Sentinel-3 Performance improvement for ICE sheets

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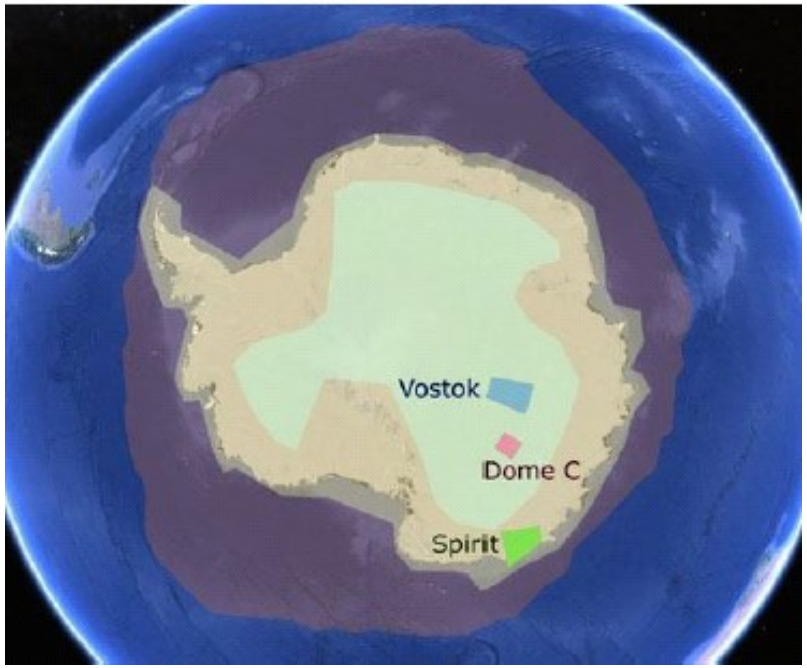
Aim

To develop and evaluate **novel Synthetic Aperture Radar (SAR) altimetry processing methods over ice sheets**, to contribute to the future exploitation of Sentinel-3.

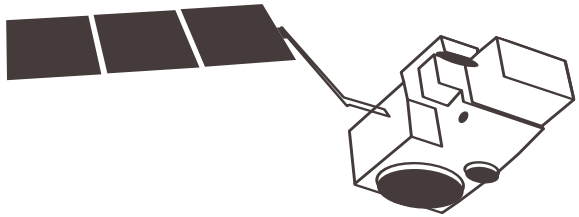


Dedicated SAR patches acquired by CryoSat-2 in 2014.

Objectives

Assess and develop **SAR retracking** for ice sheets.

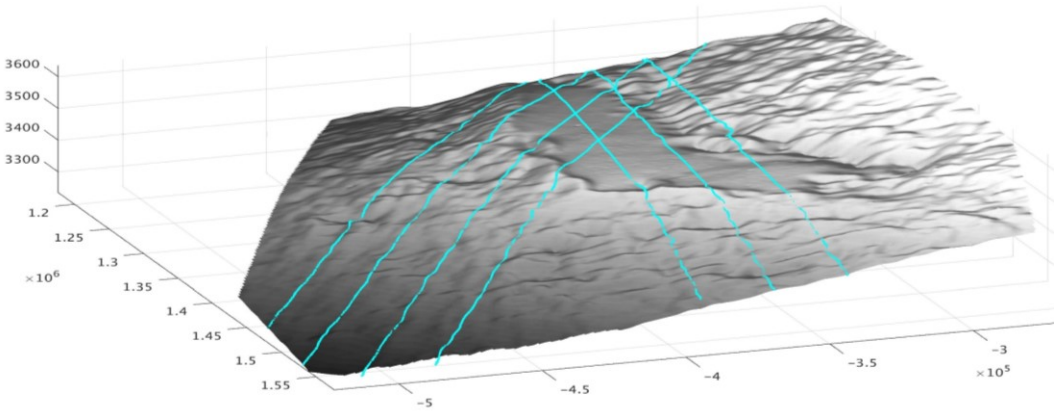
Assess and improve L1B **Delay-Doppler altimeter processing** for ice sheets

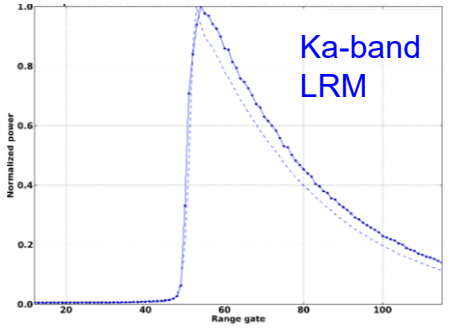


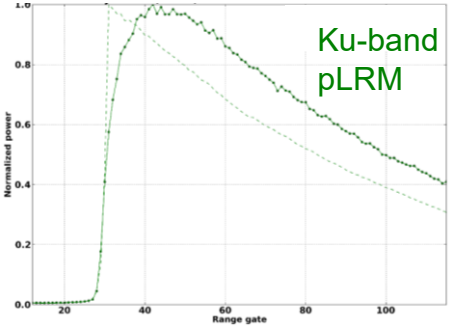
Assess the impact on SAR altimeter measurements of **radar wave interaction with the snowpack**.

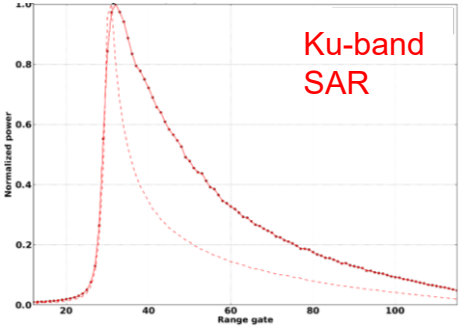
Evaluate the performance of **SAR altimetry relative to conventional pulse limited altimetry**.

Operating modes & frequencies









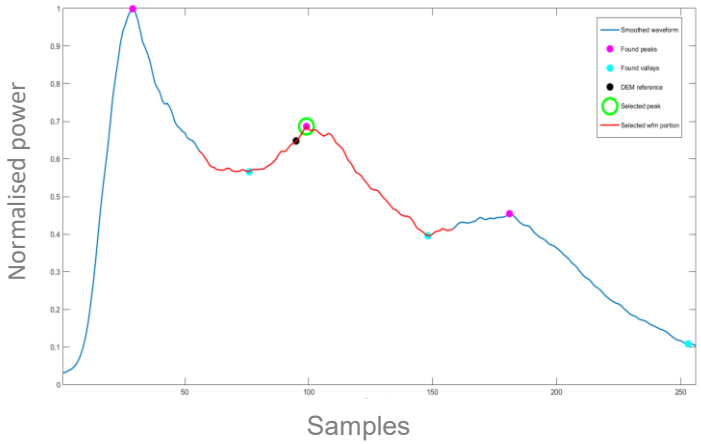
[Left panel] CryoSat-2 SAR tracks across the smooth Lake Vostok site, East Antarctica.

[Right panels] Comparison of ocean (dashed lines) and ice sheet (solid lines) waveforms acquired at Ku and Ka, and in different operating modes over Lake Vostok.

The plotted waveforms are 4 second averages.
Note neither of the Ka LRM or Ku SAR leading edges show apparent sensitivity to volume scattering.

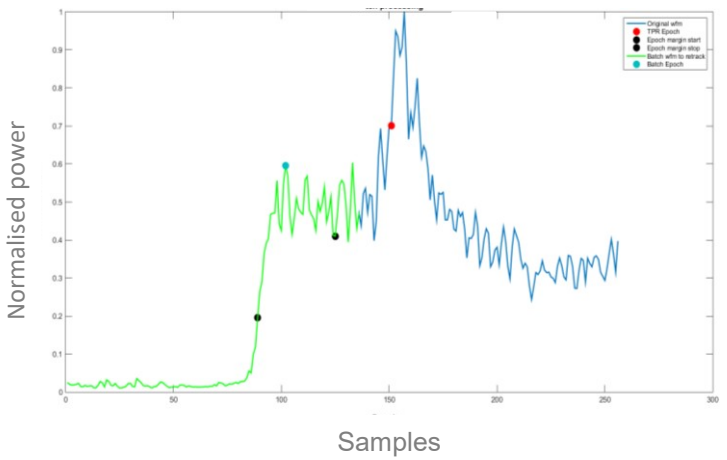
Pre-retracking Innovation

DEM pre-retracking module



Auxiliary DEM (black dot) is used to identify the peak (red) that corresponds to the nadir reflection within a complex waveform.

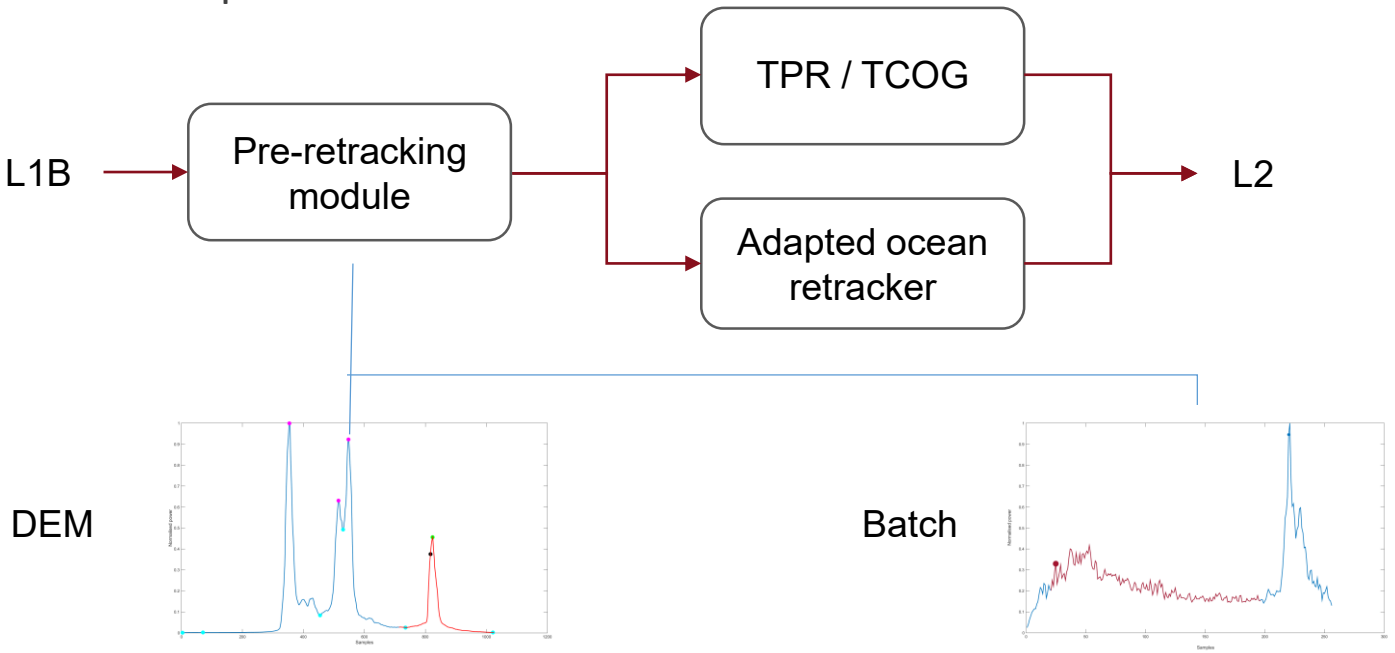
Batch pre-retracking module



Batch processing uses the history of previous waveforms to maintain consistency in the peak selection, for complex multi-peaked waveforms.

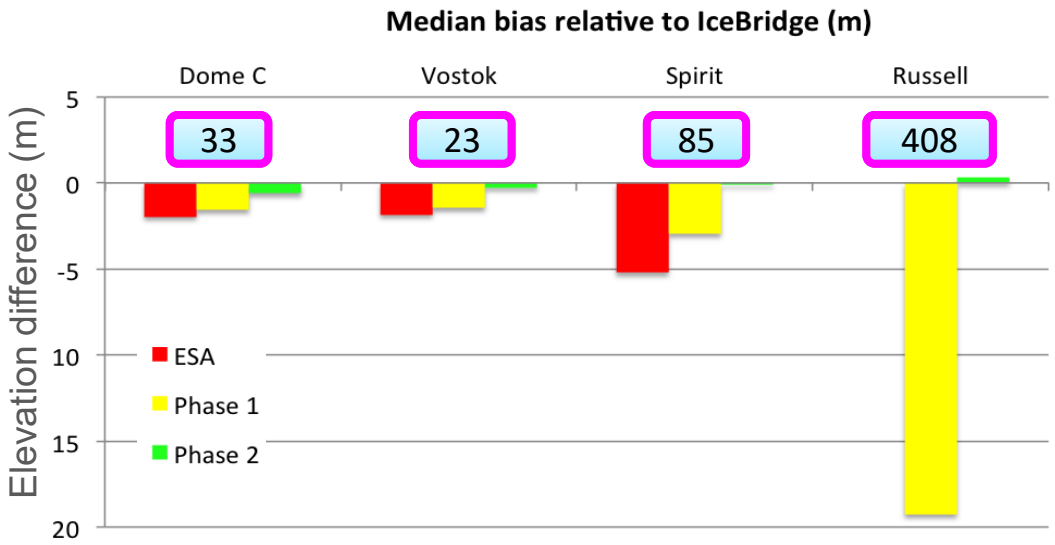
Development of novel pre-retracking modules

- '**DEM**' and '**Batch**' pre-retracking modules were developed, and added into the L2 processing chain.
- These modules were designed to improve the performance of SAR altimetry in ice margin regions, where complex topography can produce multipeak waveforms.
- The 'DEM' module aimed to identify the nadir reflection within multi-peaked waveforms. The 'Batch' module was designed to ensure along-track consistency in the waveform peak that was tracked.



SPICE Products Performance Improvement

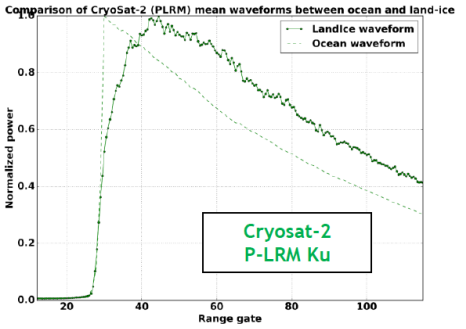
- Validation of SPICE products showed that the optimal processing configuration for SAR used the **DEM pre-retracking** module.
- 68% improvement in the median bias (compared to the baseline processing).
- 39% improvement in the median absolute deviation from the median (compared to the baseline processing).
- The Level-1 Delay-doppler processing options made less difference, although using a zero-padding factor of 4 offered a slight improvement.
- SAR consistently outperformed pLRM, particularly at coastal sites where topography is complex.

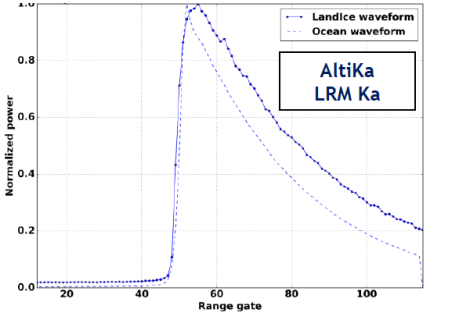


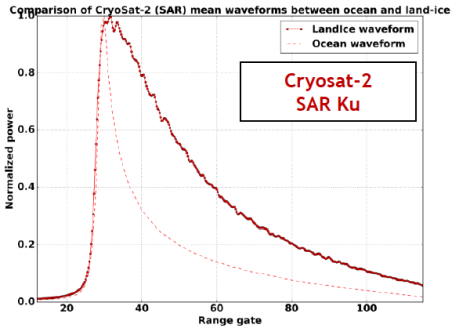
Radar Wave Interaction with the Snowpack

- **Volume scattering effect on the waveform shape from CryoSat-2 / AltiKa:**
  - **In P-LRM Ku band:** waveform leading edge is significantly distorted by the volume scattering effect.
  - **In LRM Ka band:** the waveform is weakly impacted by volume scattering. Although the snowpack still modifies slightly the waveform shape.
  - **In SAR Ku band:** thanks to the reduced SAR footprint, the waveform leading edge remains relatively peaky, and is therefore less sensitive to volume scattering, compared to PLRM.

- Over lake Vostok, from austral spring acquisitions, surface elevation estimated from **CryoSat-2 & AltiKa** are aligned when the epoch is positioned at the following thresholds on the waveform's leading edge:
  - **~ 25%** of maximum power in **P-LRM Ku** band
  - **~ 80%** of maximum power in **SAR Ku** band
  - **~ 50%** of maximum power in **LRM Ka** band







SPICE Publication and Outreach

- The results of the SPICE project have been published in Presentations at 16 international conferences and in:

McMillan, M., Muir, A., Shepherd, A., Escolà, R., Roca, M., Aublanc, J., Thibaut, P., Restano, M., Ambrozio, A., Benveniste, J. (2019). **Sentinel-3 Delay-Doppler altimetry over Antarctica**. **The Cryosphere**, 13(2), 709–722. https://doi.org/10.5194/tc-13-709-2019

- The **first paper using Sentinel-3 data over ice sheets!** **~ 1400 views or downloads to date.**

The article has been promoted with several on-line stories:

https://**eo4society.esa.int**/2019/03/07/sentinel-3-keeps-watch-on-antarctic-ice-loss/
https://**sentinels.copernicus.eu**/web/sentinel/news/-/article/copernicus-sentinel-3-provides-new-measurements-of-antarctic-ice-sheet
https://www.**lancaster.ac.uk**/news/new-satellite-keeps-close-watch-on-antarctic-ice-loss
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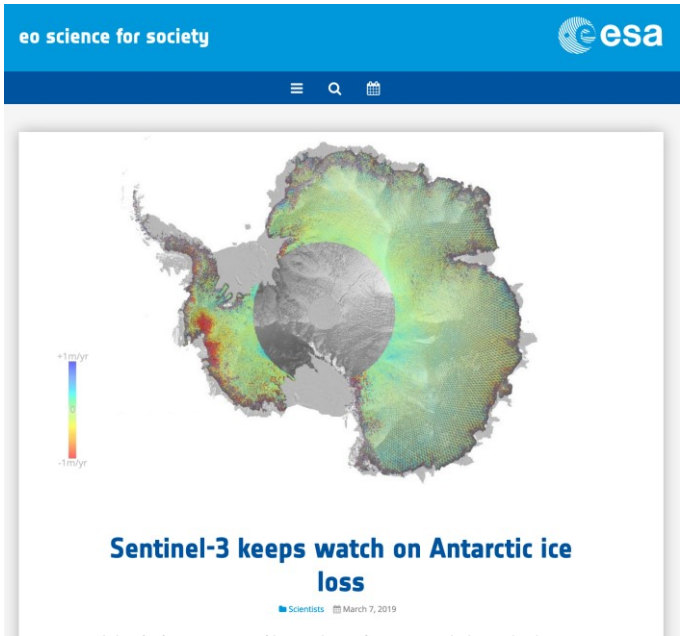

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