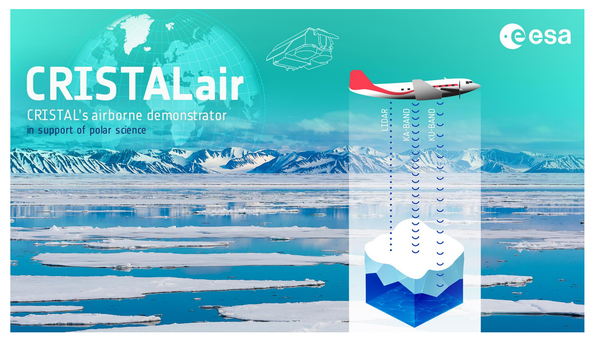
The laser scanner onboard CRISTALair



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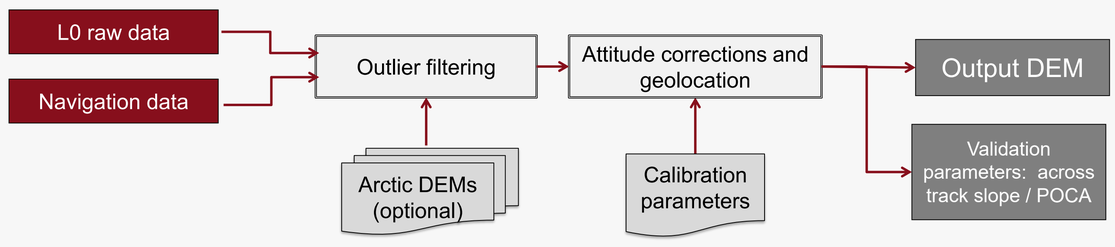
Introduction

CRISTALair is the airborne demonstrator for the future CRISTAL mission, It essentially consists of a multi-sensor platform including a full interferometric Ku/Ka nadir radar, a laser scanner, and a multispectral camera. The main role of the laser scanner is to provide complementary range measurements for validation of the radar range measurements. For such purpose, the laser scanner was selected so as to provide optimal measurements over sea ice, land ice and water. The laser scanner was first employed alongside CRISTALair in the Functional Flight Campaign in Iceland and Greenland in September 2025. In this contribution we will provide an overview of the measurements undertaken and the procedures done to post process the data and calibrate the instrument. Also, some examples of significant data obtained during the campaign will be presented along with some parameters that can be deduce from it to use as validation for the radar.

RIEGL VQ-580II laser scanner

RIEGL VQ-580II specifications	
Pulse Repetition Rate (PRR)	150 kHz
Frequency / Wavelength	NIR / 1064 nm
Field of View (FoW)	75º (effective 32º)
Range	Up to 1850 m (reflectance > 20%)
Swath (at 1000m AGL)	573 m



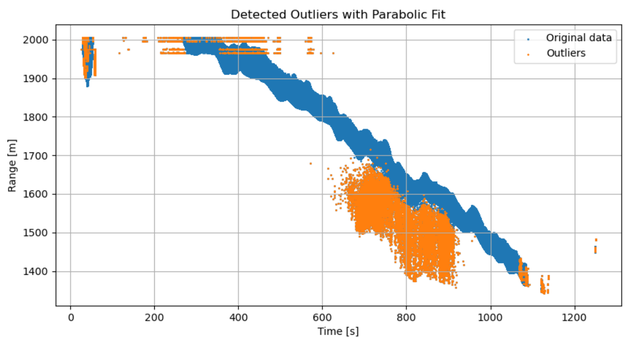
Schematic diagram of the laser post processing chain

Post processing and calibration

1 Outlier filtering

First, two sequential filters are applied prior to geolocation to remove outliers in raw data:

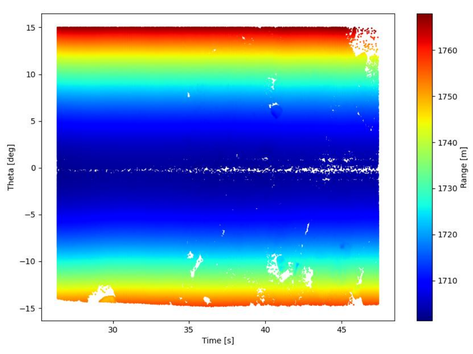
- An estimated range is computed using preexisting Digital Elevation Models (DEM) and the navigation data, which gives an estimated range window at which the results should be expected. Points outside this window are removed.
- A second filter is implemented by fitting a parabola to the range profile of each isolated scan line. Points deviating from the fit beyond a fixed threshold, and scan lines with too few points, are discarded.



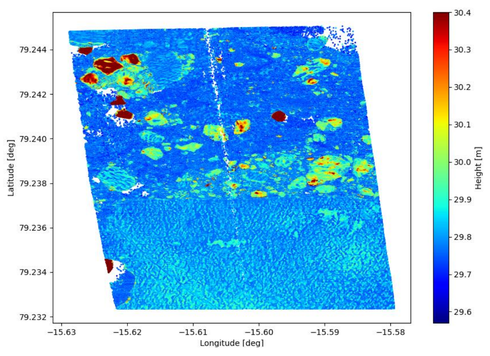
Example of outliers detected in the range data with the parabolic filter

2 Attitude corrections and geolocation

Raw laser range and angle measurements are projected from the Laser Reference Frame (LRF) into the North-East-Down (NED) frame via an attitude rotation matrix, then geolocated to geodetic coordinates (WGS84) using the aircraft's GNSS-derived position.



Laser raw range data



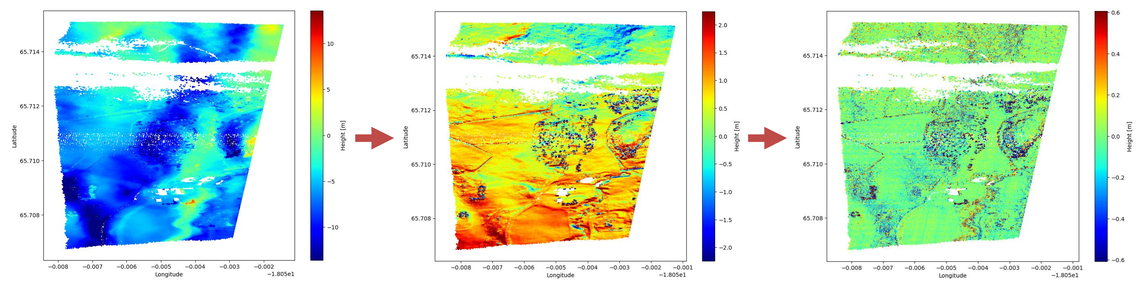
Geolocated elevations (DEM) after attitude compensation

3 Calibration

Although the laser scanner is intended to be mechanically aligned with the IMU on the stabilised platform, some residual misalignments in the three rotational degrees of freedom (roll, pitch, and yaw) must be characterised and compensated for before generating the output DEMs.

Method 1: Crossovers over natural areas

To characterise the offsets, a cross-over analysis is performed over some target areas. An optimisation algorithm has been implemented to find the set of offset angles that minimise the elevation differences between overlapping passes.

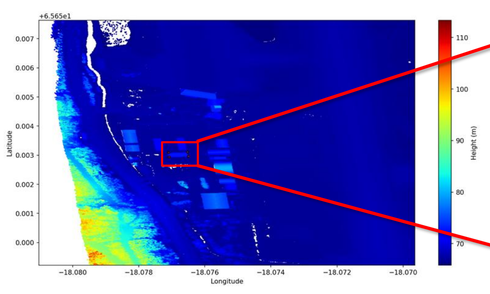


First iteration: Zero offsets — Intermediate iteration — Final iteration

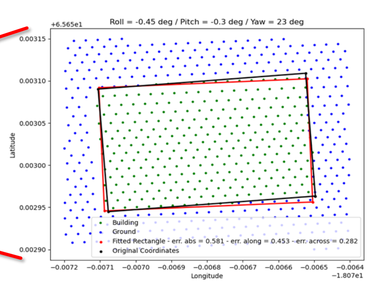
Method 2: Building with known coordinates

A site with known coordinates can also be used to calibrate the instrument. For the FFC, a building with known coordinates in the Akureyri airport is used to verify the calibration parameters previously found using the crossover approach. The along track error obtained is within requirements, since it's lower than 0.5 m.

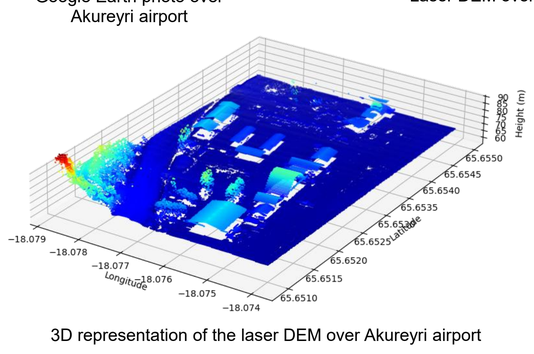
Google Earth photo over Akureyri airport



Laser DEM over Akureyri airport



Zoom in over the building with known coordinates



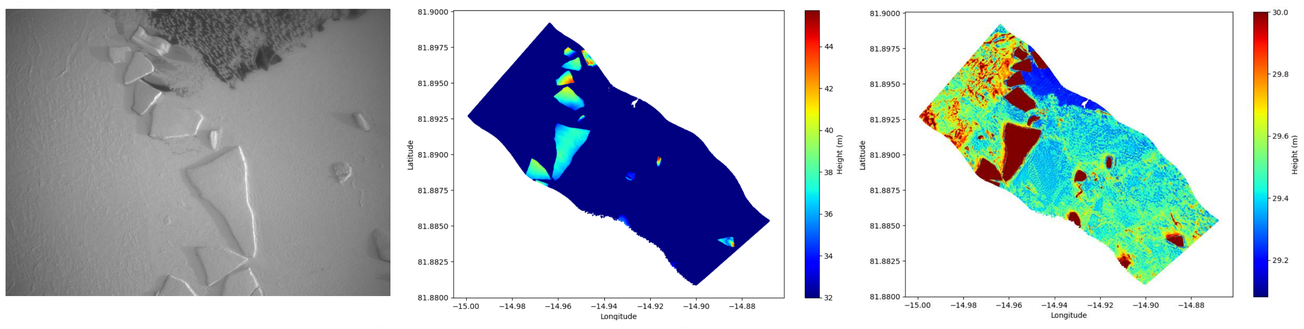
3D representation of the laser DEM over Akureyri airport

CALIBRATION PARAMETERS			
	Crossover #1 (Iceland)	Crossover #2 (Iceland)	Crossover #3 (sea ice)
Roll offset [deg]	-0.451	-0.461	-0.452
Pitch offset [deg]	-0.295	-0.289	-0.227
Yaw offset [deg]	0.255	0.290	0.577
Time offset [s]	-0.001	-0.0003	-0.008
RMSE [m]	0.329	0.390	0.303

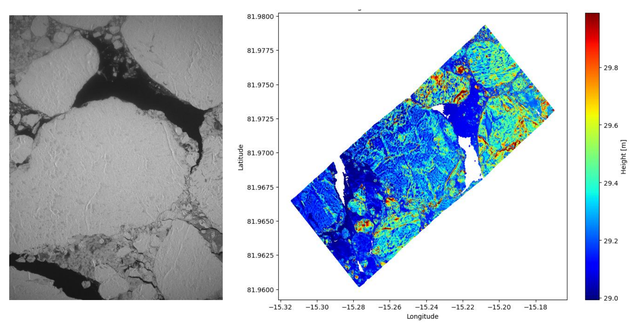
Example datasets during the Functional Flight Campaign

During September 2025, the CRISTALair instrument was tested on a series of flight campaigns over Iceland and Greenland. Several types of scenarios were overflown, such as sea ice, land ice, open ocean and inland waters. Here we present some examples of the resulting DEMs obtained with the laser scanner, along with the comparison of the images obtained by the optical camera.

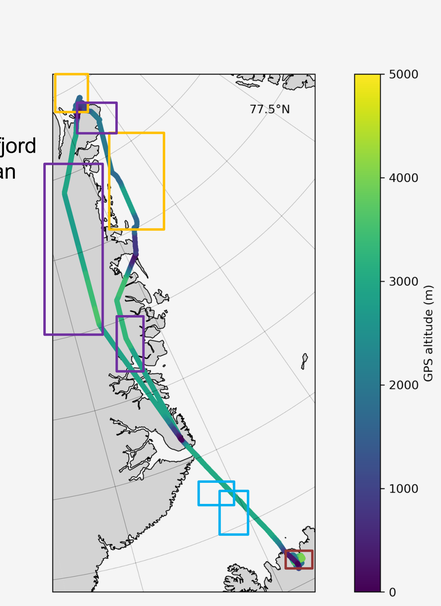
Sea ice



Icebergs trapped in sea ice at the coast of Greenland: optical camera (left), laser DEM with elevation scaled to highlight icebergs dimensions (centre) and laser DEM with the elevations scaled to highlight the sea ice roughness (right)

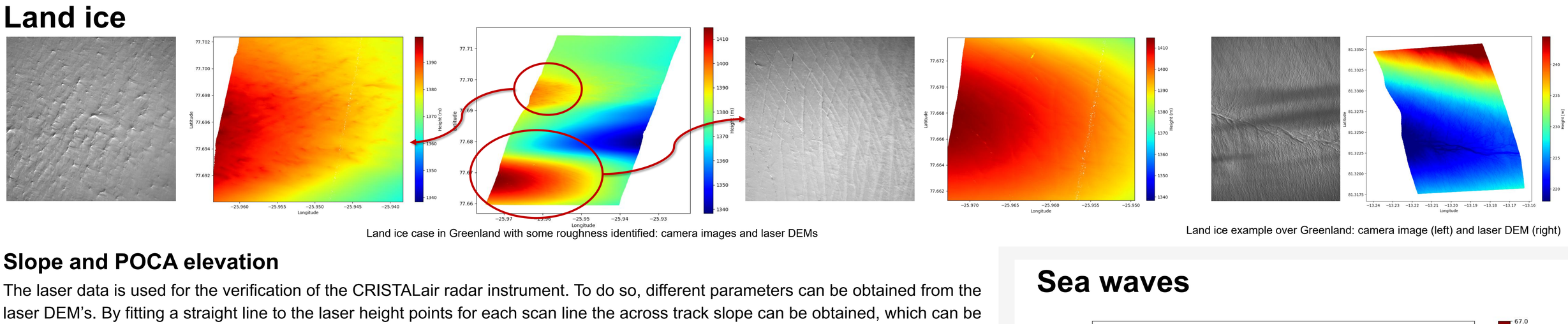


Sea ice with some big floes at the north of Greenland: camera image (left) and laser DEM (right)



Flight track of the Functional Flight Campaign

Land ice

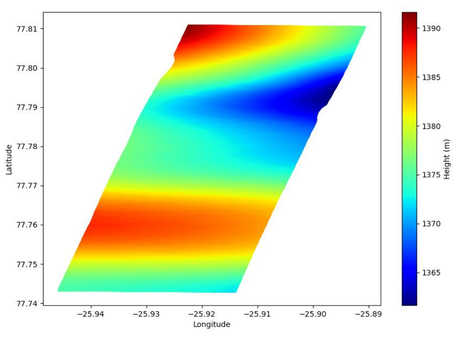


Land ice case in Greenland with some roughness identified: camera images and laser DEMs

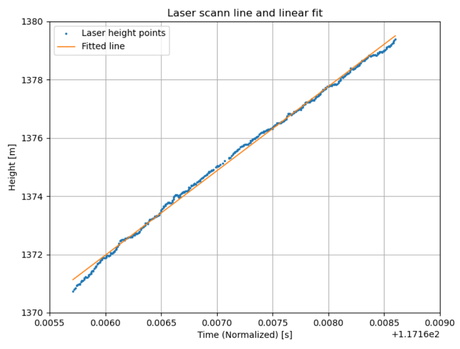
Land ice example over Greenland: camera image (left) and laser DEM (right)

Slope and POCA elevation

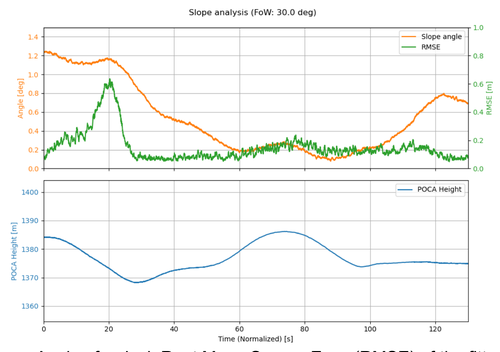
The laser data is used for the verification of the CRISTALair radar instrument. To do so, different parameters can be obtained from the laser DEM's. By fitting a straight line to the laser height points for each scan line the across track slope can be obtained, which can be compared to the radar's Angle of Arrival (AoA). The ultimate point is to estimate the elevation of the Point of Closest Approach (POCA). Following there is an example of such calculations:



Land ice laser DEM

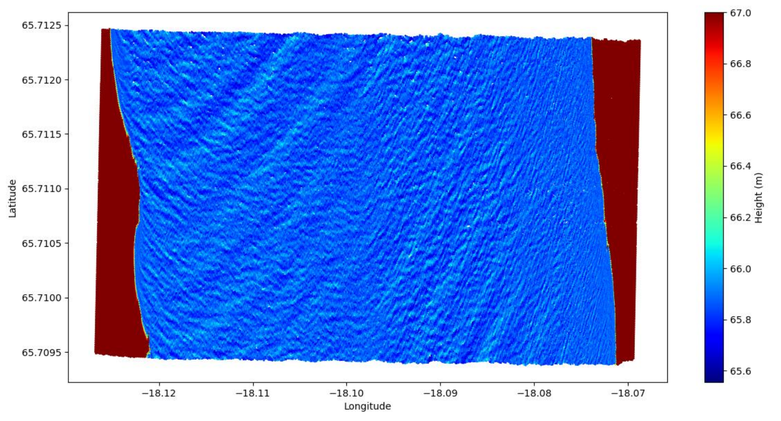


Example of linear fitting to laser scan line



Angle of arrival, Root Mean Square Error (RMSE) of the fitted line and POCA estimation for the same land ice track

Sea waves



Sea waves identified with the laser DEM when overflying the Akureyri fjord