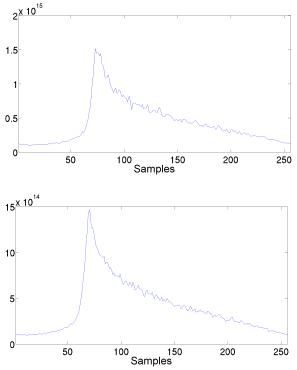
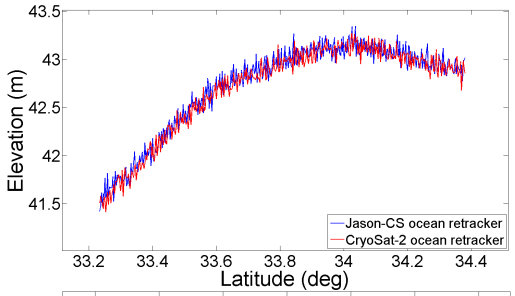
Jason-CS P4 GPP Verification using CryoSat data adapted to Jason-CS

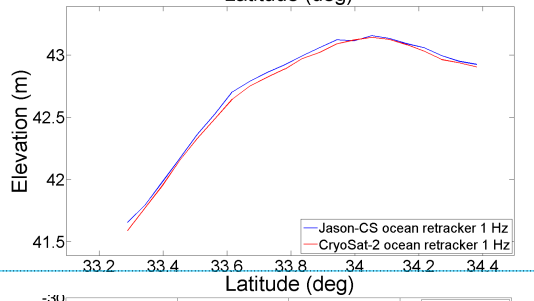






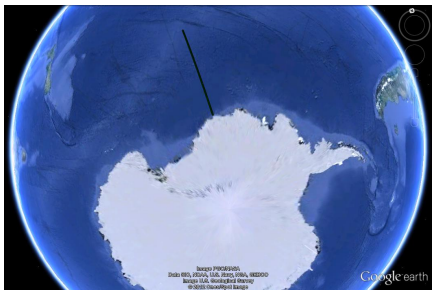


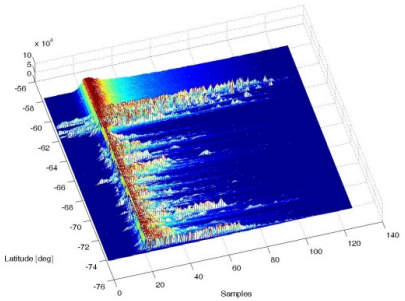
20 Hz

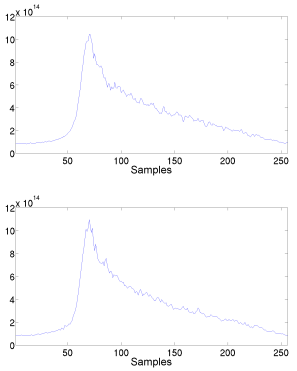


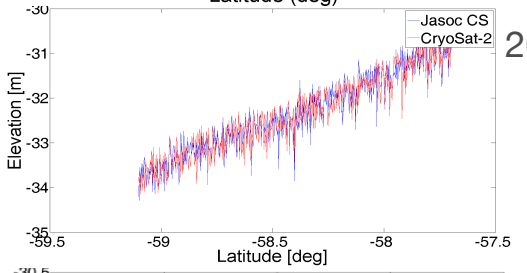
1 Hz

Numerical comparison provided later in this presentation

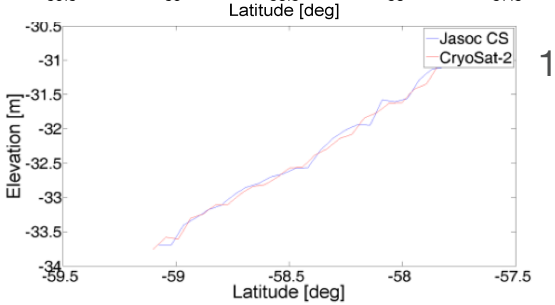








20 Hz



1 Hz

2. isardSAT L1 Altimeter SAR processing

Jason-CS P4 GPP Verification using a number of adapted CRYMPS simulated data Ex:

Parameters		18B
Geometry	Scattering details	uniform scattering. ~ 4000 bursts
	DEM	No
	Orbit	Circular
	Earth	Spherical
	Earth semi major	6378000
	Earth semi minor	6378000
	Earth flattening	0
	Earth Rotation	No
Instrument	LAI	747182
	Attitude [dB]	Variable
	Path Delay [ns]	0
	Power Variation [dB]	0
	Mispointing	No

Item to be verified	Req.	18B exact	18B approx.	Pass /Fail
Along Track Sampling min/max margin	time ± 500 µs	± 2.2053 µs	± 2.2054 µs	☑
	space ± 3.5 m	± 1.1369 mm	± 1.1369 mm	☑
Along Track Sampling STD	time < 10 µs	0.7207 µs	0.7208 µs	☑
	space < 70 mm	0.40159 mm	0.40159 mm	☑
Re-tracked range difference with expected: Elevation	mean < 0.4 m (1Hz)	-0.00408 m	0.07409 m	☑
Re-tracked range difference with DEM	std < 0.008m (1Hz)	0.06249 m (10 Hz) 0.01976 m (1Hz)	0.06249 m (20Hz) 0.01976 m (1 Hz)	☑

2. isardSAT L1 Altimeter SAR processing

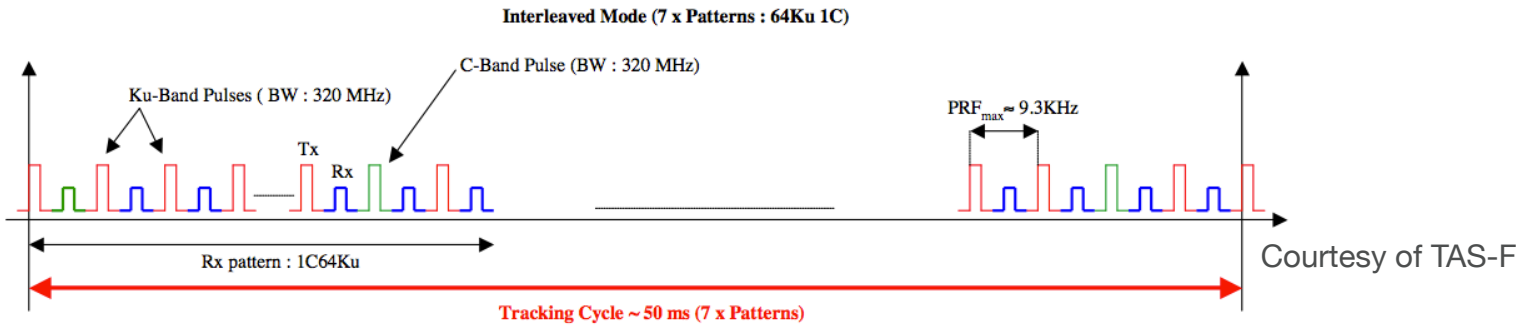
- New features and conceptual processing improvements are being investigated in different parts of the processing chain.
- Some results will be presented at the ESA Living Planet Symposium:
  - Numerical Performance of Jason-CS SARM
    C. Martin-Puig; A. Garcia-Mondéjar; R. Escolà; M. Roca;
    isardSAT
  - Jason-CS Poseidon-4 Ground Processor Prototype: Results Using Interleaved Mode Simulated Raw and In-Orbit CryoSat Data.
    M. Roca (1) ; R. Escolà (1); A. Garcia-Mondéjar (1); B. Martínez-Val (1); P. García-Arnaud (1); M. Fornari (2); K. Köble (3); R. Francis (2); R. Cullen (2)
    1: isardSAT; 2: ESA; 3: Astrium GmbH
  - Sigma-0 Estimation Improvements, using Jason-CS Altimetric SAR Mode: Results using Simulations and in Orbit CryoSat Data
    R. Escolà; C. Martin-Puig; A. Garcia-Mondéjar; M. Roca
    isardSAT
  - CryoSat-2 SARin Mode for Coastal Altimetry
    P. García-Arnaud; C. Martin-Puig; A. García-Mondéjar; M. Roca
    isardSAT

3. Jason-CS P4 interleaved design

3. Jason-CS P4 interleaved design

New design (interleaved and digital architecture) characteristics:

- Received pulses in-between transmitted pulses
- with a high PRF so echoes are correlated for Doppler processing
- PRF varies around the orbit (so tracking cycle duration)



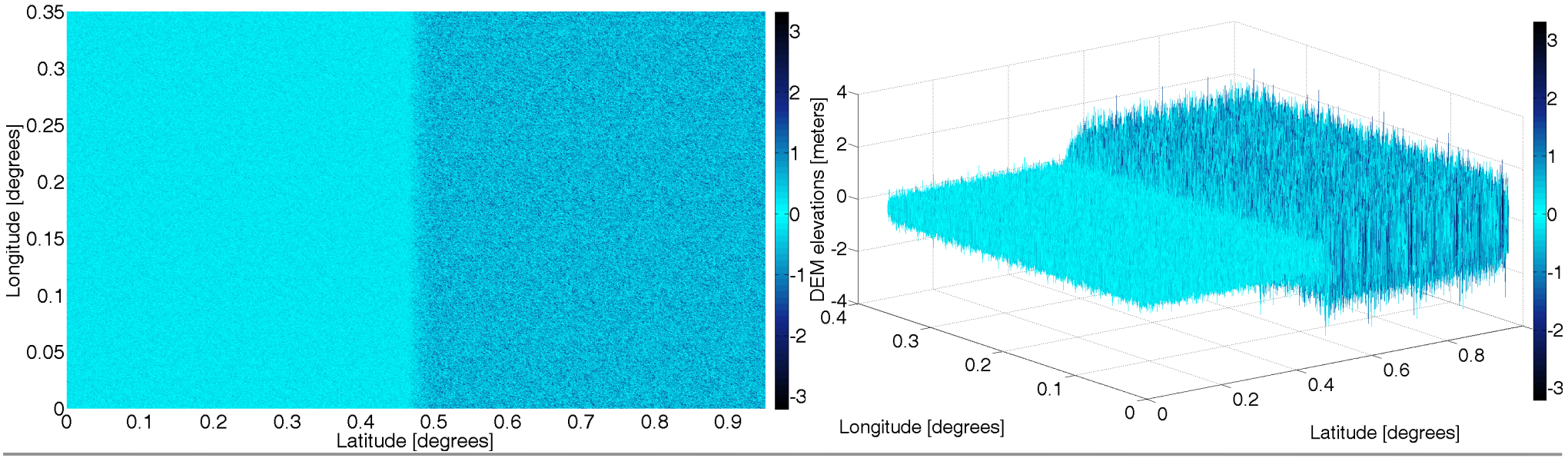
Courtesy of TAS-F

- Digital sampling not coinciding with range resolution
- C-band pulses also interleaved with Ku-band pulses

New design already incorporated in isardSAT's prototype definition.

3. Jason-CS P4 interleaved design

- Results of preliminary testing are successful.
- Example of an ocean surface area with the following characteristics:
  - 2 different SWH: SWH1 = ; SWH2 =
  - Constant Sigma zero = 15 dB
  - Polar angle = 15º



3. Jason-CS P4 interleaved design

- Results of preliminary testing are successful.
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  - 2 different SWH: SWHa ; SWHb
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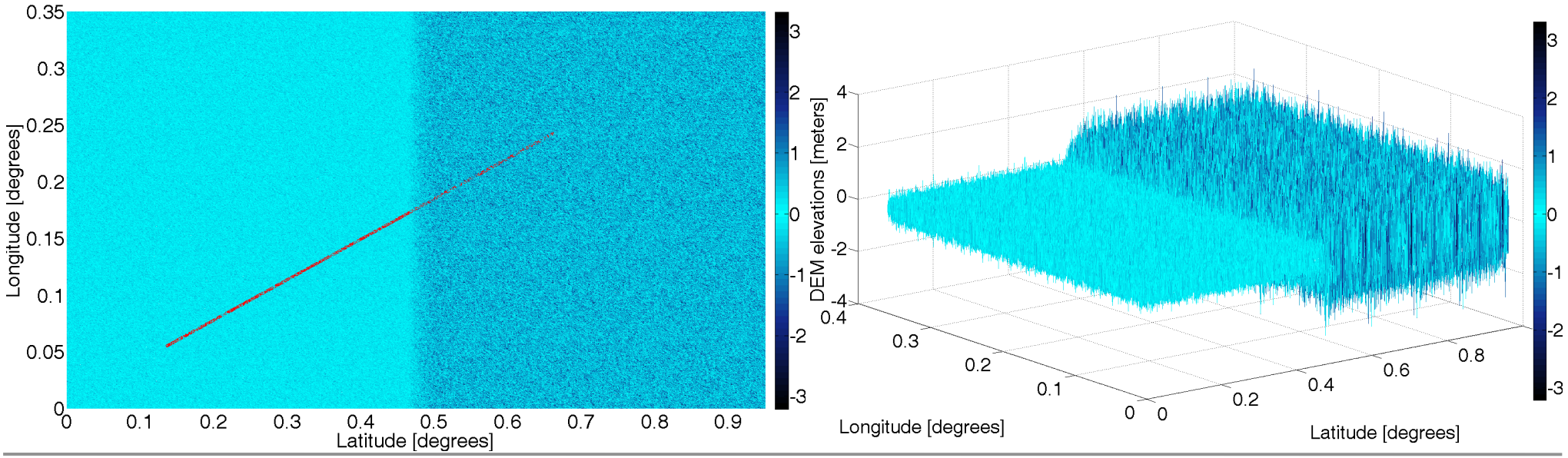
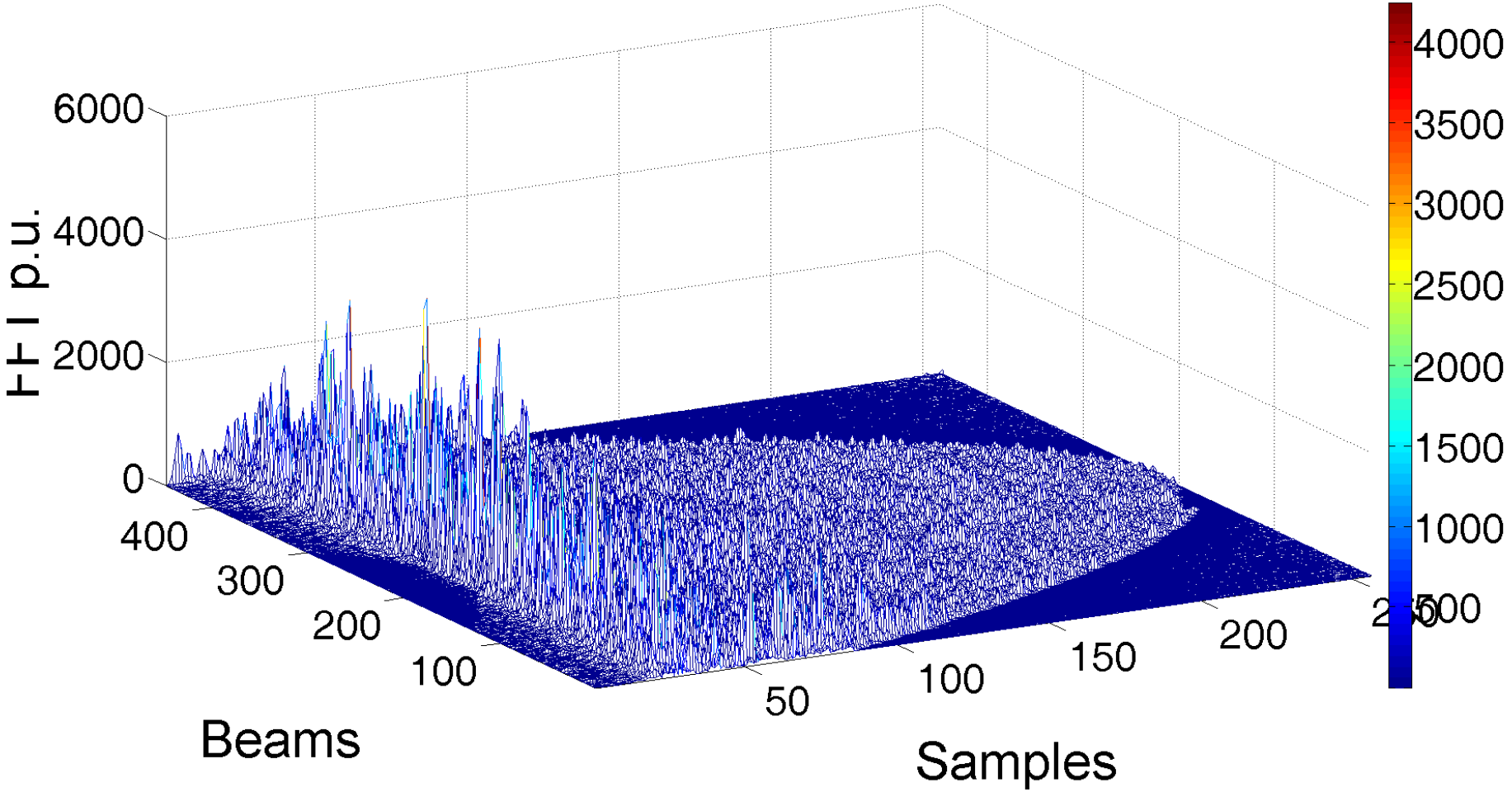


3. Jason-CS P4 interleaved design

Stack with geometry corrections applied: SWHa



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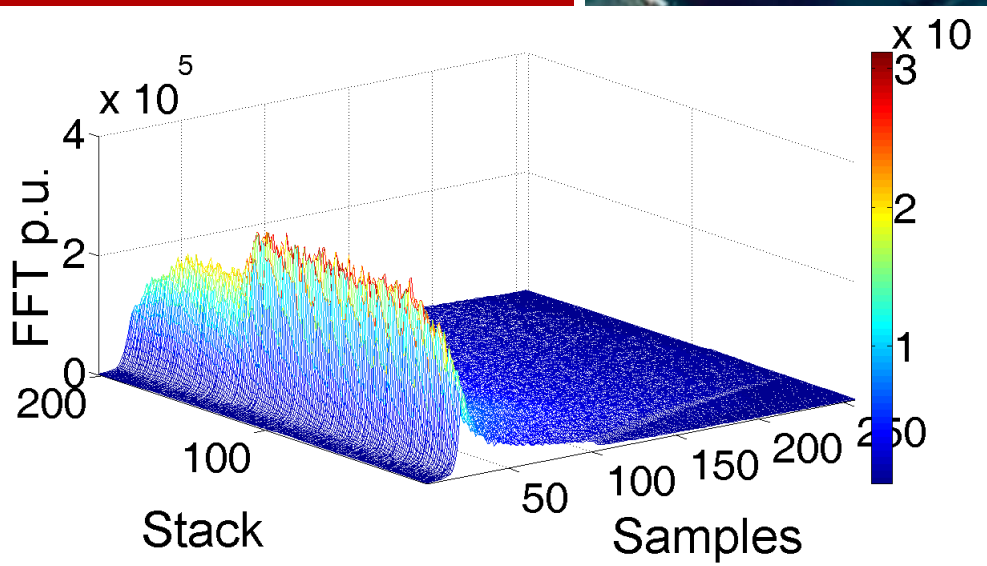
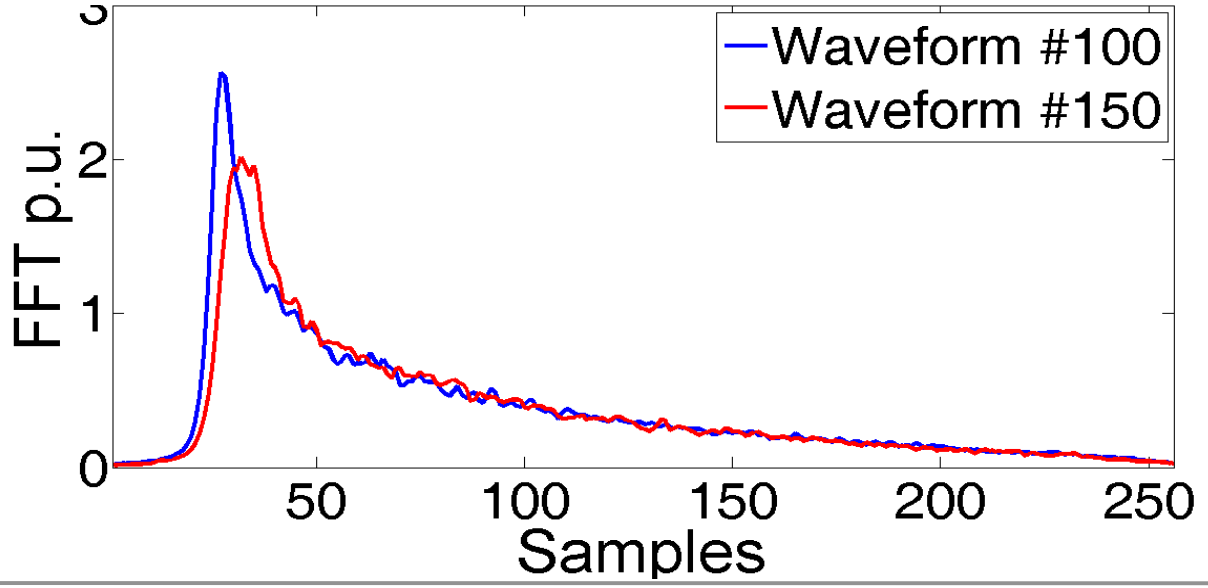
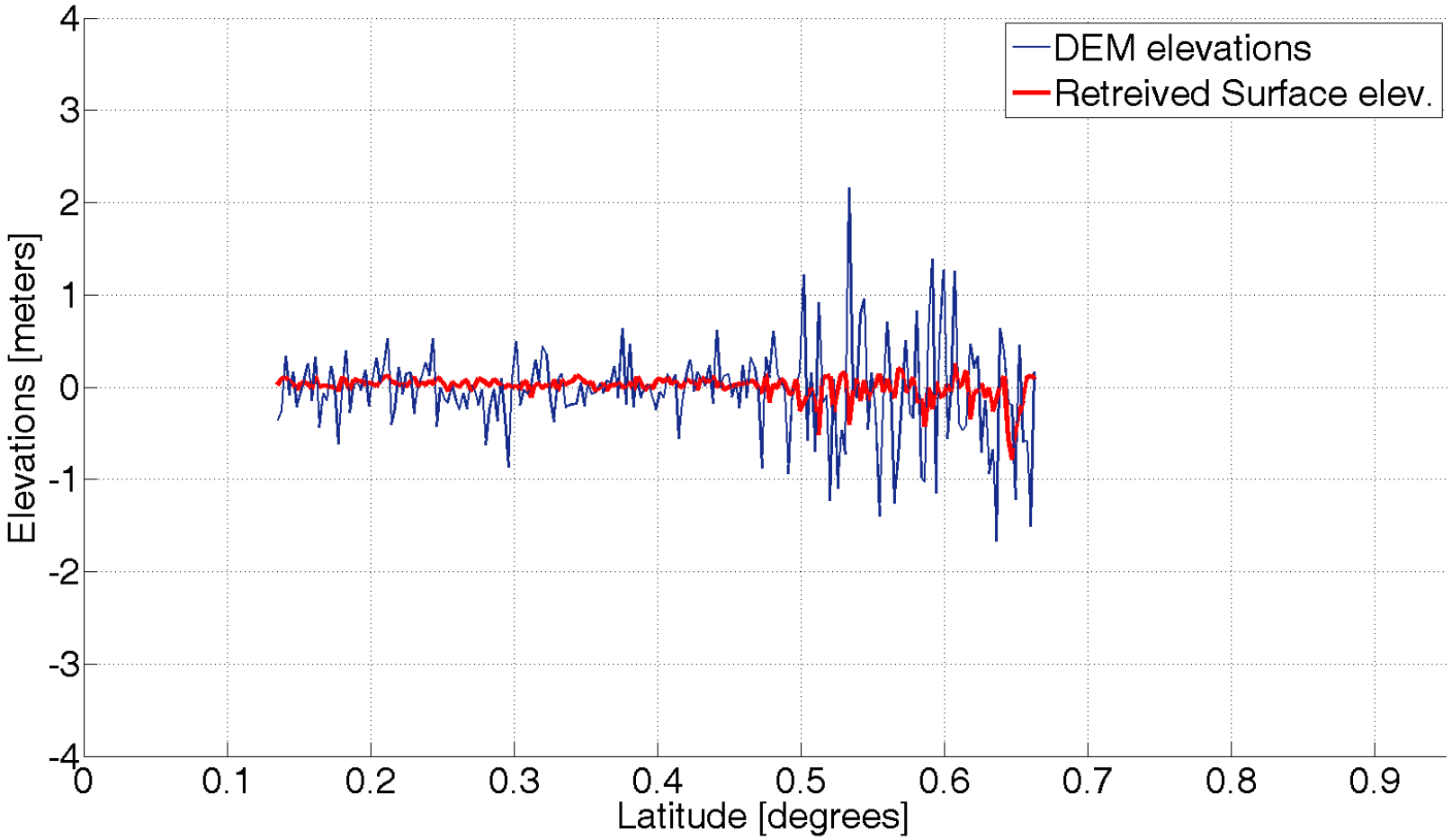




3. Jason-CS P4 interleaved design

Elevation results using a simple 87% of maximum detection.



- SAMOSA retracker will be adapted to interleaved. Results will be presented at ESA LPS.

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SAR mode L2

Why are we all here discussing ☺

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SAR mode L2

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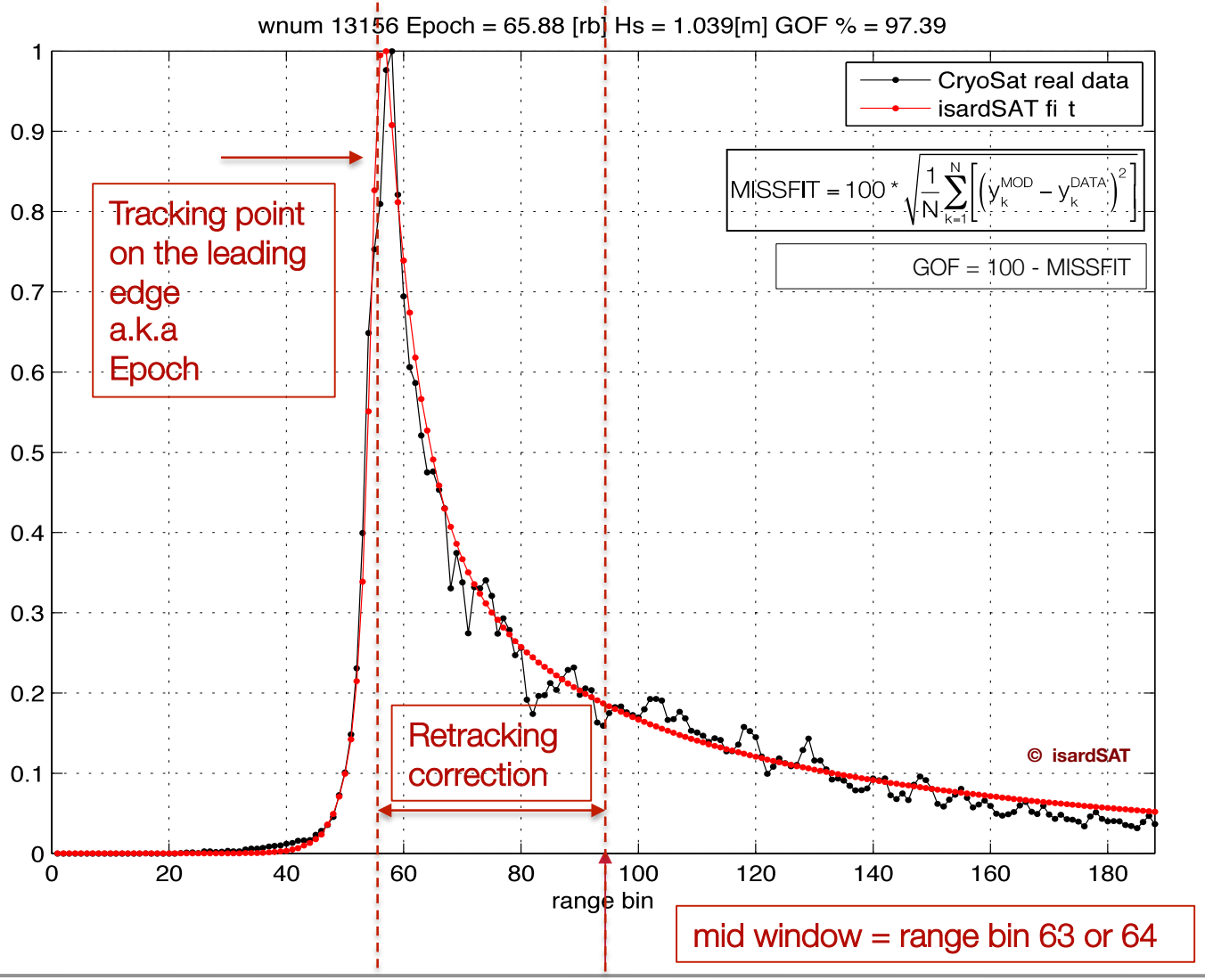

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4. Motivation for studying L1 impact on L2

SAMOSA seemed not to perform well for Baseline B

- Motivation of this second part of the talk:
  - The SAMOSA model was defined under certain assumptions which do not fully agree with CryoSat L1 Baseline B processor, but it is brought to incorporate these easily
  - The model is currently under peer review and the proper reference for it is:
    - C. Ray, C. Martin-Puig, M.P. Clarizia, G. Ruffini, S. Dinardo, C. Gommenginger and J. Benveniste. SAR Altimeter Backscattered Waveform Model. *Submitted to IEEE Trans. On Geoscience and Remote Sensing. 2013. [currently under peer review]*
  - As in the paper above the model has shown good performances as shown in previous conferences by:
    - Gommenginger et al. OSTST 2011, etc.
  - But what happens with baseline B? Why the results presented so far are not so good?

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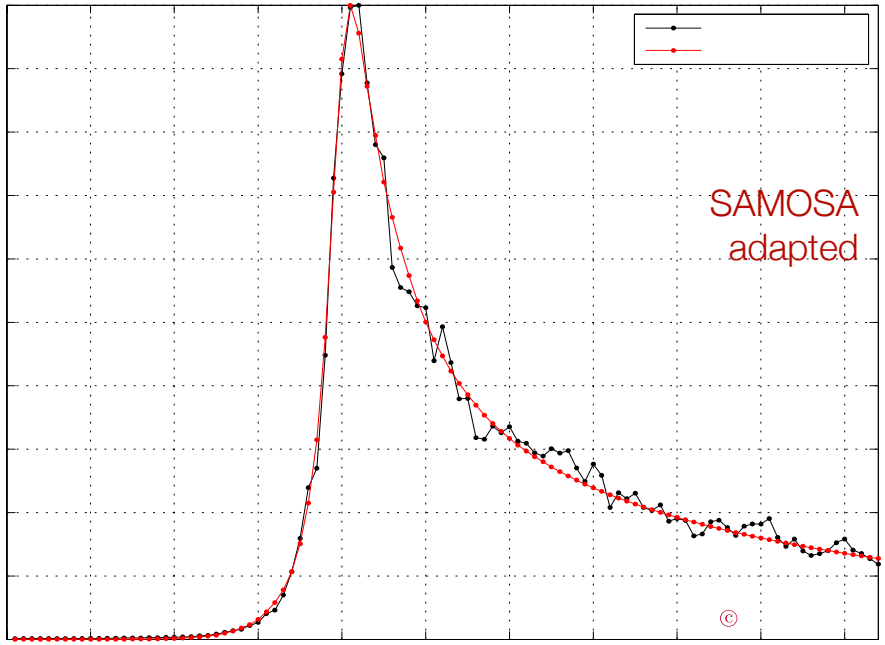
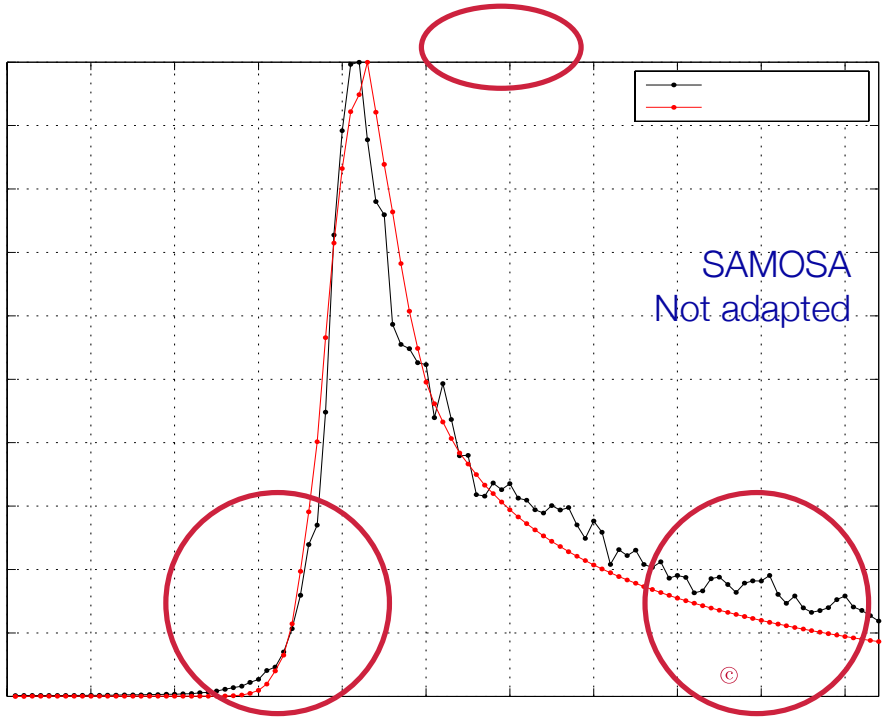
  - But what happens with baseline B? Why the results presented so far are not so good?

SAMOSA IS NOT OPTIMAL FOR ALL L1 PROCESSING AS BASELINE B, BUT WITH A FEW ADAPTATIONS WHICH STILL LEAD TO AN ANALYTICAL SOLUTION THE MODEL CAN BE MADE OPTIMAL TO ANY L1 PROCESSING DIFFERENT TO THEORETICAL DELAY-DOPPLER → work to be published soon

SAR Retracker Adapted or not to L1

The SAMOSA model … Adapted to Baseline B !



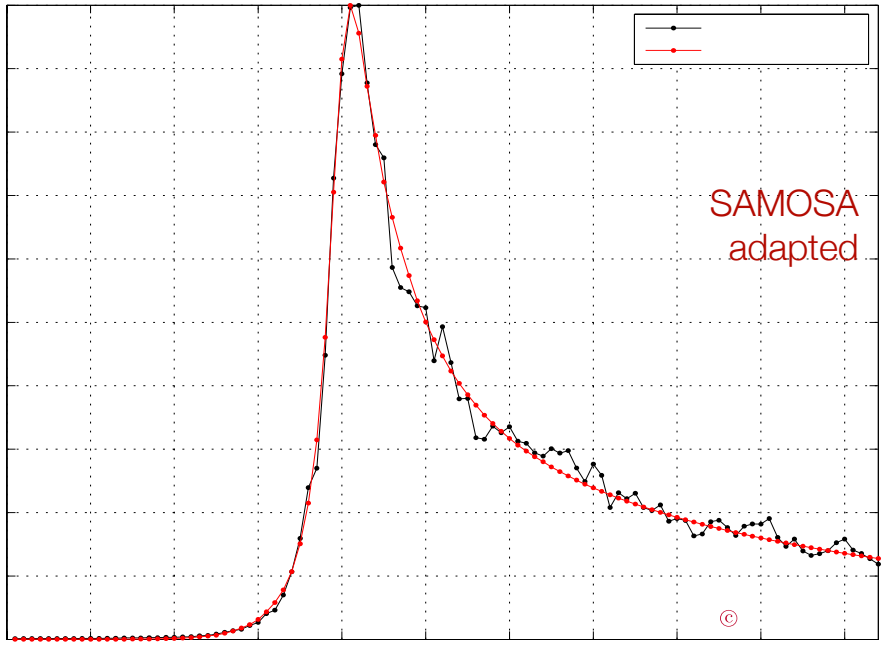


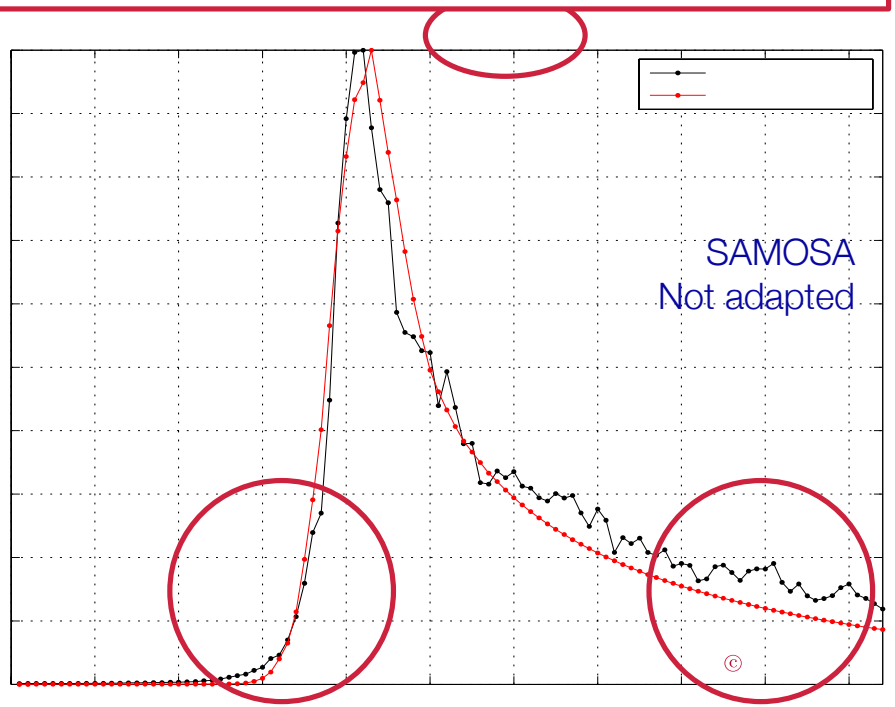
SAR Retracker Adapted or not to L1

The SAMOSA model … Adapted to Baseline B !

CONCLUSION: L1 AND L2 IN SARM ARE STRONGLY CORRELATED

Buoy Hs = 1.2m
1.5h difference between buoy acquisition and track pass
Distance ~ 10km





6. SAMOSA Adaptation to Baseline B

Verification of isardSAT adaptation of the model to any L1b

- The adaptation to CryoSat-2 Baseline B
  - Theoretical adaptation of the model
  - Implementation of code
  - Hs validation
    - Comparison with buoy data
  - SSH variability analysis
  - Quantification of performances
- Going a bit further …
  - Adaptation to SARin data
  - Adaptation to the Jason-CS mission

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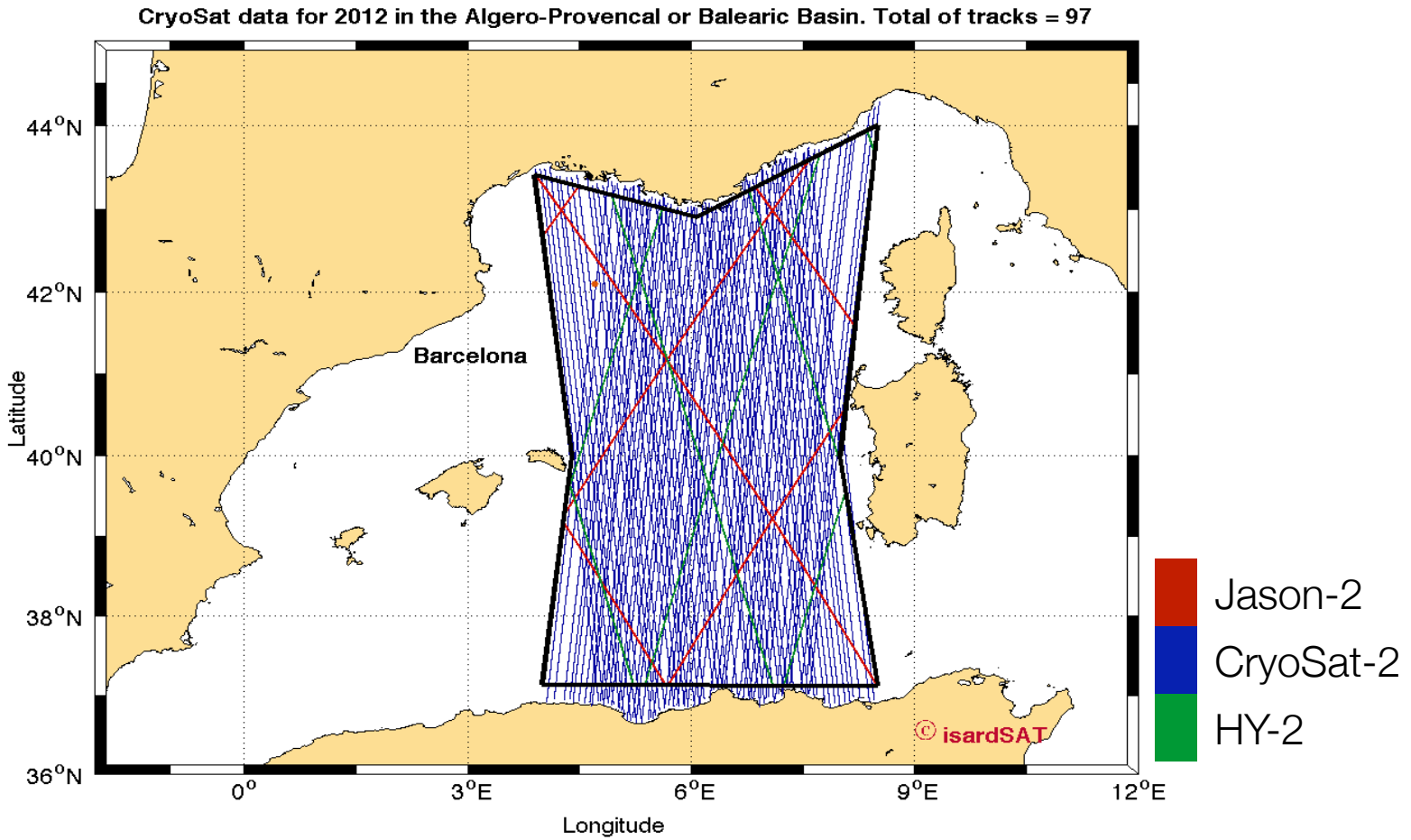
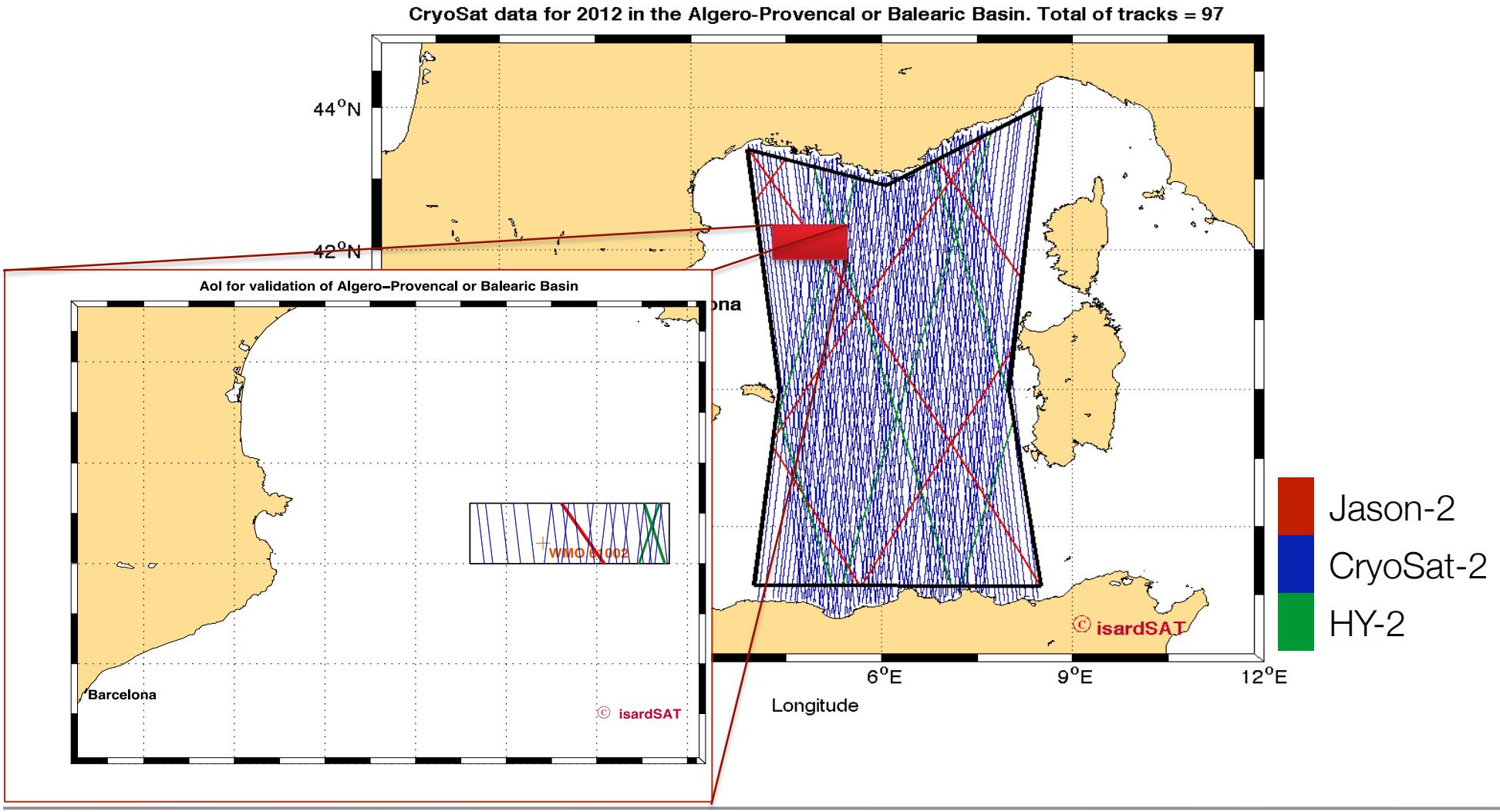
On Testing Baseline B

Area of Interest



On Testing Baseline B

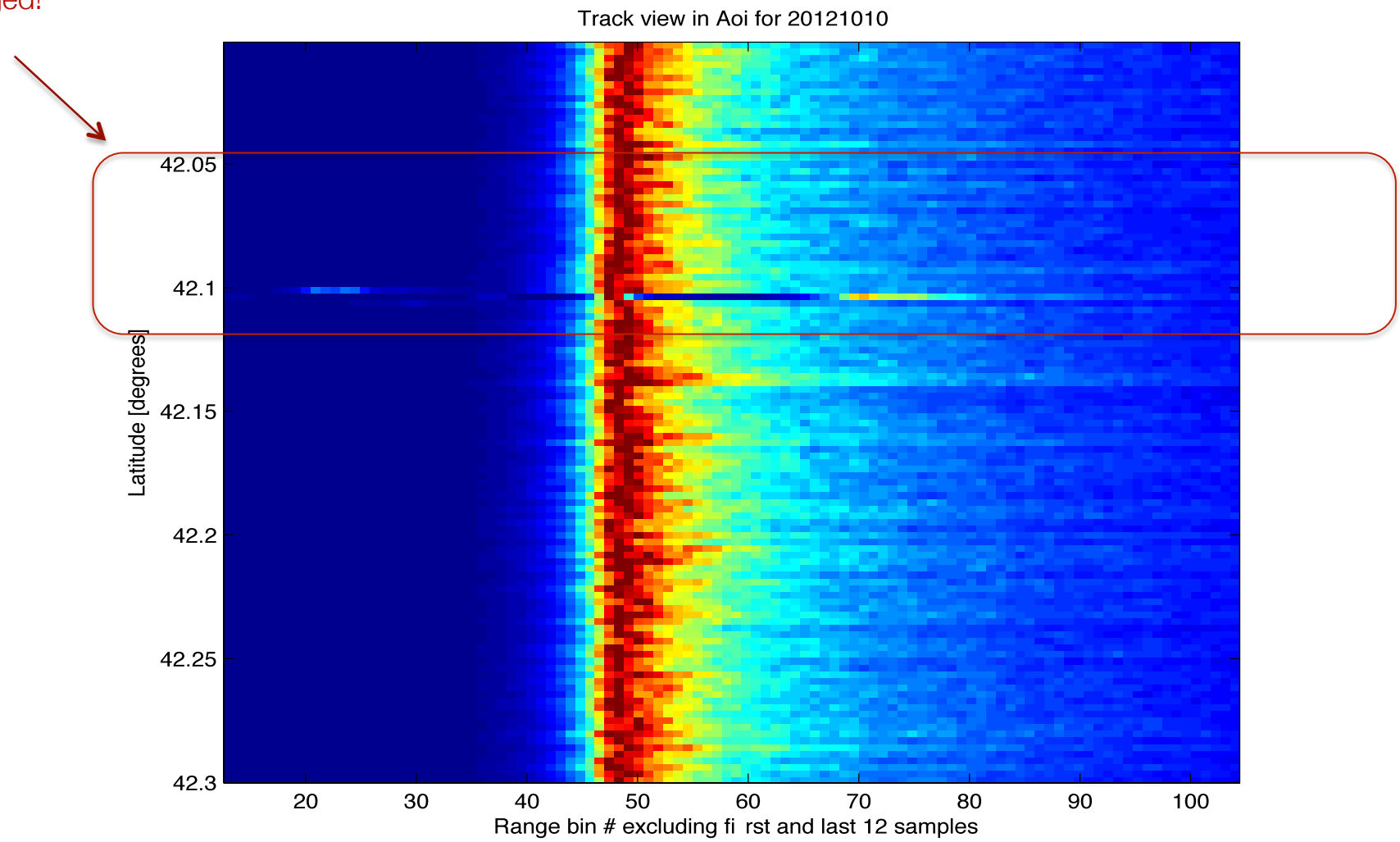
Validation of Hs



SAR Retrackers for Ocean

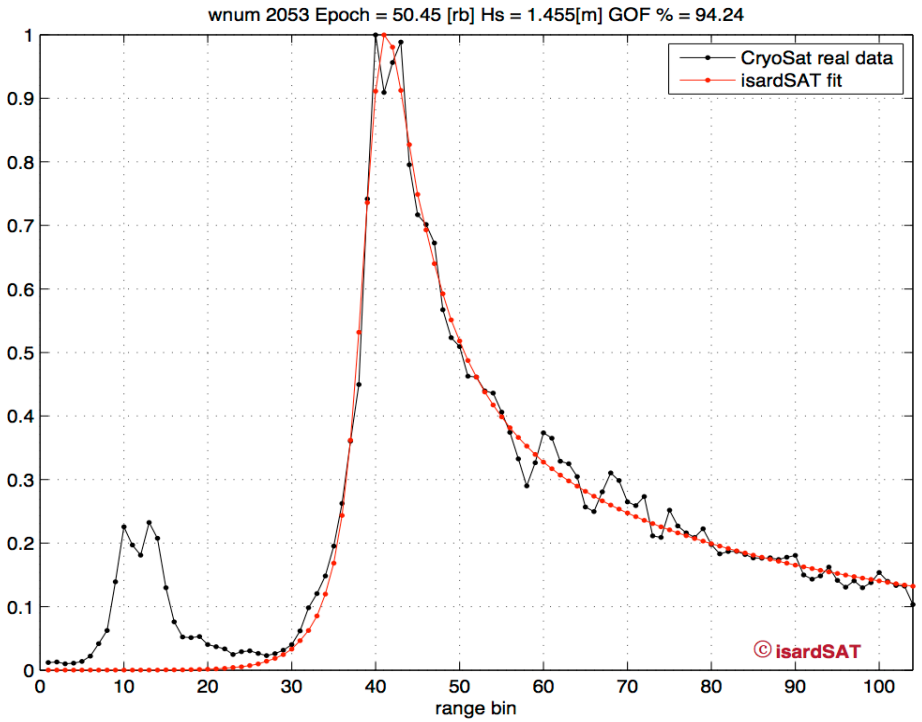
Lots of effort in assessing data quality

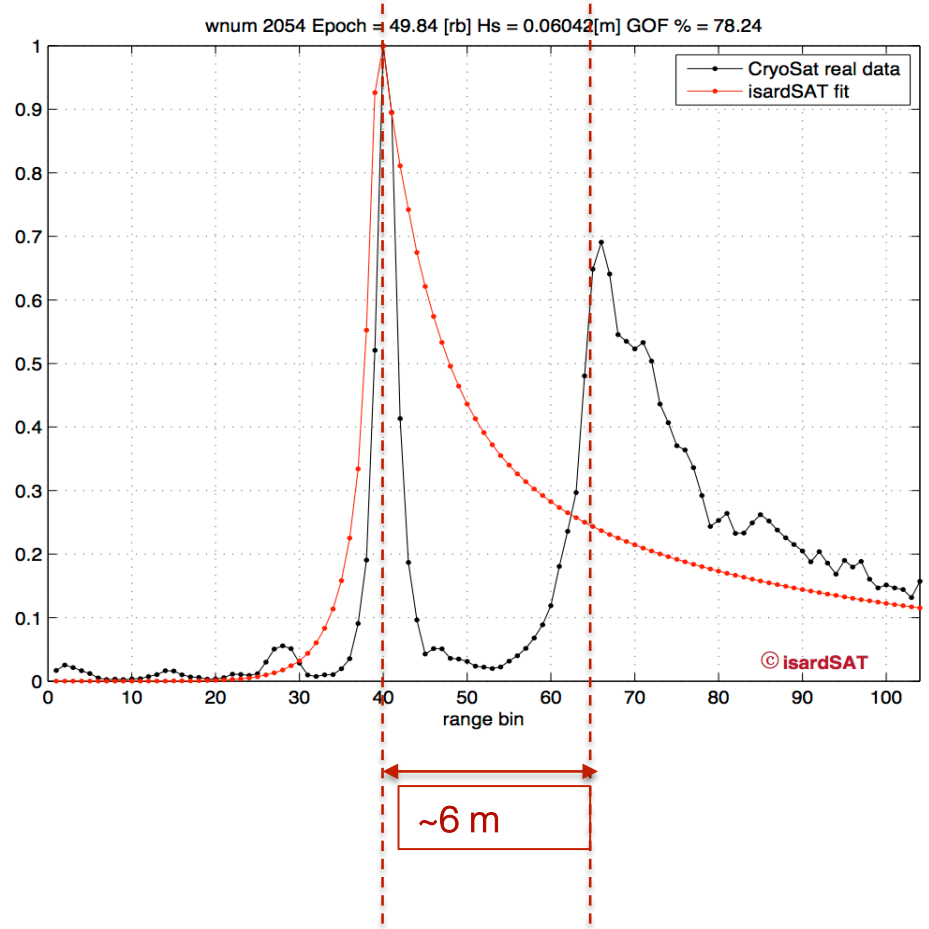
Not flagged!



SAR Retrackers for Ocean

Not ocean type, but information in the middle of the ocean





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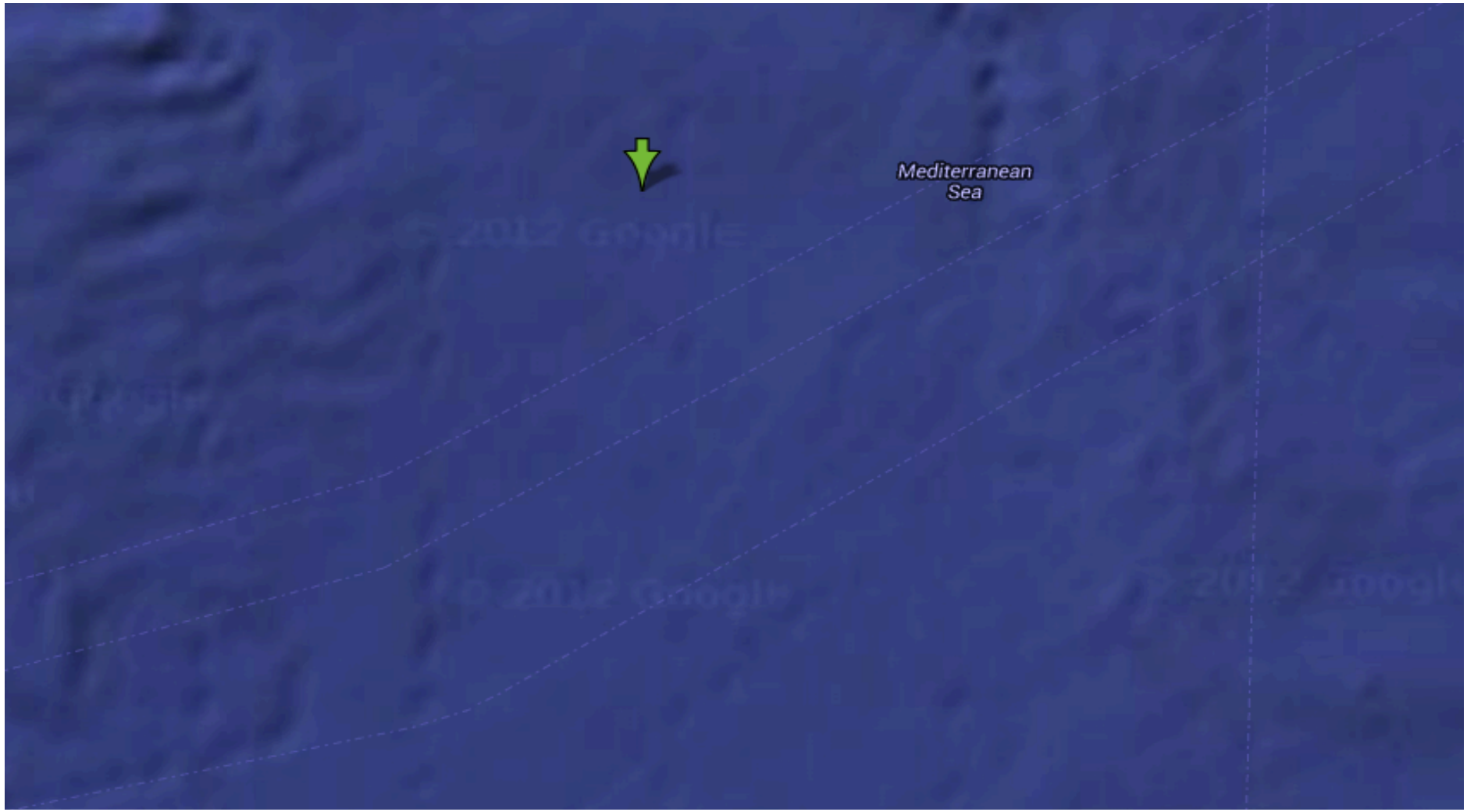
The ship routes



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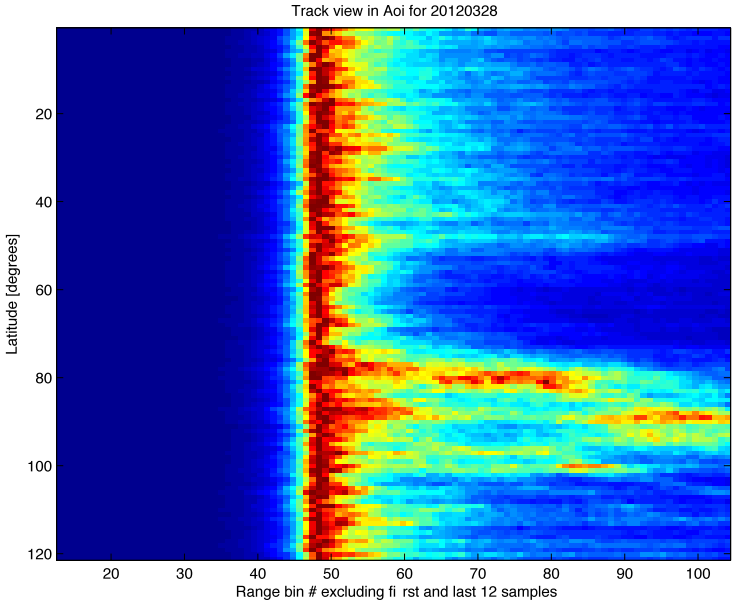
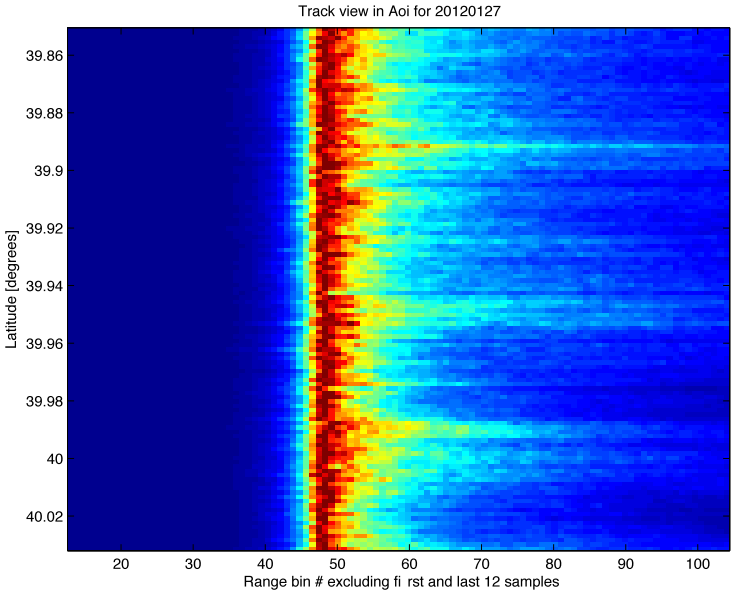
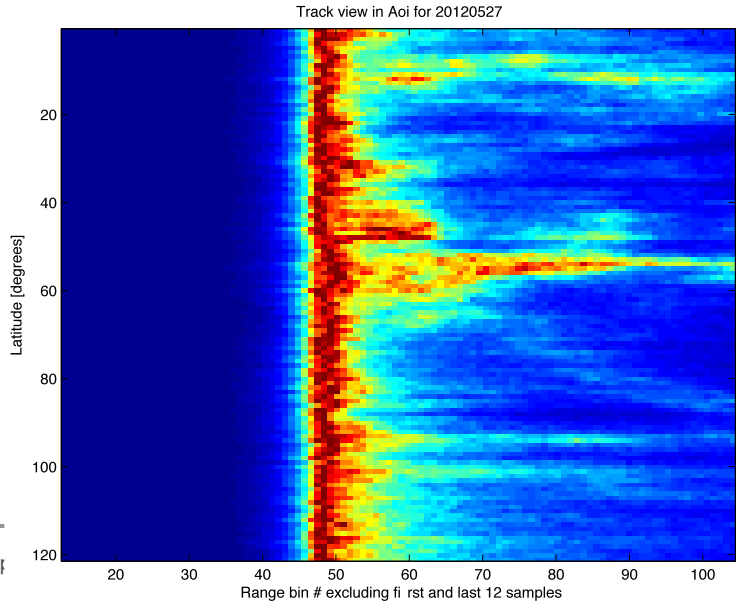
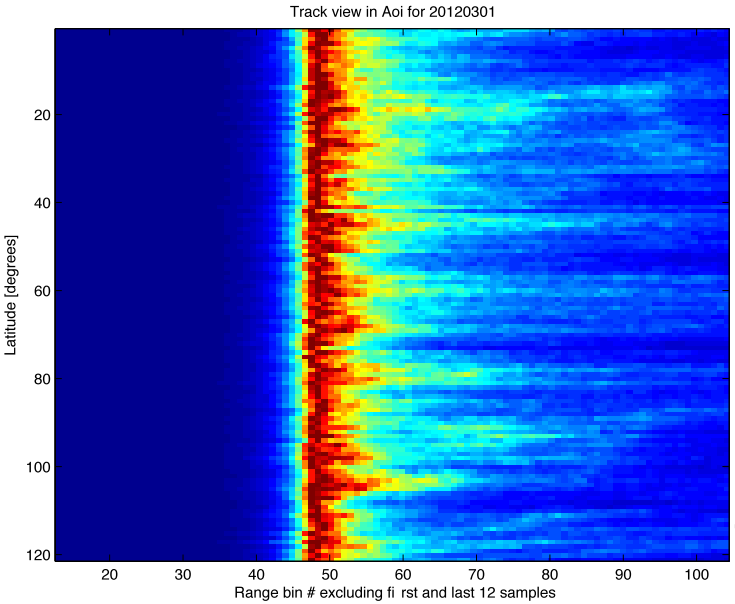
Other examples









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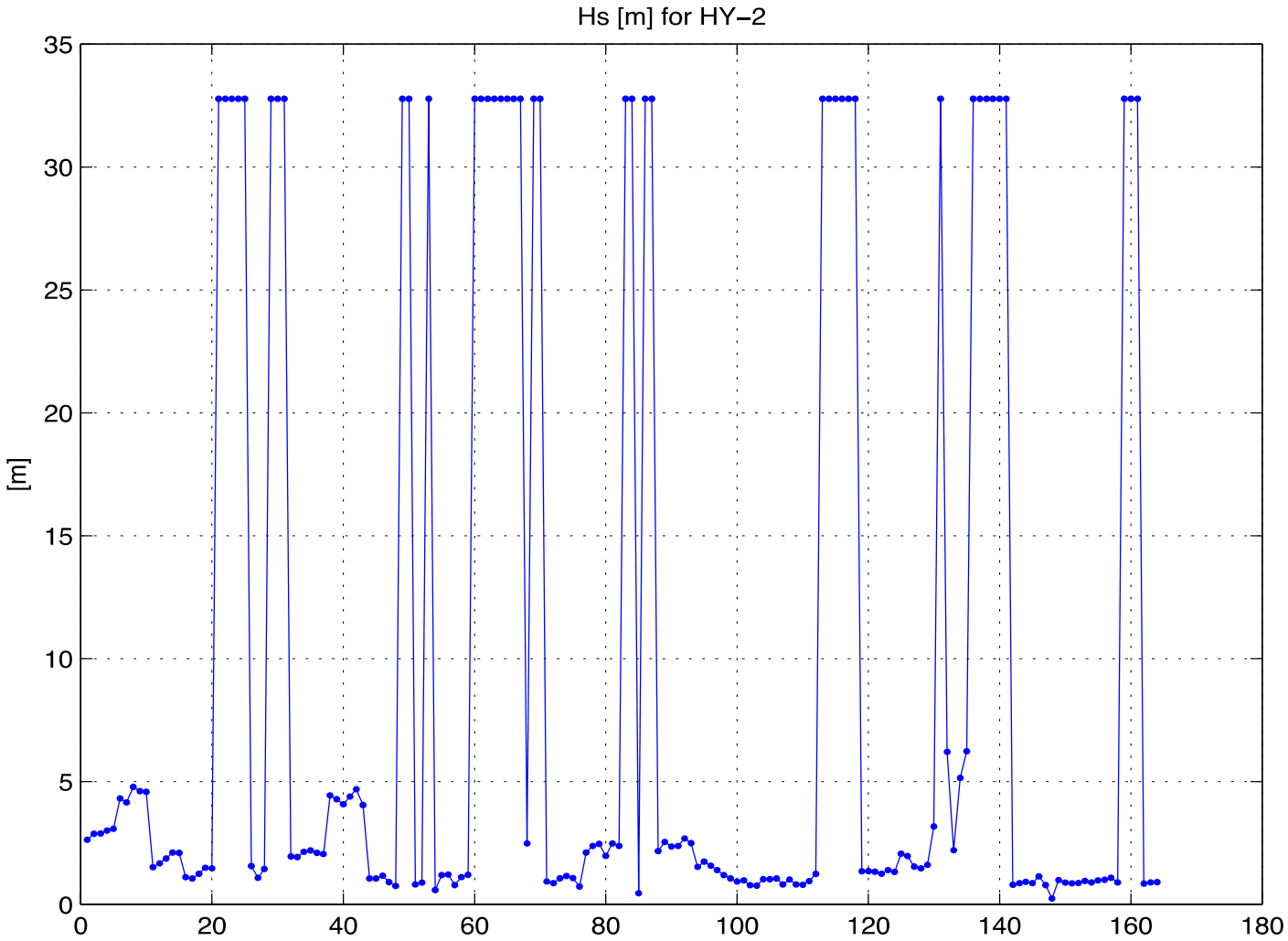
Hs and SSH from Baseline B

Approach

- A few geo collocation between CryoSat and Jason-2 / HY-2
- For the areas selected, which corresponds to ~ 6 secs of data
  - Processed CryoSat-2 L1b SAR mode data from baseline B
    - SAMOSA adapted
    - SAMOSA only adapted for ZP (semi-adapted)
    - SAMOSA not-adapted at all
  - Jason-2 GDR(D) data
  - HY-2 GDR data
- Both Cryo and Jason-2 data correspond to one year data from 1st Jan 2012 to 31st Dec 2012. We only have HY-2 data from March 2012.
- NOTE: Data is not collocated in time!

HY2

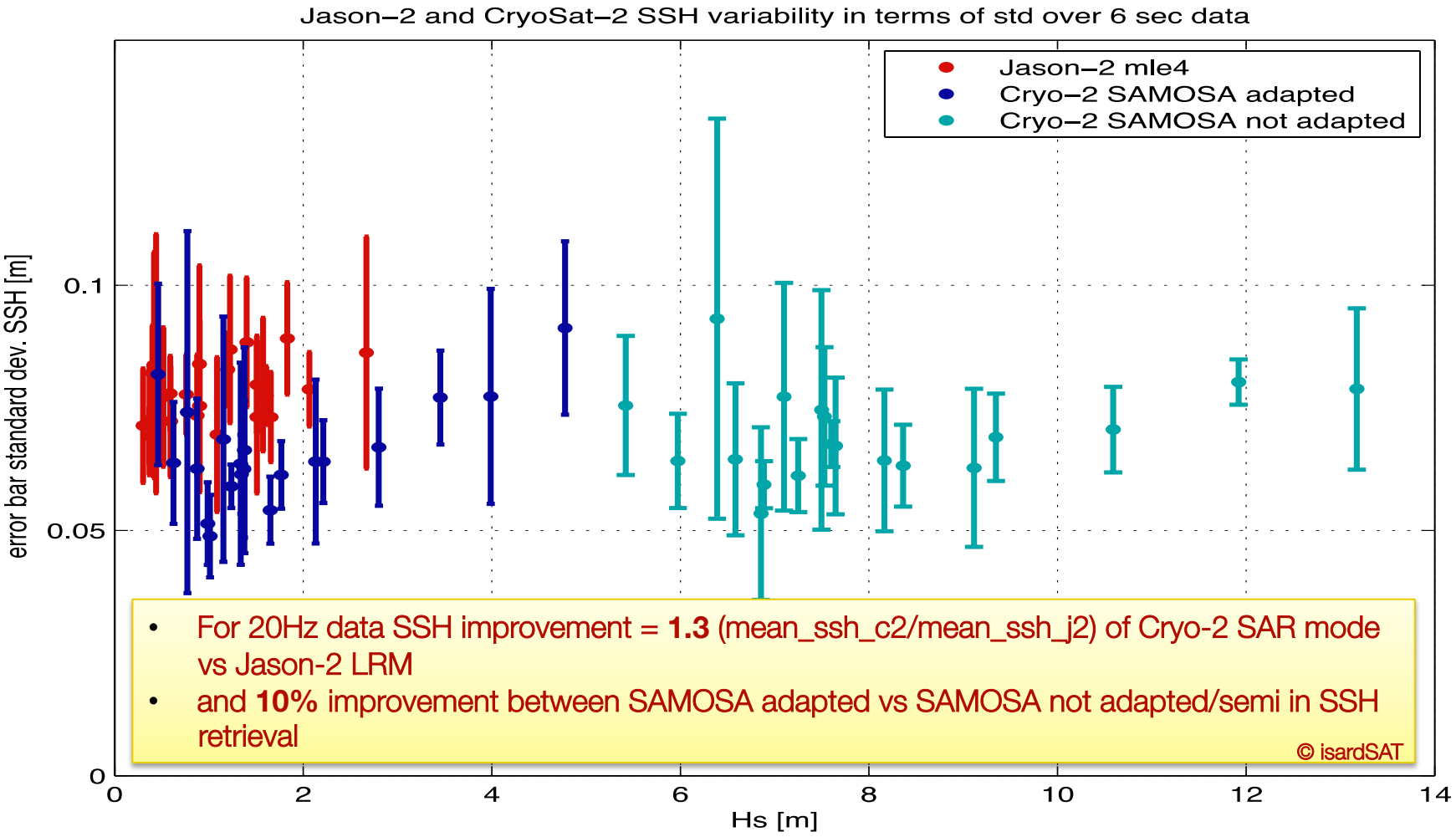
Hs in HY-2 … trying to understand what is happening



SAR Retrackers for Ocean

SSH variability

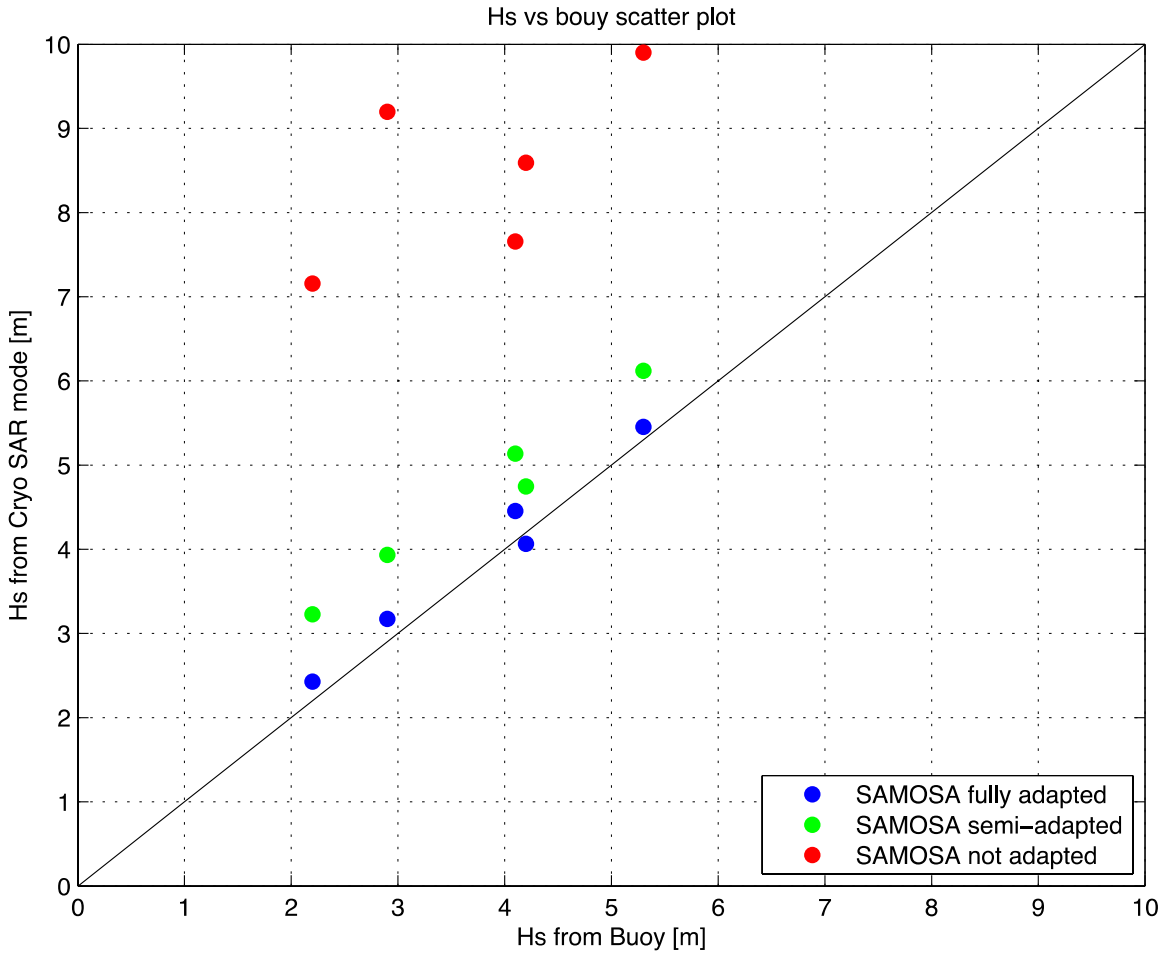
Monte-Carlo → We analyze SSH 20Hz in patches of 20 waveforms and analyze variability



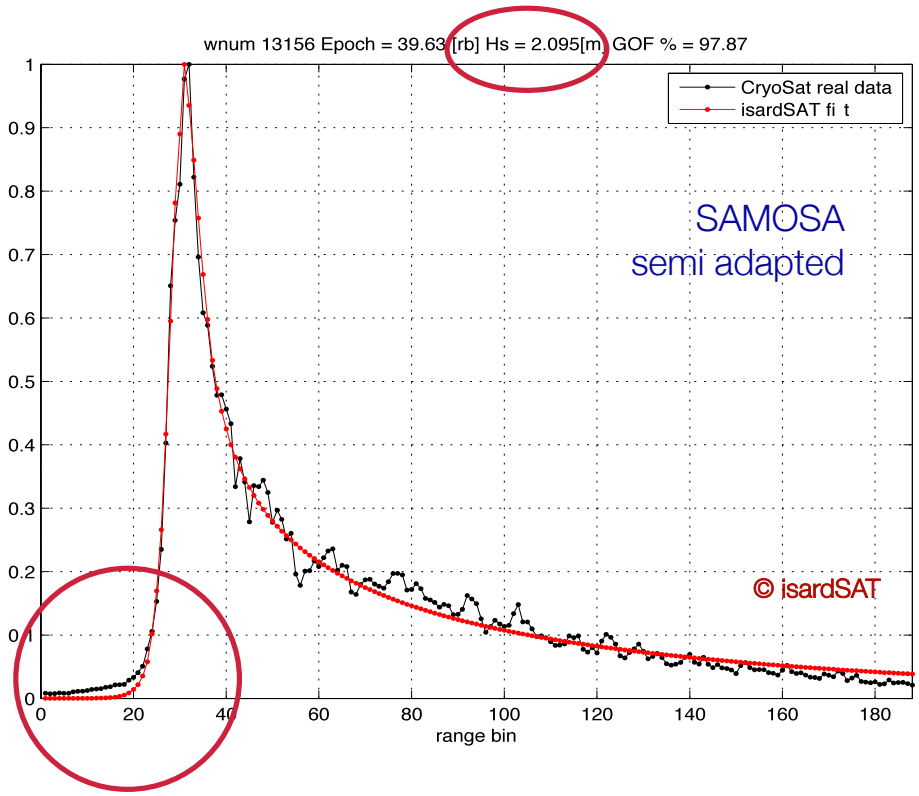
- For 20Hz data SSH improvement = **1.3** (mean_ssh_c2/mean_ssh_j2) of Cryo-2 SAR mode vs Jason-2 LRM
- and **10%** improvement between SAMOSA adapted vs SAMOSA not adapted/semi in SSH retrieval

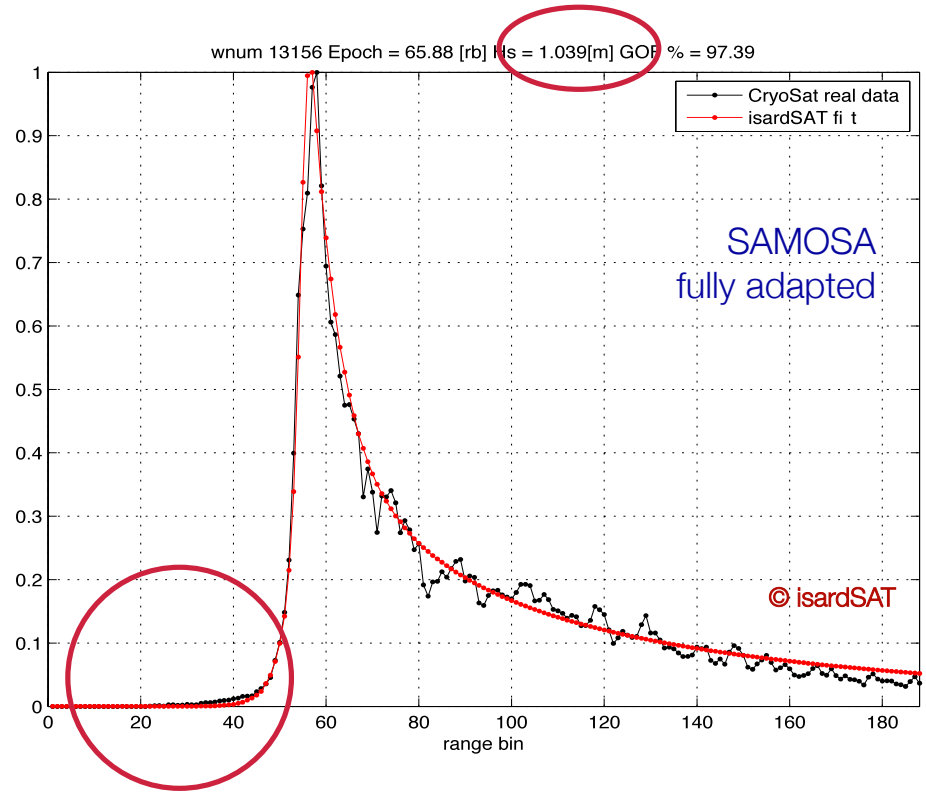
Hs validation

Comparing the three versions



Semi or fully adapted!





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Hs validation

GOF results

Version	Hs	GOF
SAMOSA fully adapted	Hs < 2m	97.42%
	Hs > 2m	96.66%
SAMOSA semi-adapted	Hs < 2m	97.00%
	Hs > 2m	96.50%

In terms of GOF is difficult to appreciate the difference between the semi and full adapted versions of the SAMOSA model. The main difference remains in the leading edge and trailing edge, or end of cue.

However, in terms of Hs retrieval there is a considerable difference! (see next slide)

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Hs error estimation

Parameter	Formula	SAMOSA fully adapted to Baseline B	SAMOSA semi adapted to Baseline B
Bias Systematic errors	$N^{-1}\sum_{i=1}^{N}(x_i - T_i) = \bar{x} - \bar{T}$	32.49 [cm]	1.10 [m]
Root mean square difference (RMSE):	$\sqrt{N^{-1}\sum_{i=1}^{N}(x_i - T_i)^2}$	39.22 [cm]	1.13 [m]
Standard deviation of the difference (SDD):	$\sqrt{N^{-1}\sum_{i=1}^{N}(x_i - T_i - \mathrm{Bias})^2}$	21.98 [cm]	27.73 [cm]
Scatter index (SI):	$\mathrm{SI} = \mathrm{SDD} / \bar{T}$	0.08	0.1

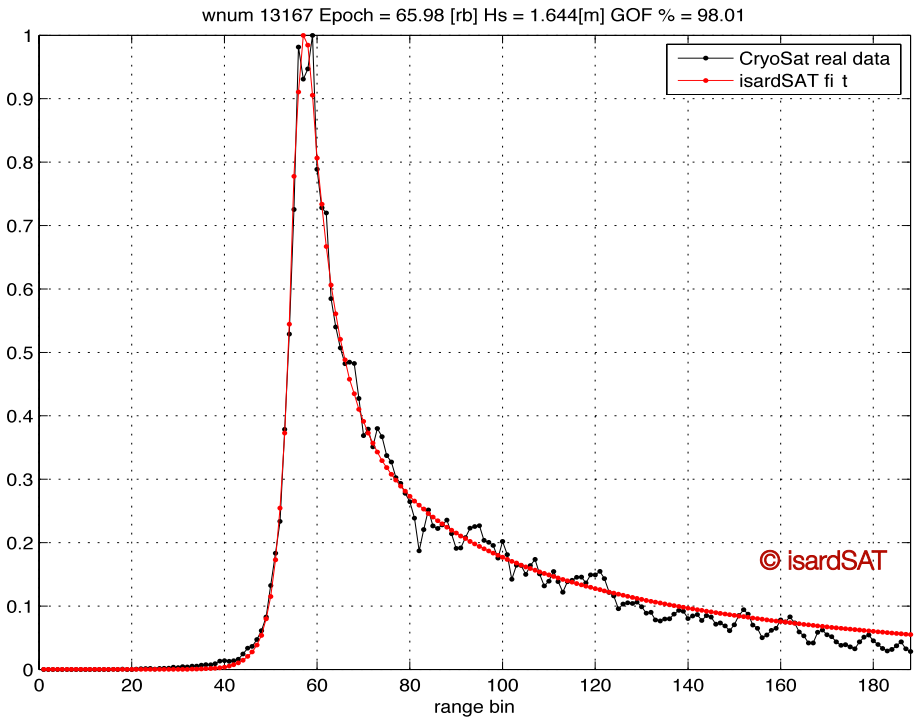
Error estimation – following mathematics from a presentation of ECMWF by S. Abdalla

Adapted to Jason-CS GPP

We have also adapted the model to Jason-CS GPP

- isardSAT is building the Jason-CS P4 GPP for L1
- For L1b verification purposes we have adapted the SAMOSA model to the Jason-CS L1b processor not for interleaved yet
- So far we are working with:
  - Simulated Jason-CS data (no interleave)
  - And CryoSat data adapted to Jason-CS
- Next …

CryoSat data adapted to Jason-CS
GOF: 98.01%



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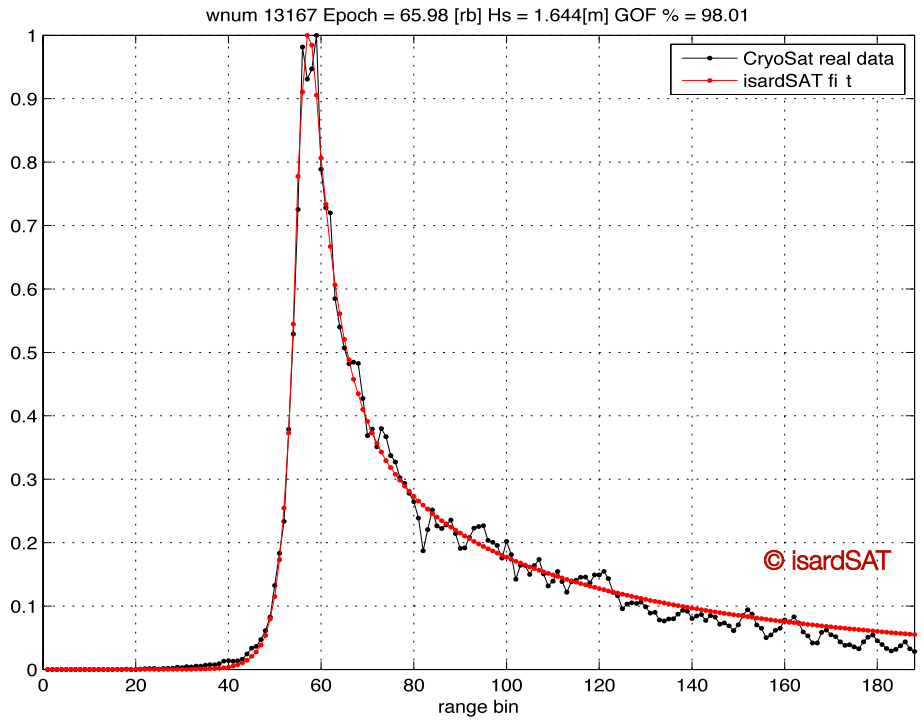
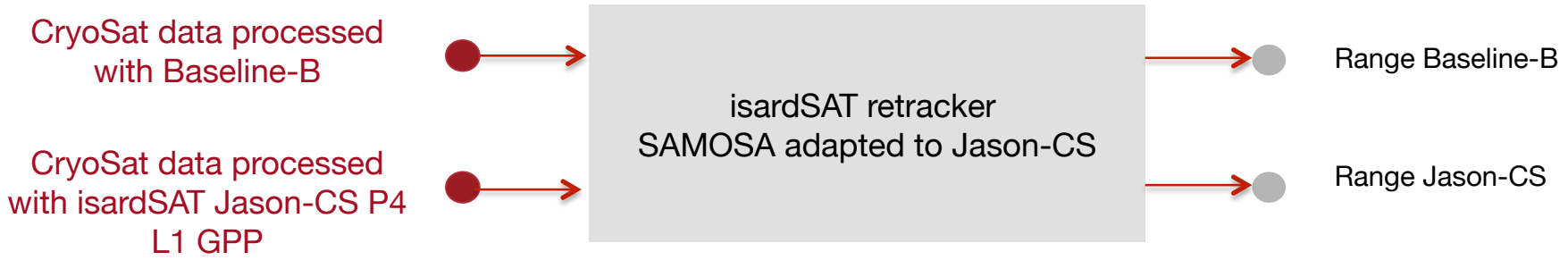
  - And CryoSat data adapted to Jason-CS
- Next …
  - Adapting SAMOSA to Jason-CS interleaved mode! → more … @ ESA Living Planets

CryoSat data adapted to Jason-CS
GOF: 98.01%



Baseline-B vs Jason-CS GPP



Retracked range difference = [Range Jason-CS] – [Range Baseline-B]

Retracked Range Difference [MEAN]	20Hz	0.02802 [m]
	1Hz	0.0283 [m]
Retracked Range Difference [STDEV]	20Hz	0.10312 [m]
	1Hz	0.02306 [m]

Hs stdev difference = [stdev of Hs as derived by Jason-CS GPP] – [stdev of Hs as derived by Baseline-B]

Stdev difference	20Hz	0.02 [m]

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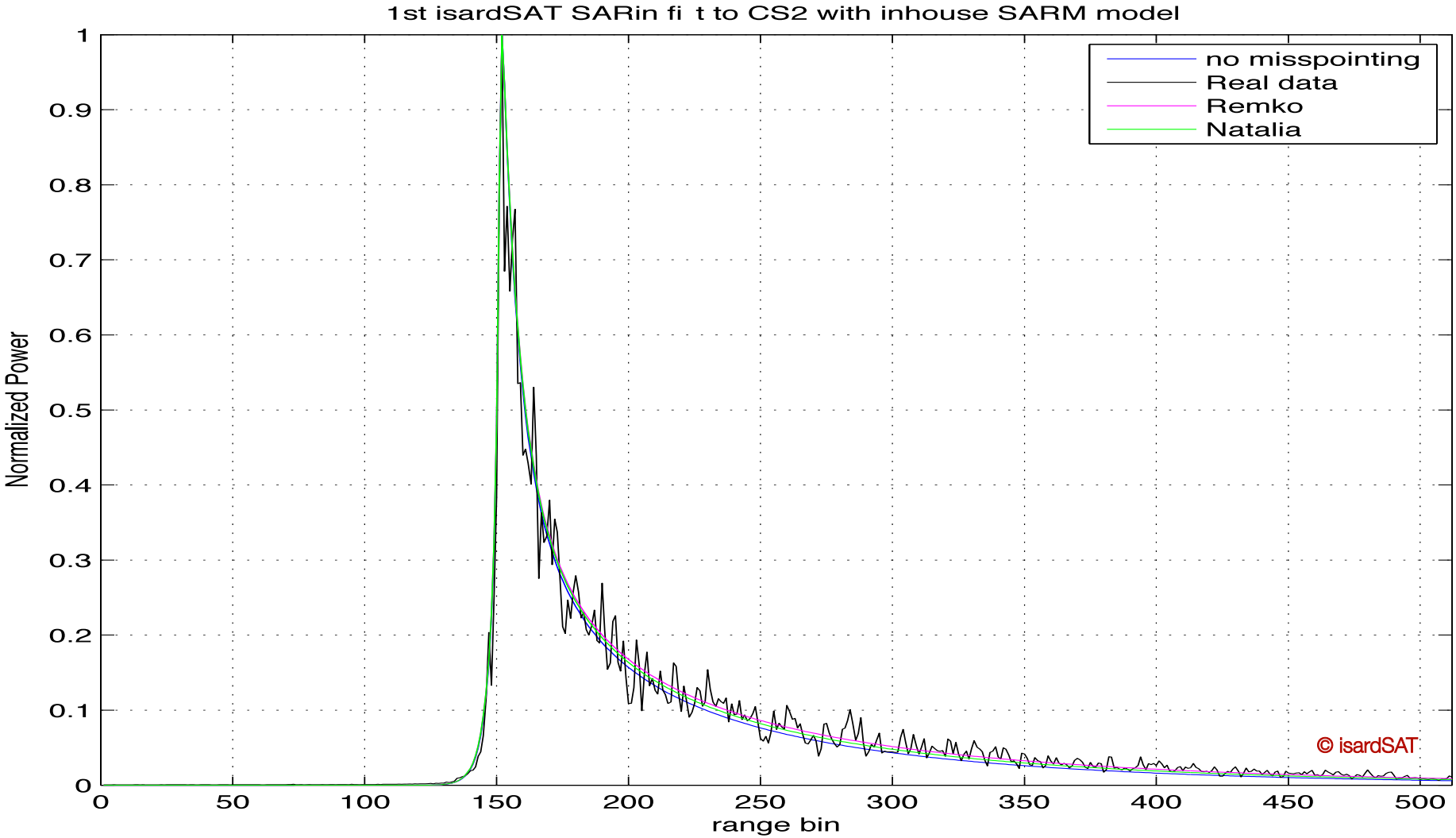
Adapted to SARin

We have also adapted the model to SAR in data



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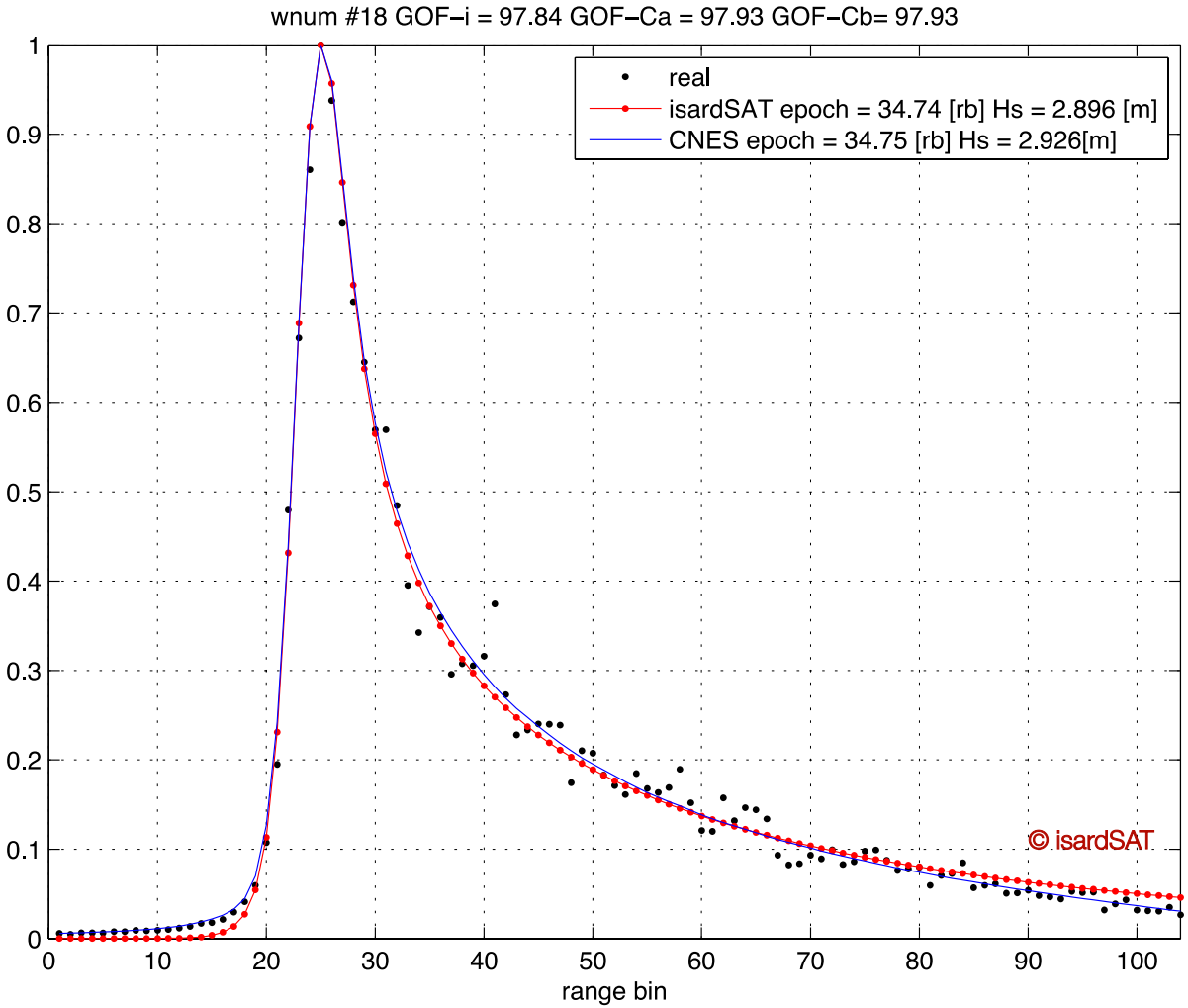
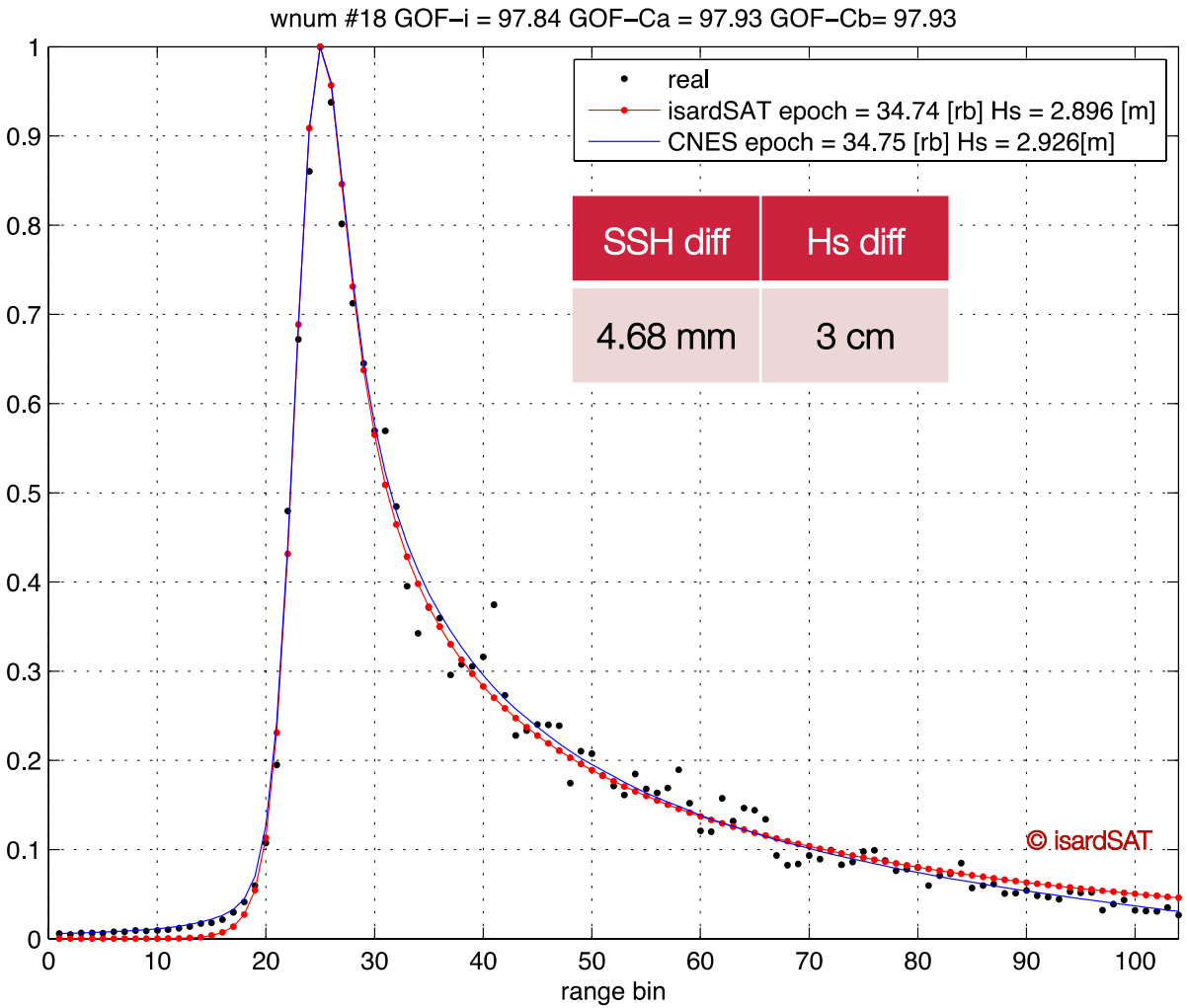
Fitting CPP Data



Fitting CPP Data



8. A few conclusions & recommendations

- isardSAT has the capability to process L1 and L2 data. We have 2 complete chain: for CryoSat and for Jason-CS (including interleaved mode)
- Retracking teams (either with analytical or non-analytical) models shall work in close cooperation with L1 teams. Otherwise they are likely to commit errors in the estimation of geophysical information
- People working with the SAMOSA model must make sure they adapt it properly to the L1 processor used to derive the L1B data retracked
- In the effort to adapt SAMOSA to Baseline B from CryoSat we have shown that non-adapting the model to L1 processing may results in errors of:
  - 10% in derivation of SSH
  - ~80 cm bias in Hs comparing the model fully adapted to the model semi-adapted. If no adaptation is done at all this bias turns to be in the order of meters!
- isardSAT team has shown the capability of SAMOSA to work for Jason-CS and other like CPP CNES … further results will be presented @ ESA Living Planet

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Thanks for your attention!

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