Coastal Altimetry :
Evolution of measurement and retracking problems when switching from conventional (Ku, Ka) to SAR altimetry

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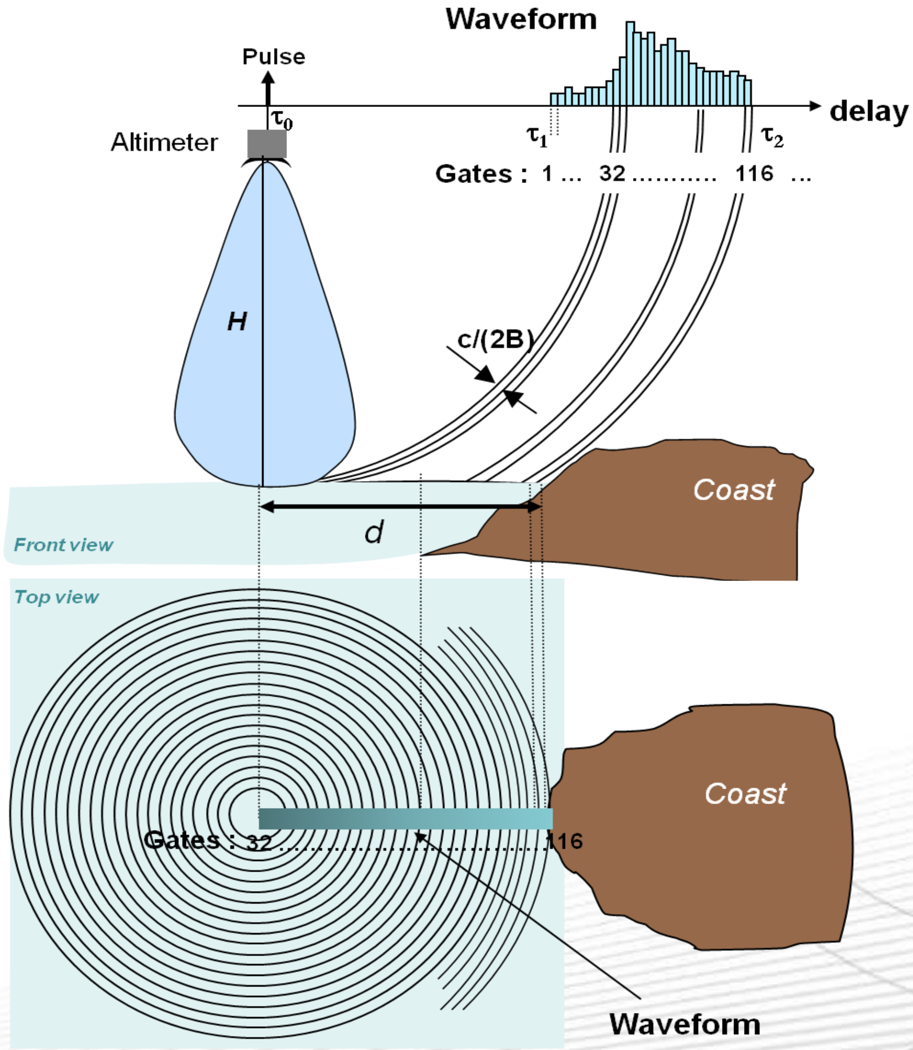
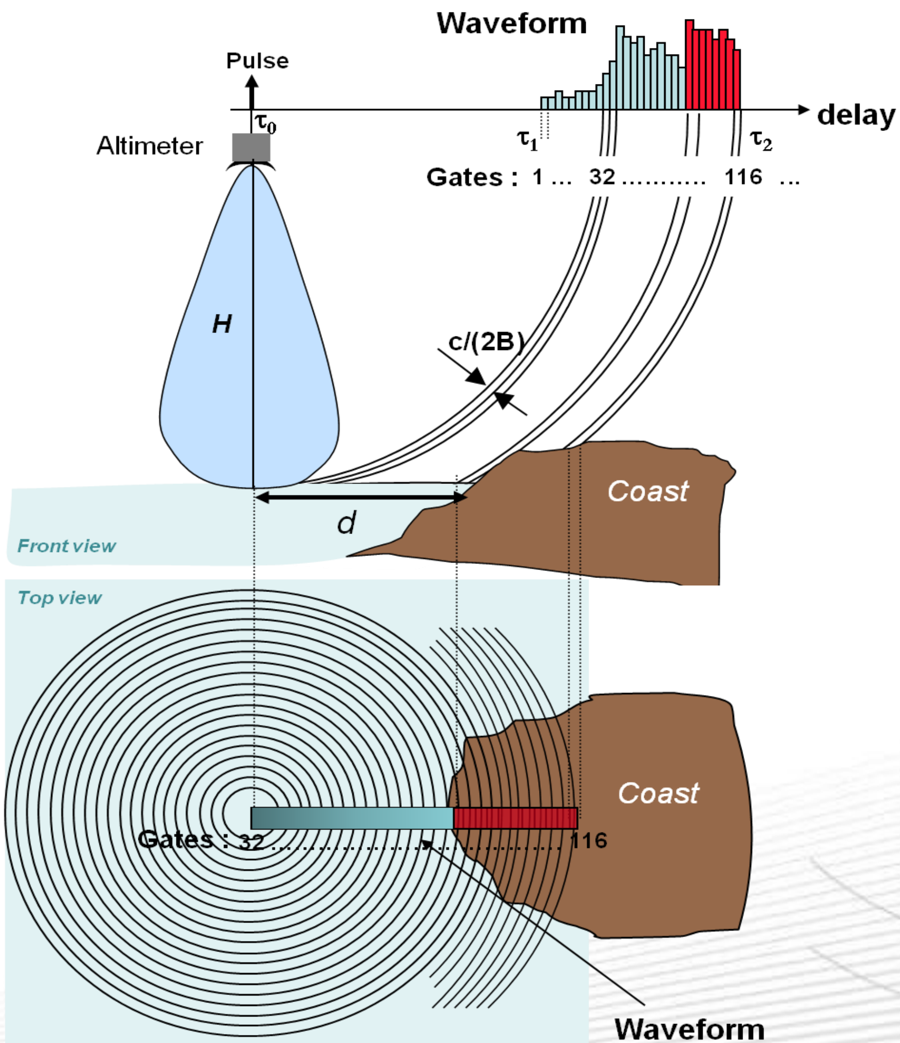
Coastal meeting – Riva del Garda - Italy -September 2012

Coastal waveforms (1/2)



Coastal waveforms (2/2)



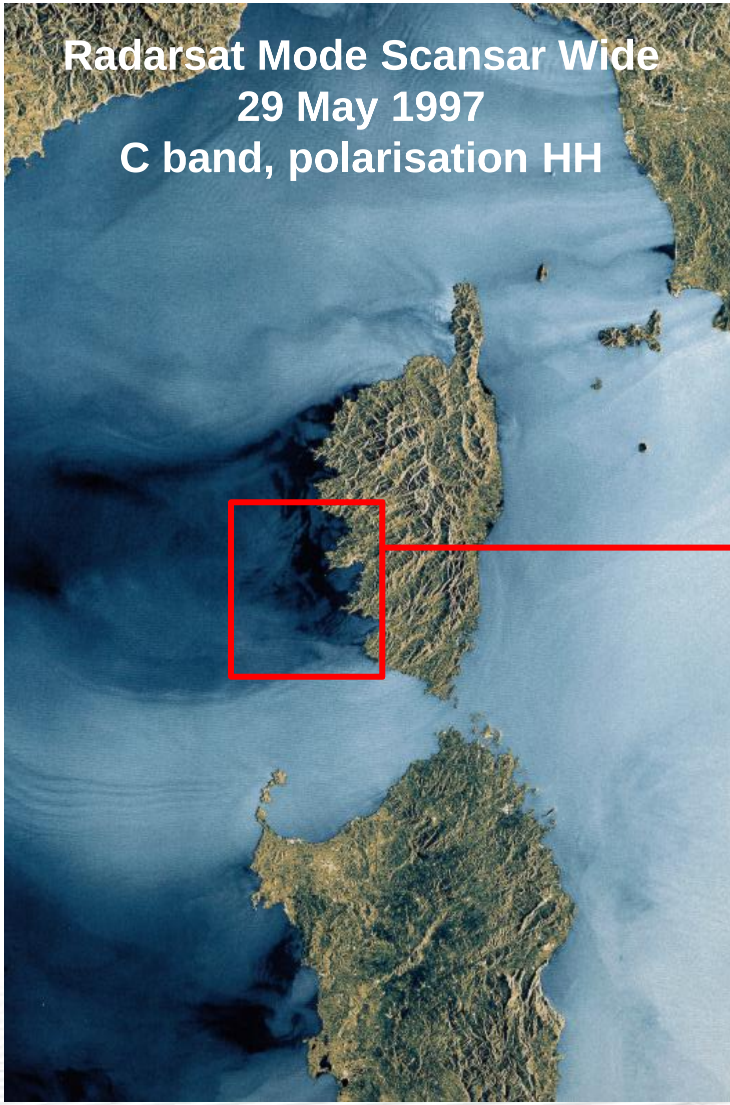
When the satellite nadir point reaches the coast line, the presence of land in the footprint may alter the shape of ocean waveforms.

➔ ***How*** the waveform is affected depends on $Area_{Land}$ times $\sigma_{0,Land}$ relative to $Area_{Ocean}$ times $\sigma_{0,Ocean}$.

- **Small effect** if $\sigma_{0,Land} < \sigma_{0,Ocean}$ (often true). If the coastal land is not mountainous and σ_0 is low, the waveform distortion may be mild until quite close to the coast, and simple (Brown model) retracking may work
- In some environments, however (coral atolls) $\sigma_{0,Land} > \sigma_{0,Ocean}$ and **the effect is large** on the waveform

➔ The waveform can also be corrupted by the modification of the sea state within its footprint (basic assumption of the Brown ocean model = homogeneity of the reflective surface)

Sea state variability

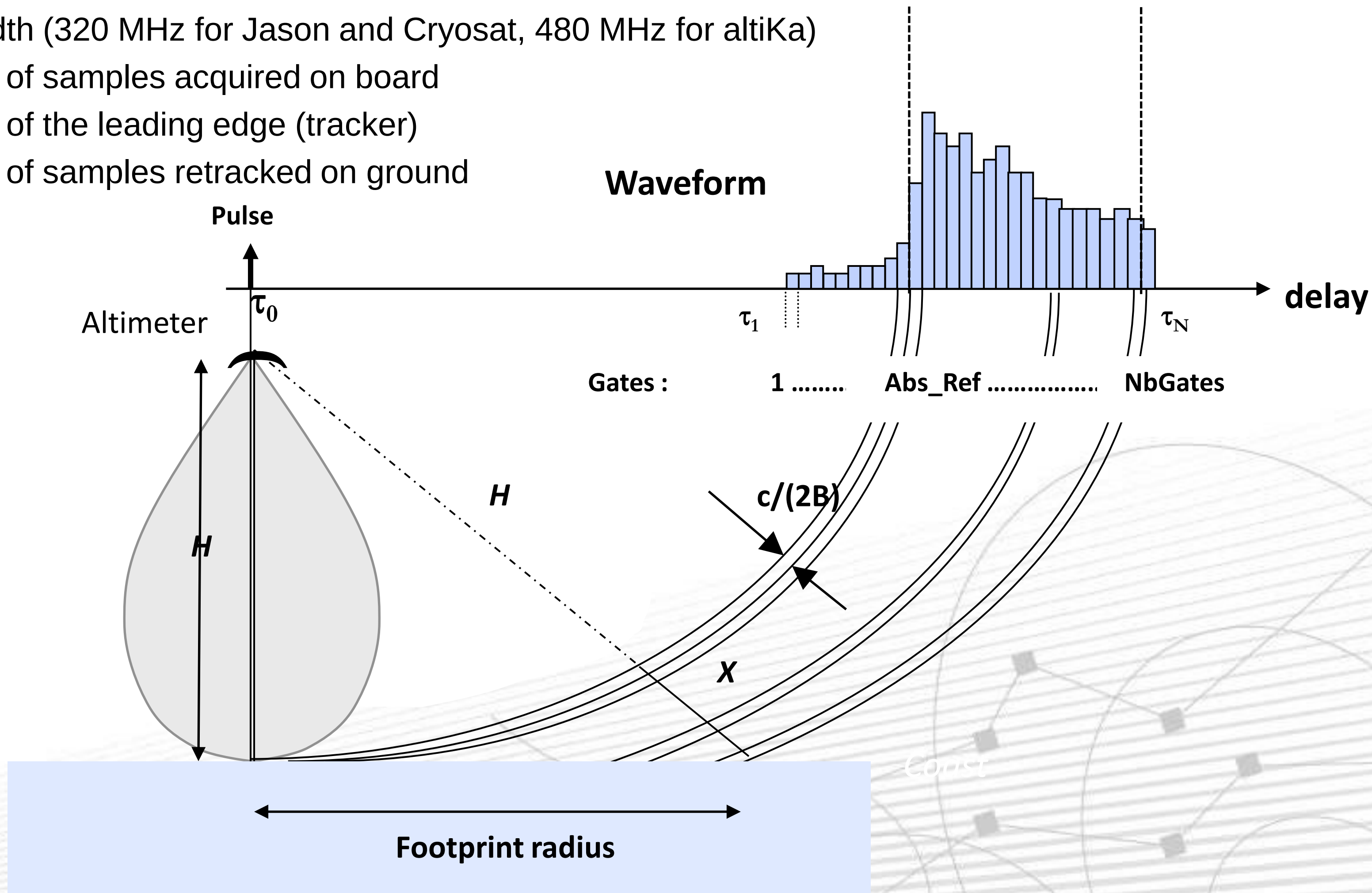


- Very small sea state structures depending on
  - ✓ wind speed
  - ✓ mountain occultation of the wind field,
  - ✓ bathymetry
  - ✓ …

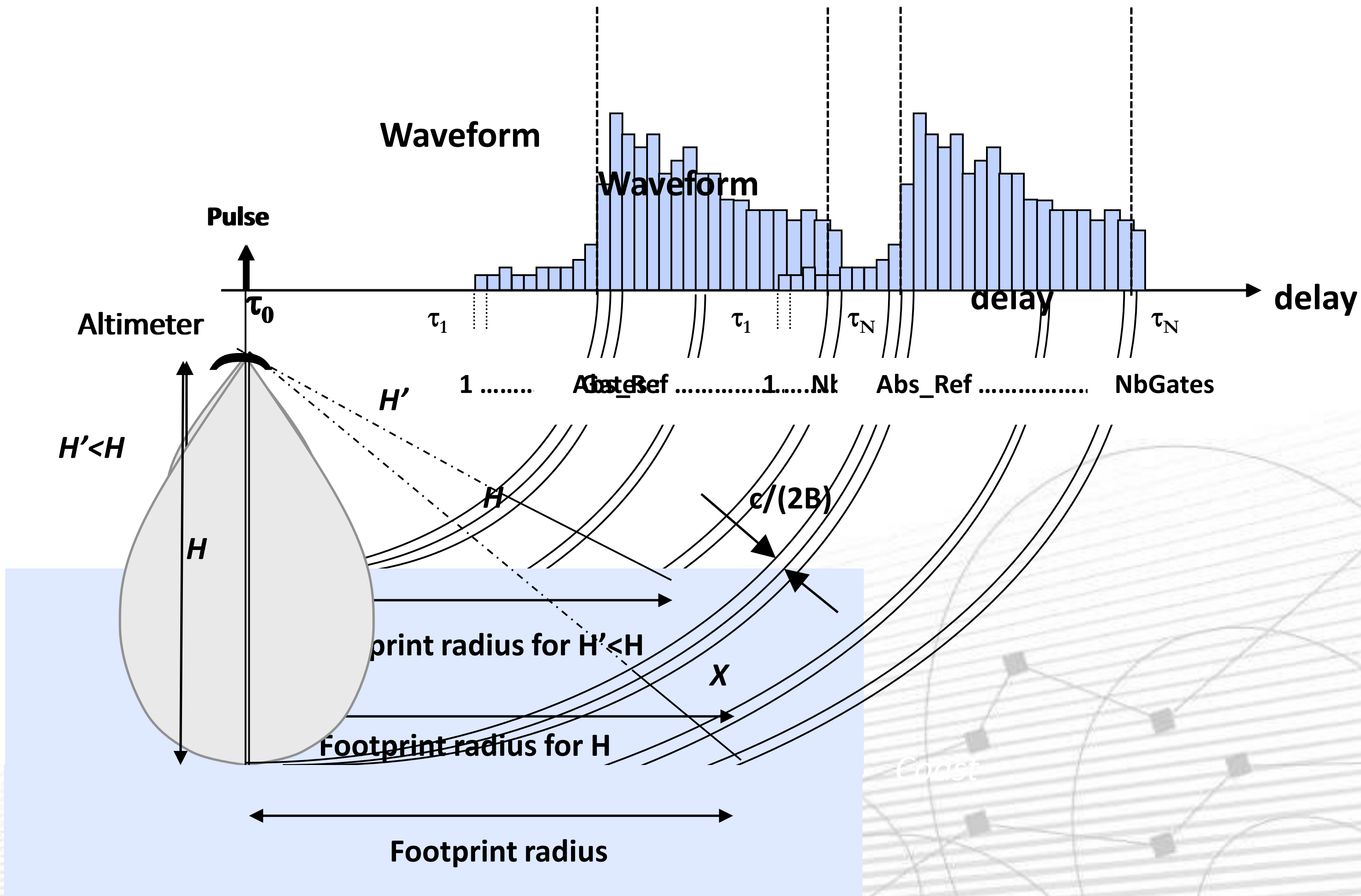
Geometry of observation

Waveforms may be corrupted depending on their footprint size which depends on :

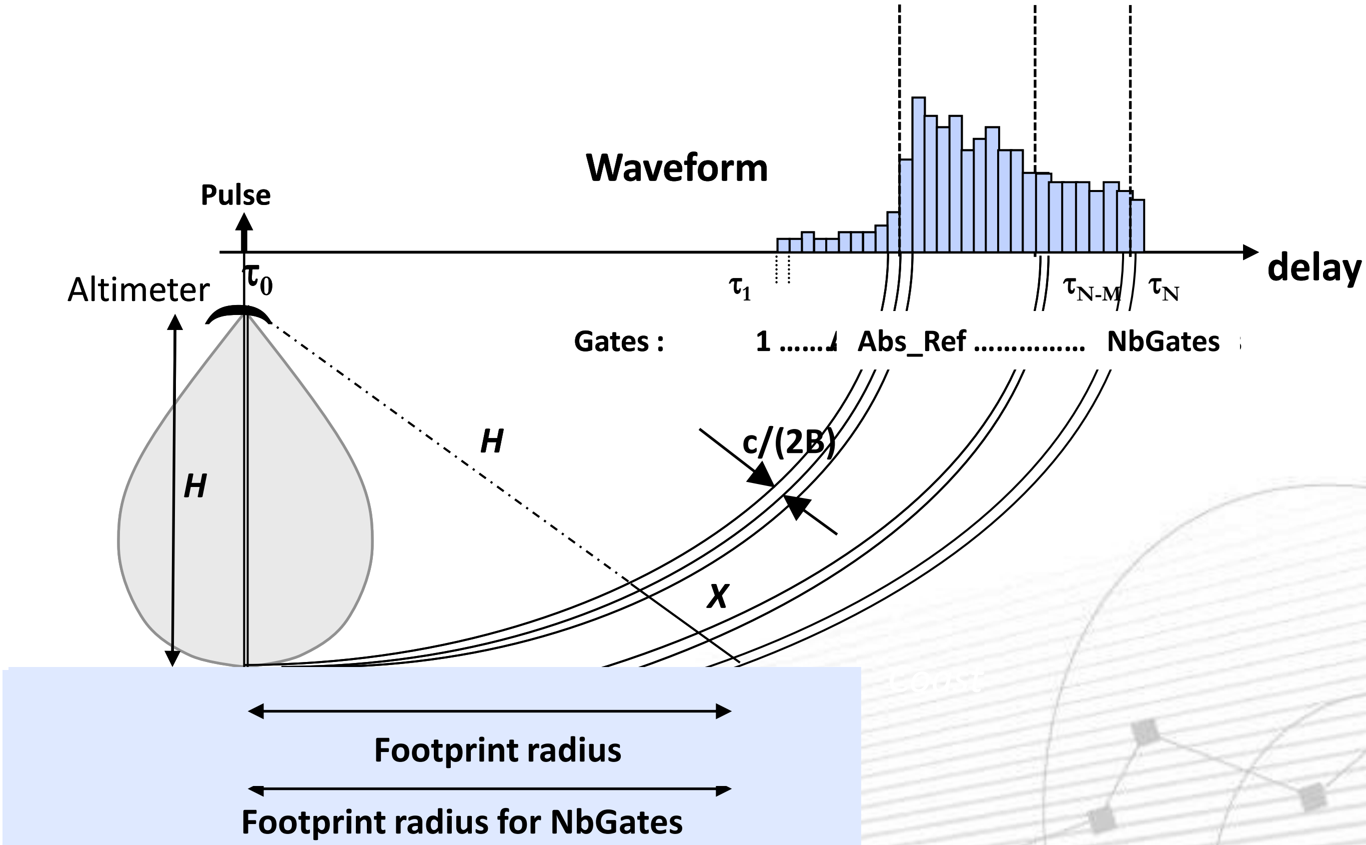
- Altitude of the platform
- Bandwidth (320 MHz for Jason and Cryosat, 480 MHz for altiKa)
- Number of samples acquired on board
- Position of the leading edge (tracker)
- Number of samples retracked on ground



Reduced altitude ➔ Reduced footprint



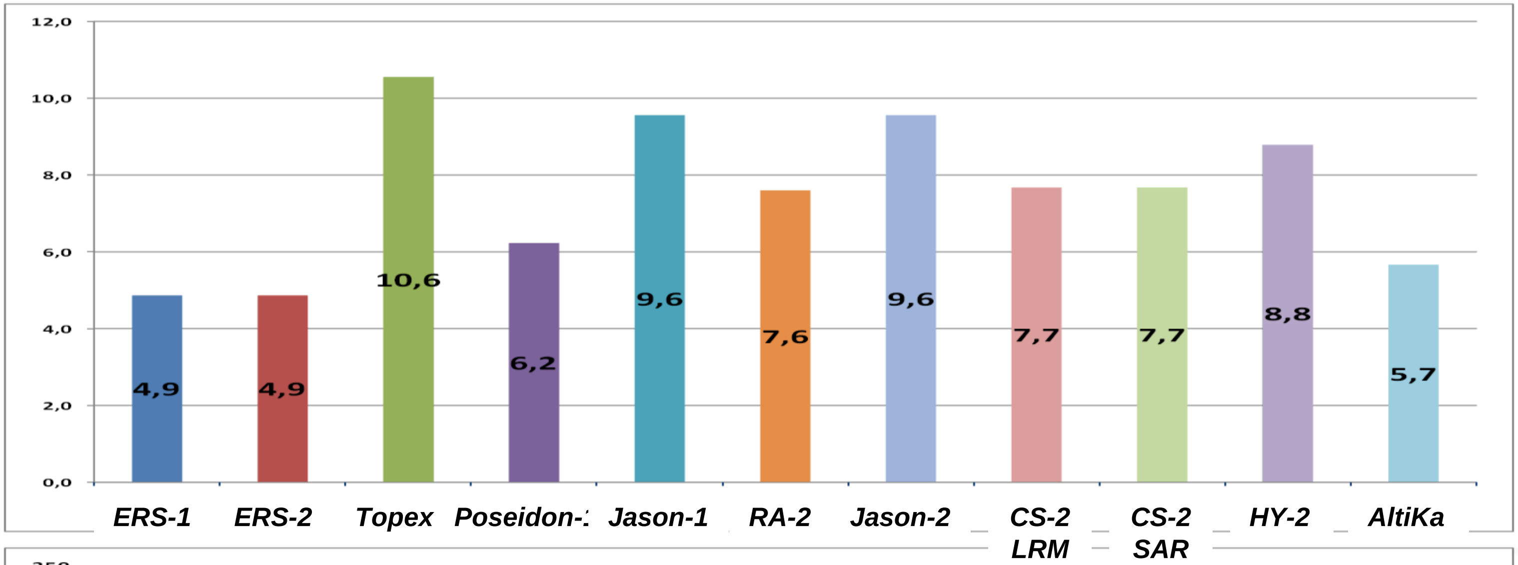
Reduction of the Number of gates used in the retracking



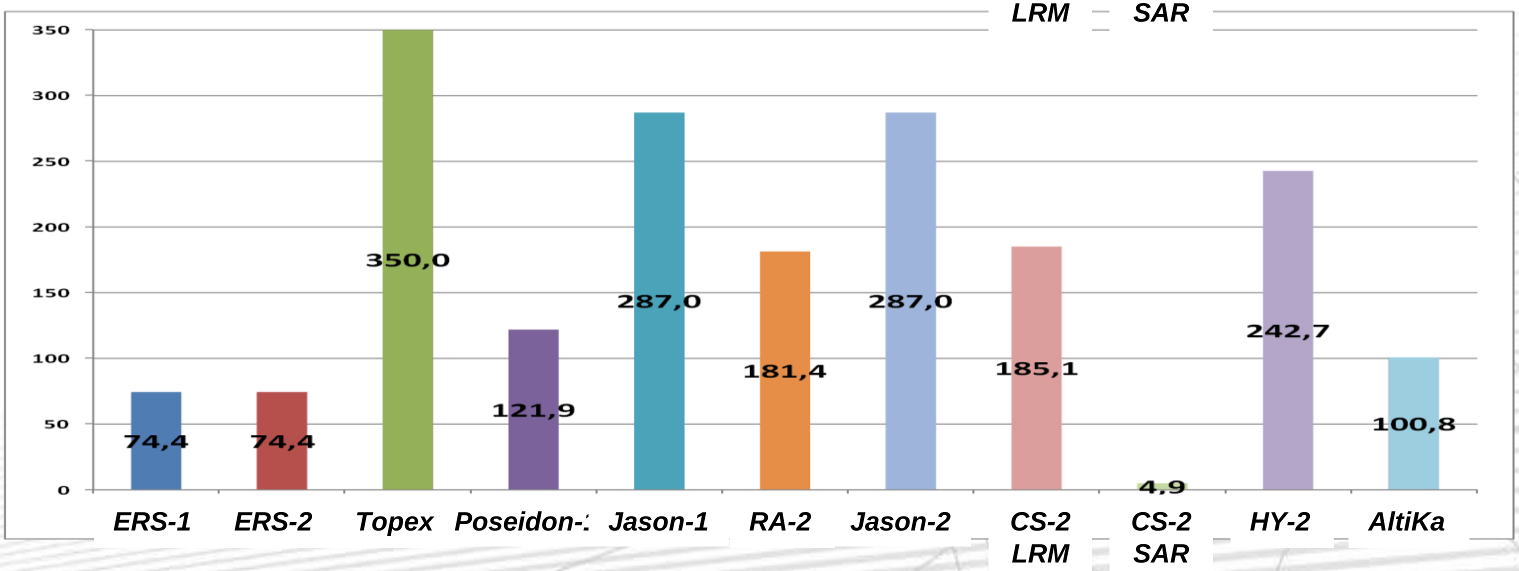
- Interest of the RED3 retracker (reduced waveform, 3 parameters) provided in PISTACH Jason-2 products

Radius and Surface of the altimeter footprint

Radius of the footprint (km)



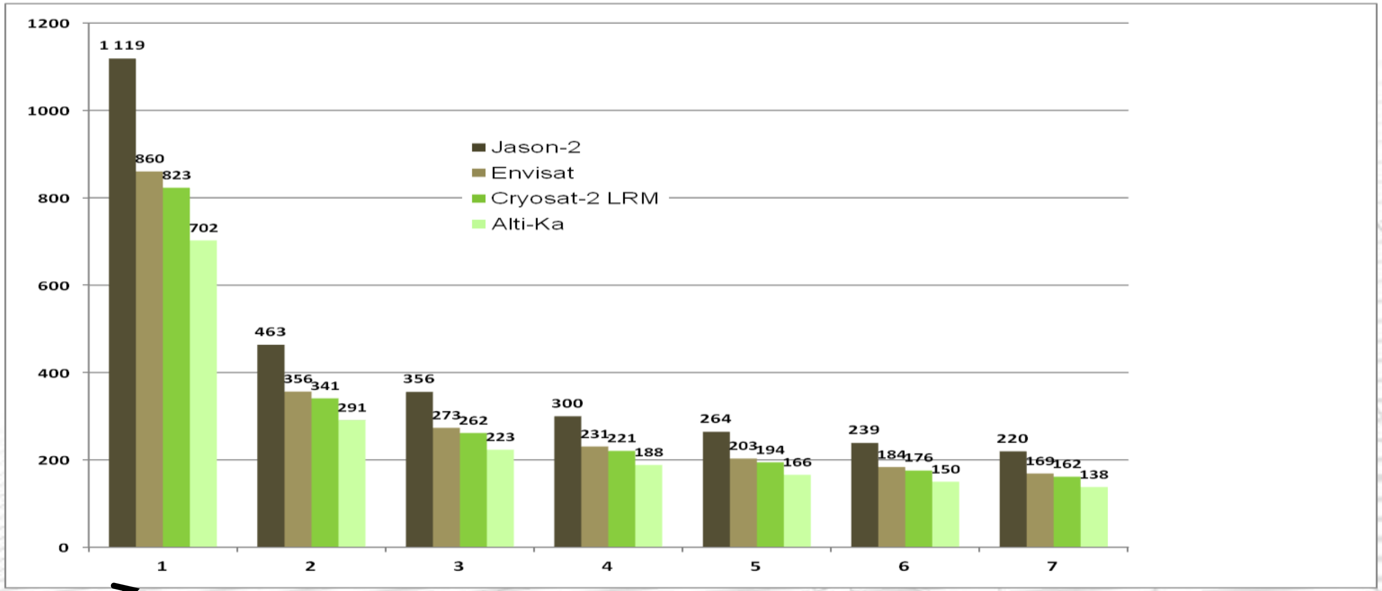
Surface of the footprint (km^2)



Radius of the first gates (from the leading edge)

- Most of the information (range, SWH, Power) is contained in the leading edge of the waveform
- The radius of the first gates (mapped on the ocean surface) varies at lot with altitude with impacts on the different noise levels.
- Any modification of the sea state in the footprint (but also in the first gates) will impact the measurement and thus the noise level of the estimated parameters

Radius of the first gates (annulus spreading onto the ocean surface) (m)

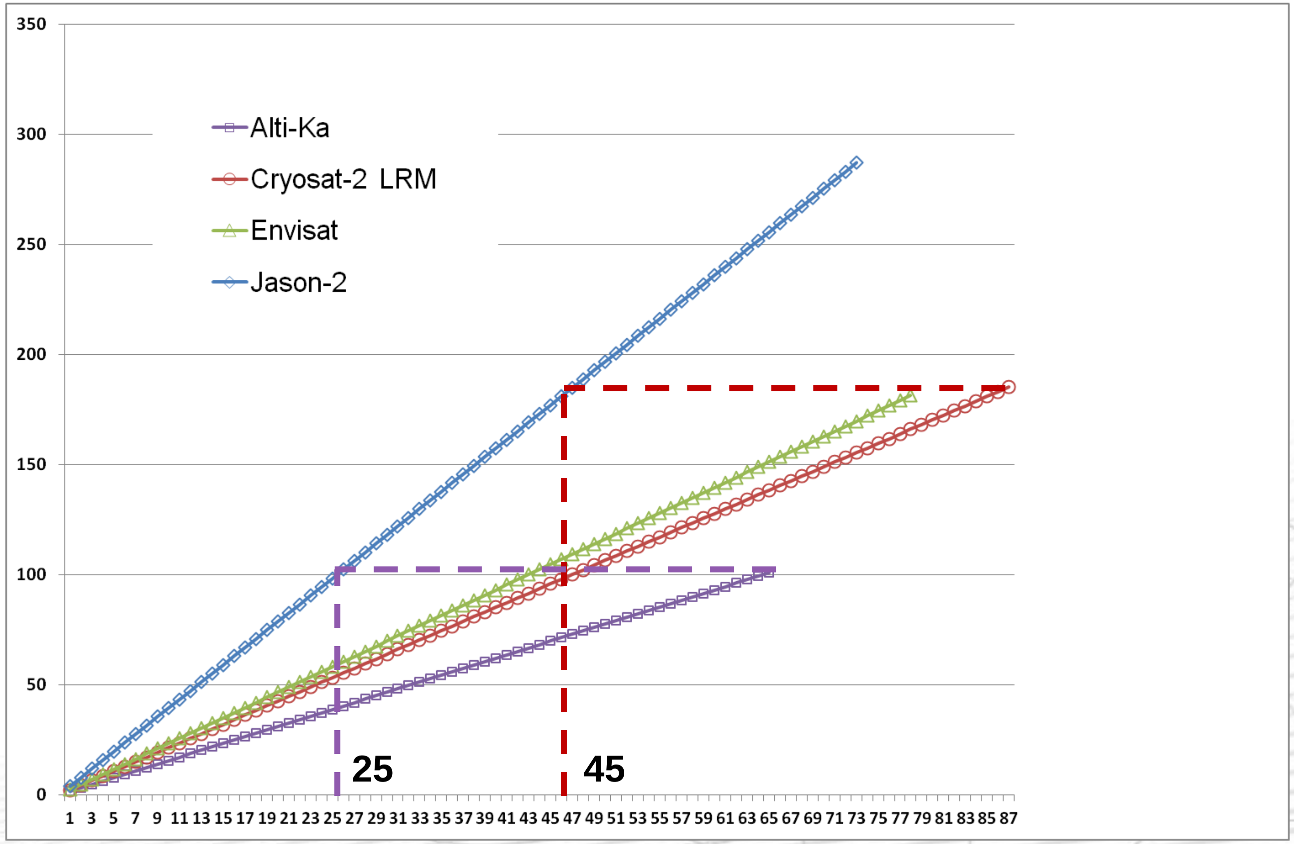


Pulse limited footprint

Gate number (from Abs_Ref_Track)

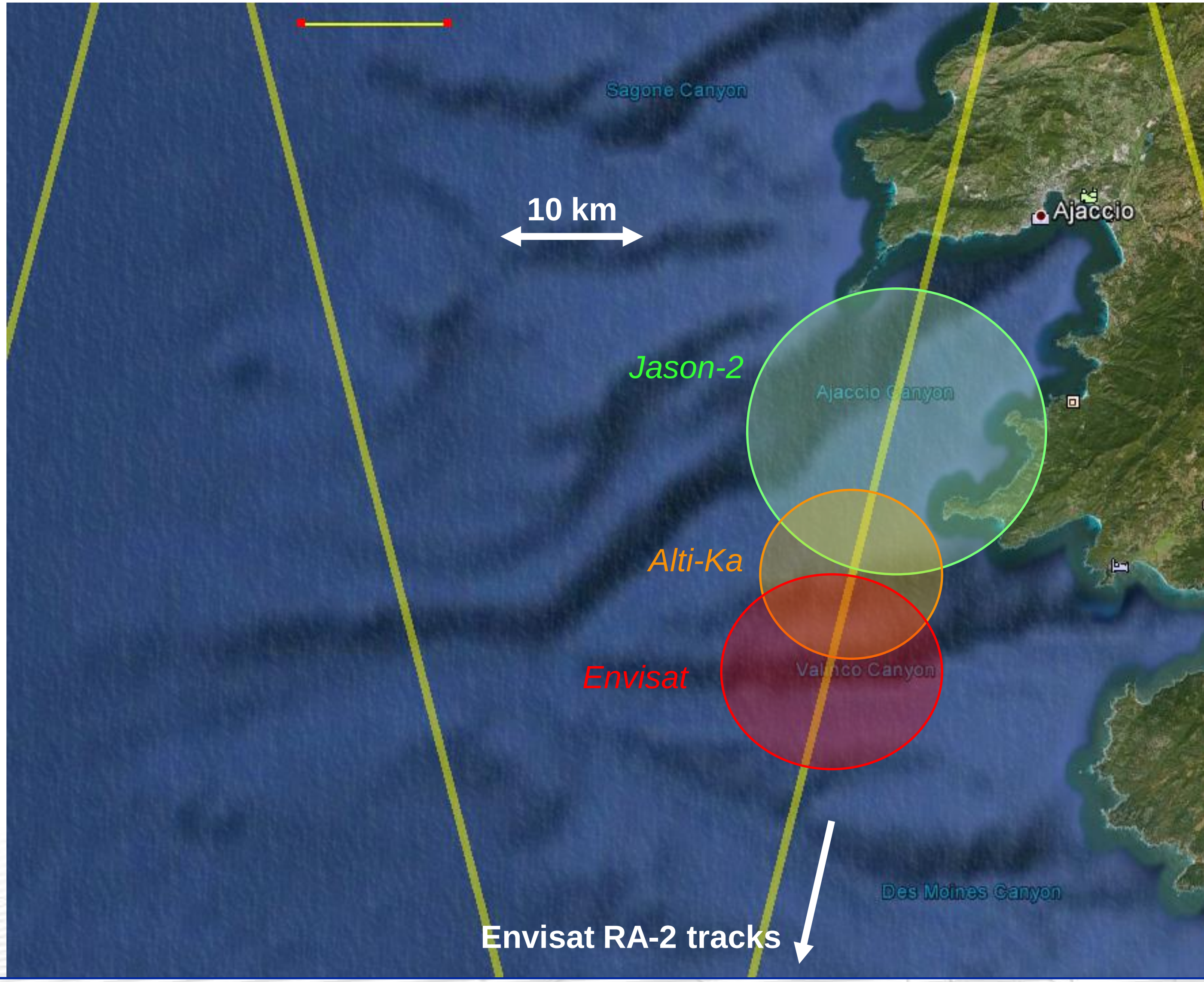
Jason-2 gate number providing a CS-2 (or AltiKa) equivalent footprint

Cumulative surfaces of the footprint for different range gates (km^2)



Number of range gates (from leading edge)

Antenna footprint near the Corsica calibration site



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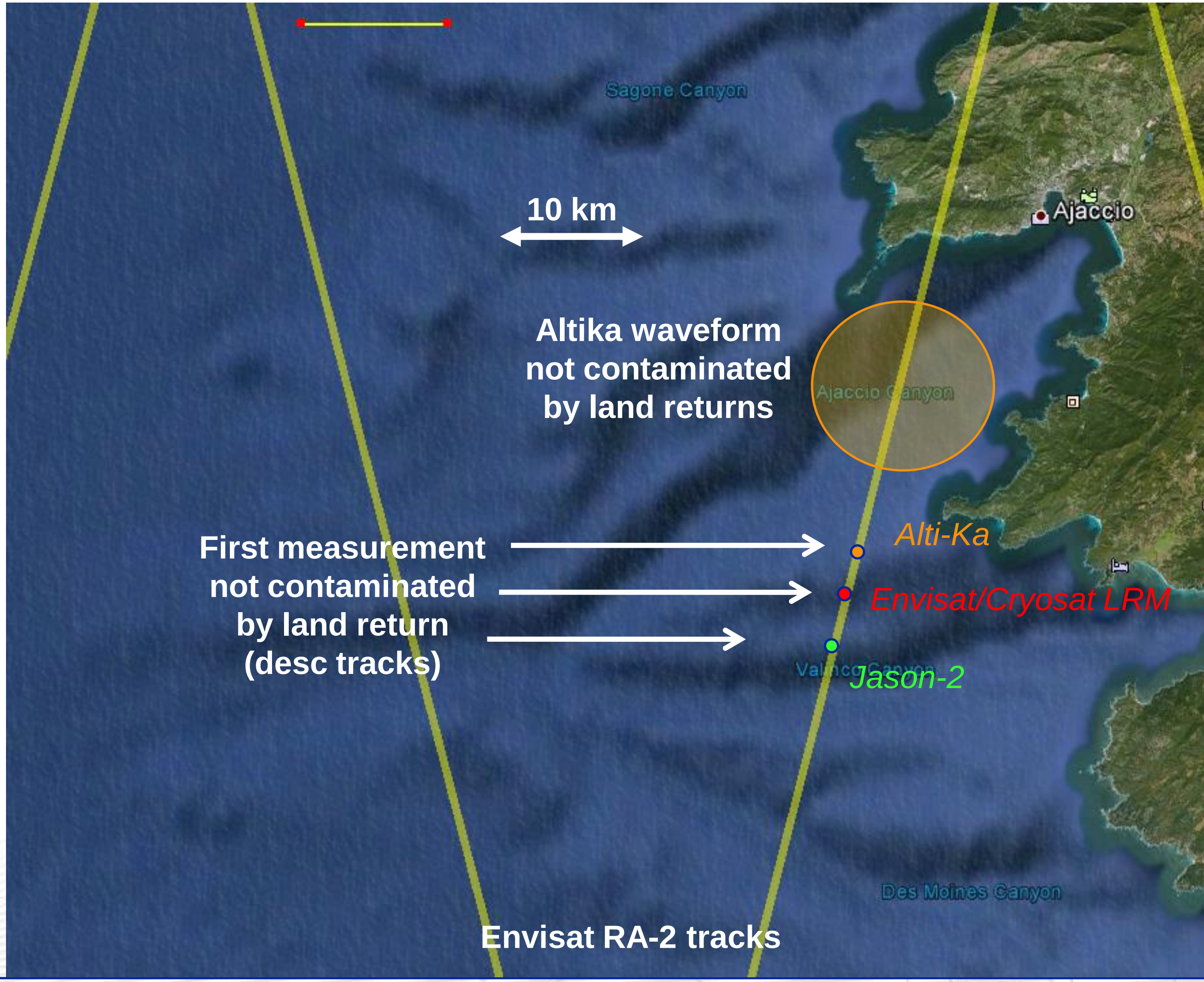


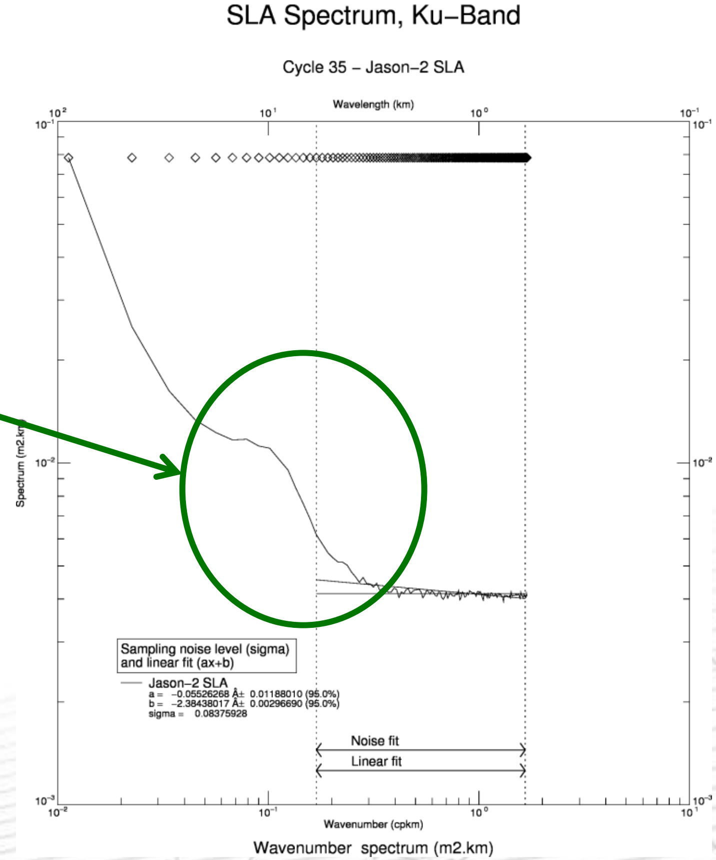
Relation footprint / SLA spectrum

- A smaller footprint induces:

  - weaker perturbations caused by land returns on the outer annulus of the LRM waveforms (same problem in deep ocean with rain cells, bloom events, …)

  - reduction of the noise level on range, correlated with geophysical signals (bump of energy in the SLA spectrum between 10 to 70 km)

  (see Thibaut's presentation in 20years of altimetry meeting, Venice)



- A recent paper (Bonnefond et al) illustrates the impact on range of land contamination and sea state variations, using GPS measurements.

  P. Bonnefond, "GPS-based sea level measurements to help the characterization of land contamination in coastal areas", Journal of Advanced Space Research (2012)

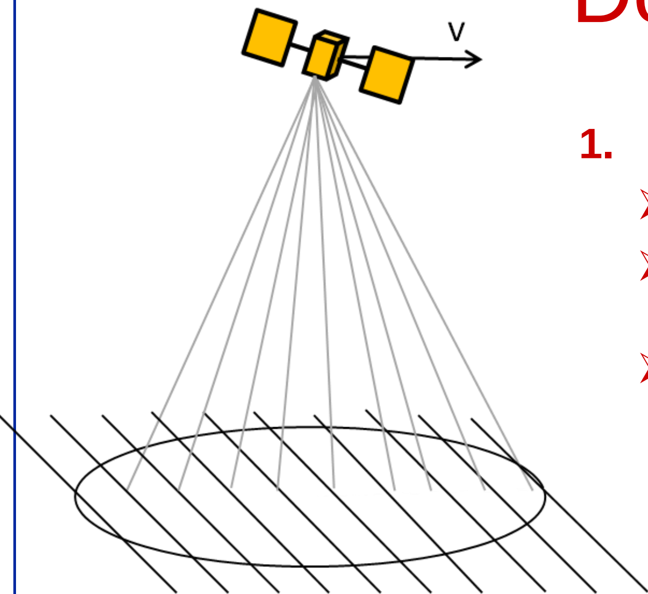
Ku ➔ Ka

- Reduction of the footprint mainly due to a larger bandwidth (480 MHz instead of 320 MHz) and a lower orbit
- Increased measurement rate (PRF) and rate of the averaged echo (40Hz)
- Reduction of the antenna aperture (but doesn't impact the footprint)
- Smaller SNR (around 11dB)

Three main consequences :

- Reduced range noise level (-40% wrt Jason)
- Reduced bump of energy in the SLA spectrum but to be confirmed because of the sensitivity to clouds and rain cells
- Measurements closer to the coasts (because of footprint and 40Hz rate)

Doppler processing : 3 main steps



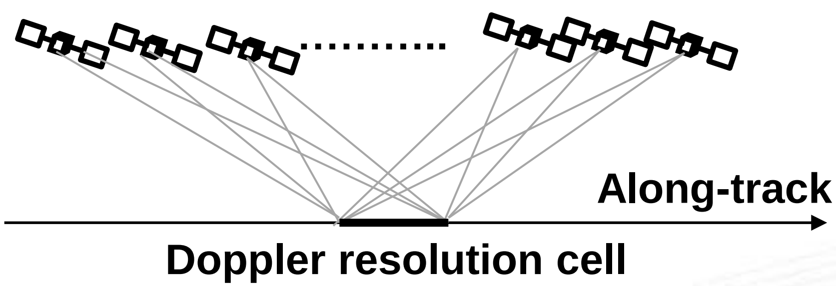
1. Doppler processing of each burst (« single look processing »)

- The 64 pulses of a burst are processed coherently
- The Doppler processing splits the observed scene in a 2D map (doppler frequency (320 m Along Track resolution) / radial distance)
- **Improvement of the spatial resolution of the image**

2. Multi look processing

- Several single looks of the same scene are stacked incoherently to reduce the speckle noise and form a Multi look waveform

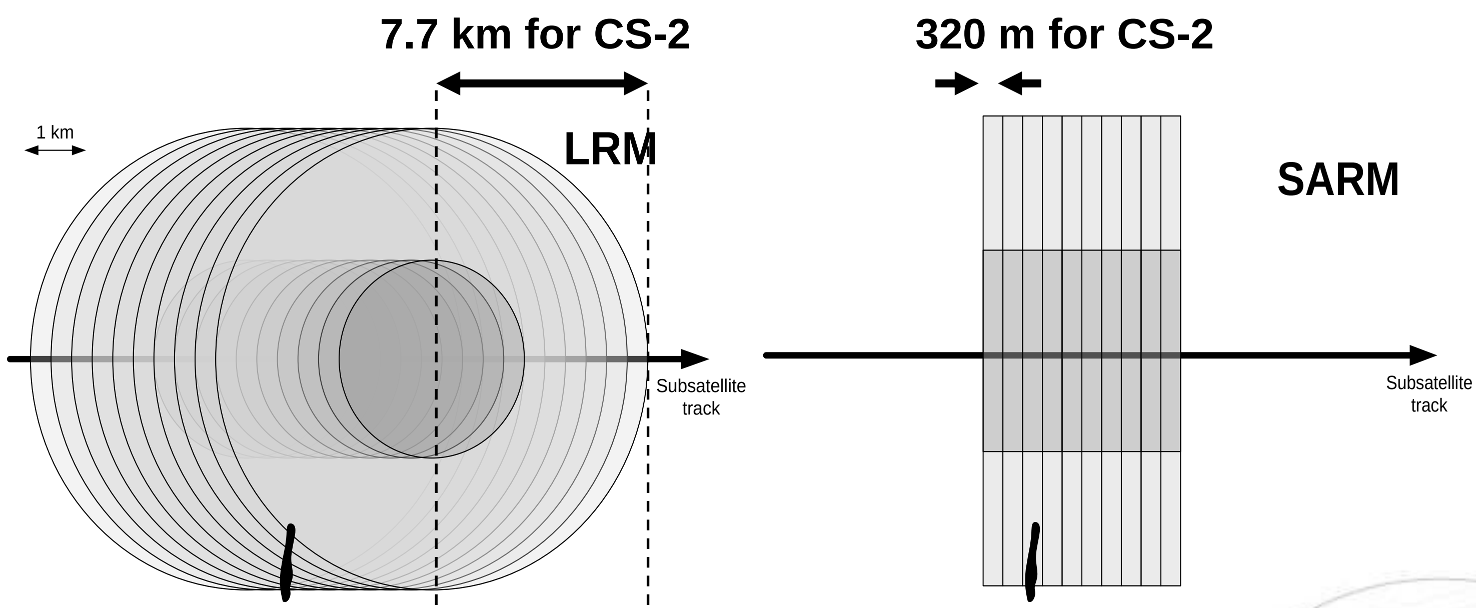
3. Retracking of the multi look waveforms



All these processing must be designed coherently but could vary with the observed geophysics (Hydro/SeaIce/Ocean/Coastal)

- The doppler processing leads to an along track resolution of about 320 m
- Accumulation of a large number of views of the same surface (256) leads to a strong reduction of the speckle noise after averaging (LRM average around 100 pulses)
- Improvement of the range noise after retracking (see F.Boy presentation)

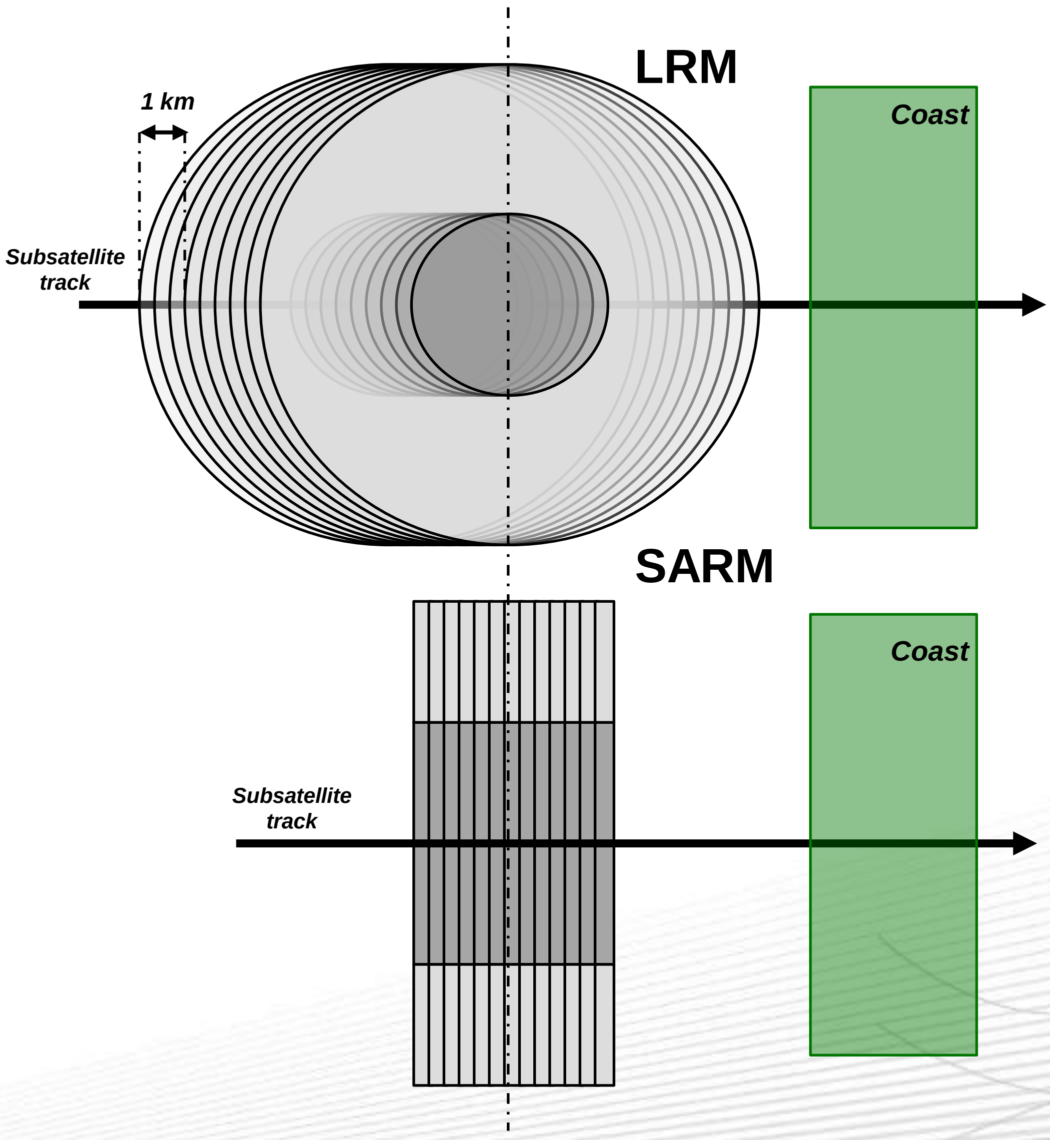
Footprint : from LRM to SAR ?



- Altimeter footprint geometry on a 3-kilometer segment for LRM (left) and SARM (right). Darker zones highlight the footprint zones providing the bulk of the SSH content through the leading edge of the waveform.

- The black shape at the bottom of each subplot illustrates how a single SARM footprint (i.e. waveform) can be affected by isolated spurious reflections whereas larger LRM footprints can absorb the error over multiple waveforms (i.e. correlated error).

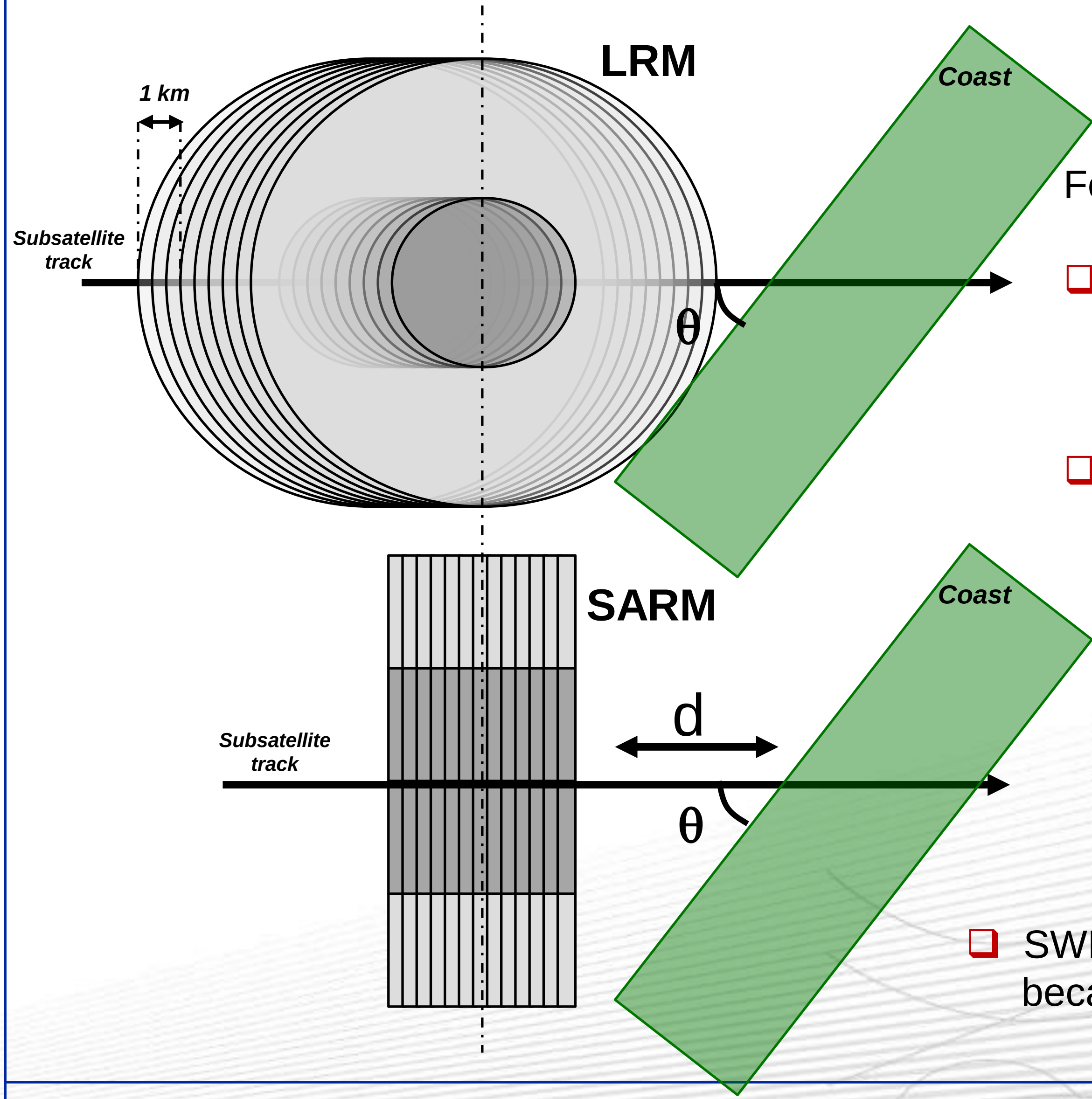
Impacts of coasts on altimeter measurements



For tracks perpendicular to the shore lines :

- 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)

Impacts of coasts on altimeter measurements



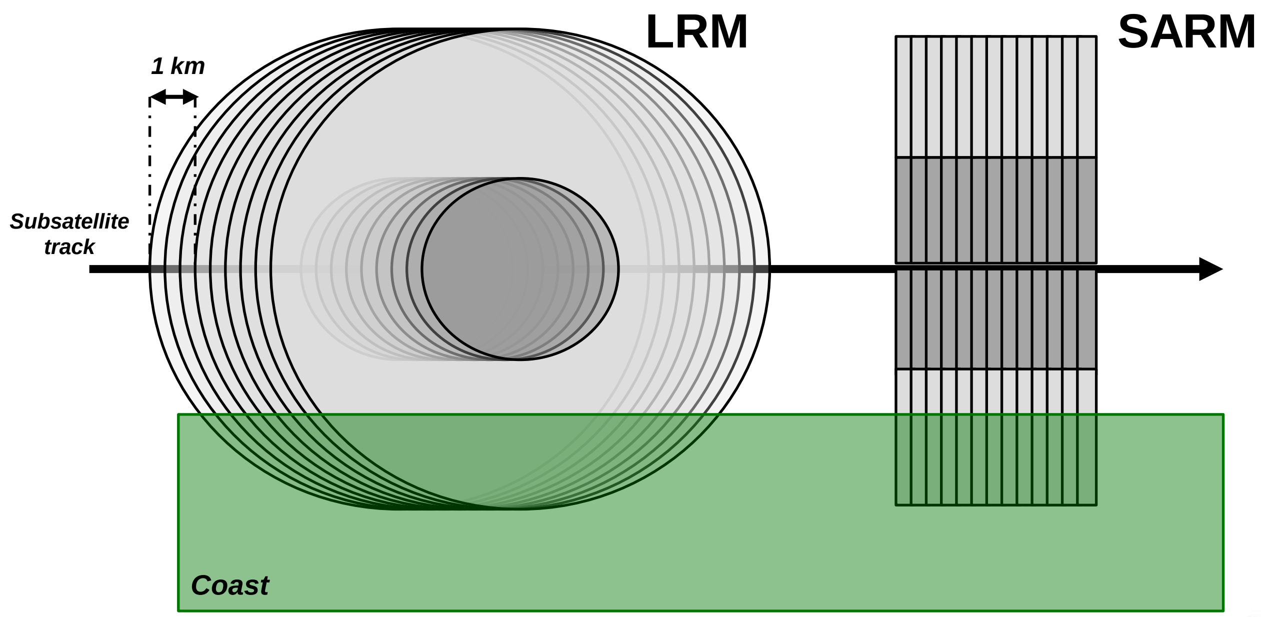
For tracks crossing the shore lines with θ :

- LRM impacted as soon as its footprint touch the nearest coast whatever θ (9.6 km for Jason, 7.7 km for CS-2)
- SARM impacted from the distance

$$d = \frac{Footprint\_Size}{tg(\theta)}$$

- SWH more impacted on SAR than on LRM because on SAR, SWH signs on trailing edge

Impacts of coasts on altimeter measurements



For tracks parallel to the shore line :

- LRM and SAR impacted as soon as their footprints touch the coast (9.6 km for Jason, 7.7 km for CS-2)
- SWH more impacted on SAR than on LRM because the SAR trailing edge correlated to SWH
- For the same reason, more difficult to reduce the retracked range gates(as on RED3 PISTACH)

WARNING on SAR Cryosat processing

For CRYOSPHERE purposes, 2 processing have been implemented in CS-2 SAR PDS for the purpose of improving results on sea ice.

- Along Track Hamming weighting on bursts to reduced side lobes effects
- Oversampling of the waveform in order to broaden the trailing edge of the waveform

They are applied EVERYWHERE (since Feb this year ?)

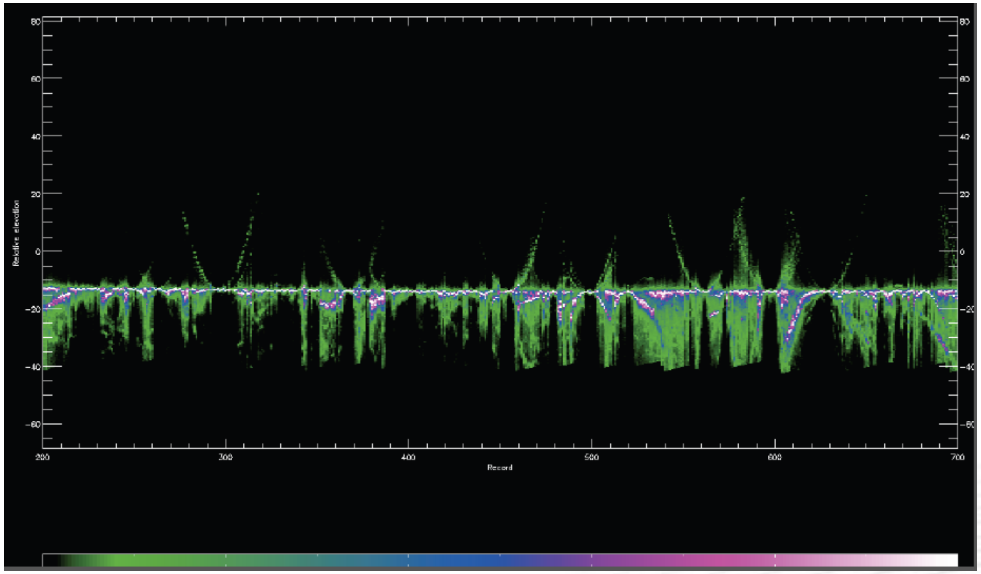
➔ Are they suitable for ocean purposes ?

ESA SAR Cryosat PDS

Interests for Ice returns

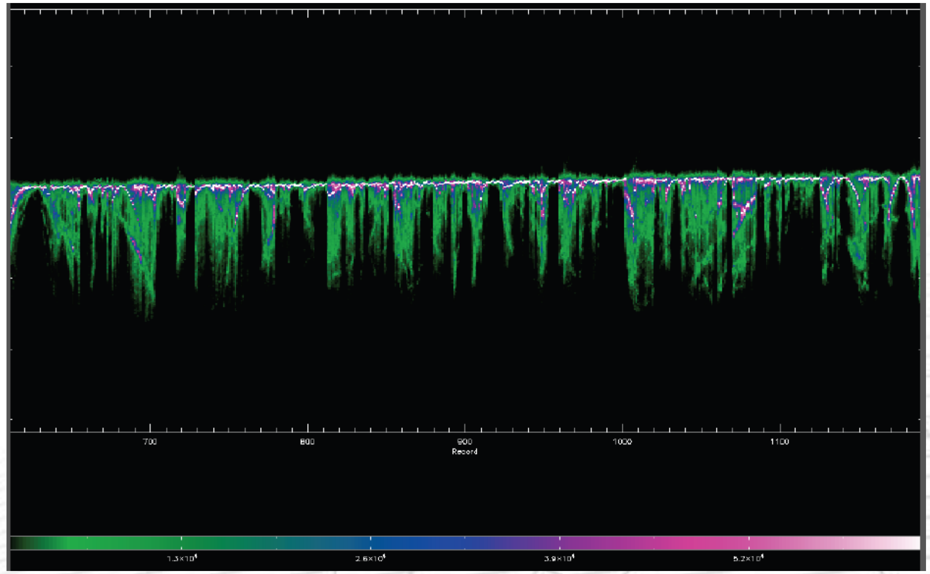
Courtesy Rob Cullen, ESA

Cryosat SAR waveforms over ice
No Along Track Hamming weighting

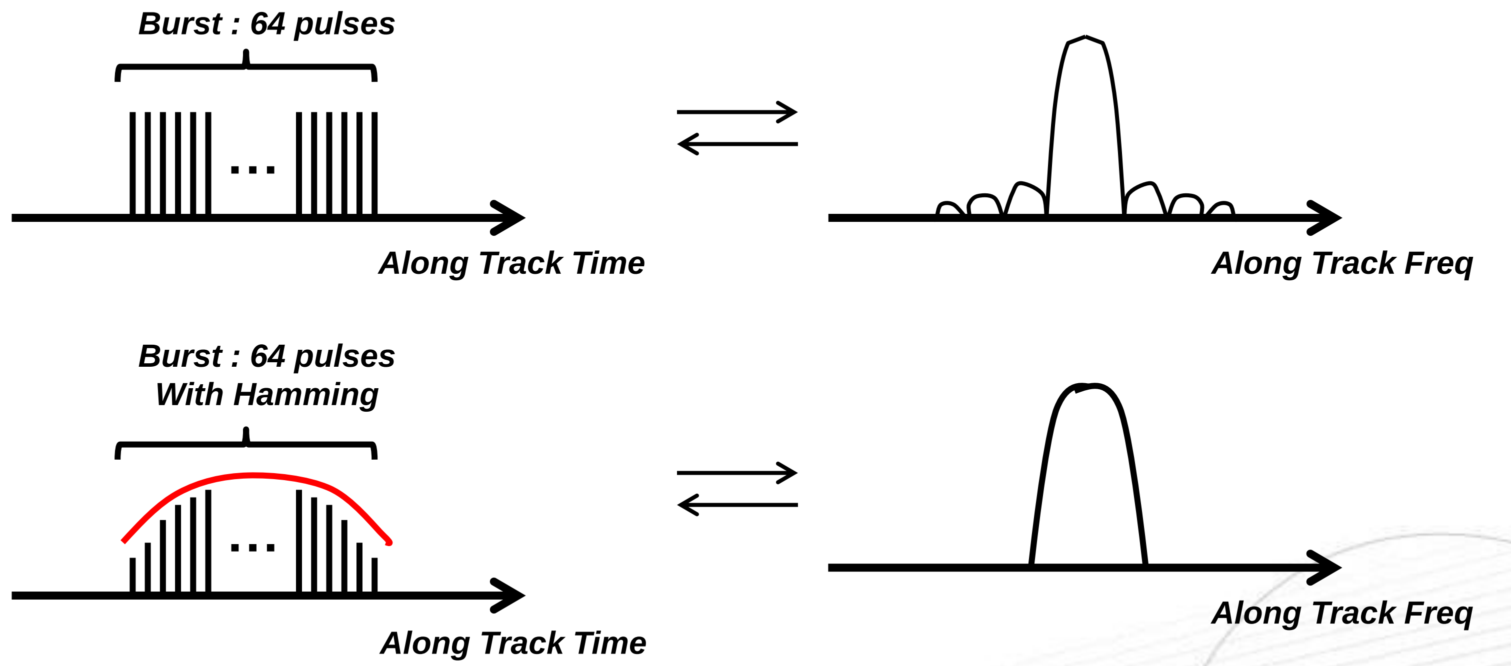


high levels of energy entering side lobes of azimuth impulse response

Cryosat SAR waveforms over ice
with AT Hamming weighting applied



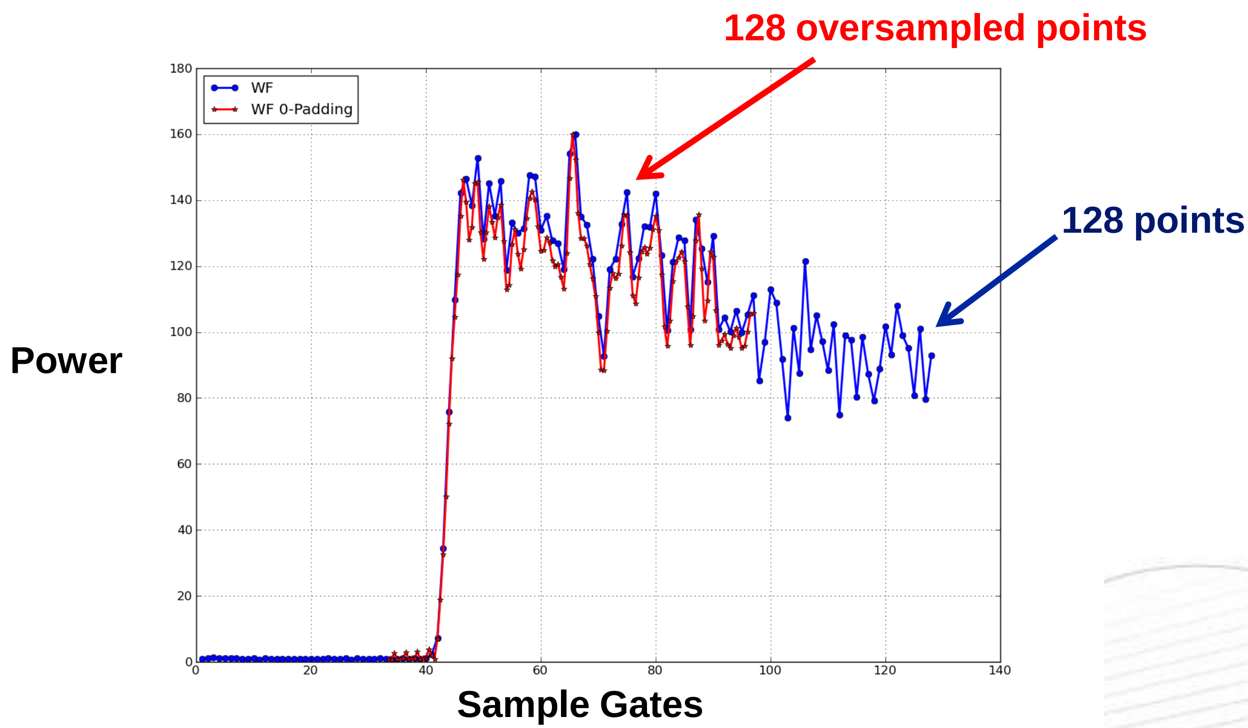
Along Track Hamming Weighting



Consequences :

- Enlargement of the main lobe of the Along Track PTR
- Reduction of the side lobes of the Along Track PTR
- Reduced impact of spurious signals (coming from highly reflective surfaces)
- Loss of resolution of the Azimuth Impulse response (AT sampling remains)
- May introduce pulse to pulse correlation (as what is seen on RA-2 with the instrumental PTR)

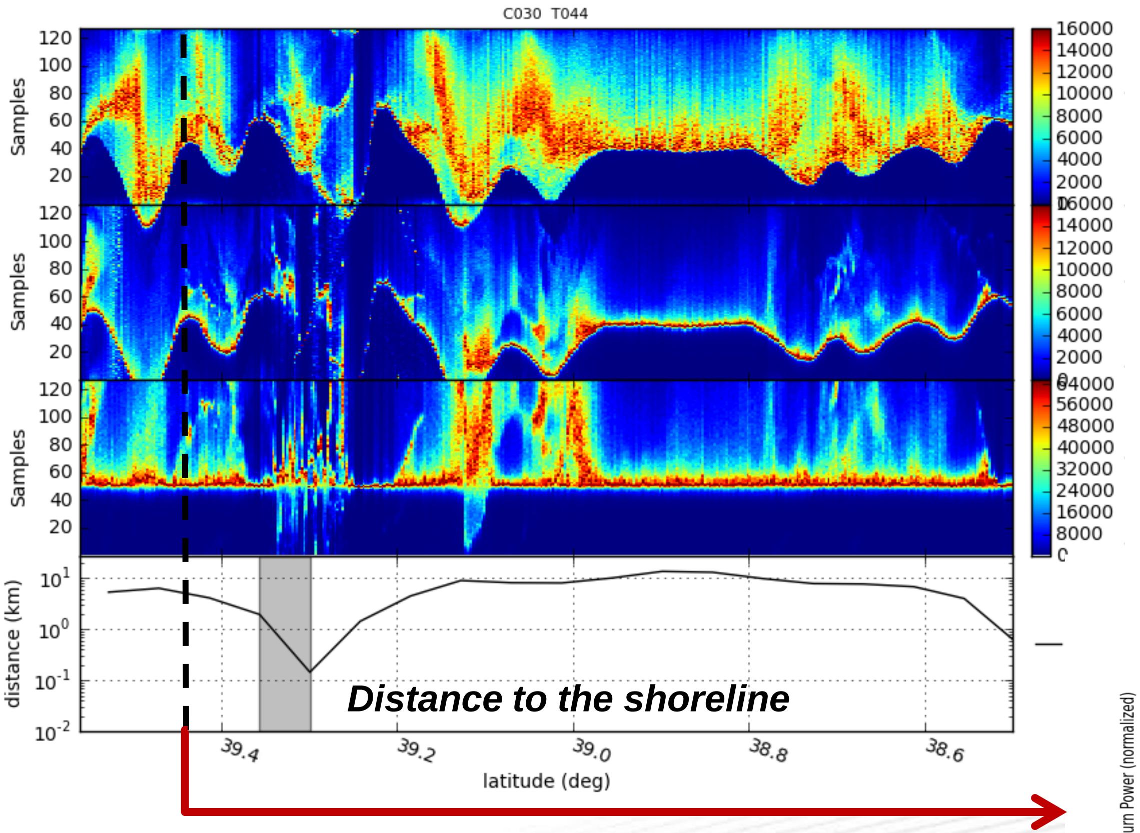
Oversampling on Conventional waveforms

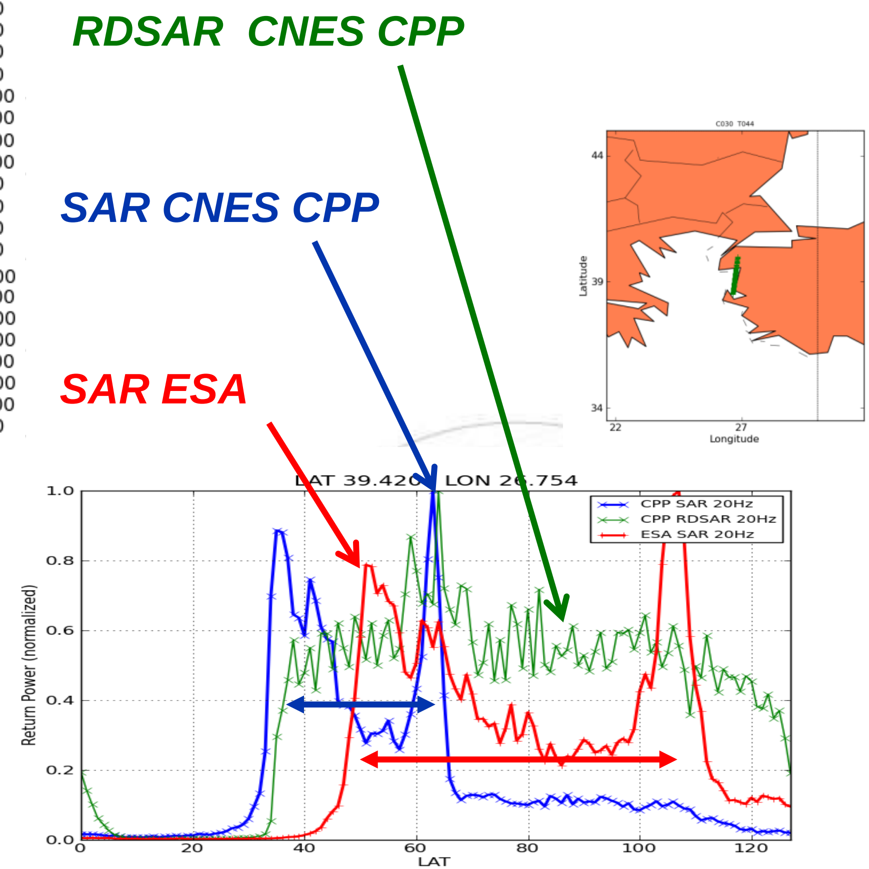


- Reduced waveform window ➔ impacts on all estimated parameters (SWH not only on leading edge like in LRM)
- Is oversampling suitable for altimetry ?
  - Modification of the speckle properties
  - Speckle interpolation

Comparison ESA and CNES CPP processing

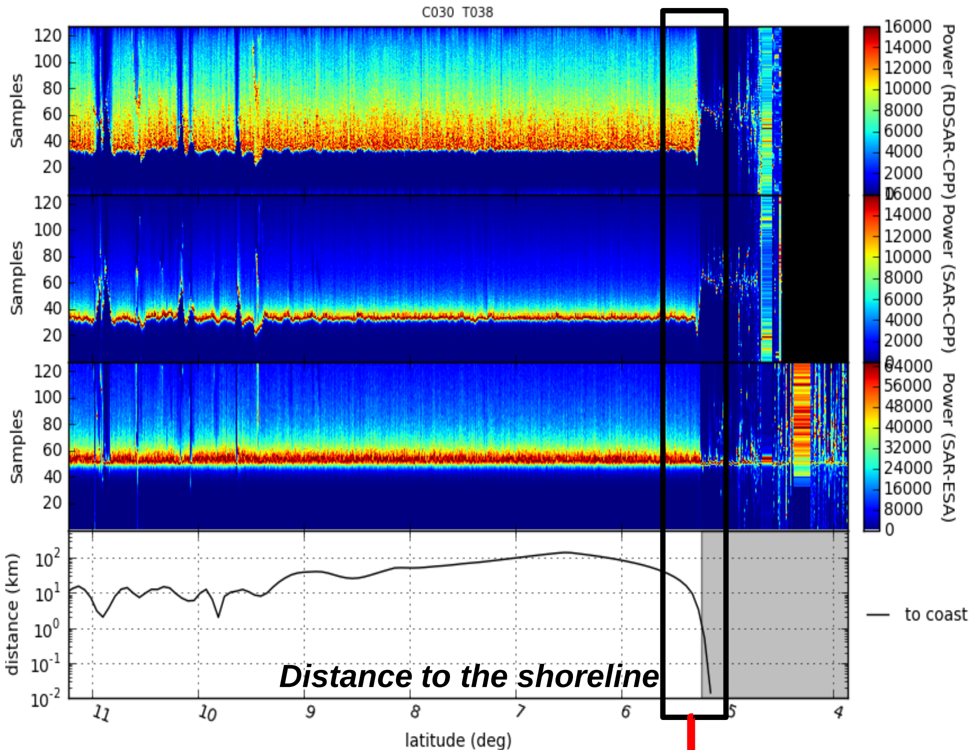
CPP : Cryosat Processing Prototype developped by CNES in the frame of the preparation of the S3 mission





- Good coherence between CNES CPP RDSAR and SAR echos (leading edge and signal)
- Oversampling ESA : spreading of the waveform
- Alignment of the leading edge on ESA but tracker ranges modified

Land contamination RDSAR vs SAR

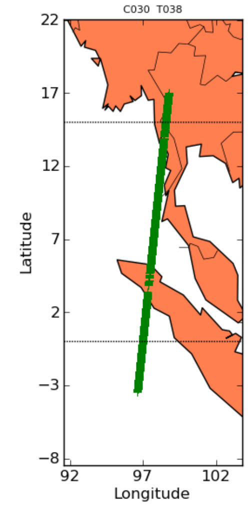


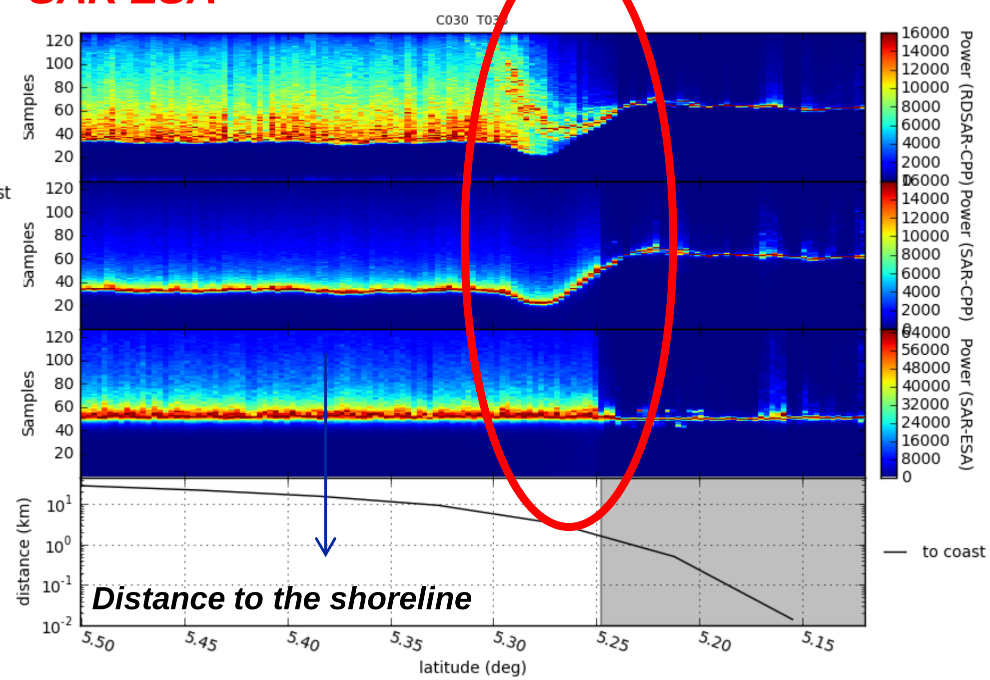
zoom

RDSAR CNES CPP

SAR CNES CPP

SAR ESA





Thank you !

Some Mission characteristics

	ERS-1	ERS-2	TOPEX	Poseidon-1	Jason-1	Envisat	Jason-2	Cryosat-2 LRM	HY-2	Alti-Ka
Nominal Altitude (km)	790	790	1336	1336	1336	790	1336	723	970	790
Bandwidth (kHz)	330	330	320	320	320	320	320	320	320	480
Nb_Gates_WF	64	64	120	62	104	122	104	120	116	116
Abs_Ref_Track	32	32	32	32	32	45	32	34	32	52
Footprint Radius (km)	**4,87**	**4,87**	**10,55**	**6,23**	**9,56**	**7,60**	**9,56**	**7,68**	**8,79**	**5,66**
Footprint Surface (km2)	**74,40**	**74,40**	**349,96**	**121,90**	**287,05**	**181,36**	**287,05**	**185,14**	**242,67**	**100,76**