Jason-CS Poseidon-4 Ground Prototype Processor (GPP):

Processor results using interleaved mode simulated raw data and in orbit CryoSat-2 data

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Jason-CS introduction: mission and instrument

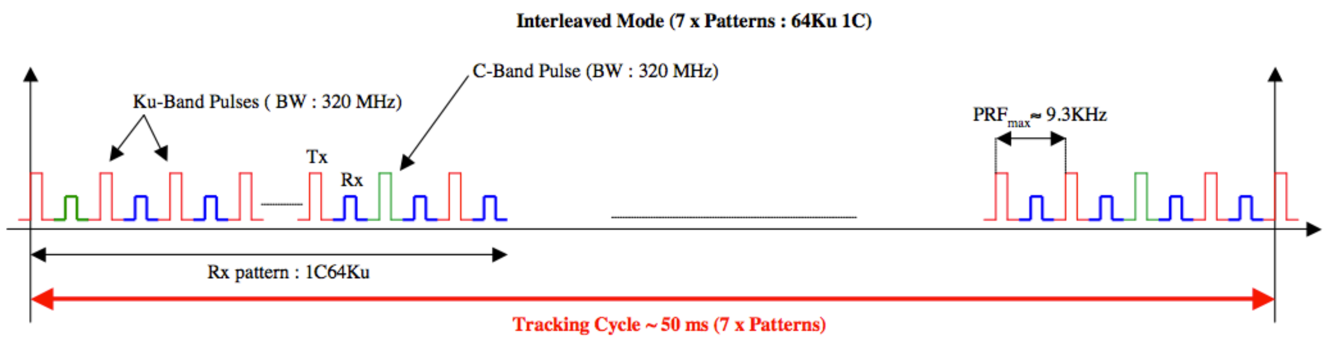
JASON-CS

- Jason-CS is an operational oceanography programme of two satellites.
- The mission being developed by a multi Agency partnership of ESA, EUMETSAT, NOAA, CNES and NASA-JPL.
- Shall ensure continuity to the Jason series of operational missions.
- The main payload is the Poseidon-4 radar altimeter (P4) that
  - has evolved from the altimeters on-board the Jason satellites (Poseidon-2 of Jason-1, Poseidon-3A of Jason-2 and Poseidon-3B of Jason-3).
  - inherits the Synthetic Aperture Radar (SAR) Altimeter mode of CryoSat-2 SIRAL and Sentinel-3 SRAL now proven to reduce errors in elevation and SWH retrieval over ocean.
- As with the Jason series and Sentinel-3, P4 transmits C-band pulses in order to retrieve a correction for ionospheric path delay.

Jason-CS introduction: mission and instrument

- Poseidon-4 will be the first radar altimeter embarked on a satellite that includes:
  - improved digital and radio frequency unit design, and
  - open burst Ku-band pulse transmission (*interleaved mode*):
  - Large data volume requires on-board function to reduce it – Reversible Range Migration Compensation (RMC)

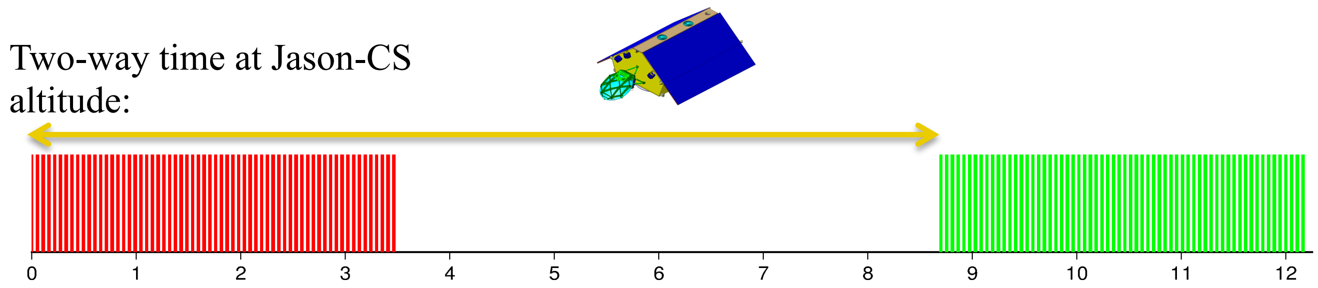
⇒ **performs a near continuous transmission of Ku-band pulses, that will allow SAR and pulse limited data to be gathered simultaneously.**



Courtesy of TAS-F

Jason-CS introduction: mission and instrument

Closed Burst



Open Burst
'Interleaved'

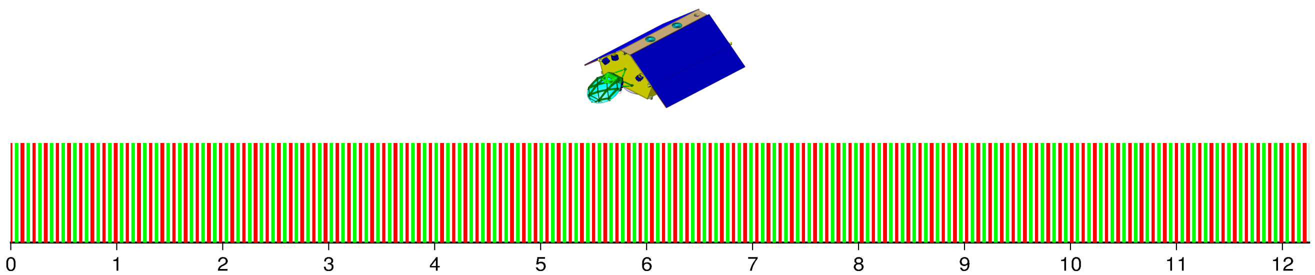


Figure courtesy of Walter Smith

Jason-CS introduction: mission and instrument

- ESA is responsible for the Jason-CS Space Segment development along with Astrium GmbH as a prime contractor.
- isardSAT is developing the Ground Prototype Processor for the Poseidon-4 under Astrium GmbH.
- This prototype processes all the chains starting from the Instrument Source Packets, and up to the Level 1b (calibrated pulse-width limited or multi-looked SAR data).
- The prototype has been verified:
  - Before being adapted to interleaved: using (1) simulated data generated by the Jason-CS mission performance simulator and (2) using in-orbit CryoSat data adapted in format to Jason-CS.
  - After adapted to interleaved: using simulated data generated by the Jason-CS mission performance simulator.
- These data have been provided by ESA.

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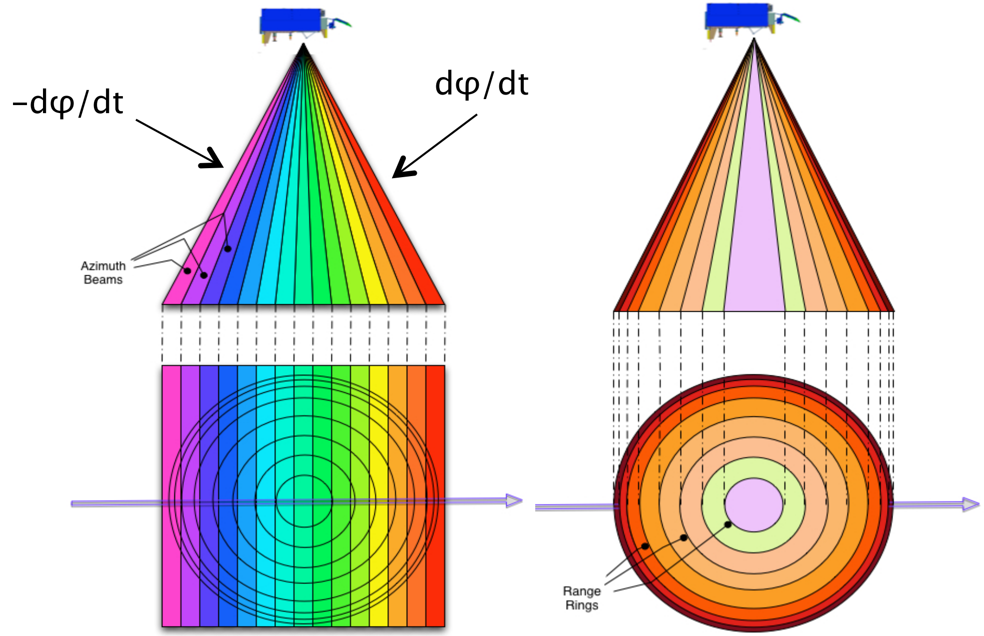
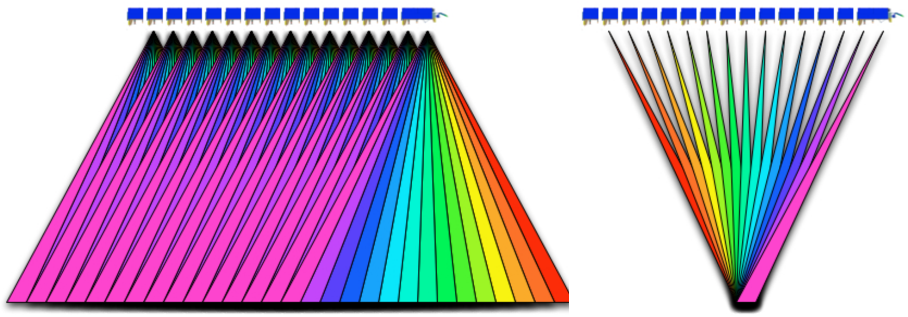
Jason-CS GPP: Science Product

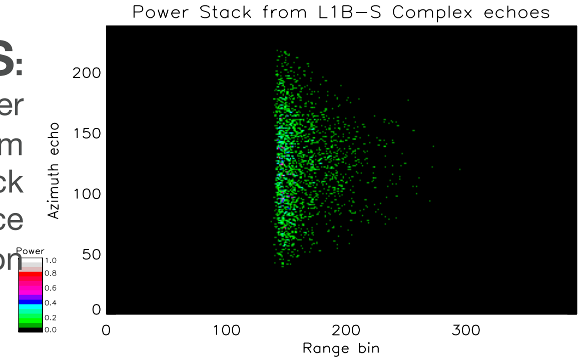
L1A provides complex echoes at the instrument timing: Allowing azimuth and Brown echo generation

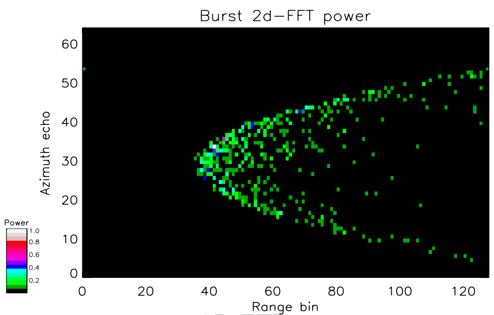


Azimuth Processing provides Complex Stack Data (L1B-S) and Multi-looked echoes (L1B)

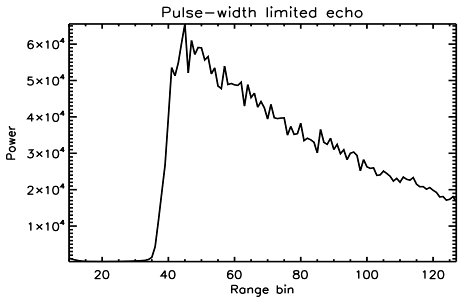


L1B-S: Stack Power echoes from complex stack allow surface characterisation



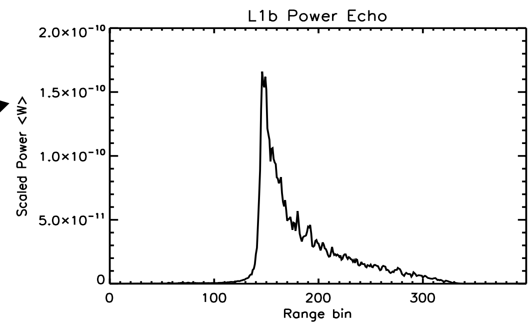


2D FFT power processed from a burst



Pulse limited echo

L1B: Multi-Looked Power echoes



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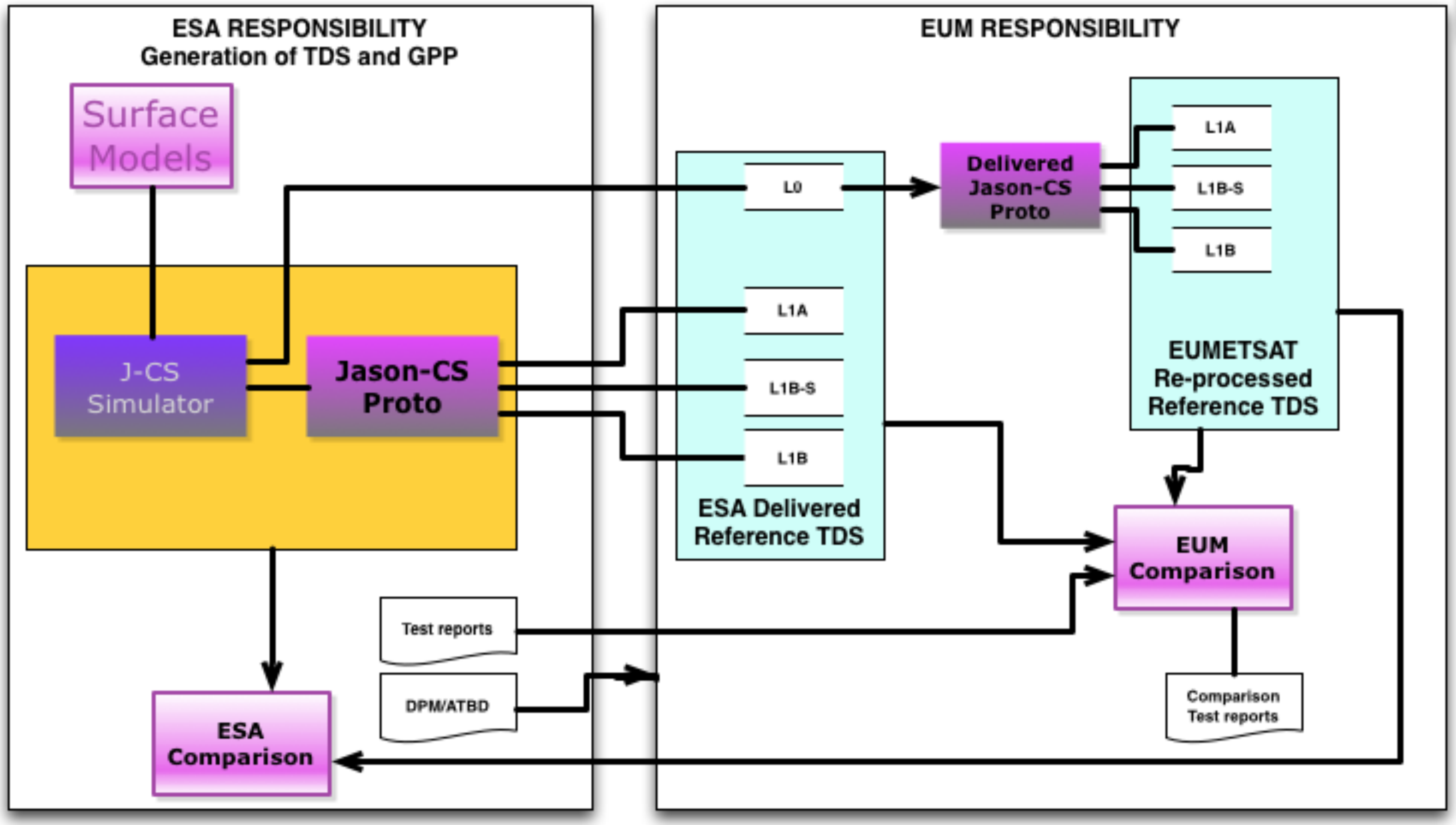
Jason-CS GPP: overall

Jason-CS ESA-EUM Delivery Proposal



Level 1A : Geolocated, Calibrated unpacked L0 (Allowing studies on beam formation)
Level 1B-S : Stack complex waveforms (Transponder calibration & surface characterisation studies)
Level 1B : Multi-looked power waveforms (for geophysical parameter retrieval similar to CryoSat L1B)

ESA_EUM_GPP_DELIVERABLES_Proposal_v1_20130218

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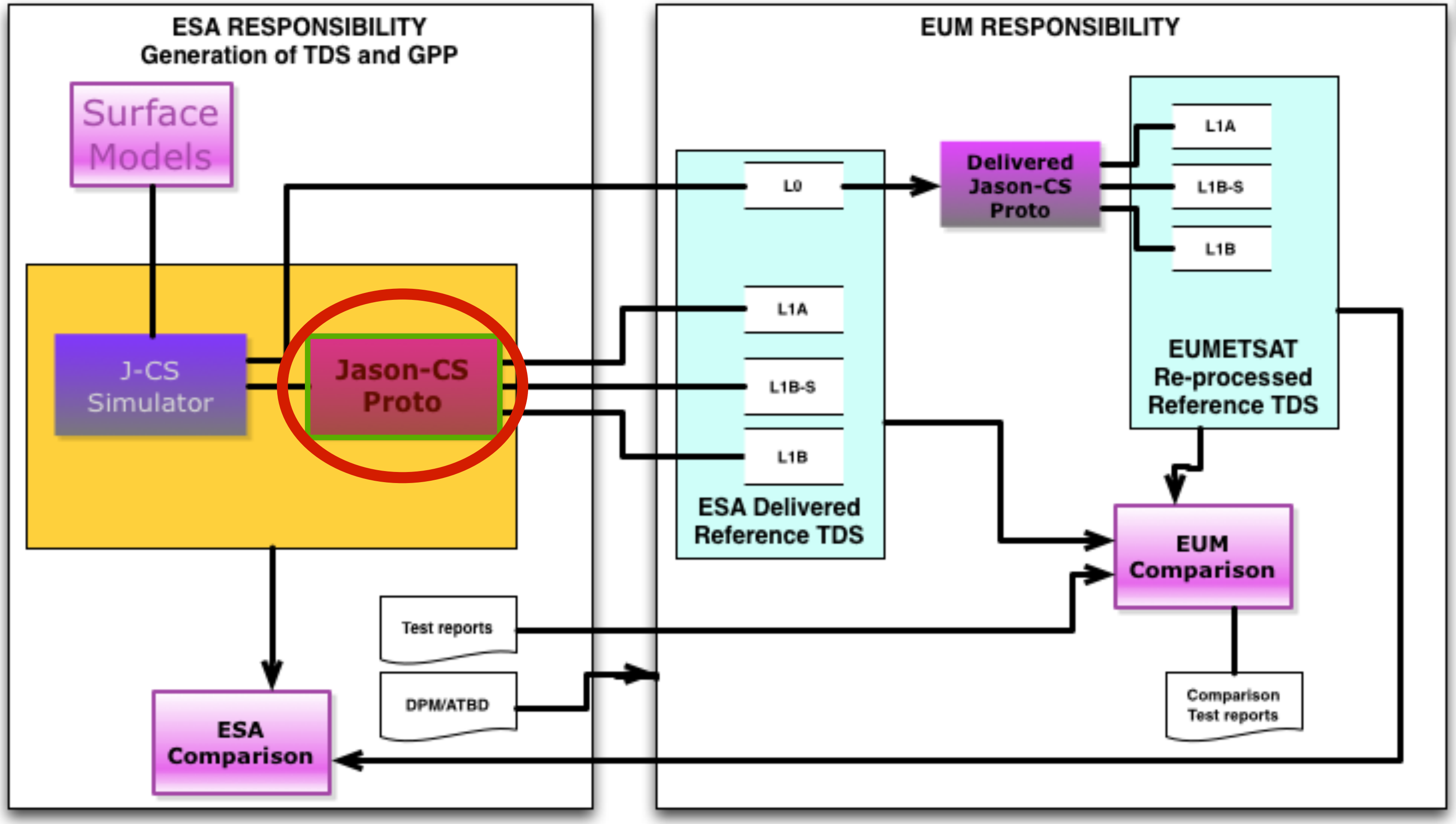
Jason-CS GPP: overall

Jason-CS ESA-EUM Delivery Proposal



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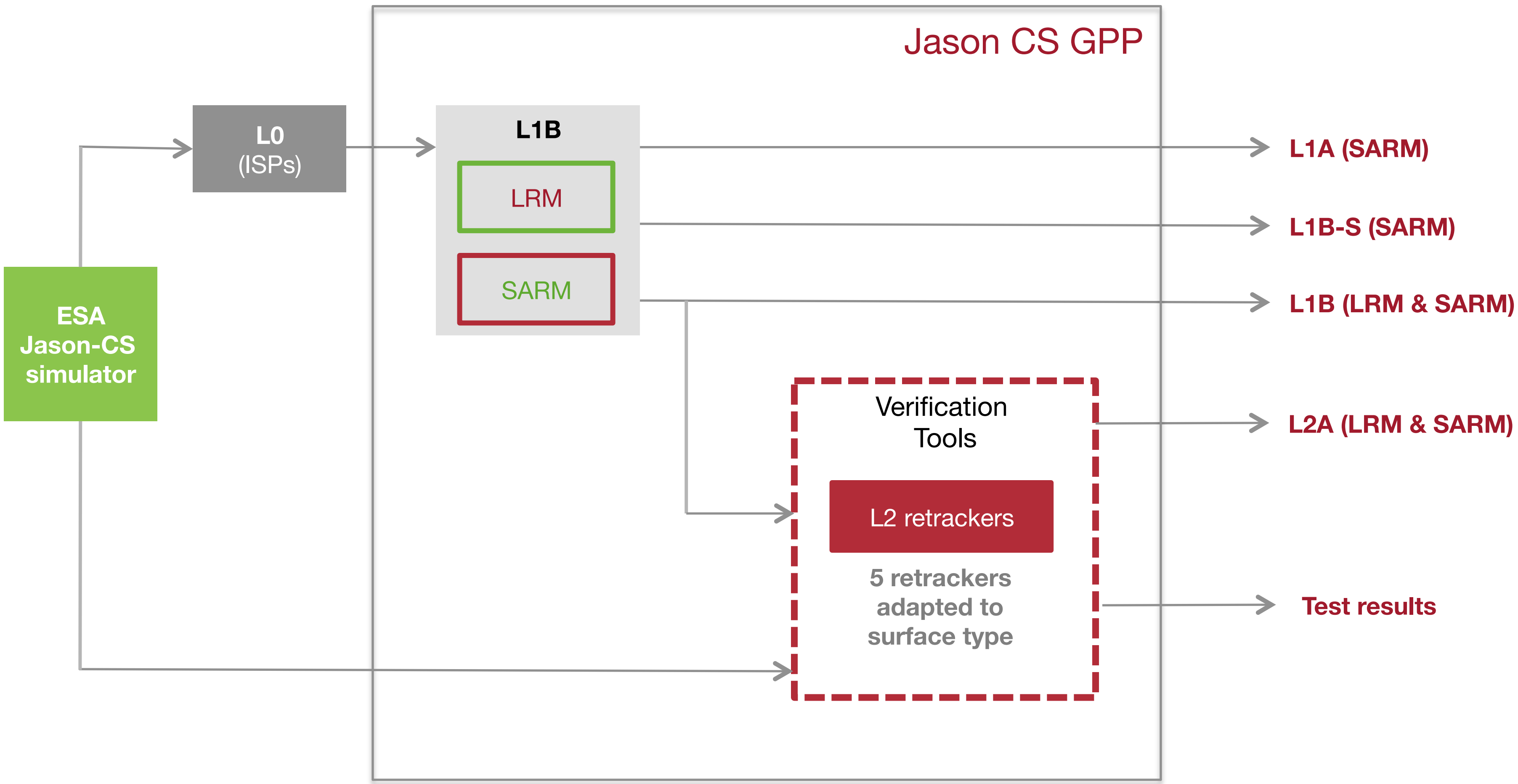
ESA_EUM_GPP_DELIVERABLES_Proposal_v1_20130218

Jason-CS GPP: isardSAT's



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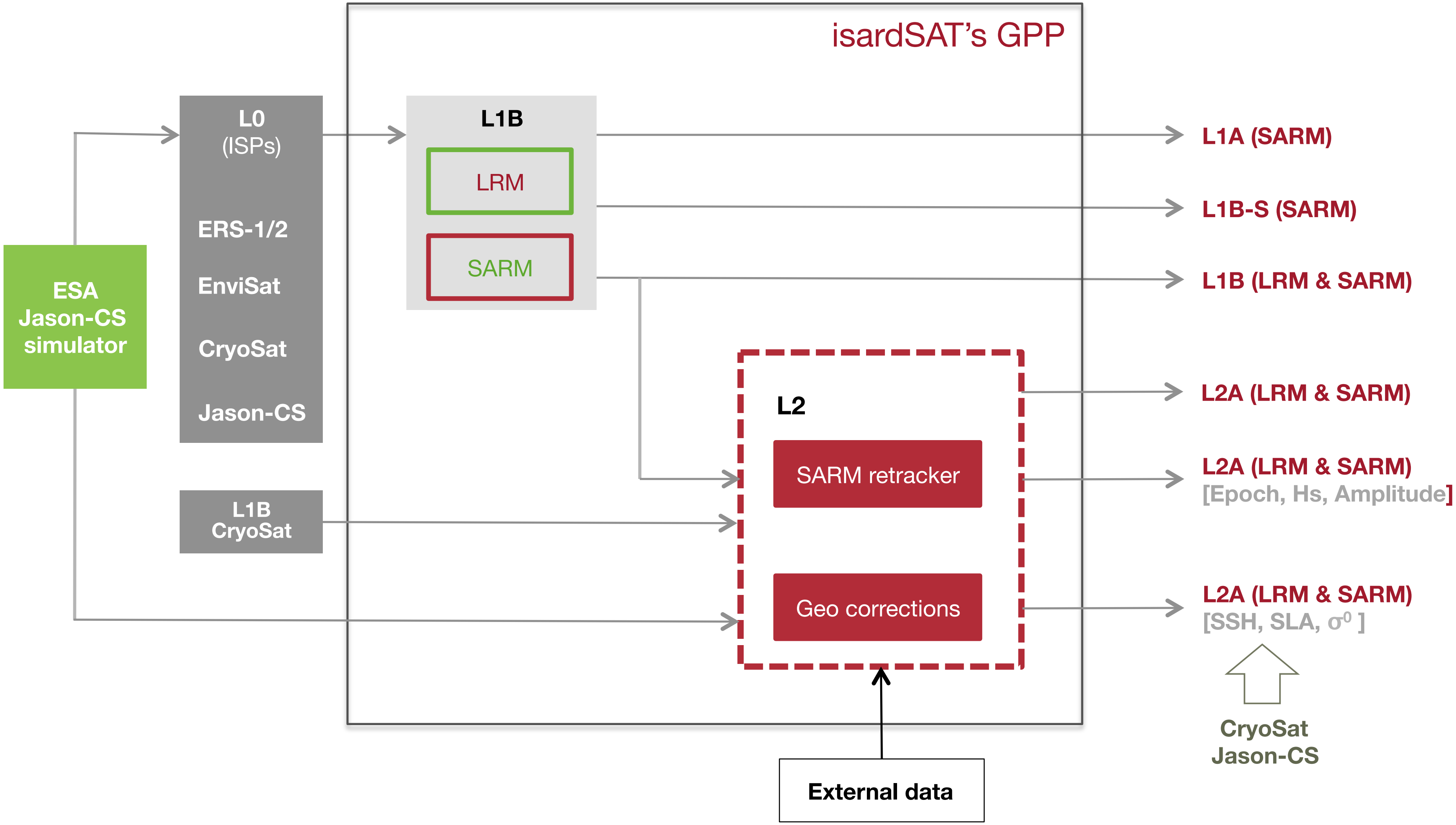

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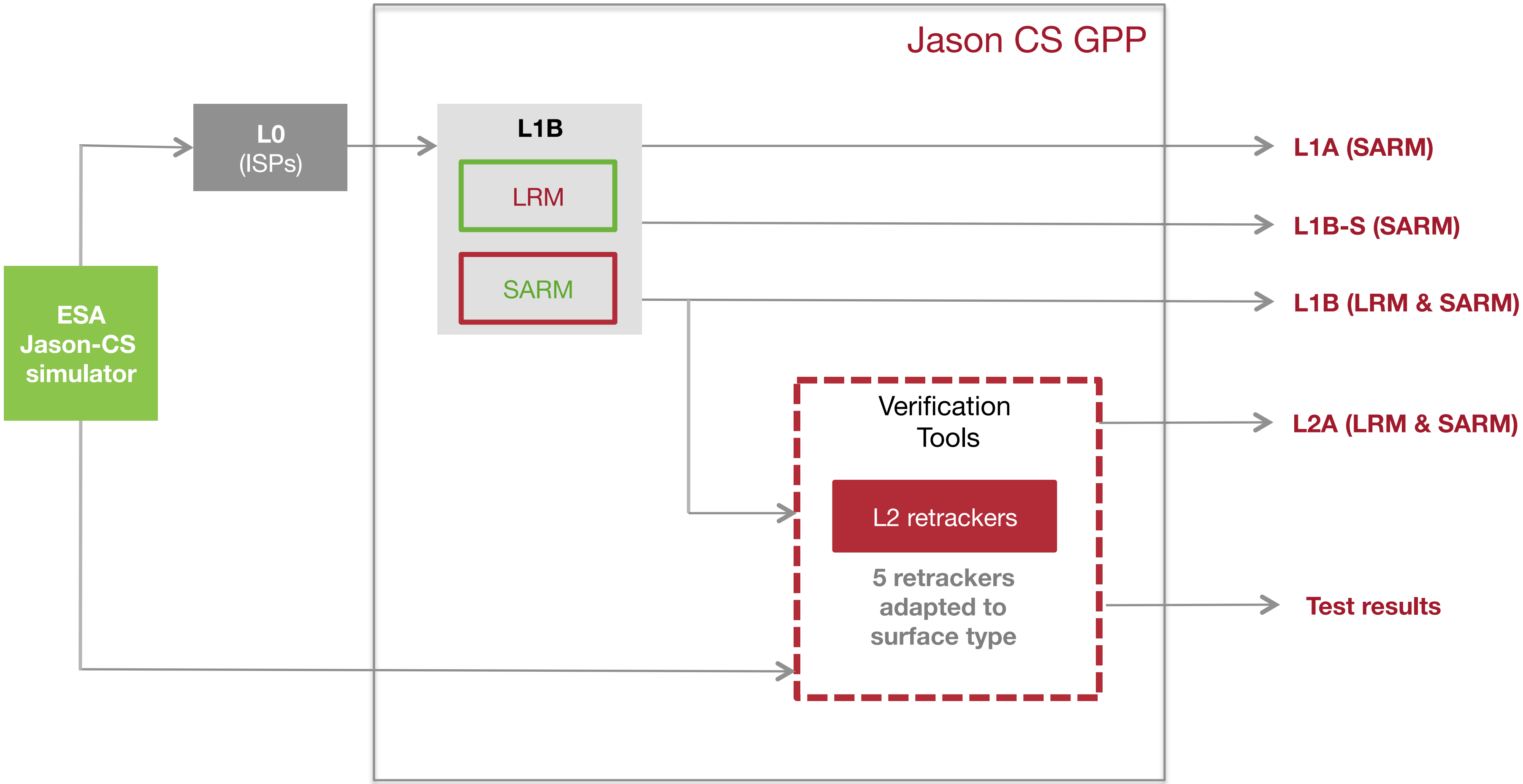

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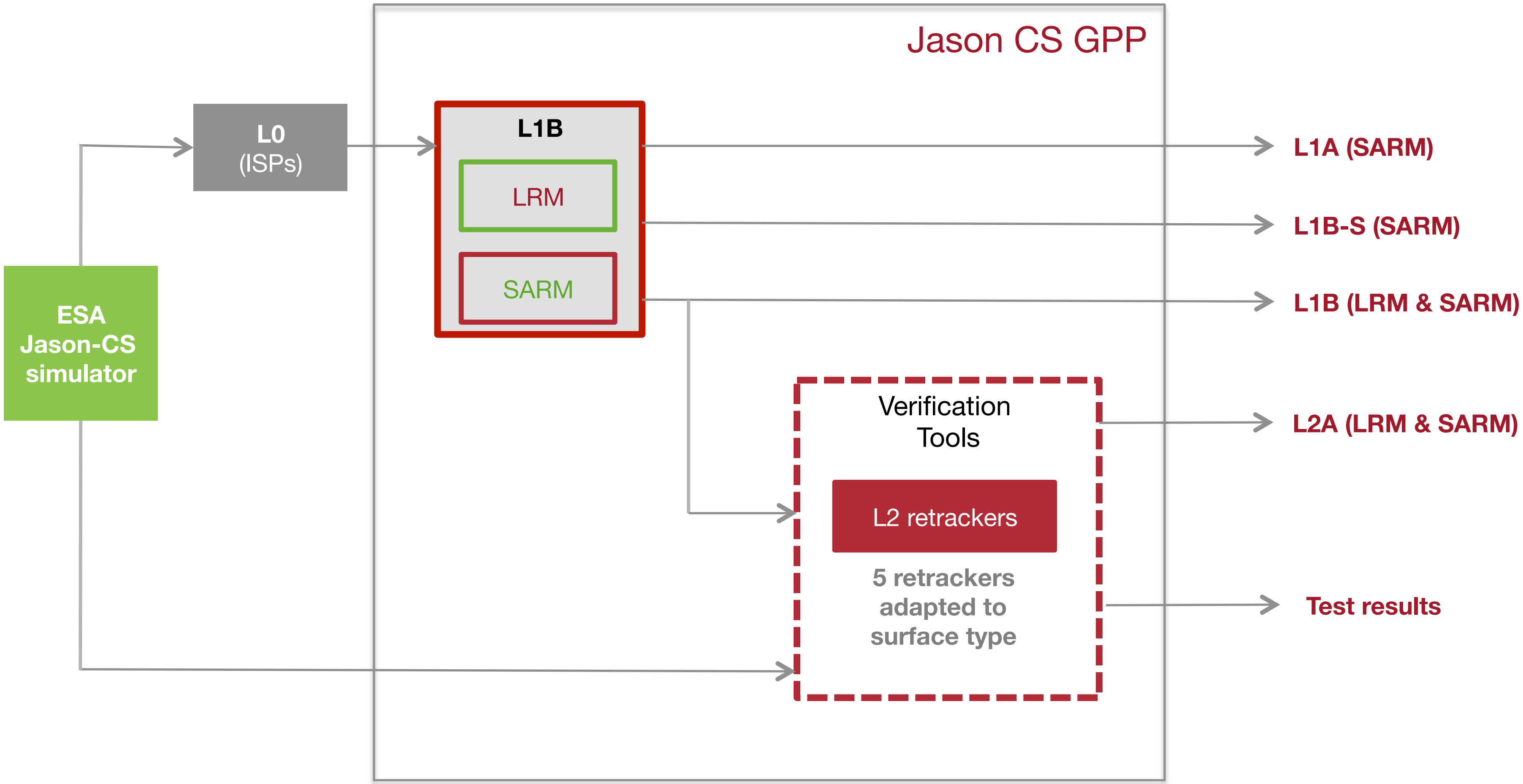
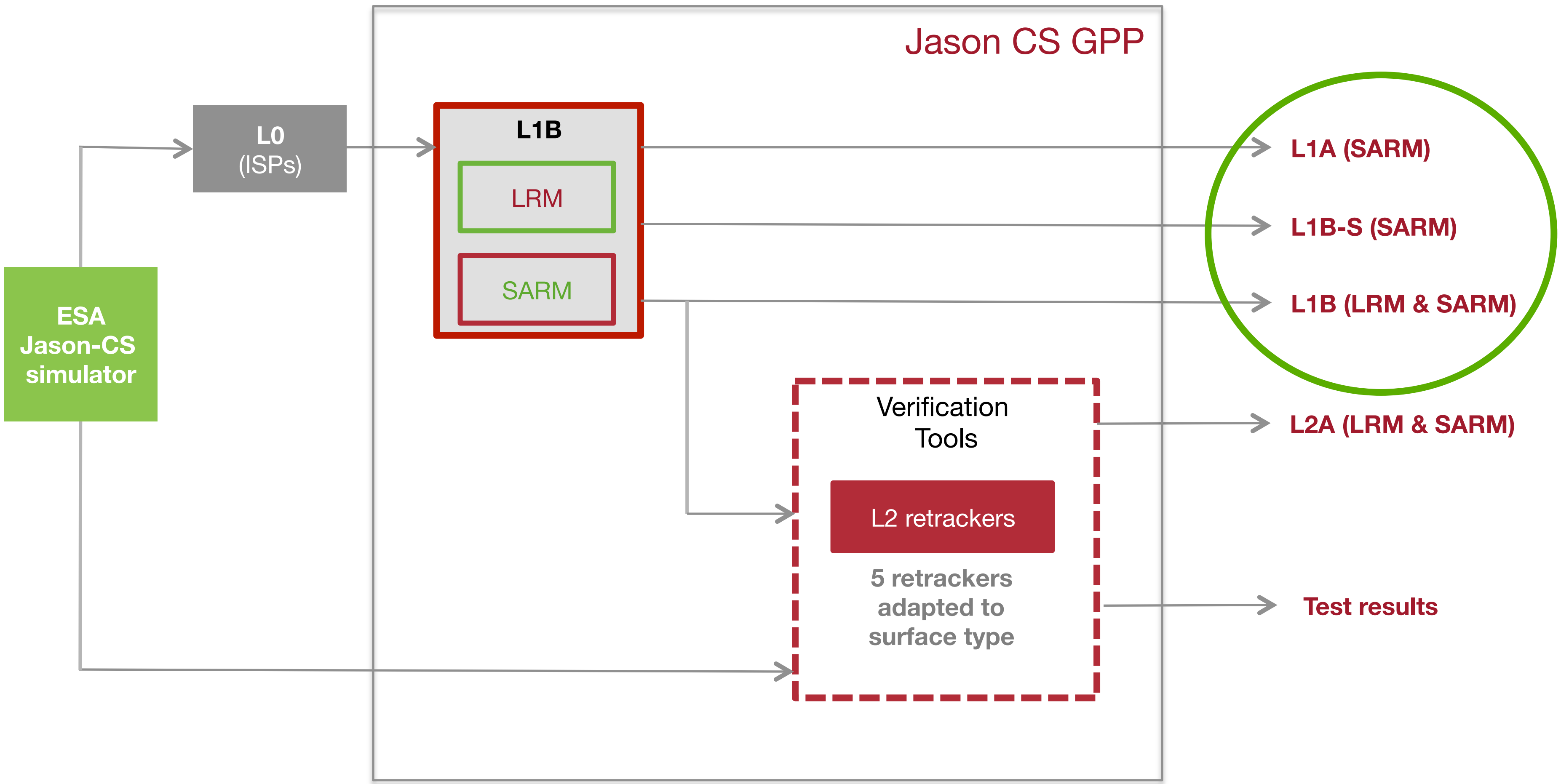


Jason-CS GPP: isardSAT's



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Jason-CS GPP: Science Product

- There is no formal agreement between ESA and EUMETSAT as to the content of the delivery of the GPP to EUMETSAT.
- ESA have therefore made an assumption on the content which may change in due course.

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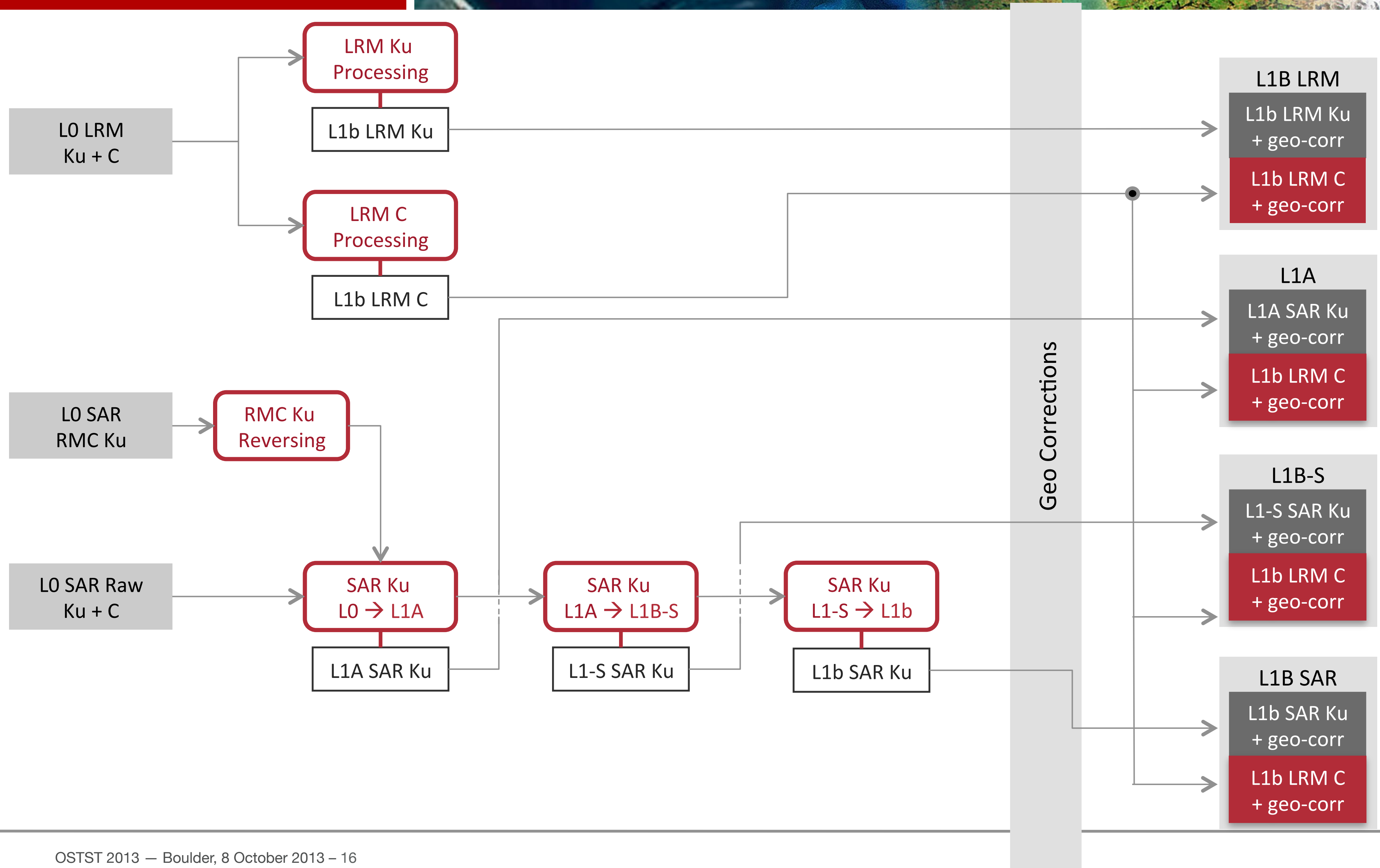
Jason-CS GPP: Science Product



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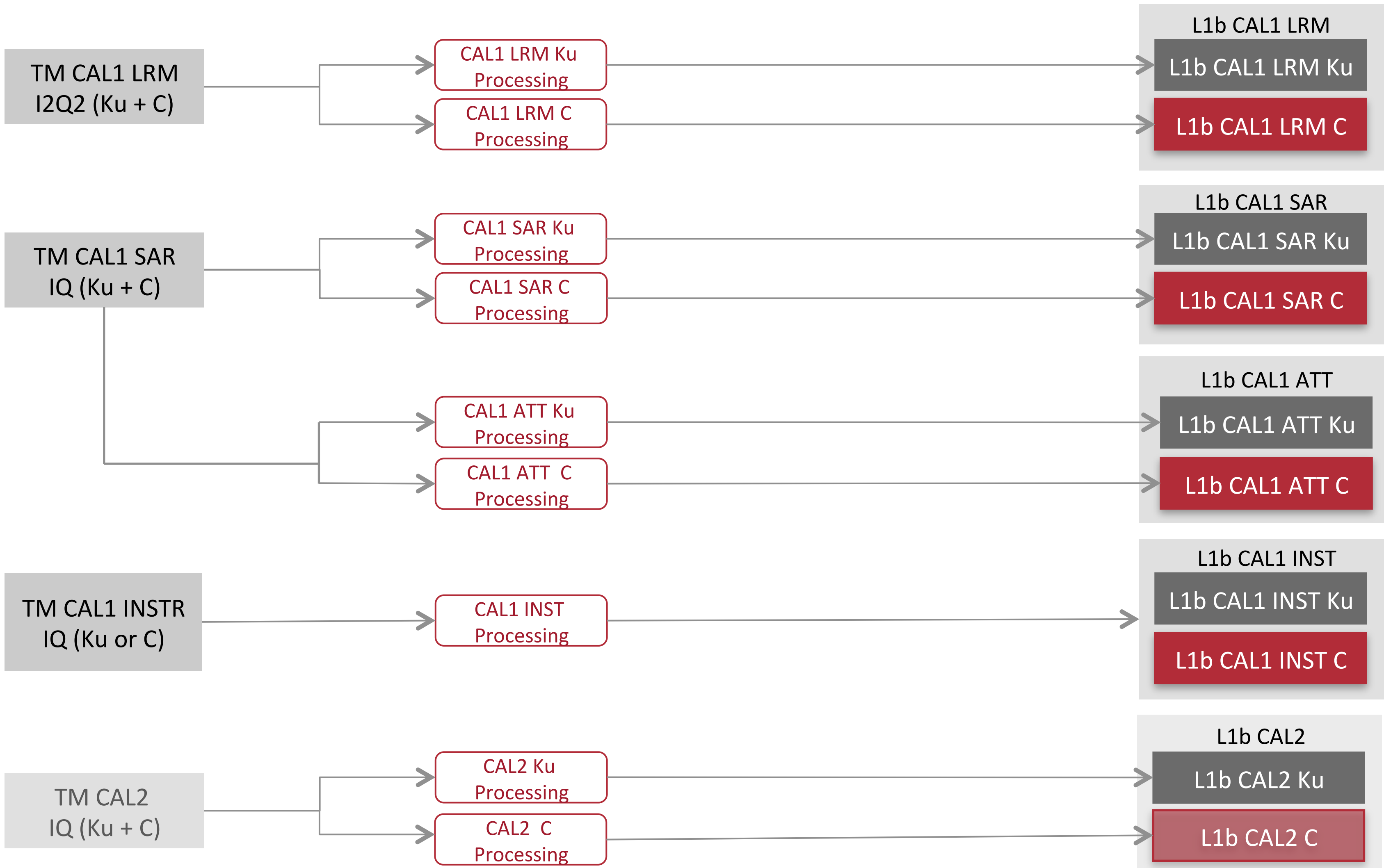
Jason-CS GPP: CAL Products



Jason-CS GPP: Verification

Verification

Verification using:

- Jason-CS simulated data
- CryoSat adapted FBR data (only before interleaved)

Several scenarios tested:

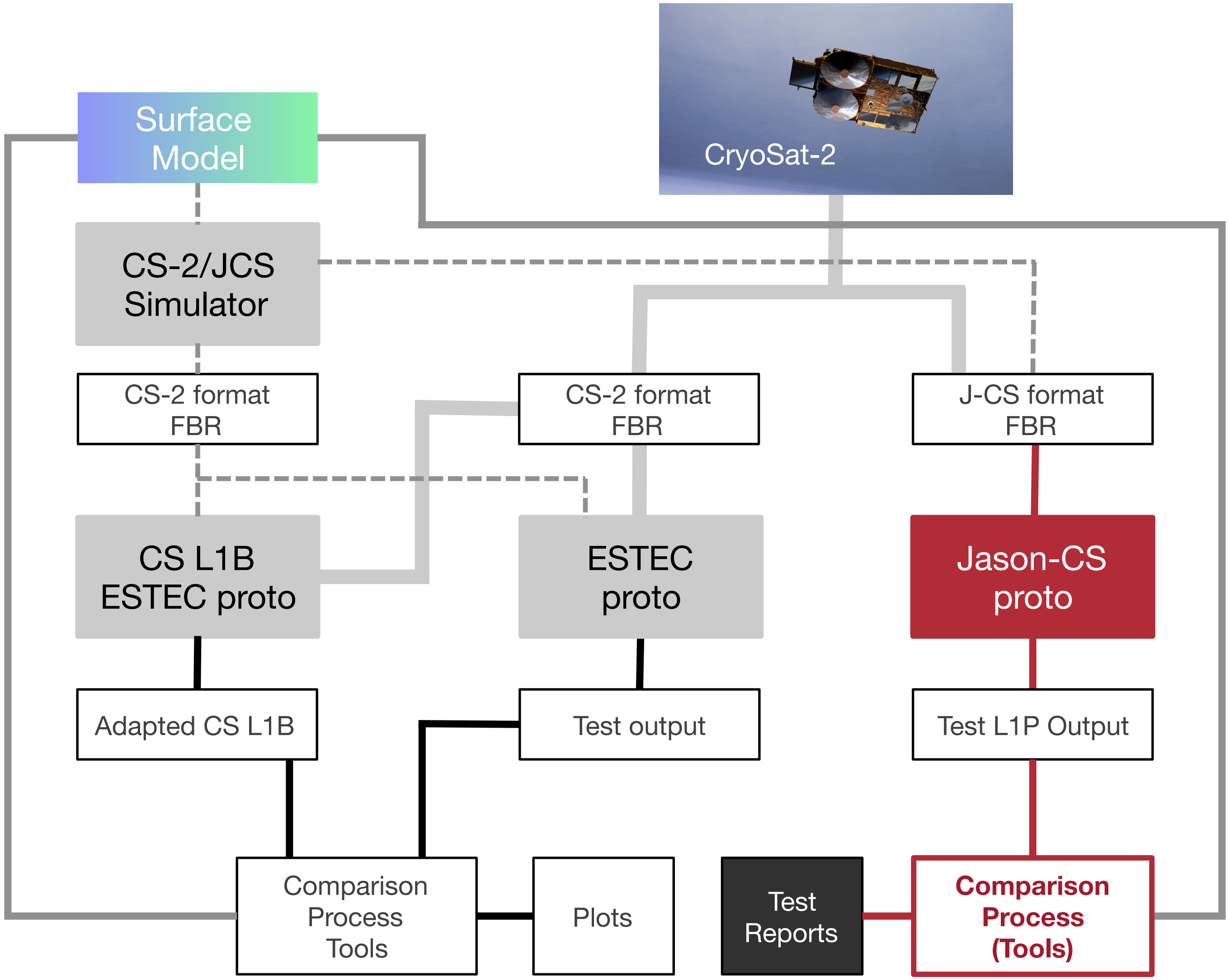
- Point Targets
- Ocean Surfaces
- Other surfaces (specular)

Using several geometries:

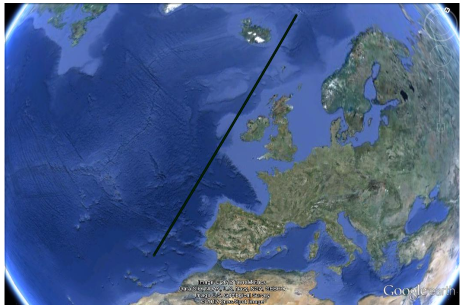
- Simplified: circular orbit, spherical Earth
- Real: real orbit, real Earth, with mispointing, etc.

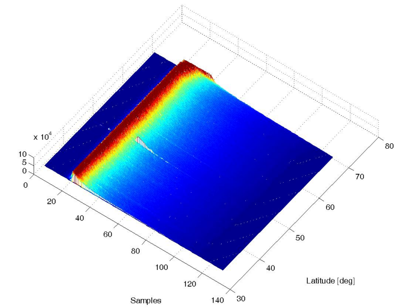
All modes (LRM, SAR, CALs)

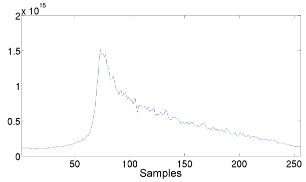
Requirements defined between ESA and isardSAT

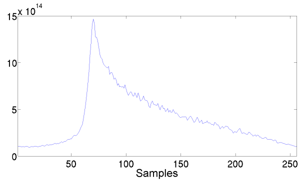


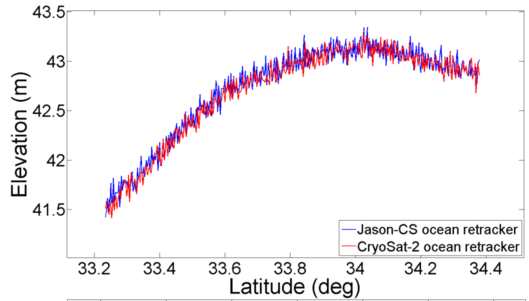
Verification: Example of Jason-CS P4 GPP Verification prior interleaved using CryoSat data adapted to Jason-CS



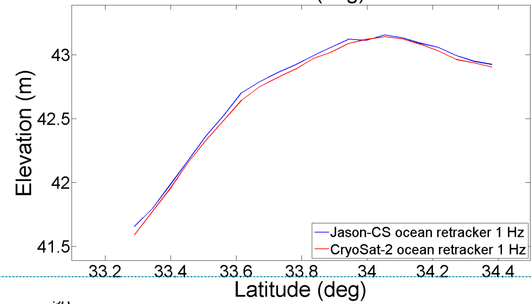




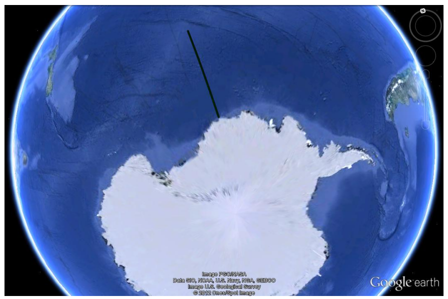


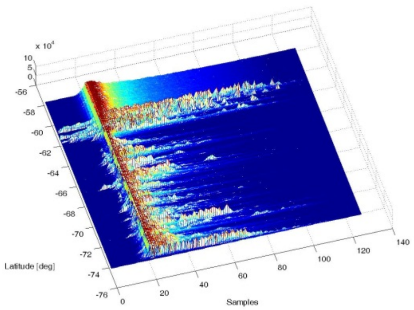


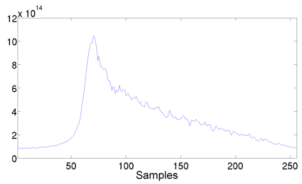
20 Hz

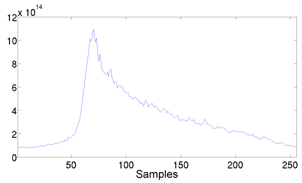


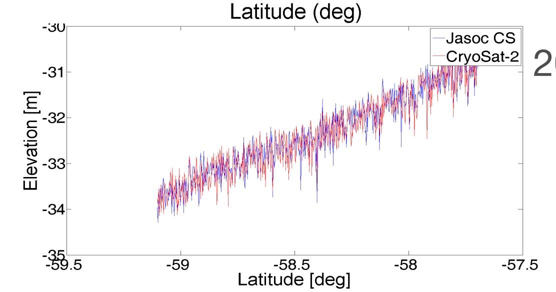
1 Hz



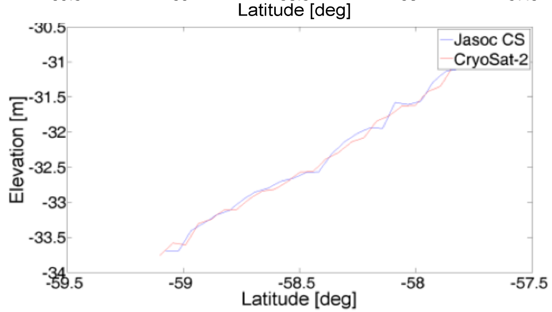








20 Hz



1 Hz

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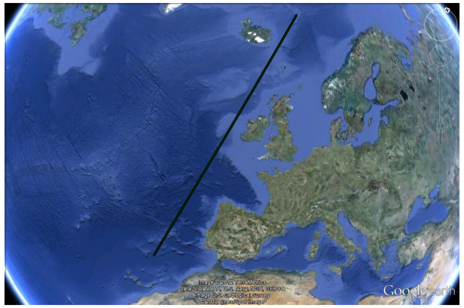
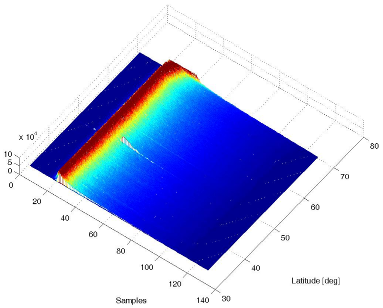
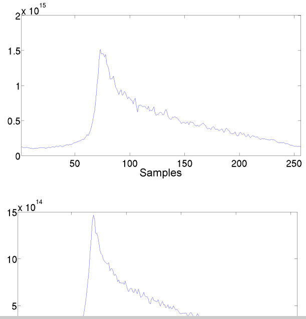
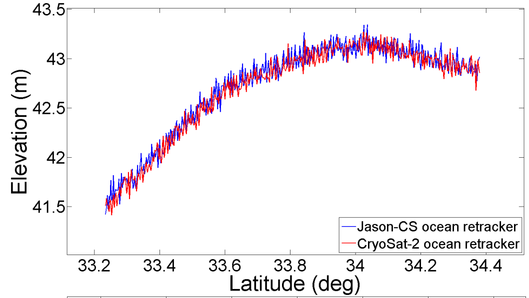
Jason-CS GPP: Verification

Verification: Example of Jason-CS P4 GPP Verification prior interleaved using CryoSat data adapted to Jason-CS

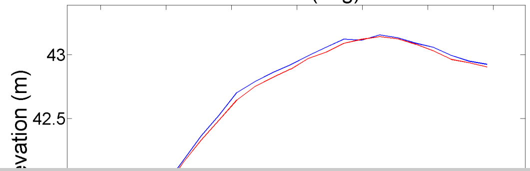








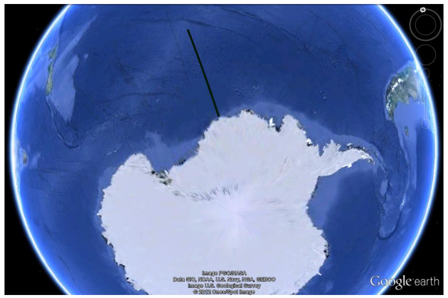
20 Hz

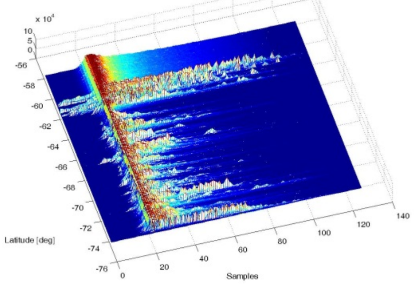


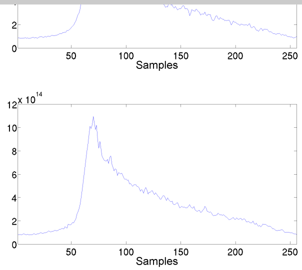
1 Hz

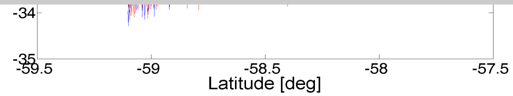
Details in
“Numerical Performance of Jason-CS SARM”
C. Martin-Puig; A. Garcia-Mondéjar; R. Escolà; M. Roca; isardSAT

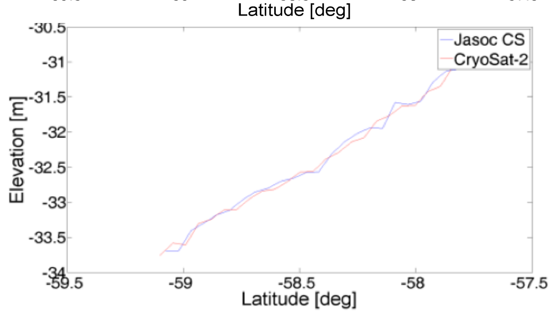
ESA Living Planet Symposium, Edinburgh, 9-13 September 2013











1 Hz

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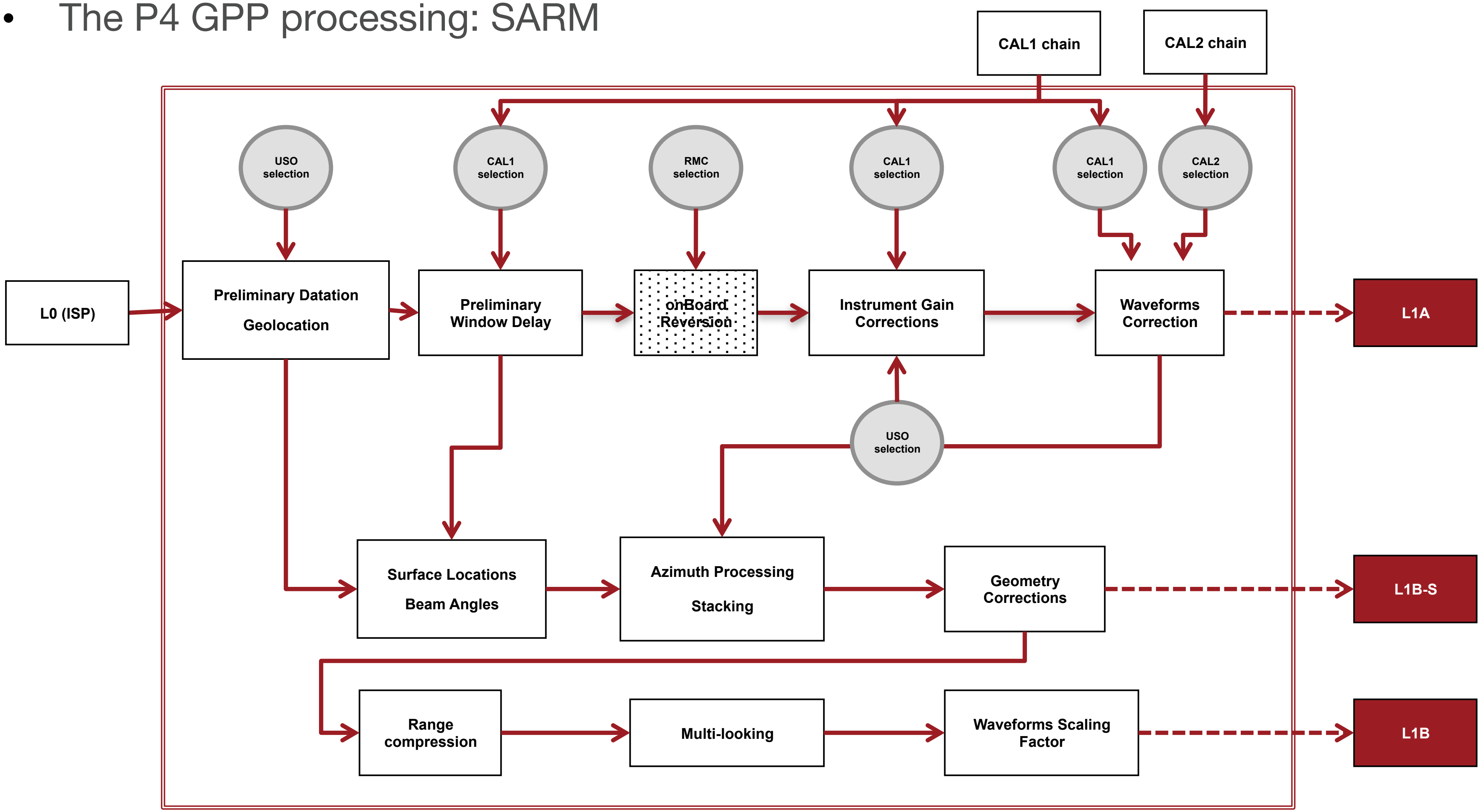
Testing results of P4 GPP New Features

- New features and conceptual processing improvements are being investigated in different parts of the processing chain:
    1. assessment of performance improvement thanks to the interleaved mode;
    2. reversal of the Range Migration Correction (RMC) performed on-board in order to reduce the data rate;
    3. weighting applied to the Doppler beams before the multi-looking to correct the different echo shapes as a function of the incidence angle;
    4. reconstruction of the waveform scaling factor in order to be able to compute the surface backscatter.

Testing results of P4 GPP New Features

- The P4 GPP processing: SARM



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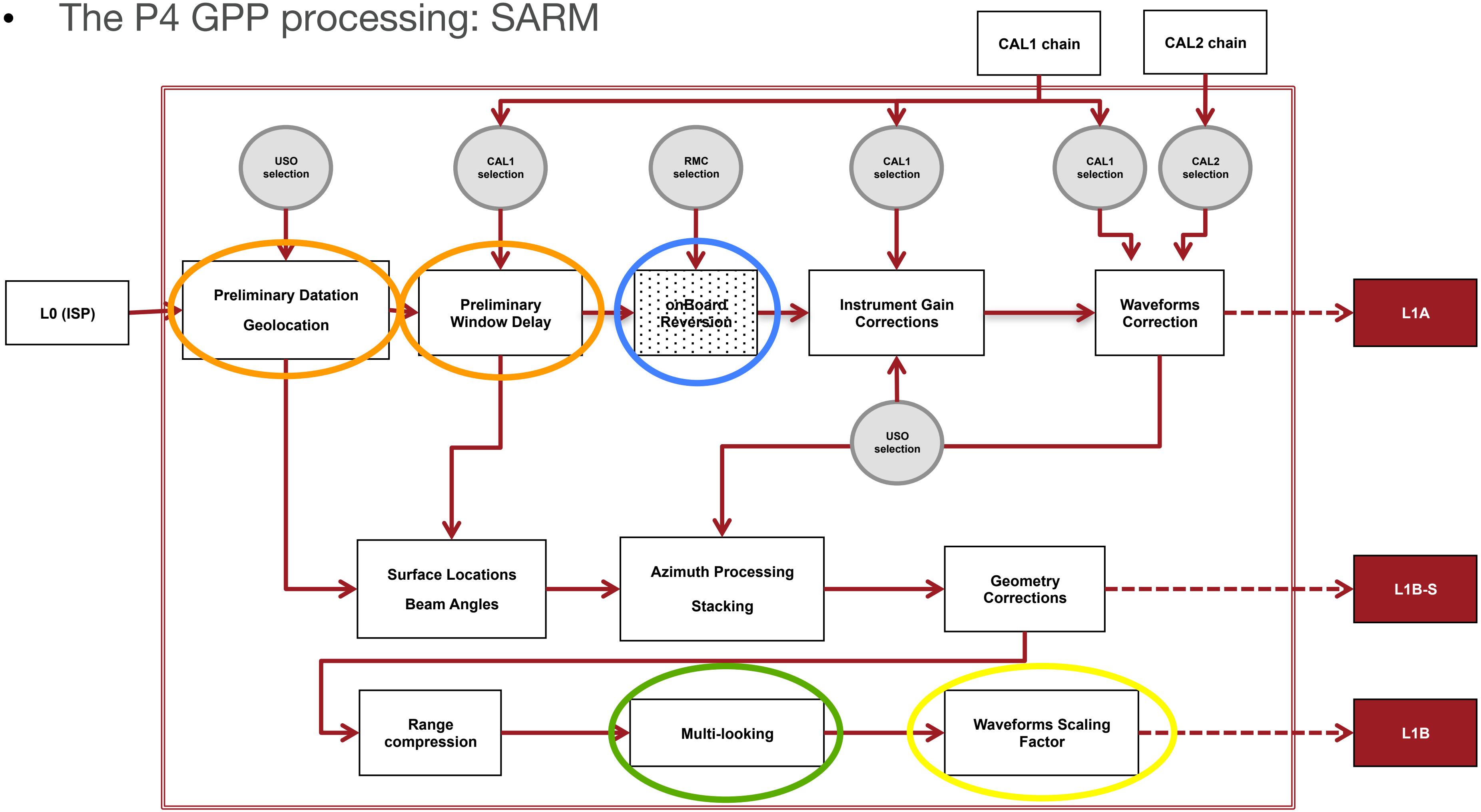
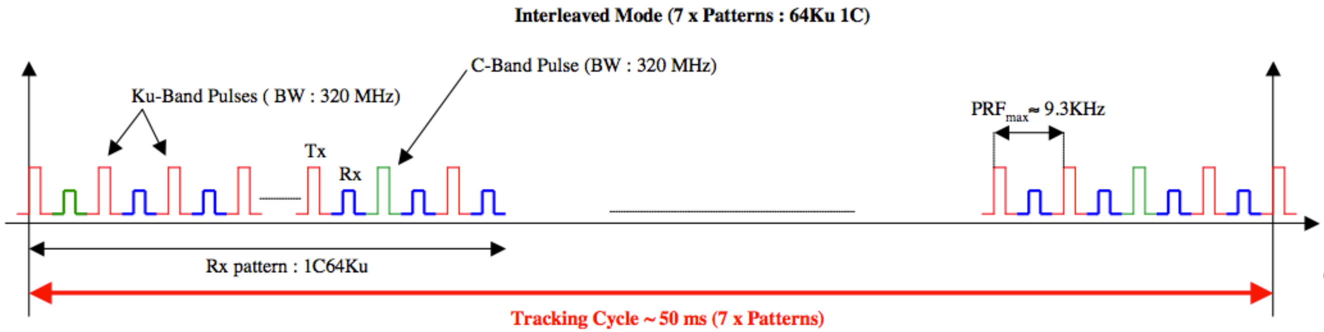


1. Interleaved performance improvement

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.

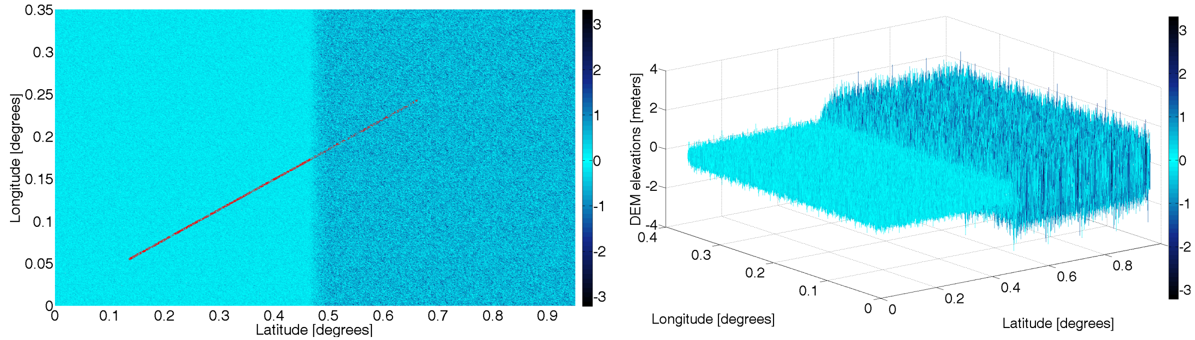
1. Interleaved performance improvement

Change	Implication
Burst length longer than before interleaved (64 pulses @ 9KHz)	Surface locations closer together (~300 m) Note: with the Jason orbit (higher than CryoSat) surface locations before interleaved ~500 m)
Open burst => use of the full radar cycle	We can achieve an improvement of **2*SNR** compared to LRM (sqrt(64*7)/sqrt(64*7/4) = 2)
Lower PRF (9KHz)	Possible Doppler ambiguity! Can be accounted for in L1B processing or in L2 processing

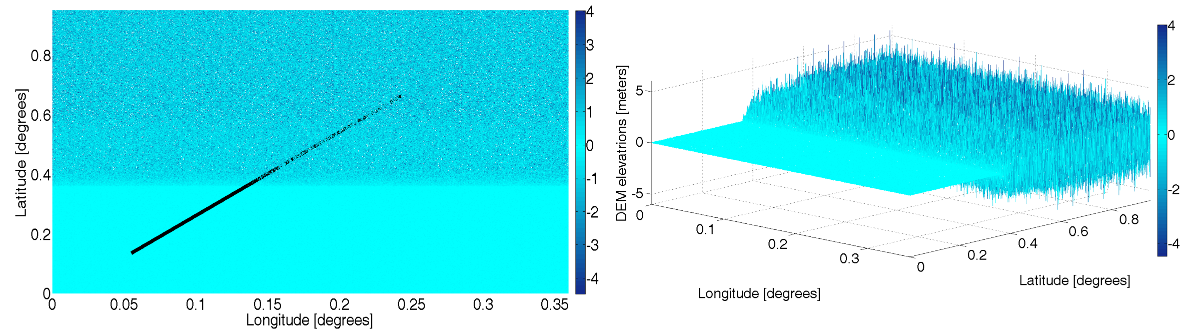
1. Interleaved performance improvement

2 preliminary tests cases used for preliminary verification:

– SMC04:
  - 2 different SWH,
  - constant Sigma-0 = 15 dB
  - polar angle = 15º



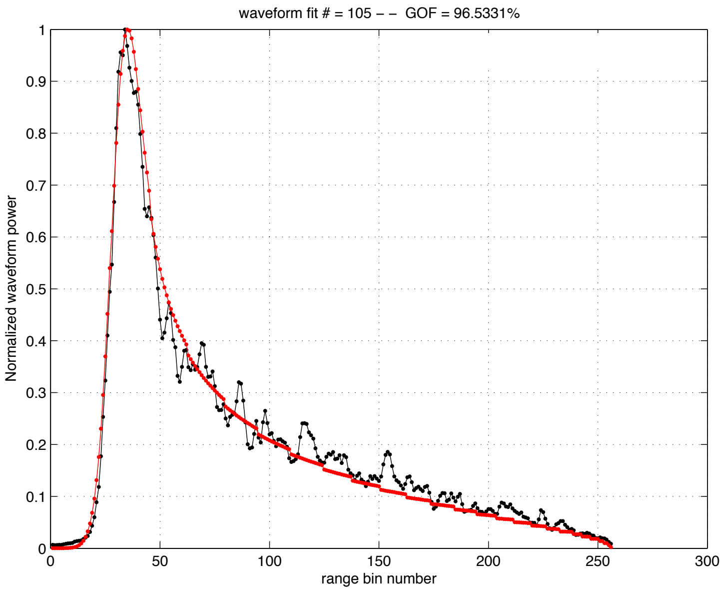
– SMC01:
  - 3 different SWH,
  - constant Sigma-0



For the test of the interleaved mode, ESA has re-used its investment in the SAMOSA project and processed the Ocean DEMs, generated by NOC, with ESA Jason-CS simulator.

1. Interleaved performance improvement

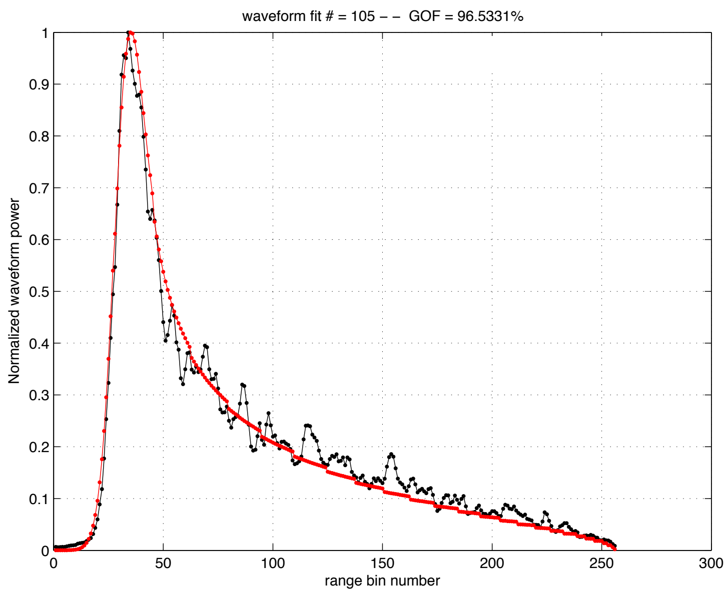
- Results using SMC04 test case:



- Retracking was undertaken by a LS fitting using the SAMOSA3 adapted model.
- This model corresponds to a meliorated version of SAMOSA3 fully adapted to any kind of L1 SAR mode processing and
- adapted to the Jason-CS interleaved mode developed by isardSAT

1. Interleaved performance improvement

- Results using SMC04 test case:



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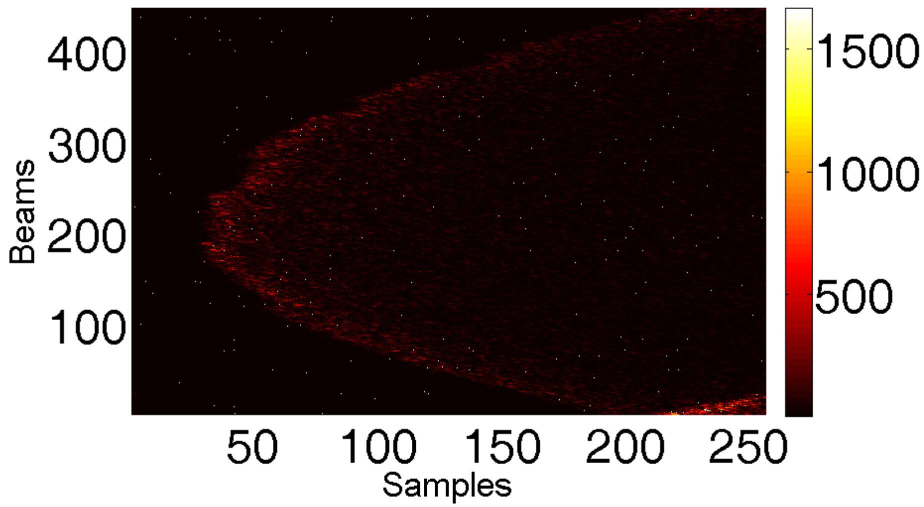
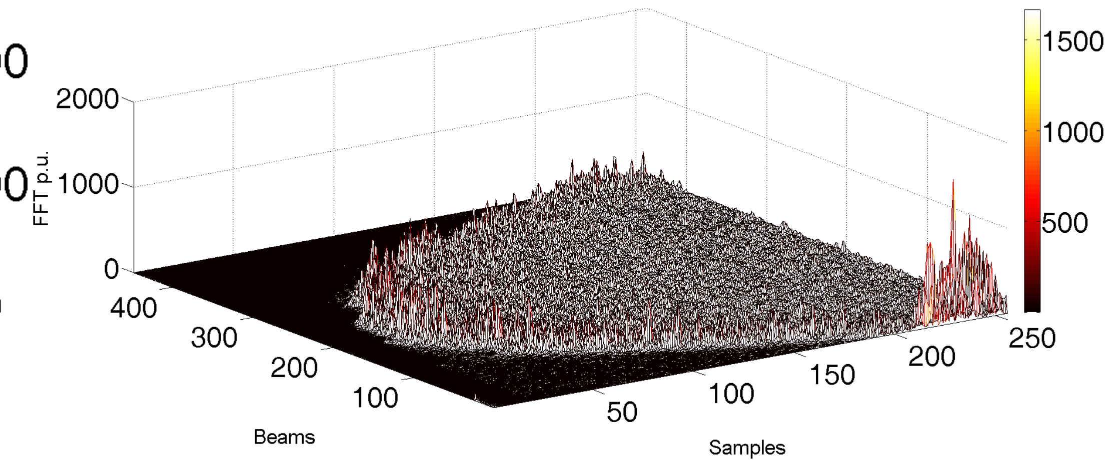
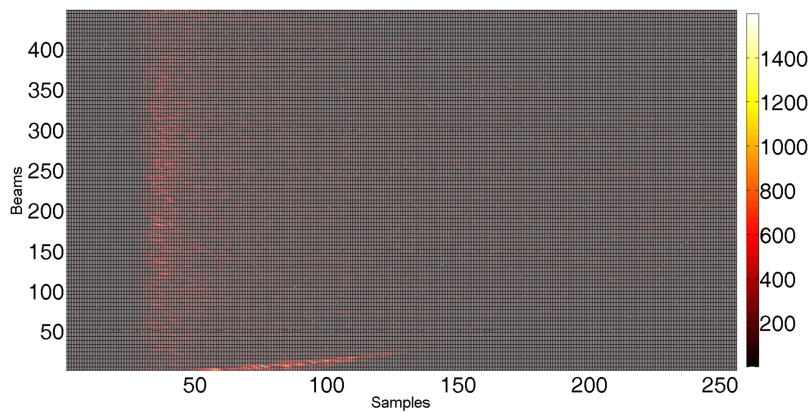
Testing results of P4 GPP New Features

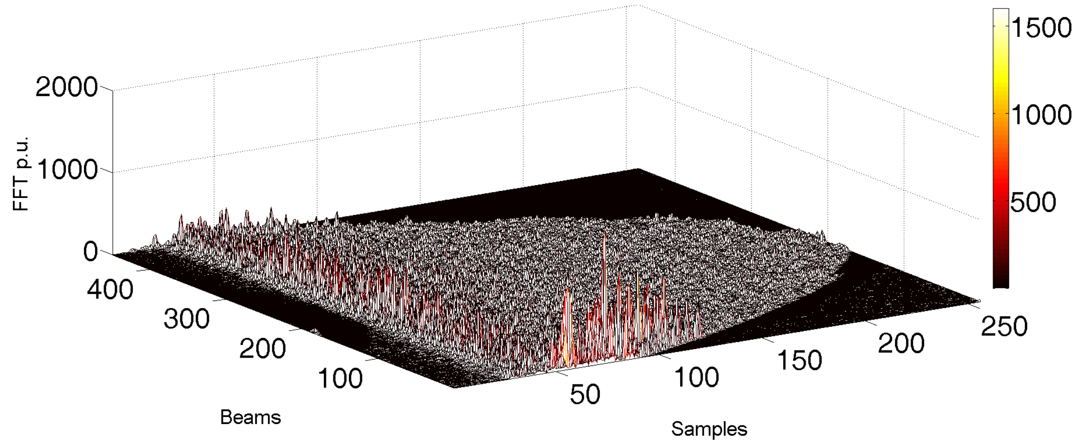
1. Interleaved performance improvement

- Doppler ambiguity removal









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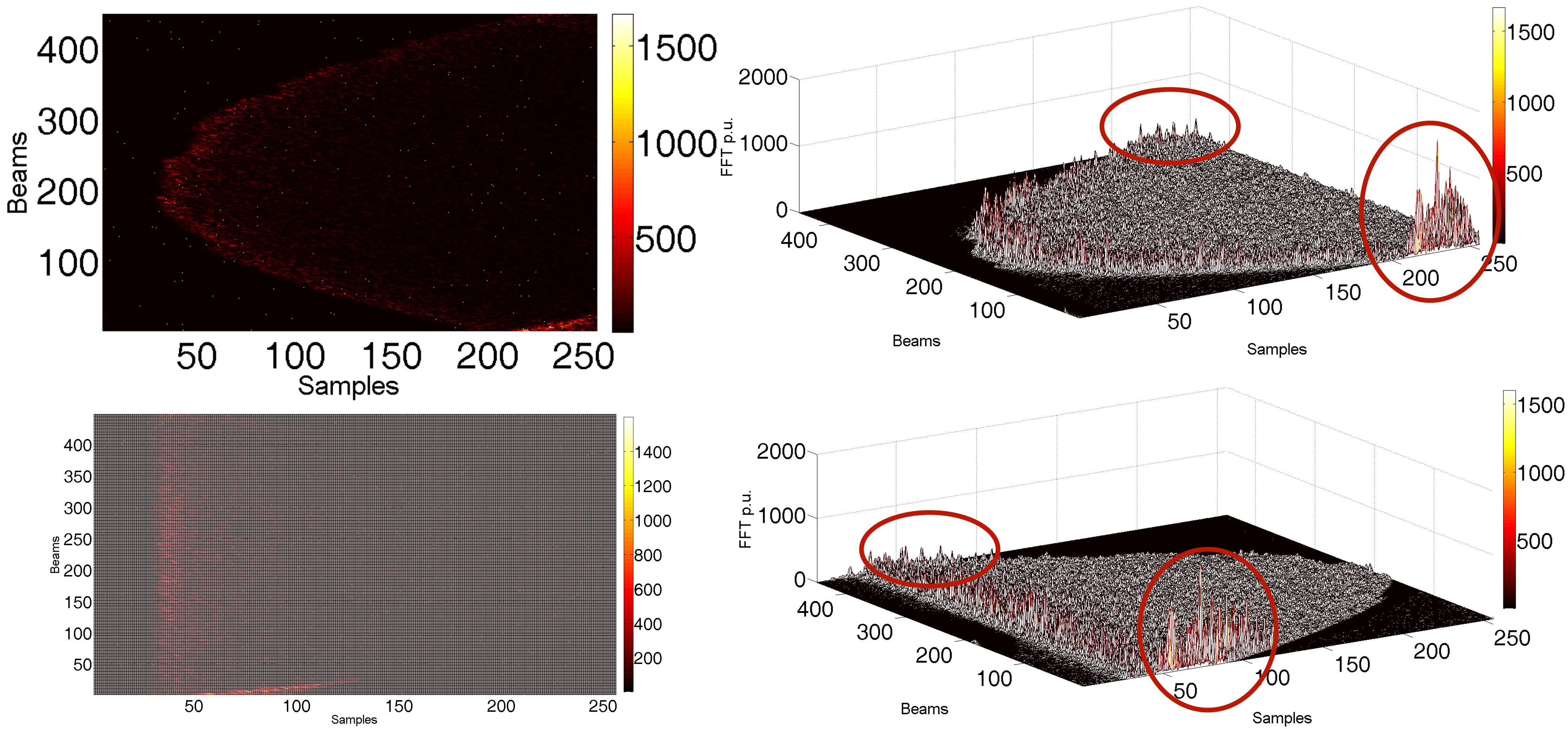
- Doppler ambiguity removal



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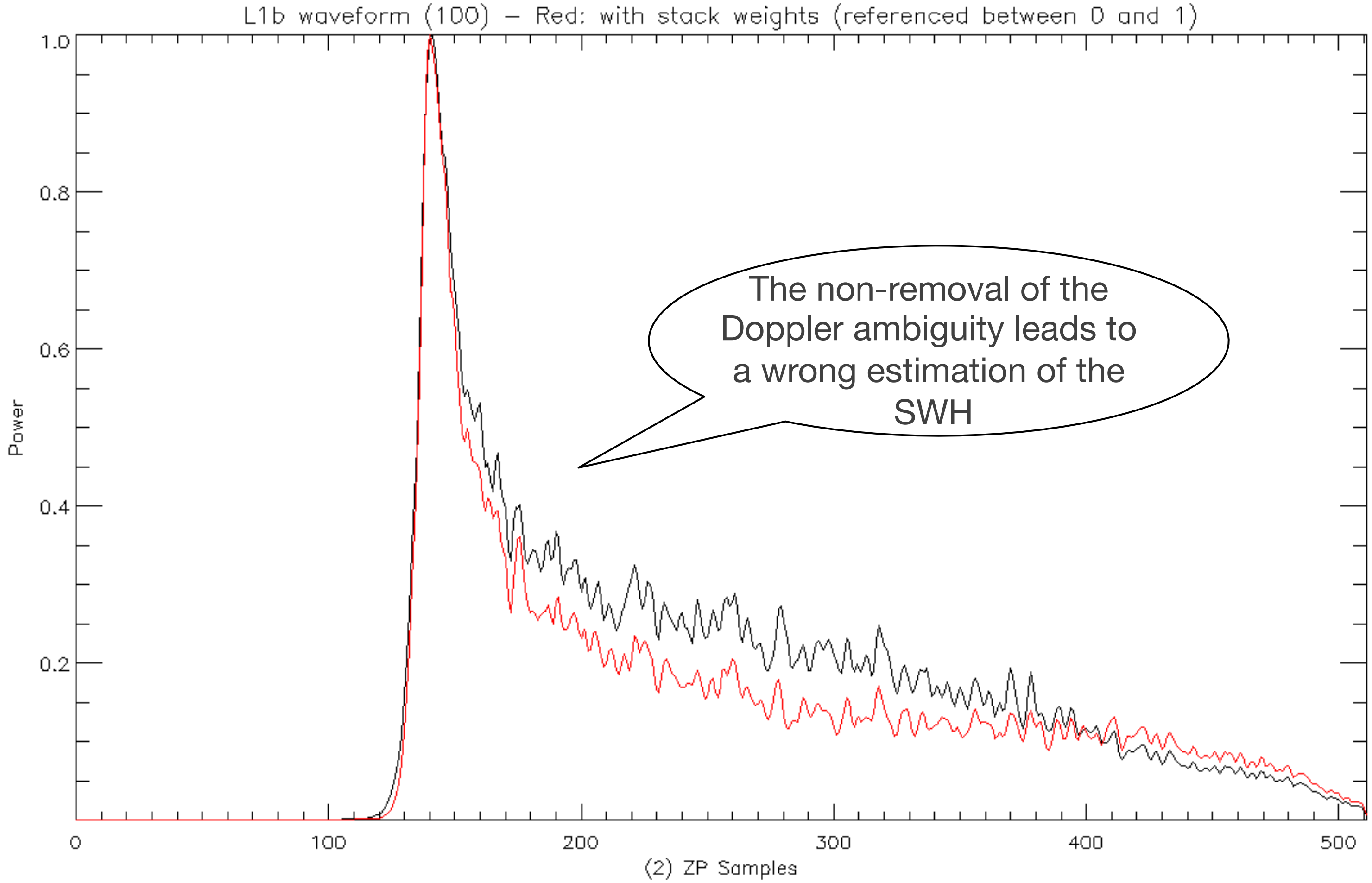

2. On-board Range Migration Correction

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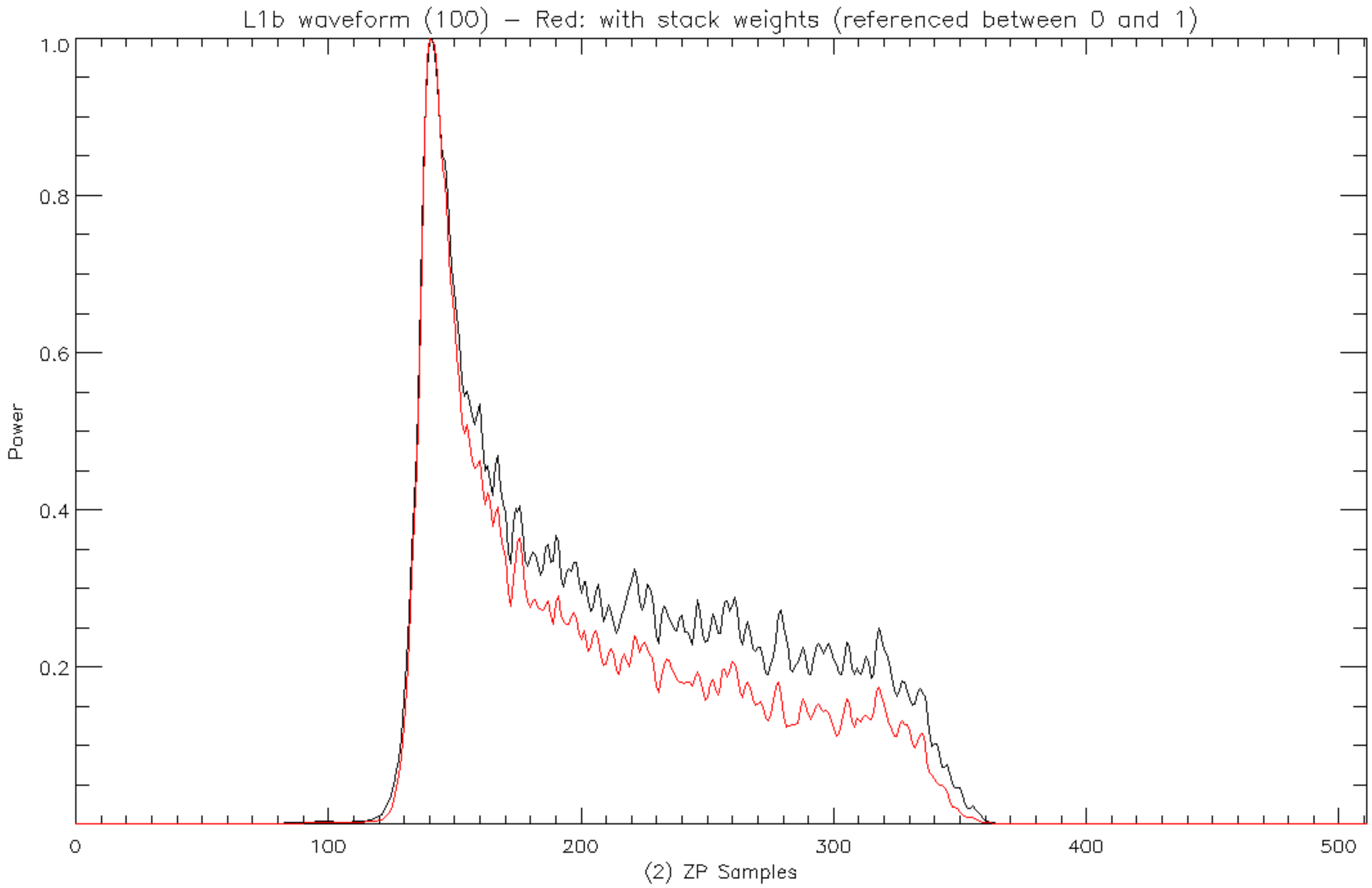

3. **Weighting:** Doppler beams weighting before multi-looking to correct the different echo shapes as a function of the incidence angle

Testing results of P4 GPP New Features

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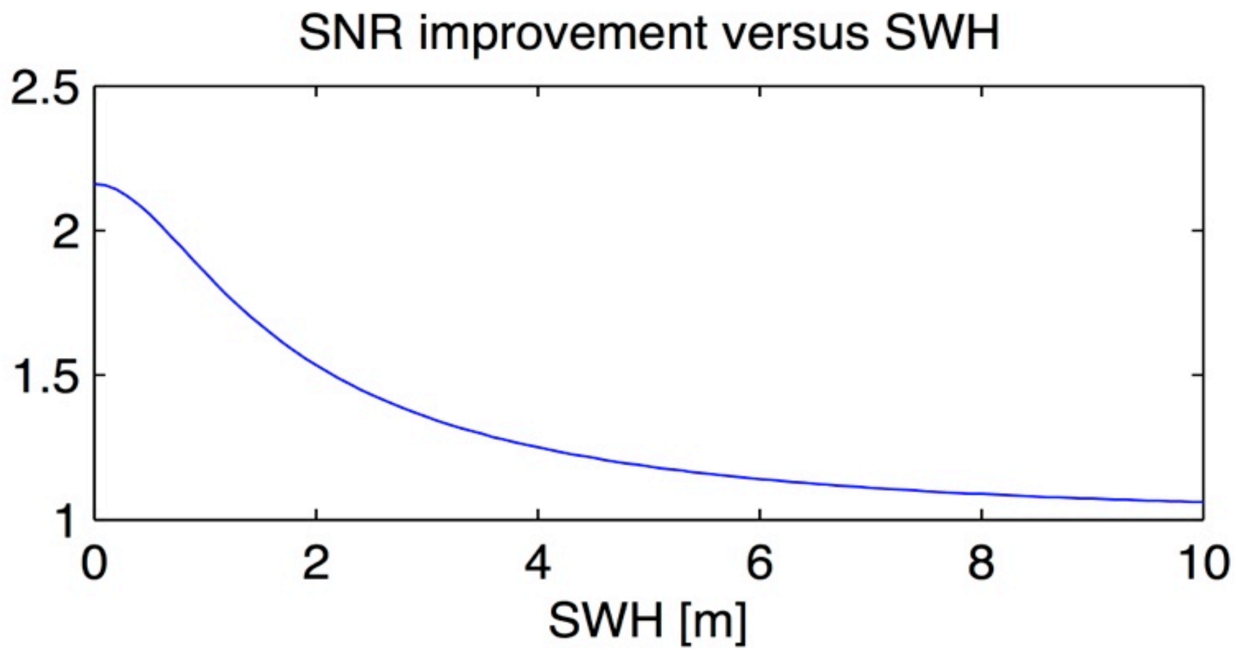
- isardSAT has developed an algorithm that weights the different beams before they are multi-looked.
- The algorithm implies a theoretical increase of the SNR, particularly for small SWH.



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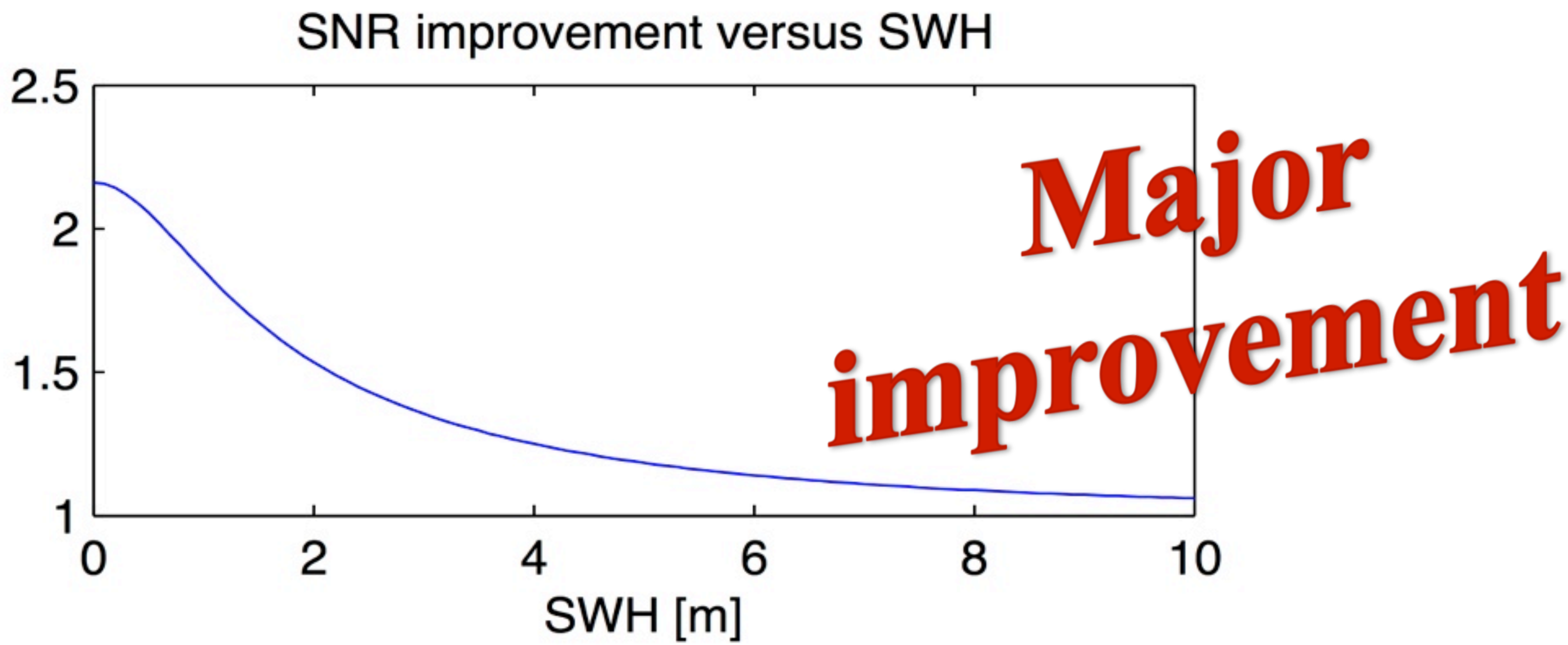

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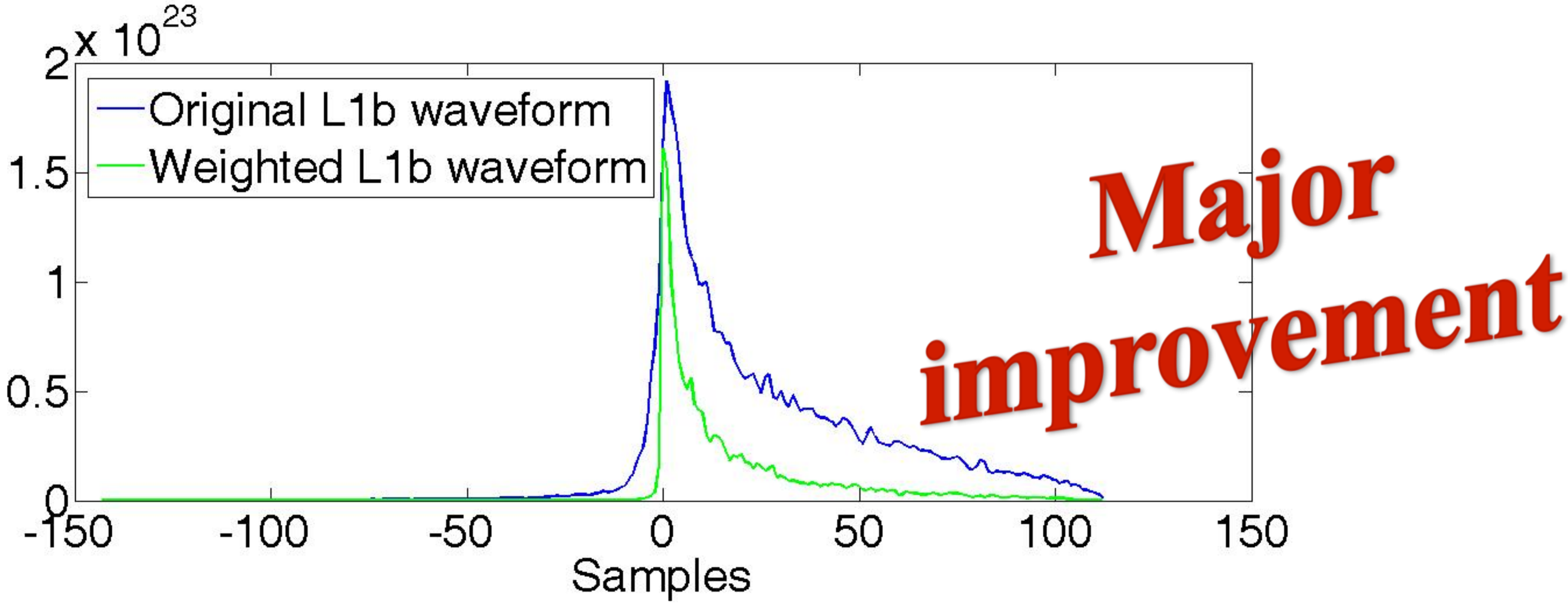

4. **Reconstruction of the waveform scaling factor to compute the surface backscatter**
(provided in the J-CS L1B product)

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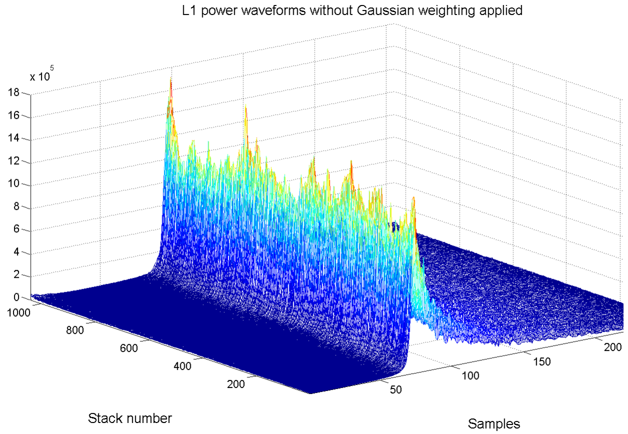

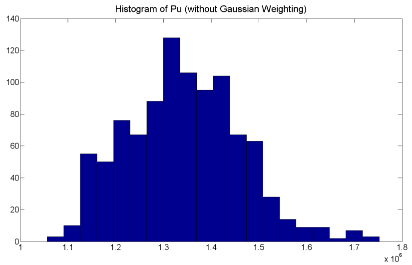

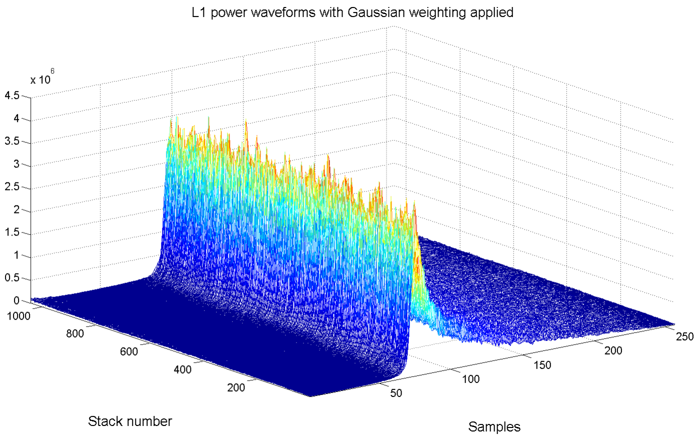

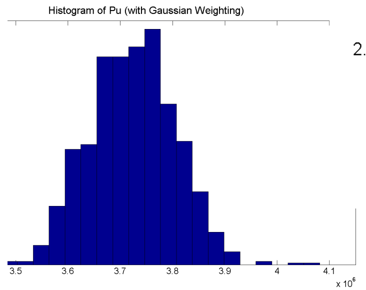

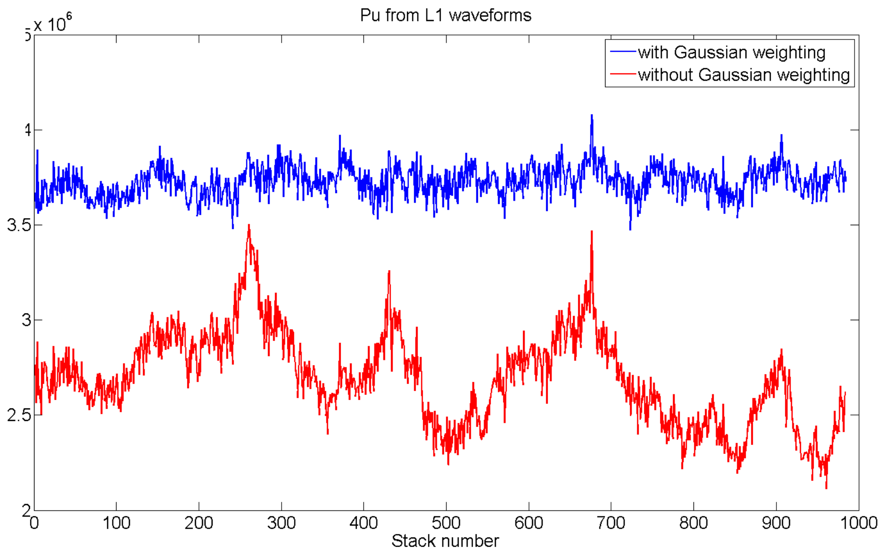

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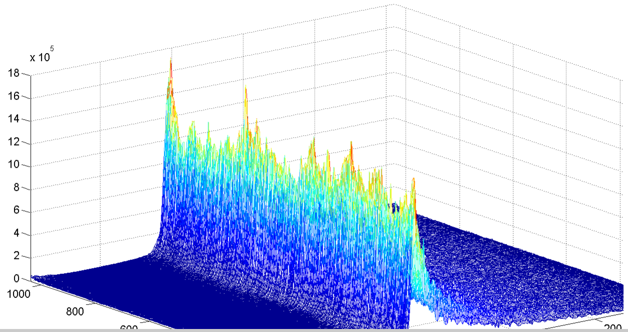
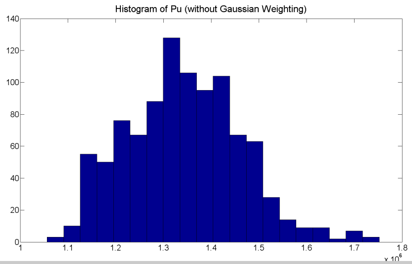
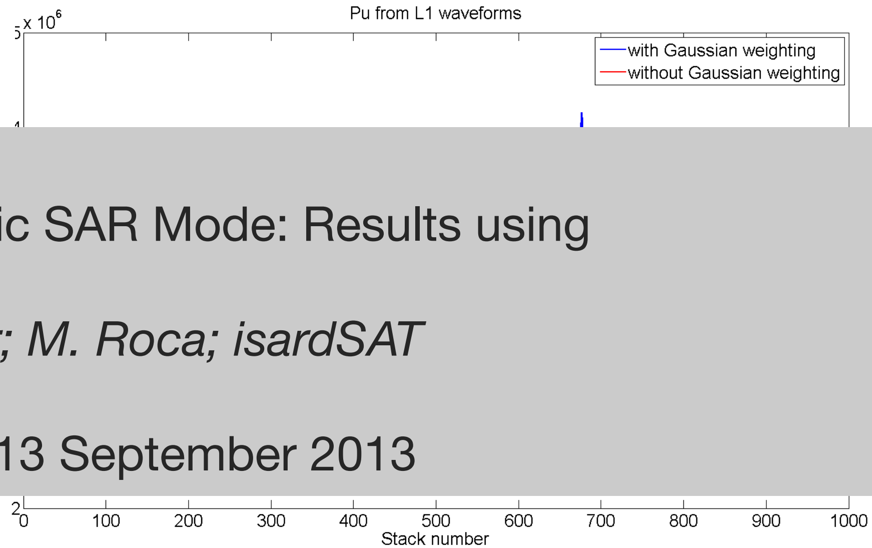
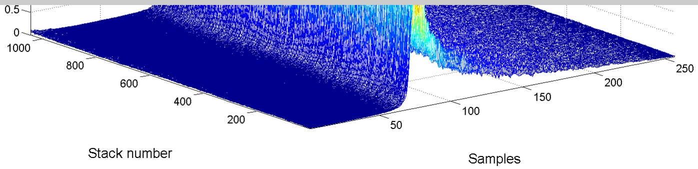


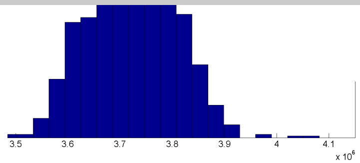




Details in
"Sigma-0 Estimation using Jason-CS Altimetric SAR Mode: Results using Simulations and in Orbit CryoSat Data"
R. Escolà; C. Martin-Puig; A. Garcia-Mondéjar; M. Roca; isardSAT

ESA Living Planet Symposium, Edinburgh, 9-13 September 2013





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Conclusions

- Under ESA requirements isardSAT has specified, developed and tested the Jason-CS P4 GPP, under an ESTEC/ESA contract through Astrium GmbH.
- This GPP is now fully adapted to open burst interleaved mode.
- The open burst interleaved data stream allows **simultaneous** production of heritage pulse-width limited and the newer azimuth (SAR) echo generation.
- In line with theory, open burst operation improves performances compared with closed burst.
- Because of the PRF (9KHz) is lower than the Doppler bandwidth, one will observe Doppler ambiguity (or aliasing). This effect needs to be taken care off.
- isardSAT is also working on further improving the data processed, e.g.:
  - Providing the all scaling factors to compute Sigma-0 in SAR mode;
  - Innovatively weighting the beams in the stack data prior multi-looking that shall improve the SNR up to 2 with very low SWH.

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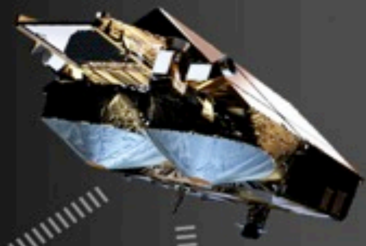
Thank you



Additional viewgraphs

Jason-CS GPP: Science Product

L1A (calibrated, geolocated bursts: Calibrated CS FBR) containing:

- Burst geolocation information
- Complex waveforms (scaled to reduce size)
- All information to generate L1B-S and in turn L1B
- Uses:
  - Comparison of PL with SAR (this doesn't make sense with open burst for Jason-CS) derived geophysical parameters such as sigma 0, SWH, wind speed, etc.)
  - Study of different beam formation method (FFT - exact or approximate or z-transform, for example).
  - Data ideally should be calibrated.
  - Cost of developing L1A-L1B processors is significant so in general only a few users.
  - Data volume similar to L0.

Jason-CS GPP: Science Product

L1B-S azimuth processed complex echoes immediately prior to multi-look:

- Scaled complex echoes with scaling information.
- Window delay variation (change in on-board tracking due to orbit and surface) over stack applied.
- Contain all information of L1b.
- Allow studies on surface characterisation, detailed calibration studies (transponders, for example), beam weighting, range dilation, etc.
- Note this is not stack data breakpoint (we are used to using in CryoSat) that holds complex echoes and range correction info.
- Data are calibrated.
- Larger distribution to users.
- Product volume similar to L0.

L1B Multi-looked power echoes (equivalent to CS-2 L1b)

- Scaled Power echoes with scaling info
- Geolocation information
- Stack characterisation information (example, beam behaviour parameters in CS-2 product)
- Product size ~ L1b for other missions (apart from 256 range samples)