CryoSat-2 over Rivers : a present mission, An insight into the future of Altimetry

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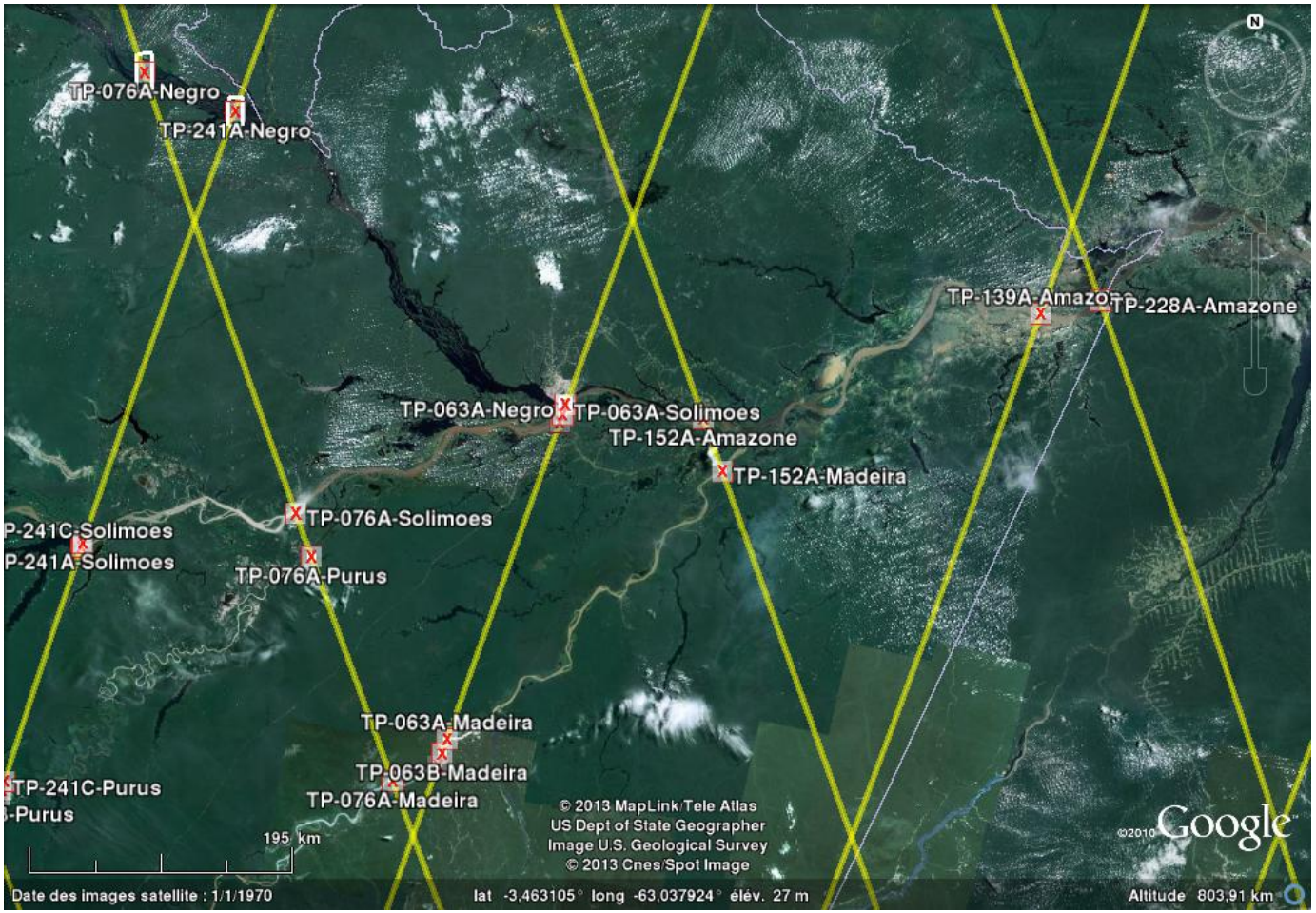
(3) CNES, Toulouse, France ; (4) ALONG-TRACK, Brest, France

Tuesday 28th October 2014

Introduction to CryoSat-2

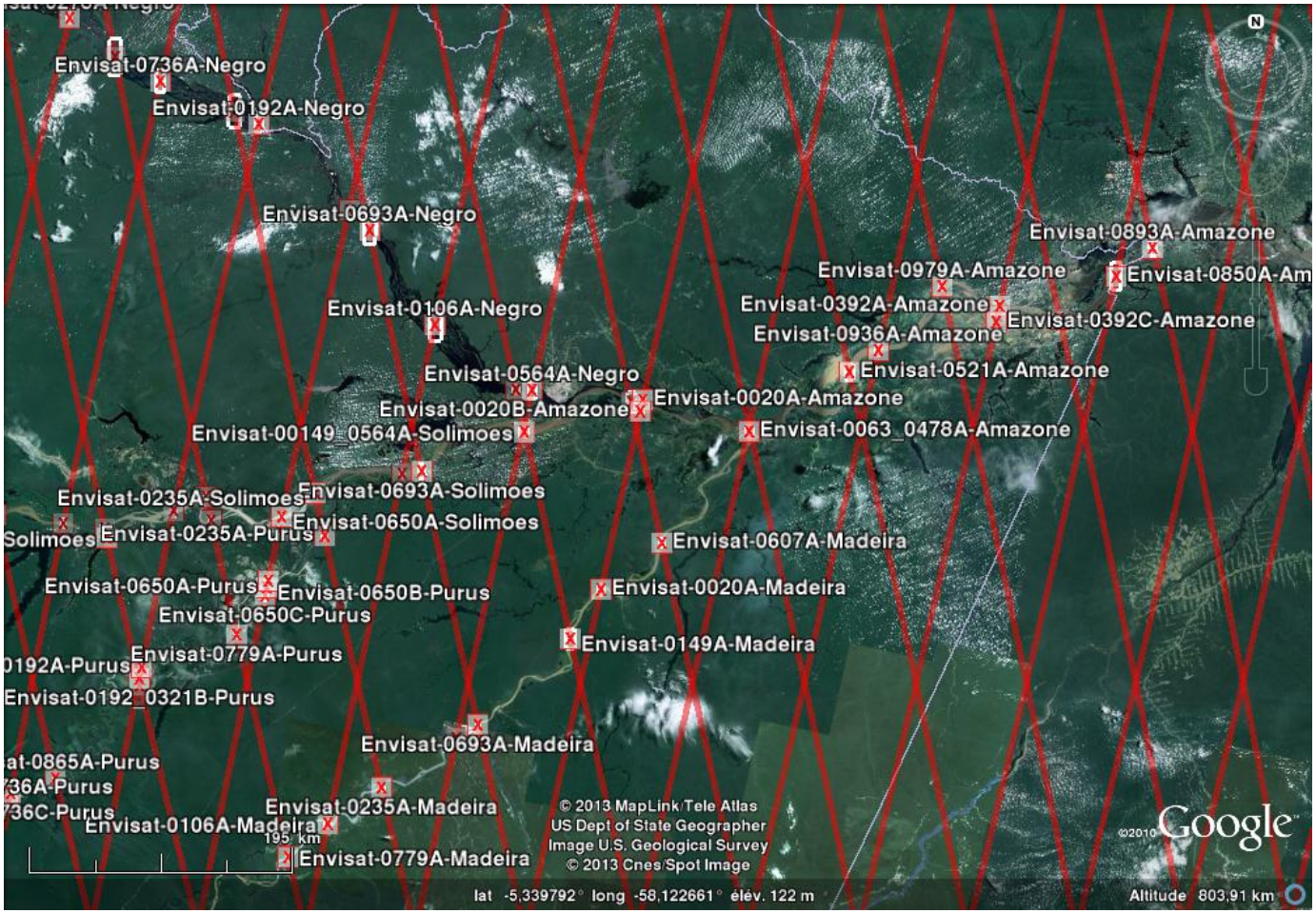
CryoSat-2 flies on a geodesic orbit !

Topex/Poseidon & Jason-2 "virtual stations"



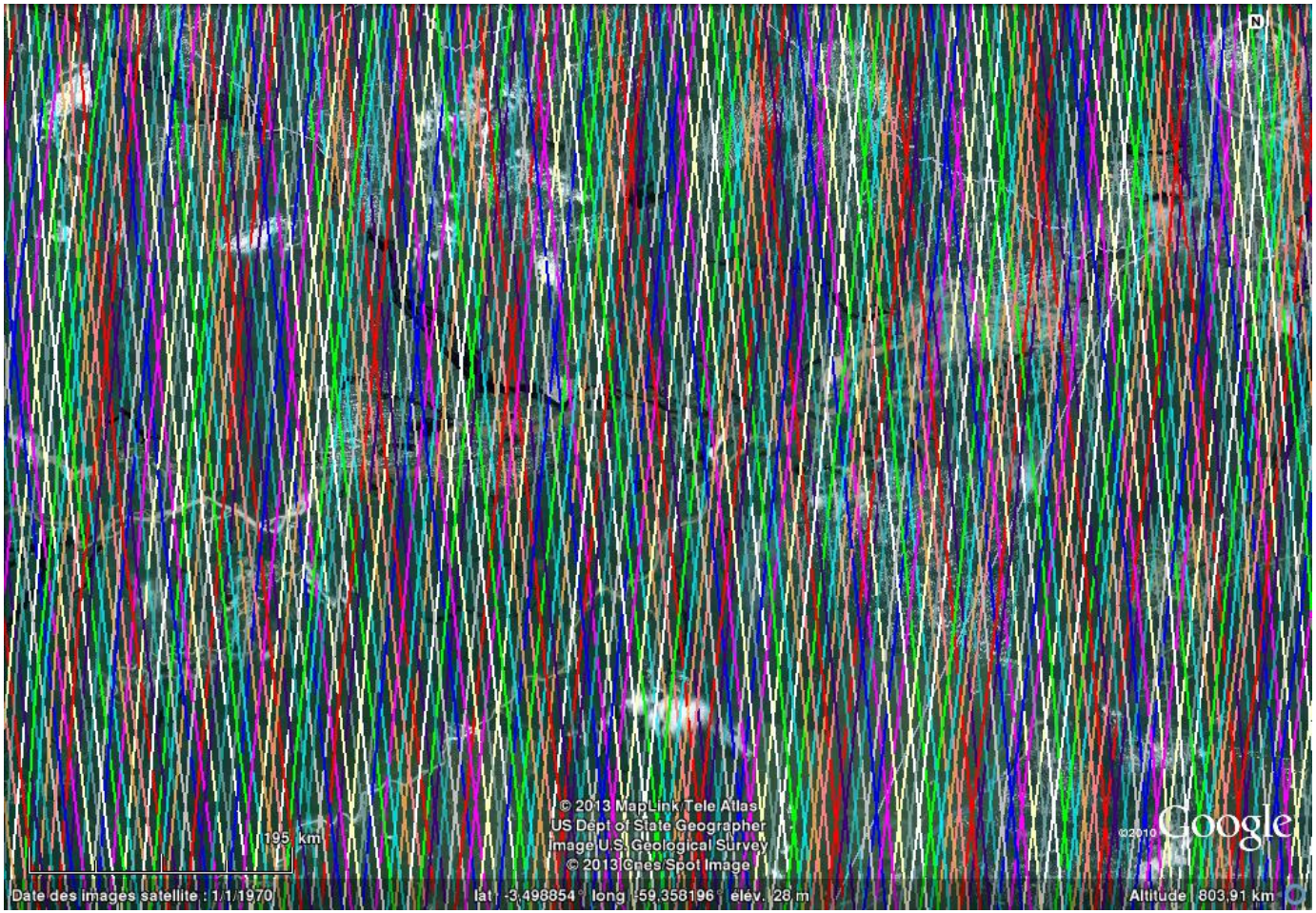
CryoSat-2 flies on a geodesic orbit !

Envisat "virtual stations"



CryoSat-2 flies on a geodesic orbit !

CryoSat-2 tracks... ! (369 days, 7 km //)



CryoSat-2 altimeter : SIRAL

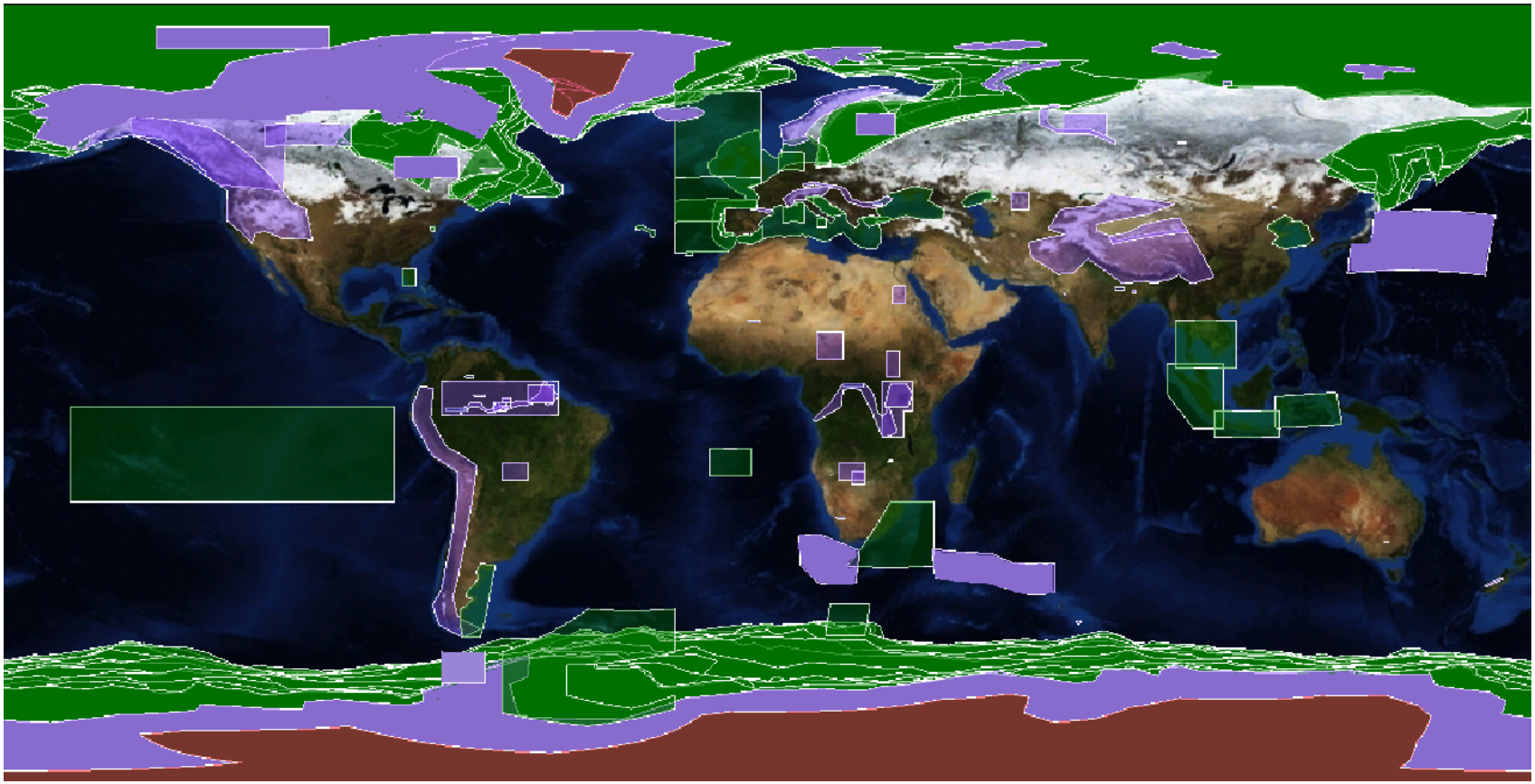
SIRAL : 3 exclusive measurement modes

- **LRM** : Wf : 128 bins, Res. : 200 km^2, L2 : 20 Hz
- **SAR** : Wf : 128 bins, Res. : 3 km^2, L2 : 20 Hz
- **SARin** : Wf : 2$\times$512 bins (dual channel), Res. : 3 km^2, L2 : 20 Hz + retracked echo (lat,lon)

- The most advanced nadir altimeter !
- Ku band
- 20 Hz tracking cycle $\rightarrow$ 20 Hz L2 products

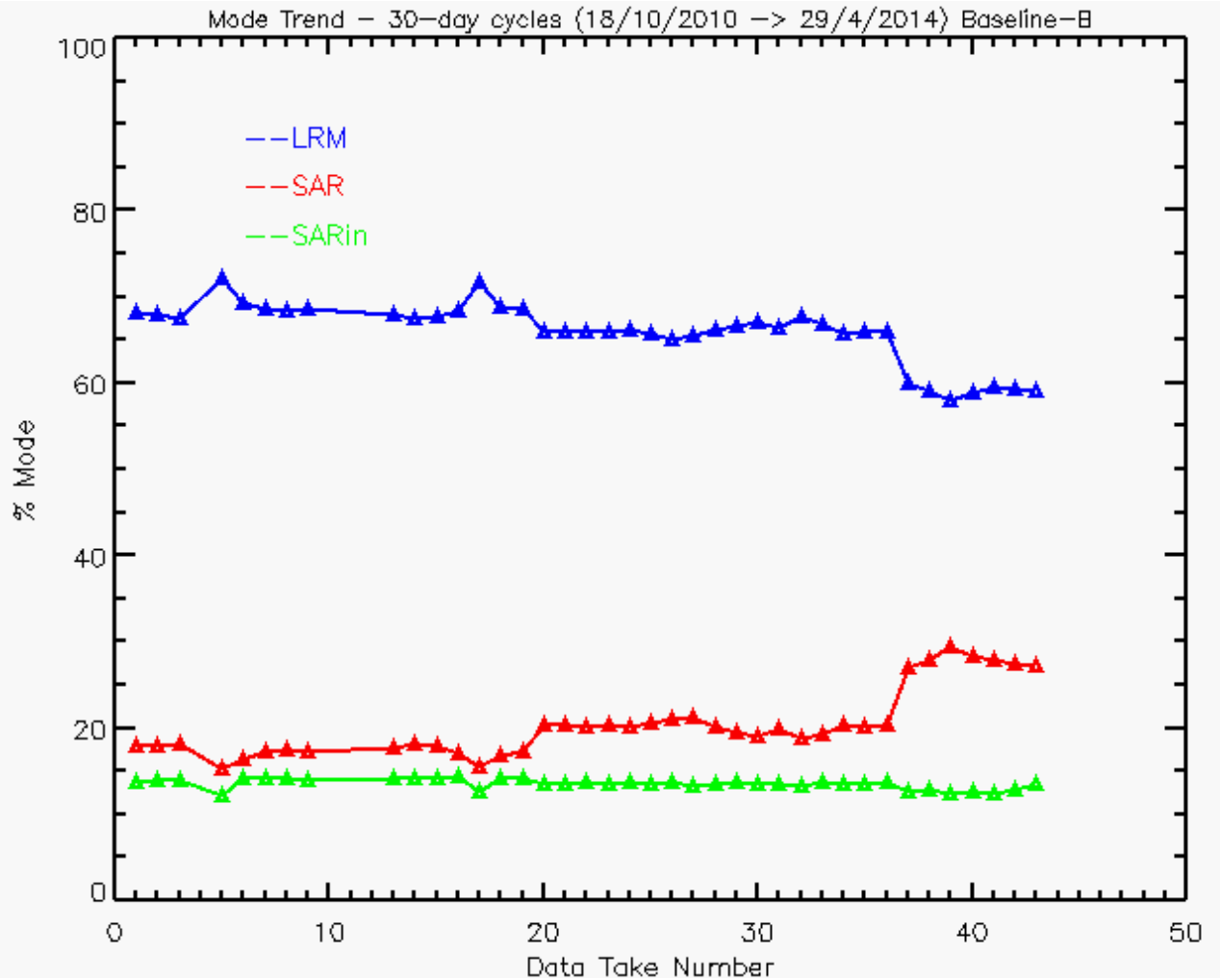
CryoSat-2 modes mask

LRM : $\approx$ 66% – SAR : $\approx$ 17% – SARin $\approx$ 17%



CryoSat-2 modes mask

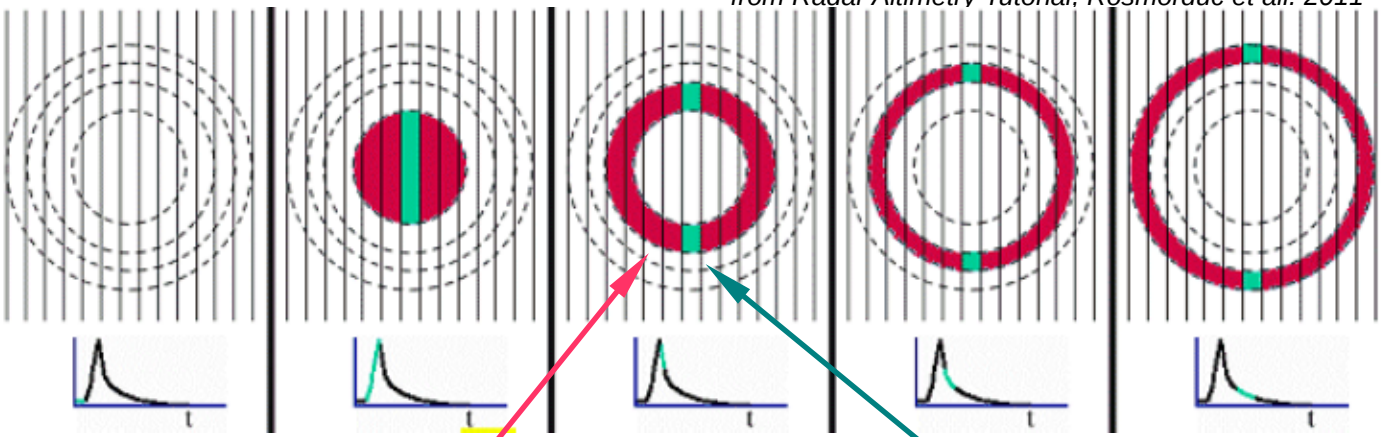
LRM : $\approx$ 66% – SAR : $\approx$ 17% – SARin $\approx$ 17% (data from UCL)



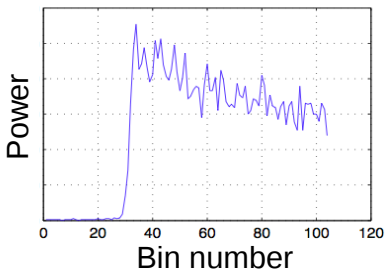
The SAR waveform

Doppler beam footprint

from Radar Altimetry Tutorial, Rosmorduc et all. 2011

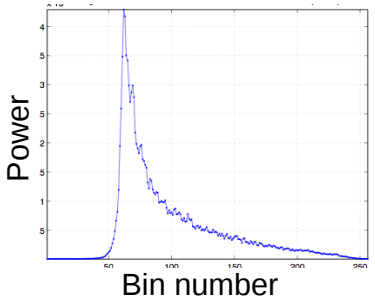


Brown wave-form



SAR wave-form much more « peaky » than Brown's wave-form (because of surface reduction from internal to external rings)

Doppler wave-form



CryoSat-2

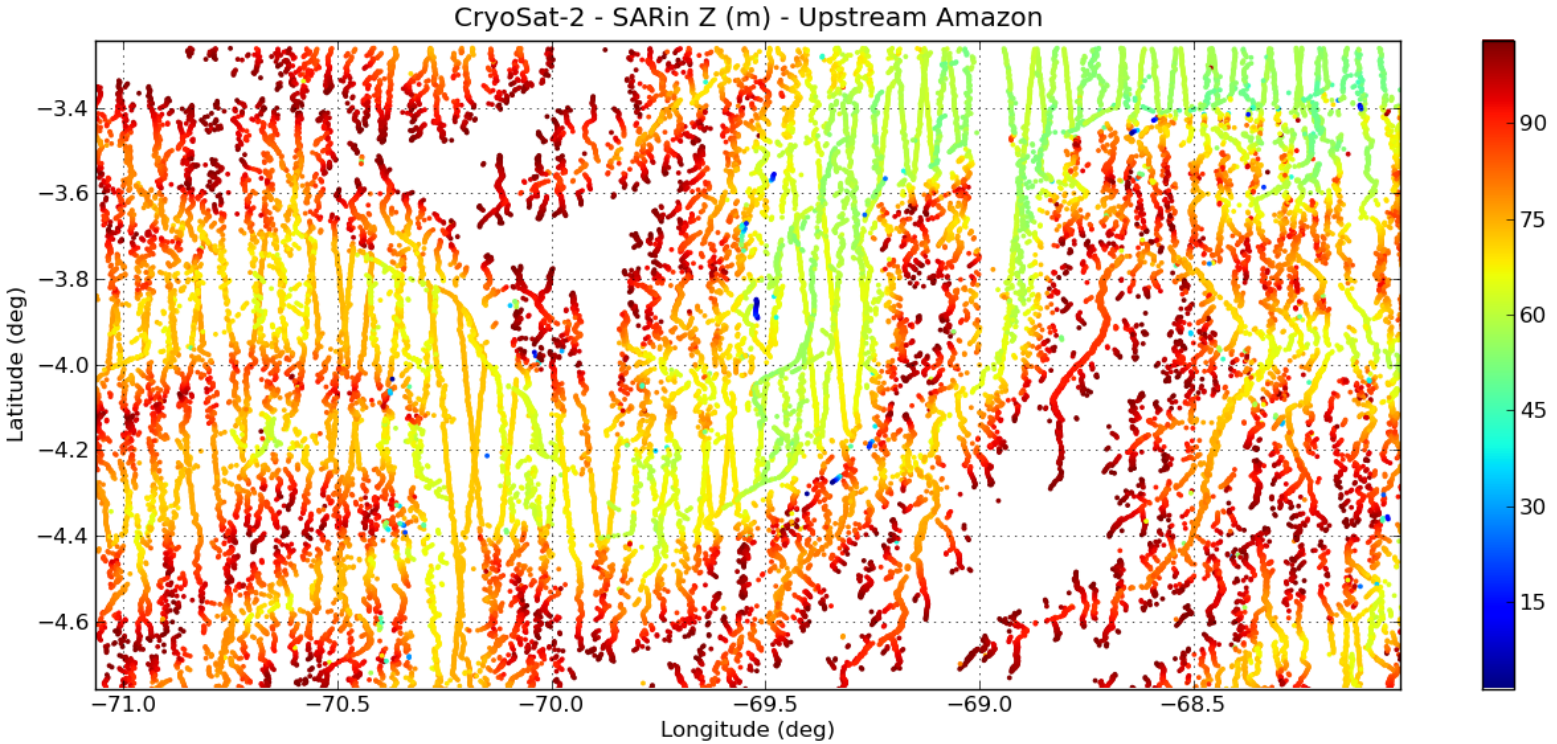
Past, Present and Future. . .

- Past -

LRM vs. SARin mode

Past : LRM vs. SARin mode

Map of SARin measurements over the Solimoes river (L2/ESA)



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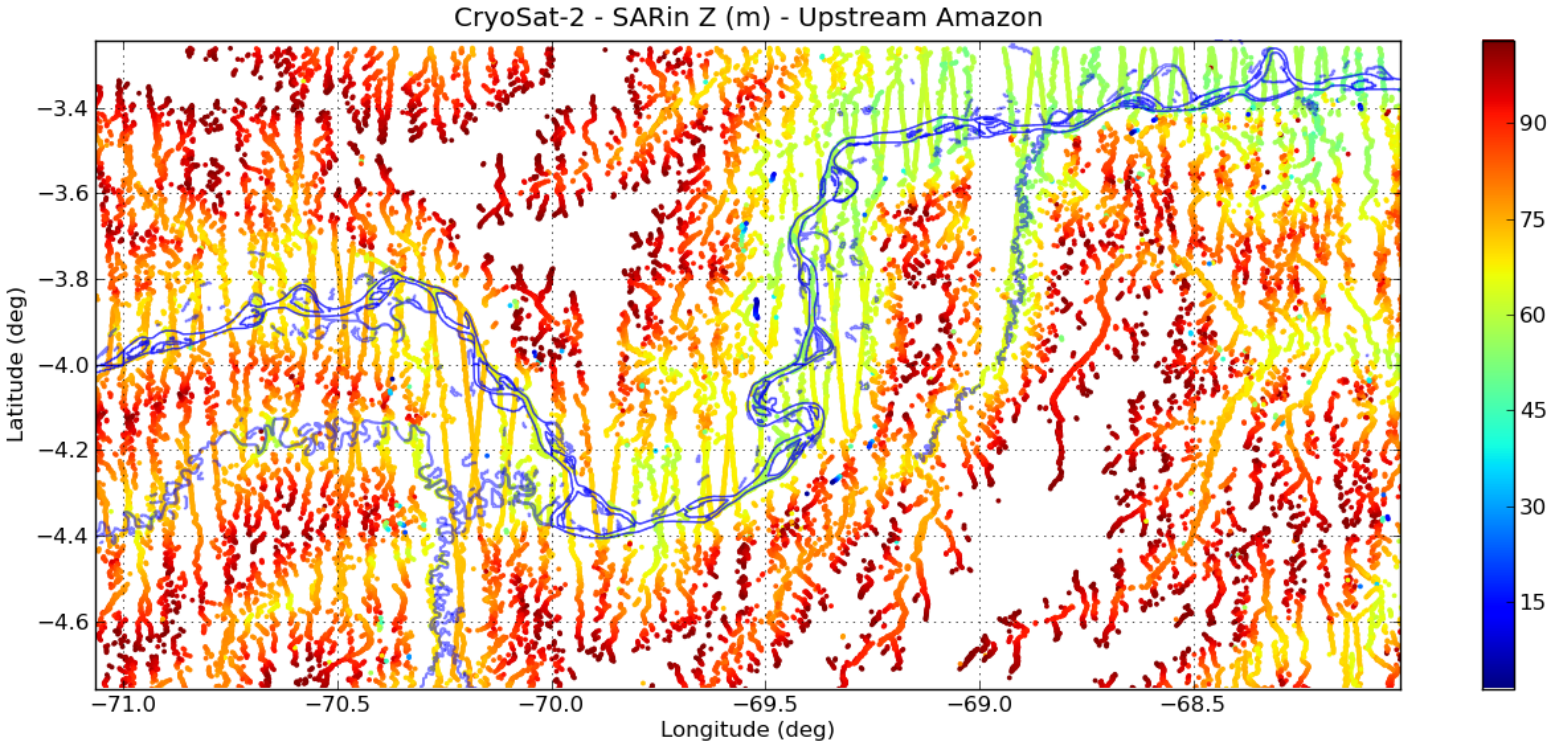
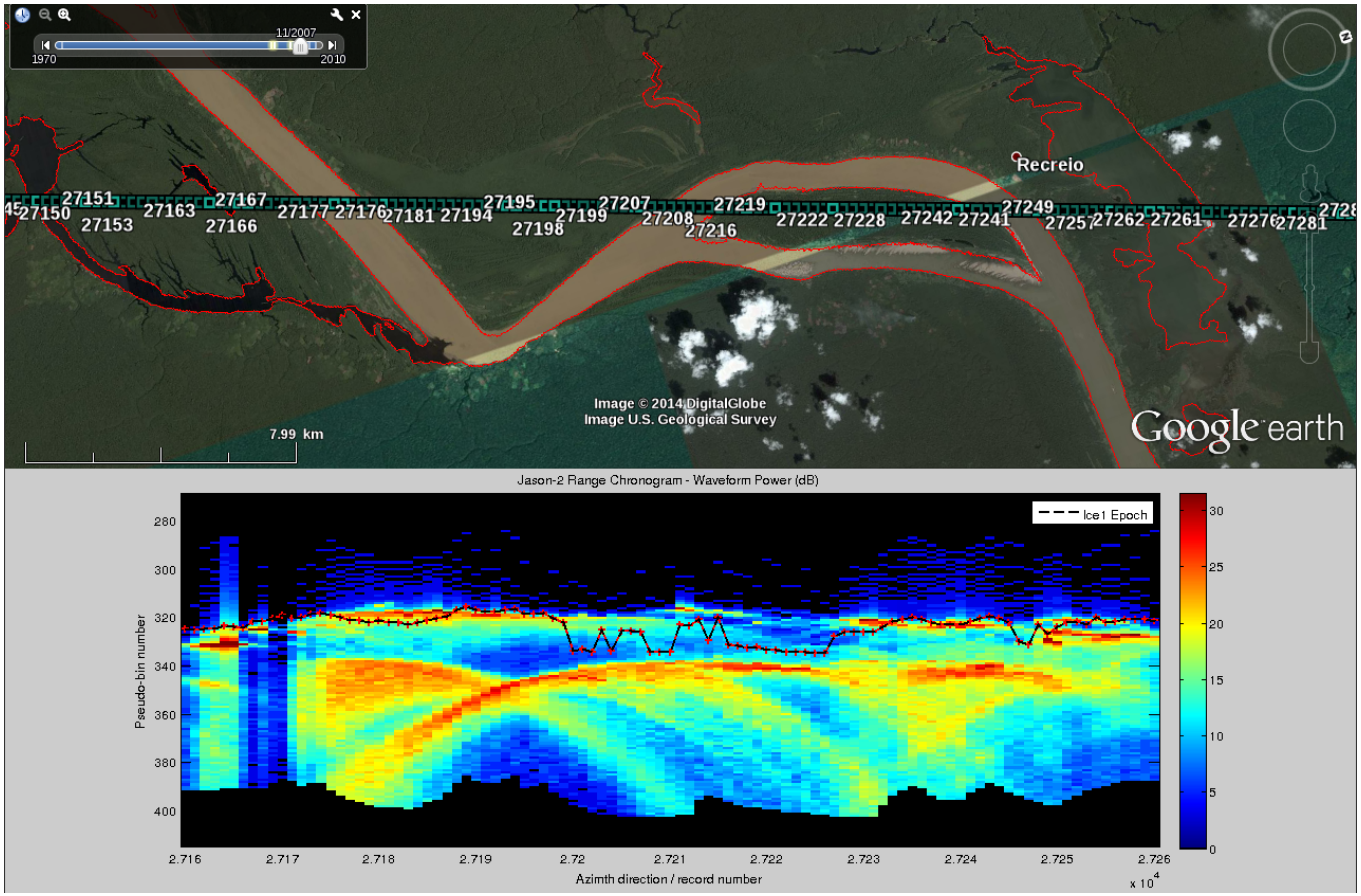


Retracked echoes comes really often from off-nadir directions
$\rightarrow$ SIRAL is nearly mapping the hydrographic network !

Past : LRM vs. SARin mode

Jason-2 waveforms over the Madeira river (AVISO/S-GDR)



Past : LRM vs. SARin mode

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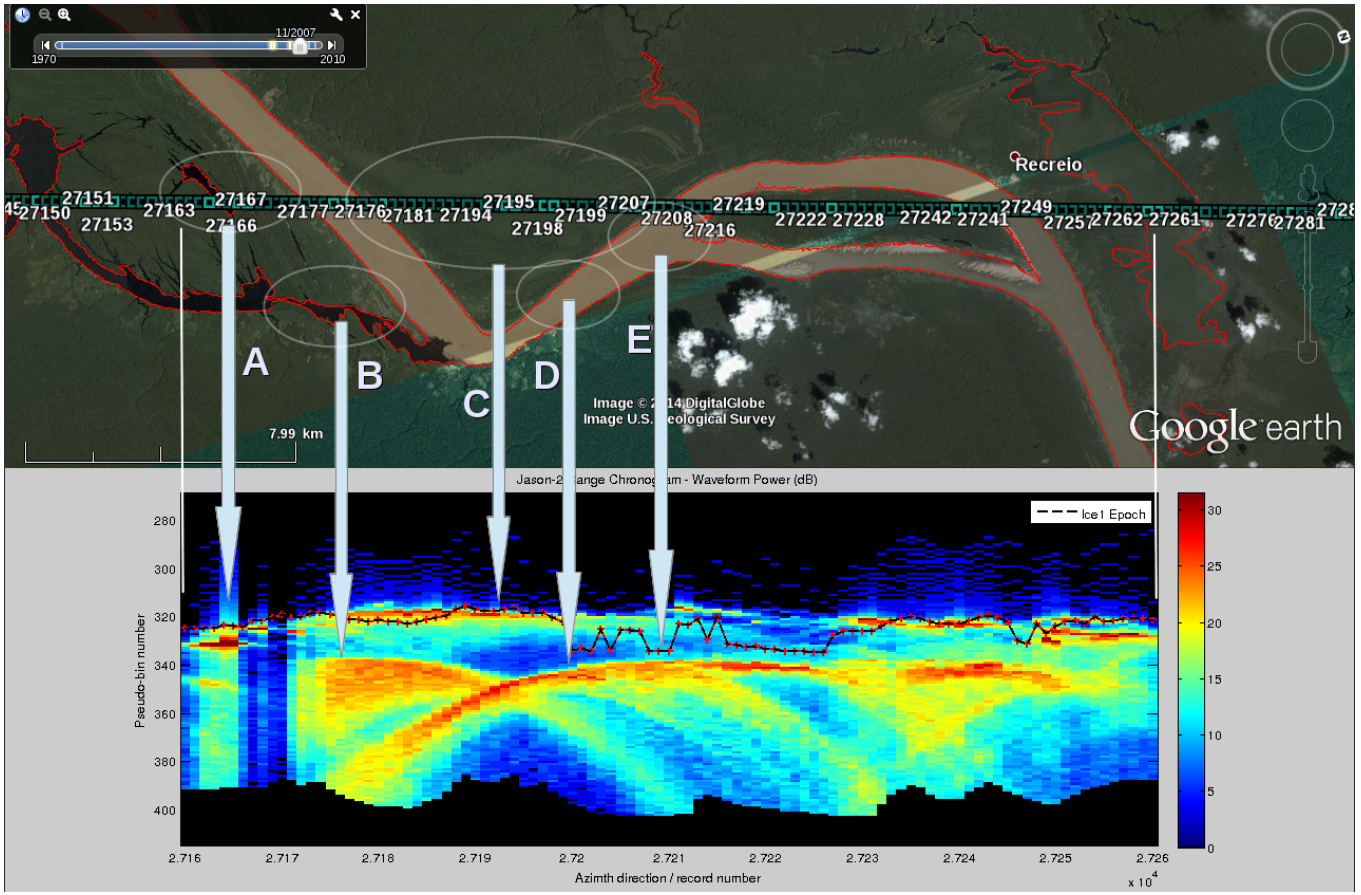
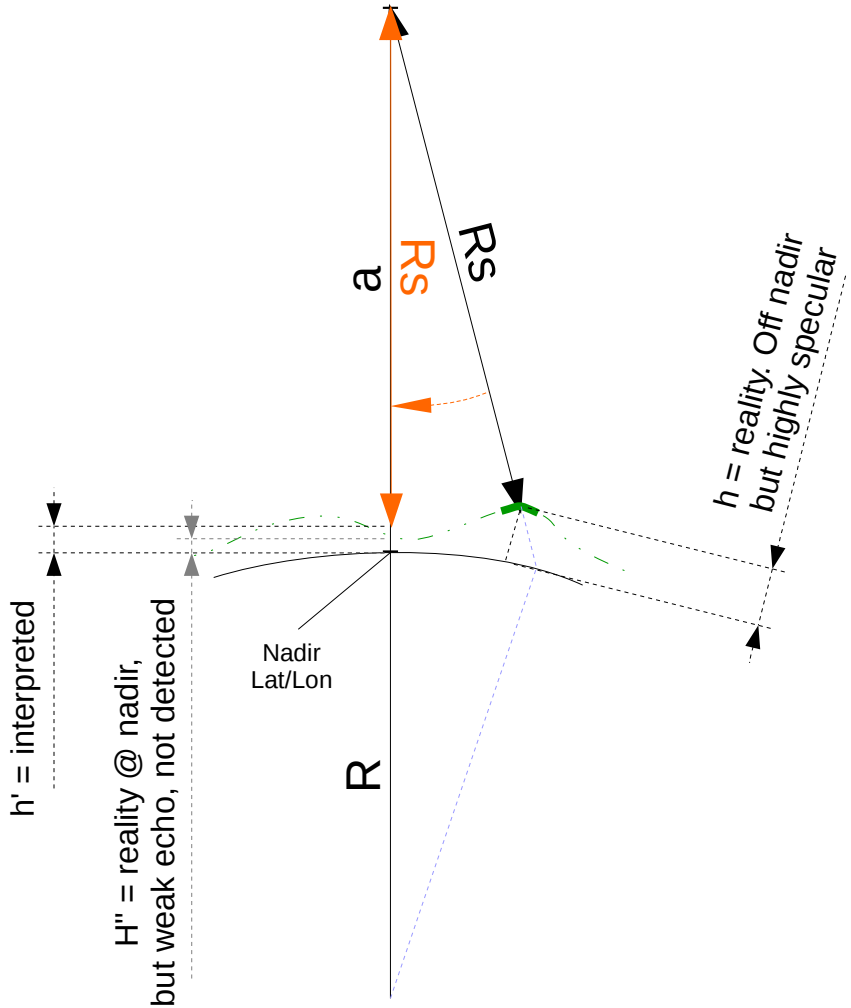


Echoes really come from off-nadir directions !

SARin → LRM : the Height Anomaly Experiment



Schema kindly designed by Pierre-Antoine Baffaut

Scene

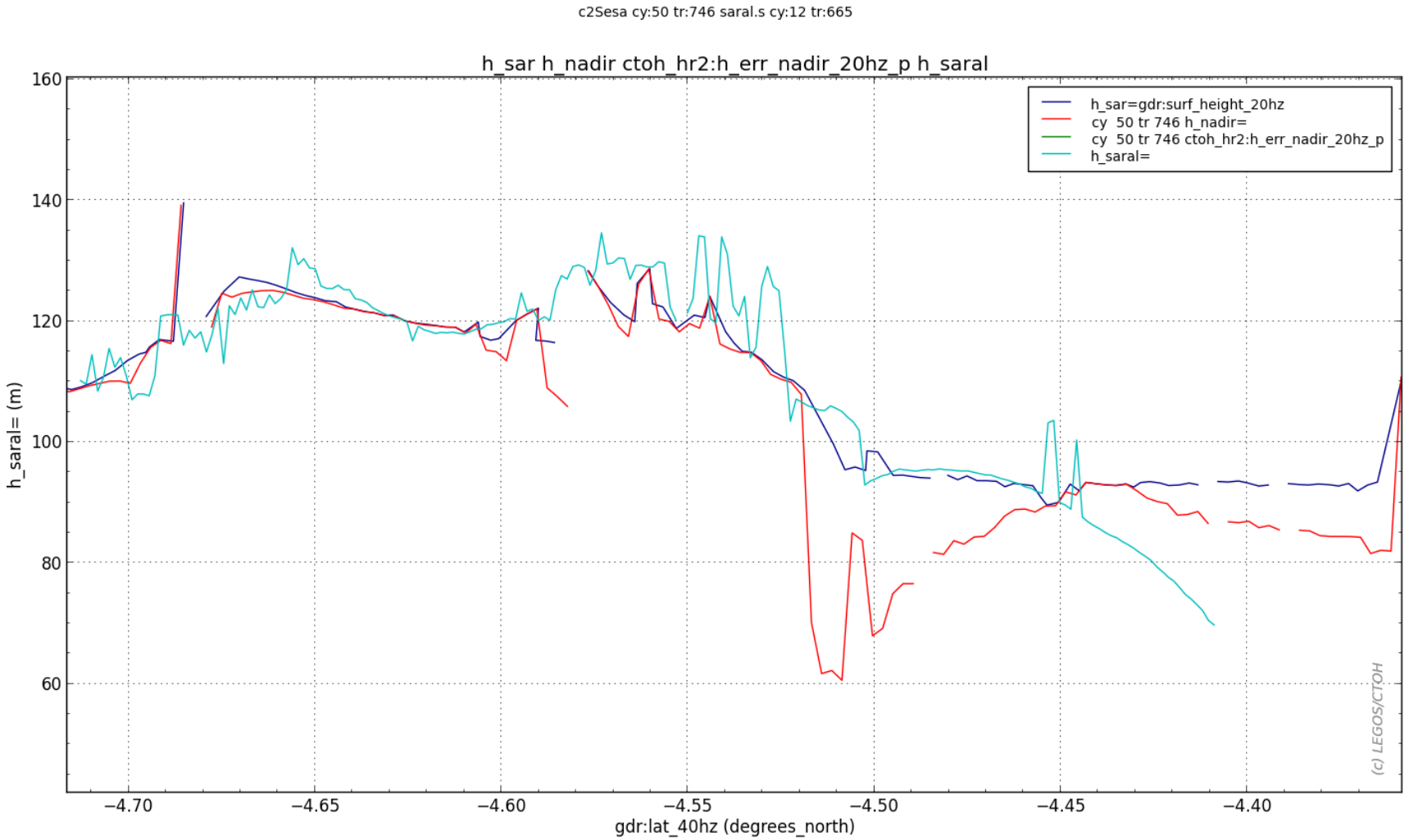
- Assume off-nadir specular reflector (Rs)
- SARin gives real off-nadir height h (and location)
- What about LRM h' ?

  (reflector location assumed at sat. nadir)
- Height Anomaly = $h' - h$

SARin → LRM : the Height Anomaly Experiment

Sara Fleury, LEGOS/CTOH, Toulouse France.

SARin → LRM : the Height Anomaly Experiment

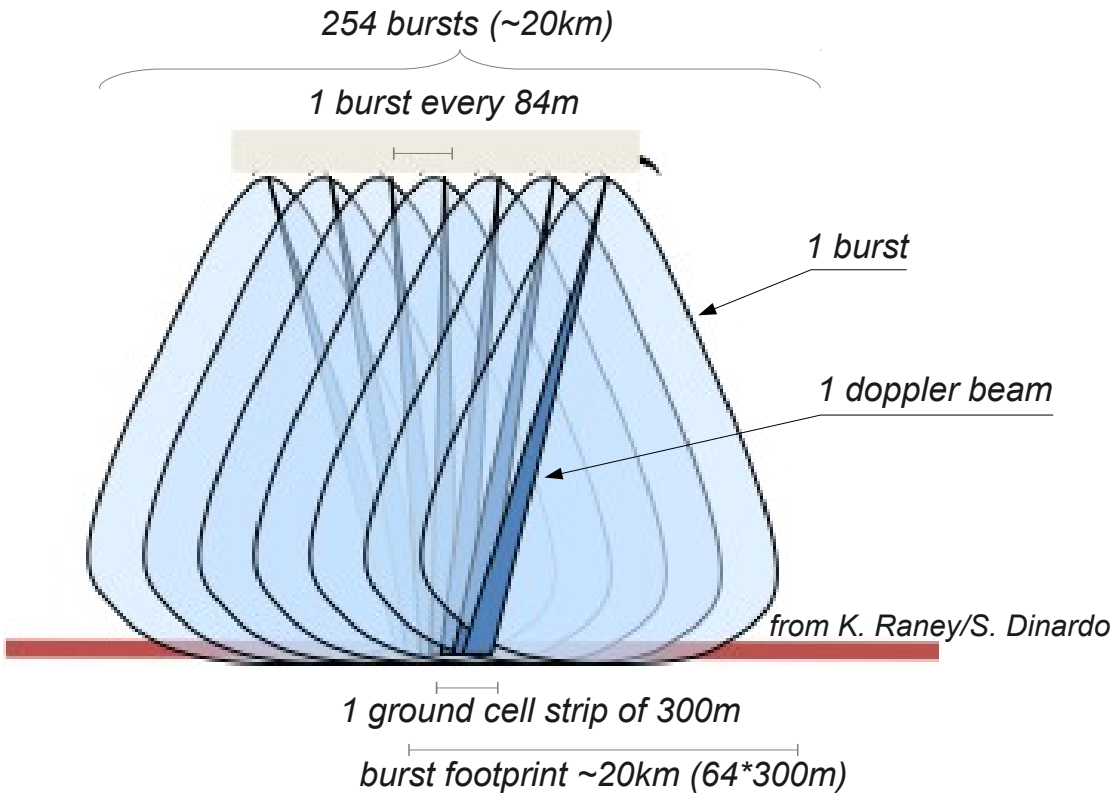


Sara Fleury, LEGOS/CTOH, Toulouse France.

- Present -

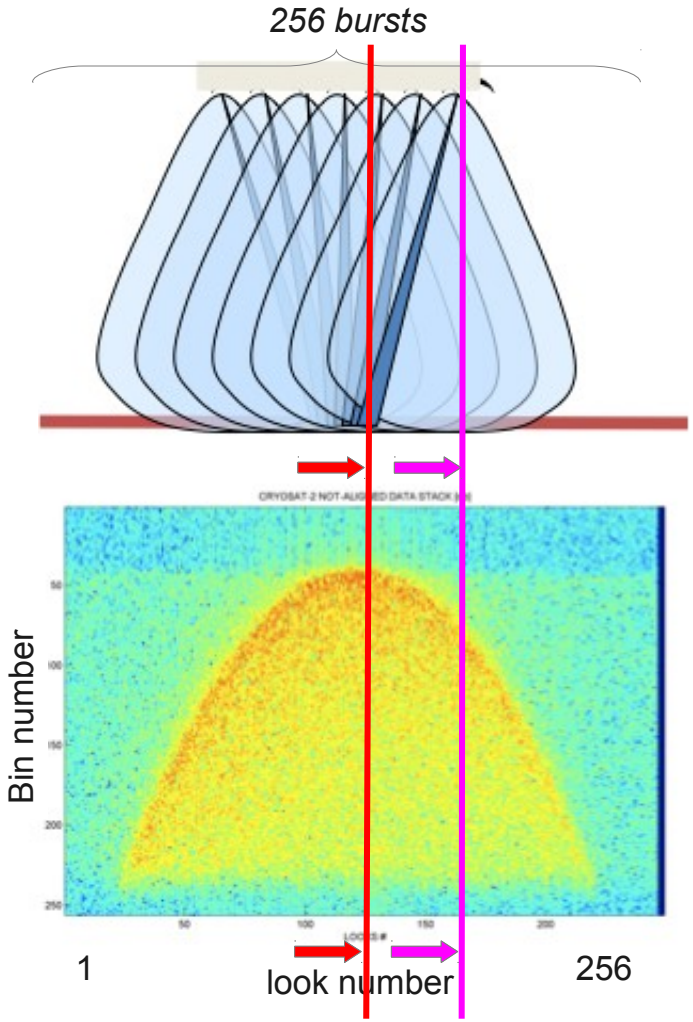
Applications of CryoSat-2 SAR & SARin modes

The multi-look over one ground cell

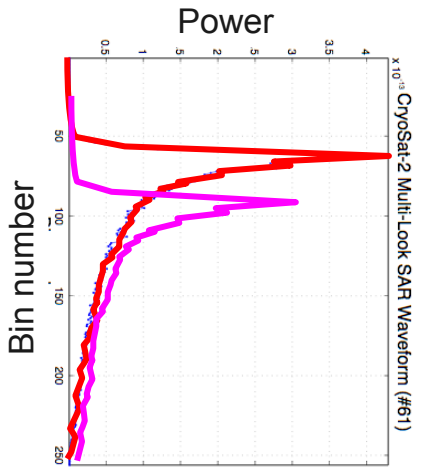


Each ground cell can be seen per theoriticaly 256 bursts
(~223 in practice over ocean)

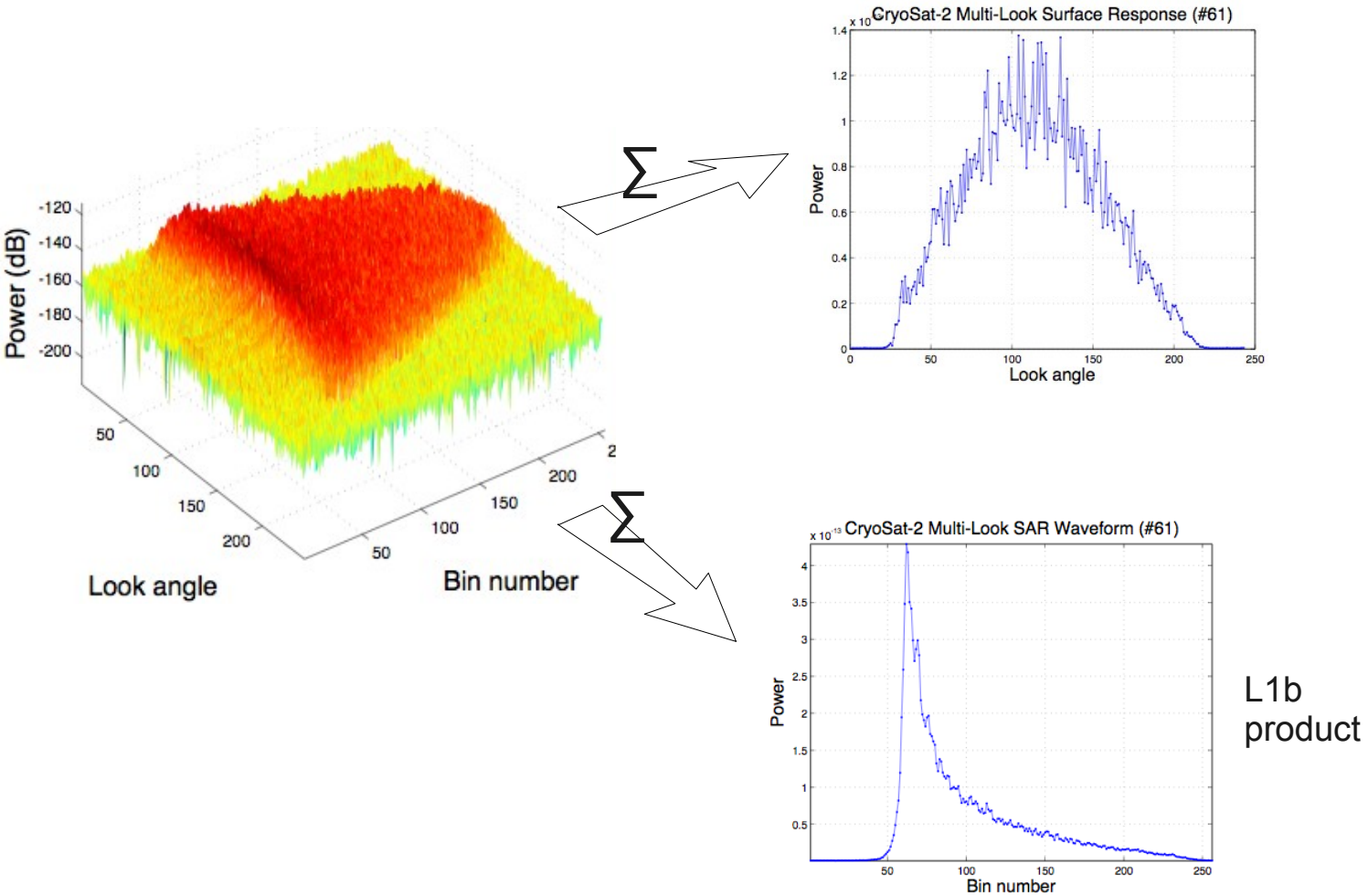
The multi-look : the stack



2 Doppler waveforms « looking » the same ground cell

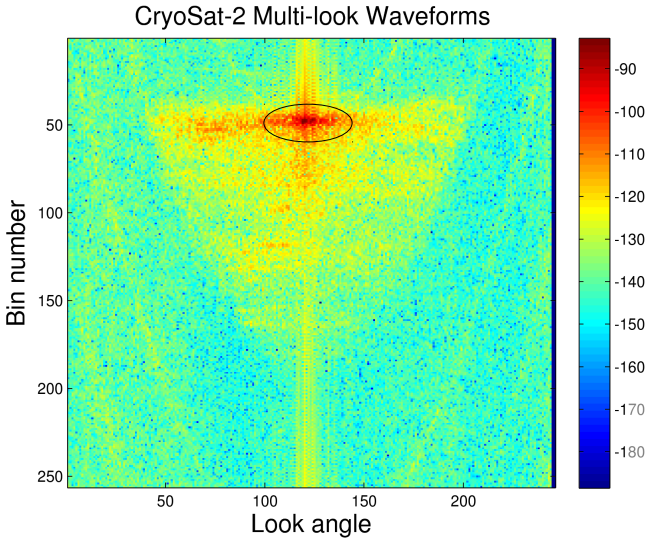


The multi-look: stack

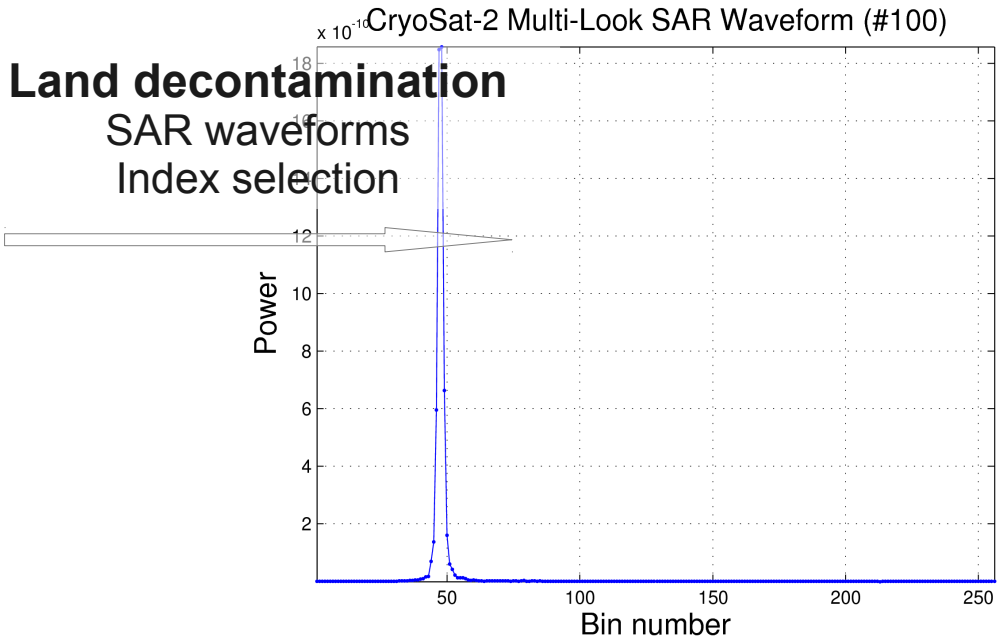


L1b product

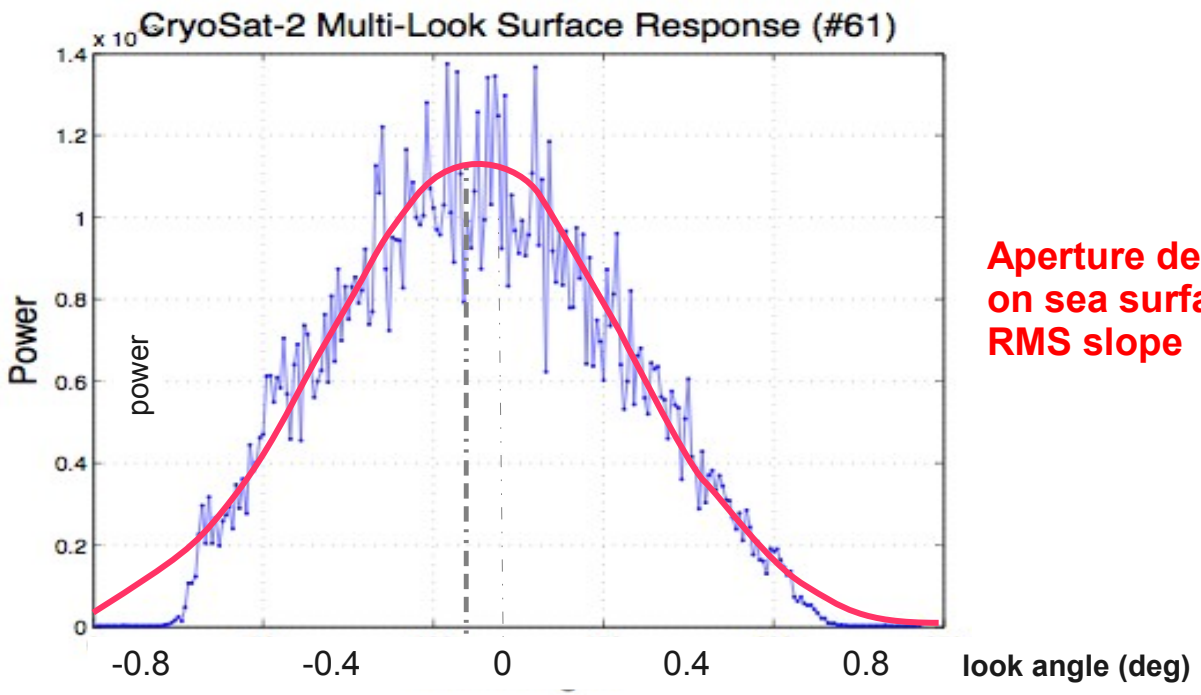
Stack: mean waveform



Land decontamination
SAR waveforms
Index selection



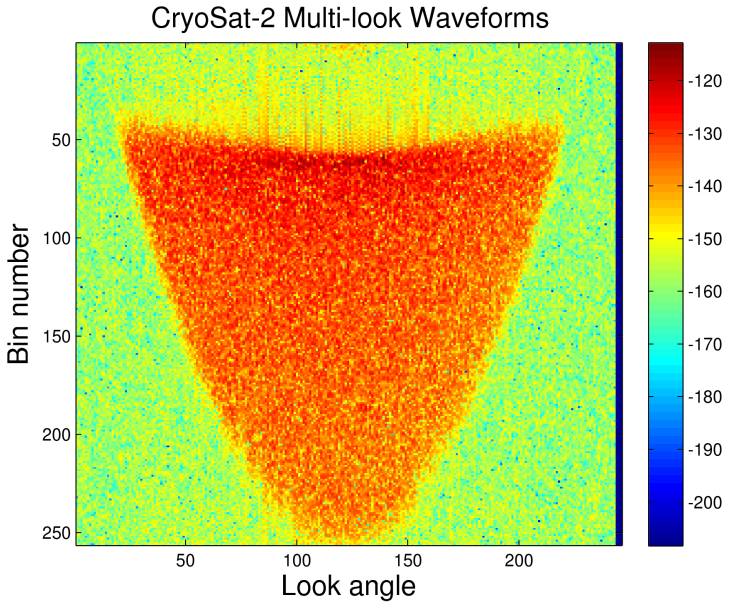
The multi-look: stack look-angles

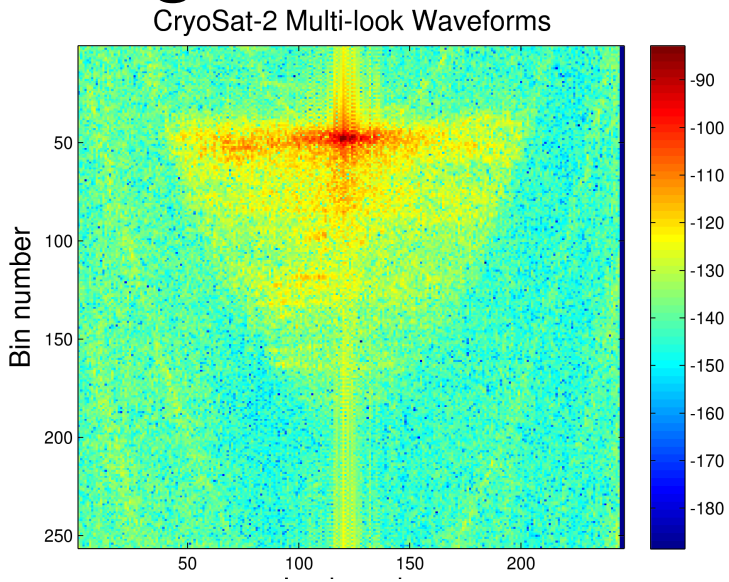


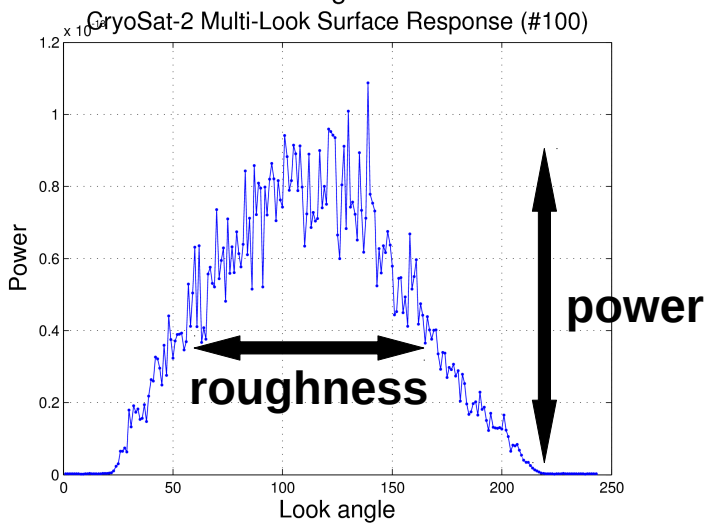
Aperture depending on sea surface RMS slope

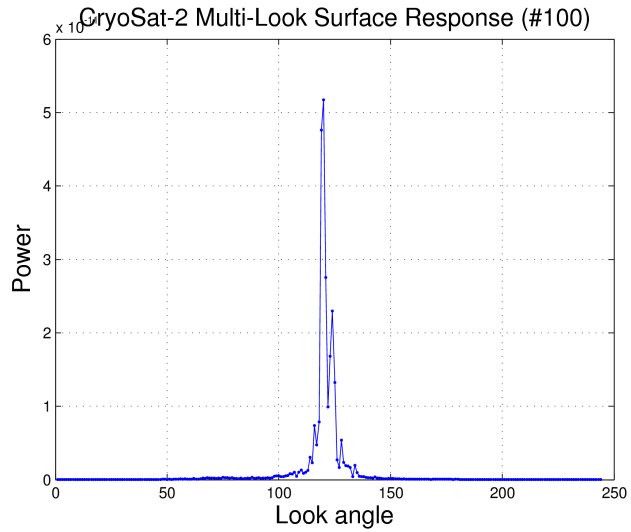
Offset depending on pitch mispointing

Stack: surface roughness

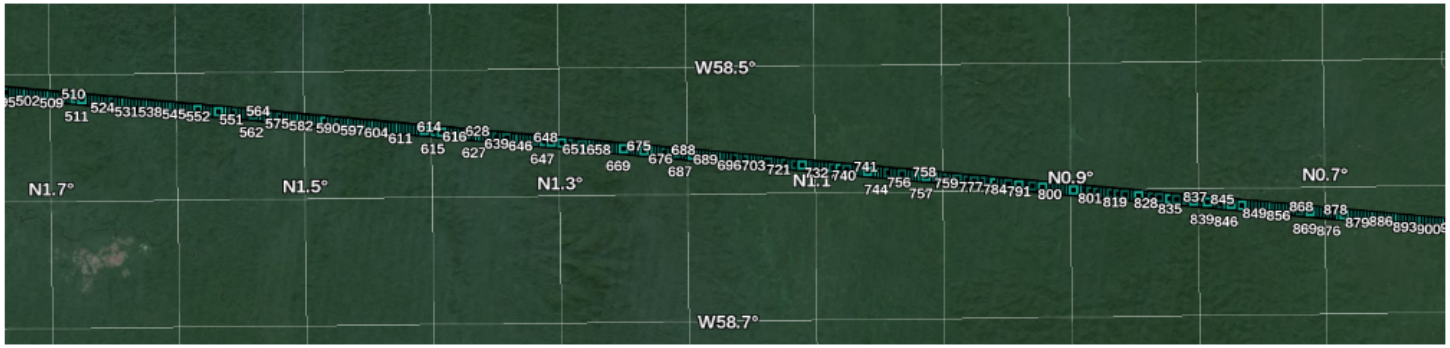


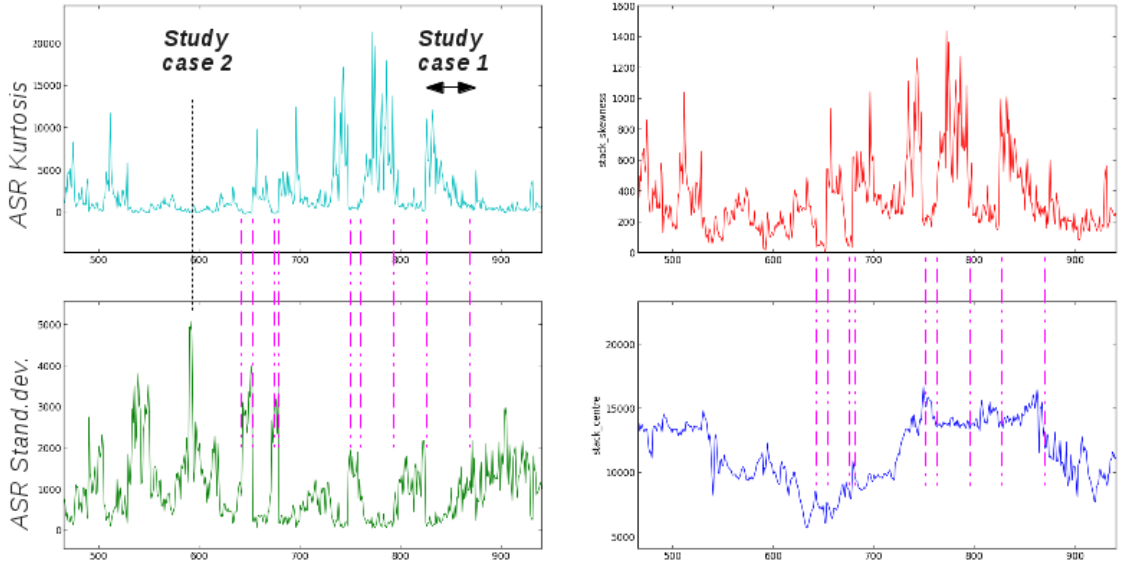






SAR : Angular Surface Response & Beam Behaviour





Kindly provided by P.Fabry (ALONG-TRACK, Brest, France)

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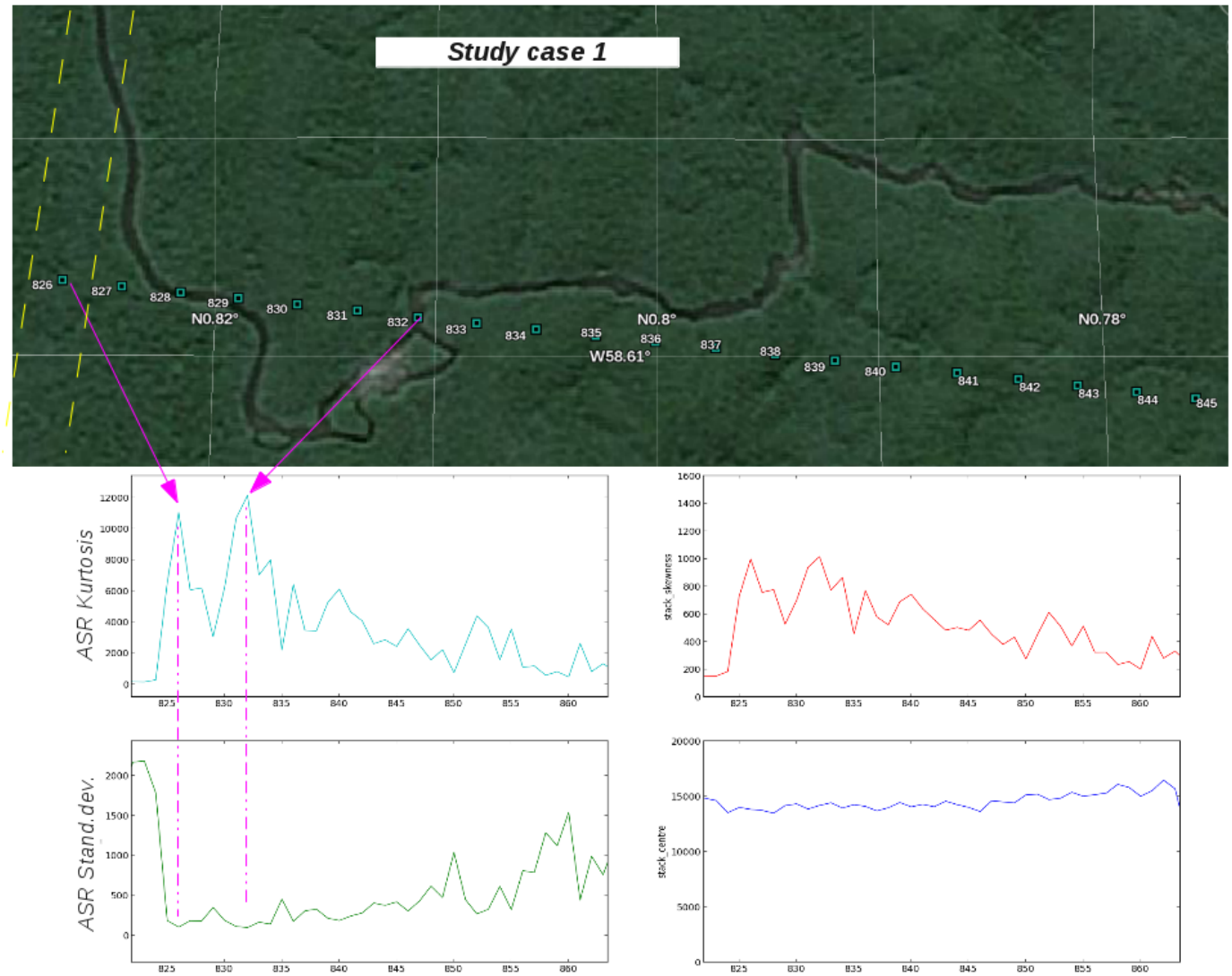

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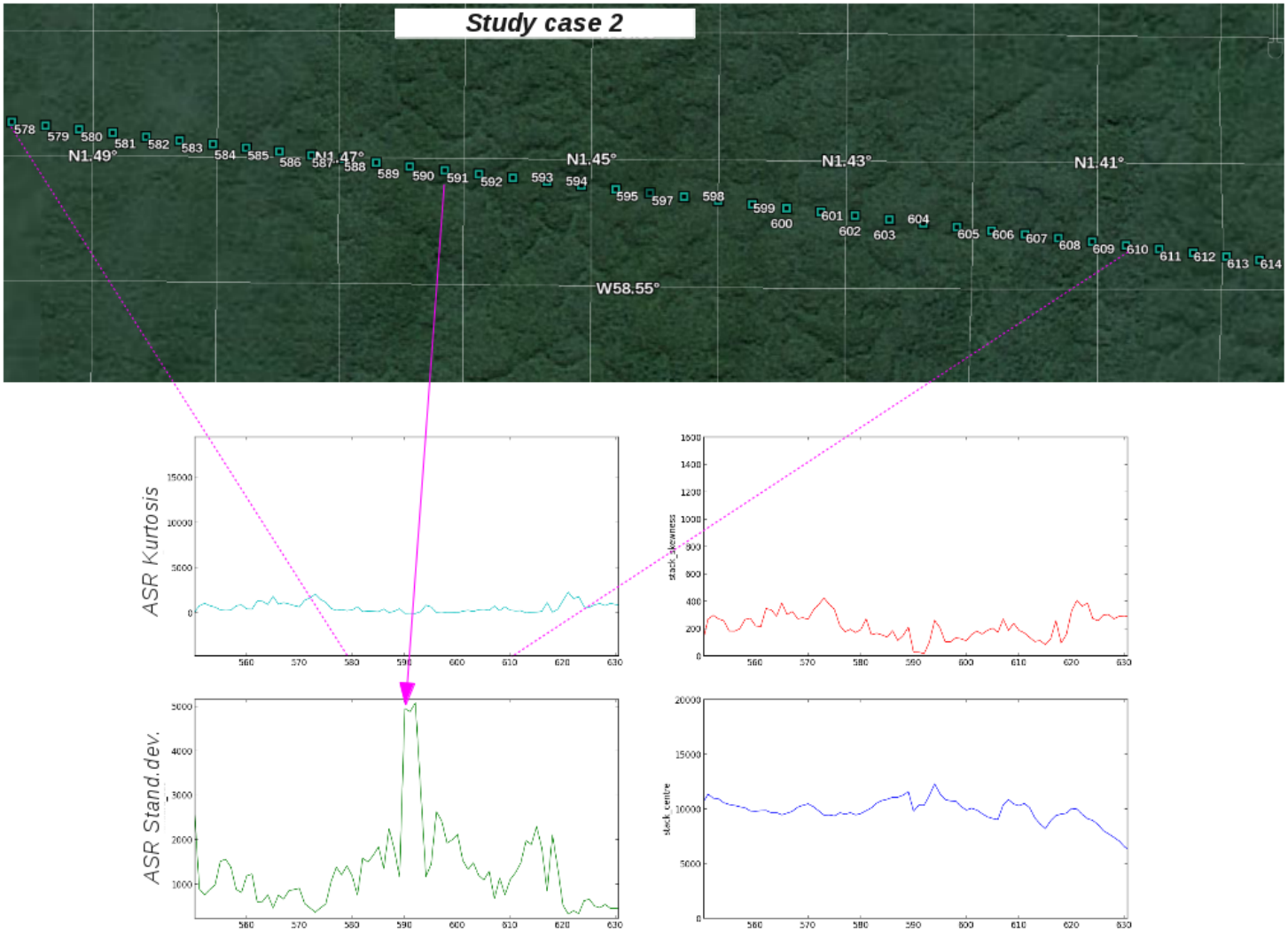


Kindly provided by P.Fabry (ALONG-TRACK, Brest, France)

SAR : Angular Surface Response & Beam Behaviour

The **Angular Surface Response properties** (derived from a fit of the Multi-Look Stacks) may be quite **usefull to discriminate water to non water measurements** :

- Water : High Kurtosis (peakiness) & Low Standard Deviation
- Non Water : Low Kurtosis & High Standard Deviation
- *Consolidation : Skewness High when Kurtosis High*

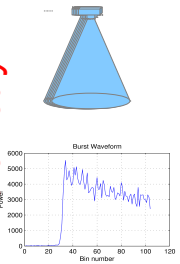
Product Levels

1Hz-20hz products

L0 / FBR | **L1b** | **L2 / L2I**

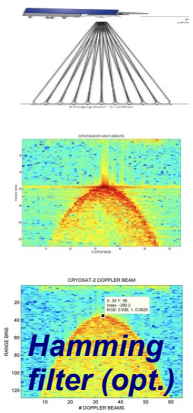
SAR mode

Telemetry



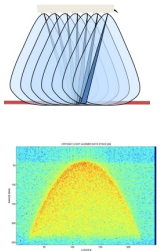
Bursts
64 echoes
Brown WF(I,φ)

SAR coherent sum



Doppler Beams
SAR WF(I)

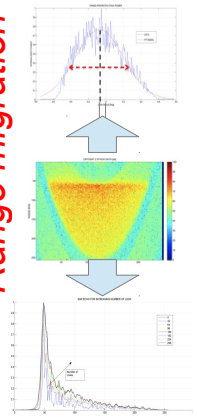
Merge SAR echoes



Multi-look

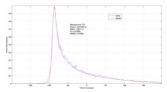
Stack (1/2)
256 ground
cell views

Range migration



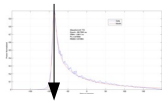
Stack (2/2)
256 ground
cell views

Mean waveform



Waveforms
128 samples

SAR Retracking

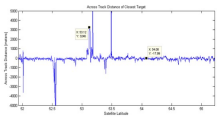


r

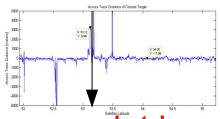
Range

SARin mode

...the "same" for 2 channels...
two reception antennas,
64 look angles instead of 256



Waveforms & Phase diff.
2×512 samples each



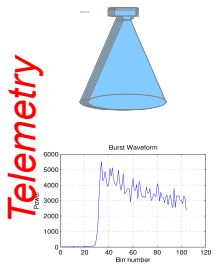
α,lat,lon

Cross-track Angle / Coords
(retracked bin, L2I only)

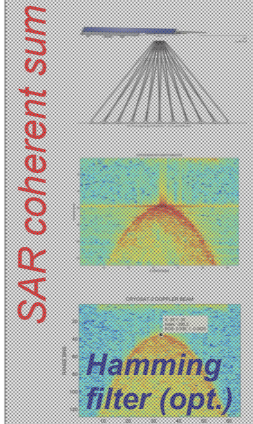
Product Levels

SAR mode

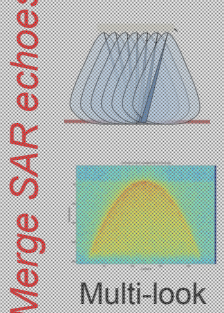
L0 / FBR



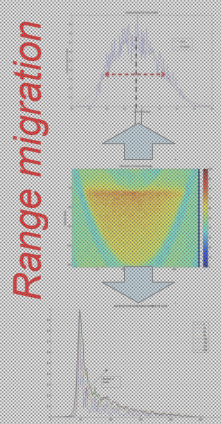
Bursts
64 echoes
Brown WF(I,φ)



Doppler Beams
SAR WF(I)



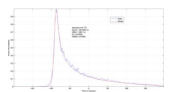
Stack (1/2)
256 ground cell views



Stack (2/2)
256 ground cell views

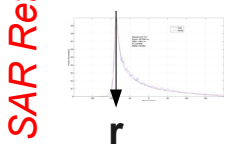
1Hz-20hz products

L1b



Waveforms
128 samples

L2 / L2I



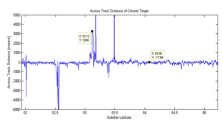
Range

SARin mode

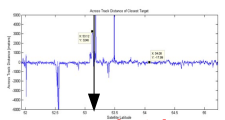
...the same for 2 channels...
(two reception antennas)

Intermediate stack
2×64 ground cell views

Stacks of 2×64 ground cell views



Waveforms & Phase diff.
2×512 samples each



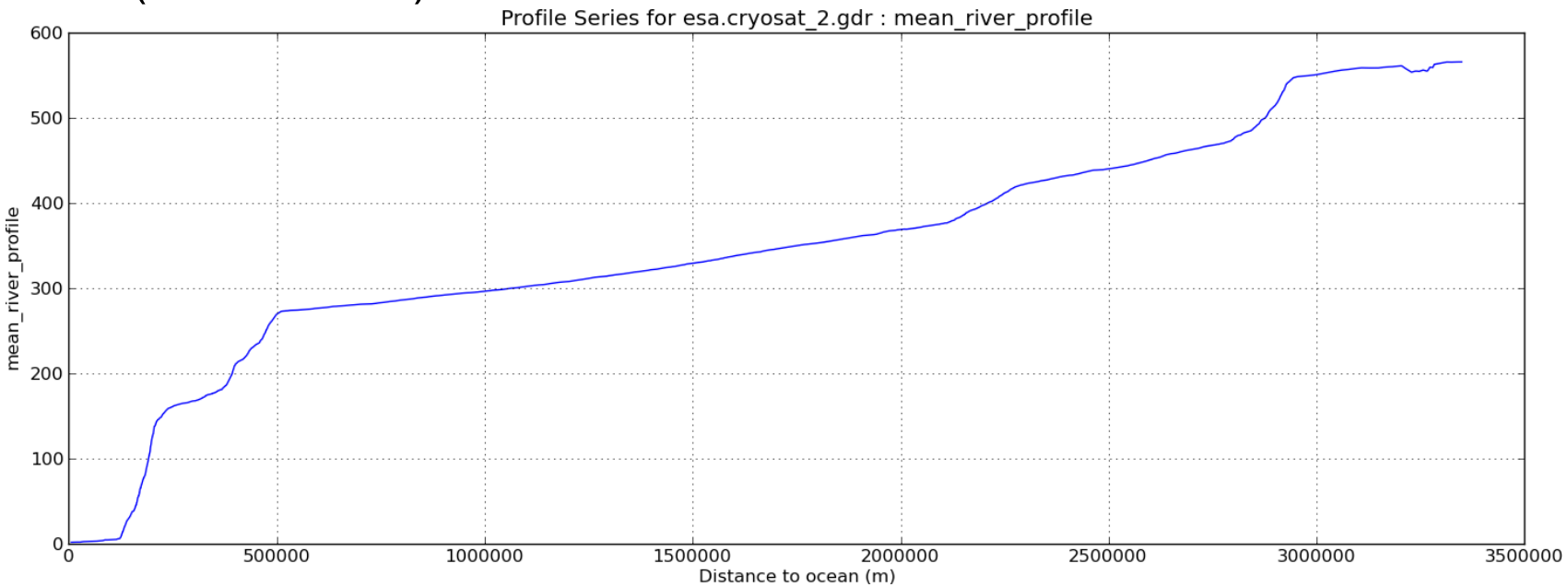
Cross-track Angle / Coords
(retracked bin, L2I only)

We (the users) are waiting for
Multi-Look Stacks in products !

(Thank you !)

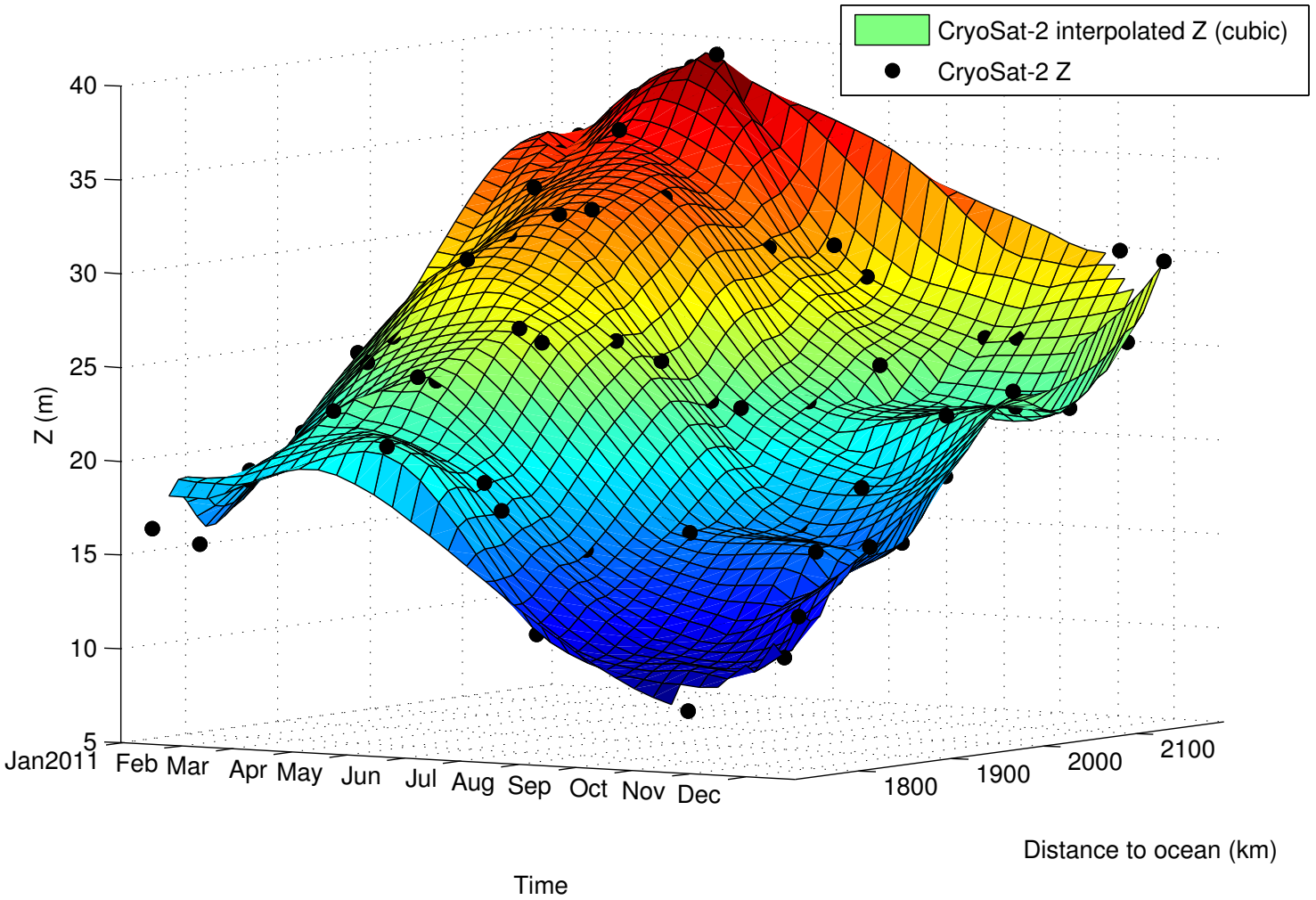
Present : Application examples

Congo river mean profile derived from CryoSat-2 ESA/GDR data (Baseline B)



Present : Application examples

Mapping rivers topography (Madeira river)



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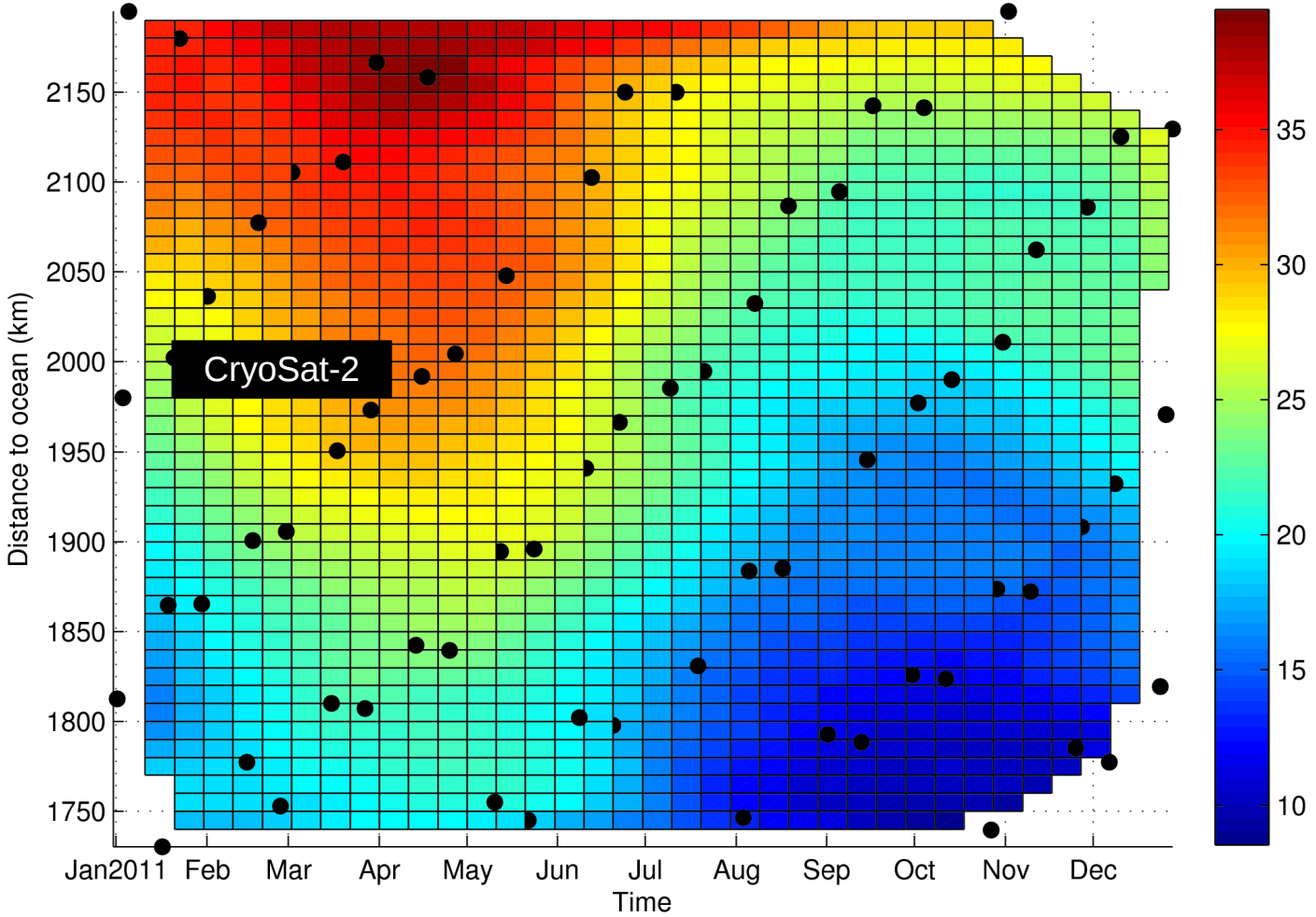

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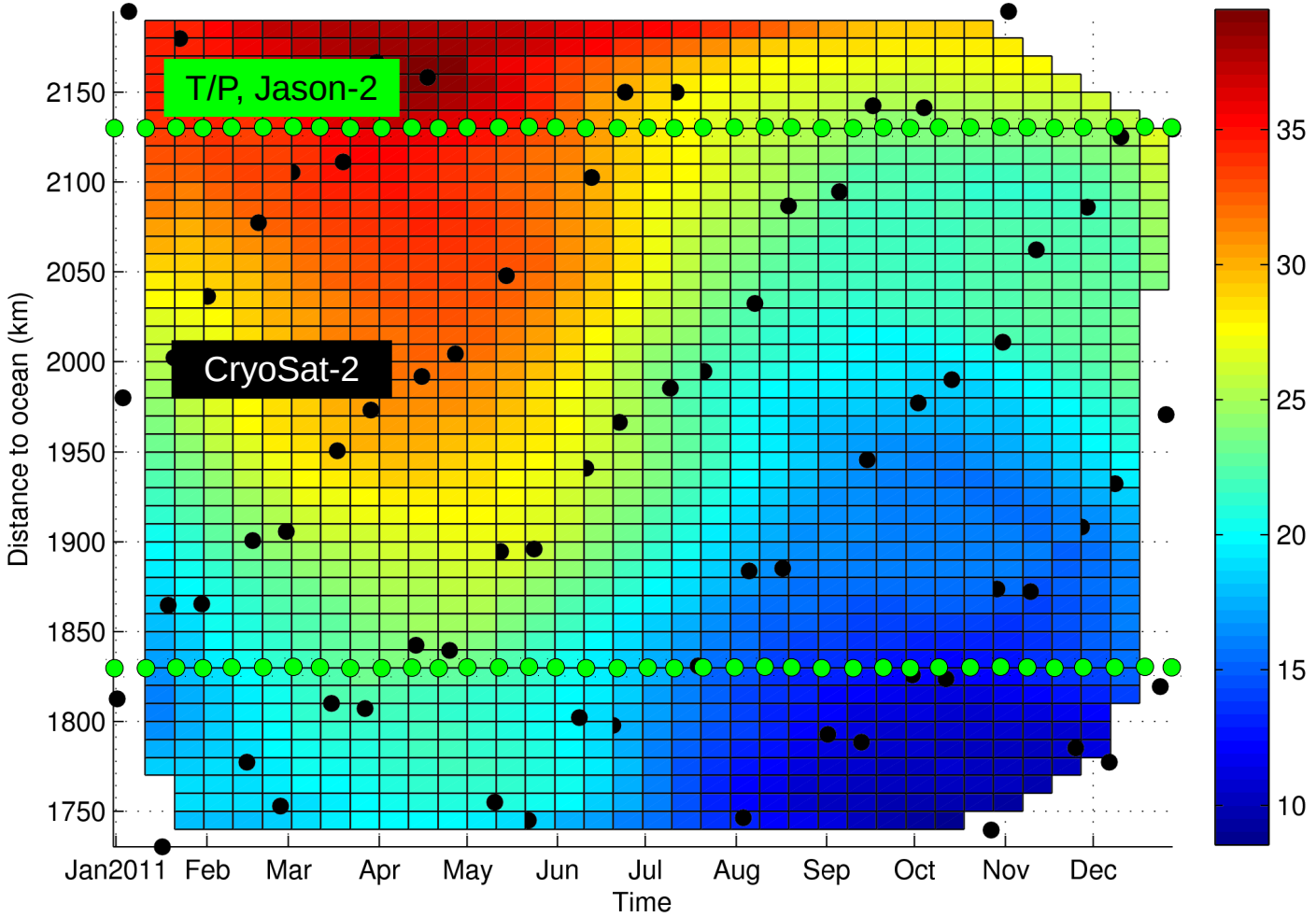
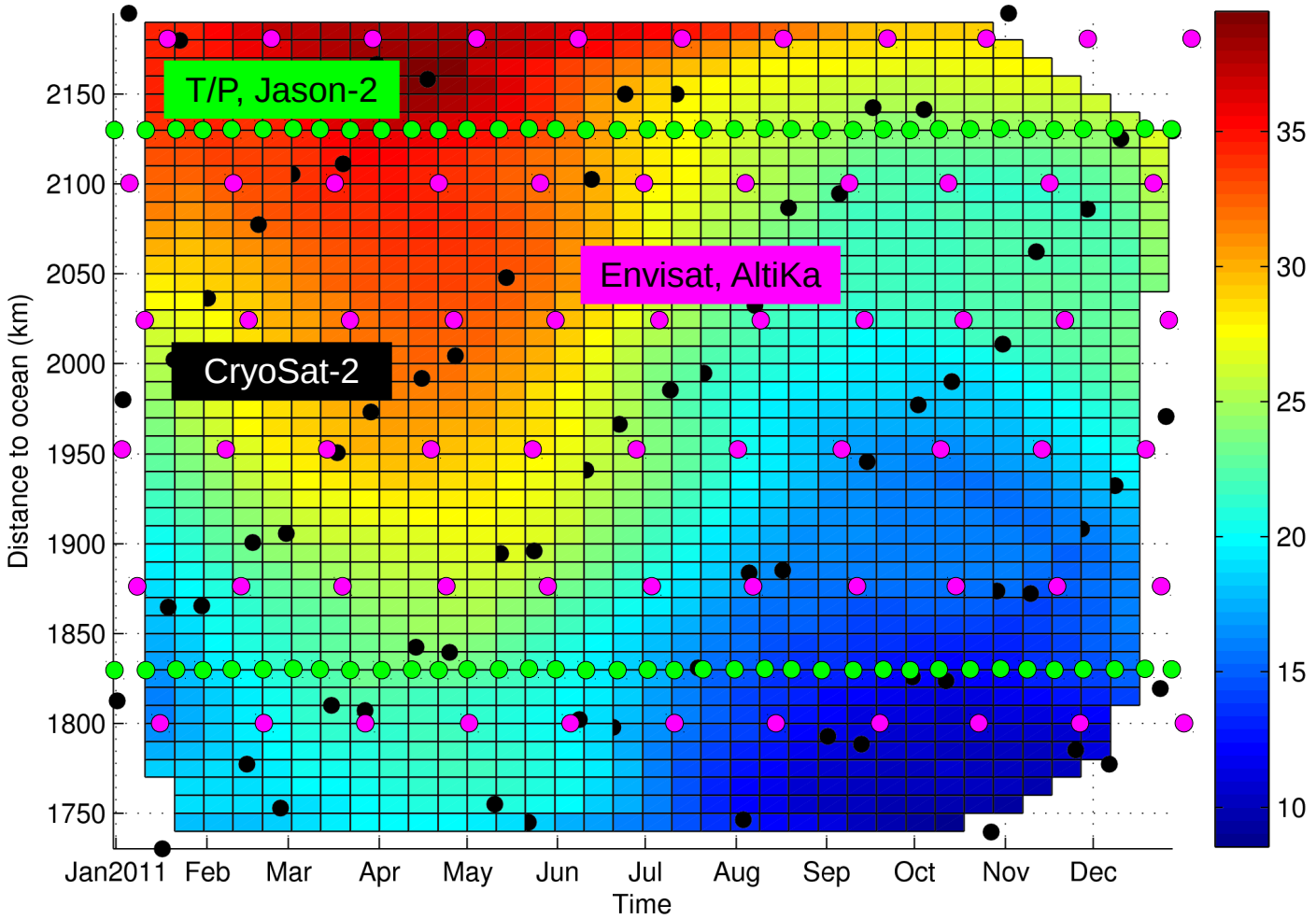


Present : Application examples

Mapping rivers topography (Madeira river)



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- Need to develop physical interpolation methods using hydraulic constraints/models

- Future -

Sentinel-3, Sentinel-6/JasonCS, etc.

Sentinel-3

- Repetitive orbit, 27 days, inclination 98.65°
- 100%SAR mode (land and ocean)
- closed burst (like CryoSat-2), Pseudo-LRM only
- PRF is nominal at 18kHz (no aliasing in Stack/Wf)

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Sentinel-6 (is JasonCS)

- Repetitive orbit : T/P & Jasons orbit
- 100%interleaved SAR mode (land and ocean)
- open burst, allow true LRM
- PRF at 10kHz : aliasing in Stack/Wf !

Conclusion

CryoSat-2...

- ...is not "Yet Another Ku Mission" !
- ...is a breakthrough mission !
- ...is a major transition mission for both instrumental (SAR/SARin) and thematic aspects (geodesic orbit)
- ...is a glue mission for multi-mission hydrology and rivers dynamic topography monitoring

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- SAR : higher along-track resolution (beam limited), same across-track resolution (pulse limited)
- SARin cross-track angle
  - Reflectors are rarely located exactly at satellite nadir !
  - Potential for small rivers detection and mapping of hydrographic networks

Perspectives

Extensive products assessment

- Validation against in situ data (not yet available !)
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- Comparison to Jason-2 & AltiKa LRM missions

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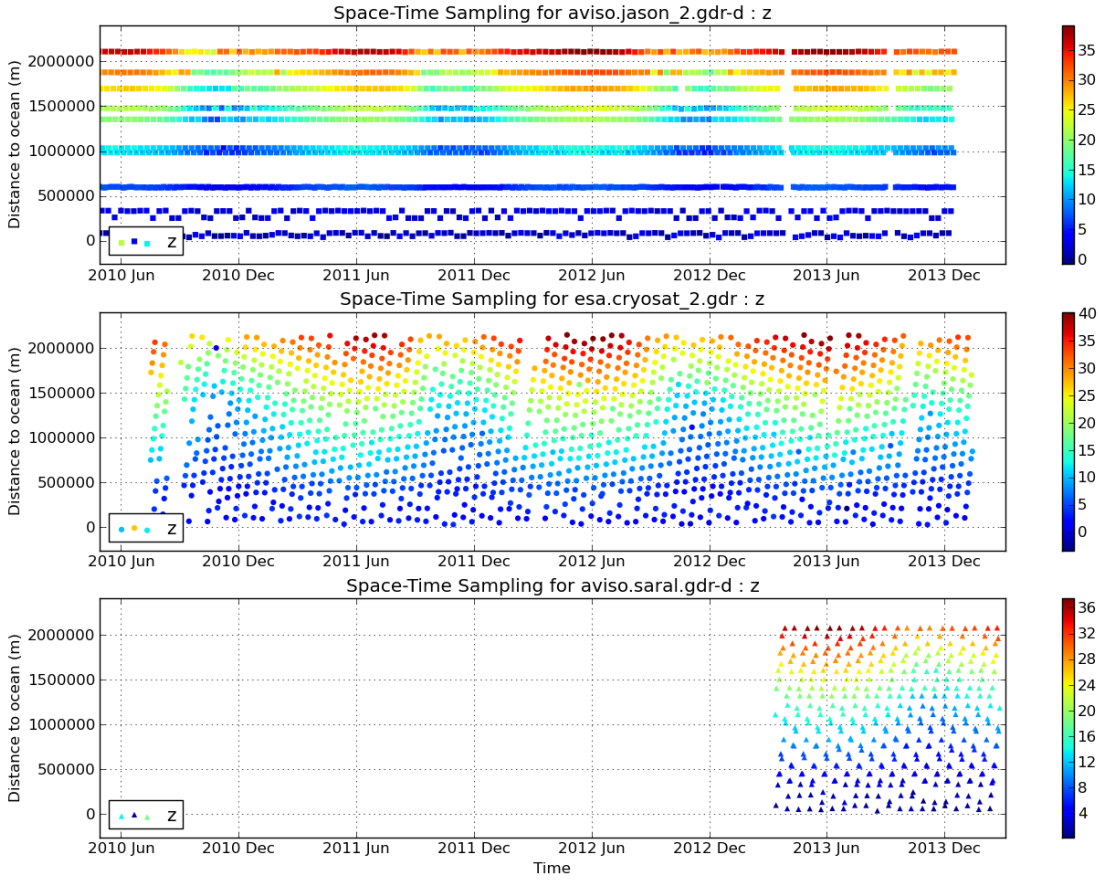
ESRIN proto : more explorations using the stacks

- Slicing stacks for better land decontamination
- ASR beam behaviour : more investigation needed

– Thank you ! –



Spatio-Temporal sampling of Jason-2 (top), CryoSat-2 (middle) and SARAL/Altika (bottom) of River Water Level Measurements Amazon and Solimoes rivers)