Cryo-SEANice

CryoSat SciEnce-oriented data ANalysis over Sea-ICE areas

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Project Overview

Context

- Monitoring sea ice thickness variations (a major objective of the CryoSat-2 mission) → need for a good estimate of freeboard + snow depth.
- Sea-ice remains a challenging subject because of :
  - the very little ground truth,
  - Hurricanes : up to 20-30 °C variation in few days,
  - snow grains size, salinity and humidity 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),

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 & Freeboard uncertainties

WP2000 : Implementation & Assessment of New Algorithms, Metrics and Tools
(Similar structure as WP1000 but on implementation and Validation)

WP3000 : Exploration of SARIN Swath Processing over Sea Ice
- WP3100 - Swath Processing Experiment Design
- WP3200 - Swath Processing Test Bench
- WP3300 - Swath Experiment Qualitative Verif.
- WP3400 - Swath Test Data Pack

Objectives

- **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
- **Snow cover impact assessment** : characterize 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**
- **Exploit SARIN mode** : test existing and/or innovative methods based on SARin
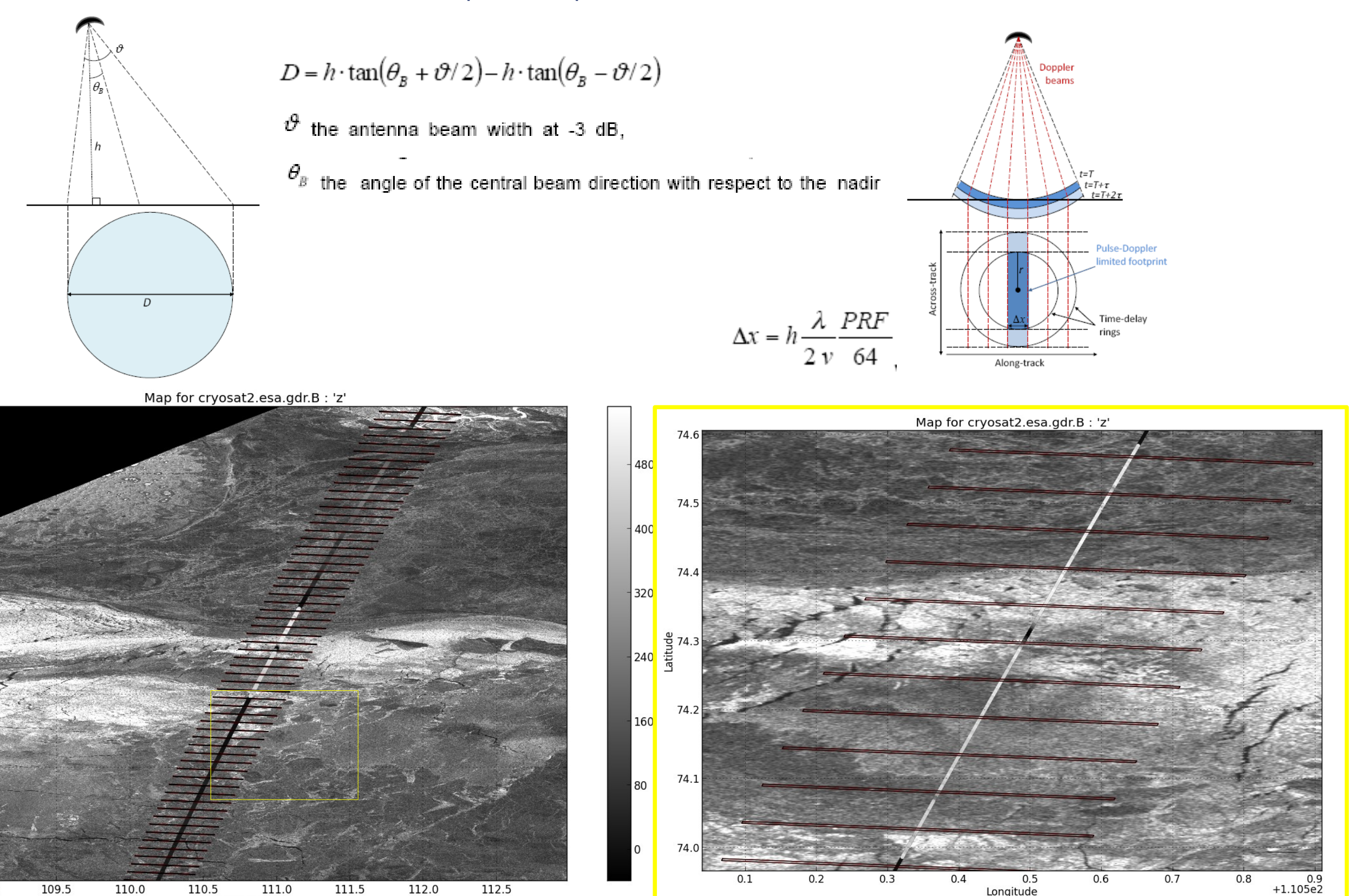- **Explore SARIN swath processing over sea-ice** : theoretical and experimental aspects.

Project Logic
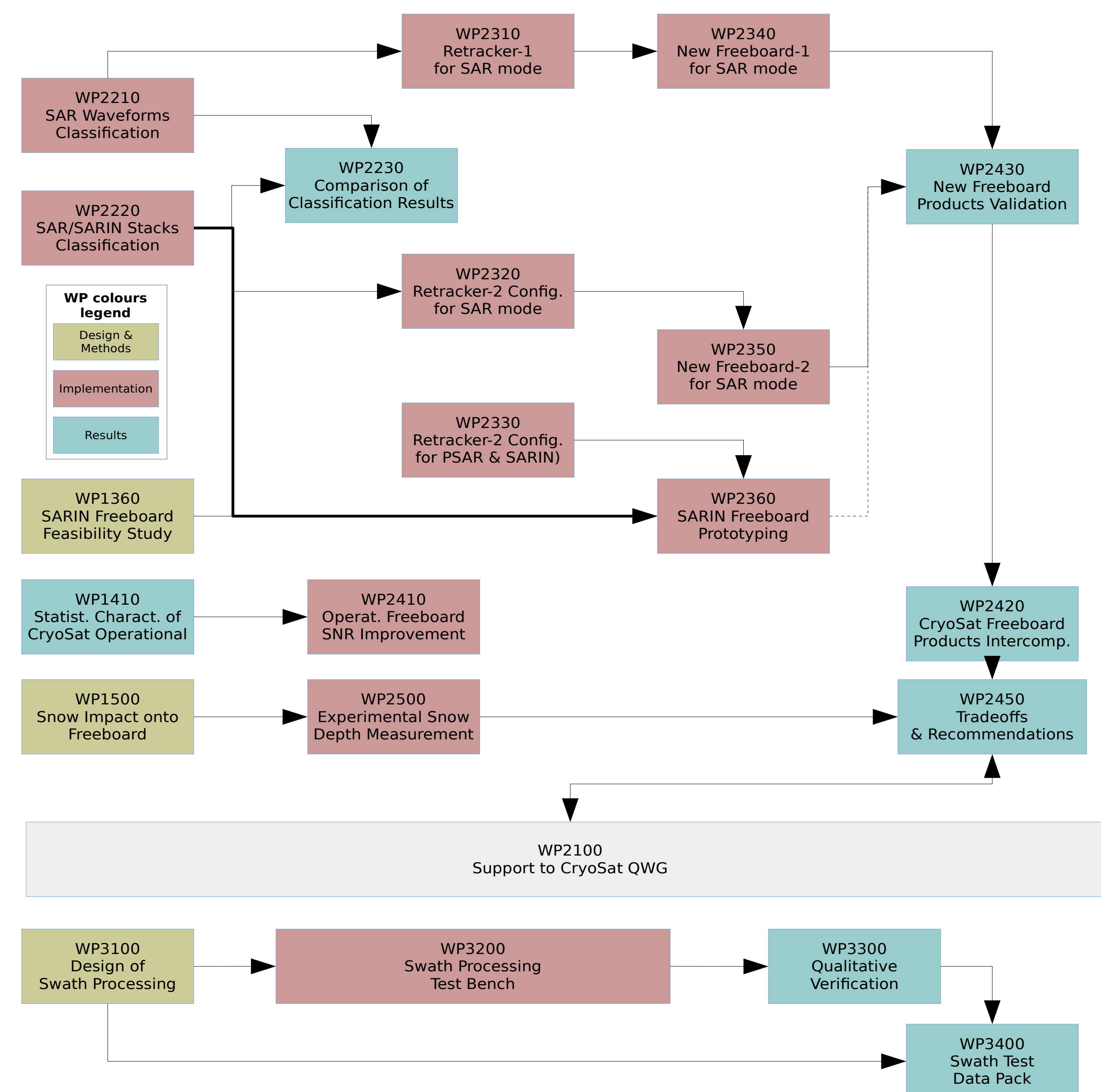
Altimetry-Imagery synergy

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

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

ϑ the antenna beam width at -3 dB,

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

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

Surface Identification

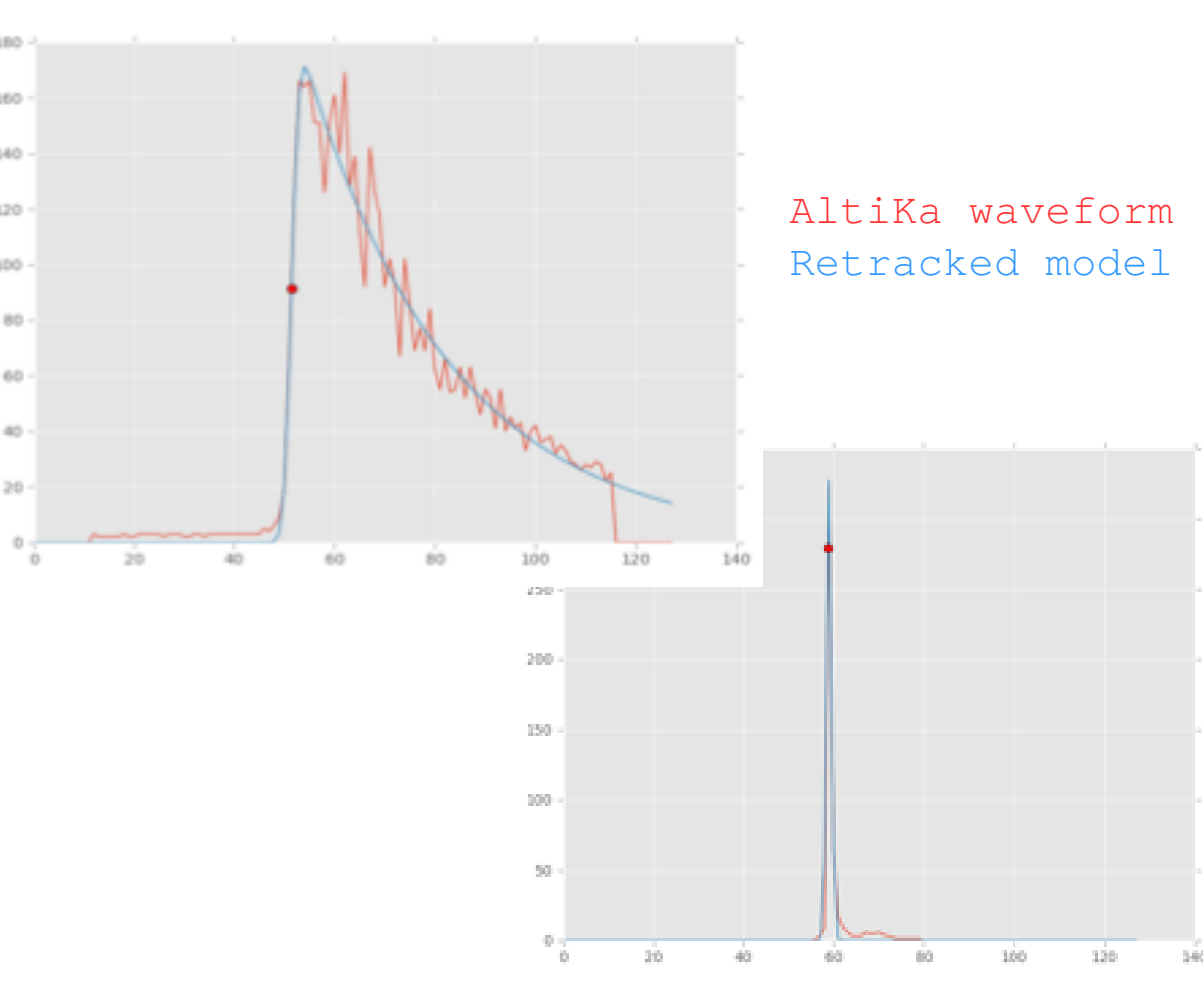### Currently, in the CryoSat-2 ground segment:
- Ice floes and leads are discriminated using a pulse peakiness threshold.

We propose:
- To develop and test new waveform classification based on a Neural Network algorithm.
- Technique already developed and successfully validated on LRM measurements (SARAL/AltiKa, ENVISAT/RA-2) and extended to CryoSat-2 SAR waveforms.
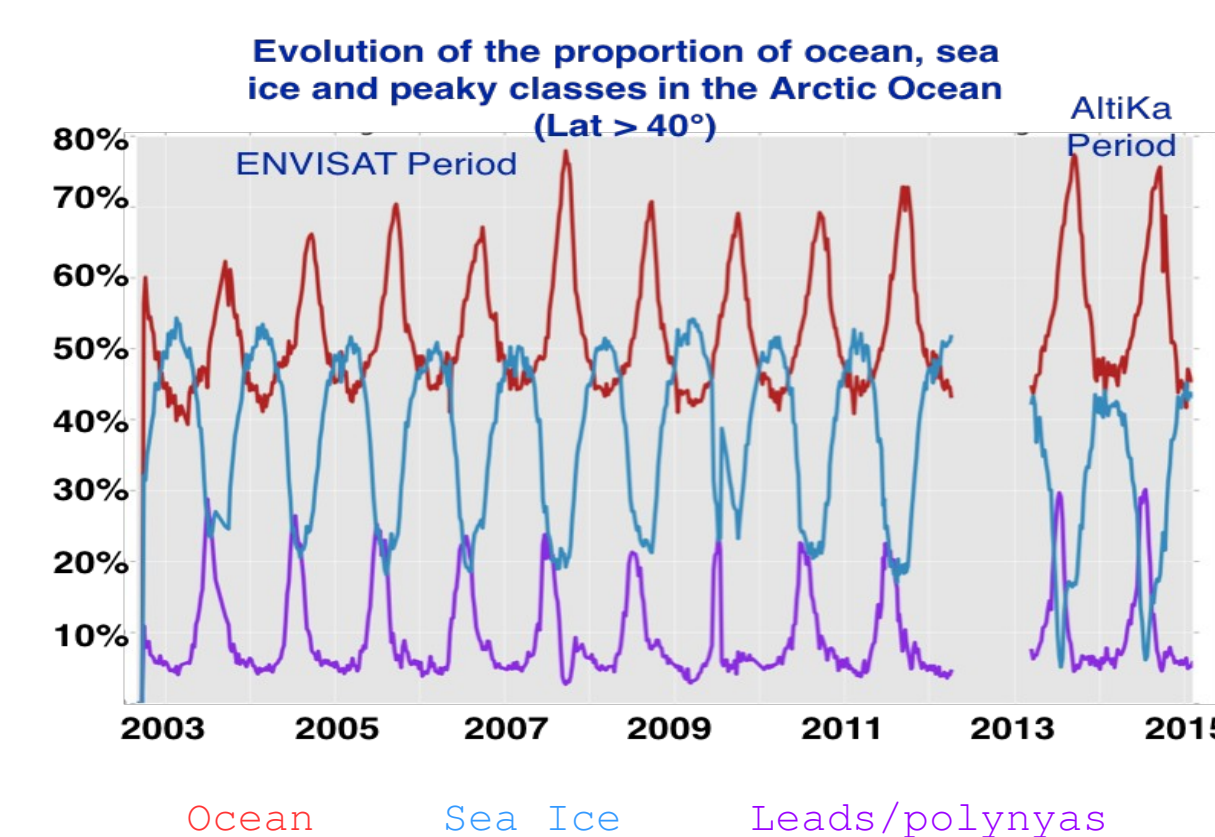
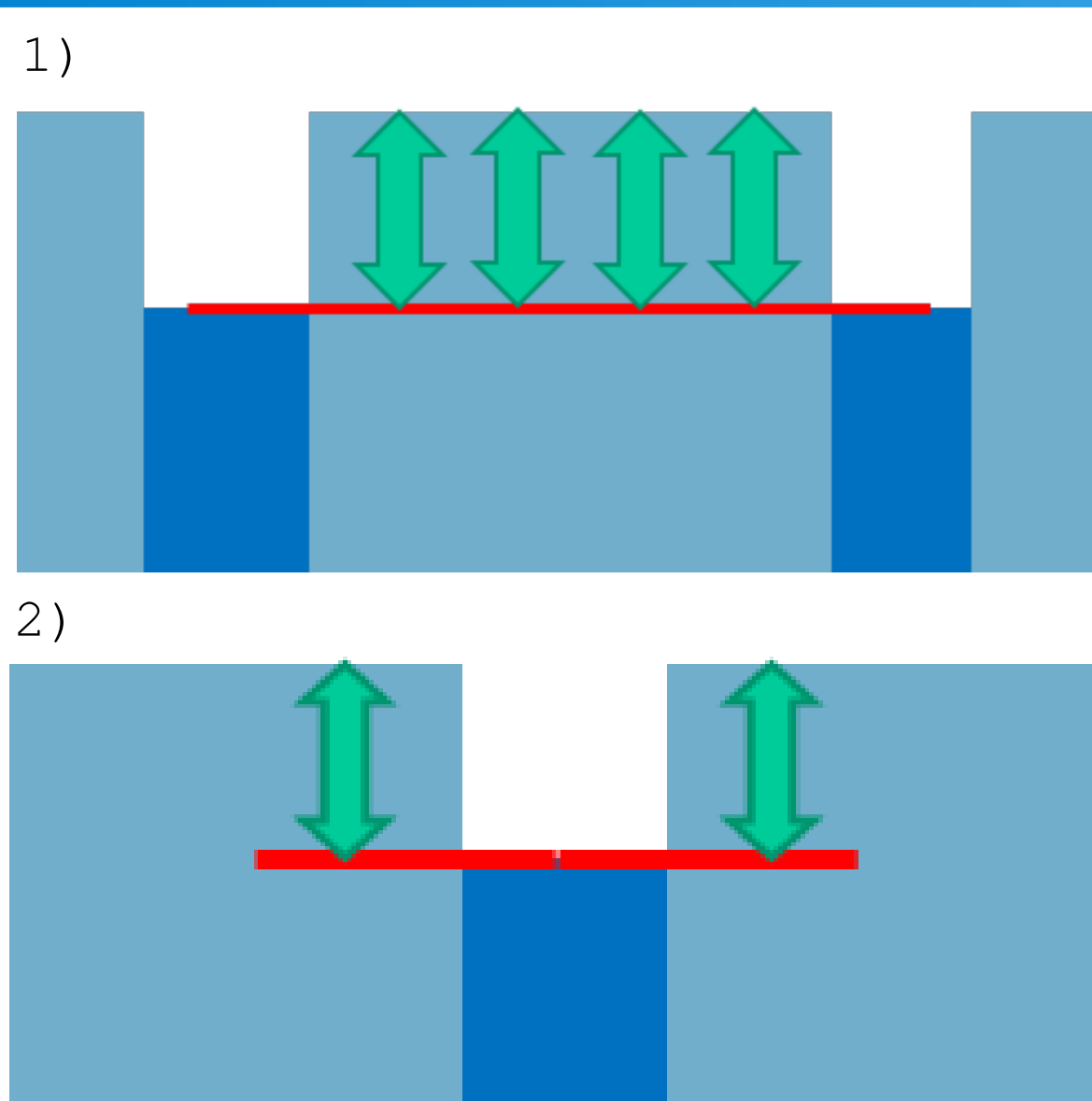# New Retracking Algorithms

Currently, in the CryoSat-2 ground segment:
- Sea ice and lead waveforms are processed using 2 different empirical retrackers without any physical assumptions.

We propose:
- A new adaptive retracker has been developed to process both leads and sea ice LRM waveforms using a physical model (including the surface mean square slope). The validation has shown very promising results on SARAL and RA-2 data.
- The same approach is developed for CryoSat-2 SAR waveforms and will be validated in the frame of this project

Impact of the Snow Layer

The snow cover over Arctic sea-ice is still poorly known, but it has an important impact on the Sea Ice Thickness (SIT) retrieval from altimetric measurements for 2 mains reasons: (1) the load of the snow reduces the FreeBoard (FB) without reducing the SIT, (2) the radar wave slows down in the snow layer, which, without correction, extends the range and reduces the height. These 2 effects are cumulative and induce an error proportional to the Snow Depth (SD) as shown in the SIT equation below.

For a typical example of a FB of 27cm and a SD of 35cm, the error may reach 60% of the SIT. One objective of this project is to estimate the SD using different frequencies of satellite altimeters.

New Freeboard Computation Strategy

Currently, in the CryoSat-2 ground segment:
- In the CryoSat-2 ground processing, the freeboard is computed along-track by linearly interpolating lead water level under ice floe level on tens of kilometers.

We propose:
- We propose a new approach performing the interpolation around sea ice leads in order to reduce interpolation errors. The results will be compared to those of the classical method and to in situ measurements.

$$SIT = \frac{\rho_w}{\rho_w - \rho_i} FB + \frac{\rho_s}{\rho_w - \rho_i} SD + \frac{(1 - c_s/c)\rho_w}{\rho_w - \rho_i} SD$$

Snow Load correction

Snow Speed Propagation correction