SAR Altimetry Processing Development for Ice Sheets

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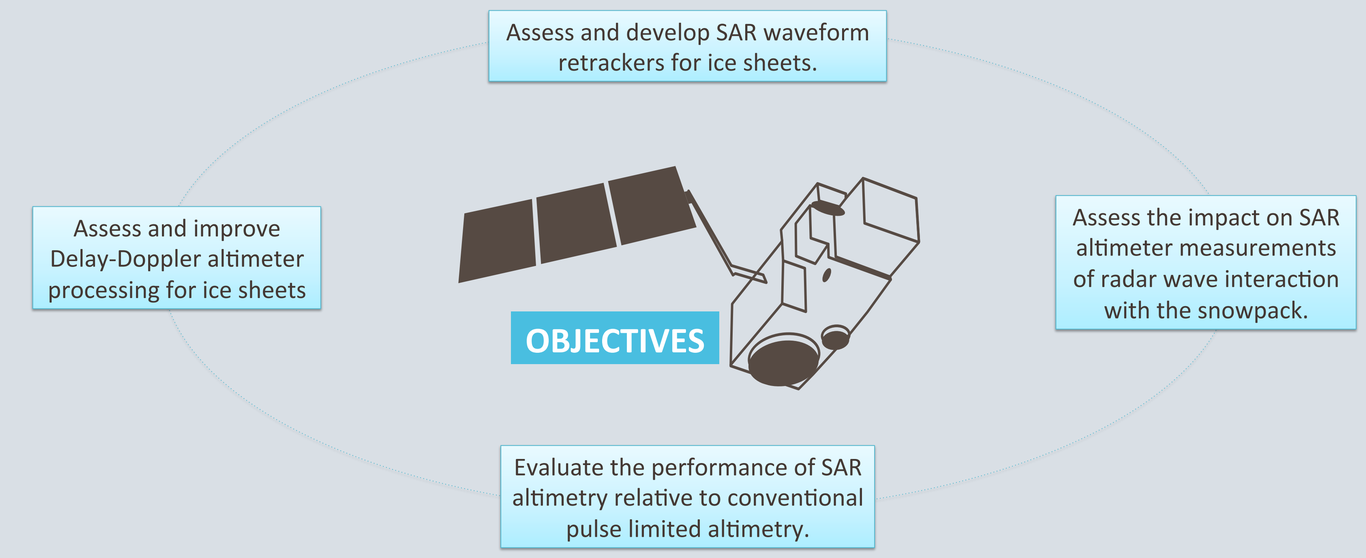
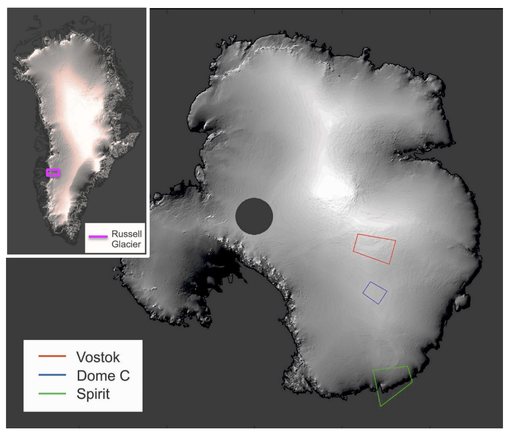
SUMMARY

- SPICE (Sentinel-3 Performance improvement for Ice sheets) is a study funded by ESA's SEOM (Scientific Exploitation of Operational Missions) program.
- The project aims to develop and evaluate **novel Synthetic Aperture Radar (SAR) altimetry processing methods over ice sheets**, and **investigate radar wave penetration through comparisons of Ku- and Ka-band satellite measurements**.
- Dedicated Full Bit Rate CryoSat-2 SAR acquisitions over several ice sheet sites have been processed using both existing and novel methodologies, with a view to investigating and improving the performance of Sentinel-3 over ice sheets.



CONTEXT & STUDY SITES

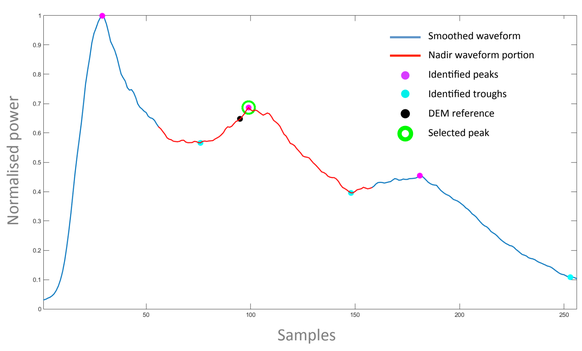
- Since 2010, CryoSat-2 Interferometric SAR altimetry has provided detailed measurements of ice sheet change.
- Non-interferometric SAR acquisitions have, however, been primarily limited to sea ice and water surfaces.
- In preparation for Sentinel-3, which is a global SAR mission, several dedicated SAR campaigns were made by CryoSat-2 over East Antarctica.
- The SPICE study is using this unique dataset to evaluate and develop SAR processing techniques for ice sheet surfaces.
- SPICE is also assessing the impact of Ku-band penetration on SAR altimeter measurements, through comparison to Ka- and Ku-band LRM data.
- SPICE has focused on four study sites:
  - The **Lake Vostok, Dome C** and **Spirit** sites in Antarctica, where dedicated SAR acquisitions have been made by CryoSat-2.
  - The **Russell Glacier** in Greenland, where SAR interferometric (SARIn) Full Bit Rate (FBR) data has been used to generate pseudo-SAR measurements.



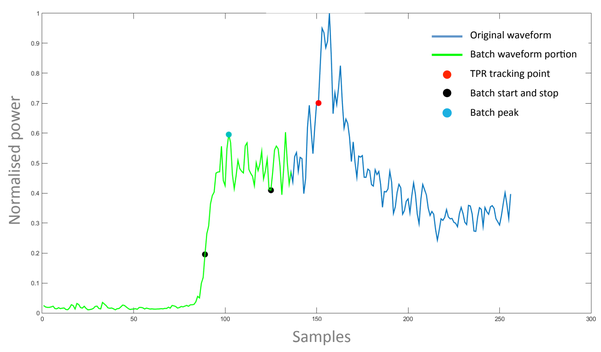
The location of SPICE study sites in Antarctica (main panel) and Greenland (inset).

SAR ALTIMETRY PROCESSING IMPROVEMENT OVER ICE SHEETS

- The SPICE study has developed and tested new SAR altimetry processing algorithms, with a view to ultimately improving Sentinel-3 performance over ice sheets.
- One of the primary objectives has been to develop novel approaches to SAR retracking.
- This activity aims to improve non-interferometric elevation retrievals across ice margin regions, where rugged topography produces complex waveforms and complicates conventional retracking approaches.
- We have developed two approaches that are designed to improve retrievals for complex, multiple peak waveforms, where reflections are received from several distinct surfaces:
  - In the first approach an auxiliary Digital Elevation Model is used to select a consistent peak (i.e. target within the beam footprint) to retrack. By choosing to identify peaks corresponding to the nadir echo, we also eliminate the need to apply a slope correction (i.e. echoing point relocation), as is the case with conventional Level-2 processing.
  - In the second approach, batch processing of waveform sequences is used to maintain along-track consistency in the choice of peak selection. This is designed to increase the along-track stability of the retracking algorithm in the presence of multi-peaked waveforms, by using the epoch history to avoid switching between different peaks in the echo.



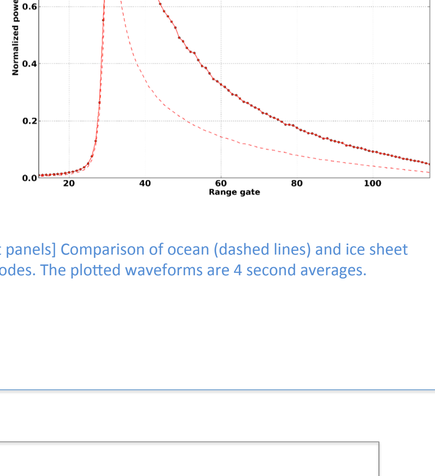
Example of the use of an auxiliary DEM to identify the peak that corresponds to the nadir reflection within a complex waveform. Shown here is a smoothed 20 Hz SAR waveform from the Spirit site in East Antarctica. The DEM is from CryoSat-2 SARIn mode data.

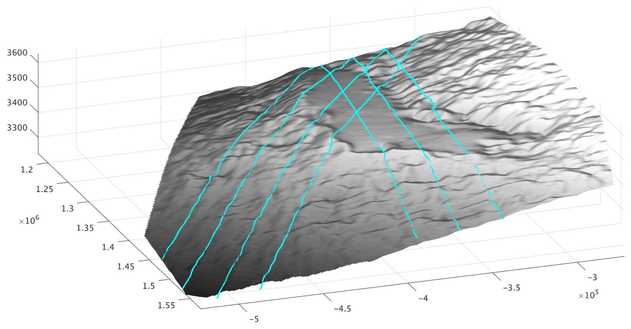


Example of the use of Batch processing to identify a consistent leading edge in the waveform, based on the history of previous records. Shown here is a 20 Hz waveform from the Spirit site with the retracking point identified from a threshold of the maximum peak (TPR; red), together with the waveform segment and peak identified by the Batch processing (black; turquoise).

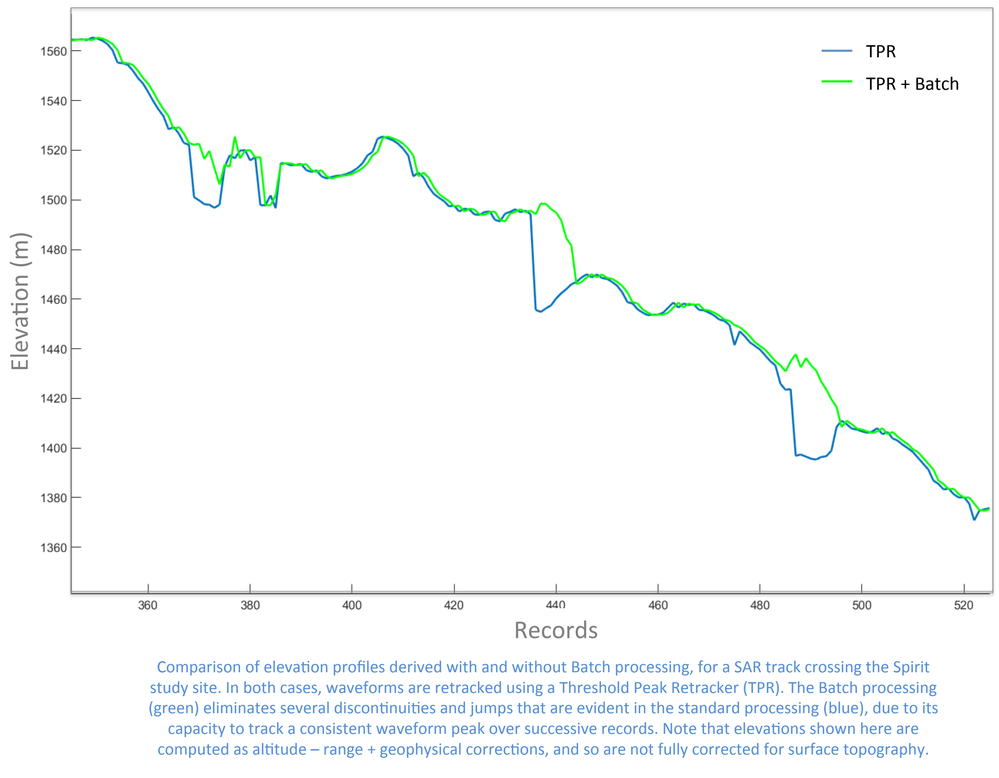
RADAR WAVE INTERACTION WITH THE SNOWPACK

- To evaluate the impact of volume scattering on waveform shape across different modes and frequencies bands, mean ocean and ice sheet waveforms were compared.
- To minimise the impact of ice sheet surface topography on the detected echo, waveforms from the flat surface above Lake Vostok were used.
- The AltiKa Ka-band LRM data show some sensitivity to volume scattering, but the oceanic and ice sheet leading edges have similar shapes.
- The CryoSat-2 Ku-band SAR and pLRM waveforms are modified more by volume scattering.
  - The Ku pLRM leading edge is affected from around mid-power.
  - The Ku SAR leading edge is not impacted, but the effect can be seen in the trailing edge.





[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 different frequencies and in different operating modes. The plotted waveforms are 4 second averages.



Comparison of elevation profiles derived with and without Batch processing, for a SAR track crossing the Spirit study site. In both cases, waveforms are retracked using a Threshold Peak Retracker (TPR). The Batch processing (green) eliminates several discontinuities and jumps that are evident in the standard processing (blue), due to its capacity to track a consistent waveform peak over successive records. Note that elevations shown here are computed as altitude – range + geophysical corrections, and so are not fully corrected for surface topography.

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