A step towards the characterization of SAR Mode Altimetry Data over Inland Waters – SHAPE project

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The SHAPE project: “Sentinel-3 Hydrologic Altimetry Processor prototype”

Funded by ESA through the SEOM Programme Element to prepare for the exploitation of Sentinel-3 data over the inland water domain, with Objectives:

- **Characterise available SAR mode data over inland water.**
- Assess the performances, in Hydrology, of applying the Sentinel-3 IPF to CryoSat-2 data and emulating repeat-orbit Alti-Hydro Products (AHP).
- Analyse weaknesses of the Sentinel-3 IPF at all levels.
- Assess the benefits of assimilating the SAR/RDSAR derived AHP into hydrological models.
- Design innovative techniques to build and/or to refine the L1B-S and assess their impact onto L1B and AHP.
- Improve SAR/RDSAR retracking over river and lakes.
- Provide improved L2 Corrections (tropospheric, geoid) for Sentinel-3 over land and inland water.
- Specify, prototype, test and validate the Sentinel-3 Innovative SAR Processing Chain for Inland Water.
Even with SAR mode, Alti-Hydrology is a difficult topic

- very wide variety of scenarios
- wide across-track integration → 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 …
  - High waters → flooded areas sometimes (outside water masks)
- Existing SARM data (CS2) faces most of these issues

Questions

- How characterize S3 waveforms over inland from Cryosat-2 data ?
- Is geodesic orbit an issue ?
Objectives

New framework with Automated Water Masking

- use updated water masks => synergy with imaging missions (S1)
- L1B → characterization
- L2 → measurements within the new framework

• How to?

- Compute the Doppler Footprints – 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

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

Map for cryosat2.esa.l1b.C : 'ratio_water_pix_in_DF'

Water Fraction

Latitude: -2.60 to -2.90
Longitude: -58.3 to -57.9
Methodology
Methodology

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

Across-track beam size

\[ D = h \cdot \tan(\theta_B + \theta/2) - h \cdot \tan(\theta_B - \theta/2) \]

- the antenna beam width at -3 dB,
- \( \theta_B \) the angle of the central beam direction with respect to the nadir

Along-track beam size

\[ \Delta x = \frac{h \lambda \text{PRF}}{2v} \]

Along-track
Methodology

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

**Across-track beam size**

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

\[ \tau = \frac{1}{B} \quad \text{with } B \quad \text{being the pulse bandwidth}. \]

**Along-track beam size**

\[ \Delta x = \frac{h \cdot \lambda \cdot \text{PRF}}{2 \cdot v \cdot 64} \]
Methodology

- Compute:
  \[
  \% \text{ water} = \frac{\text{footprint}_{\text{water}} \text{ pixels}}{\text{footprint}_{\text{all}} \text{ pixels}}
  \]

- While reading the acquisition parameters for each record and building the Beam-Doppler limited footprints we also access the **beam behaviour parameters** contained in the L1B products.

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

- CryoSat-2 L1-B **Baseline C** data over Amazon (  
- Time Period: 2014-01 to 2015-02:  
- 210 / 289 L1B files (120000 records → 12000 selected records)  
- 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
SWBD based file selection

Raw data selection & Histogram: 115113 records, smallest 2000 records
SWBD based file selection

Histogram Equalisation (random data selection): 2000 records/class
Mean Waveform - All Water fraction classes

- Class 1: 0-20
- Class 2: 20-40
- Class 3: 40-60
- Class 4: 60-80
- Class 5: 80-120

Bin number
Mean WF per Water Fraction

Class 1: Water fraction 0-20 %
Class 2: Water fraction 20-40 %
Class 3: Water fraction 40-60%
Class 4 : Water fraction 60-80 %
Mean WF per Water Fraction

Class 5 : Water fraction 80-100 %
Waveforms per Water Fraction

Class 1: Water fraction 0-20%
Waveforms per Water Fraction

Class 2: Water fraction 20-40%
Waveforms per Water Fraction

Class 3: Water fraction 40-60%
Waveforms per Water Fraction

Class 4: Water fraction 60-80%
Waveforms per Water Fraction

Class 5: Water fraction 80-100%
Range Chronograms

Range-Chronogram - cryosat2.esa.l1b.C (SAR, Ku-band)
Range Chronograms
Results on the RIP

Standard Deviation of the RIP vs Skewness

High Water Fraction $\Rightarrow$ High Standard Deviation and average asymmetry

Angular Response due to Wind, Targets at Far End and ?
Kurtosis of the RIP vs Skewness

High Water Fraction => small asymmetry, small peakiness

Angular Response due to Wind, Targets at Far End and?
Results on the RIP

Standard Deviation of the RIP vs Stack Scaled Amplitude

High Water Fraction $\Rightarrow$ High Standard Deviation and Low Amplitude

Angular Response due to Wind, Targets at Far End and ?
• 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!
• We developed a tool to generate Doppler Footprints per record from the L1-B data
• And to intersect it with watermasks
• We've highlighted the need to use the water fraction information within the Footprints to help analysis
• 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
Perspectives

- More editing: use products quality flags
- Antenna Gain weighted Water Fraction
- Use platform attitude for an improved footprint placement
- Use up to date water masks derived from Sentinel-1
- Seasonal Climatologies to better understand the Relationships between parameters within a Water Fraction Class