DANISH NATIONAL SPACE CENTER

Comparison of Airborne Laser Scanning and D2P Radar Altimetry

Lars Stenseng[1] Rene Forsberg[1] Kristian Keller[1] Sine M. Hvidegaard[1] Carl Leuschen[2]

[1]Danish National Space Center, Juliane Maries Vej 30, DK-2100 Copenhagen , Denmark
[2]Applied Physics Laboratory, Johns Hopkins University, USA

contact:stenseng@spacecenter.dk

Introduction

The CRYOVEX (CRYOsat Validation EXperiment) campaign was the first airborne and in-situ campaign to prepare for CryoSat. One of the main objectives of the campaign was to collect simultaneous and collocated airborne laser and radar altimetry for understanding of the CryoSat measurements. The survey aircraft was equipped with an INS, three GPS receivers, a Riegl laser scanner which provides cross track scans and the 13.9 GHz APL D2P (delay/Doppler phase-monopulse) radar. The D2P radar has the same overall characteristics as the SIRAL (SAR/Interferometric Radar Altimeter) which will fly on CryoSat.

Overview of Collected Data

The campaign took place in the period from April 5th to April 21th 2003 and there was collected data for more than 50 hours in some 13 flights.

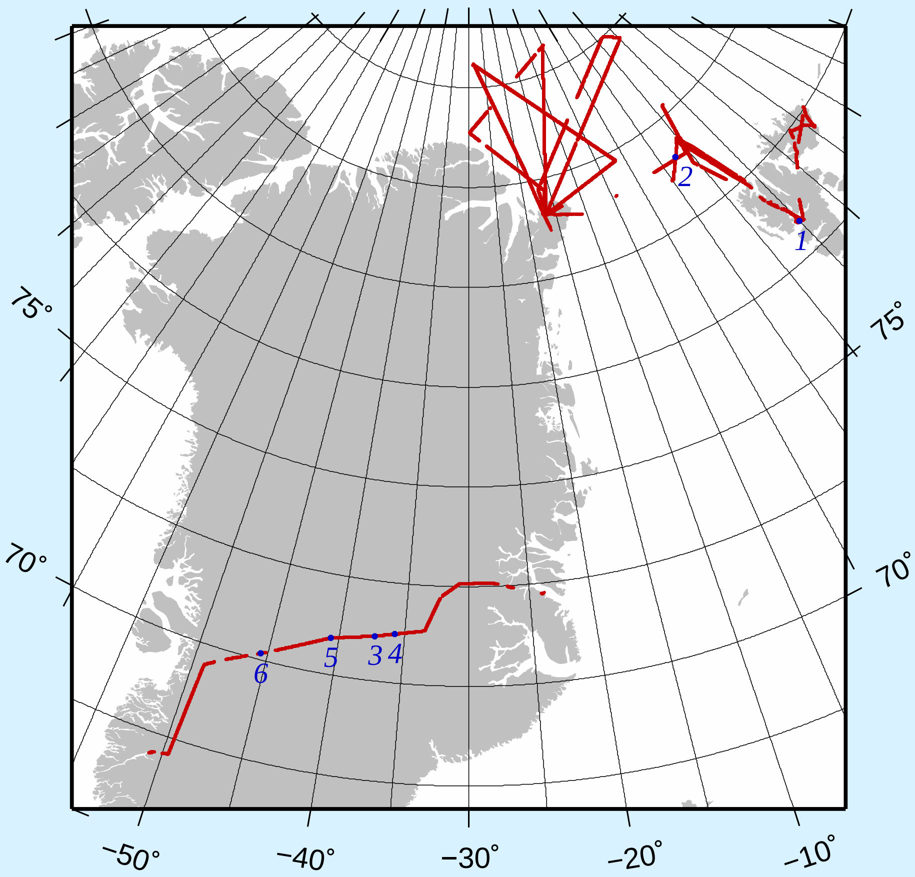

Fig. 1: Areas with collocated radar and laser altimetry

Besides radar and laser data, fotos were taken with a camera which pointed downwards. These fotos can help in visual classification of sea ice.

Laser Scanner Processing

The processing of the laser data involves the following steps:

1. Synchronize the laser data to GPS time.
2. Determine the orientation of the laser scanner relativ to the plane.
3. Extract time, mirror angle, range and returned power from the raw measurements.
4. Interpolate the combined GPS/INS solution to obtain position and attitude for each measurement.
5. Ground reference each measurement using three dimensional geometry.

Radar Processing

All radar data processing from level-1 to level-1b for this study was done by APL. Prosessing of the level-1b data is desribed below.

1. Extract complex waveform data and construct amplitude and angle waveforms.
2. Retrack amplitude waveforms to get a height estimat.
3. Determine offsets between radar and laser (see fig. 2a and 2b).
4. Ground reference retracked points using three dimensional geometry.

Several different retracking algorithmes has been used to estimate heights. For this analysis we have used a *half power of leading edge* algorithme but *first peak* was also found usefull.

Unfortunaly some syncronazion problems between the laser and the radar were found but not fully resolved.

Examples

Because water reflects both laser and radar from the same surface it is possible to determine offsets between the laser and the radar. These offsets have been applied to to all plots below. The calibration flight took place near Svalbard (see fig. 1 area 1).

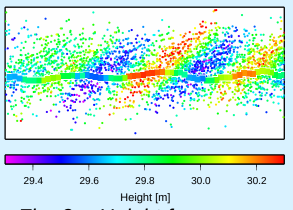

Fig. 2a: Height from scanner (dots) and radar (squares)

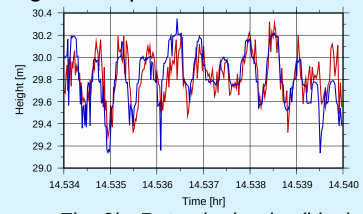

Fig. 2b: Retracked radar (blue) and averaged laser (red)

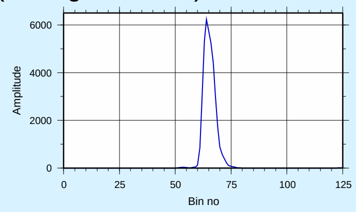

Fig. 2c: Typical waveform from open water

The second test area (see fig. 1 area 2) was over sea ice. There is a generaly a good corralation between the laser and the radar, but rifts and ridges are better resolved by the laser. For flat snow covered areas we find a slight difference between laser and radar derived heights, this indicates that the laser/radar combination can measure snow thickness.

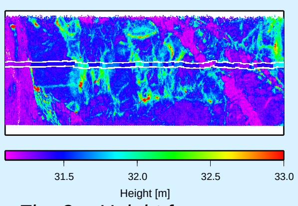

Fig. 3a: Height from scanner (dots) and radar (squares)

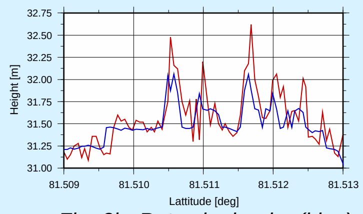

Fig. 3b: Retracked radar (blue) and averaged laser (red)

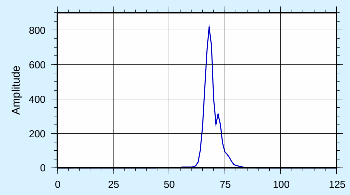

Fig. 3c: Typical waveform from sea ice

The third test area (see fig. 1 area 3) was near Summit Greenland and is a area with dry inland snow. The radar signal was found to penetrate 1 meter into the dry snow (see fig. 4b).

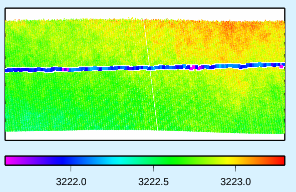

Fig. 4a: Height from scanner (dots) and radar (squares)

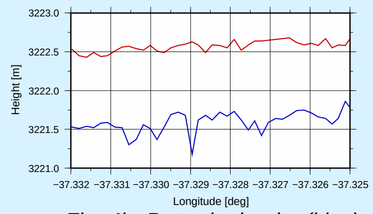

Fig. 4b: Retracked radar (blue) and averaged laser (red)

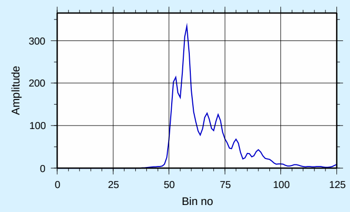

Fig. 4c: Typical waveform from dry inland snow

Annual Layers in Inland Snow

In the figure below one can clearly see five layers and these are thought to be annual layers showing the density difference in winter and summer snow. However a comparison of three profiles (see fig. 1 area 4, 5 and 6) from areas with different accumulation does not show a clear correlation between layer thickness in the profiles and the accumulation found by A. Ohmura and N. Reeh (*New precipitation and accumulation maps for Greenland*).

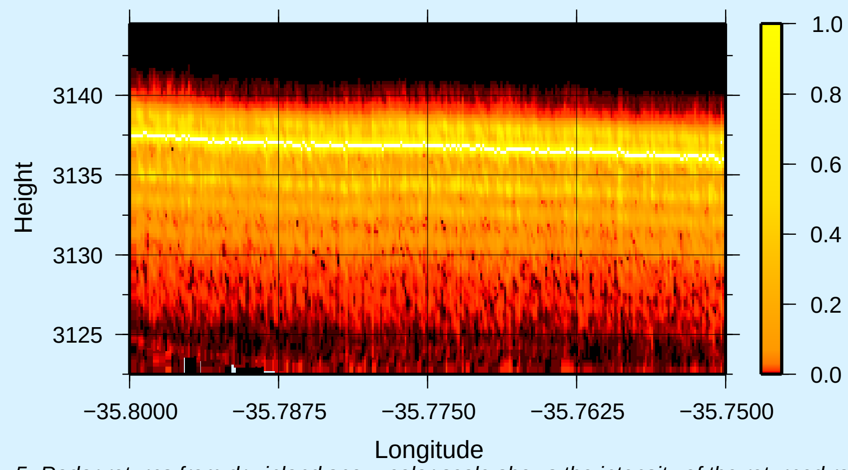

Fig. 5: Radar returns from dry inland snow, color scale shows the intensity of the returned radar signal (see fig. 1 area 4).

Conclusion and Future Work

We have found that even with a simpel retracker there is a good agreement between laser and radar derived heights over open water and sea ice. For two of the test areas (see fig. 2b and 3b) we find a std. dev. of 20 cm which is comparabel to the raw resolution of the radar. In areas with sea ice we see a slightly larger offset than over open water. This indicates that the radar/laser system can be used to determine snow depths in these areas. In areas with dry snow the radar penetrates up to a meter into the snow pack and detects internal layers, possibly showing annual accumulation.

We have found that there is a good correlation between laser and radar, but more in-situ measurements of snow on sea ice and snow density profiles in dry snow areas is needed to understand and develop the laser/radar combination for snow applications.