→ 10th COASTAL ALTIMETRY WORKSHOP

SAR Altimetry Training Course

Future missions: Sentinel-6/Jason-CS

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and

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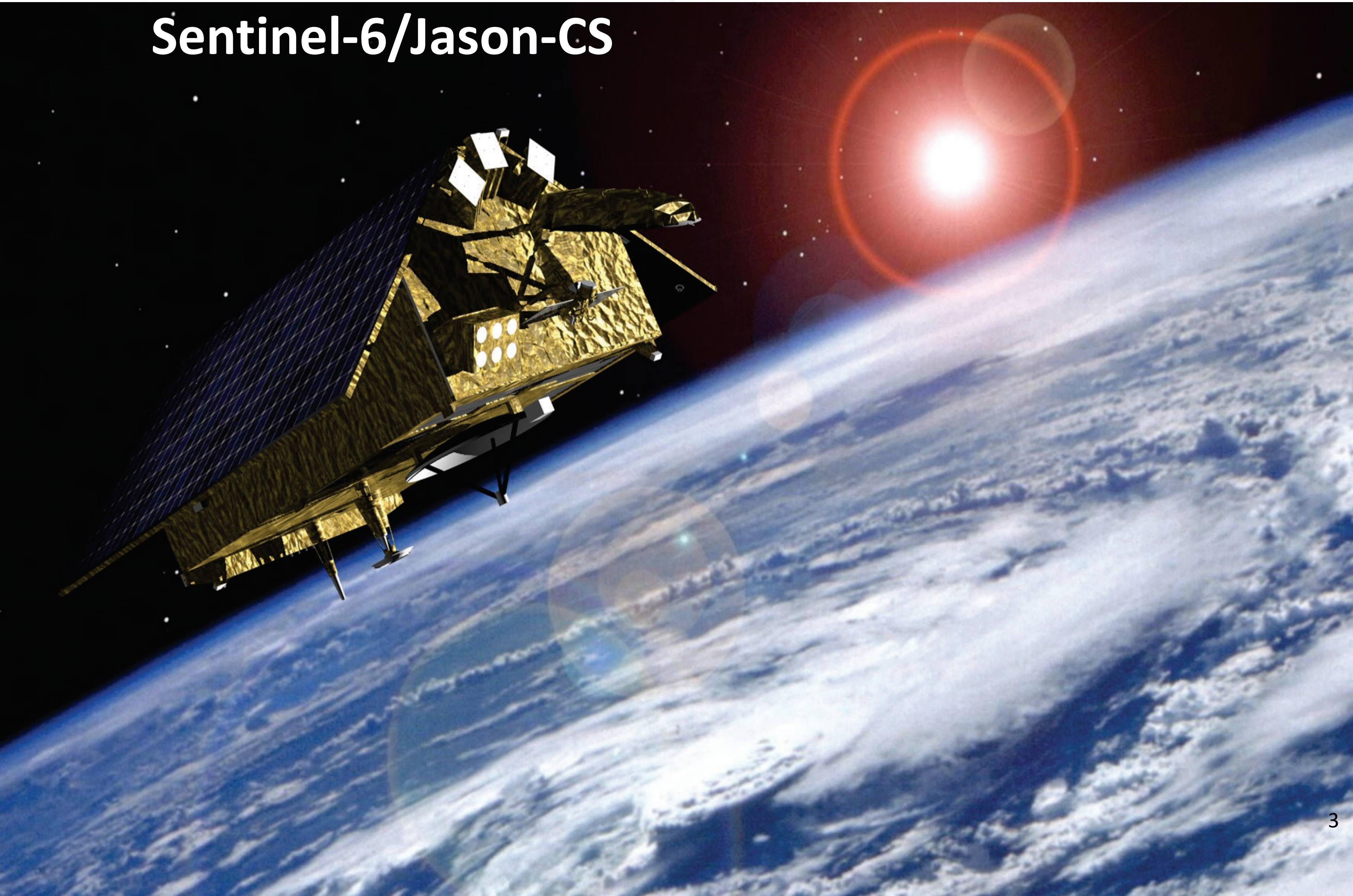
21–24 February 2017 | Florence, Italy

Outline

1. Mission Partners and Satellite
2. Instrument
3. Sentinel-6/Jason-CS P4 GPP
   – New features for research purposes
4. S6/JCS P4 GPP data results with simulated data

Sentinel-6/Jason-CS



Partners

ESA: Majority funding for development of Satellite A. Procurement of Satellite B.

EUMETSAT: Complementary funding for Satellite A, funding of GS (European part), operations & shared funding of Satellite B with EU.

EU: Shared funding of Satellite B & funding for all operations.

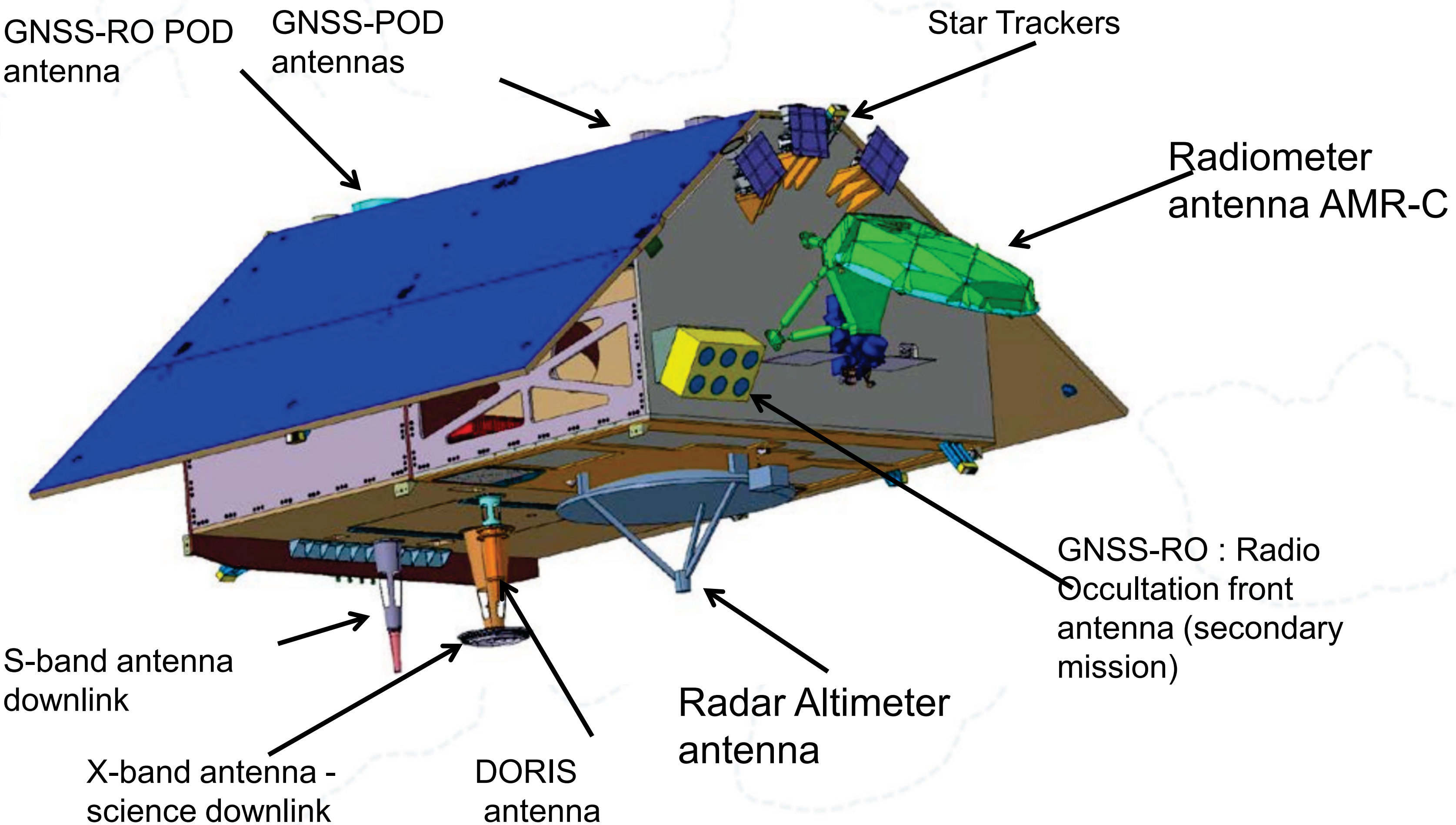
CNES: Provision of system expertise, performance analysis & orbit determination.

NOAA: Provision of some payload, launcher and ground station.

NASA: development of payload instruments and funding of US science teams.

Satellite

- The Platform Structure end Phase B2



Instrument

Main innovations of Poseidon-4 (P4):

1. Includes improved **digital** and radio frequency **hardware**.
2. Includes open burst Ku-band pulse transmission (**interleaved** mode): performs a near continuous transmission of Ku-band pulses. *It will allow simultaneous processing of the measurements to obtain High Resolution along-track (HR or SAR) and Low Resolution along-track (LR or LRM) data.*
3. As previous satellite RA, the P-4 transmits **C-band** pulses in order to retrieve a correction for ionospheric path delay.
4. Implementation of On-board "Range Migration Correction" (**RMC**) processing in order to reduce data rate.

Instrument

- Implications of main innovations of Poseidon-4 (P4):
  1. **Digital HW**:
     Sampling frequency= 395 MHz (Δr between samples= ~37.9 cm), different from Bandwidth= 320 MHz (Δresolution= ~46.8 cm).

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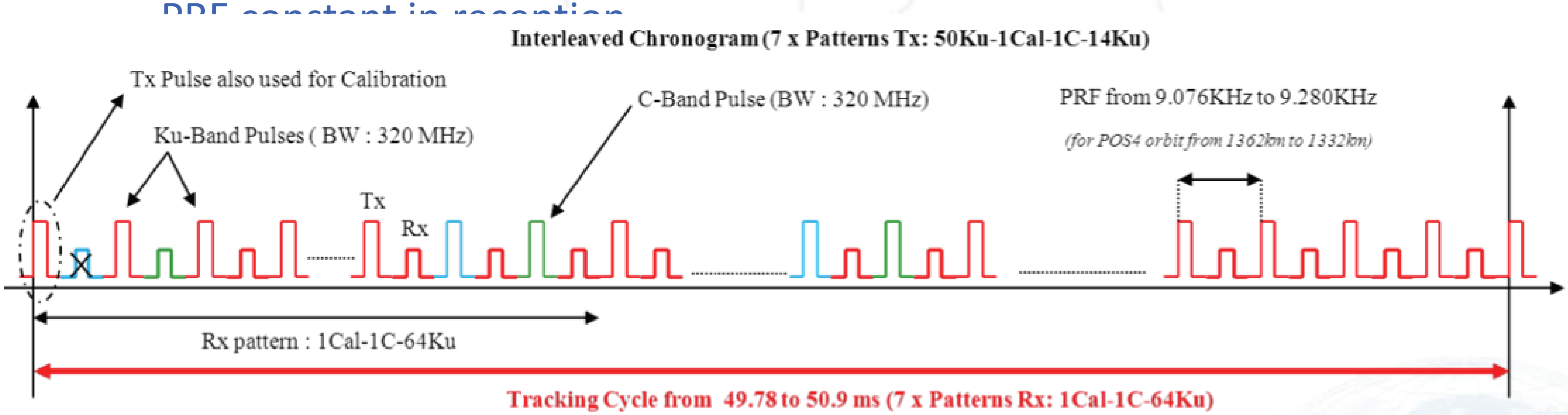
  2. **Interleaved**:
     PRF ~ 9 KHz Careful with Doppler ambiguities !

     PRF (or PRI) changes around the orbit.
     PRF constant in reception



Instrument

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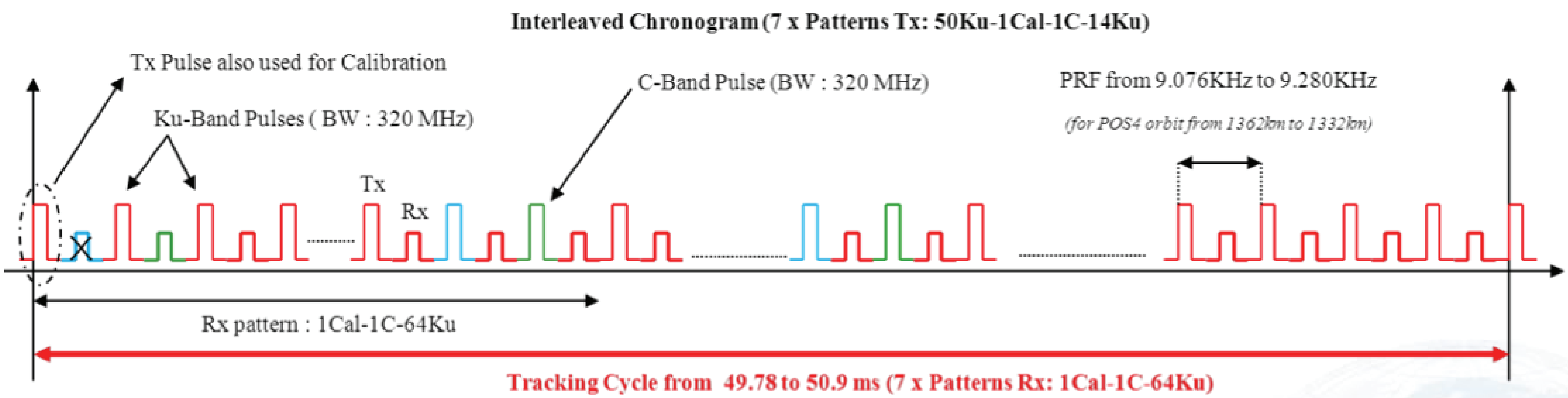


Transmission Schemes

- **Possibility to obtain both LRM and SAR waveforms if the interleaved transmission mode is adopted.**

- The statistical equivalence to native LRM waveforms is not given by RDSAR waveforms.

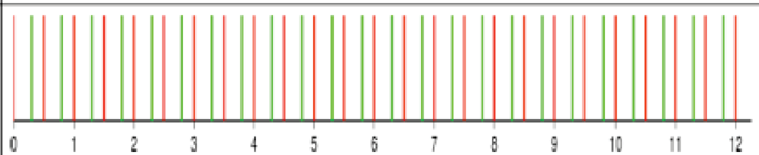
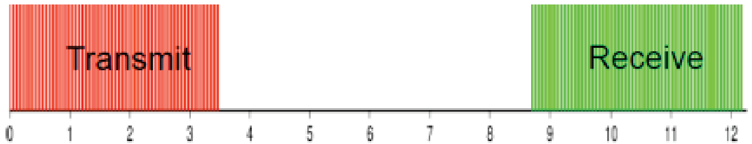
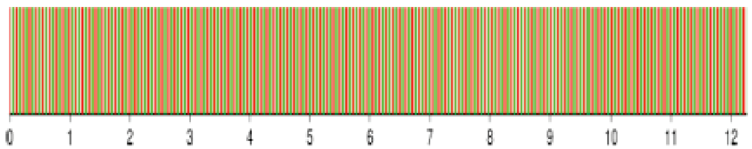
OPERATION MODE	CHRONOGRAM	ALTIMETRIC MISSIONS
Low Resolution Mode (LRM) Low PRF (1-4kHz) Continuous Tx/Rx		All past ocean altimeter missions Cryosat-2 LRM AltiKa Jason-3
SAR Closed-Bursts High PRF (~20 kHz) Tx/Rx in bursts		Cryosat-2 SAR Sentinel-3
SAR "Interleaved" Moderate PRF (~ 9 kHz) Continuous Tx/Rx		Jason-CS

FIGURE 2: CHRONOGRAMS FOR LRM (TOP), SAR CLOSED BURST MODE (MIDDLE) AND SAR INTERLEAVED MODE (BOTTOM) (SOURCE: ADAPTED FROM SMITH ET AL., 2013)

Credit: Gommenginger et al. (2013)

Transmission Schemes

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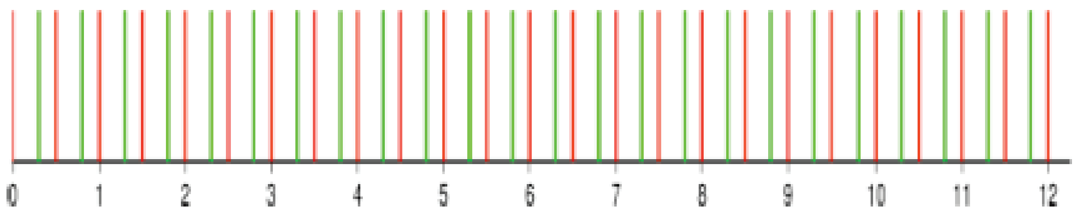
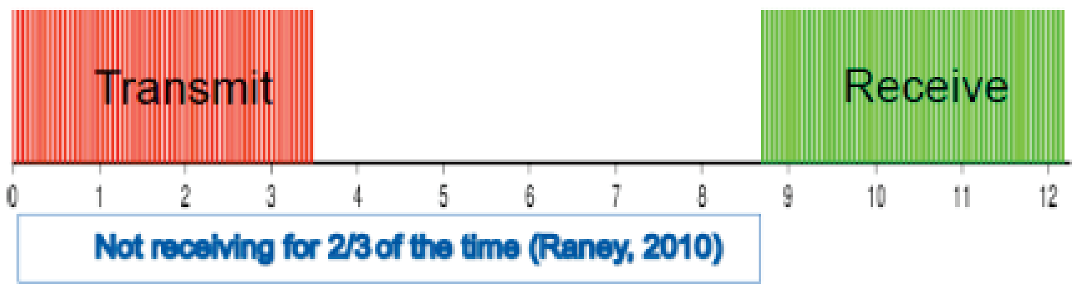
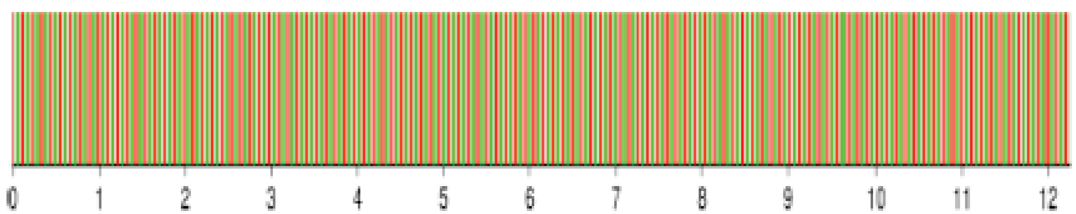
Low Resolution Mode (LRM) Low PRF (1-4kHz) Continuous Tx/Rx		All past ocean altimeter missions Cryosat-2 LRM AltiKa Jason-3
SAR Closed-Bursts High PRF (~20 kHz) Tx/Rx in bursts		Cryosat-2 SAR Sentinel-3
SAR "Interleaved" Moderate PRF (~ 9 kHz) Continuous Tx/Rx		Jason-CS

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Transmission Schemes

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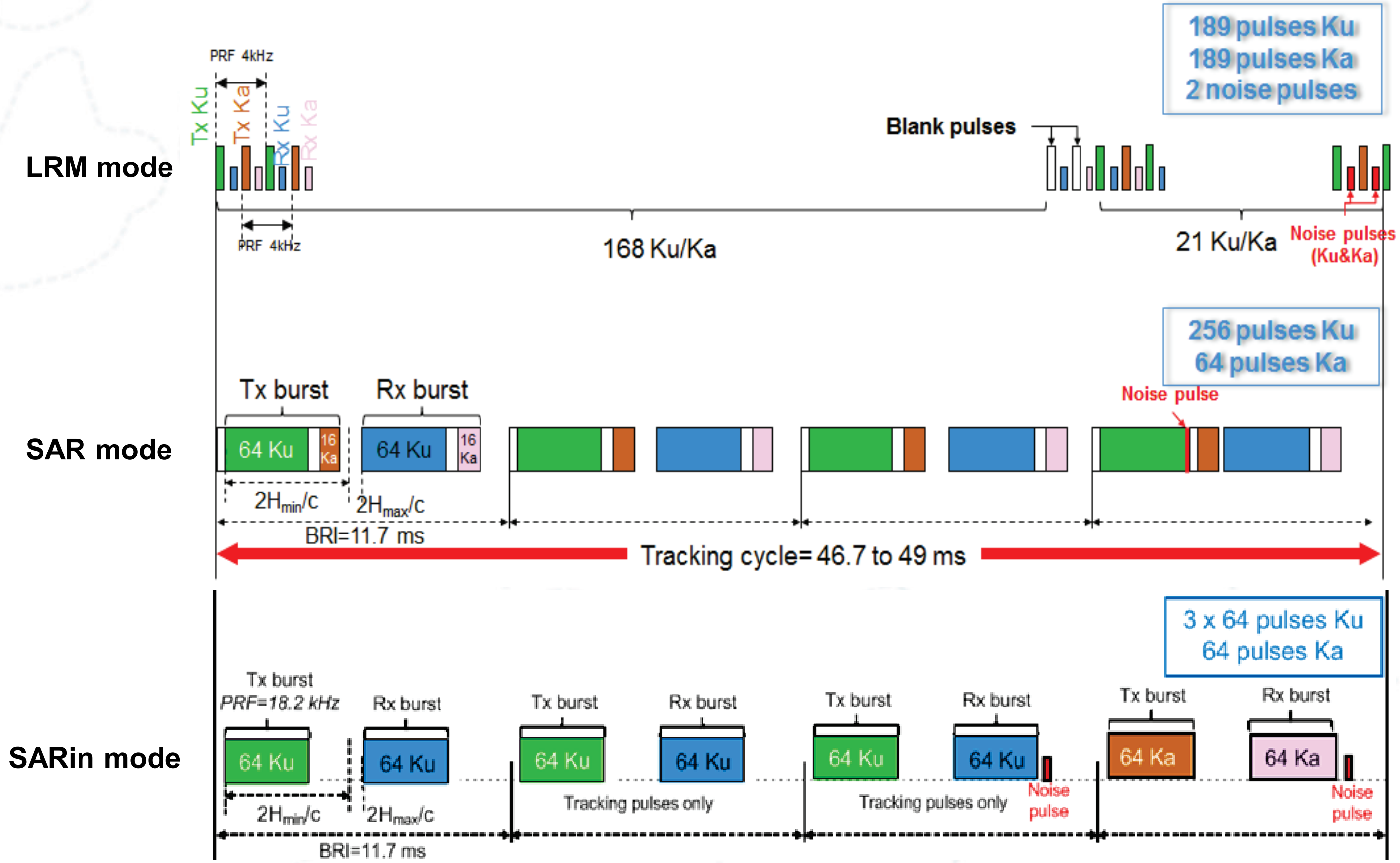
Concepts For Cost-Effective Enhanced CryoSat Continuity

(Ku+Ka)-Band radar configuration

WE LOOK AFTER
THE EARTH BEAT

(Ku+Ka)-Band radar configuration

- (Ku+Ka)-Band nadir altimeter timeline
  - Ku-Band chronogram not modified wrt nominal configuration
  - Alternate operation between Ku- and Ka-Band pulses



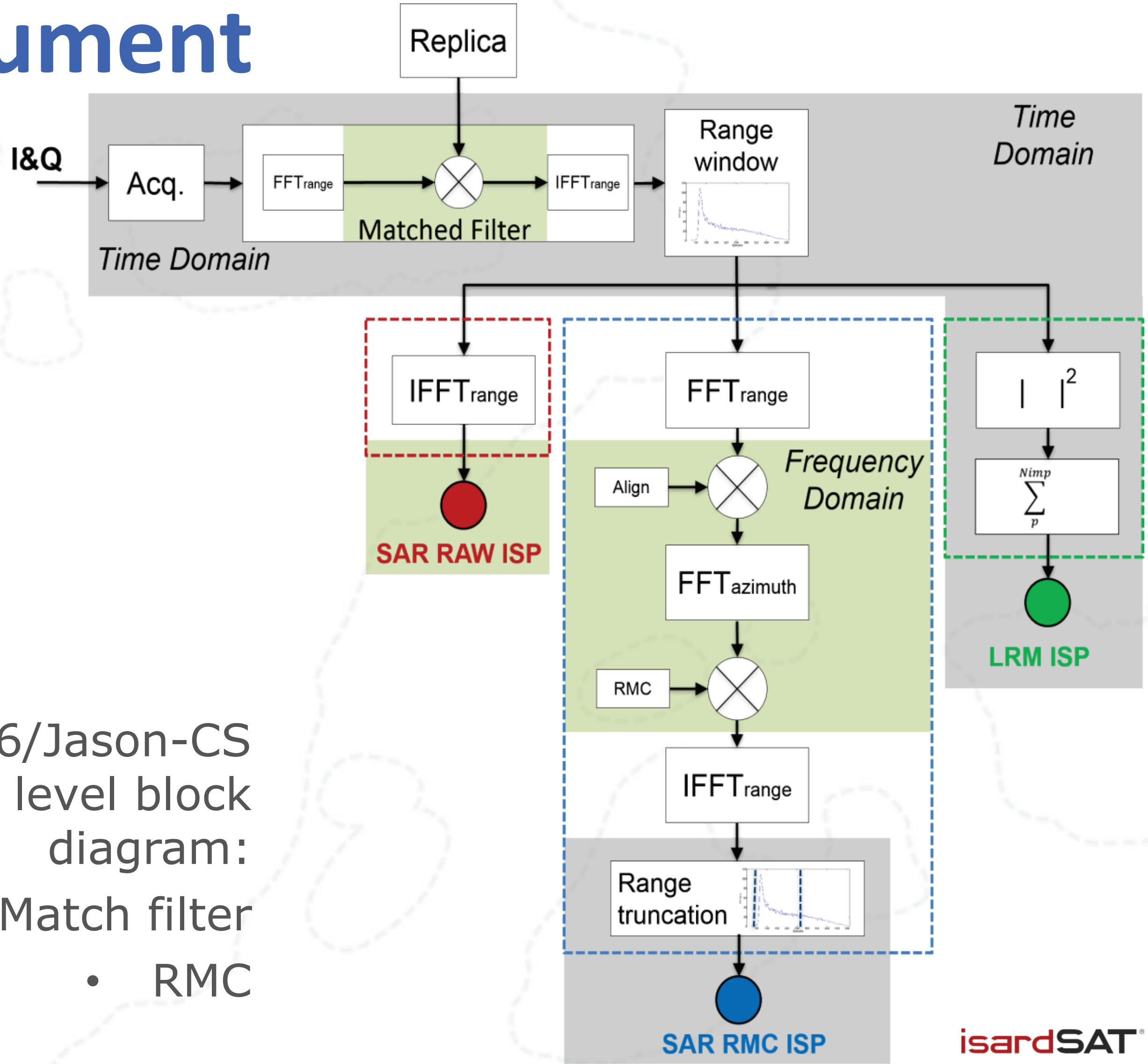
Instrument

- Implications of main innovations of Poseidon-4 (P4):

1. **Digital HW**:
   Sampling frequency= 395 MHz (Δr between samples= ~37.9 cm), different from Bandwidth= 320 MHz (Δresolution= ~46.8 cm).
2. **Interleaved**:
   PRF ~ 9 KHz Careful with Doppler ambiguities !

   PRF (or PRI) changes around the orbit.
   PRF constant in reception.
3. **C-band** pulses also interleaved with Ku-band pulses.
   C-band at 5.41 GHz with Bandwidth= 320 MHz.
4. **RMC**: echo cut off (tail).

Instrument



Sentinel-6/Jason-CS high level block diagram:

- Match filter
- RMC

Sentinel-6/Jason-CS P4 GPP

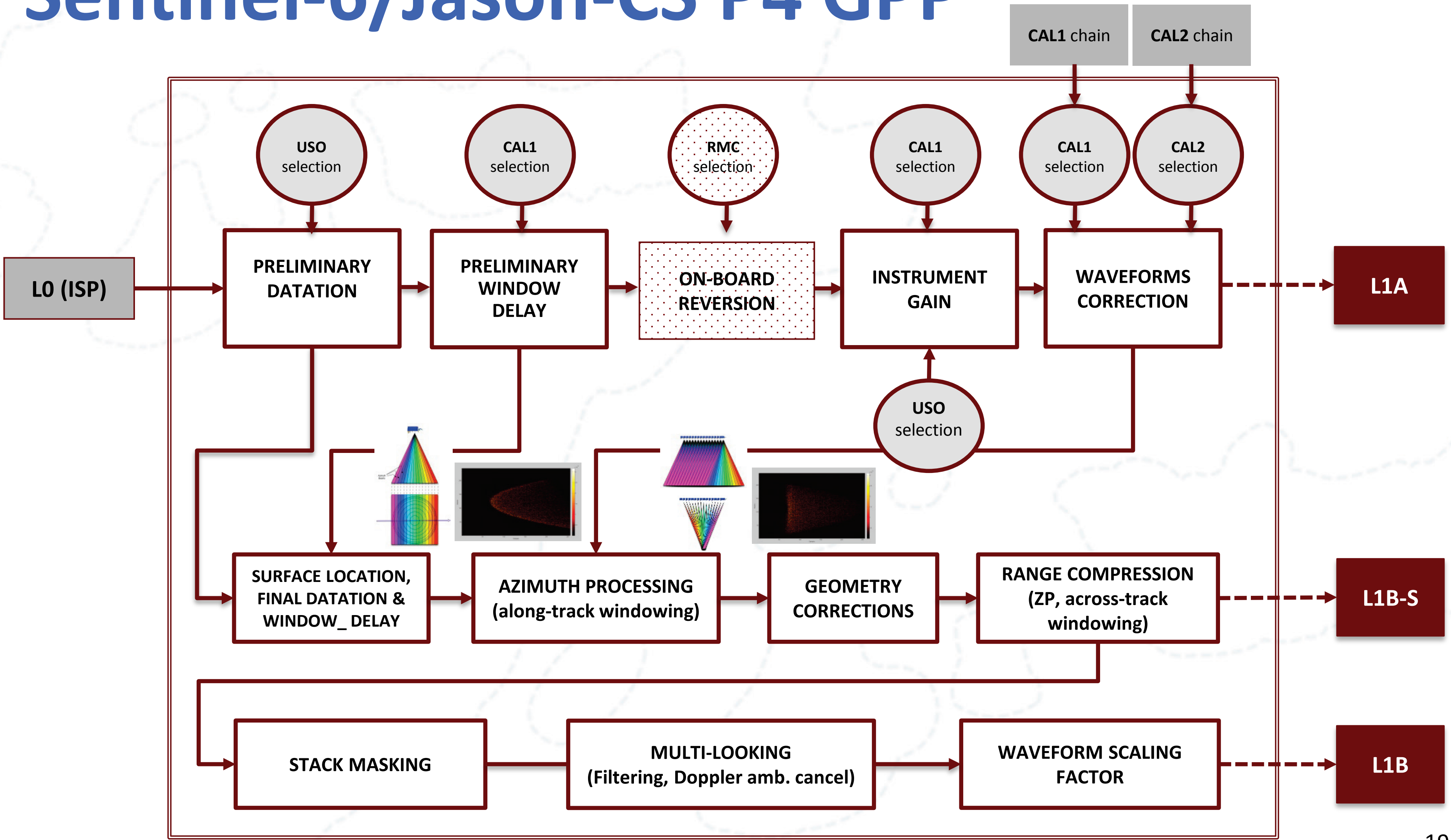
- The Ground Prototype Processor (GPP) for the Poseidon-4 is being developed under an ESA contract awarded to isardSAT.
- This prototype processes all the chains starting from the Instrument Source Packets (ISPs), and up to the Level 1B (calibrated pulse-width limited or multi-looked SAR data).

Sentinel-6/JCS P4 GPP: new features

Special attention to new features:

- Un-correction of the Range Migration Correction (RMC) performed on-board in order to reduce the data rate.
- Doppler ambiguity effects, due to the low PRF, onto the geophysical retrievals.
- Match filter implications.
- Gaps and mode transition approach and surface reconstruction.
- Stack masking to remove clutter effects such as Doppler ambiguity, land contamination, gaps and transitions, aliasing, etc.
- Amplitude Compensation and Dilation Correction (ACDC) stacking algorithm.
- *Weighting applied to the Doppler beams before the multi-looking to correct the different echo shapes as a function of the incidence angle.*
- *Reconstruction of the 3D waveform scaling factor in order to account for the angle of incidence when computing the surface backscatter.*

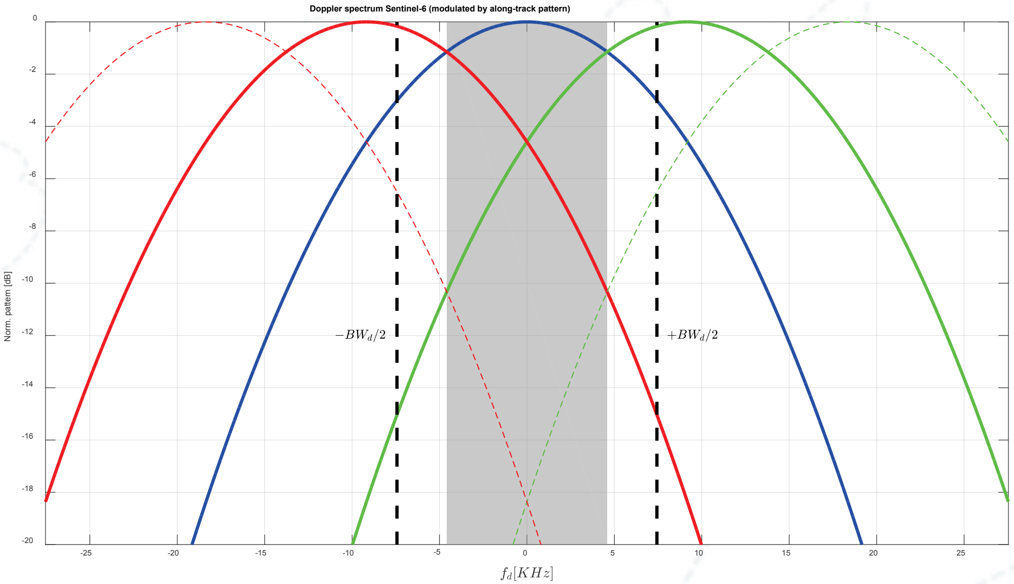
Sentinel-6/Jason-CS P4 GPP



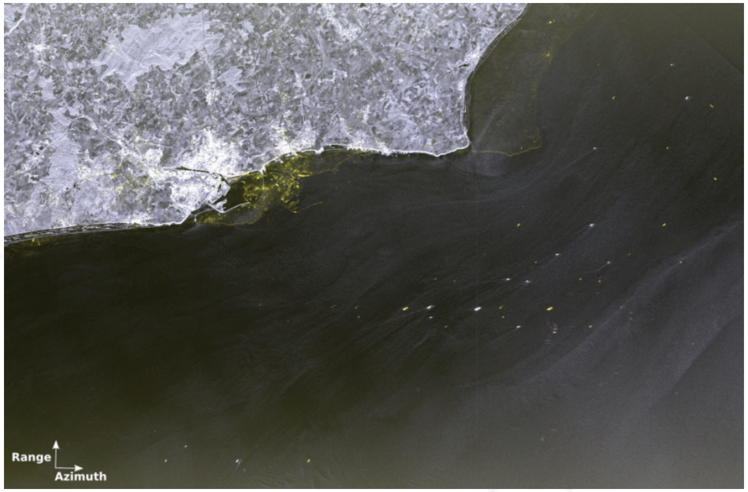
Sentinel-6/JCS P4 GPP: Doppler ambiguity

- It is well known that the digitised signal shall be sampled at a rate above the Nyquist frequency (>Bandwidth of the signal of interest), to avoid aliases in the digitised signal, so the signal can be recovered unambiguously.
- The along-track (azimuth) signal is received in a discrete-time basis (sampled by the PRF) and it is not "effectively" band-limited as the Doppler bandwidth is modulated by the antenna pattern in azimuth. This means that depending on the sampling rate, defined by the PRF (and normally constrained by system operation itself), some specific azimuth (Doppler, along-track) **ambiguities** may rise up.

Sentinel-6/JCS P4 GPP: Doppler ambiguity



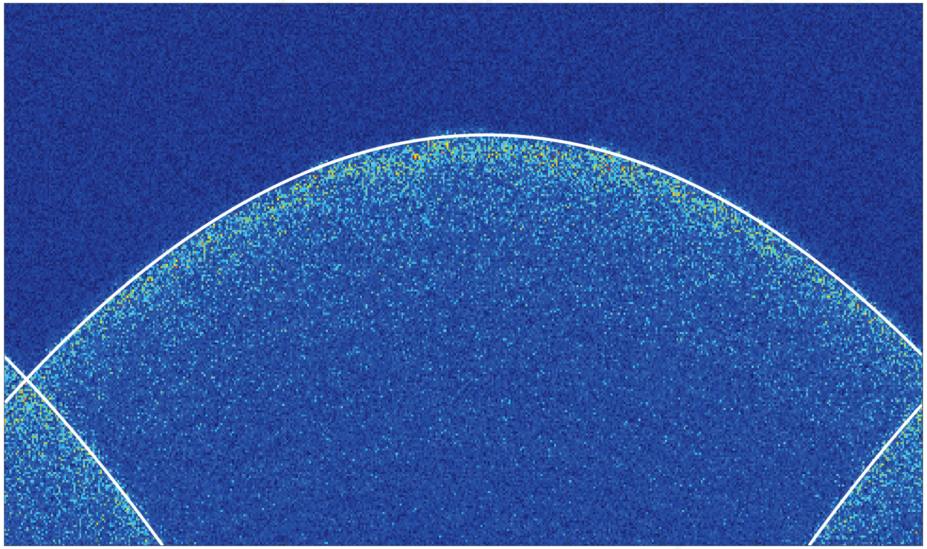
Spectrum representation of the Doppler ambiguities or aliases: the spectrum of the signal of interest (blue line); the left and right Doppler replicas (red and green lines); fundamental Doppler band represented (grey shaded area); and antenna mainlobe (black dotted lines)



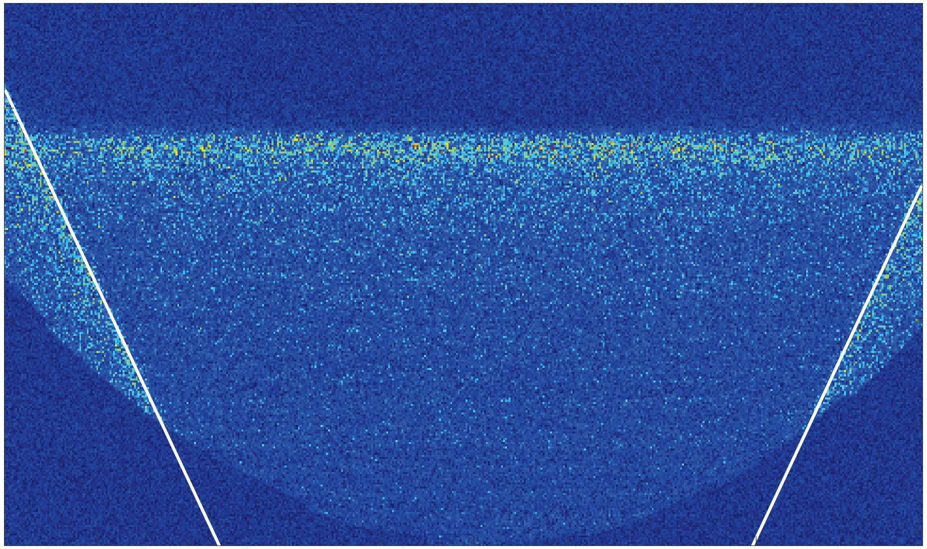
Colour composite image of TerraSAR-X over English Channel, showing the impact of azimuth ambiguities as “ghost targets” represented by the yellow colour and clearly appreciable over ocean.

Makhoul, E. *et al.*, "Multichannel SAR-GMTI in Maritime Scenarios With F-SAR and TerraSAR-X Sensors," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 8, issue 11, pp 5052 – 5067, November 2015.

Sentinel-6/JCS P4 GPP: Doppler ambiguity



Delay-Doppler map at stack level for surface #150 (overplotted as solid white line the theoretical slant range variation for the main signal as well as the aliased parts).



Delay-Doppler map at stack level for surface #150 after geometric corrections (overplotted as solid white line the theoretical residual RCMC error on the aliased parts).

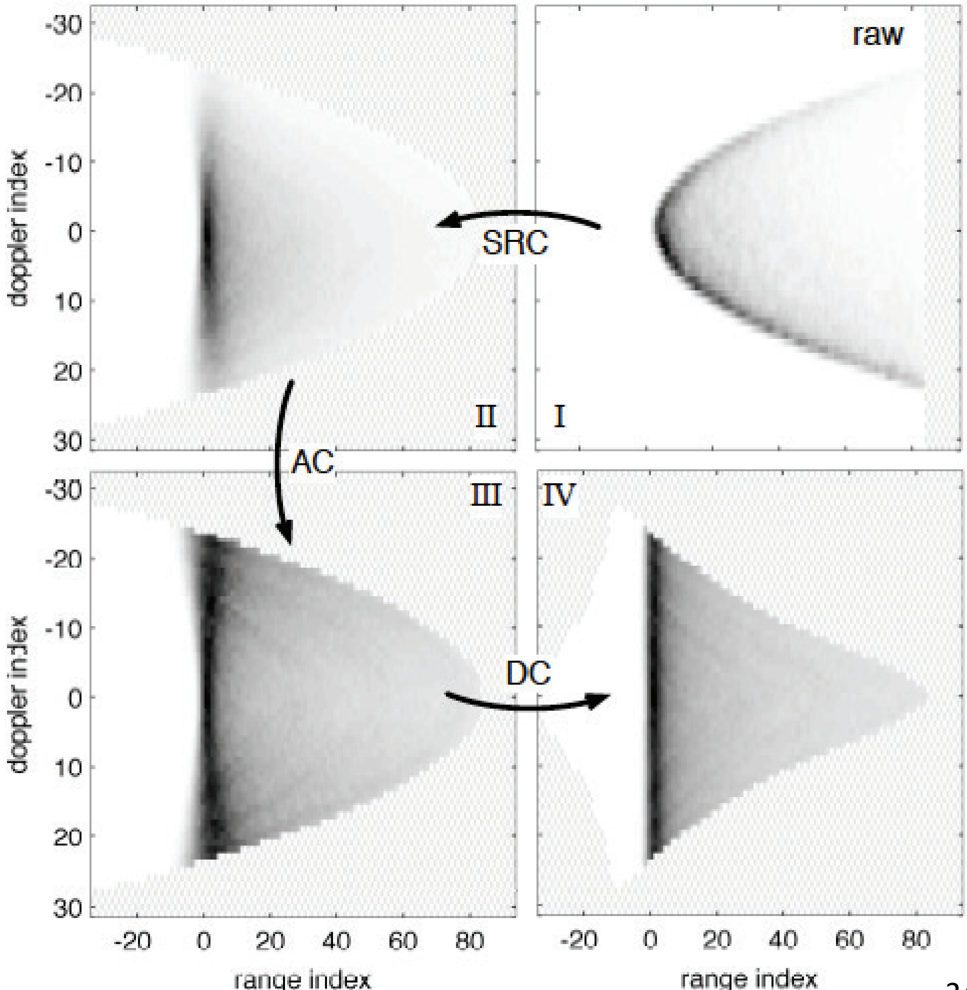
Sentinel-6/JCS P4 GPP: Stack Masking

- The concept of masking the stack has been used for the application several correction:
  - Slant range (or range migration): to avoid waveform wrapping
  - Doppler ambiguity: remove ambiguities
  - Mode transitions: to mask RAW beams until the stack is full
  - Gaps: to remove gaps beams in a stack
- Can be extrapolated to other masks (e.g. water mask) through external file or even pencil drawing

Sentinel-6 P4 GPP: ACDC

- After compensation for both along-track amplitude variation and across-track dilation the backscattered power becomes one dimensional → the power no longer varies between different Doppler looks.
- The AC/DC waveform is fit by a single one argument function by adjusting the amplitude, scale and offset, which greatly speeds the retracking computation.
- The AC/DC retracked SWH and sea surface height have reduced noise.
- The reduction in noise is greater for seas with smaller SWH.
- For SWH = 2 m.→ reduction is a factor of 3 for the sea surface height and 2 for SWH.

"Amplitude and Dilation Compensation of the SAR Altimeter Backscattered Power". By Chris Ray, Mònica Roca, Cristina Martin-Puig, Roger Escolà, Albert Garcia. In *IEEE Geoscience and Remote Sensing Letters, Vol. 12, No. 12, December 2015. DOI: 10.1109/LGRS.2015.2485119.*



S6 P4 GPP UDD with simulated data

Data to users:

- ftp.eopp.esa.int
- sentinel6-science
- yot7+scart

- 3 ocean scenarios:
  - SWH:
    - low SWH = 0.1 m
    - mid SWH = 1 m
    - high SWH = 5 m
  - Same elevation

T01 – SWH = 0.1 m

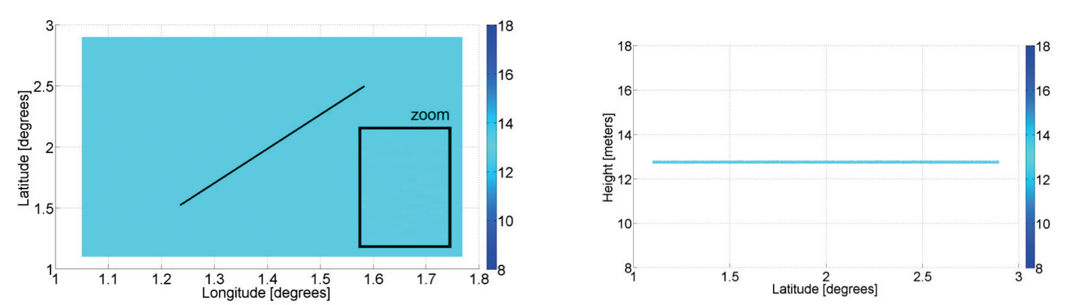


Figure **Error! No text of specified style in document.**-1 DEM of the T01 (std = 0.25 cm)

T02 – SWH = 5 m

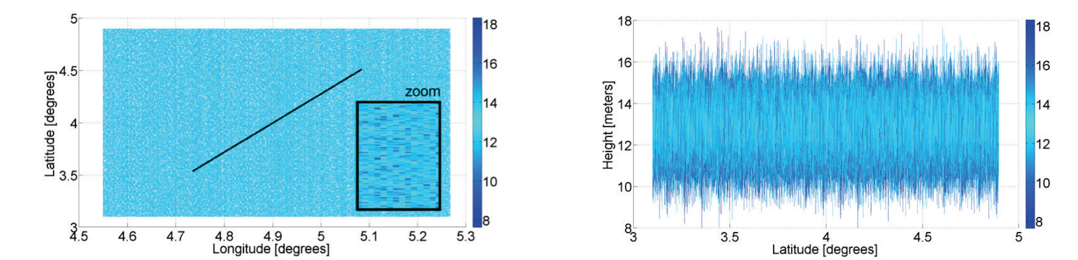


Figure **Error! No text of specified style in document.**-2 DEM of the T02 (std = 1.25 m)

T03 – SWH = 1 m

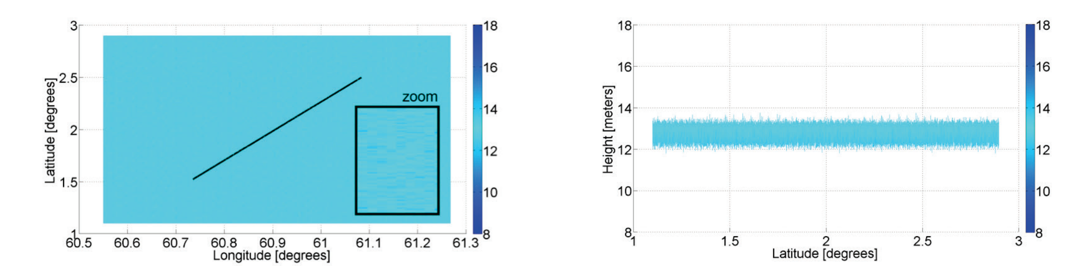


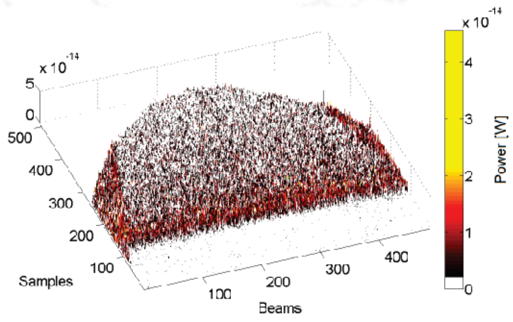
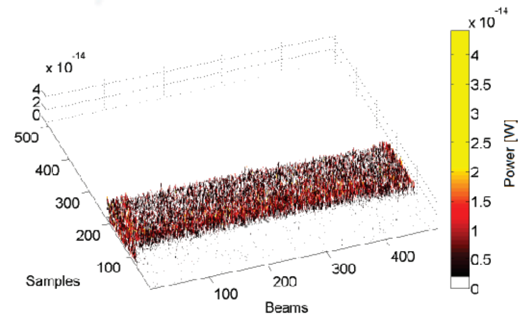
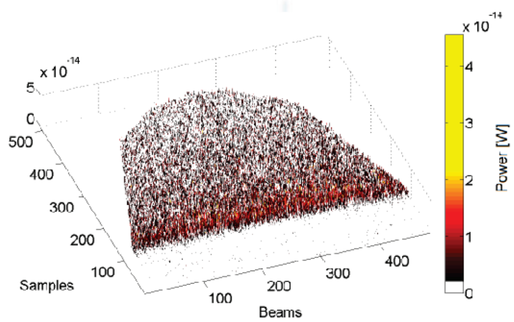
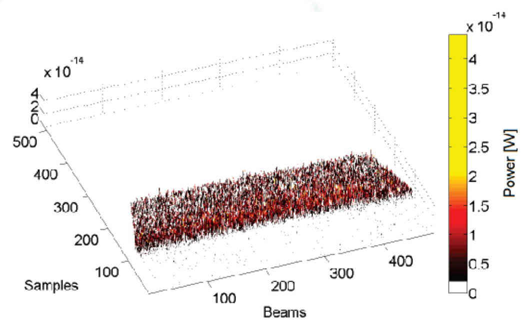
Figure **Error! No text of specified style in document.**-3 DEM of the T03 (std = 2.5 cm)

S6 P4 GPP UDD with simulated data

- Data provided:
  - 1 x LR;
  - 2 x L1A: one for each ISP_RAW and ISP_RMC;
  - 4 x L1B-S HR: two different processing configurations for each ISP_RAW and ISP_RMC;
  - 4 x L1B HR: two different processing configurations for each ISP_RAW and ISP_RMC.
- The 2 different configurations:
  - Applying Doppler Ambiguity Mask to remove Doppler ambiguities;
  - Not applying the Doppler Ambiguity Mask.

S6 P4 GPP UDD with simulated data

Mid SWH, HR (RAW&RMC) L1B-S stacks, two configurations

	RAW	RMC
With Doppler ambiguities	 Figure 1 HR RAW Stack #200 T021	 Figure 2 HR RMC Stack #200 T021
Without Doppler ambiguities	 Figure 3 HR RAW Stack #200 T022	 Figure 4 HR RMC Stack #200 T022

S6 P4 GPP UDD with simulated data

Mid SWH, HR (RAW&RMC) L1B-S stacks, two configurations

RAW | RMC

With Doppler ambiguities

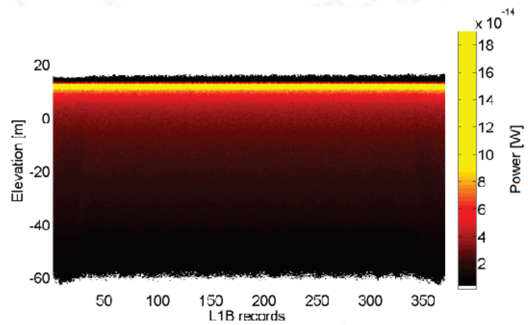


Figure 1 HR RAW L1B waveforms T031

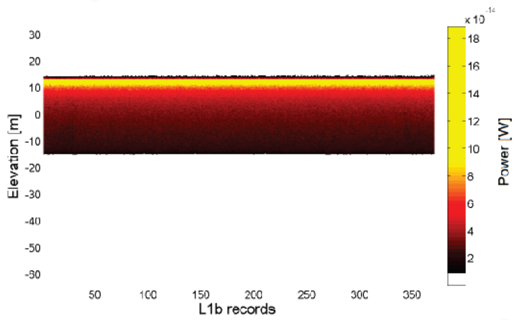


Figure 2 HR RMC L1B waveforms T031

Without Doppler ambiguities

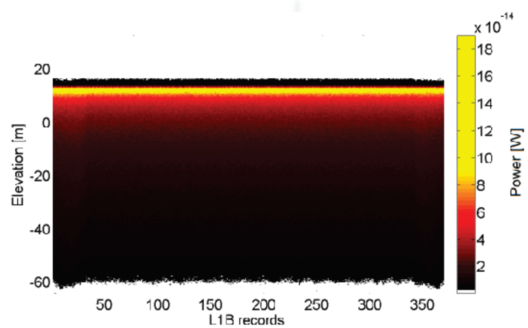


Figure 3 HR RAW L1B waveforms T032

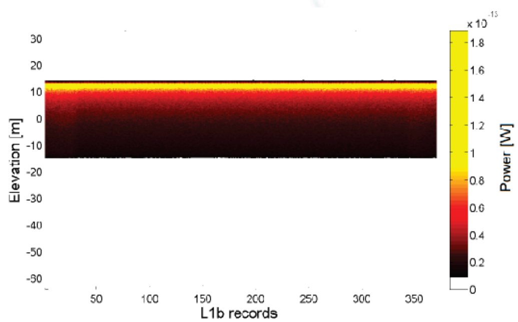
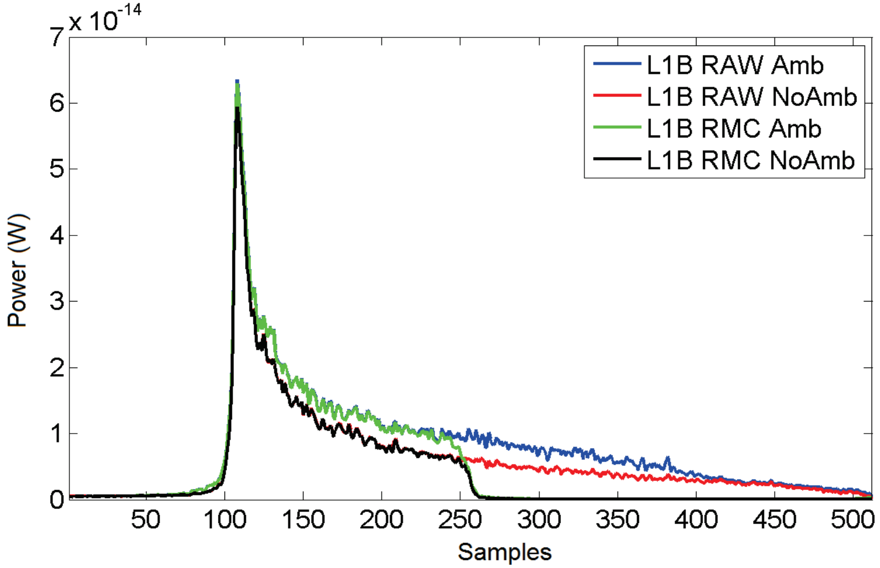


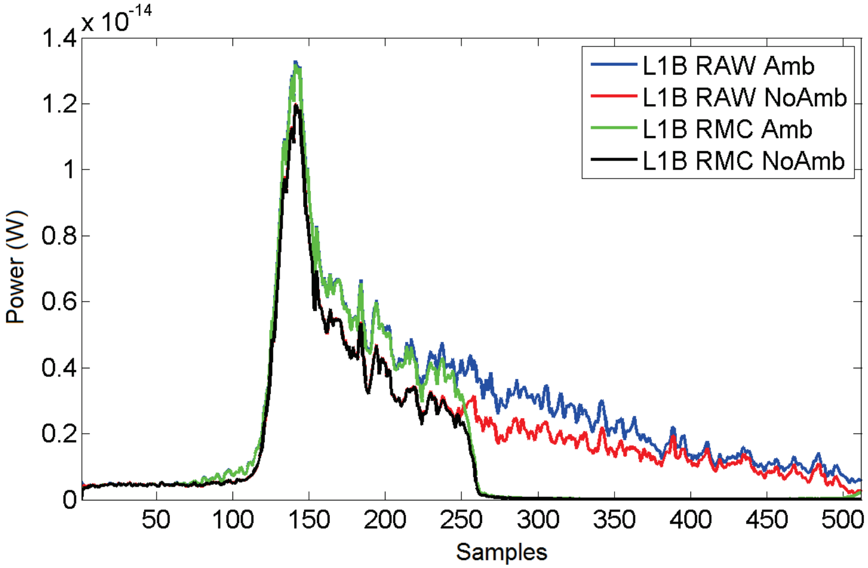
Figure 4 HR RMC L1B waveforms T032

S6 P4 GPP UDD with simulated data

Mid SWH, HR (RAW&RMC) L1B waveforms, two configurations

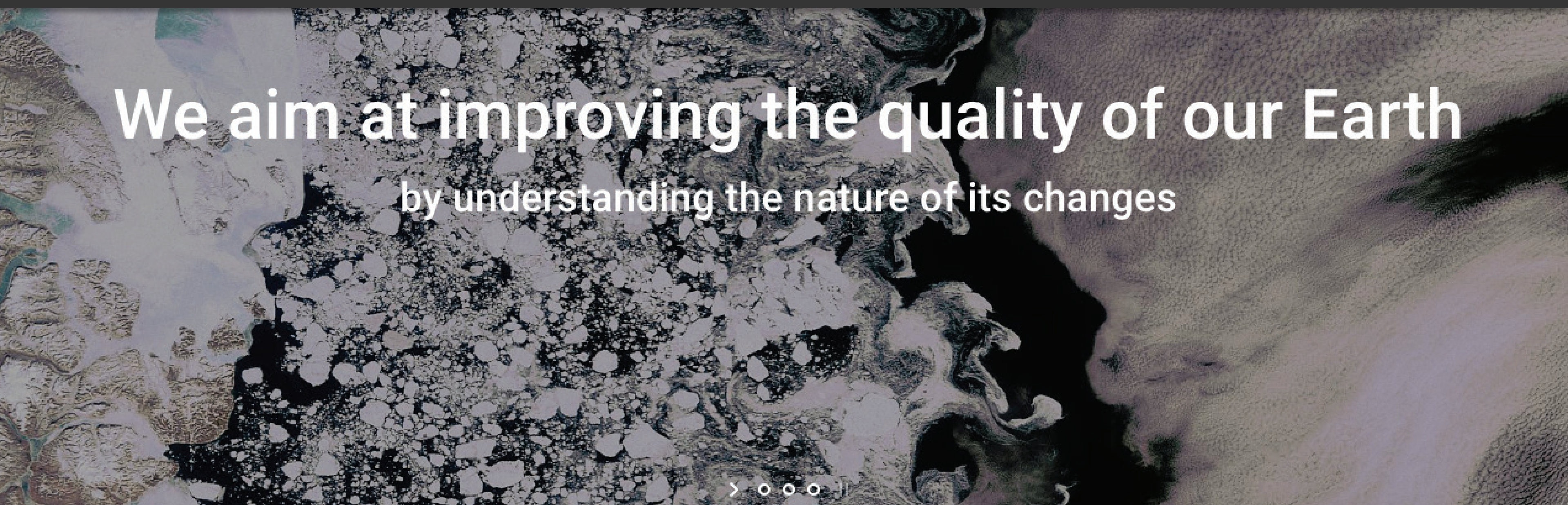


High SWH, HR (RAW&RMC) L1B waveforms, two configurations



Geophysical parameters also provided in a complementary NetCDF file, retracked using Ray *et al*., 2014. adapted to Sentinel-6/Jason-CS P4 by isardSAT.

Contribution by isardSAT kindly acknowledged



isardSAT

Research and services provider enterprise in the Earth Observation field

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

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