CLEV2ER: Development of the CRISTAL Level-2 Prototype Processors for Land Ice and Inland Water

Mal McMillan on behalf of the The CLEV2ER Consortium

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Lancaster University

cpom

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isardSAT

UCL
Mullard Space Science Laboratory

earthwave

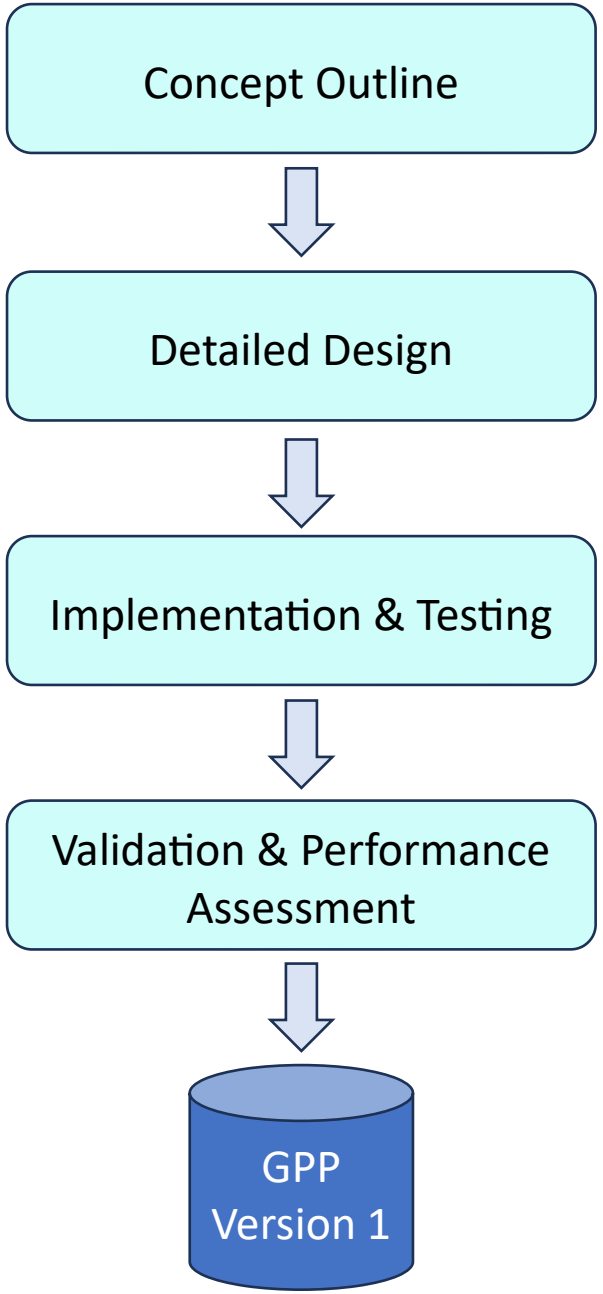
Ebrenn

DTU

CLEV2ER: Aims & Objectives

- To design and implement the CRISTAL Level-2 thematic GPP's for Land Ice and Inland Water domains.
- To define the content, structure and format of the associated Level-2 products.
- To perform R&D to address the outstanding scientific and technical questions relating to domain-specific Level-2 processing of data acquired by the IRIS instrument, to contribute to CRISTAL achieving SRL7 by the IOCR.

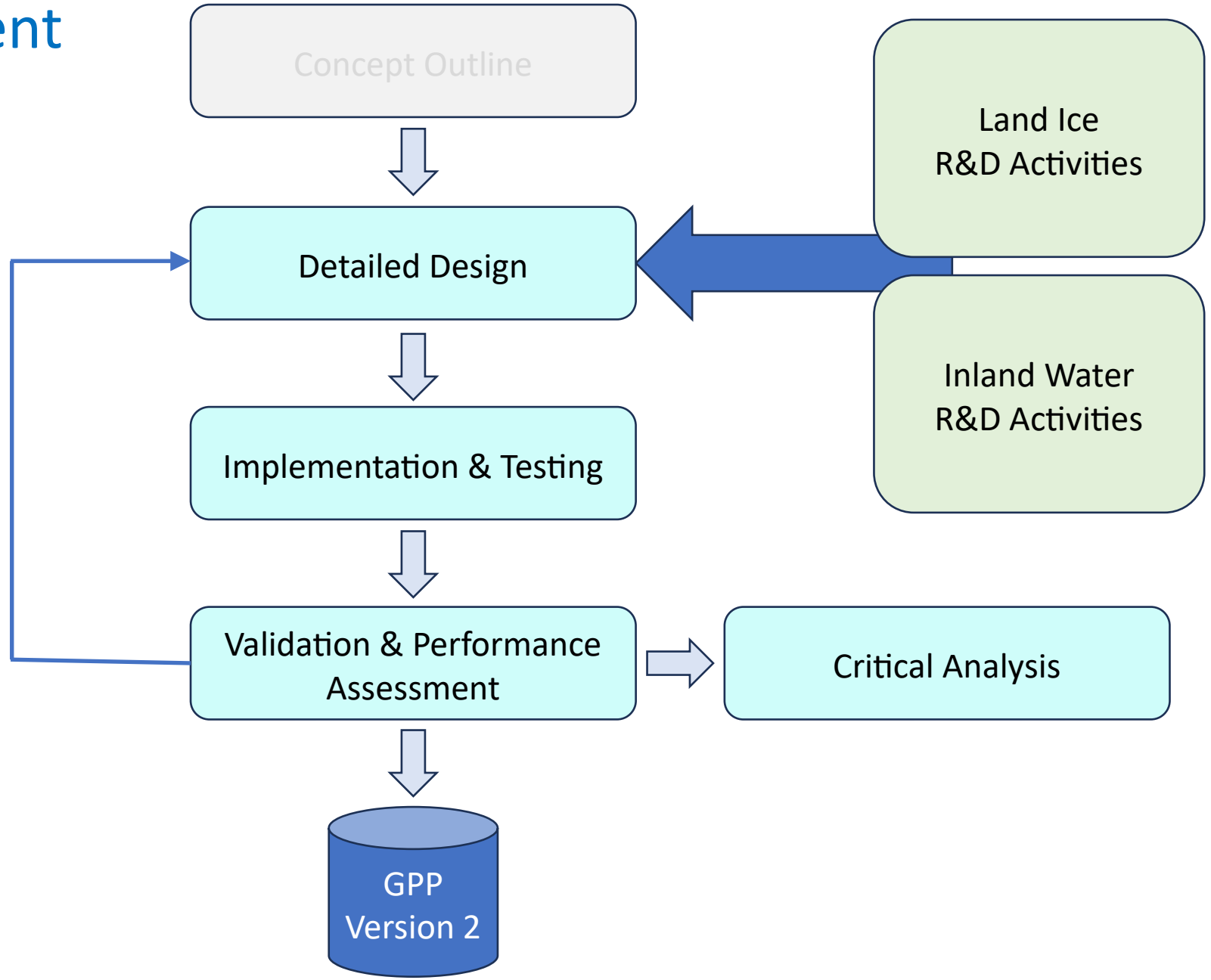
Level-2 GPP Development



Land Ice R&D Activities

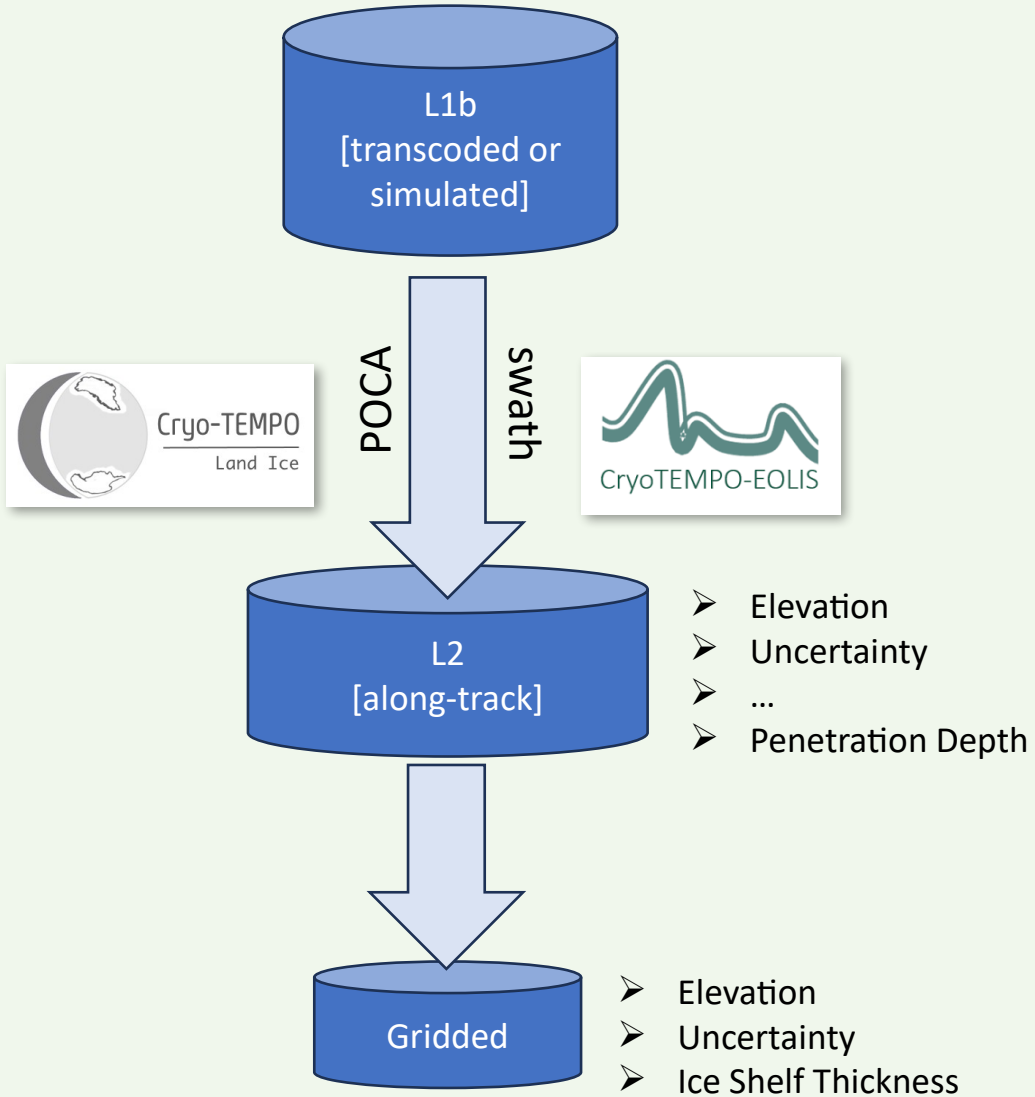
Inland Water R&D Activities

Level-2 GPP Development

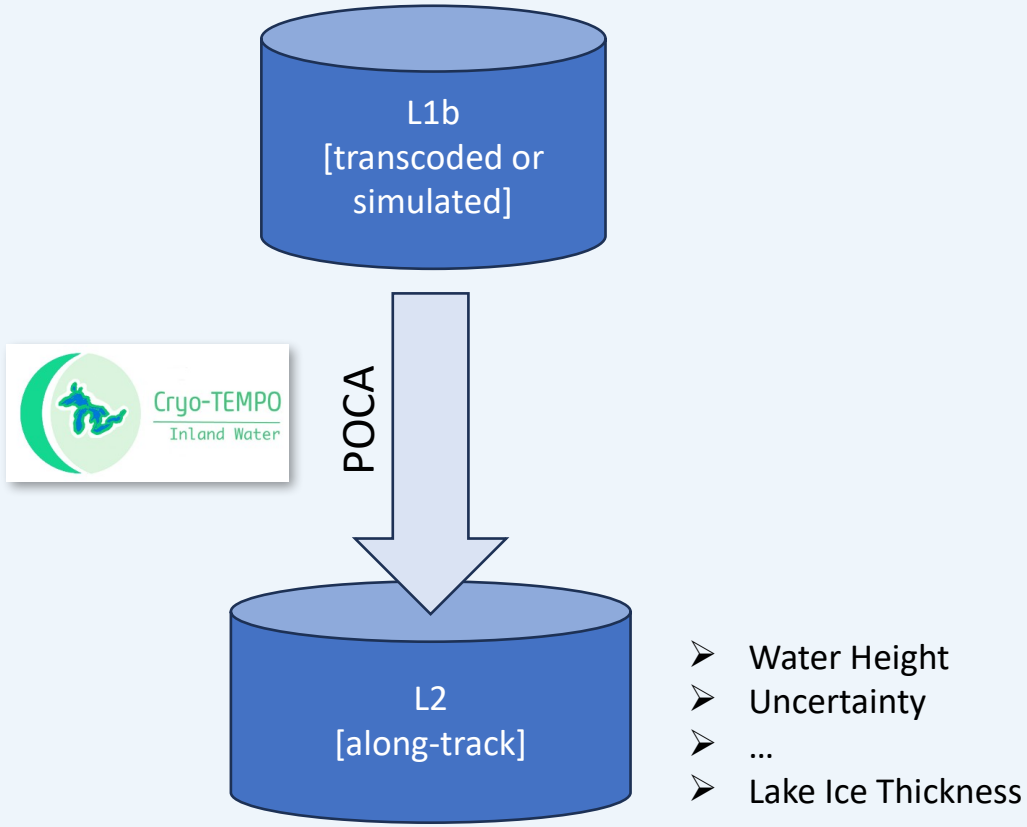


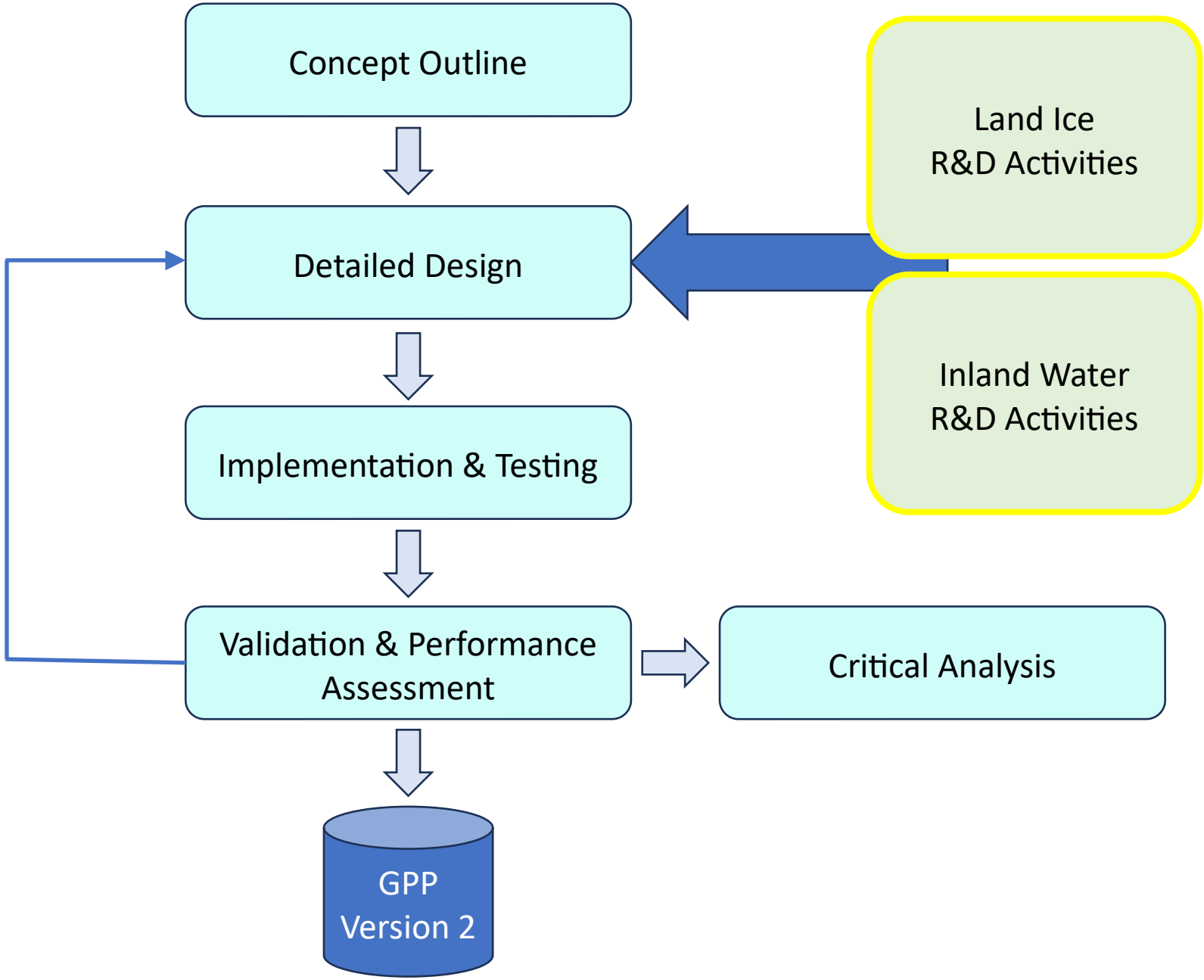
Level-2 GPP Processing Chains

Land Ice



Inland Water




Concept Outline
Detailed Design
Implementation & Testing
Validation & Performance Assessment
Critical Analysis
GPP Version 2
Land Ice R&D Activities
Inland Water R&D Activities

CLEV2ER R&D Activities

Land Ice

Study number	Title
1	Assessment of the divergence of Ku and Ka echoes over ice sheet surfaces.
2	Assessment of snowpack properties on penetration depth estimates using dual band airborne altimetry.
3	Algorithm development for the retrieval of penetration depth from dual band altimetry
4	Assessment of the limitations and applications of combining FFSAR and swath processing.
7	Determination of an optimal mispointing for swath processing.
8	Improved methods for uncertainty estimation.

Inland Water

Study number	Title
1	Lake ice thickness retrieval
2	Verification of the capability to estimate water body extent using FFSAR waveforms
3	Assessment of swath processing for water height estimation

R&D Activities

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Unknowns due to Ku-Ka mode of operation.

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Optimising swath and potential of FFSAR.

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Optimising swath and potential of FFSAR.

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Optimising swath and potential of FFSAR.

Improving uncertainty.

Inland Water

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New parameters.

Optimising swath and potential of FFSAR.

R&D Activities

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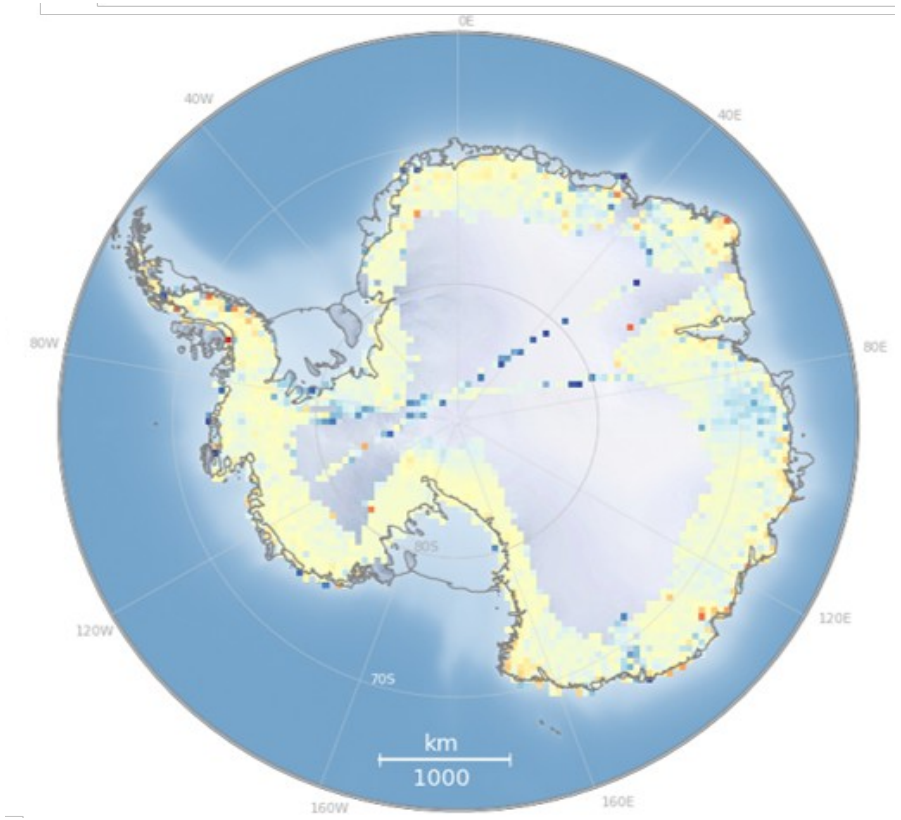
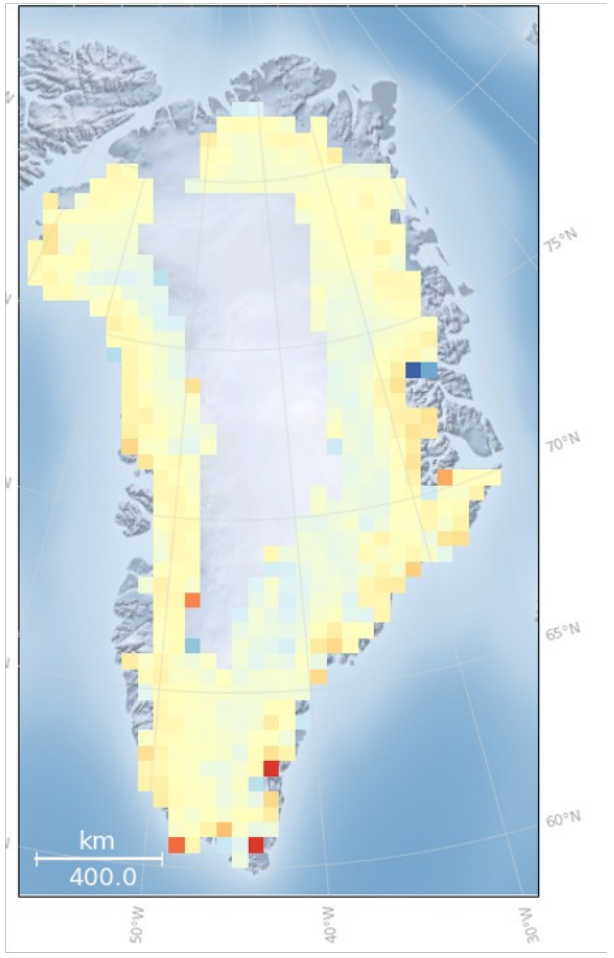
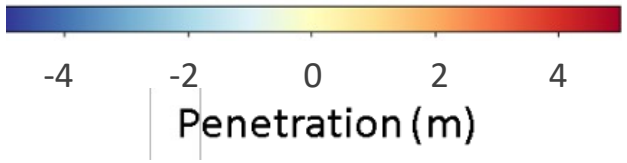
Preliminary results – work in progress

Algorithm development for the retrieval of penetration depth from dual band altimetry

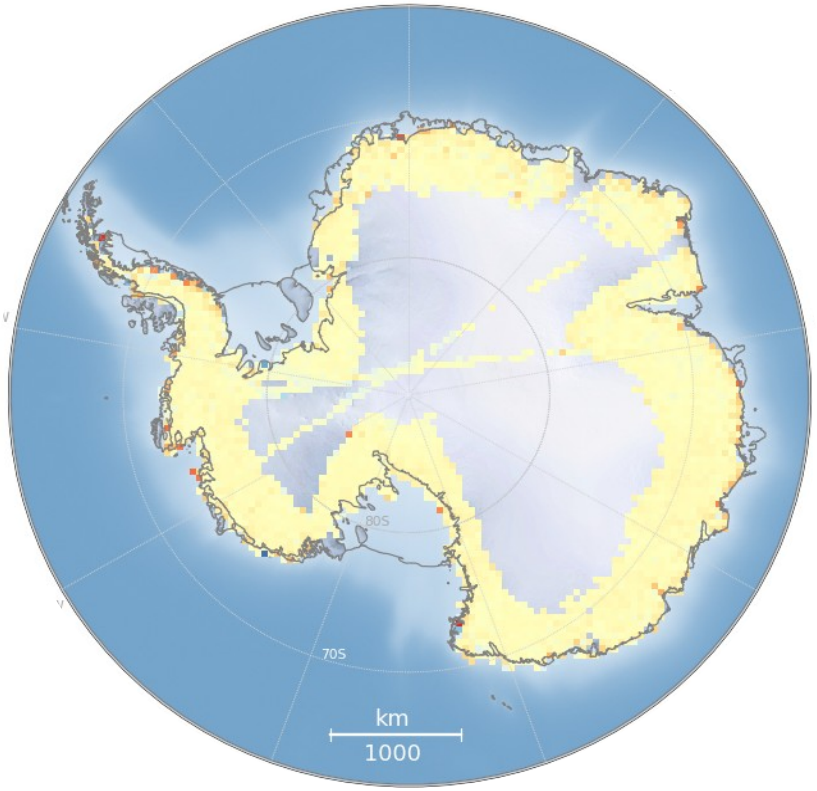


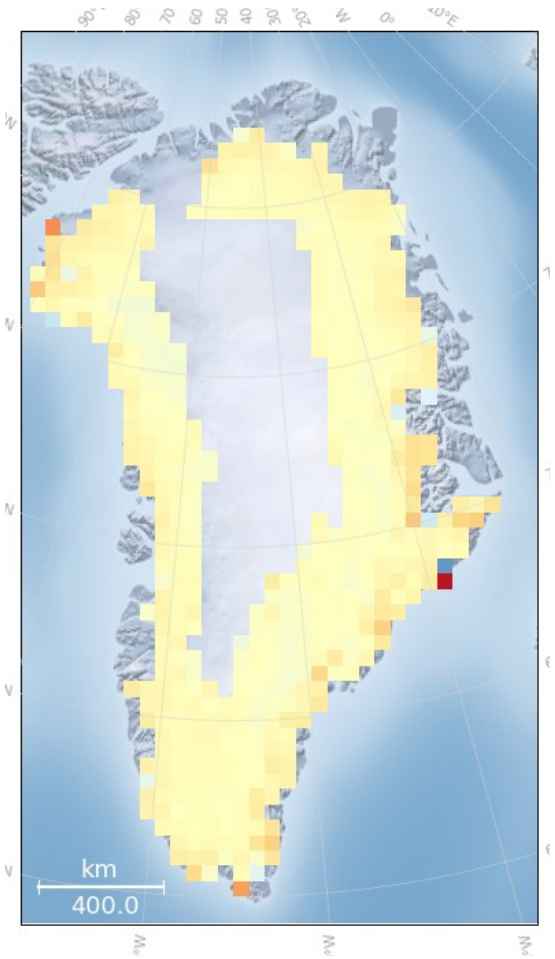


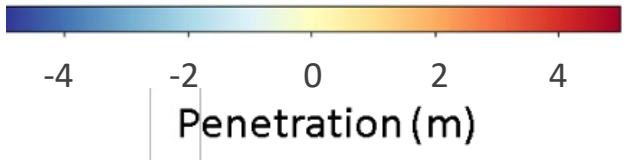


Level-2

Algorithm development for the retrieval of penetration depth from dual band altimetry



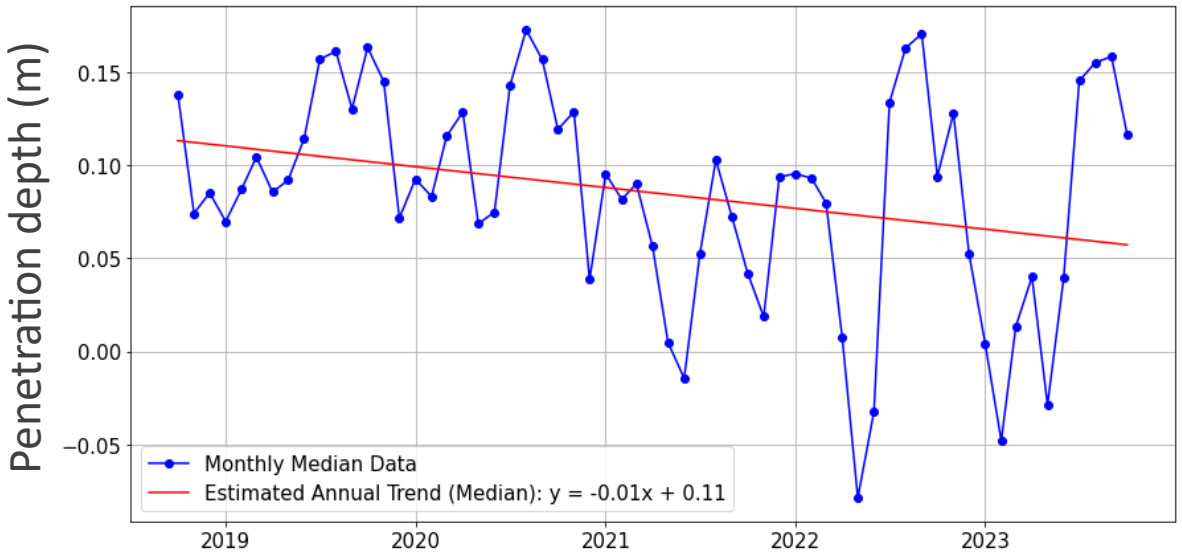




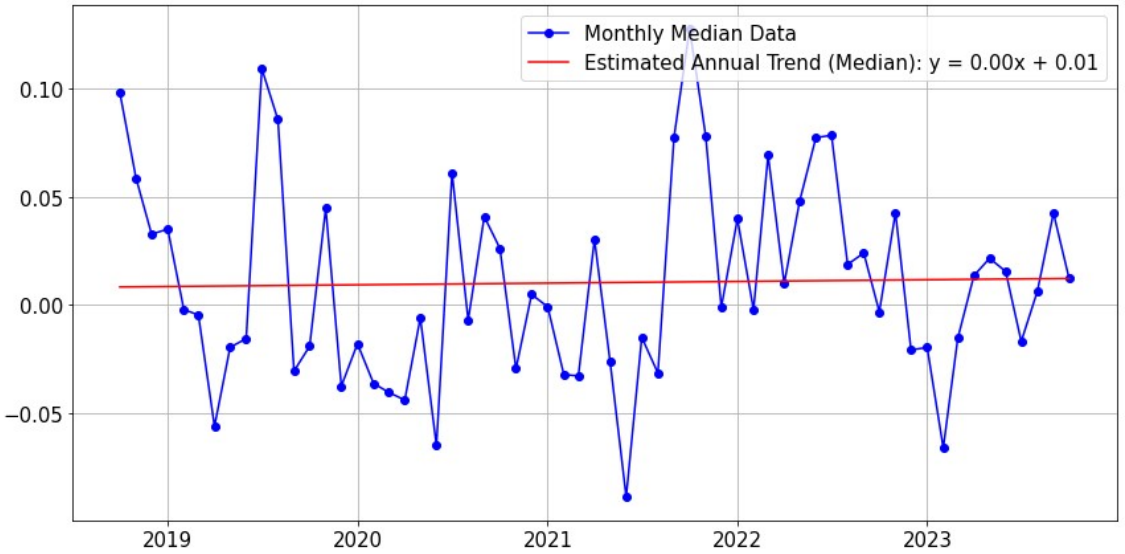
Cryo-TEMPO

Algorithm development for the retrieval of penetration depth from dual band altimetry

Greenland



Antarctica

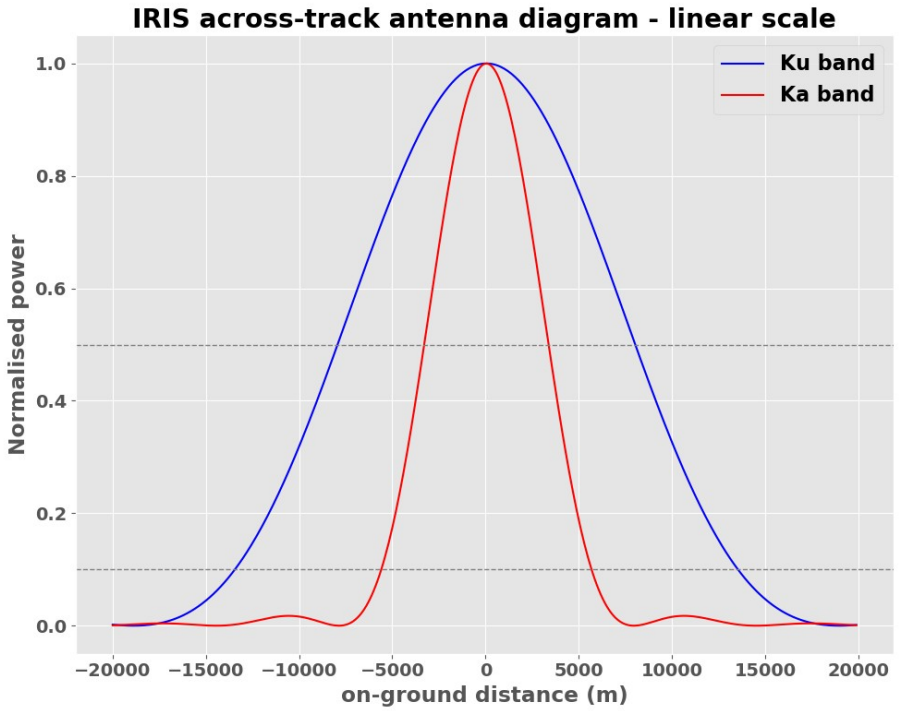


Cryo-TEMPO

Assessment of Ku and Ka divergences over ice sheet surfaces

- Ku-Ka will allow retrieval of information relating to variability in penetration.

- However, over complex ice sheet surfaces, the difference in antenna aperture may create diverging waveforms; which will complicate the retrieval of co-located Ku and Ka measurements.



Ku band: 1.22° / Ka band: 0.51°

	Ku band	Ka band
-3 dB / 50%	~7 900 m	~3 300 m

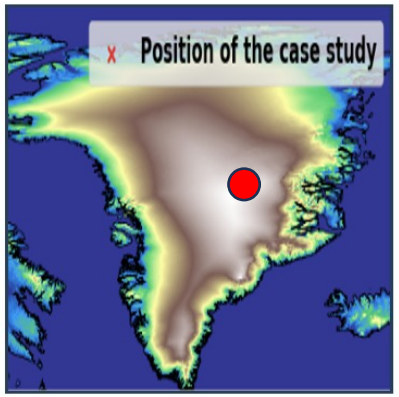
Assessment of Ku and Ka divergences over ice sheet surfaces

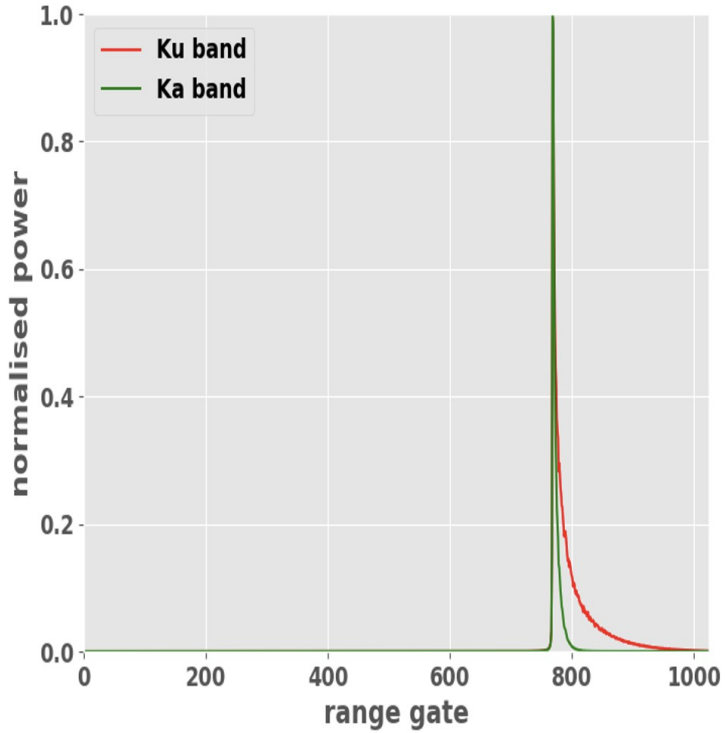
- Aim is to use AMPLI (Aublanc et al., 2024) to assess this phenomena:
  - Adapt AMPLI from Sentinel-3 to IRIS parameters.
  - Perform simulations along the theoretical CRISTAL orbit.
  - Assess the agreement between Ku and Ka first peaks; 4 retracking algorithms tested.

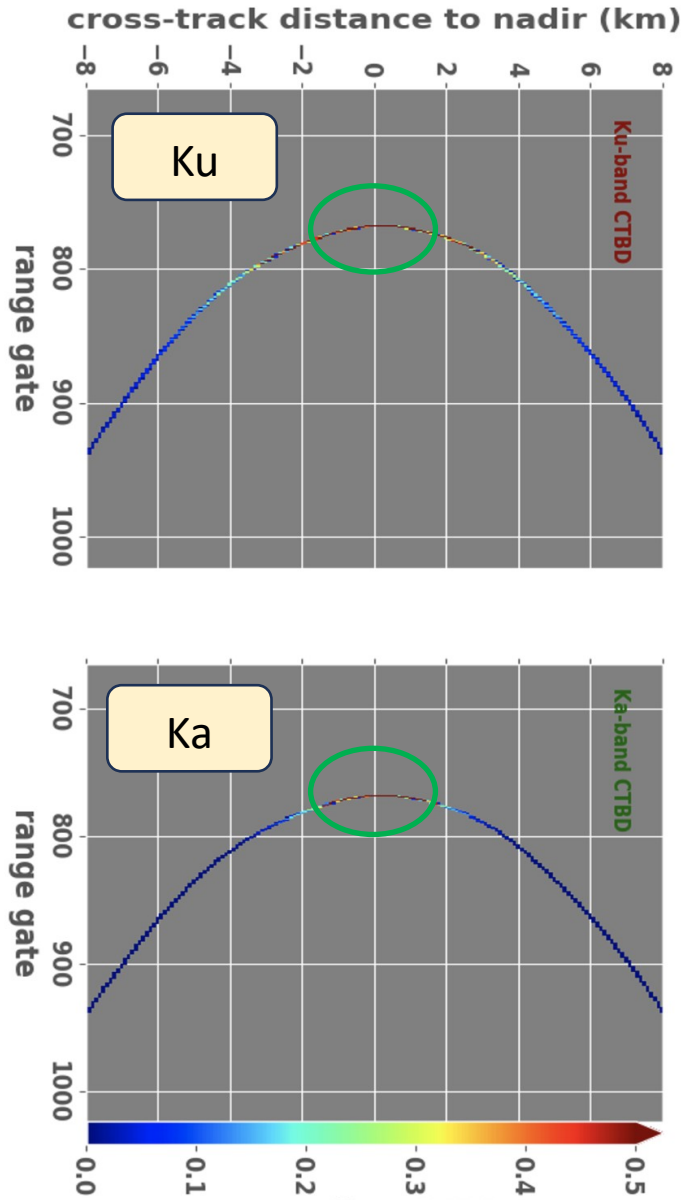
Assessment of Ku and Ka divergences over ice sheet surfaces

Example 1: Simple topography

- 0 degree across-track slope, 0.1 m roughness.





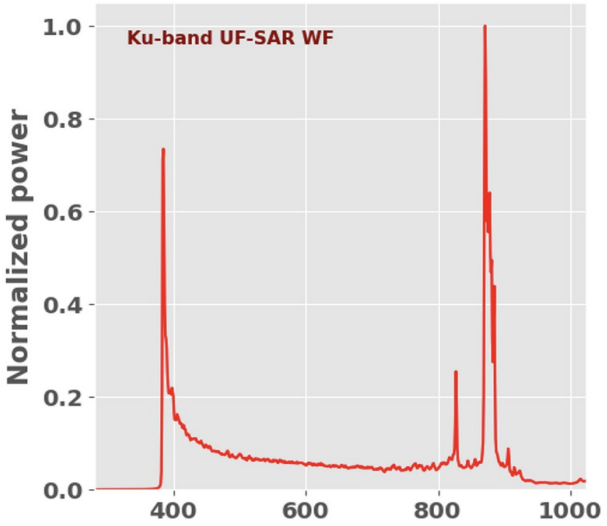


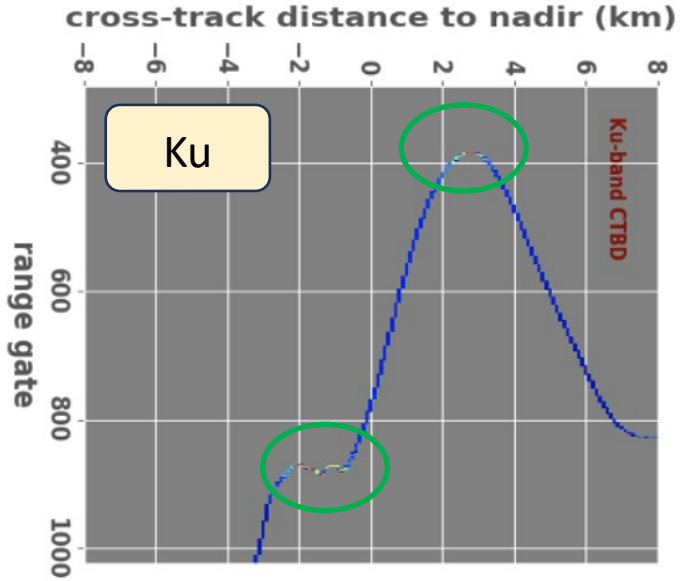
Cross Track Backscatter Distribution

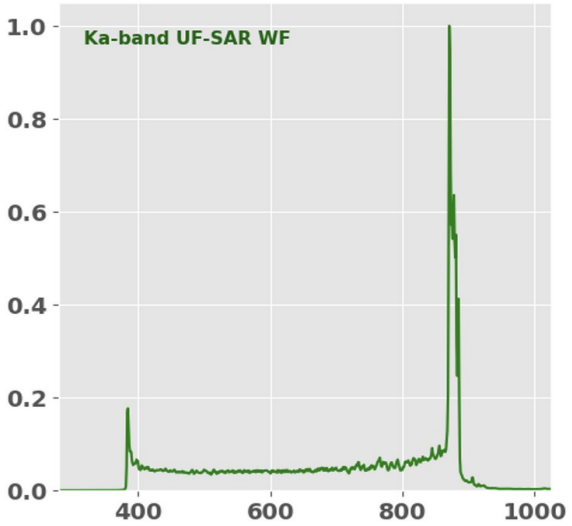
Assessment of Ku and Ka divergences over ice sheet surfaces

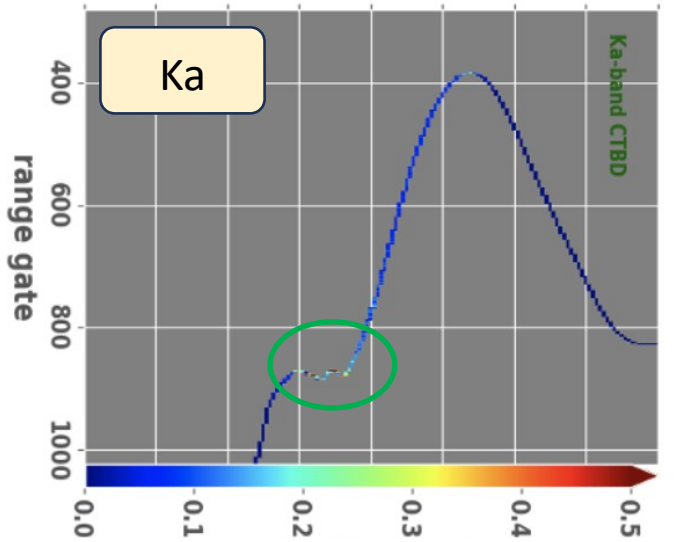
Example 2: Complex topography

- 2 degree across-track slope, 10 m roughness.









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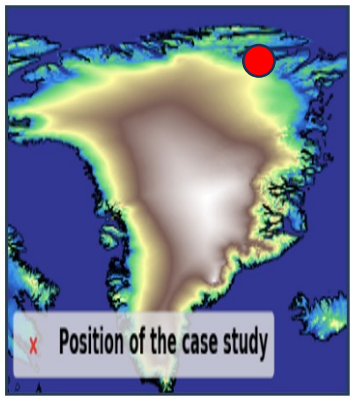

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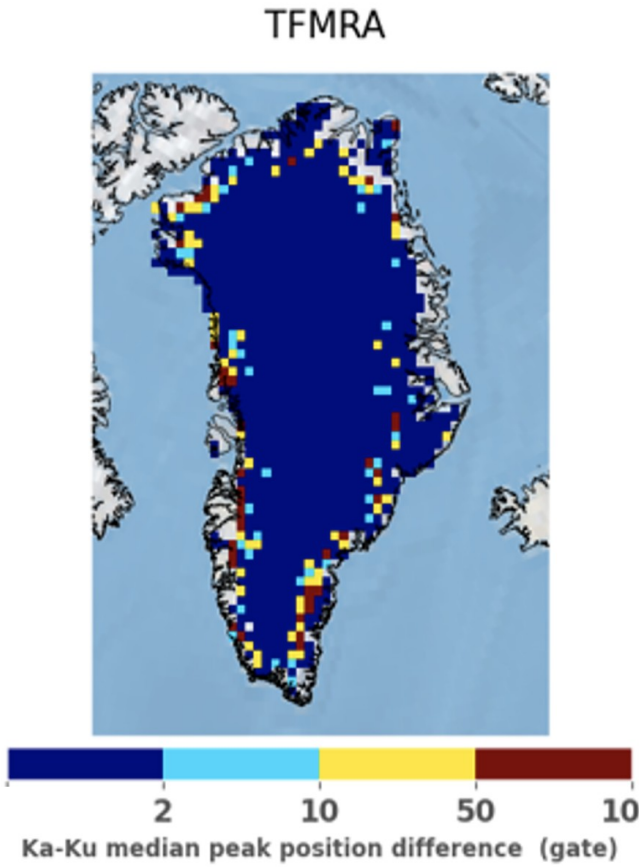
Assessment of Ku and Ka divergences over ice sheet surfaces

- CRISTAL waveforms were simulated for one monthly sub-cycle, in Ku and Ka bands.
- Retracked range computed -> used to assess the difference in epoch between Ku and Ka, due to the topography.
- The difference in the peak position is within 2 range gates for 70-75% of the measurements for Greenland[1].
- Where surface slope > 1°, the difference in the peak position is greater than 10 gates for 35-50% of measurements[2].



1. 74% for TFMRA.
2. 48% for TFMRA.

Assessment of snowpack properties on penetration depth estimates using dual band altimetry

ESA Cryo2IceEx/SILICE spring 2022

Thanks to Ines and Andy.

H. Skourup [1], E. Merola [1], S. M. Hvidegaard[1], L. Sandberg Sørensen[1], R. M. Fredensborg Hansen, D. Gomez-Garcia Alvestegui[2], A. Di Bella [3], I. Otosaka[4], A. Shepherd [4], A. Swiggs [4], A. Braakmann-Folgmann [4], S. George [5], J. Li [2], and R. Forsberg[1]

[1] DTU Space, Technical University of Denmark, Kgs. Lyngby, Denmark
[2] CReSIS, University of Kansas, USA
[3] ESA - ESRIN, European Space Agency, Italy
[4]Centre for Polar Observation and Modelling, University of Leeds, UK
[5]University of Reading, UK

satellite

Multipeak retracking of radar altimetry waveforms over ice sheets

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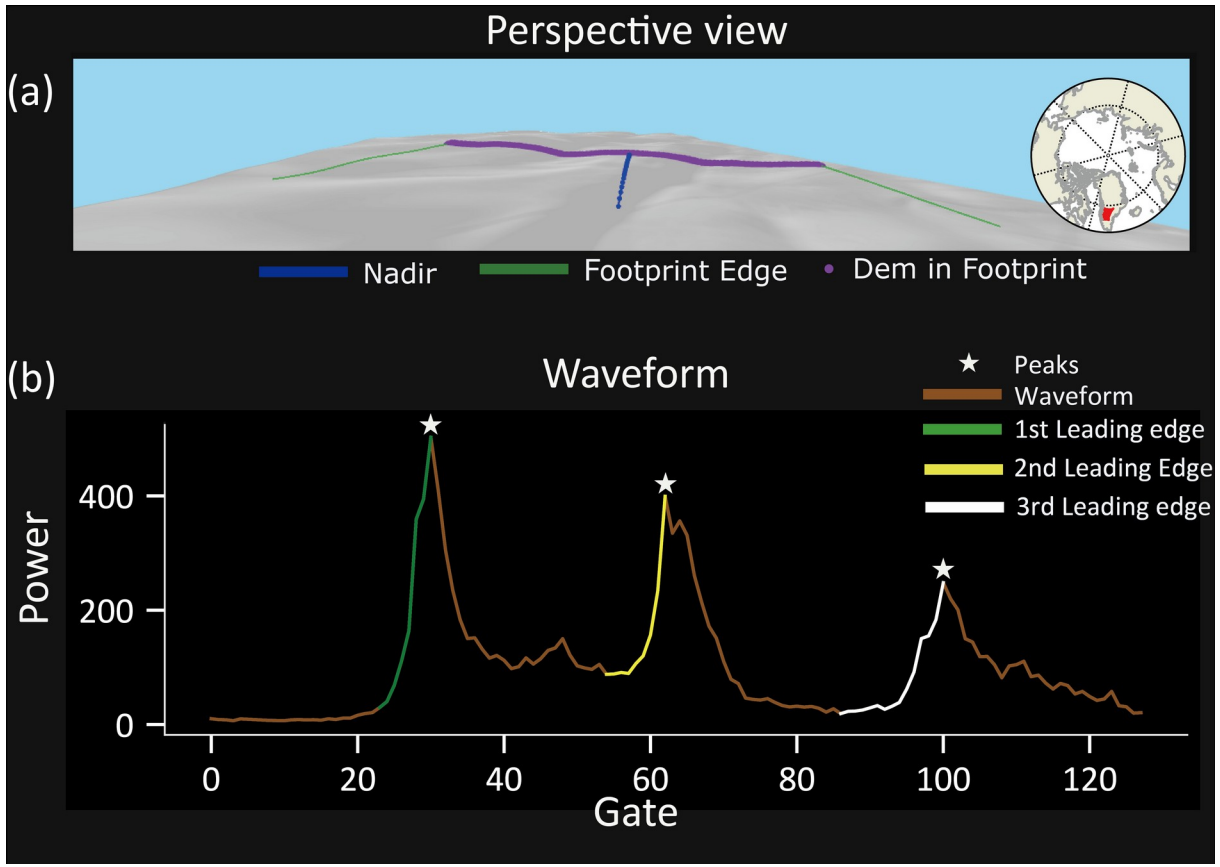
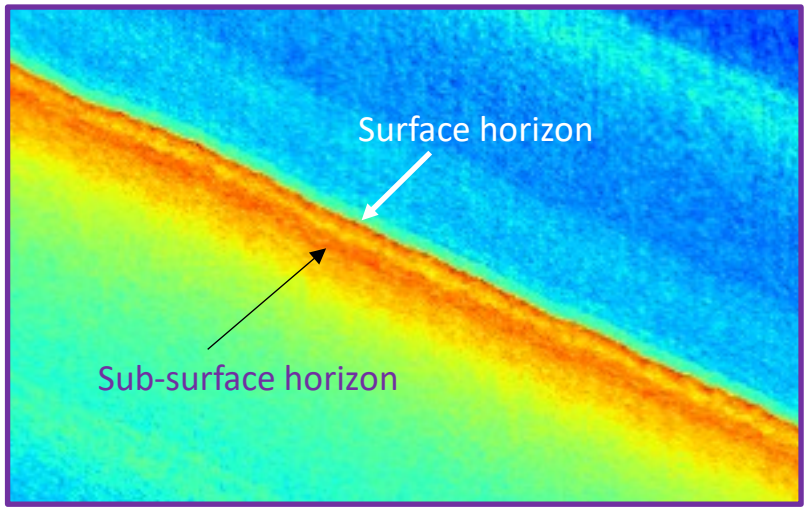
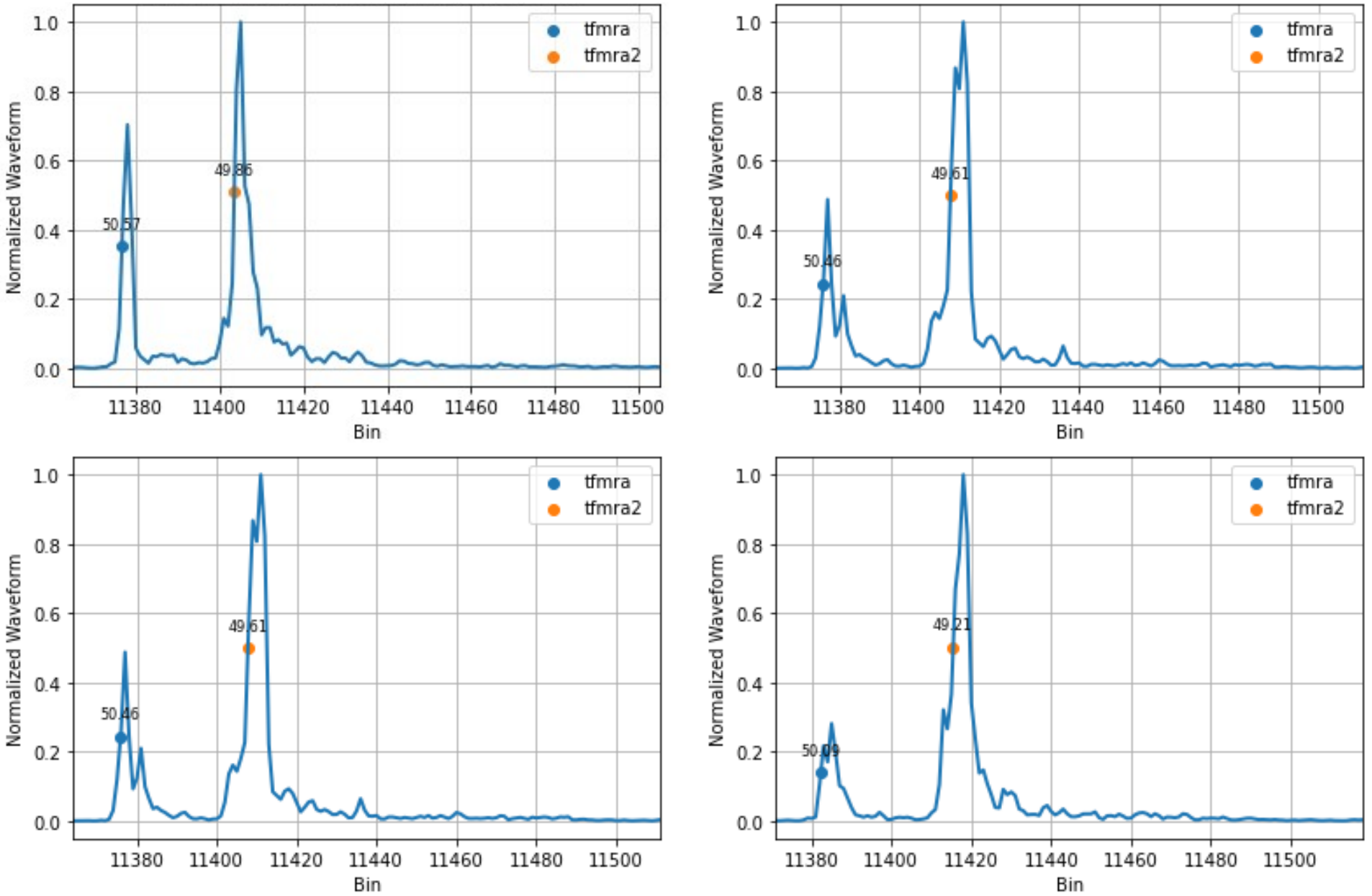
[a] UK Centre for Polar Observation & Modelling, Centre of Excellence in Environmental Data Science, Lancaster University, Lancaster LA1 4YW, UK
[b] University College London, Gower Street, London WC1E 6BT, UK
[c] School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK





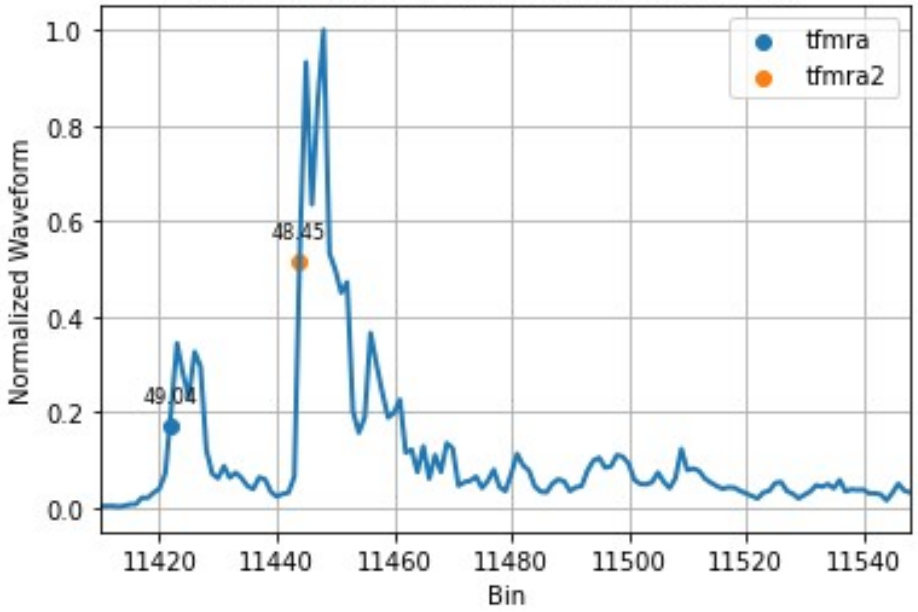
Multipeak retracking of CReSIS waveforms

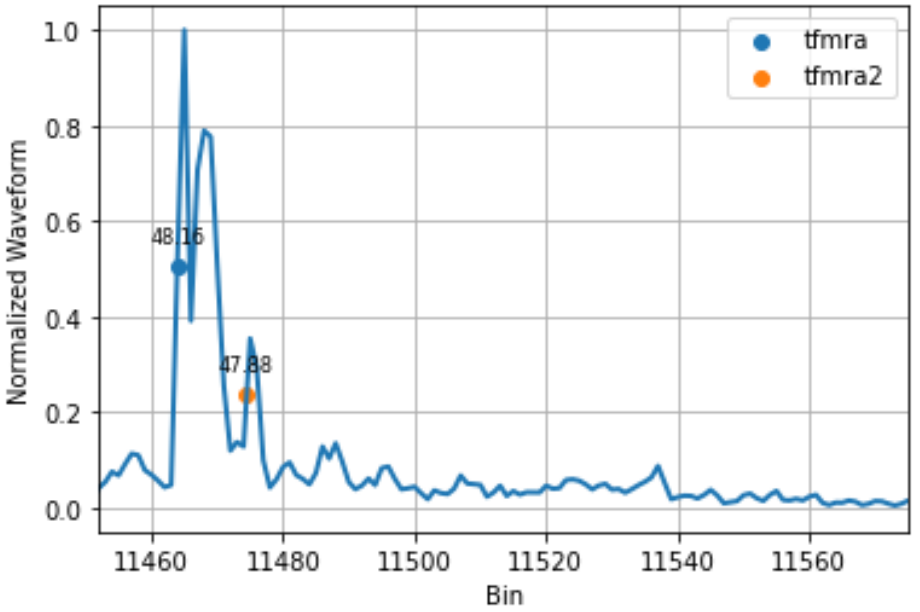
Ku

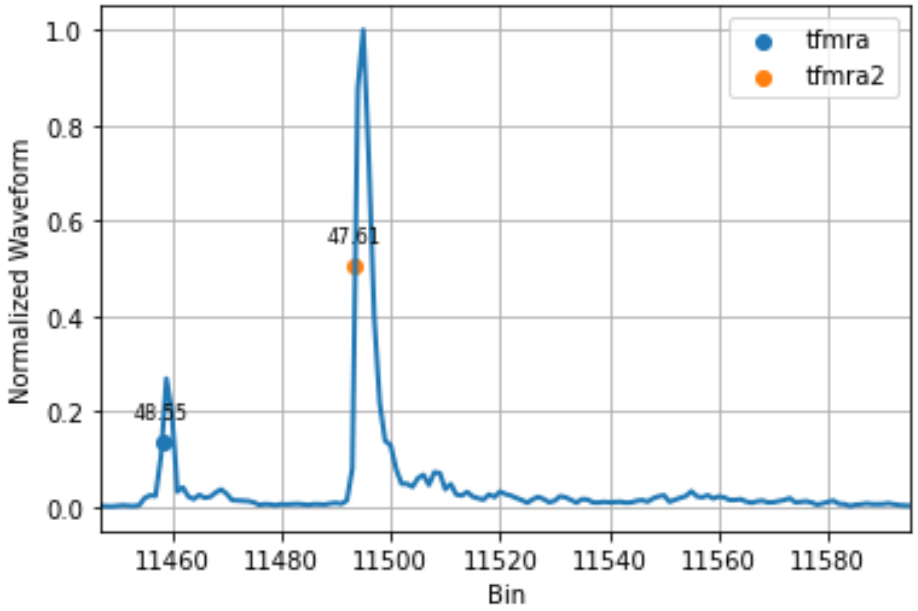


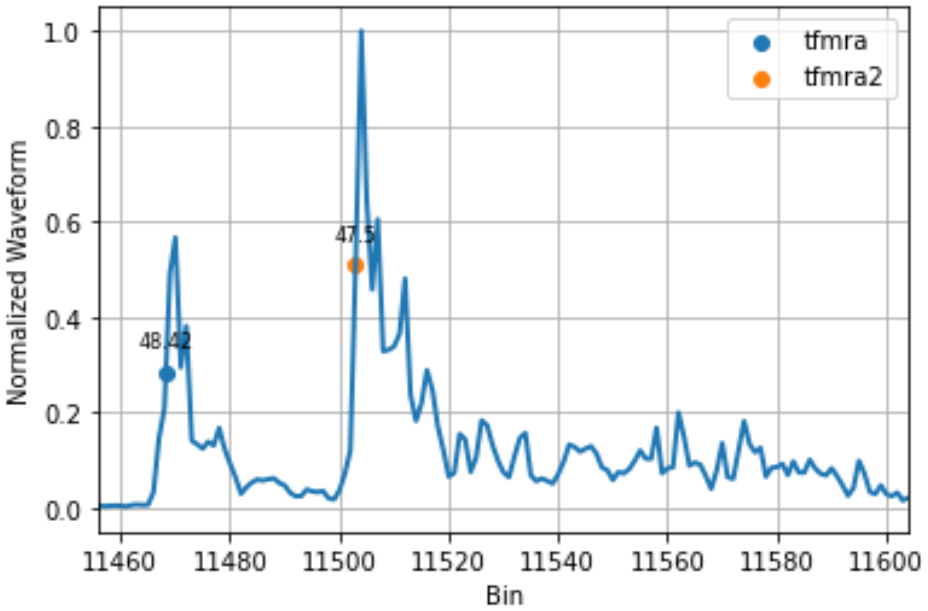
Multipeak retracking of CReSIS waveforms

Ka



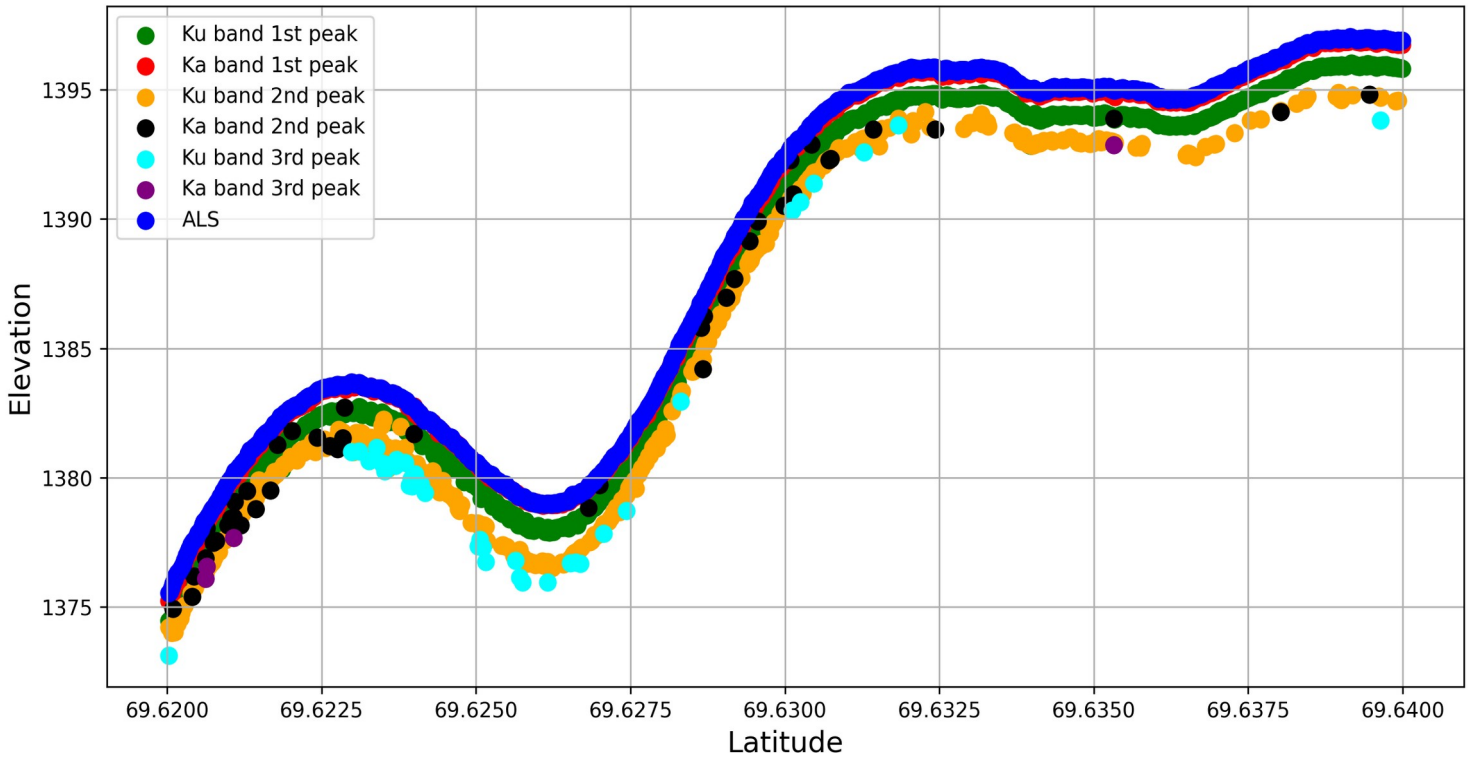






Multipeak retracking of CReSIS waveforms

- Run the multipeak retracker for up to 3 peaks in Ku and Ka.
- Calibrate relative to Airborne Laser Scanner.
- Assess depths of dominant scattering layers within the snowpack.



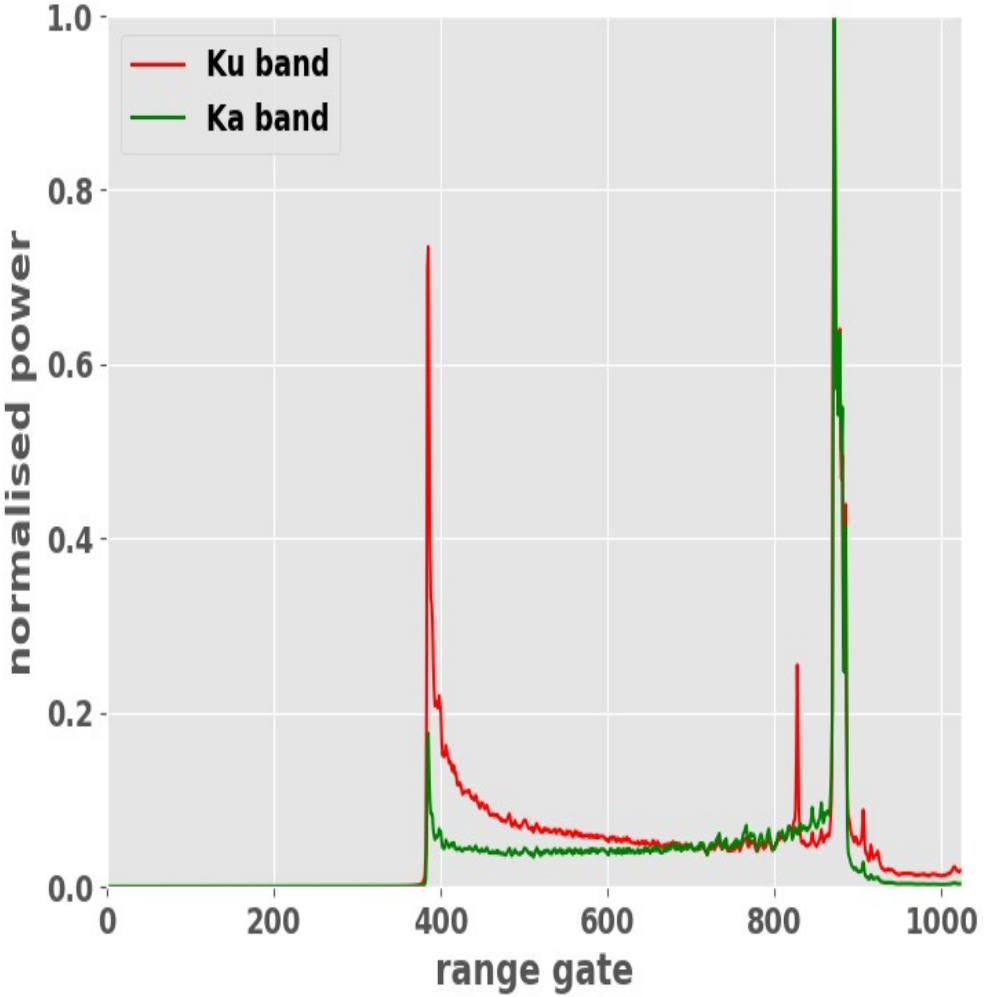
Summary & Outlook

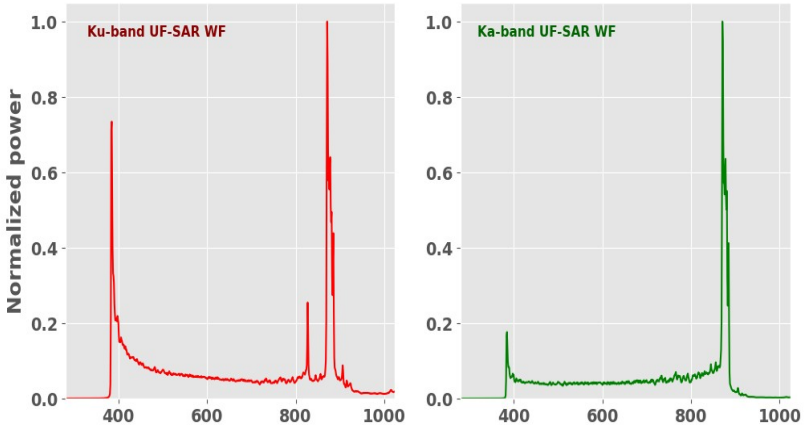
- CLEV2ER kicked off last summer and has been running for ~ 1 year.
- Principle aims are:
  - To define and implement the Land Ice and Inland Water Level 2 GPP's.
  - To perform R&D activities to address outstanding questions relating to CRISTAL's operations.
  - To contribute to the demonstration of the Scientific Readiness of the mission.
- Q1 2025: Phase 1 of the GPP completed.
- Summer 2026: Project will complete with version 2 of the GPP released.

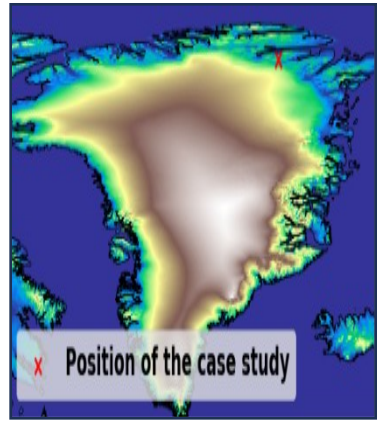
Supplementary

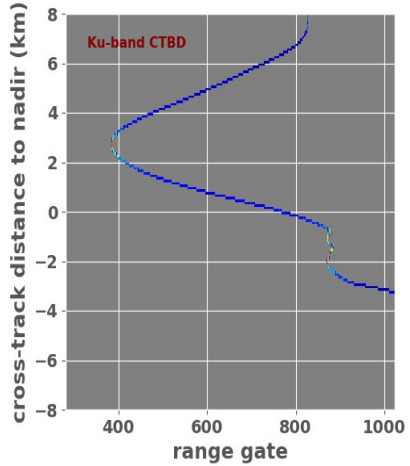
Case study 5: high values of both slope and roughness

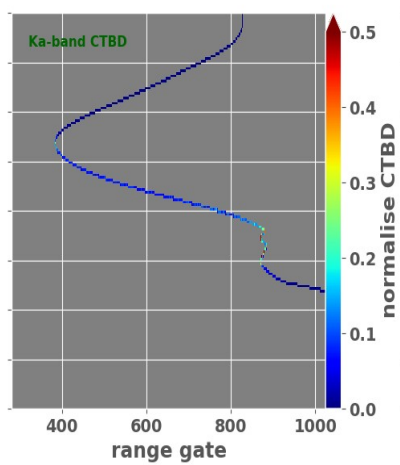
cross-track slope = 2.02° // cross-track roughness = 10.41m

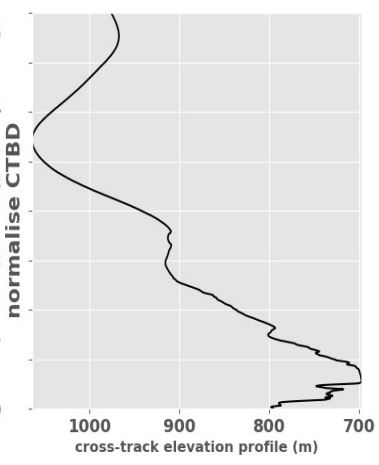












CLEV2ER: Aims & Objectives

The main technical objectives of the *CLEV2ER* study are defined as follows:

- Define the first version of the CRISTAL Level-2 product format and content over Land Ice and Inland Water domains.
- To implement fully traceable uncertainty parameters within both GPP's.
- To implement current state of the art Level-2 processing algorithms, within an agile and responsive GPP framework.
- To perform dedicated R&D to address major outstanding issues in IRIS Level-2 processing over Land Ice and Inland Water; thus contributing to raising the CRISTAL mission's SRL to 7 at the IOCR.
- To perform critical analysis, with a view to informing the further development of the CRISTAL L2 operational processor in the future.