Applications of CryoSat-2 SAR & SARin Modes for the Monitoring of River Water Levels

CryoSat Third Users Workshop, 12-14 March 2013, Dresden, Germany

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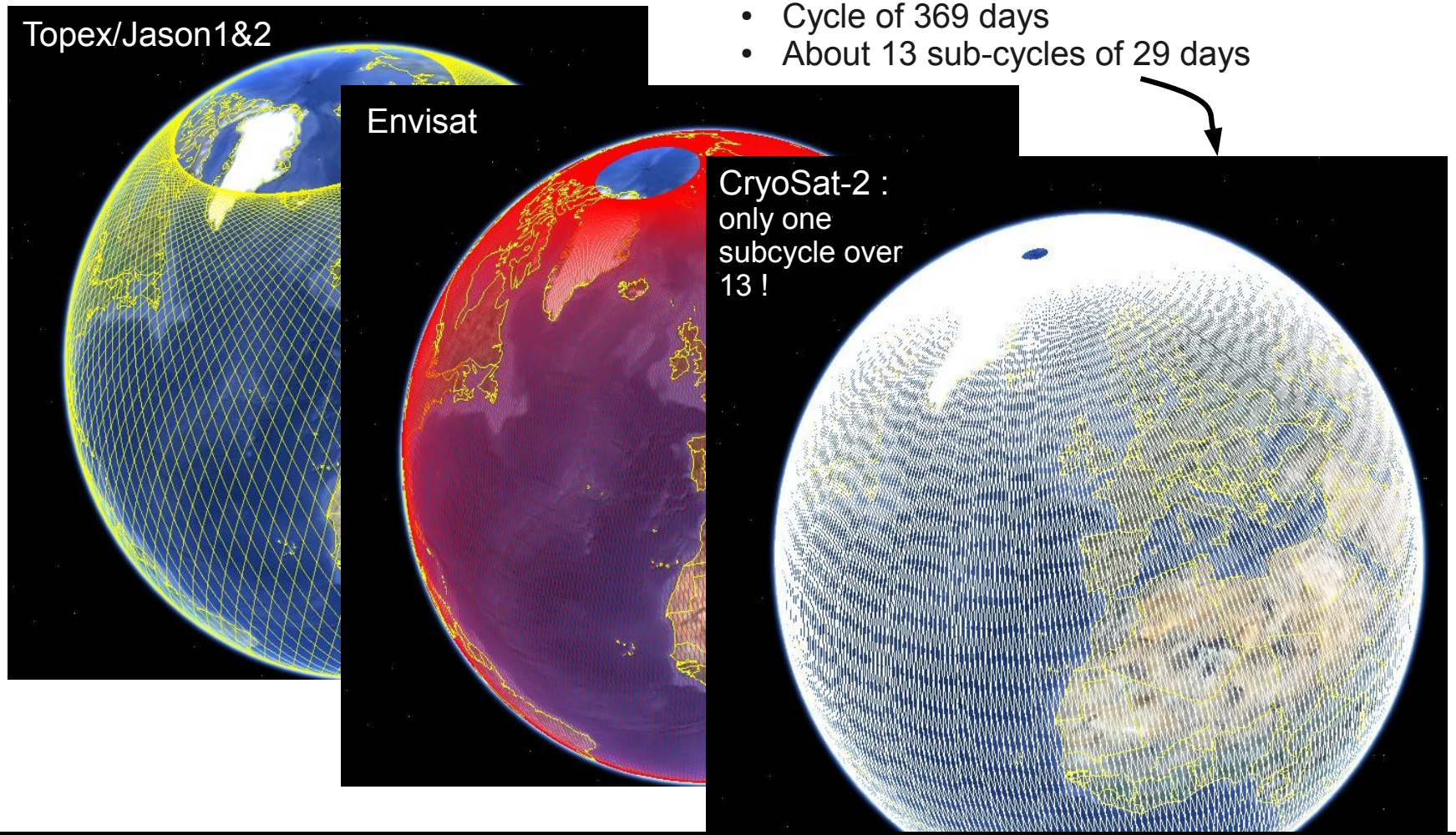
Thursday 14th March 2013

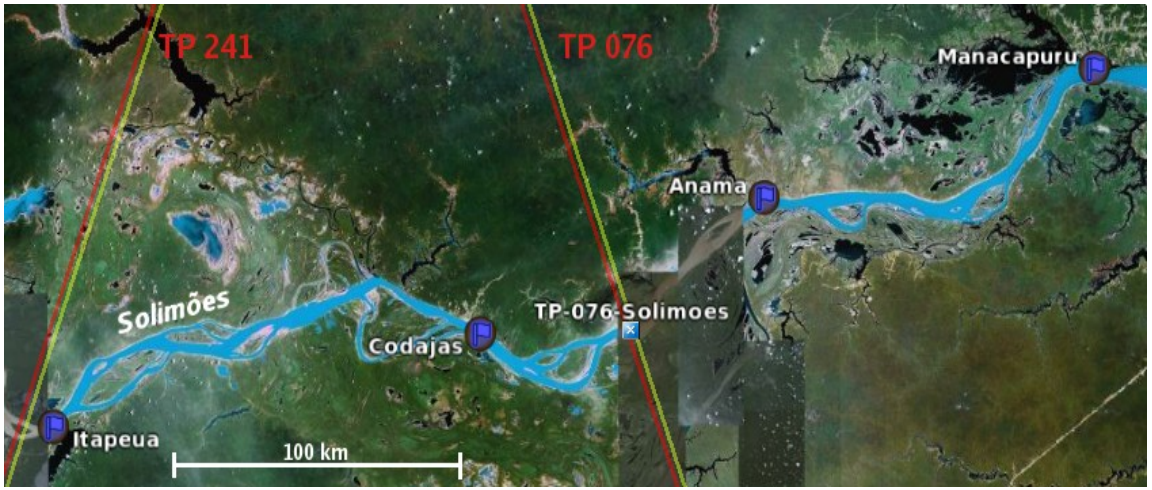
CryoSat-2 orbit

- Near polar (92°)
- Cycle of 369 days
- About 13 sub-cycles of 29 days



Repetitive orbits : time series

(Topex/Poseidon example)



Repetitive orbits : time series

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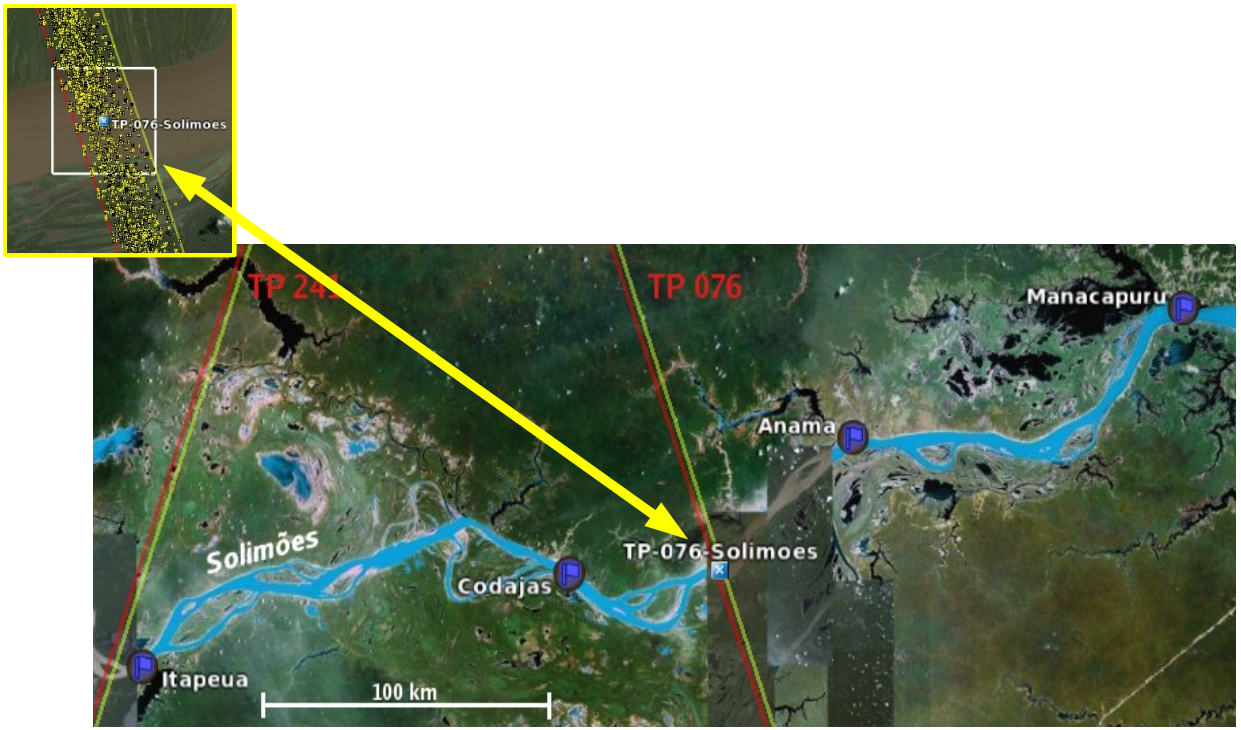

Repetitive orbits : time series

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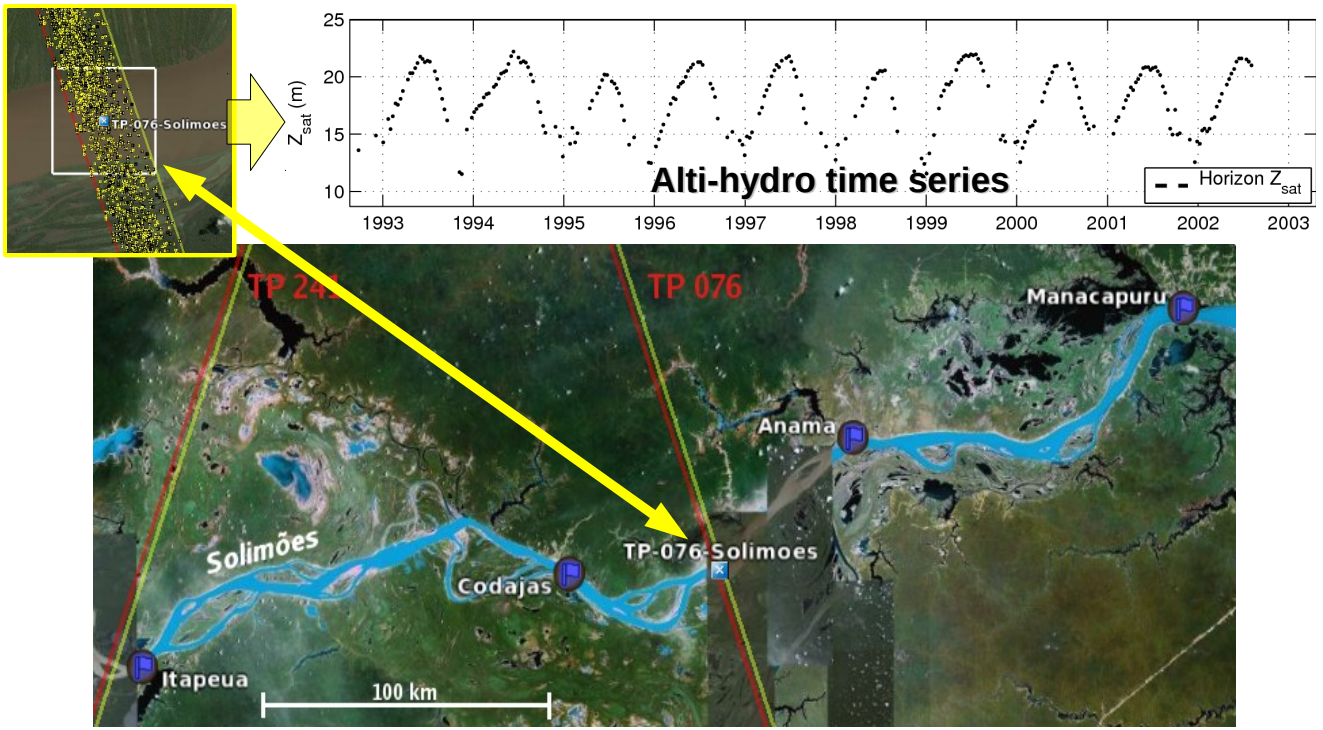

Repetitive orbits : time series

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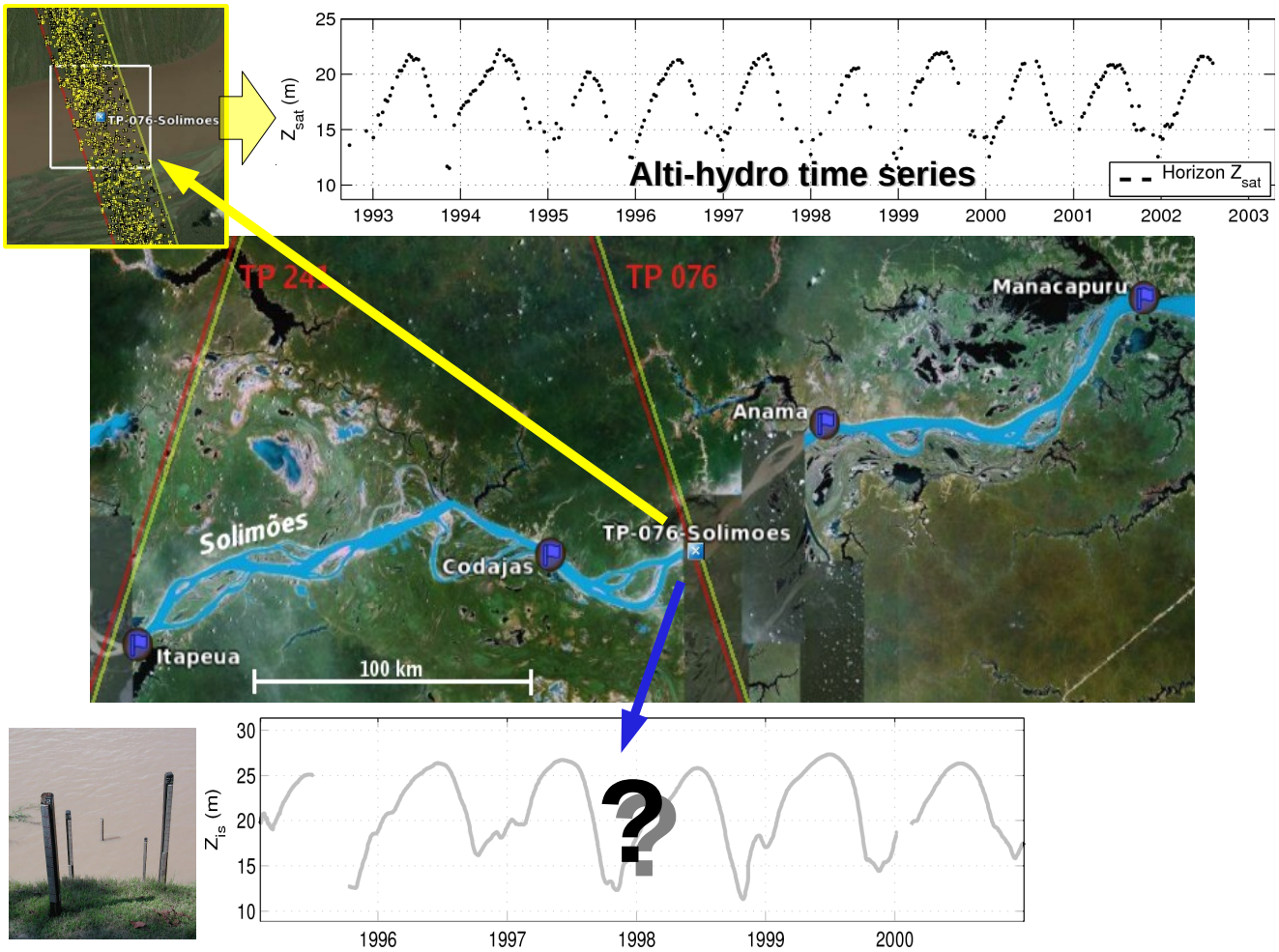

Repetitive orbits : time series

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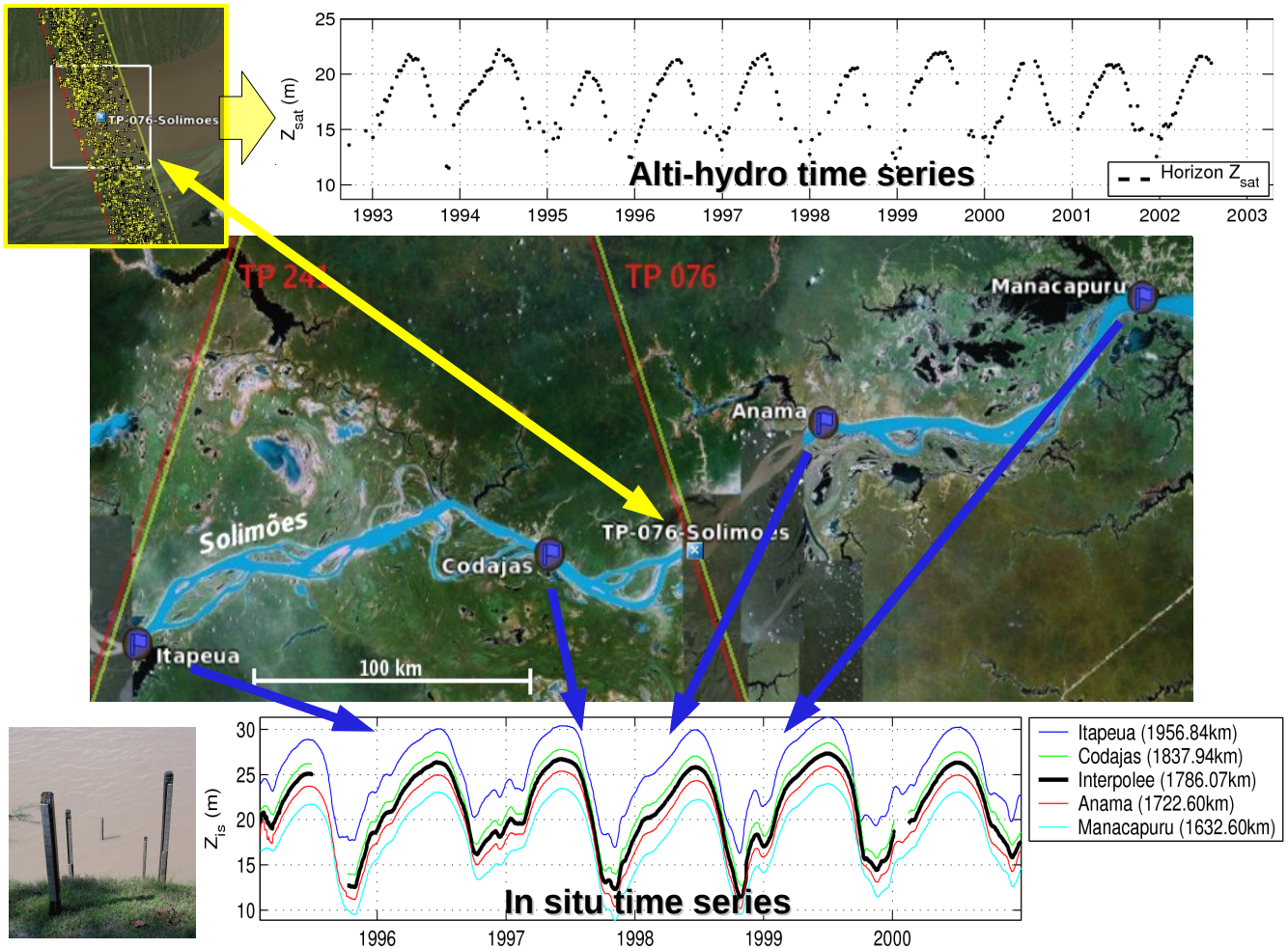
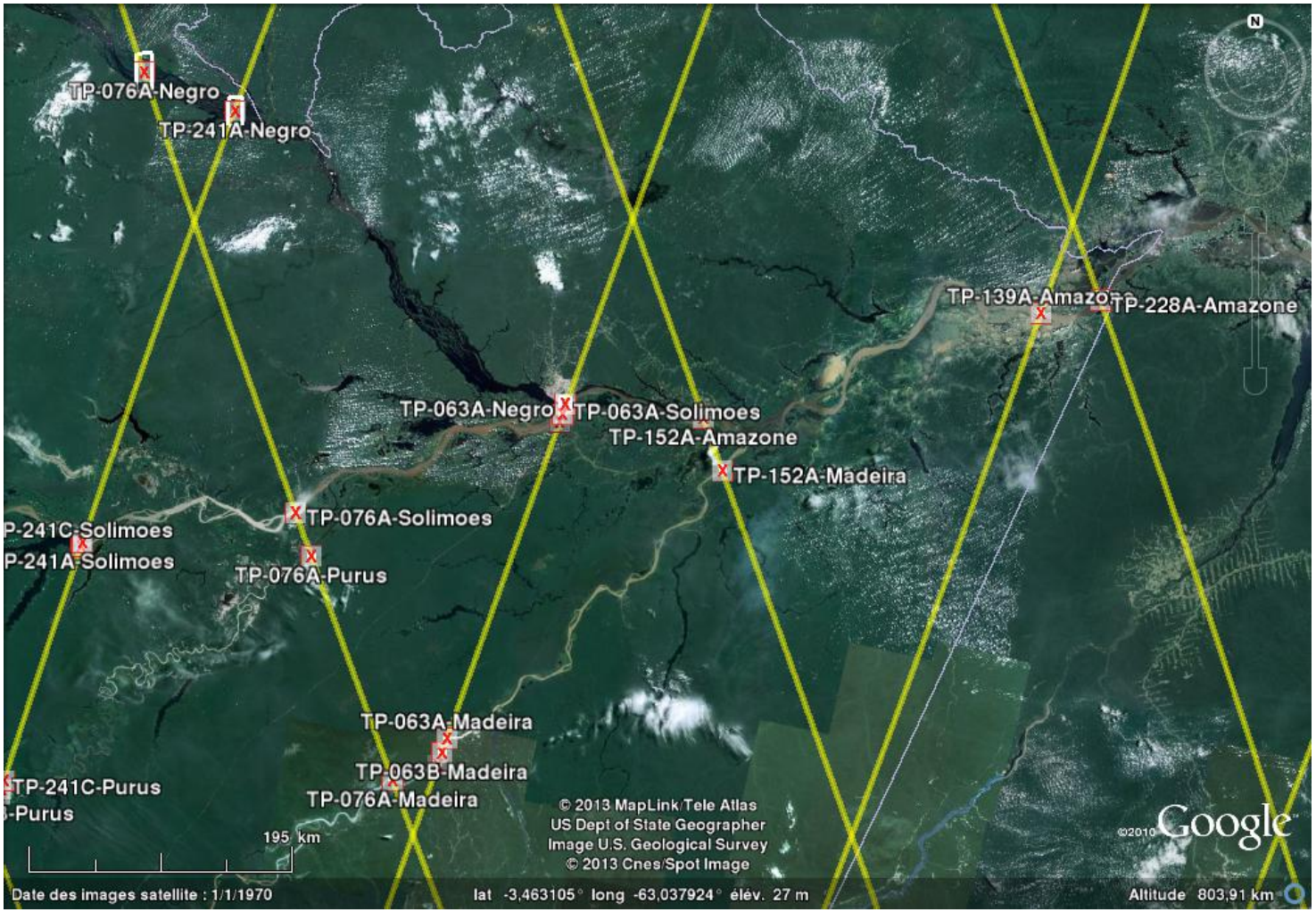


Repetitive orbits : time series

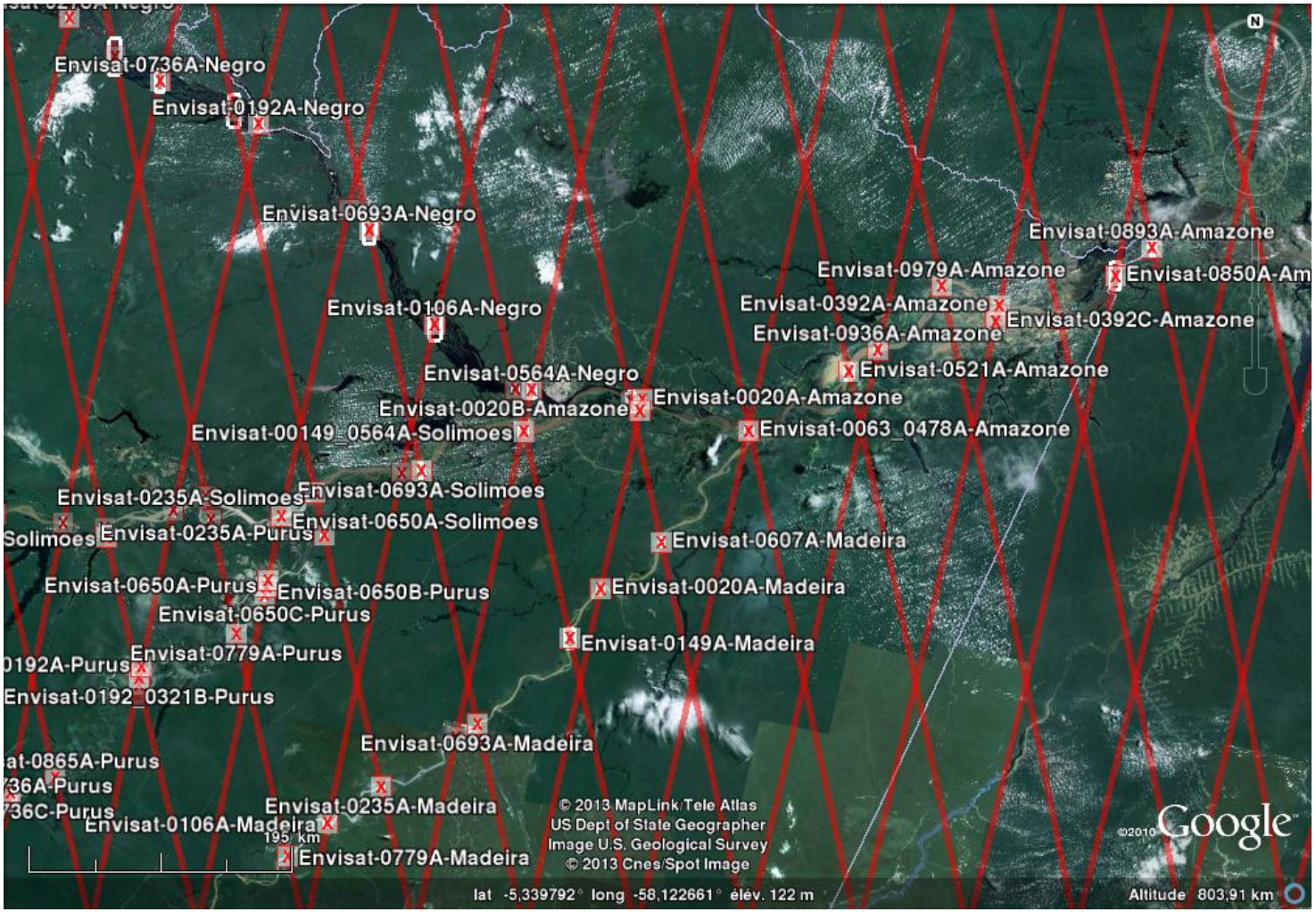
Typical processing

- Custom editing, filtering, etc.
- Time series quality validation against in situ gauging data
- Distribute time series through HydroWeb portal
  `http://www.legos.obs-mip.fr/en/soa/hydrologie/hydroweb/`

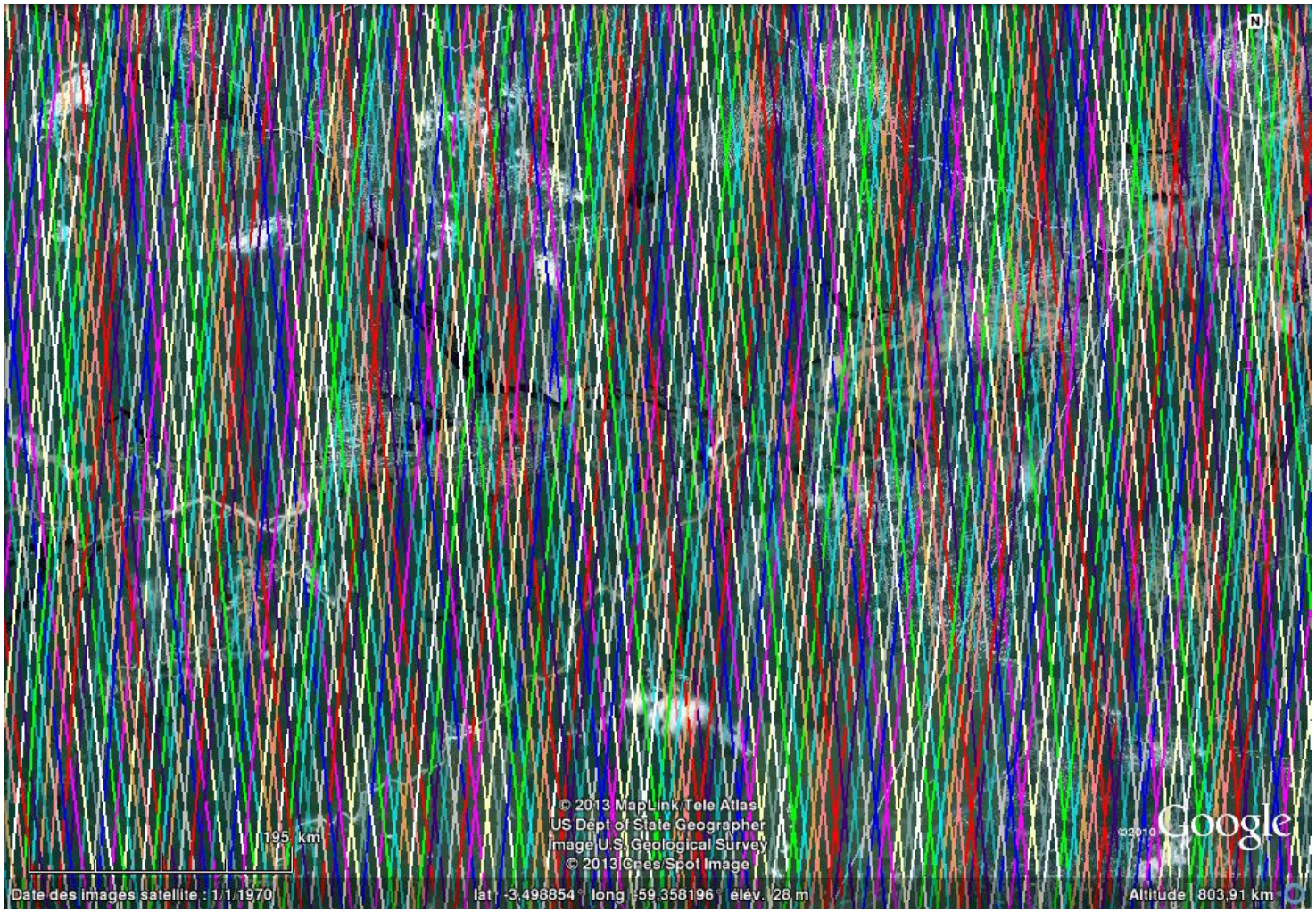
Topex/Poseidon & Jason-2 "virtual stations"



Envisat "virtual stations"

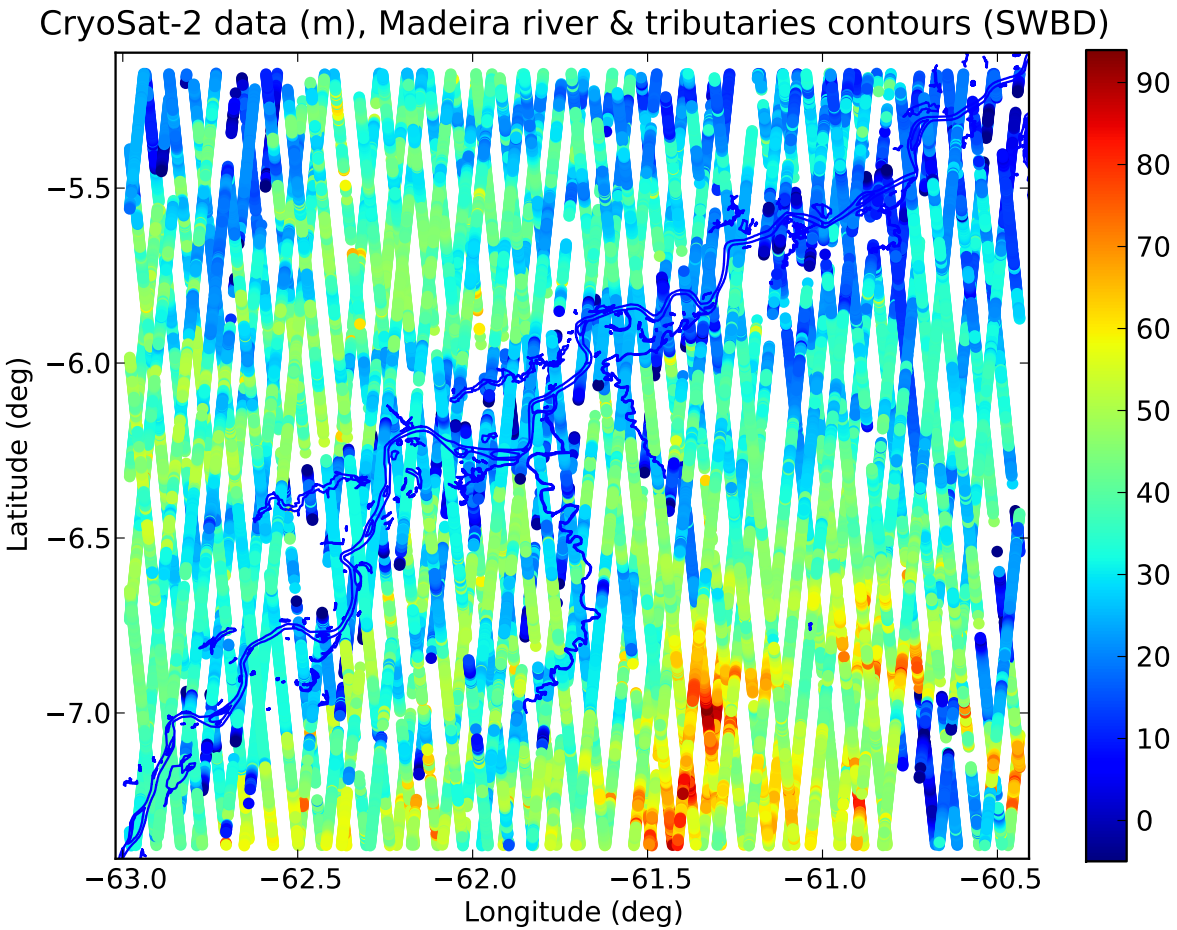


CryoSat-2 tracks. . . ! (KML file available on ESA website)



Processing spatio-temporal time series (LRM ex.)

Spatio-Temporel sampling of the river water level $Z(x, t)$



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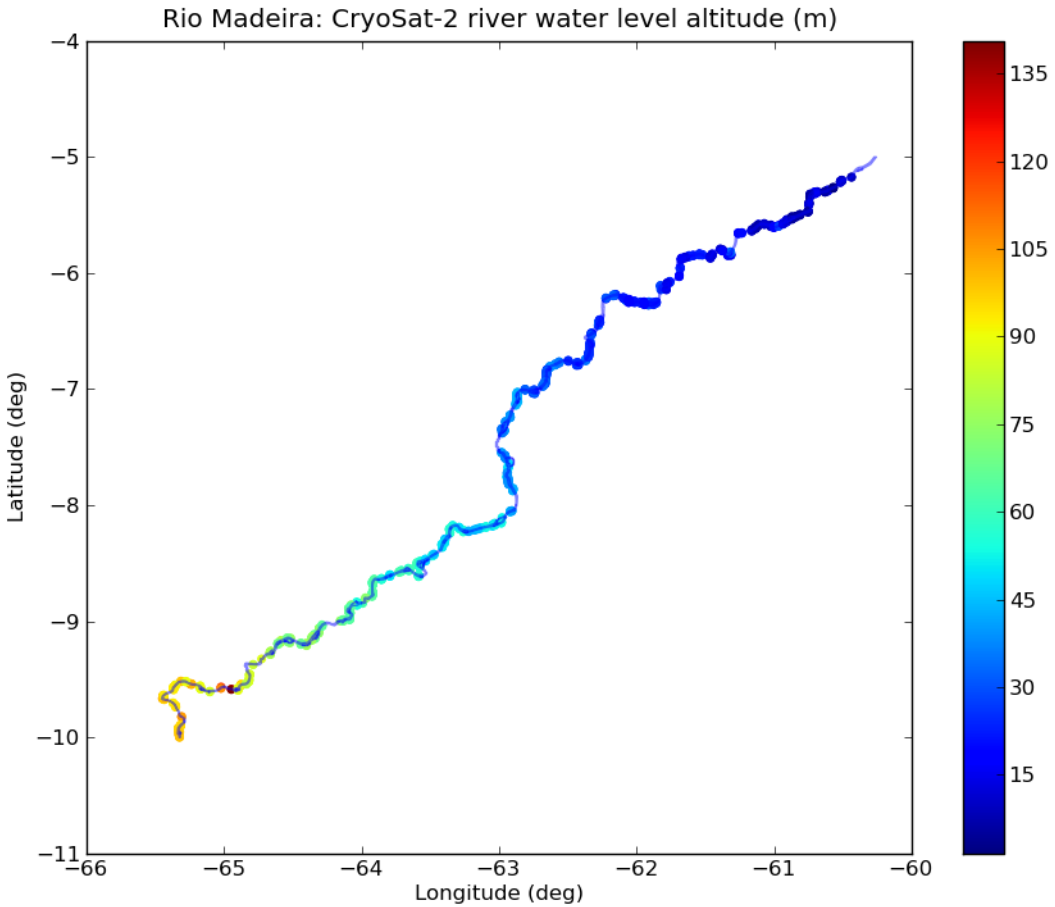
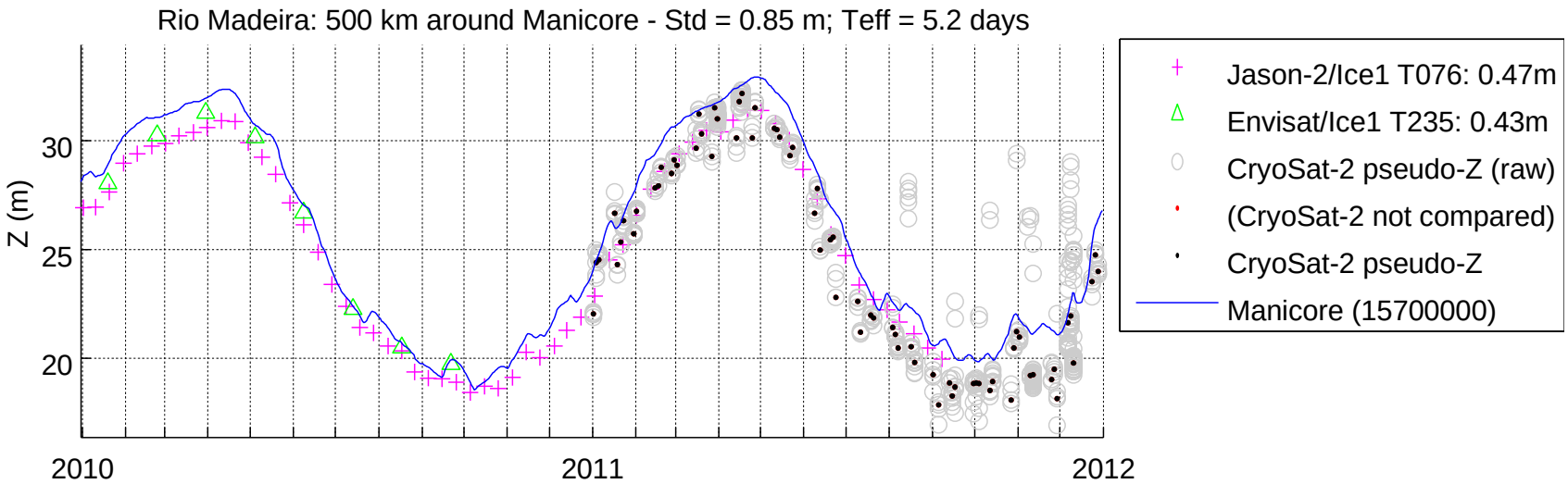


Processing spatio-temporal time series (LRM ex.)

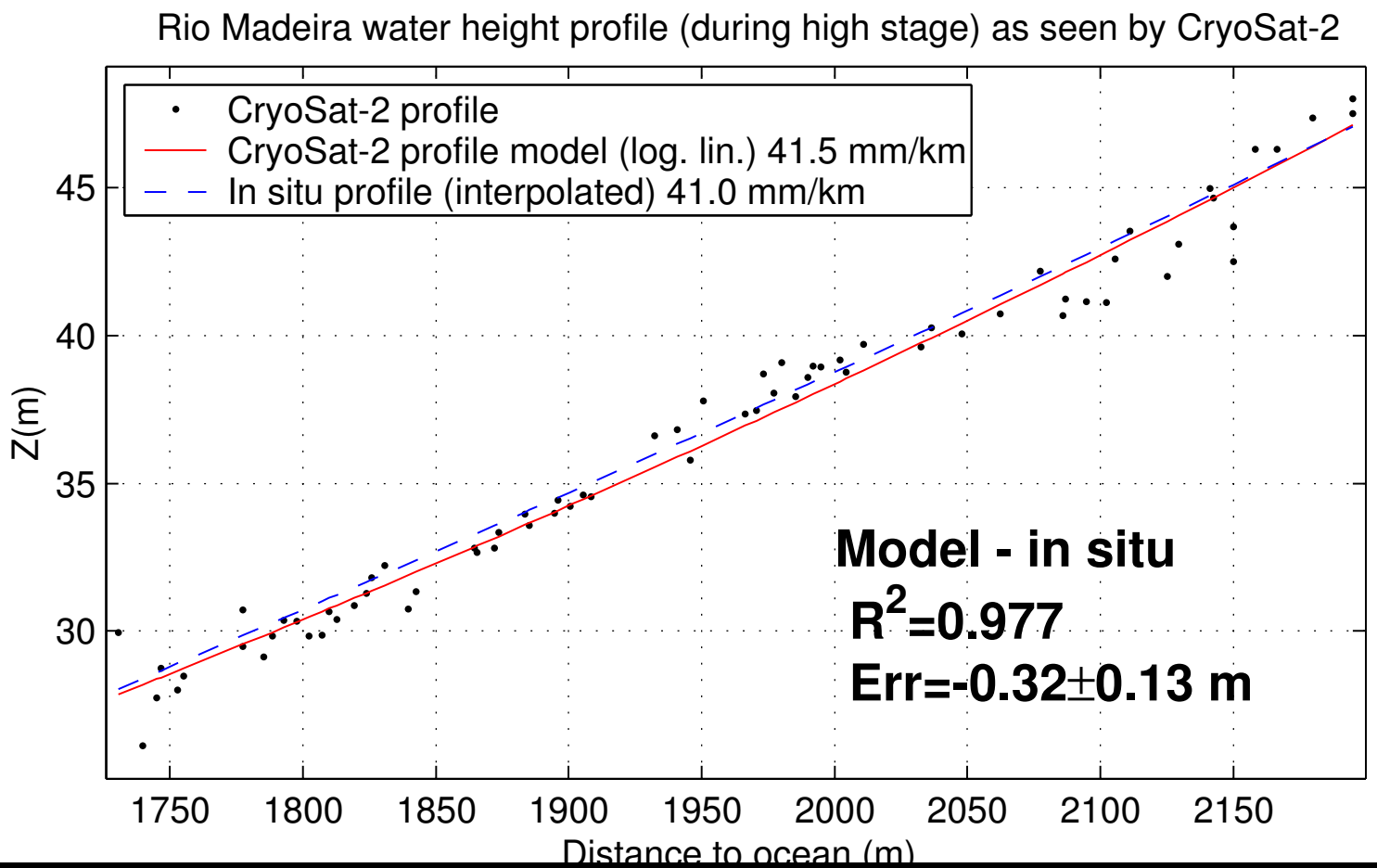
Remove spatial variations

= river water level pseudo-time series $Z(t)$



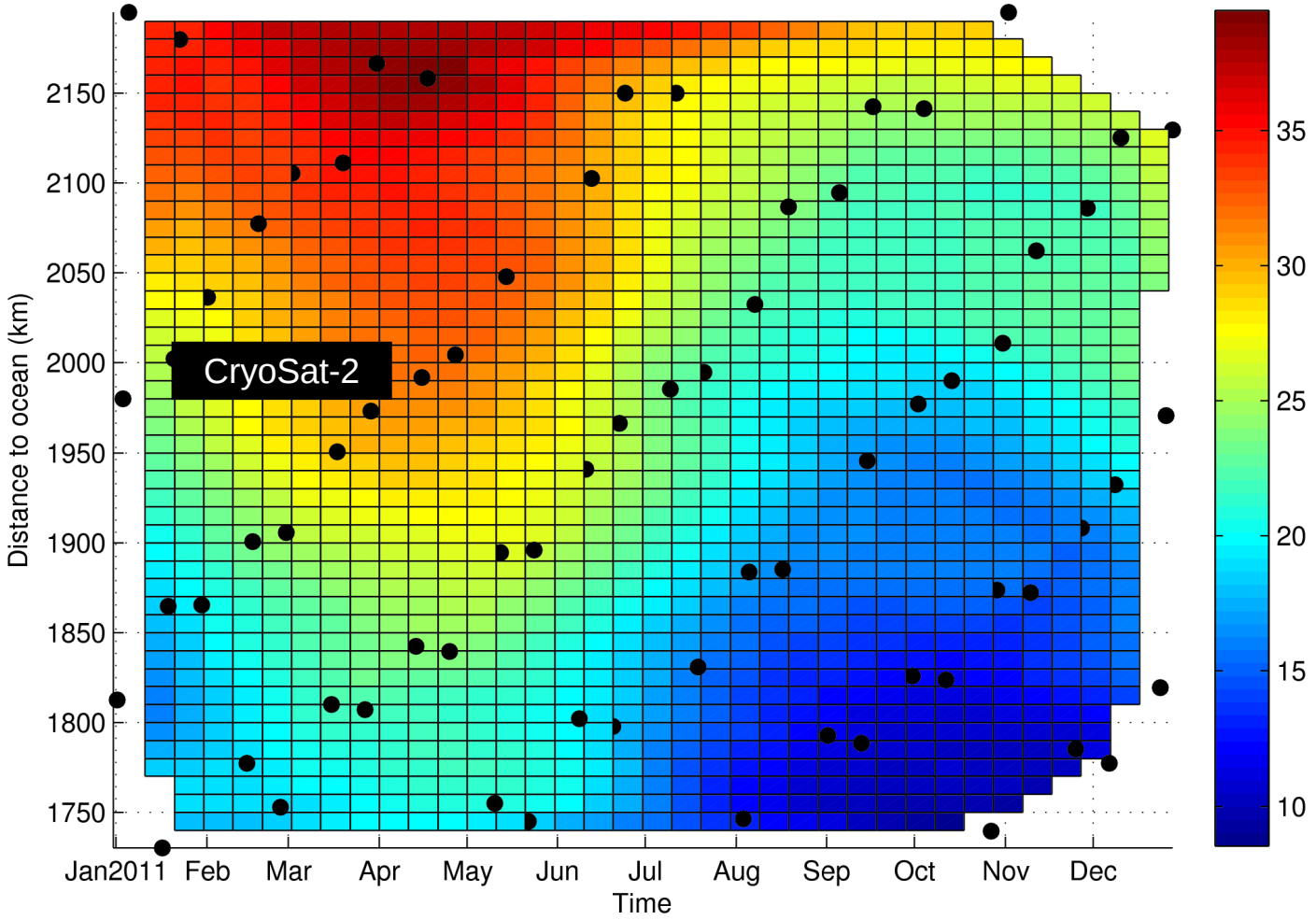
Processing spatio-temporal time series (LRM ex.)

Remove temporal variations
= river water level pseudo-profile $Z(x)$



Processing spatio-temporal time series (LRM ex.)

Spatio-Temporel sampling of the river water level $Z(x, t)$



Processing spatio-temporal time series (LRM ex.)

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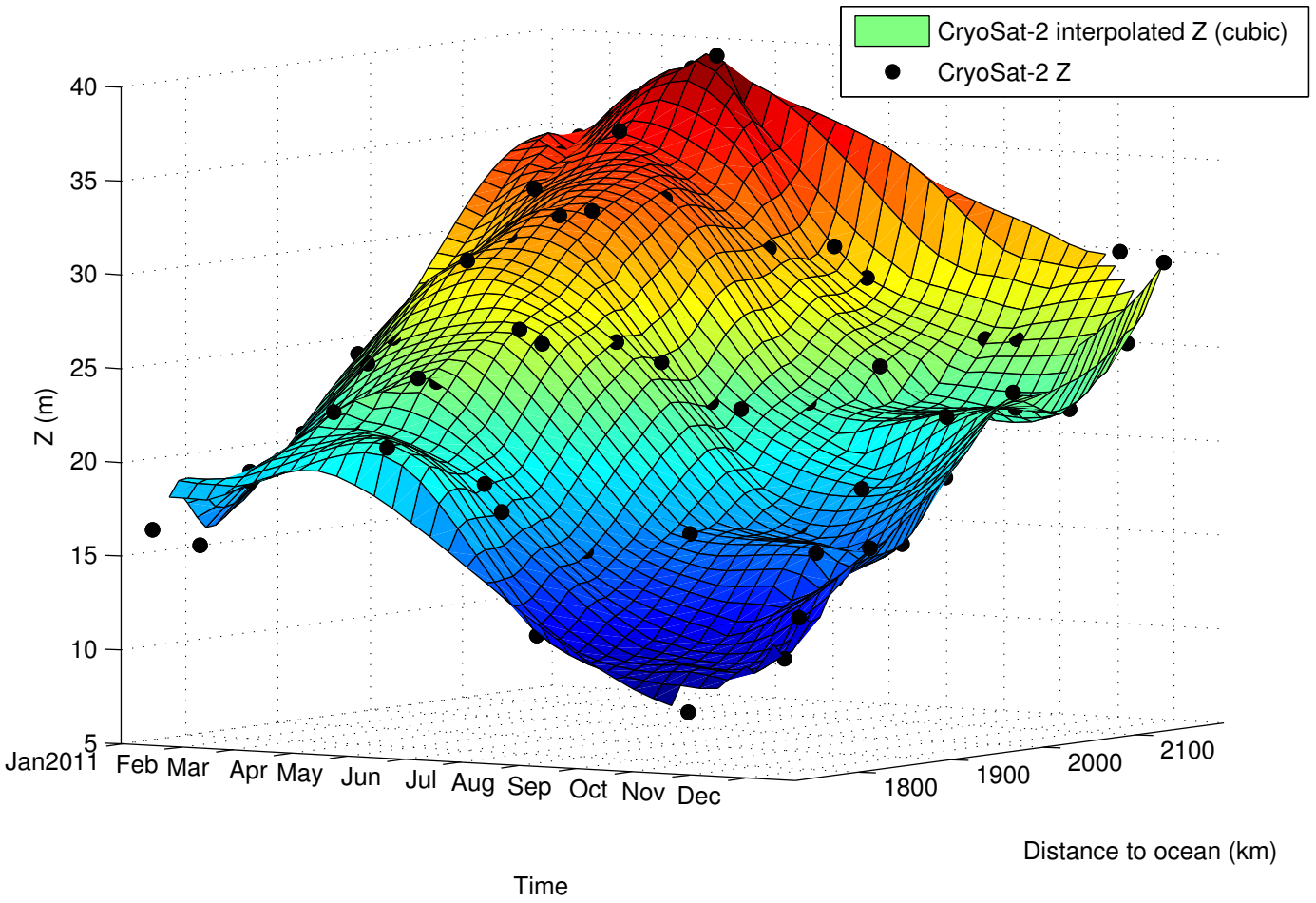


CryoSat-2 data products (and their use in hydrology)

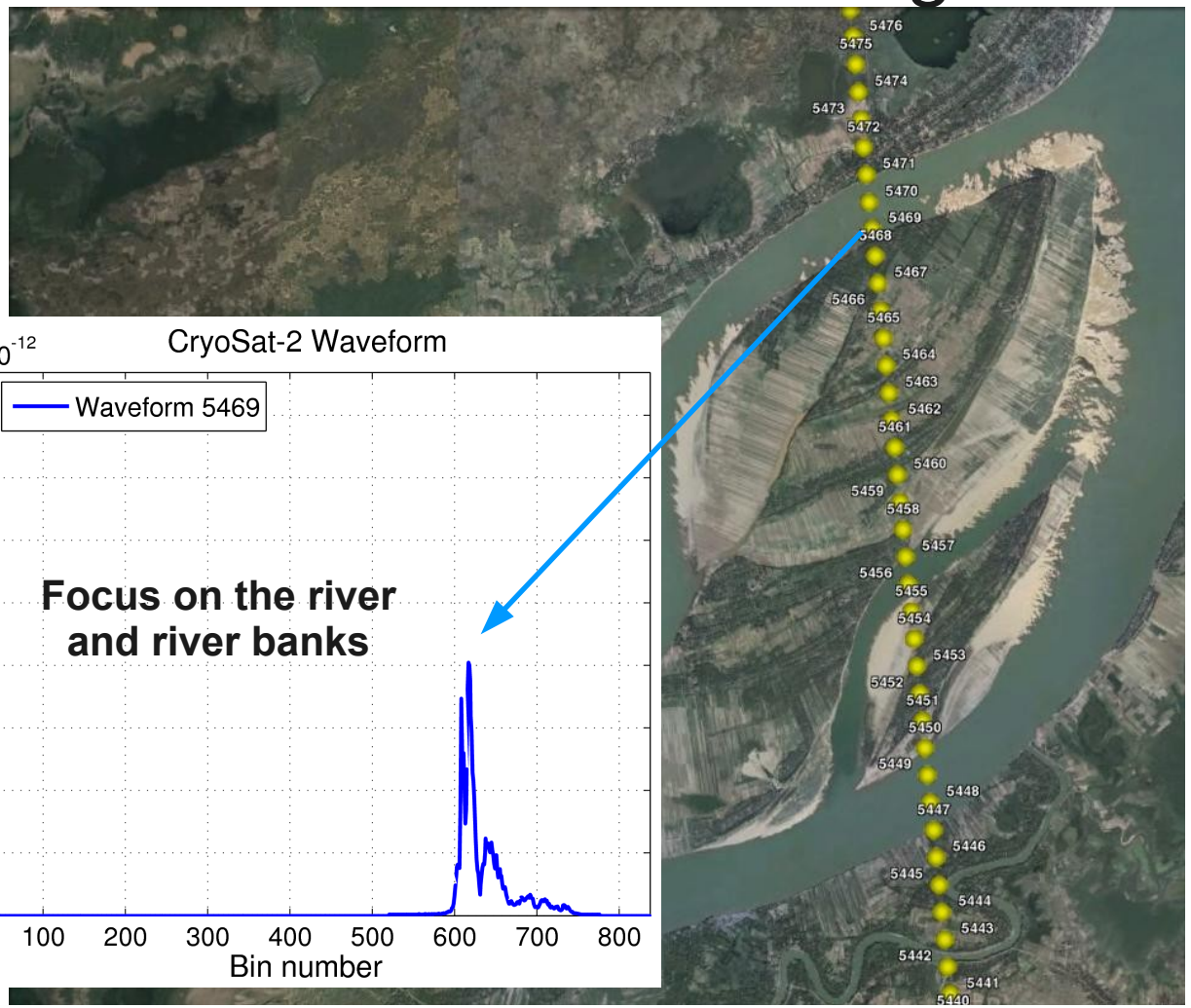
- **ESA Official L2 products (Baseline B, since Feb. 2012)**
  - Product files for LRM, SAR & SARin modes
  - Use : spatio-temporal time series, validation, longitudinal & transversal river profiles, (SAR :) along-track resolution, (SARin :) cross-track angle
- **ESA/ESRIN Sentinel-3 prototype**
  - Data samples : stack matrices, L1B (waveforms), L2 (Samosa retracker outputs)
  - Use : exploring stack applications (surface roughness & classification), along-track resampling (spotlight), etc.
- **CNES CPP (CryoSat Processing Prototype)**
  - Data samples : SAR / Reduced-SAR (aka pseudo-LRM)
  - Use : SAR / Reduced-SAR comparison and assessment
  - More to come. . .

Better along-track resolution

SAR mode over Mekong river

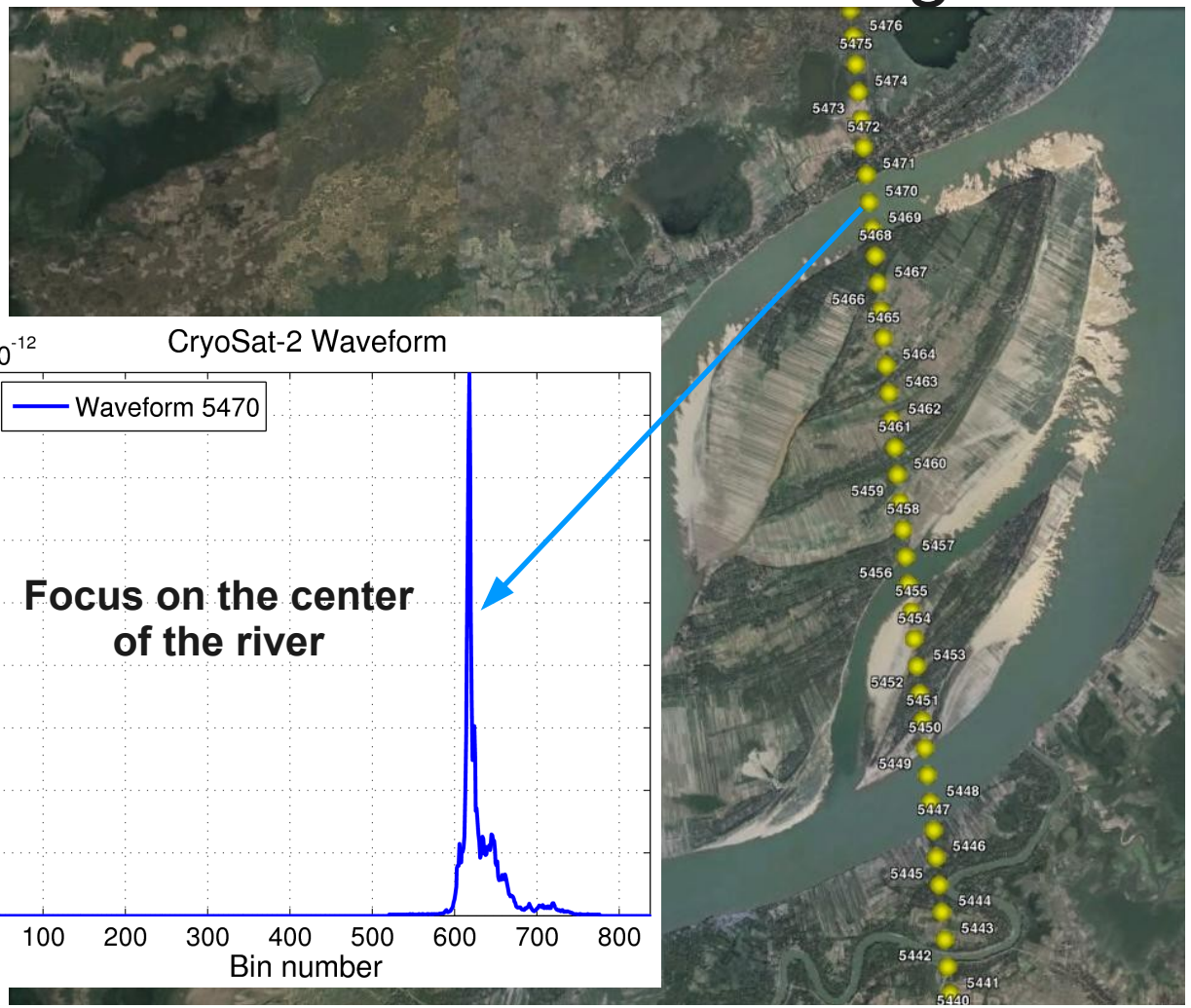
Better along-track resolution

SAR mode over Mekong river



Better along-track resolution

SAR mode over Mekong river



Better along-track resolution

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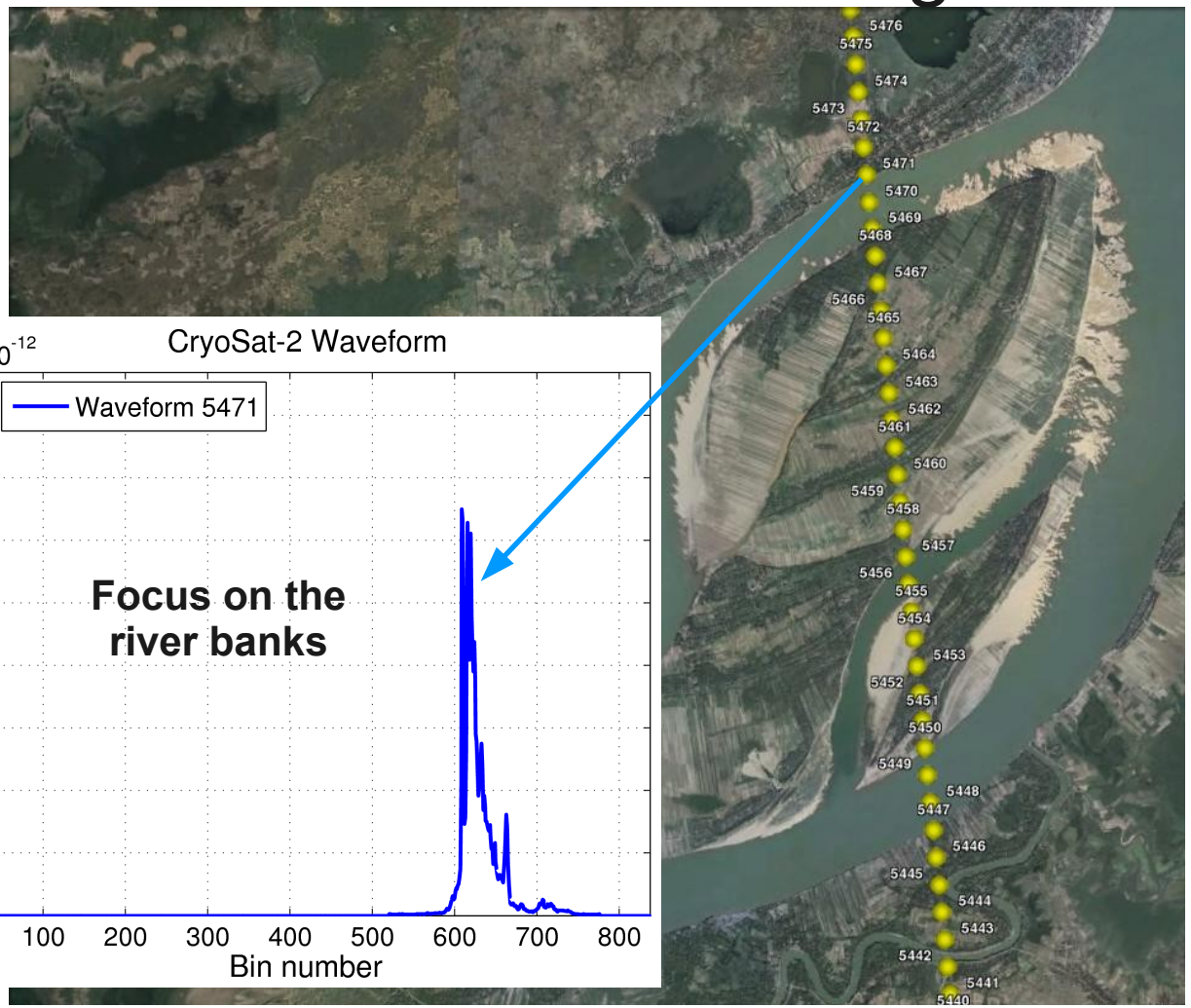
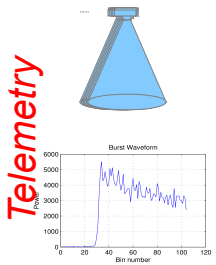


Product Levels

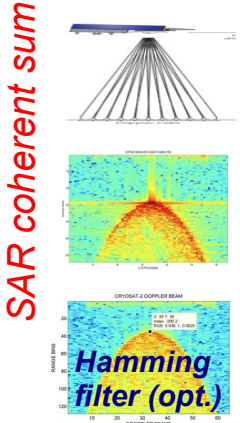
1Hz-20hz products

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

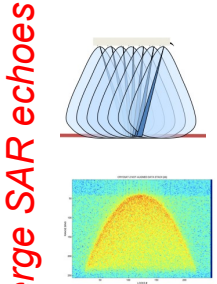
SAR mode



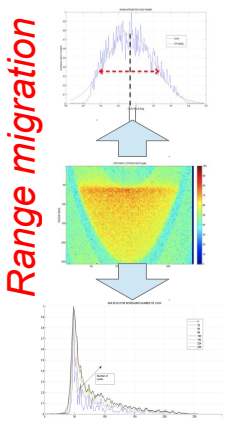
Bursts
64 echoes
Brown WF(I,φ)



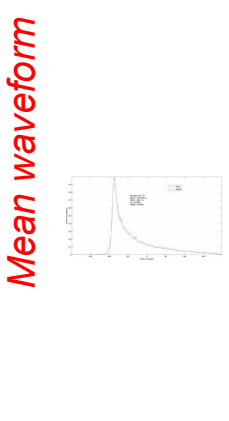
Doppler Beams
SAR WF(I)



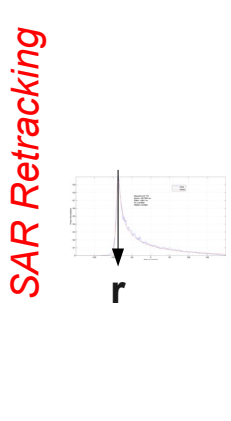
Stack (1/2)
256 ground cell views



Stack (2/2)
256 ground cell views



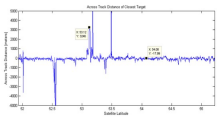
Waveforms
128 samples



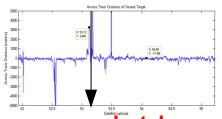
Range

SARin mode

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



Waveforms & Phase diff.
2×512 samples each

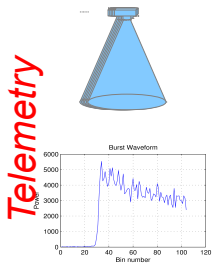


Cross-track Angle / Coords
(retracked bin, L2I only)

Product Levels

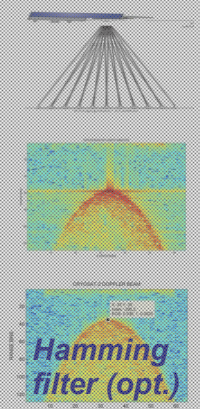
SAR mode

L0 / FBR



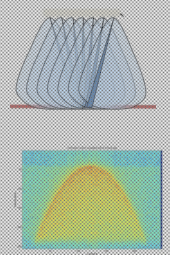
Bursts
64 echoes
Brown WF(I,φ)

SAR coherent sum



Doppler Beams
SAR WF(I)

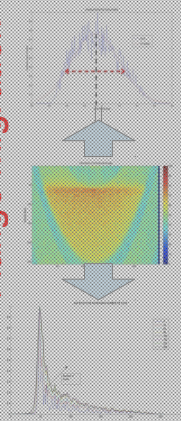
Merge SAR echoes



Multi-look

Stack (1/2)
256 ground cell views

Range migration

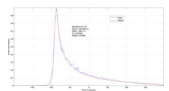


Stack (2/2)
256 ground cell views

1Hz-20hz products

L1b

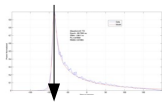
Mean waveform



Waveforms
128 samples

L2 / L2I

SAR Retracking



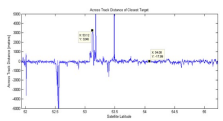
Range

SARin mode

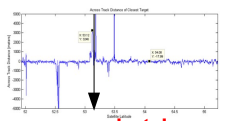
...the same for 2 channels...
(two reception antennas)

Intermediate stack
2×64 ground cell views

Stacks of
2×64 ground cell views

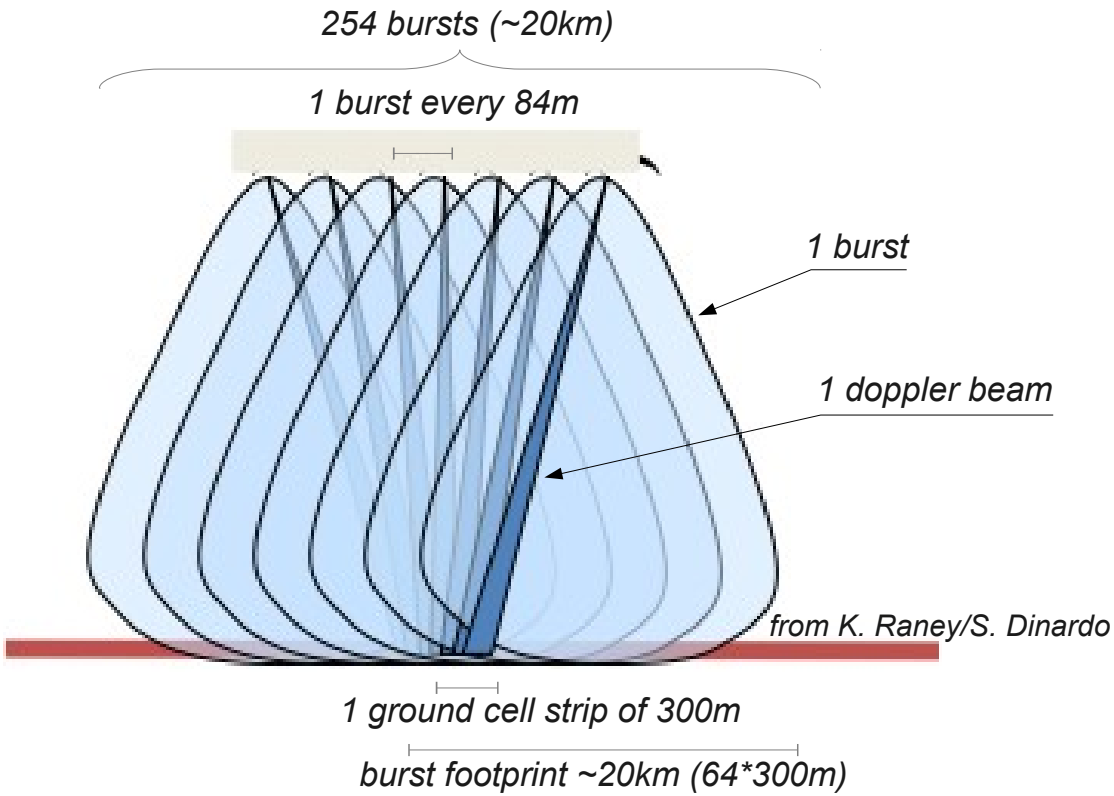


Waveforms & Phase diff.
2×512 samples each



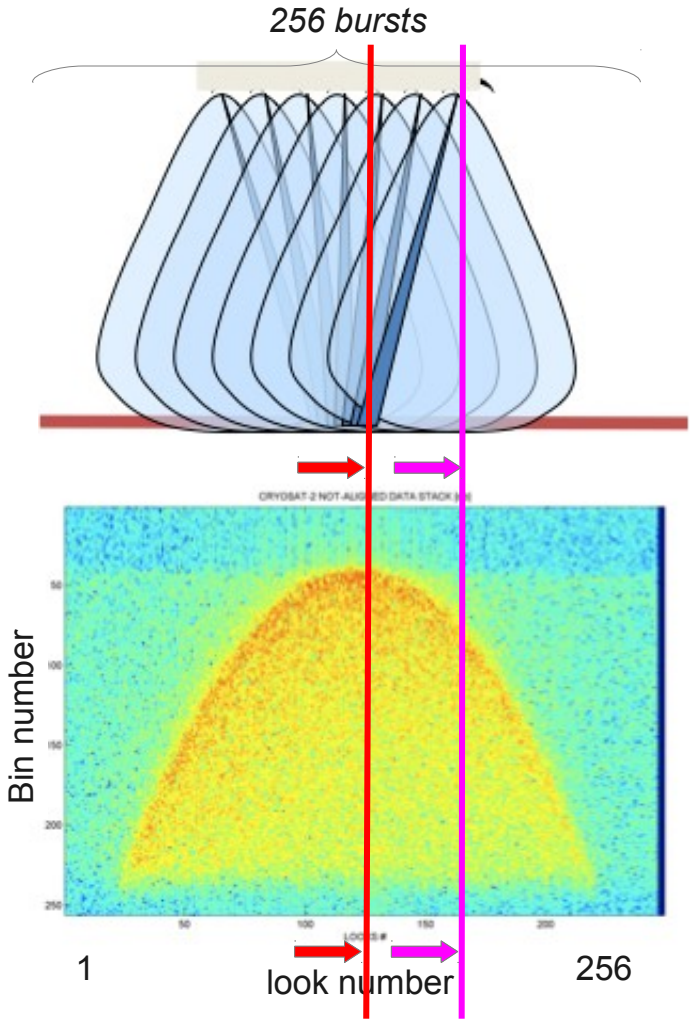
Cross-track Angle / Coords
(retracked bin, L2I only)

The multi-look over one ground cell

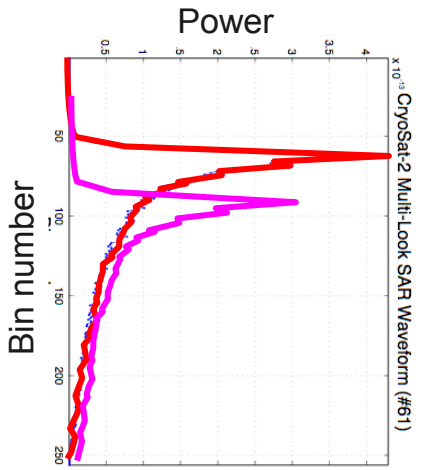


Each ground cell can be seen per theoriticaly 256 bursts
(~223 in practice over ocean)

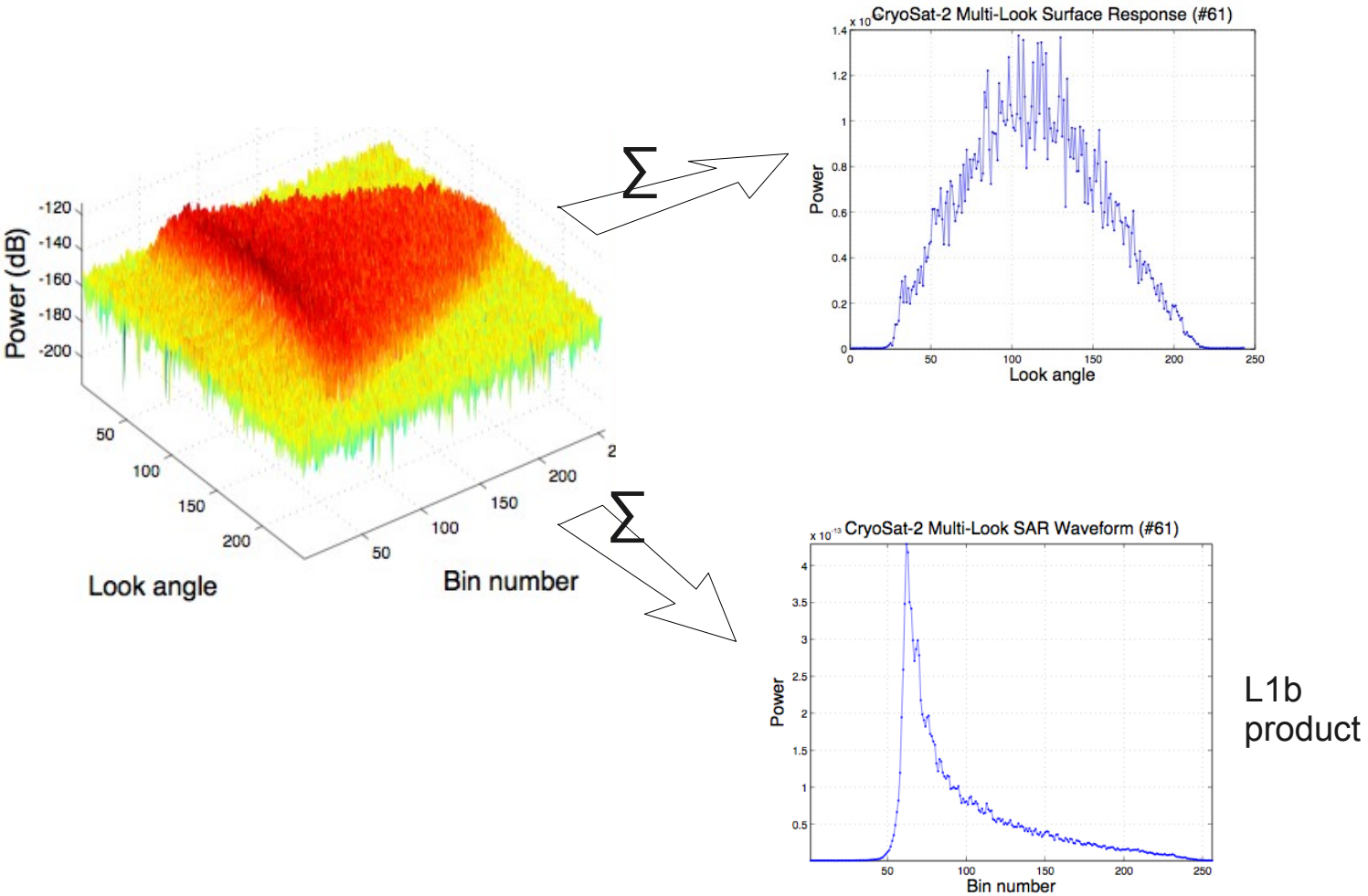
The multi-look : the stack



2 Doppler waveforms « looking » the same ground cell

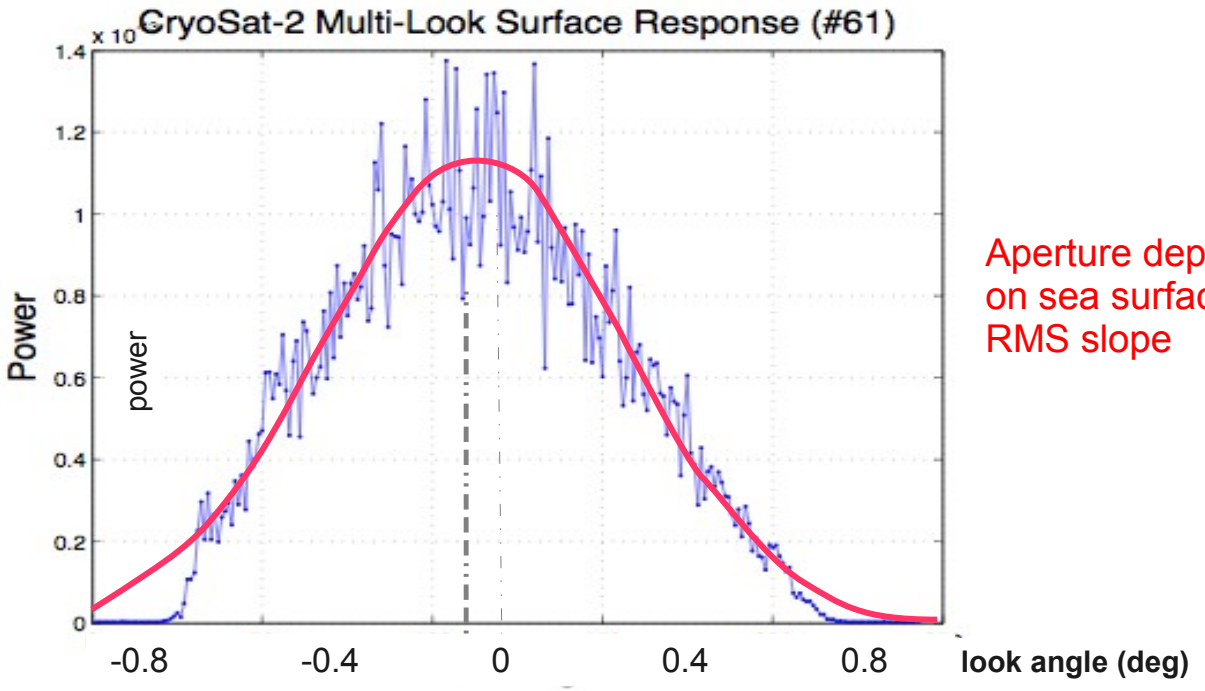


The multi-look: stack



L1b product

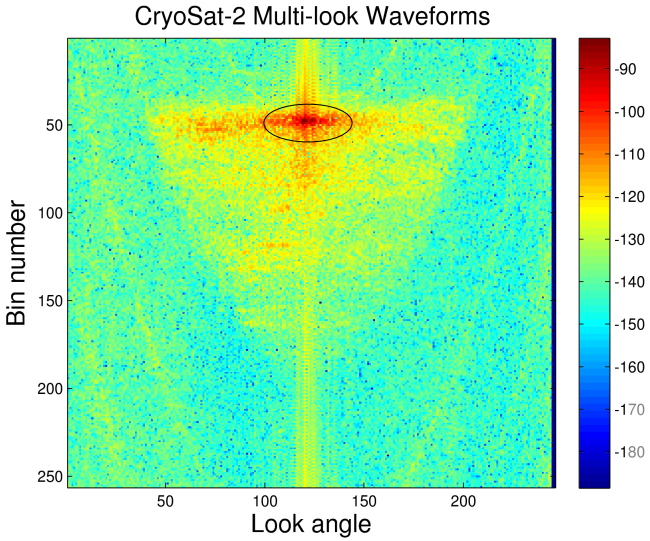
The multi-look: stack look-angles

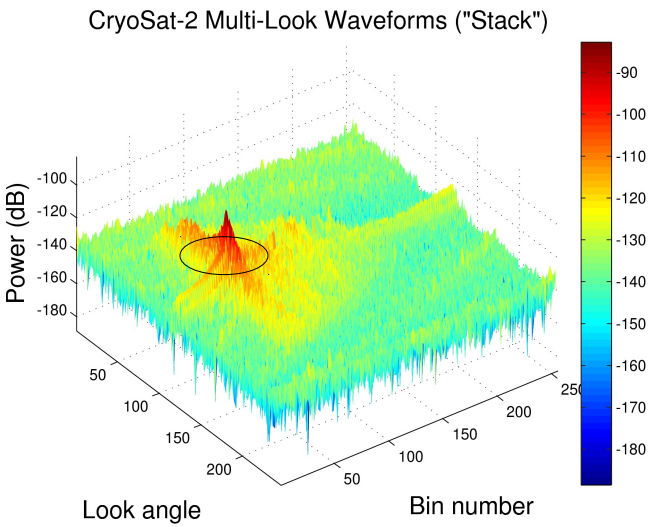


Aperture depending on sea surface RMS slope

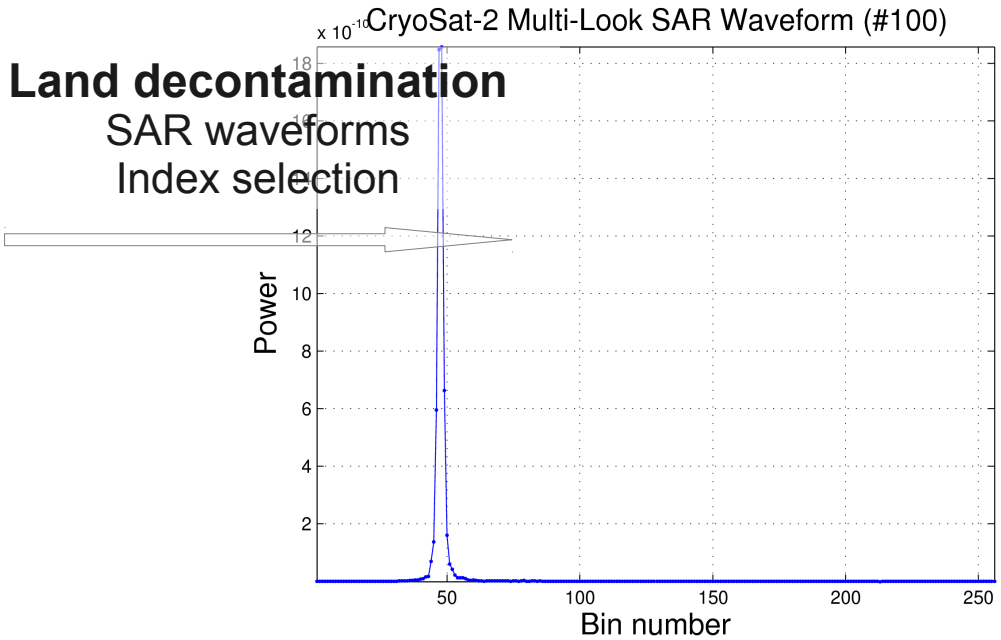
Offset depending on pitch mispointing

Stack: mean waveform

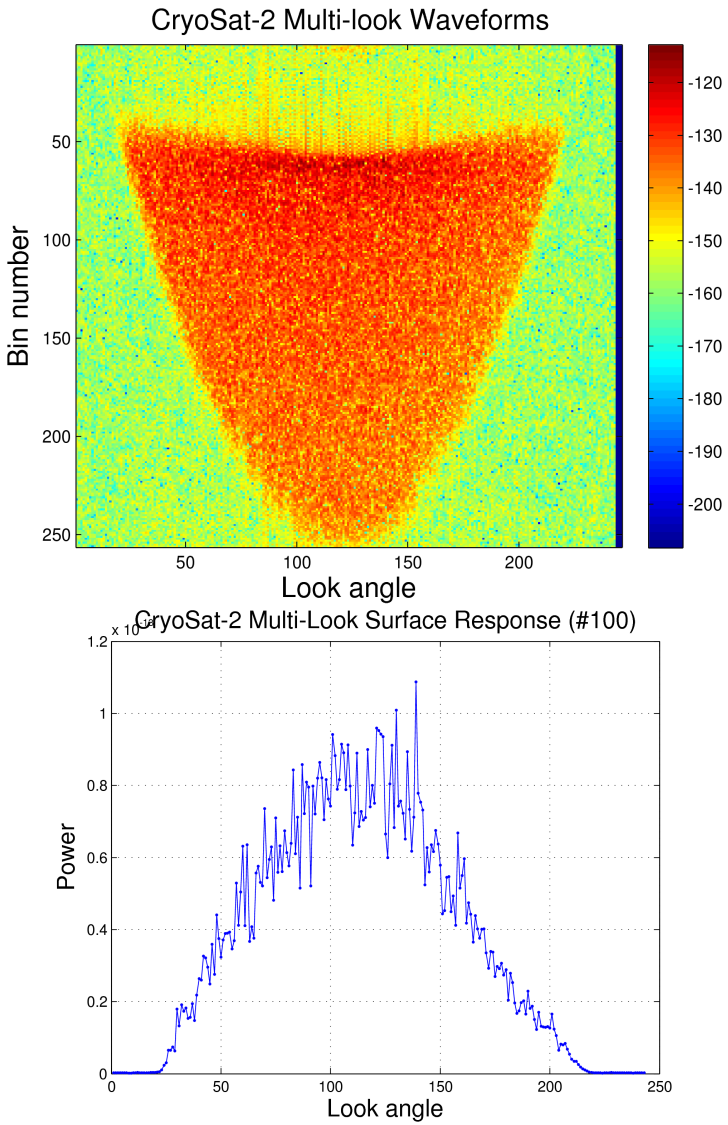


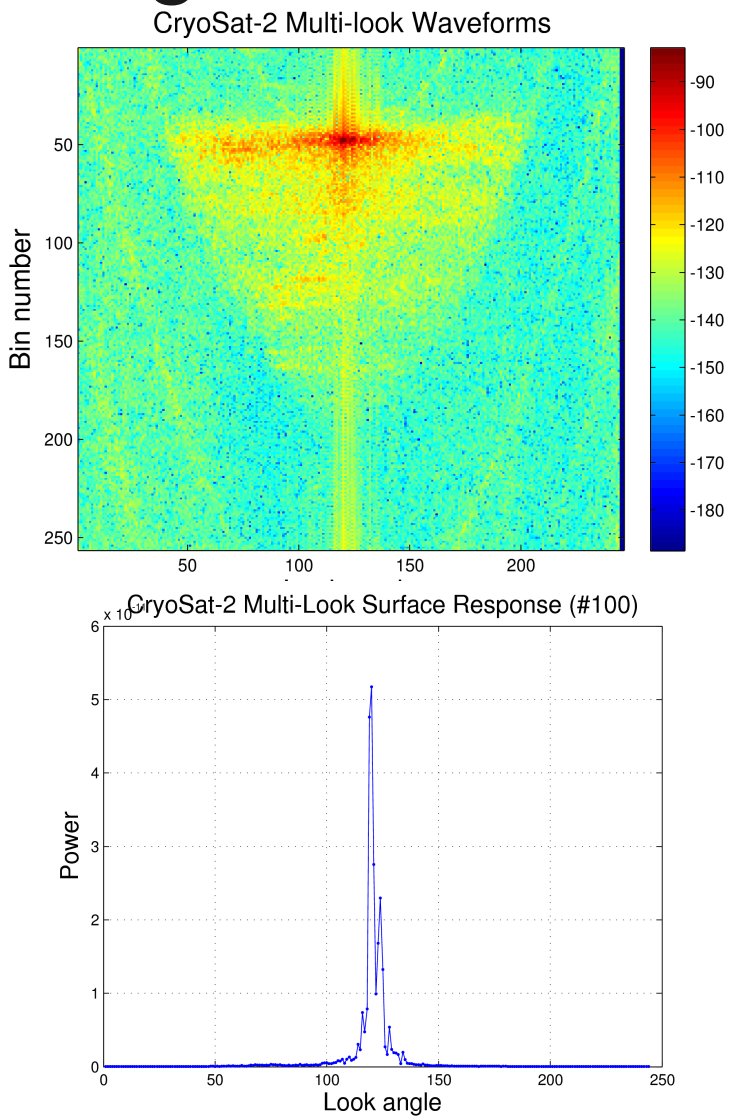


Land decontamination
SAR waveforms
Index selection



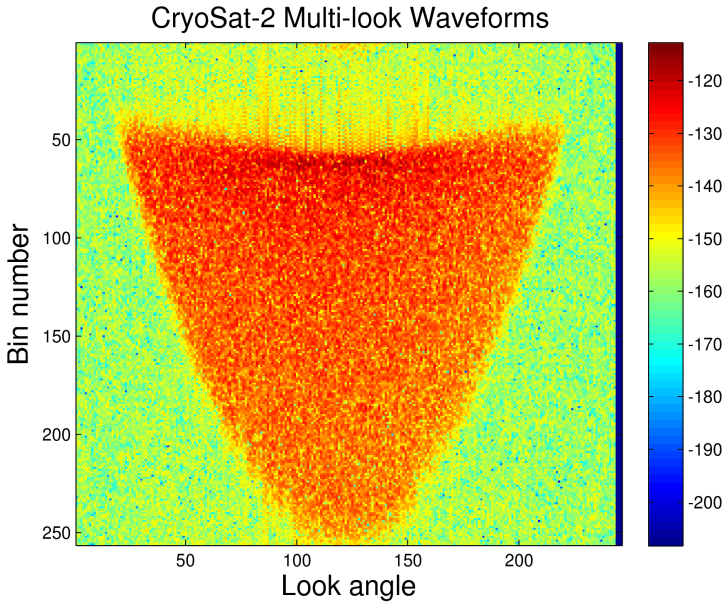
Stack: surface roughness

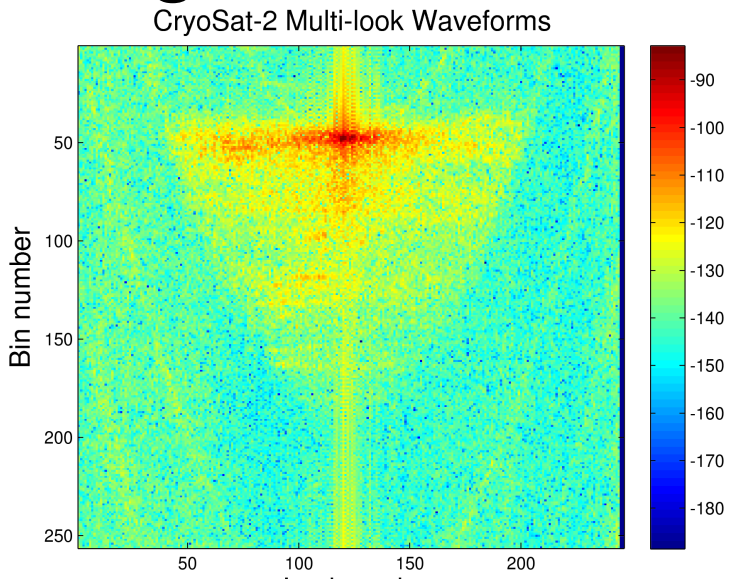


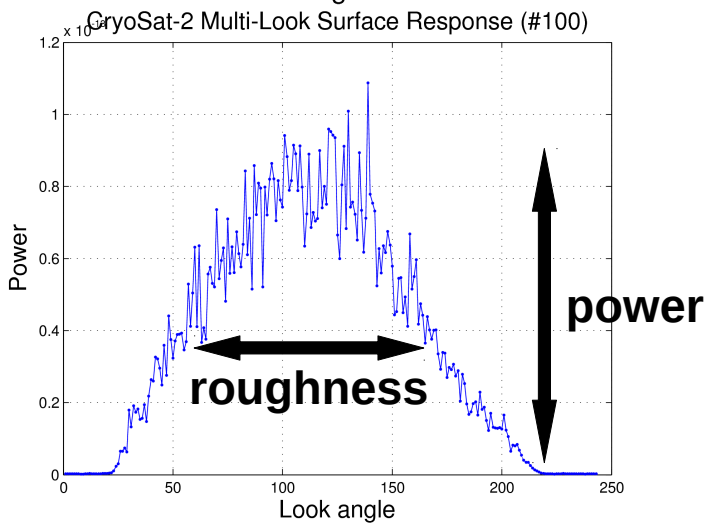


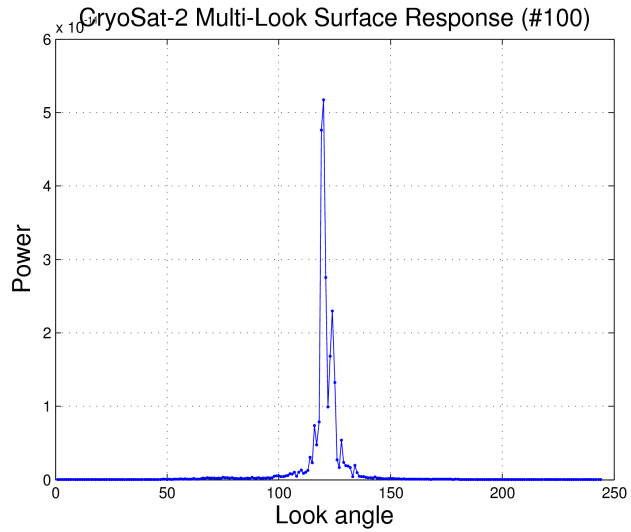
VIDEO

Stack: surface roughness

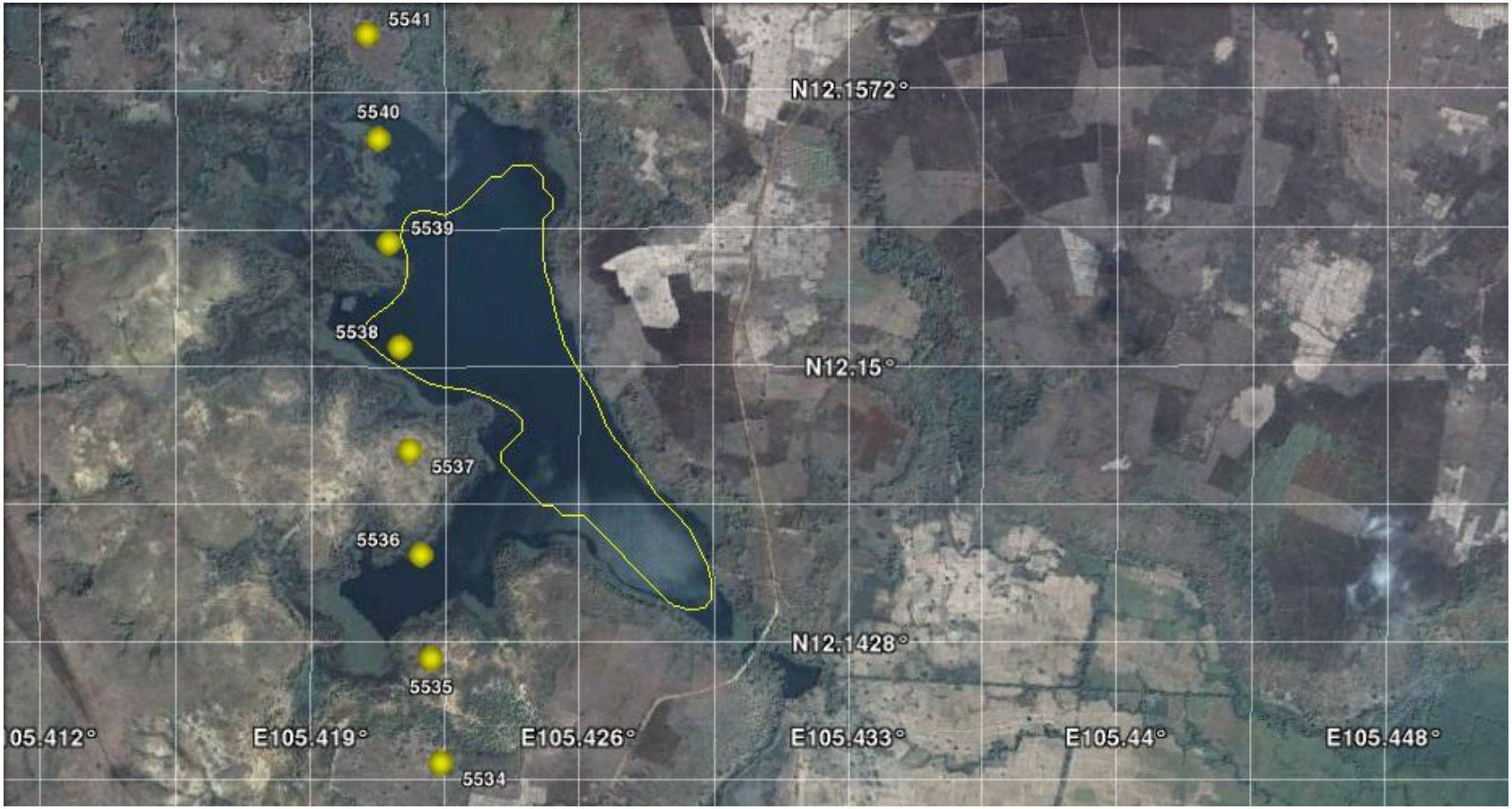






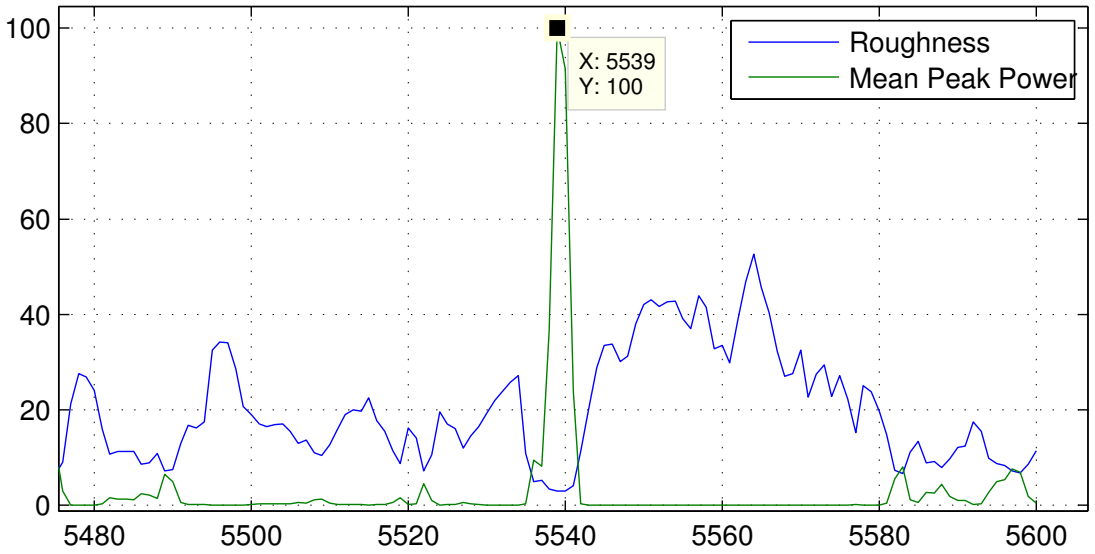


Surface response & look angle



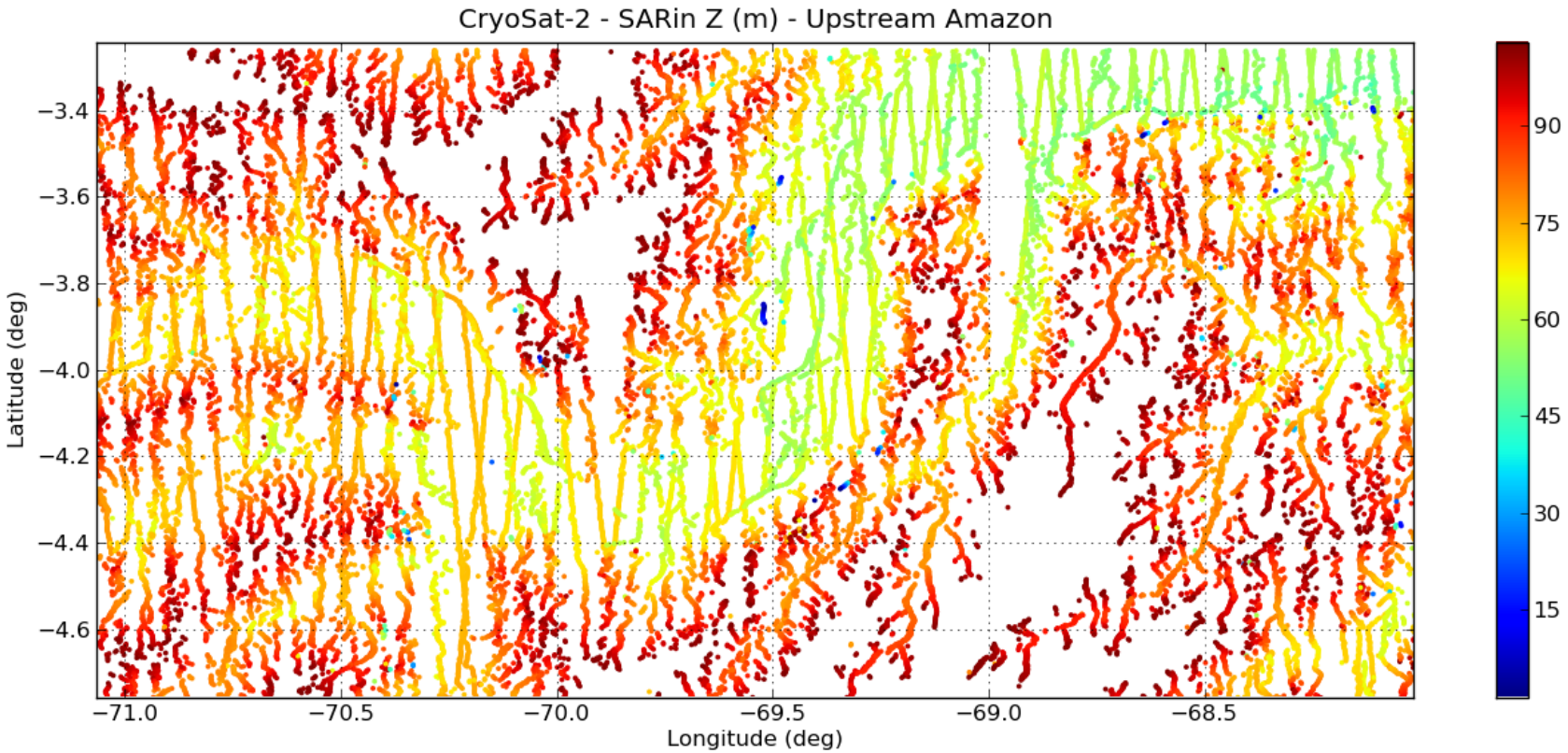

5541
5540
5539
5538
5537
5536
5535
5534
N12.1572°
N12.15°
N12.1428°
05.412°
E105.419°
E105.426°
E105.433°
E105.44°
E105.448°


5541
5540
5539
5538
5537
5536
5535
5534
N12.1572°
N12.15°
N12.1428°
05.412°
E105.419°
E105.426°
E105.433°
E105.44°
E105.448°


Roughness
Mean Peak Power
X: 5539
Y: 100
100
80
60
40
20
0
5480
5500
5520
5540
5560
5580
5600

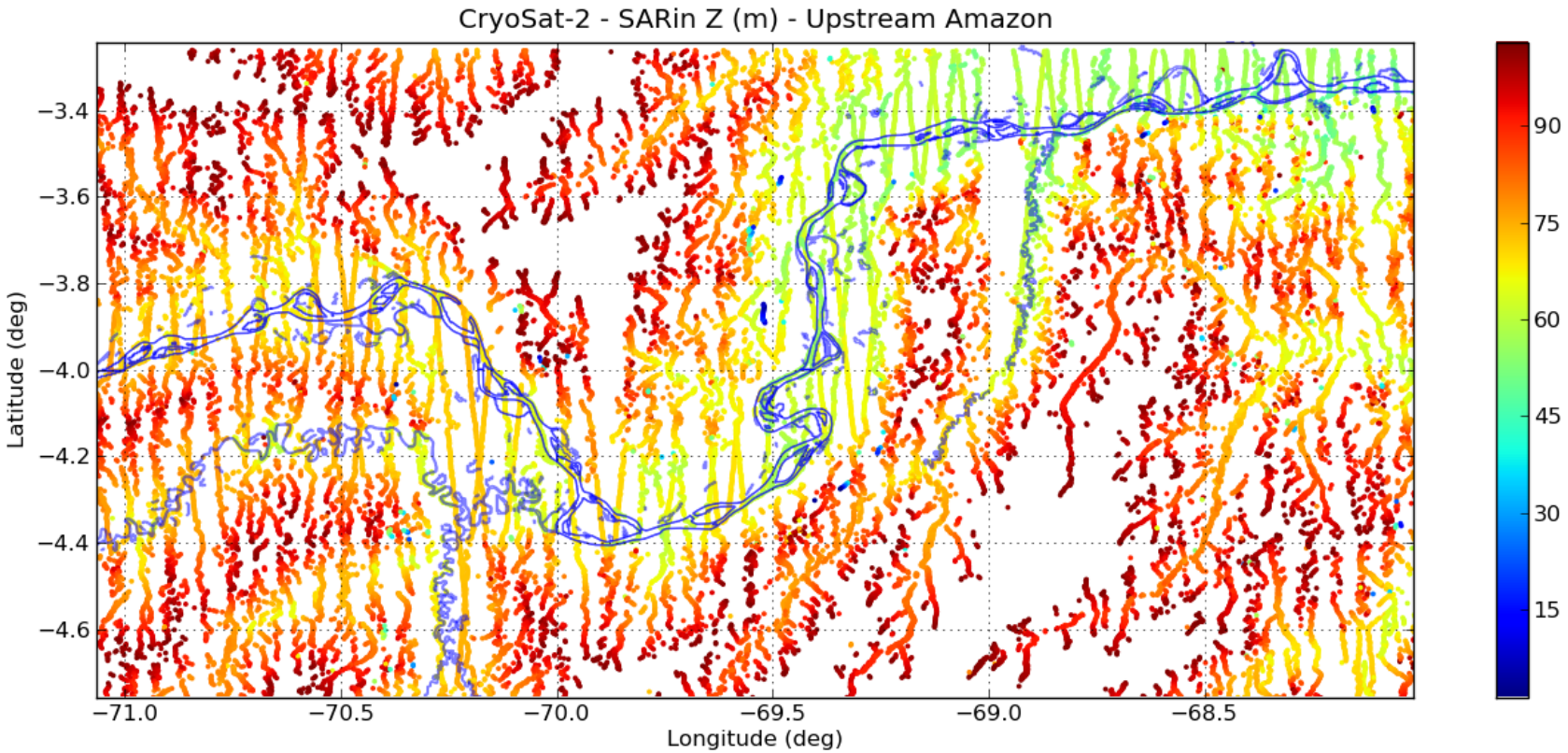
SARin & "the magic of two antennas"

SARin data extraction : tracks are zigzagging. . .



SARin & "the magic of two antennas"

SIRAL tracks a part the hydrographic network !



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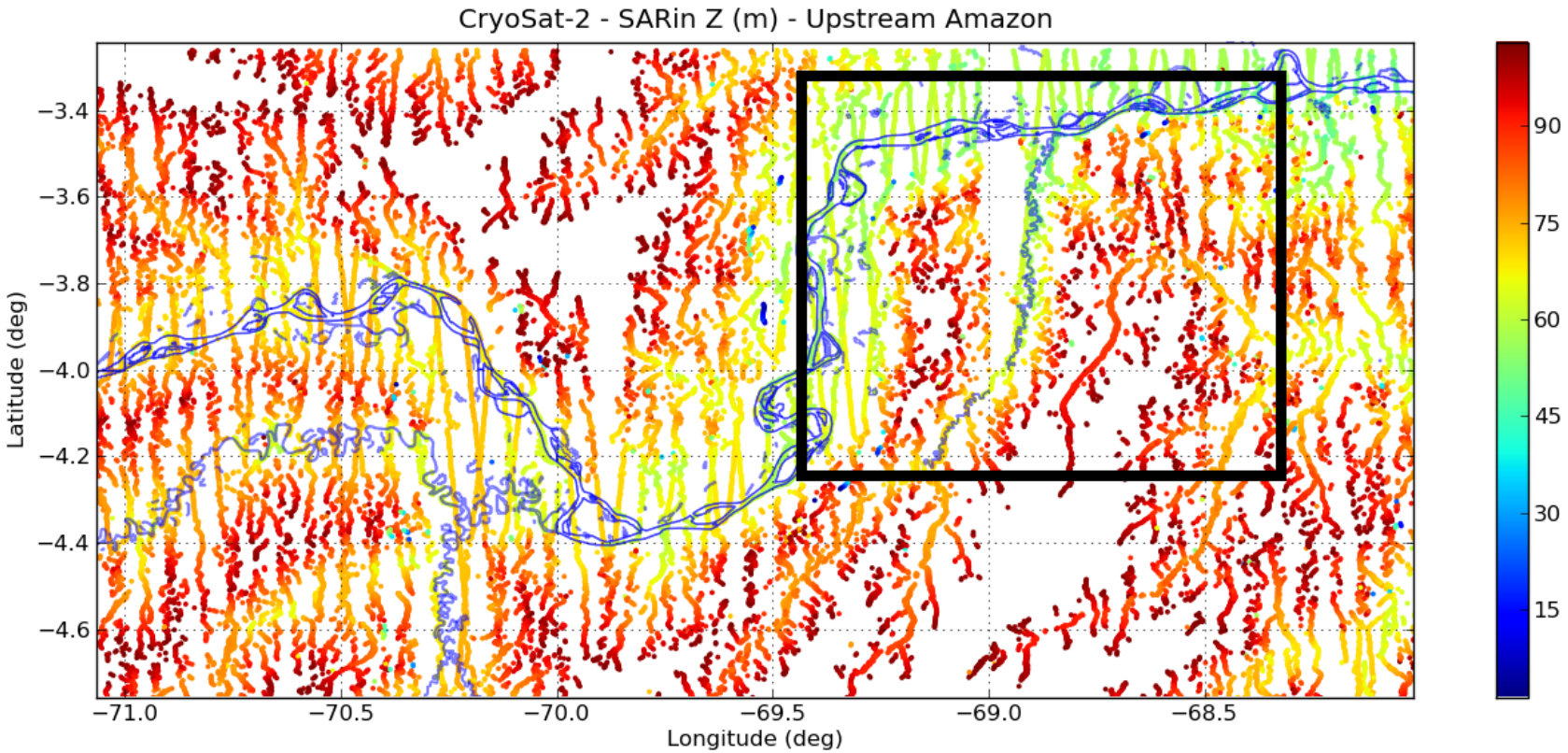


SARin & "the magic of two antennas"

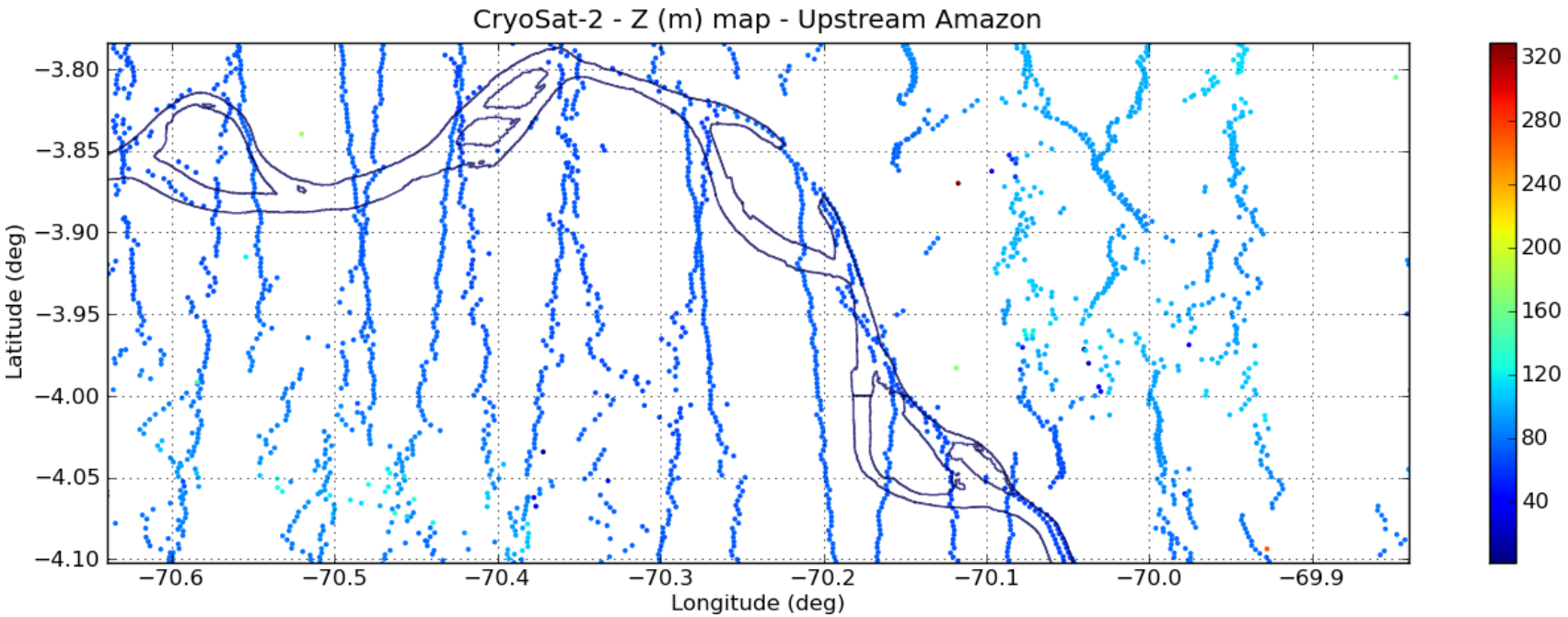
SIRAL tracks a part the hydrographic network !

SARin & "the magic of two antennas"

30 m wide rivers we can actually hardely see. . .

SARin & "the magic of two antennas"

Zoom-in examples...



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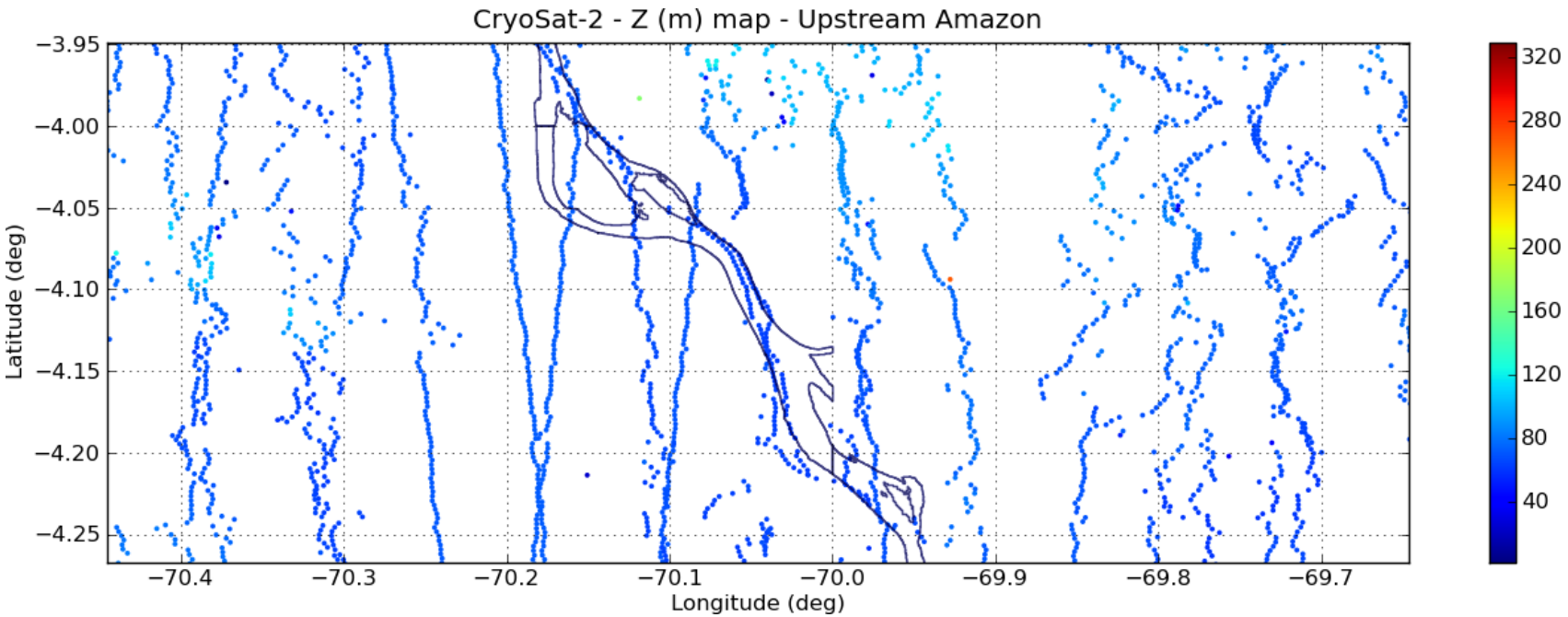

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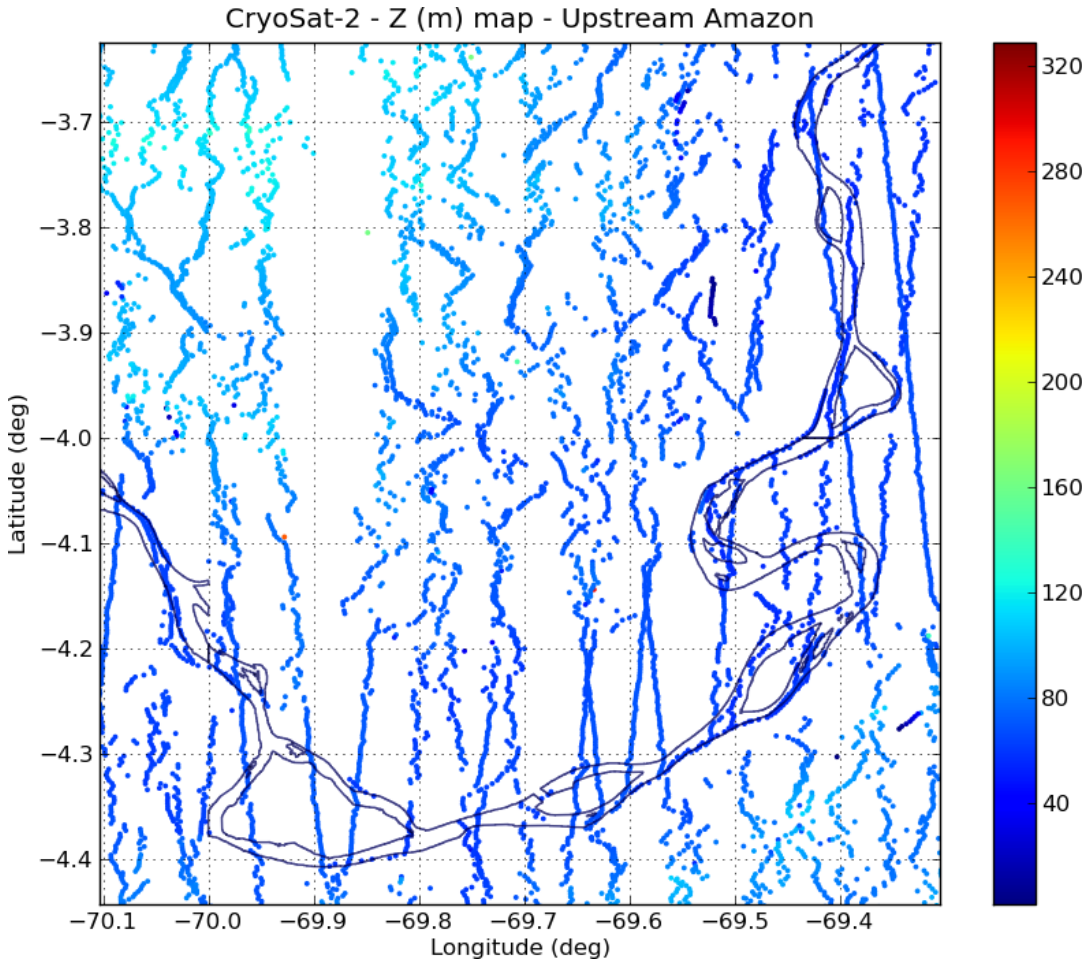

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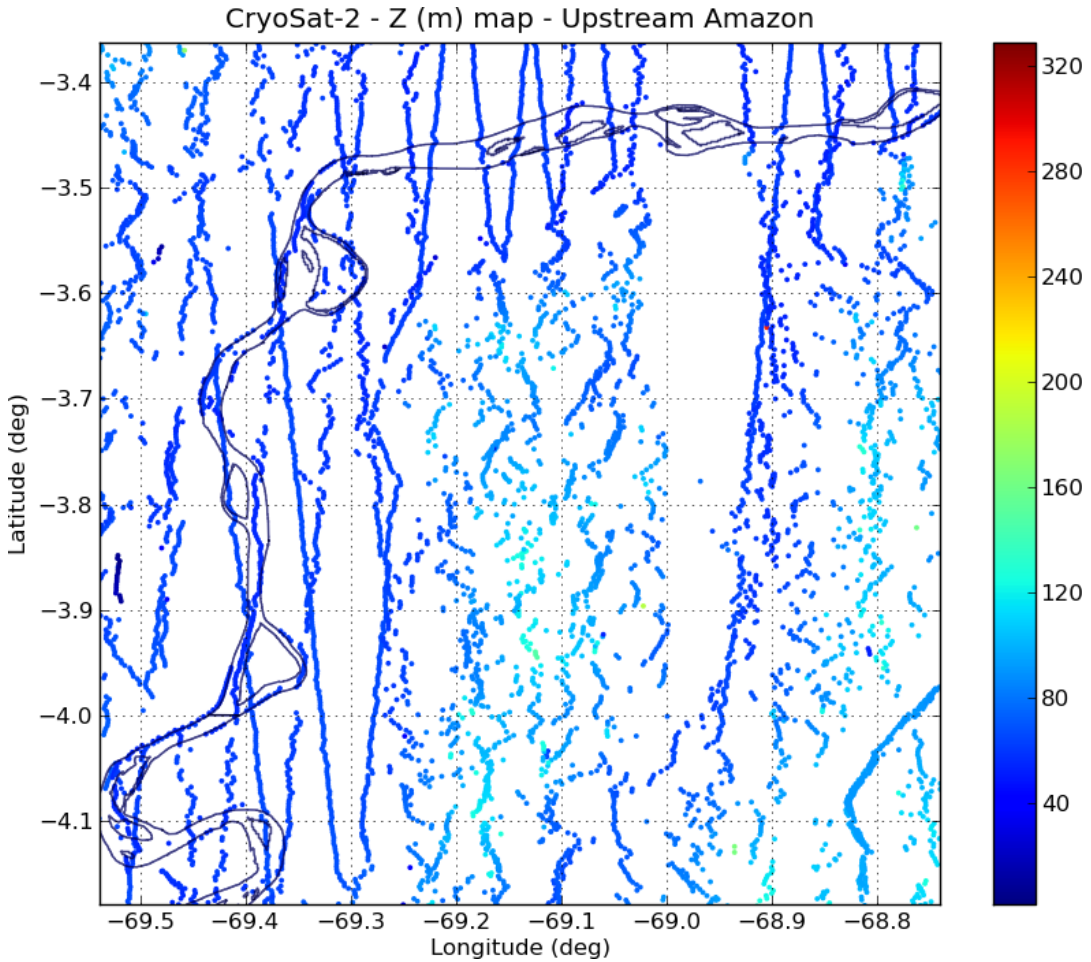

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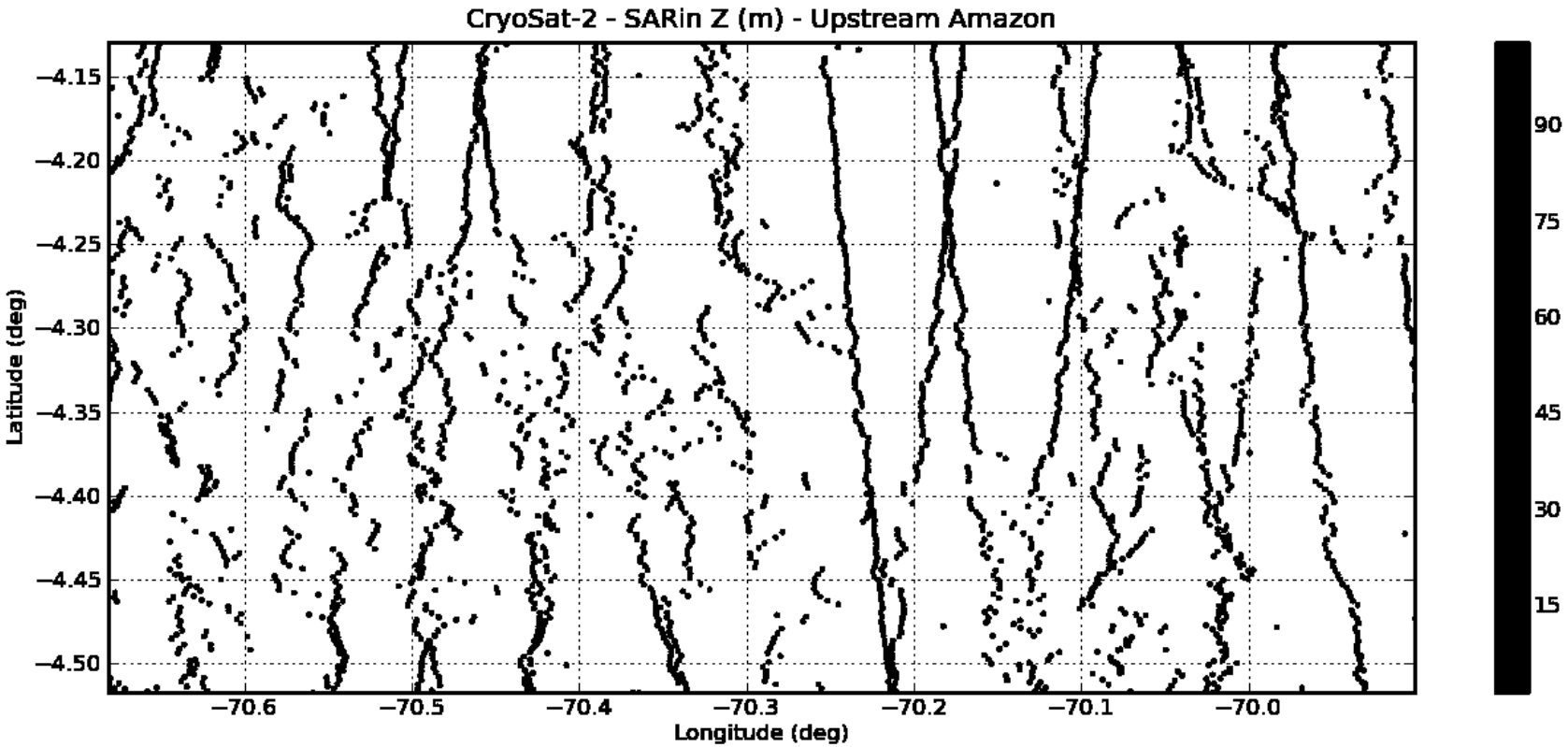

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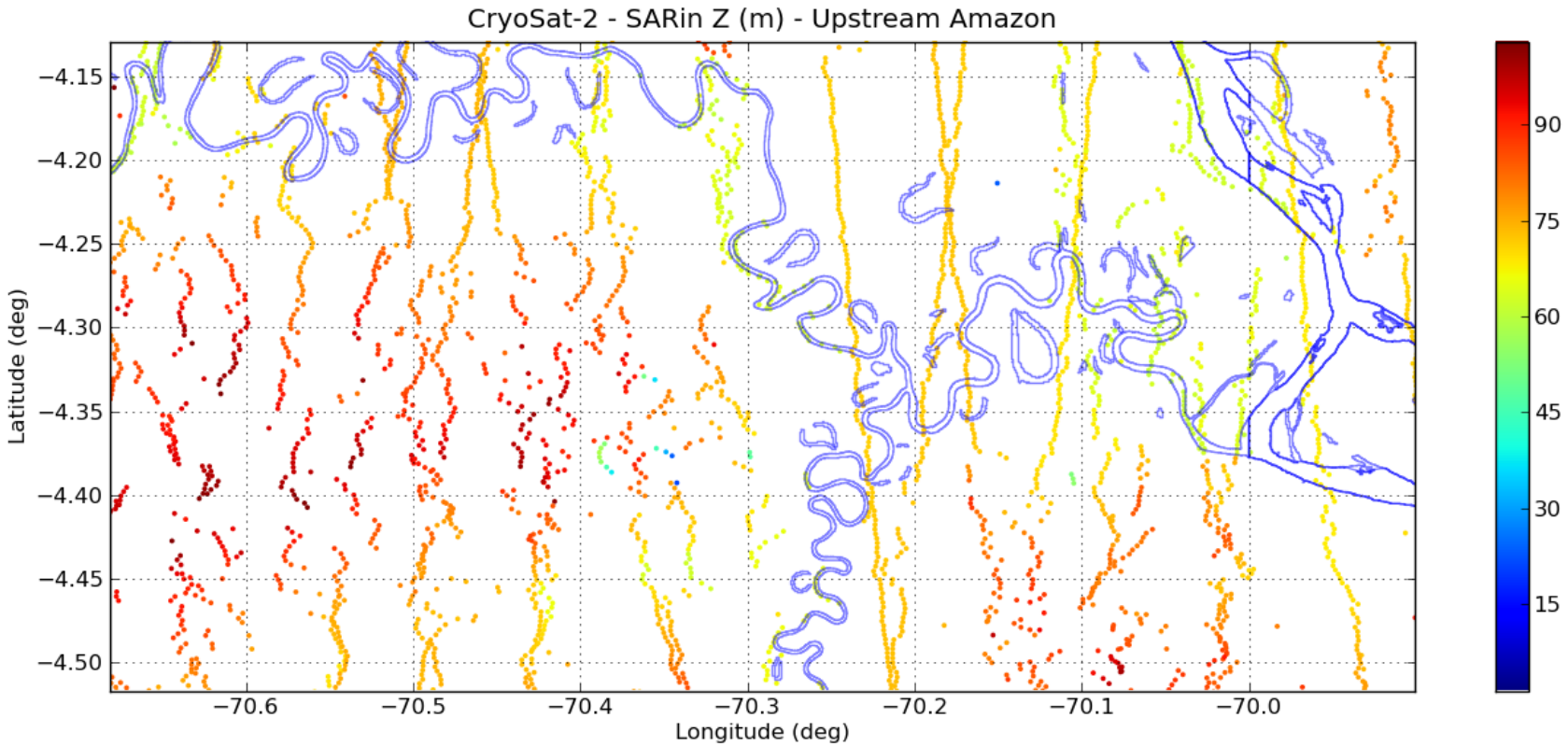

Conclusion

Background

- Complex product lines while there were issues in Baseline A products (ESA, NOAA/RADS, AVISO/Duacs, CNES/CPP, ESRIN/Proto)

Benefits of the mission for hydrology

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- But things seems to be greatly improved : more opened data policy and improved products

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Benefits of the mission for hydrology

- Cryosat-2 geodetic orbit : direct application to map rivers topography
- SIRAL : rich instrument with 3 modes, higher along-track resolution and ability to track off-nadir water surfaces (SARin)

Conclusion

Many new things can be done with CryoSat-2

- Measure rivers topography

SARin mode / CryoSat-2 orbit

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SARin mode / CryoSat-2 orbit

- Cross-track angle : great potential to detect small rivers and help mapping hydrographic networks, densify the spatial distribution of $Z(x, t)$
- Robust tracker that might be suitable to track rivers on rough terrain were conventional LRM missions usually fail

Perspectives

Potential use of SAR/SARin stacks and Doppler processing

- Beam forming : focus or along-track oversampling over rivers

SAR vs. RDSAR

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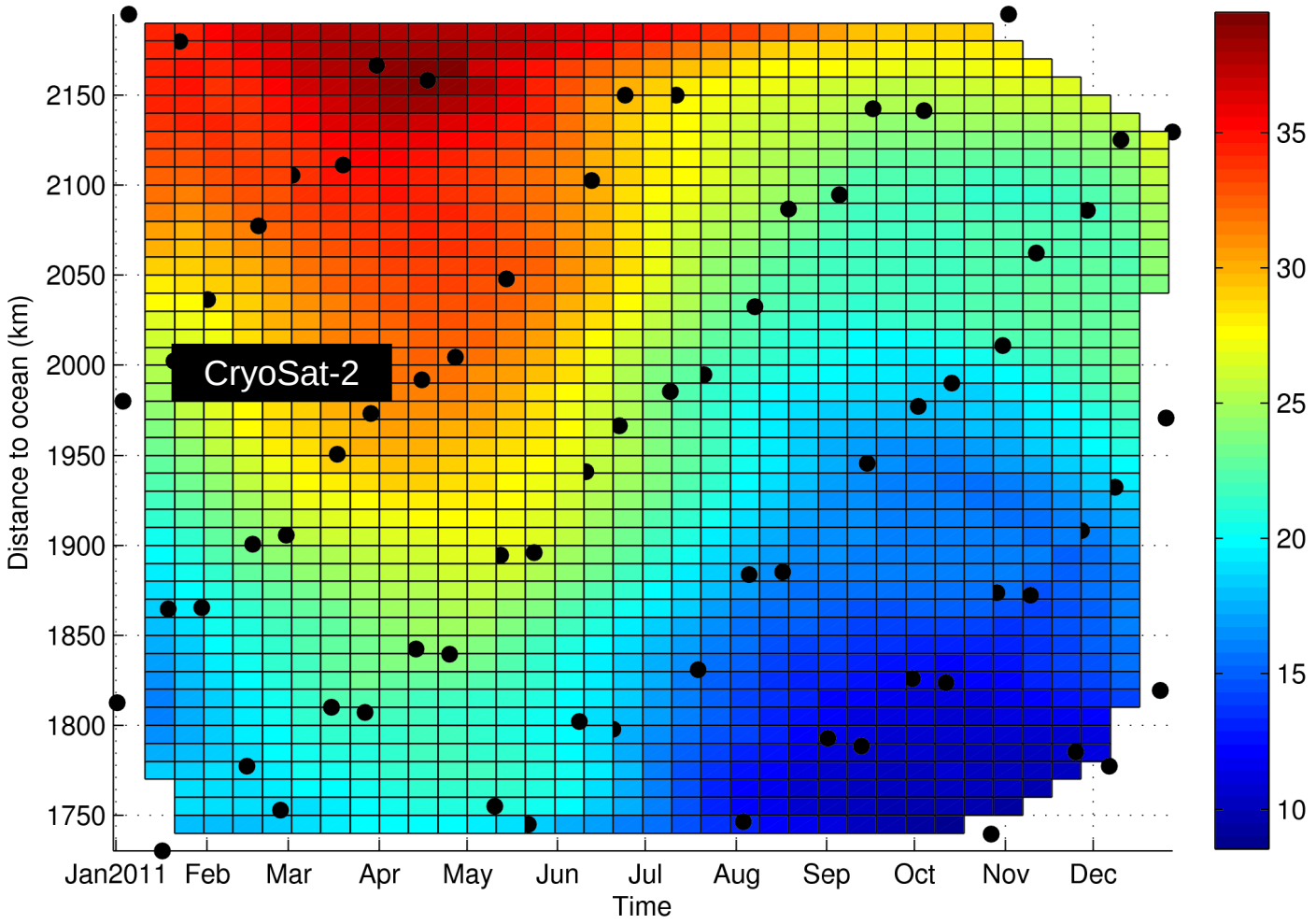
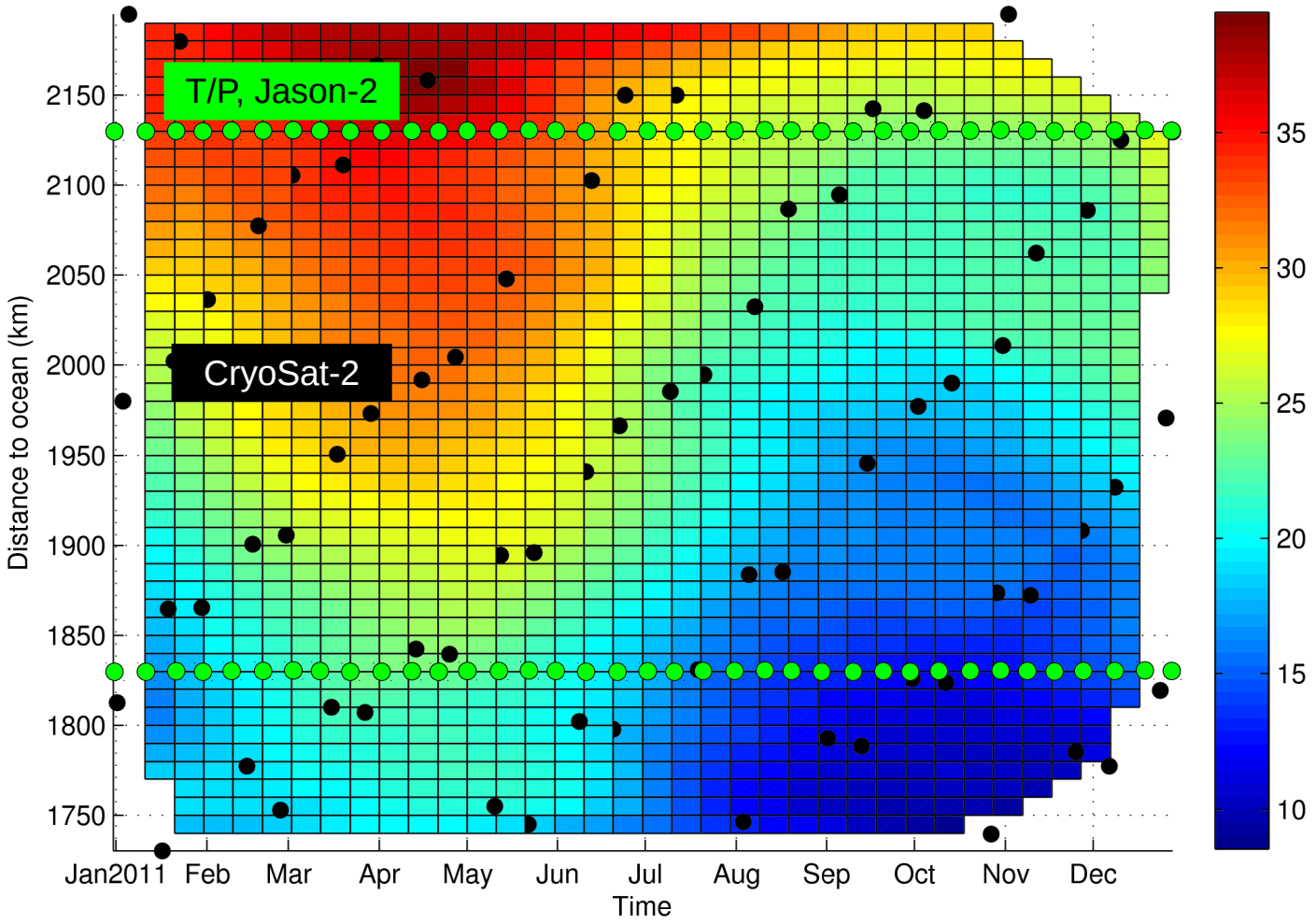
SAR vs. RDSAR

- Assess the benefits of SAR/SARin along-track resolution (work in progress !)

Perspectives : Mapping rivers topography from multi-mission data



Perspectives : Mapping rivers topography from multi-mission data



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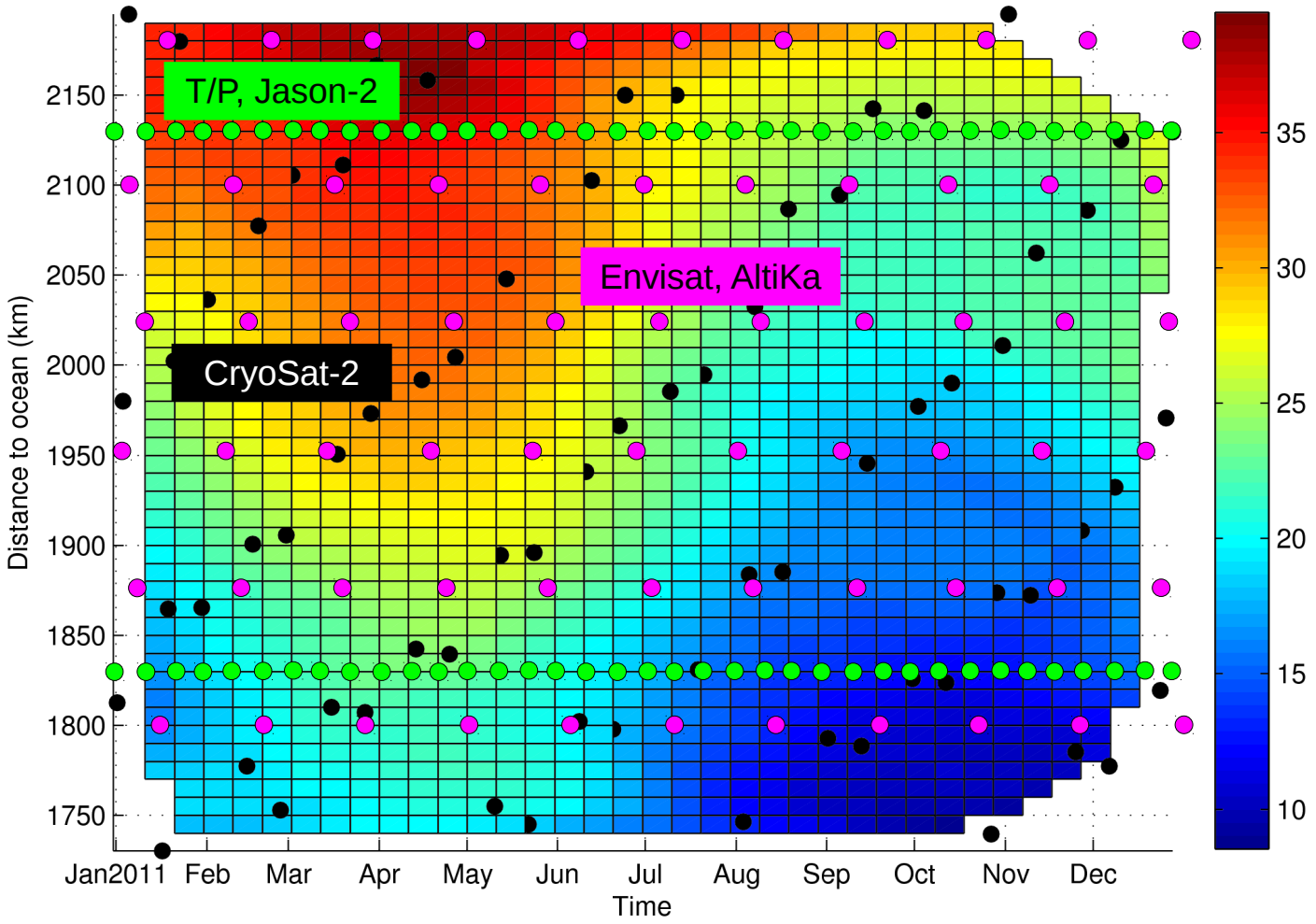

Perspectives : Mapping rivers topography from multi-mission data

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- Need to develop physical interpolation methods & filters using hydraulics and other constraints

– Thank you ! –