Cryo-SeaNice : CryoSat SciEnce-oriented data ANalysis over Sea-ICE areas

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Context

- Monitoring sea ice thickness variations : 1 major objective of the mission : requires a good estimate of freeboard + snow depth.
- Sea-ice remains a challenging subject because of :
  - the very little ground truth
  - Uncertainties on atmospheric conditions :
    - Hurricanes : up to 20-30 degrees variation in few days,
    - snow grains impact radar penetration and backscattering properties,
    - snow load over ice floes impacts the isostatic equilibrium
  - Sea-ice drifts with current and wind forcing
  - Noisy measurements (merged contributions of leads and floes on WF)

⇒ **how to build consistent gridded freeboard products ?**

Project Team with complementary expertises

- Thematic expertise over Arctic sea ice by Elena Zakharova (EZakharova ME)
- Thematic expertise over Antarctic by Frédérique Rémy (LEGOS)
- Sara Fleury + Kevin Guerreiro (LEGOS) : in-depth inspection of altimetric signals, statistical analyses and multi-mission expertise on sea-ice and snow (CTOH database)
- CLS : expertise on geophysical retrackers, freeboard and operational aspects
- ALONG-TRACK : signal and image processing, innovative inspection tools, imagery-altimetry synergy, similarities with alti-hydrology (leads like signatures).

Project Objectives 1/2

- **surface type detection** : understand the signatures and relate them to physical properties of the surface (ice and snow types, snow depth, leads, polynyas…)
- **geophysical retracking** : develop / test physical based retrackers for sea ice (improved space-time consistency : no space-time dependent threshold)
- **continuity issues** :
  - properly retrack Brownian WF (open waters and floes) and specular WF (leads) in a sequence,
  - detect off-nadir hookings (due to leads, polynyas, …)
  - detect and filter out side lobe contamination effects
  - check the existing freeboard products in terms of quality and freeboard continuity especially at the *pack ice - fast ice transitions*

Project Objectives 2/2

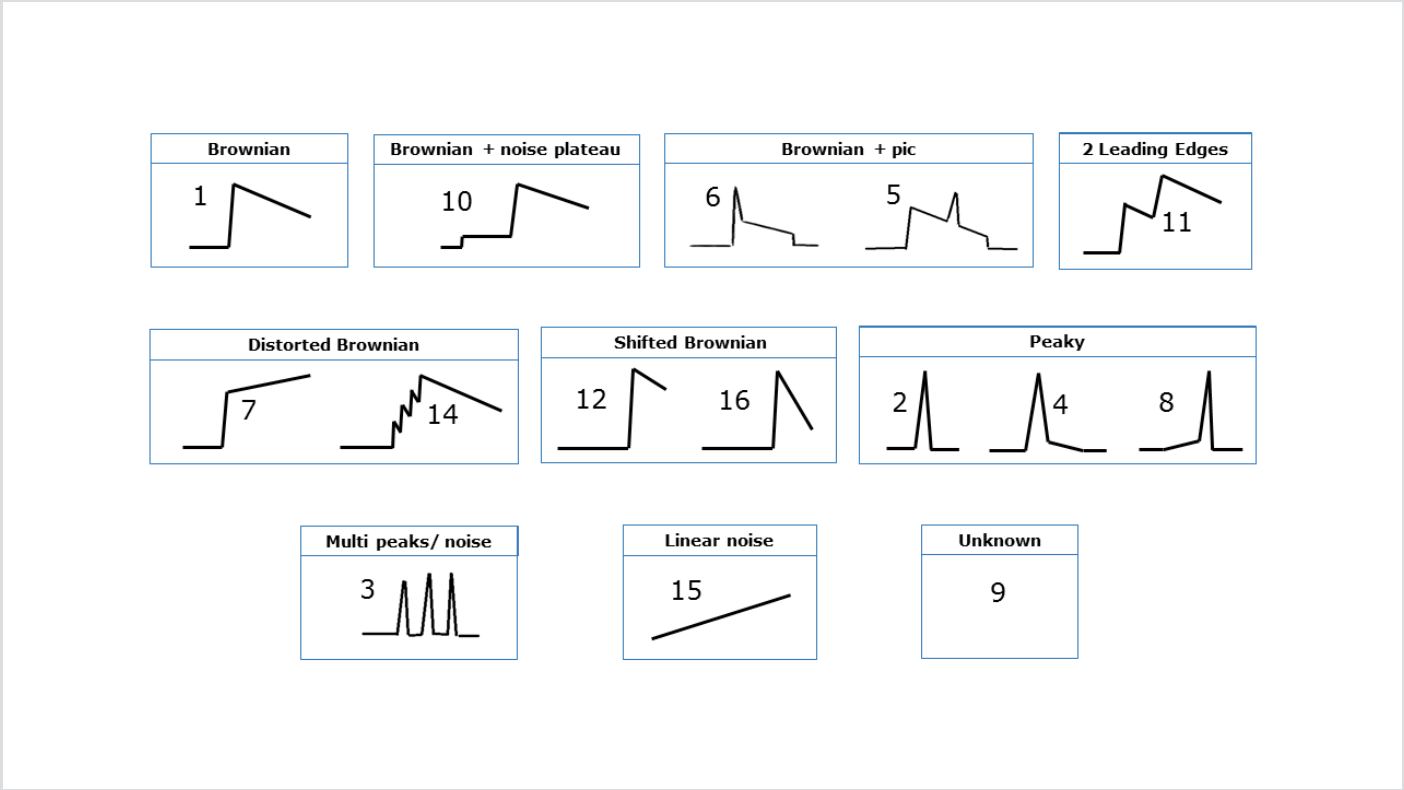
- **snow cover impact assessment** : characterise Ku band penetration onto snow cover AND the associated errors on both retracking outputs and freeboard.
- **analysis (and improvement) of IPF freeboard SNR** : detect whether the noise comes from :
  - surface type classification (undetected snow cover) and retracking
  - intra and inter-track height measurements / gridding methods in the context of fast varying environment.
- **Test new freeboard measurement techniques**
- **exploitation of the SARIN mode** : test existing and/or innovative methods based on SARin
- **Exploration of SARIN swath processing capability over sea ice** : theoretical and experimental aspects.

Project Organisation

- **WP1000 : Scientific Review & Methodology**
  - WP1100 - State-of-the-Art & Data Procurement
  - WP1200 – New Waveform Classification Methods
  - WP1300 - New Retracking Approaches
  - WP1400 - Design of Metrics & Diagnostic Tools
  - WP1500 - Snow Impact onto Freeboard uncertainties
- **WP2000 : WP2000 - Implementation & Assessment of New Algorithms, Metrics and Tools**
  - *similar structure as WP1000*
- **WP3000 - Exploration of SARIN Swath Processing over Sea Ice**
  - WP3100 - Design of a Swath Processing Experiment
  - WP3200 - Implementation of the Swath Processing Test Bench
  - WP3300 - Qualitative Verification of the Swath Experiment
  - WP3400 - Swath Test Data Pack

WP1210 - SAR Waveforms based Classification Approach

CLS classification : different surfaces types from the waveform shapes.



WP1220 – SAR/SARIN Stacks based Classification Approach

New classification throught the Stacks and Waveforms Analysis Tool, a tool to simultaneously :

- view series of aligned waveforms (Range Chronograms) and understand the scene content evolution in the occurrence of :
  - Leads though hyperbolic signatures when a lead extends over several 20Hz records
  - antenna side-lobes effect in the presence of strong reflectors outside the main lobe (polynyas, open sea, ...),
- view the SAR/SARIN Stacks, RIP and Waveforms at the current position within the RC,
- view the Sigma0 value and the values of the beam behaviour parameters associated to the current RIP (Beam Behaviour Parameter),
- view the evolution of the AGC or the maximum power along and beyond the current view of the RC,
- superimpose the retrackers outputs onto the RC.
- Build classes from the signals at current record (WF, Stack, RIP, Beam Behaviour Parameter, Sigma0, lat, lon, date, track number, record number).

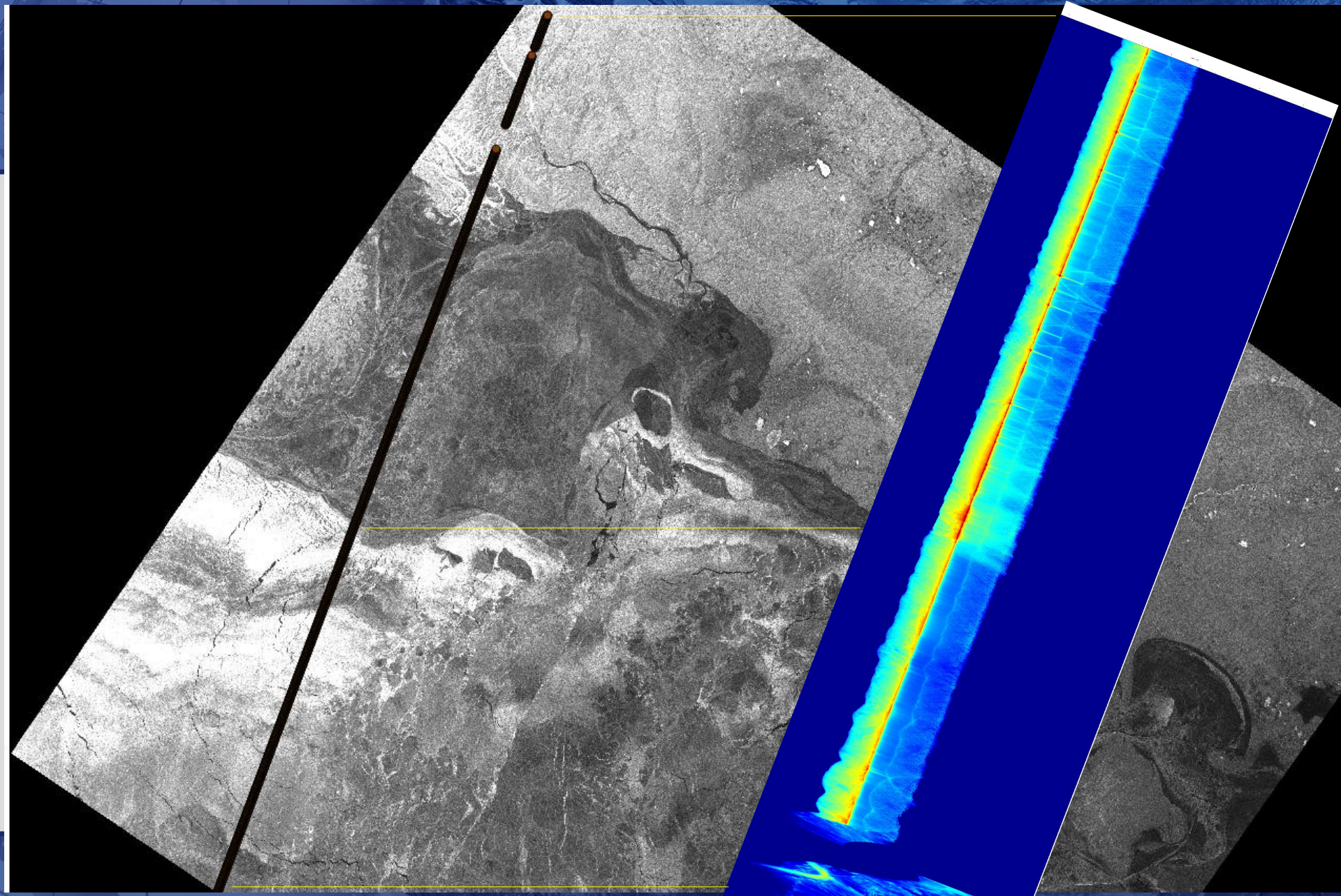
WP2220 – SAR/SARIN Stacks based Classification Approach

Potential benefits of analysing Range Chronograms jointly with imagery

Example (identified by Sara Fleury LEGOS) with :

- A Range Chronogram from GPOD SARvatore L1B reprocessing
  - CS_LTA__SIR1SAR_FR_20150216**T181026**_20150216T181711_C001.kml

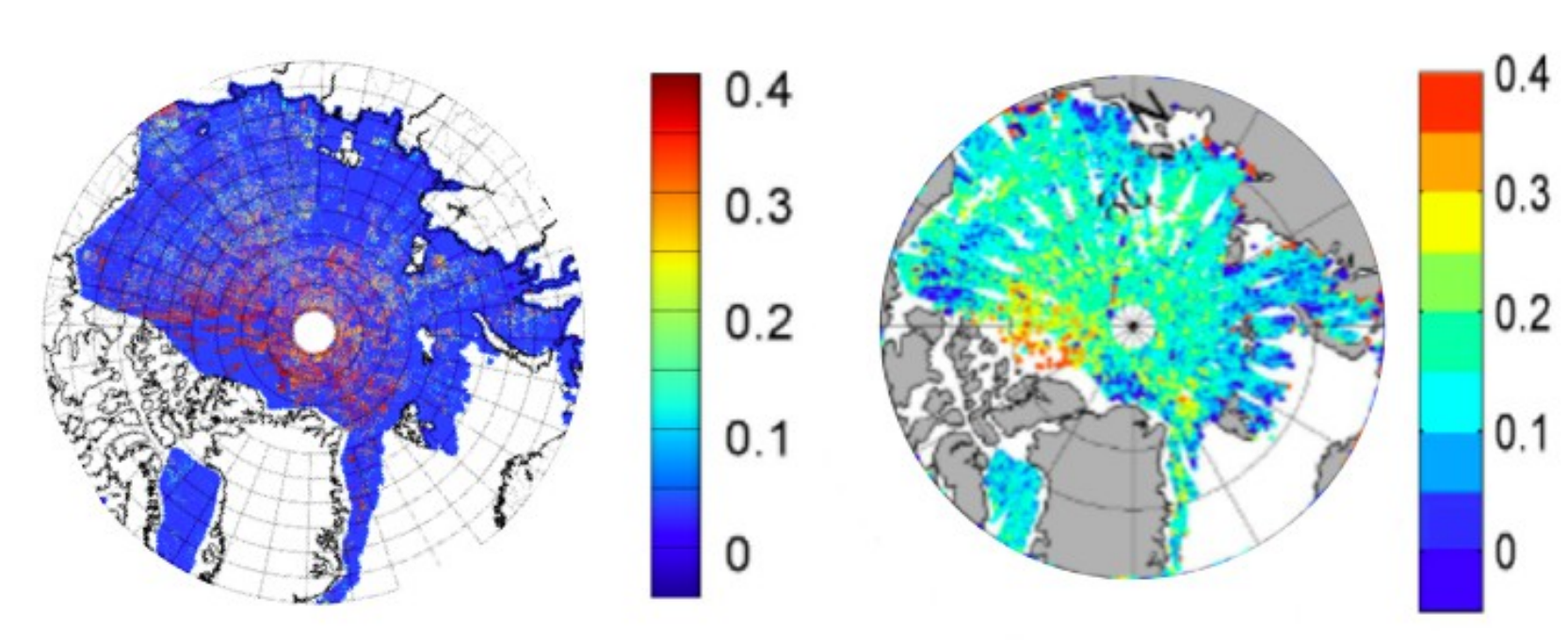
- A Sentinel 1A image
  - S1A_EW_GRDM_1SDH_20150216**T230806**_20150216T230906_004655_005BEA_3238



WP1410 - Statistical Characterisation of CryoSat Operational Freeboard Products

(Initial Investigations)

Along-track freeboard values (late March 2015) projected on a polar stereographic map.



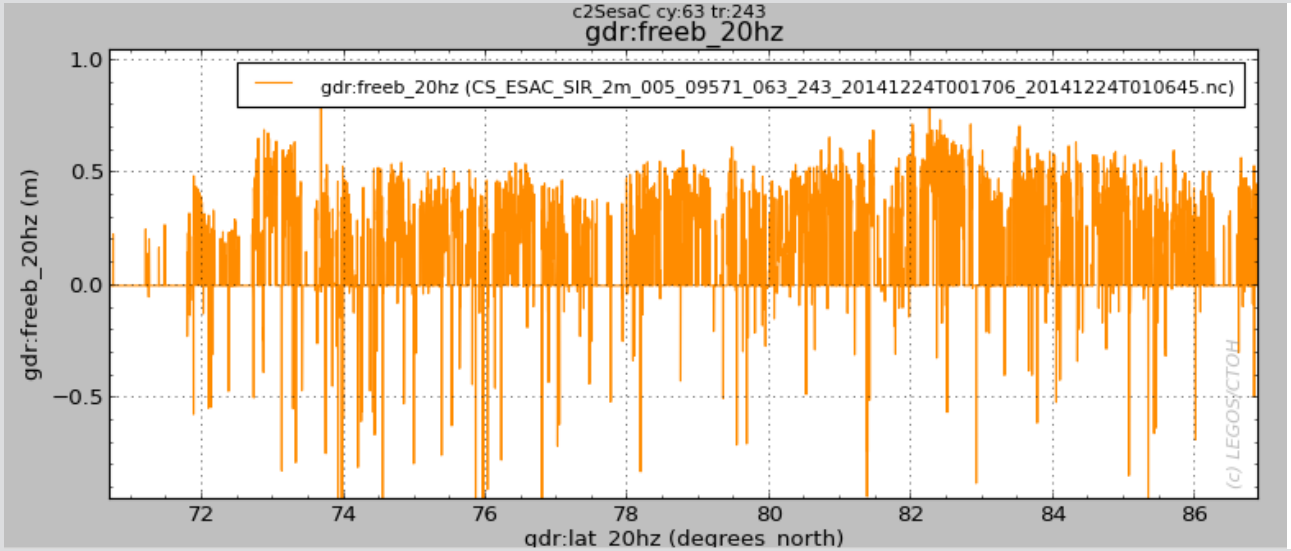
CryoSat-2 Baseline C

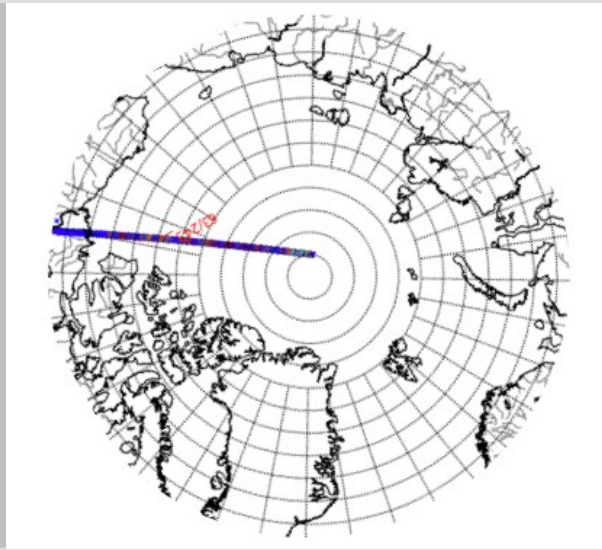
G-POD/LEGOS (Dinardo/Fleury+Zakharova).

WP1410 - Statistical Characterisation of CryoSat Operational Freeboard Products (Initial Investigations)

along-track freeboard → ranges values impacted by

- off-nadir measurements !
- Side-lobes ?





WP1420 – 2420 - CryoSat Freeboard Products Intercomparison

Inter-Comparison of 6 independent freeboard products

- ESA Baseline C freeboard product
- 2 new freeboard (CLS, GPOD/LEGOS) from this project (new surface type detection, new retrackers, editing, new freeboard measurement & interpolation & gridding)
- NASA/NSIDC dans les freeboards qu'on va comparer (avec AWI)
- AWI freeboard products ?
- SARIN freeboard ?

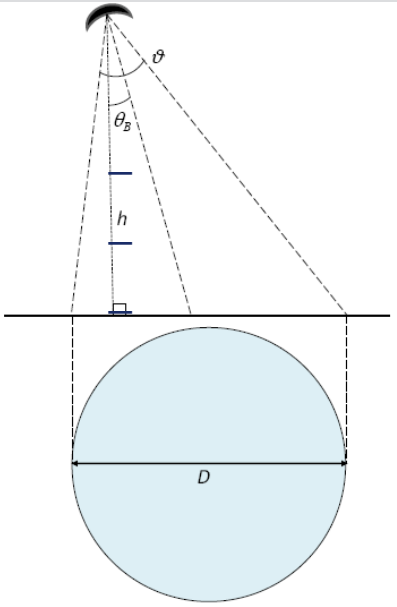
Statistical comparisons on gridded map

Direct along-track comparison methodologies

Comparison based on the multi-sources sparse reference in situ data
CRREL Ice mass balance buoys, NASA Operation Ice Bridge campaigns (OIB, https://nsidc.org/data/icebridge/)

WP1440 - Footprint Content Analysis Tool (FACT) – Alti-Imagery Synergy

- superimpose CryoSat-2 records data (centres of the Doppler-Beam limited footprints) on to a codated and collocated image,
- superimpose Beam-Doppler limited footprint computed, at each record, from the satellite's coordinates and platform parameters



Across-track beam size

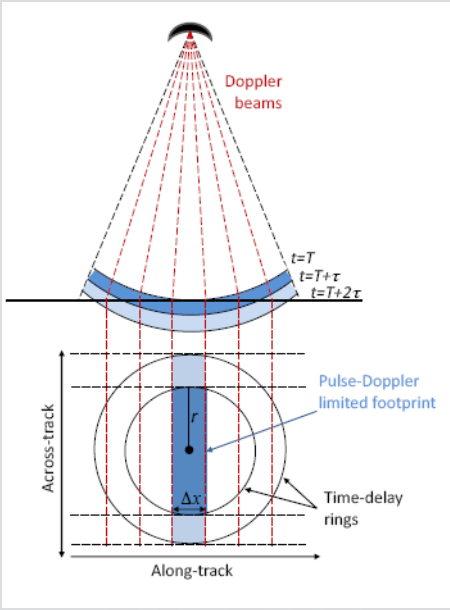
$$D = h \cdot \tan(\theta_B + \vartheta/2) - h \cdot \tan(\theta_B - \vartheta/2)$$

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

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



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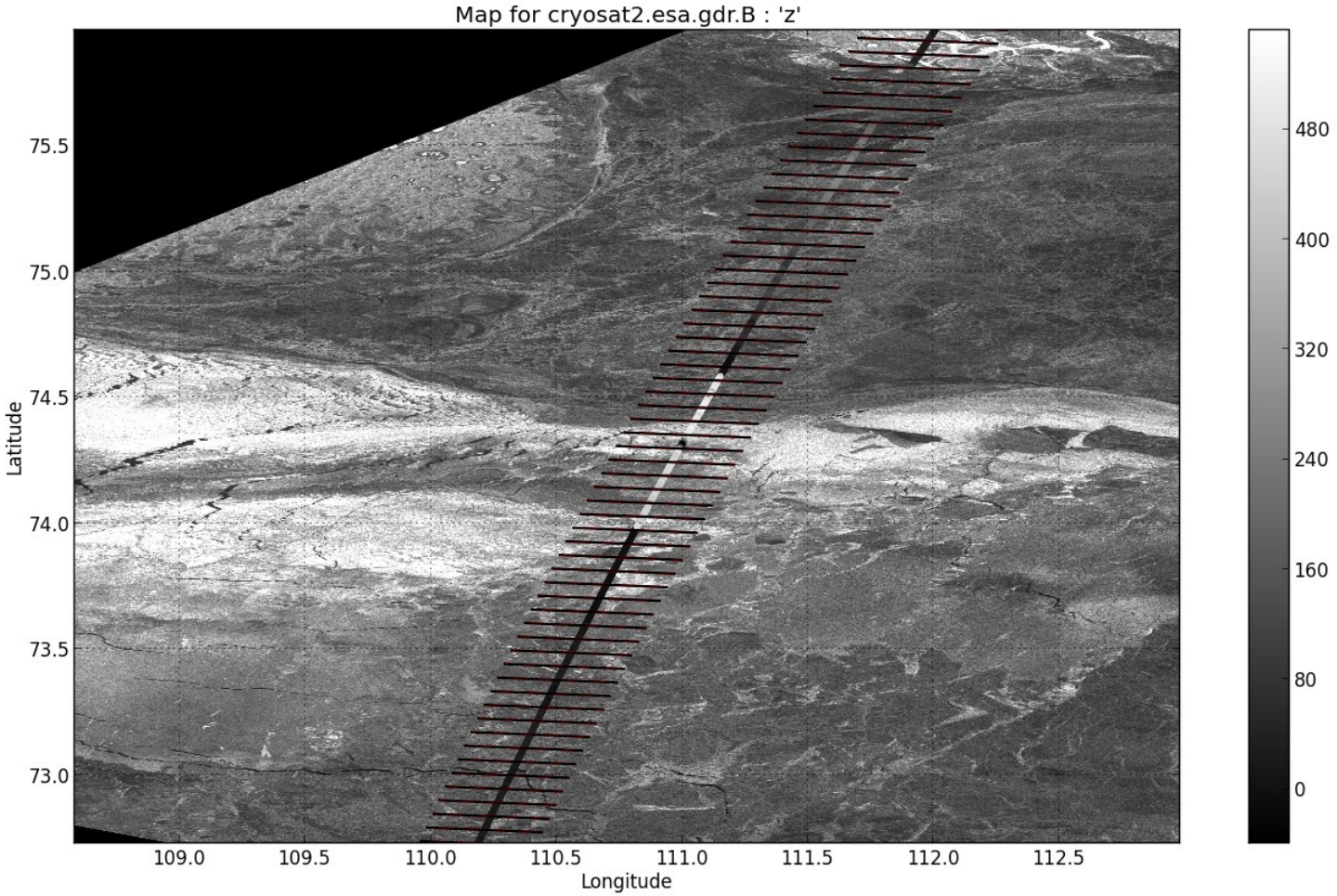

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