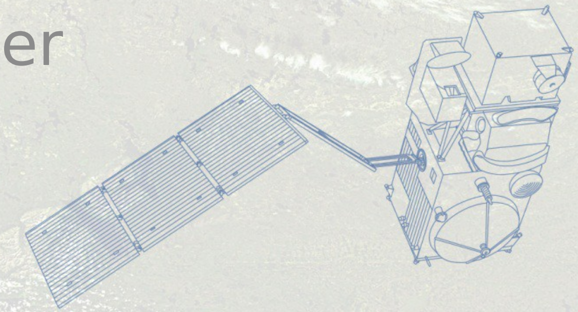
→ SENTINEL-3 FOR SCIENCE WORKSHOP

Characterization of SAR Mode Altimetry over Inland Water

Pierre Fabry, Nicolas Bercher



ALONG-TRACK.com

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European Space Agency

Context

- Space Hydrology :
  - Water bodies delineation from SAR images ... a hard subject ?

Context

- Space Hydrology is difficult because:
  - **very wide variety + variability of scenarios** (high/low waters combined to changes of lake bathymetry, river beds, river paths and islands, changes of roughness due to wind or discharge (surface current), trophic phenomenons, case of mountain lakes, vicinity of cities (high backscatter), mix of all this ...)

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  - ... *altimetry is much easier then SAR imagery ?*

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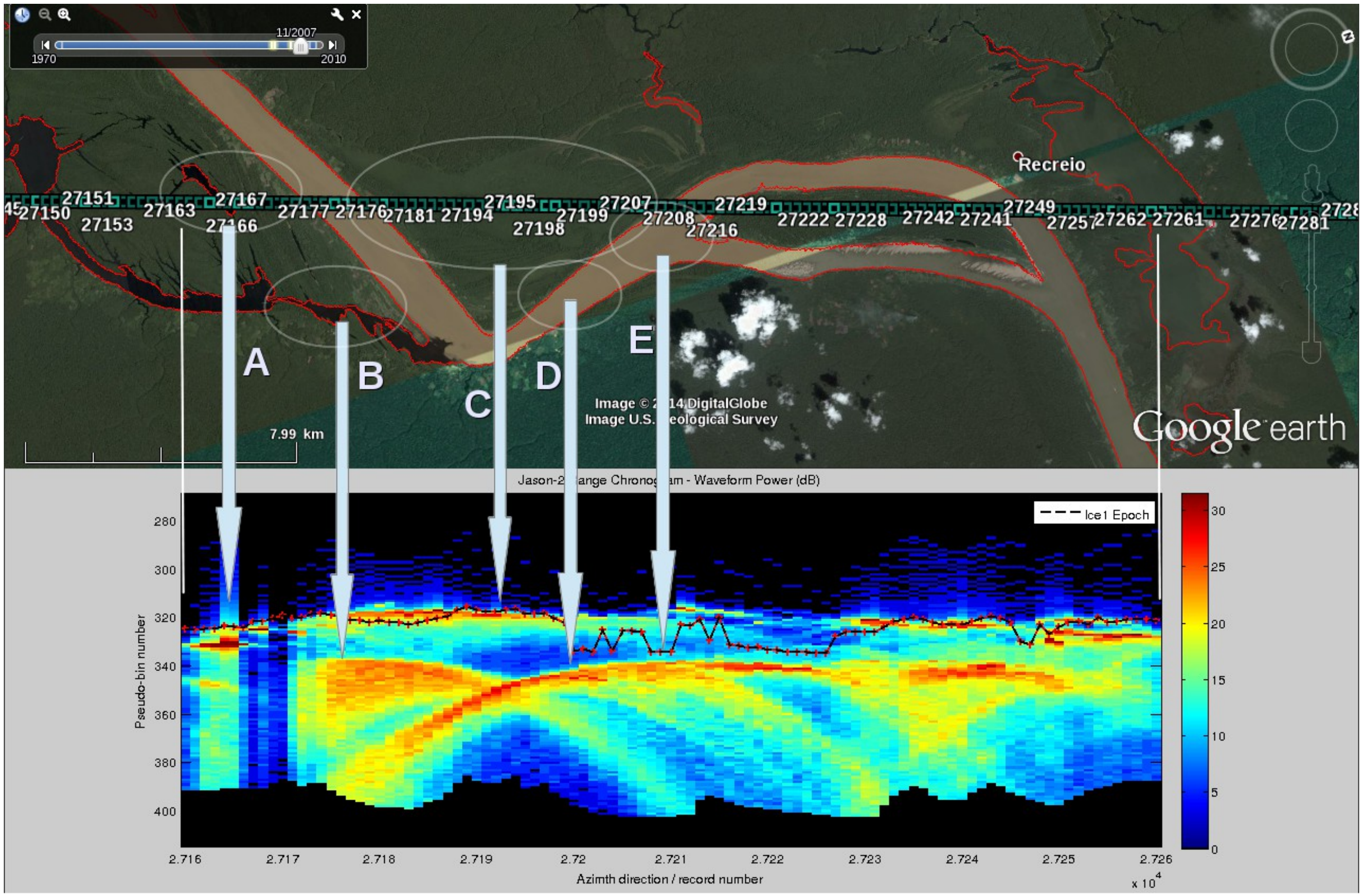
  - **off-NADIR hookings** : tracker window not always centered at NADIR

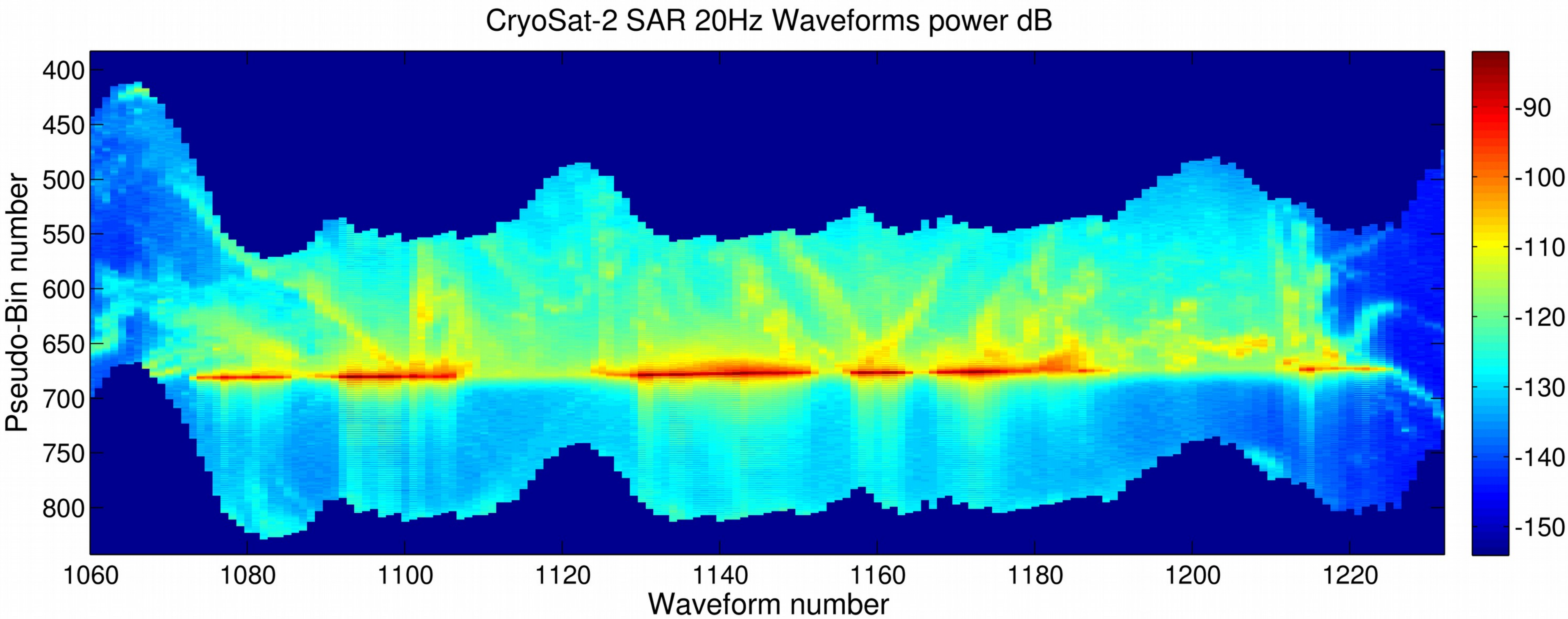
Context

- Contributions of Off-NADIR water areas : LRM case (Jason2) : → hyperboles



Context

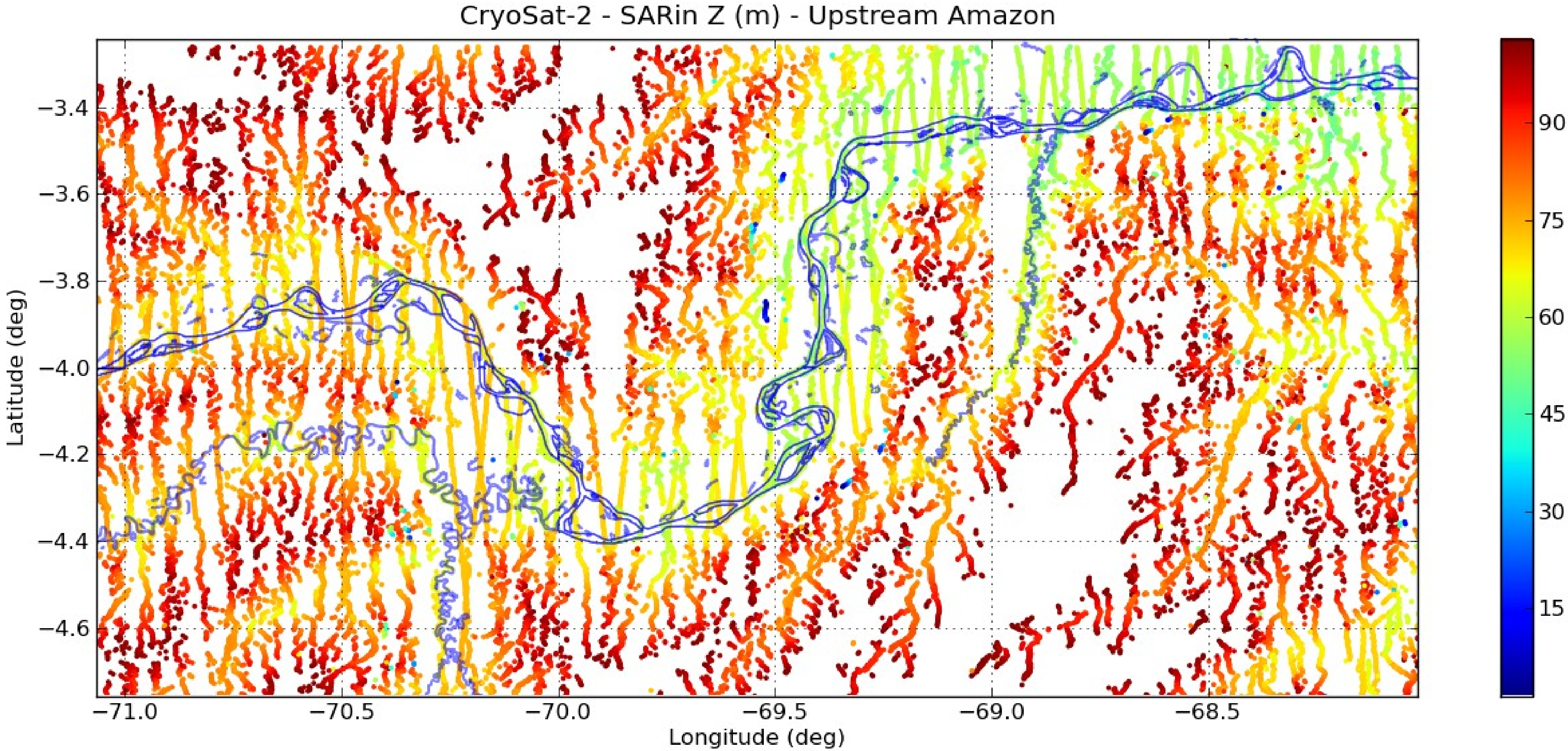
- Cryosat-2 SAR mode showing some **portions of hyperboles** due to **dominant across-track Off-NADIR water areas (Amazon)**



Data from Salvatore Dinardo Nov 2012.

Context

- Cryosat-2 ESA/L2 SARIn showing of Off-NADIR pointing, [Bercher et al., 2013]



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  - **space and time variability of the water area** with :
  - **low waters → contaminated waveforms** due to sand banks …

Context

- Space Hydrology is difficult because
  - **very wide variety of scenarios**

    → in altimetry → loss of accuracy & precision.
  - **off-NADIR hooking**: tracker window not always centered at NADIR
  - **space and time variability of the water area** with :
  - **low waters → contaminated waveforms** due to sand banks …
  - Existing SARM data (CS2) faces most of these issues + geodesic orbit !
- Questions
- **How to produce water heights with a more consistent accuracy and precision over time in both SAR and LRM ?**
- **Can we characterize S3 waveforms over inland from Cryosat-2 data ?**

Context

- **Both questions find a common answer :**
- the principle of Fixed Virtual Stations is weak, **even on repeat tracks**
  - FVS manually defined as the intersection area of satellite track and riverbed :
    - OK for large rivers,
    - **Defining FVS** on a large scale is **too much work** for small ones **+ sensitive to orbit change** or drift
    - **Huge under-sampling of hydrological basins !**
    - What if sand banks and bathymetry change over time ?
- new framework with Automated Water Masking
  - use updated water masks => **synergy with imaging missions (S1)**
  - L1B → characterization (L1B, possible backward analysis of L1A and L1B-S),
  - L2 → measurements within the new framework

Objectives

- Performing an automated water masking of L1B/L2
  - provides a **flexible frame** for the definition of VS
  - unlocks the **exploitation of geodesic orbits** (full Cryosat-2 archive)
  - eases the **waveforms characterization** (water / transition / non-water)
  - makes it possible to **account for space & time variabilities** of water-bodies.

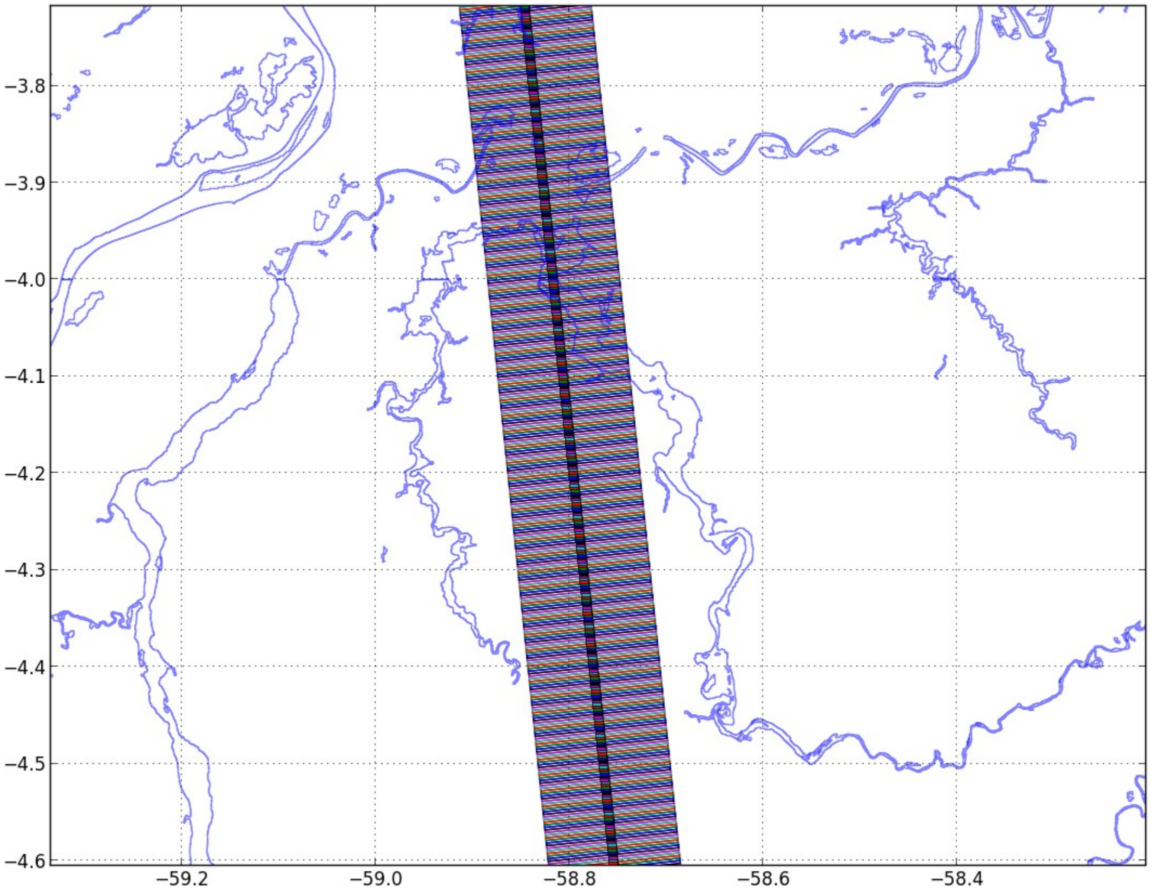
- How to ?
  - Compute the Doppler Footprint**s** – to - Water Masks **intersection area**
  - Define classes according to **% of water mask within footprint**
  - Build Statistics (from beam behaviour param.) per class.
  - Average waveforms per class.

Methodology

Track from CS_OFFL_SIR_SAR_1B_20140416T090624_20140416T090836_B001.DBL

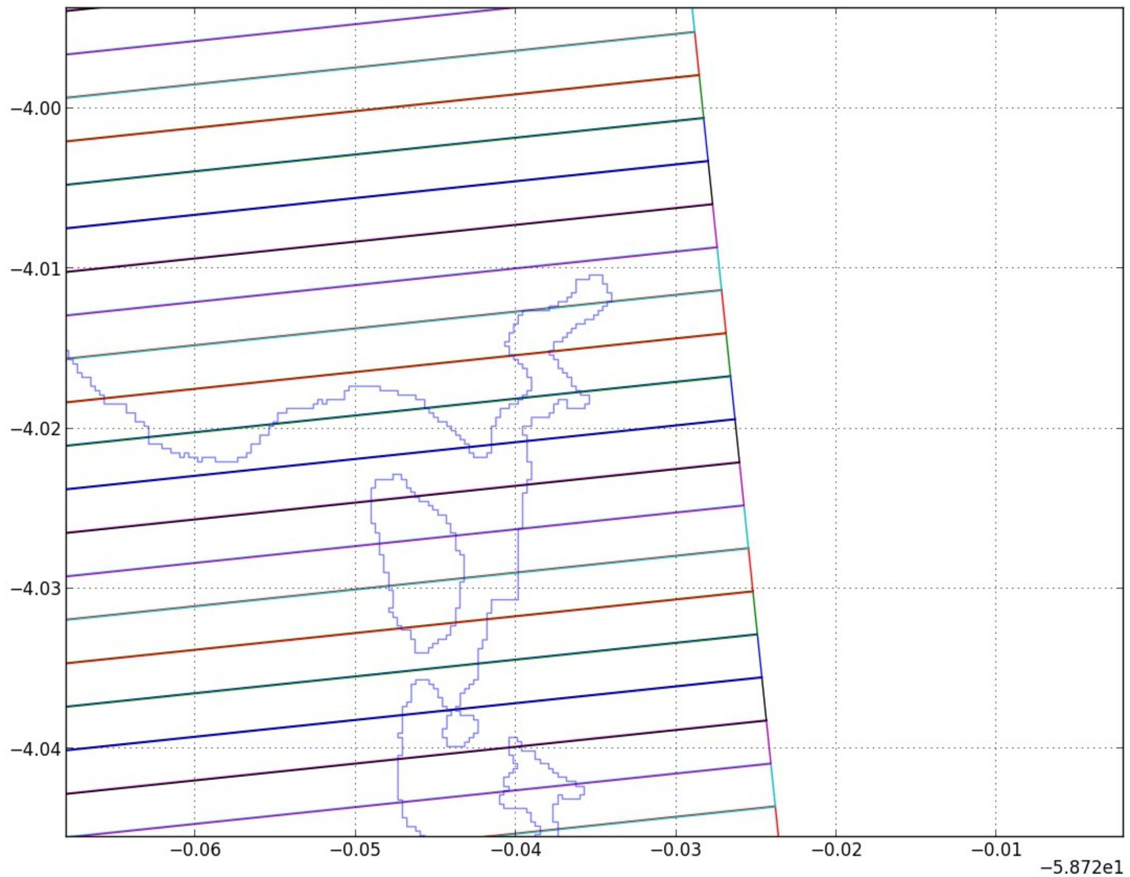
SWBD shapefiles :
w059s04s.shp,
w059s05s.shp,
w060s04s.shp,
w060s05s.shp,

Beam-Doppler limited footprint computed, at each record, from the actual system parameters found in the .DBL records !



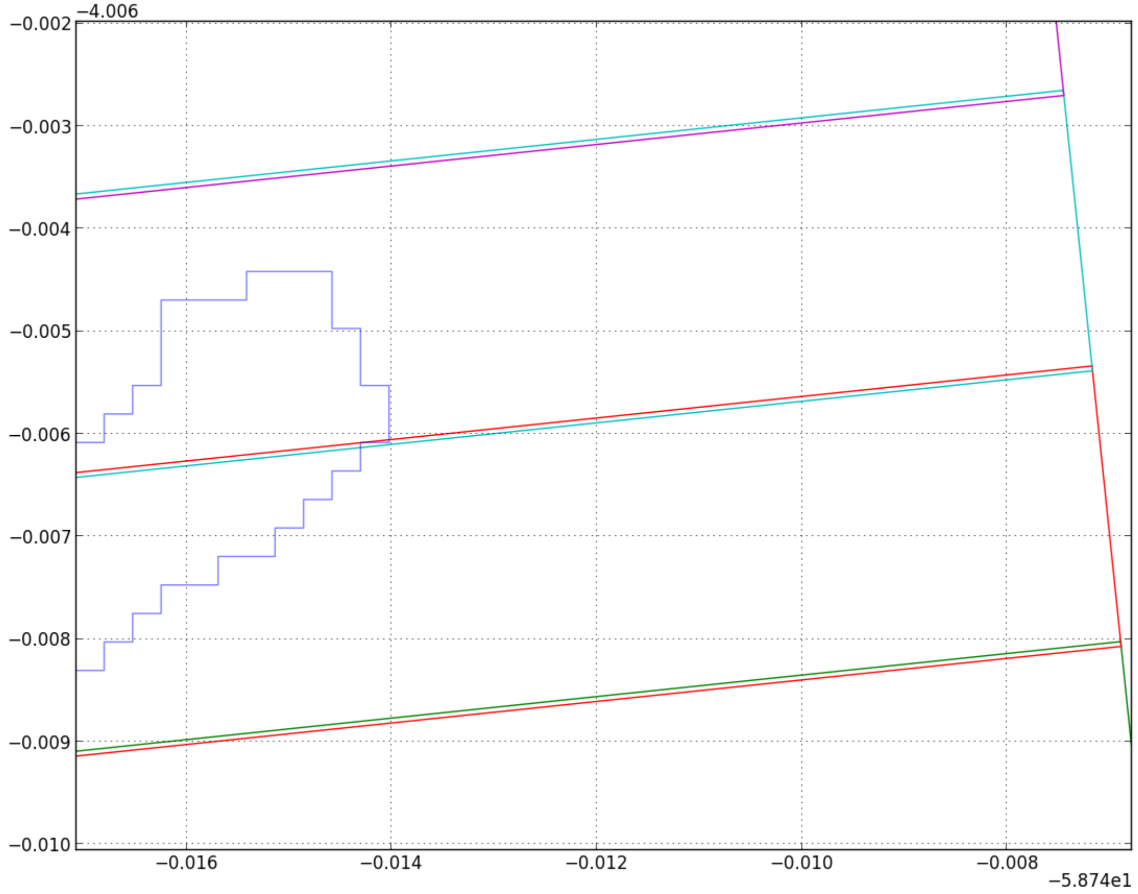
Methodology

Zoom



Methodology

Zoom more



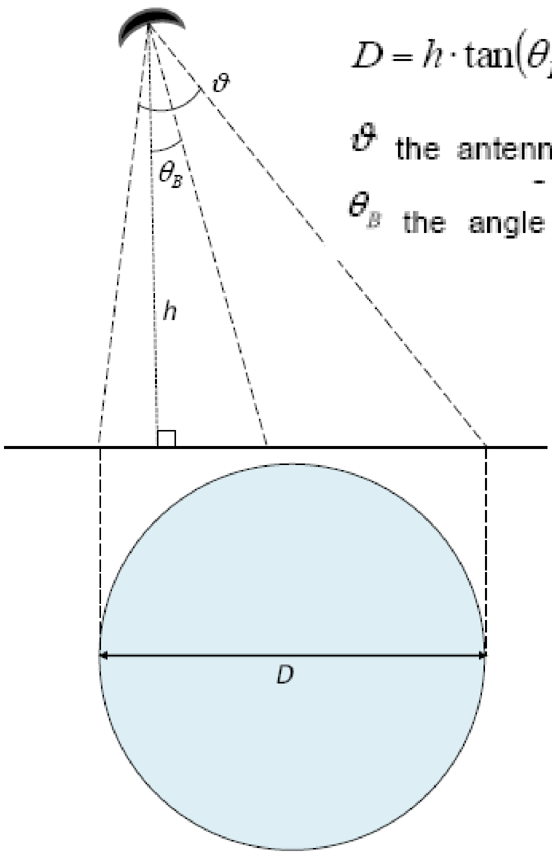
Methodology

- Automated data selection (L1Bs, SWBD) within **geo bounding box**
- Loop **i on** L1B files, Loop **j** on records
- read 2 cons. records (L1B .DBL product) : lon, lat, sat. alt & vel., tracker range
- → **sat. track** in the local Earth-tangential plane (ENU)
- → **Beam_Poly** : Beam-Doppler limited footprint Polygon in the local plane (record **j**)
- → **Pulse_Poly** : Pulse-Doppler limited footprint Polygon in the local plane (record **j**)
- convert. polygons from ENU → LLA (**back into SWBD framework**)
- count **beam_pixels**, **pulse_pixels** inside the 2 polygons
- count **beam_water_pixels** falling (inside **SWBD** + inside **Beam_Poly**)
- count **pulse_water_pixels** falling (inside **SWBD** + inside **Pulse_Poly**)
- → **scene_class** (beam_pixels, beam_water_pixels, pulse_pixels, pulse_water_pixels)
- for each class → **statistics** (from beam behaviour)
- for each class → **mean waveforms**

Methodology

- Beam-Doppler footprint (eq. From Cryosat-2 handbook)

Across-track beam size



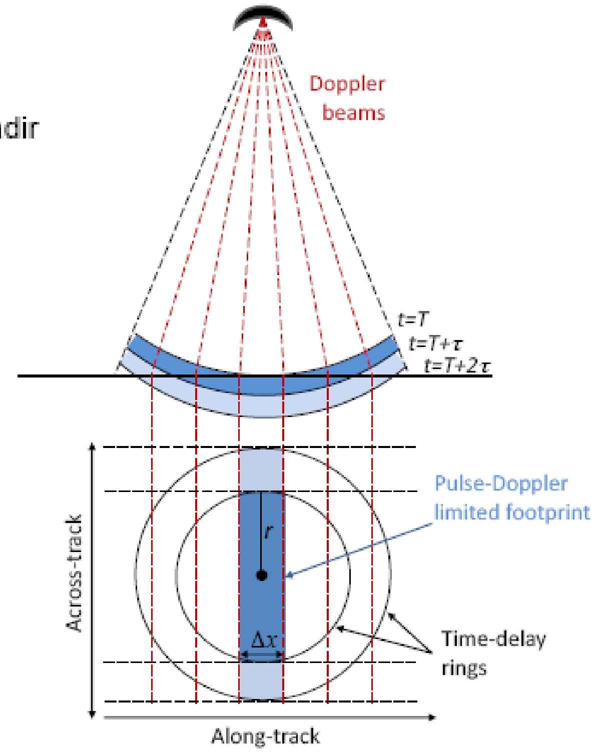
$$D = h \cdot \tan(\theta_B + \vartheta/2) - h \cdot \tan(\theta_B - \vartheta/2)$$

ϑ the antenna beam width at -3 dB,

θ_B the angle of the central beam direction with respect to the nadir

Along-track beam size

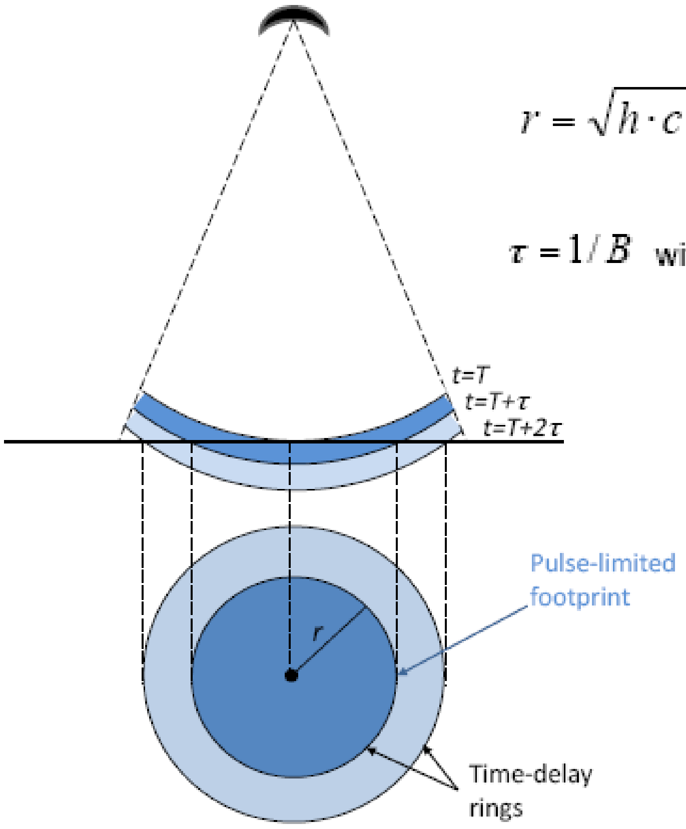
$$\Delta x = h \frac{\lambda}{2v} \frac{PRF}{64},$$



Methodology

- Pulse-Doppler footprint (eq. From Cryosat-2 handbook)

Across-track beam size



$$r = \sqrt{h \cdot c \cdot \tau} = \sqrt{h \cdot \frac{c}{B}}$$

$\tau = 1/B$ with B being the pulse bandwidth.

Along-track beam size

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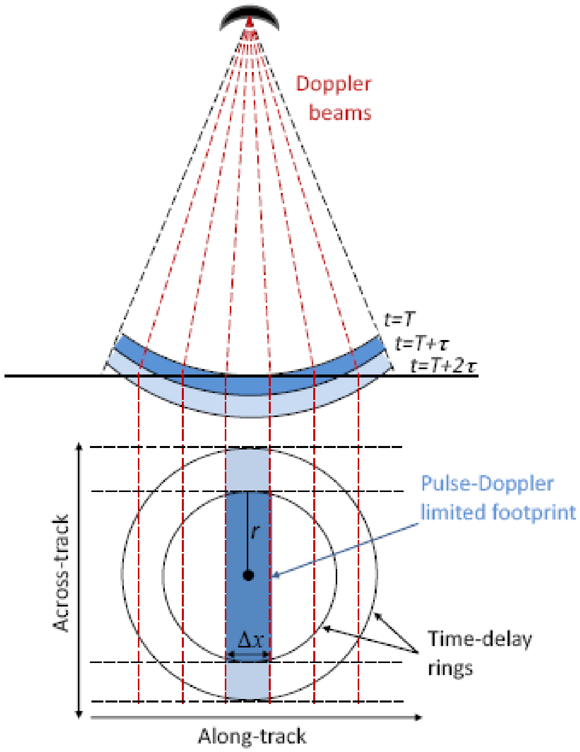


Methodology

- Compute :

  % water = beam_water_pixels / beam_pixels

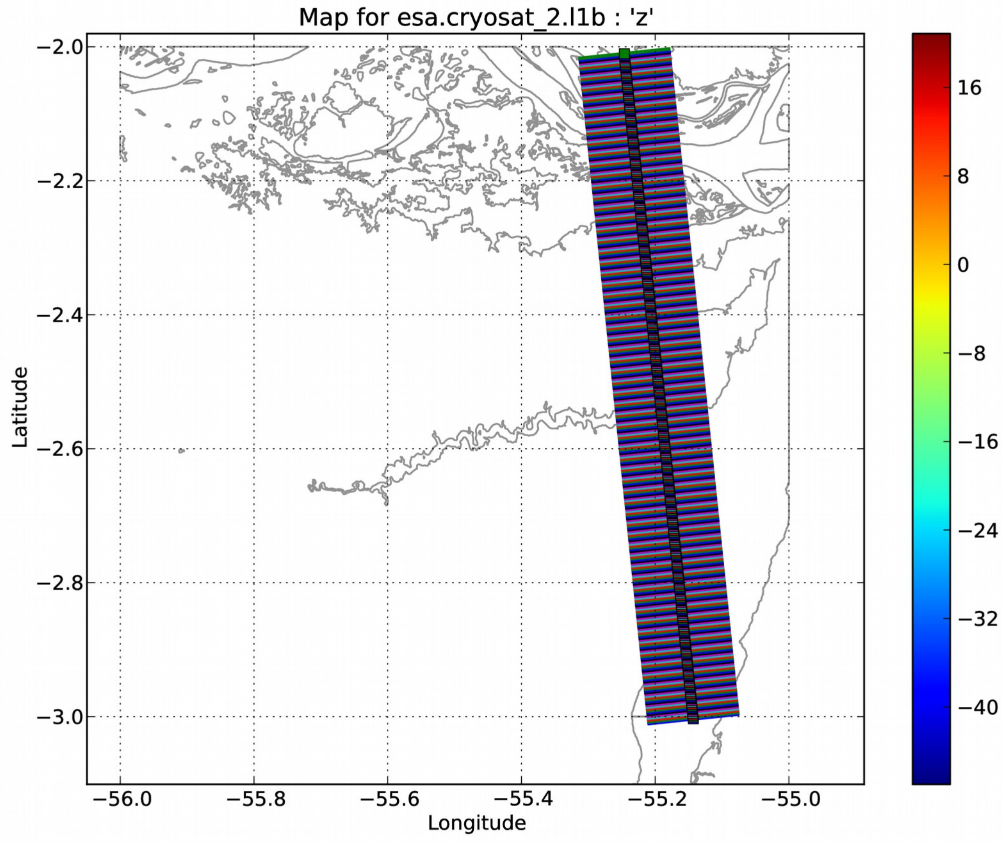
- Extract beam behaviour parameters from L1B (Stack Range Integrated Power Distributions)
  - **Standard Dev**
  - **Mean Centre**
  - **Stack Scaled** : amplitude scaled in dB/100
  - **Stack Skewness** : asymmetry of the stack RIP distribution / record
  - **Stack Kurtosis** : peackiness of the stack RIP distribution / record

Data used for this study

- CryoSat-2 L1-B baseline B data over Amazon
- Variable Instrument parameters (sat. velocity, tracker range, lat, lon) are read in the L1-B files
- Fixed bandwidth, PRF, antenna, carrier freq., etc.)
- SWBD water masks :
  - WARNING : old (SRTM) description of the Amazon
  - WARNING : preliminary results only to illustrate the method

Results

Tapajos & Amazon : CS_OFFL_SIR_SAR_1B_20140310T104112_20140310T104325_B001.DBL



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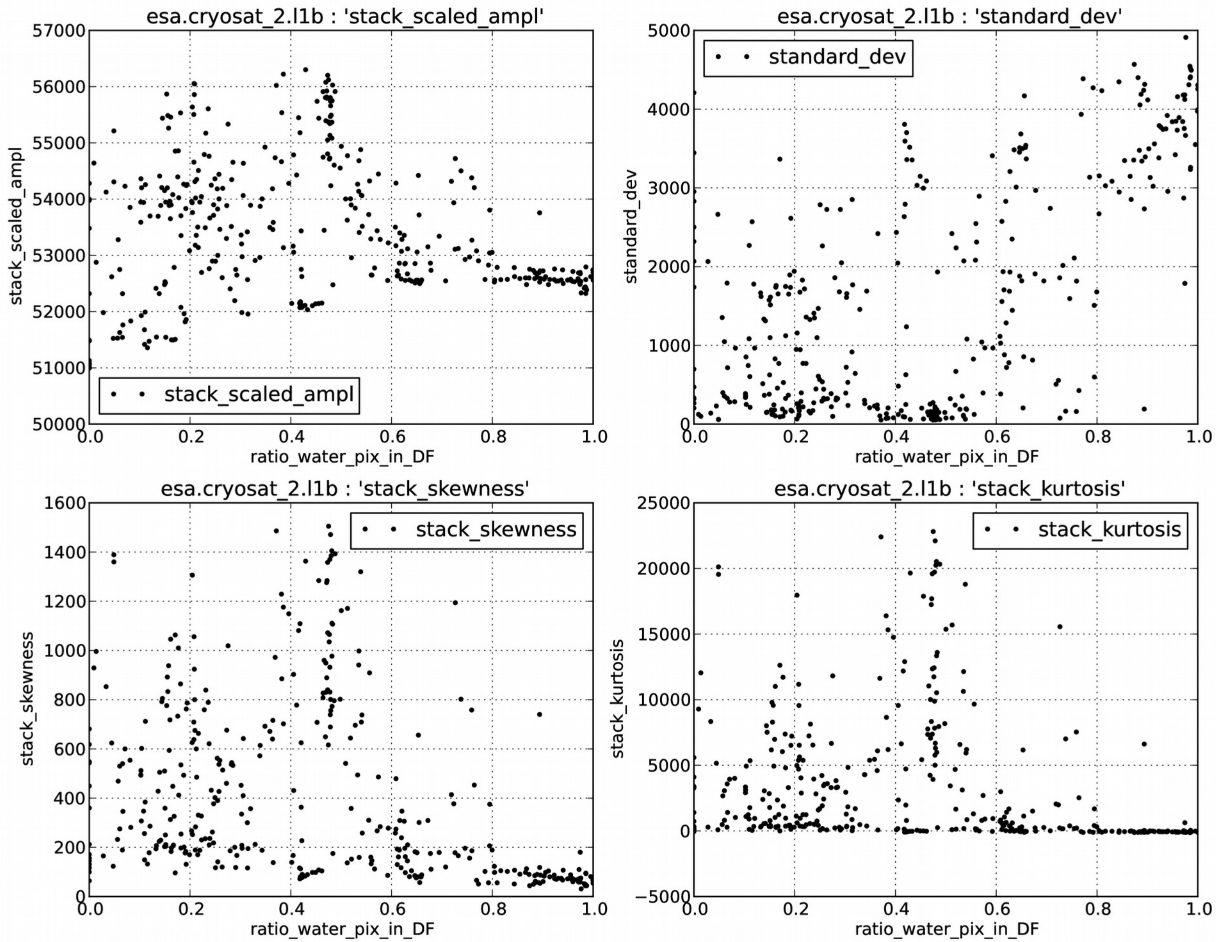

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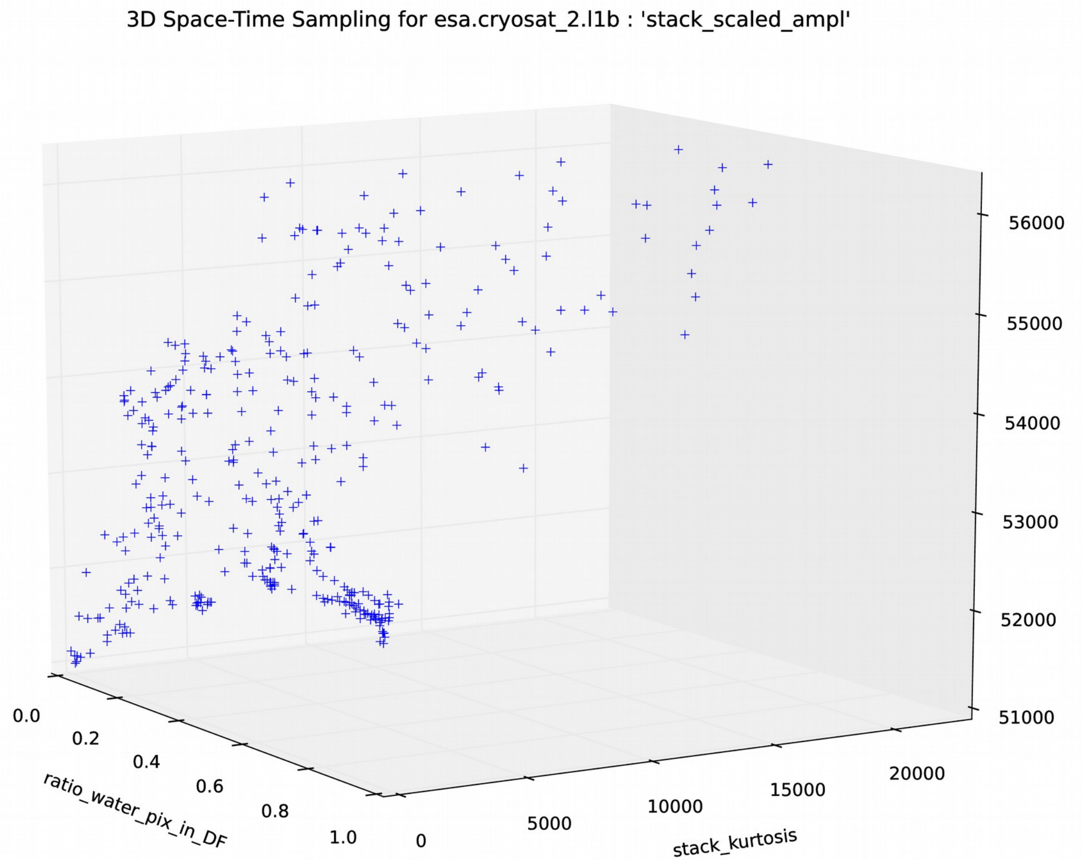
3D plot of **Stack Amplitude**

vs

water ratio, Kurtosis



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3D plot of **Stack Amplitude**

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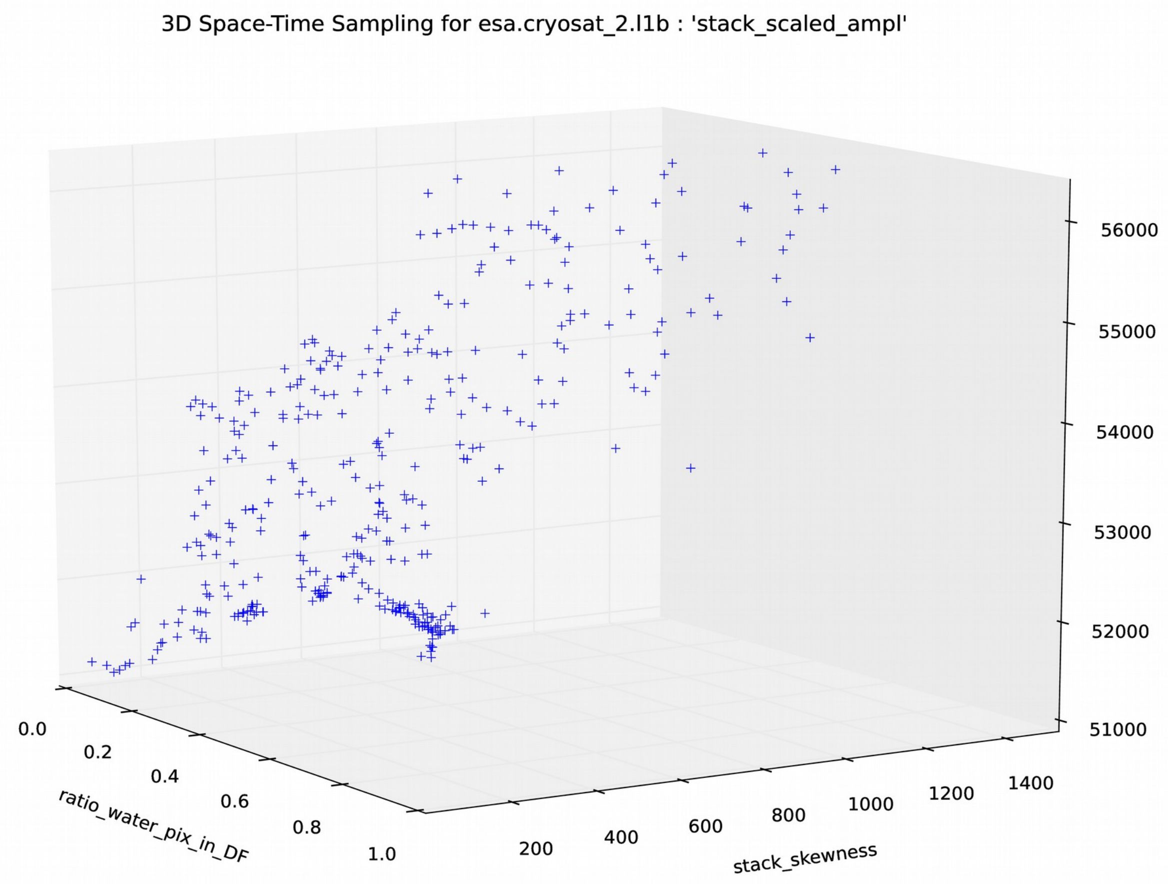

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3D plot of **Stack Amplitude**

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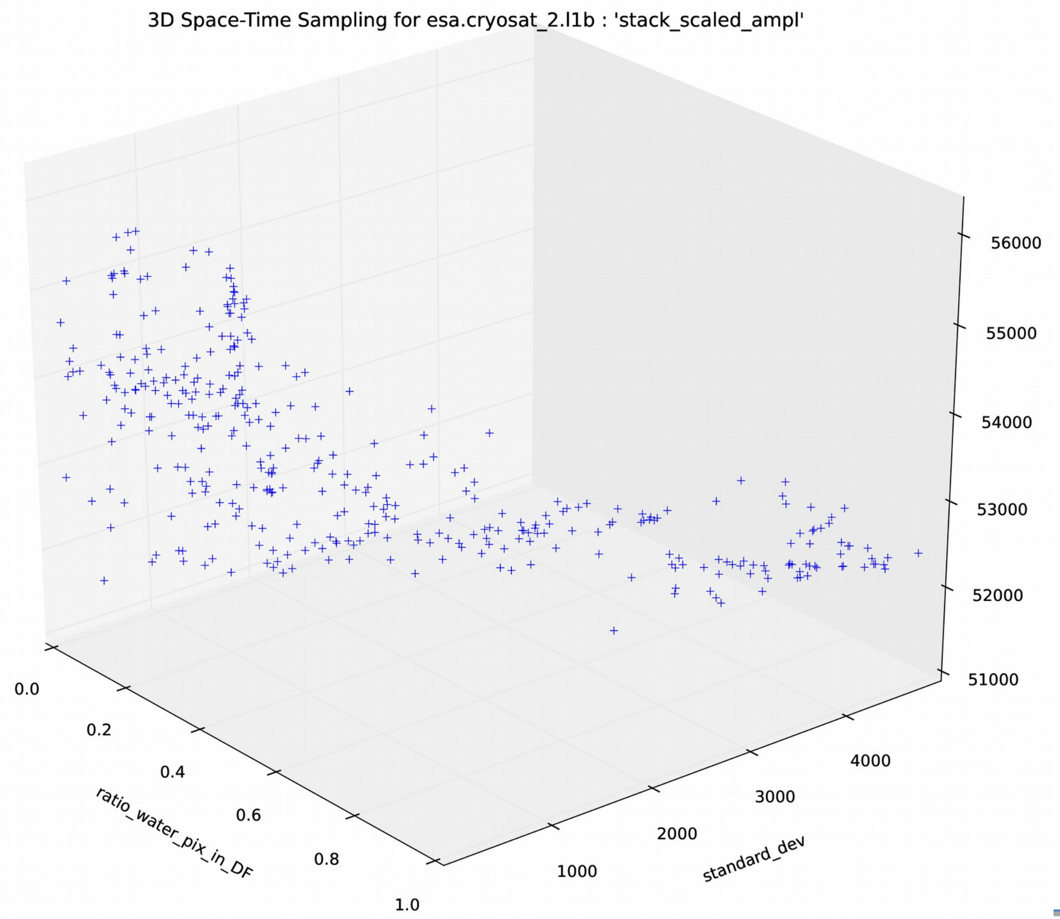
water ratio, StDev



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Perspectives

- Better define classes :

(1) : **water all over the Doppler Footprint** :

{beam_water_pixels / beam_pixels > 90%}

(2) : water mainly at nadir :

{ pulse_water_pixels / pulse_pixels >90%,
pulse_water_pixels / beam_water_pixels > 50%}

(3) : water mainly away from nadir :

{ beam_water_pixels / beam_pixels > 20%,
pulse_water_pixels / beam_water_pixels < 1%}

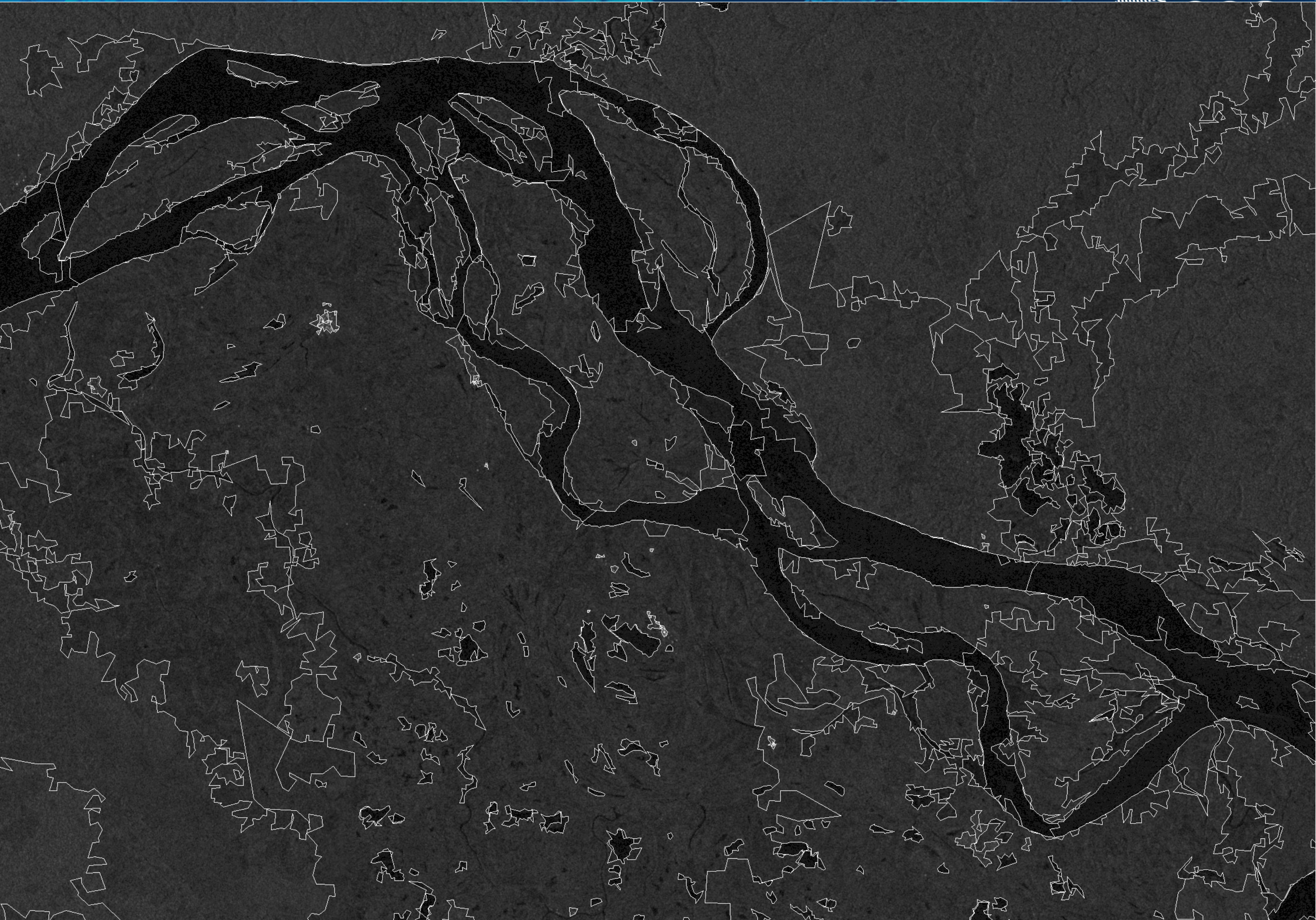
(4) : nearly no water within this beam :

{ beam_water_pixels / beam_pixels < 1%}

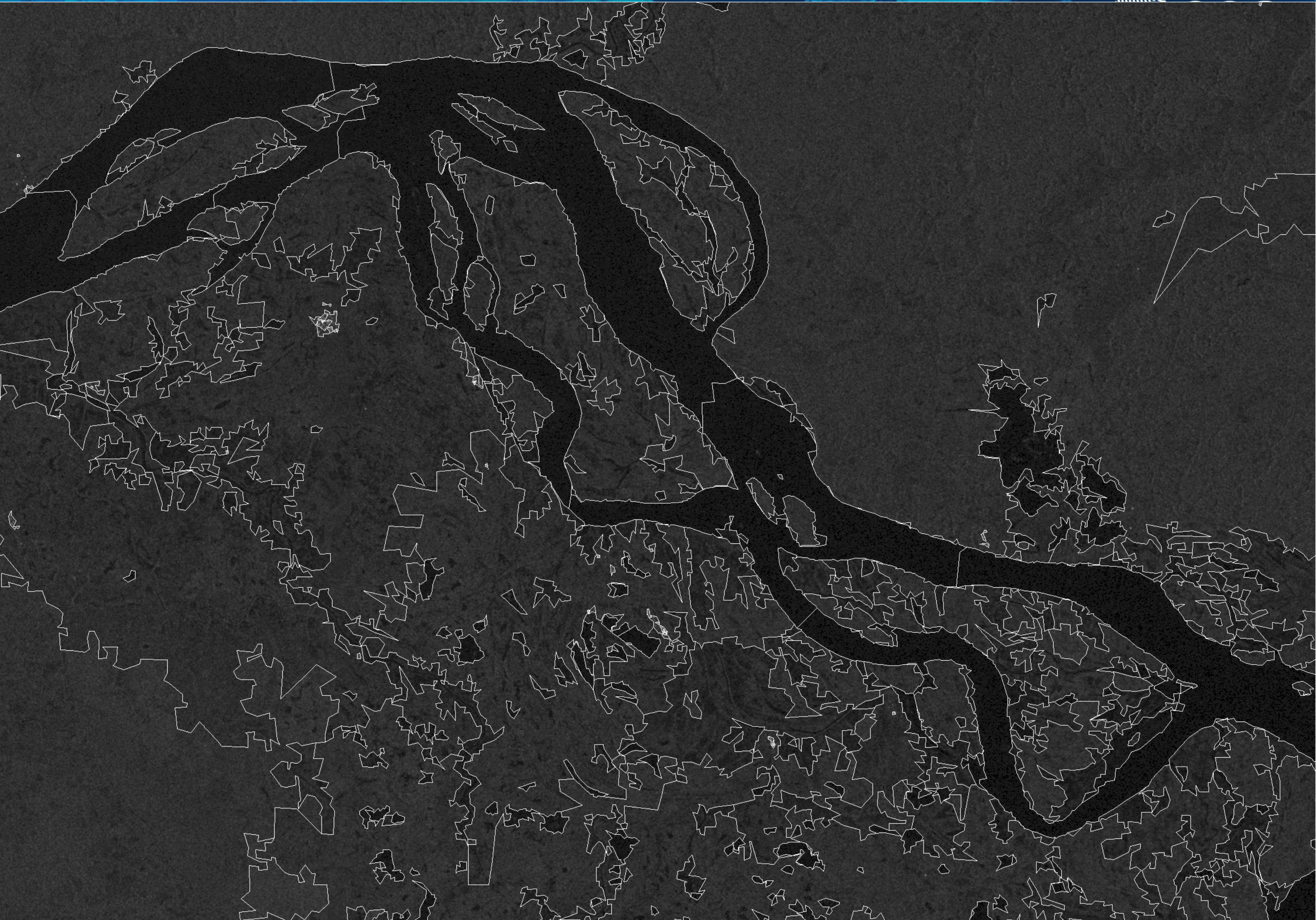
Note

- The whole technique is worth the effort if we can get watermasks in an automated manner on a regular basis.
- **Sentinel 1** offers a **perfect synergy with S3**
- **Automated delineation works** (next slide)
- **Transcription into watermasks** from delineated images **is on the way** at ALONG-TRACK !

Burman River (Sentinel-1, VV polar)



Burman River (Sentinel-1, VV polar)



Conclusions

- We've highlighted the need to adapt to the most recent situation in terms of water in the sensed area
- We've shown a technique to generate Doppler Footprints per record from the L1-B data
- And to intersect it with watermasks
- To compute % of water per record
- We've automated these tasks
- This automated framework changes the paradigm of VS and makes it possible to go further into details and better exploit Cryosat-2 data over inland water
- We are close to combine this with water masks from S1.