Combining Radar Altimetry and Lidar to Study Snow Accumulation

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contact: stenseng@space.dtu.dk Abstract no. NS11A-0165

Introduction

CryoSat-2 is an ESA satellite to be launched in spring 2009. The main purpose of the satellite is to measure sea ice thickness, which is a fast responding climate indicator. In earlier campaigns it was discovered that the a radar with frequency band similar to CryoSat could detect layering in the snow pack on the inland ice of Greenland.

Field campaign

In spring 2006 a major CryoSat-2 pre-launch campaign was carried out in the Arctic to obtain a calibration and validation dataset using laser, the ASIRAS radar and in-situ measurements. The ASIRAS, which mimics the CryoSat-2 radar, was mounted on an aircraft together with a laser scanner and support instruments throughout the five week long campaign.

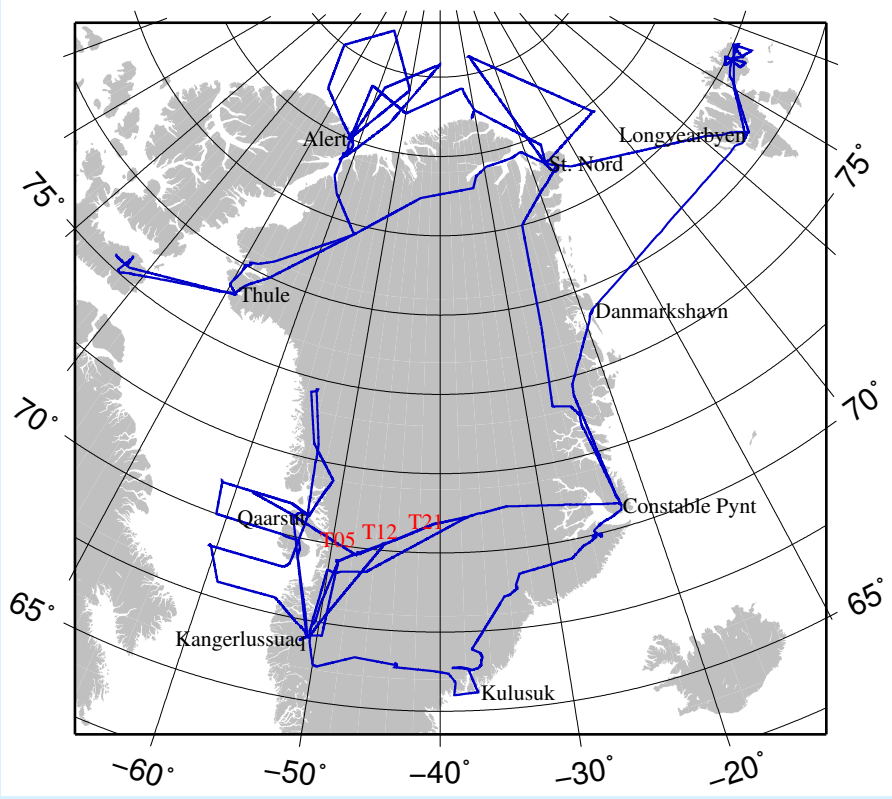

Figure 1: Flight route for the CryoVEx 2006 Campaign.

Several teams performed in-situ measurements at sites on the sea ice and inland ice in and around Greenland. The sites all had one or more radar corner reflector put up and performed measurements of snow properties.

Calibration of laser and radar

The laser scanner is calibrated using crossing overflights of a building with a known position and height. This calibration is possible because the laser has a narrow and well defined footprint. Since the radar footprint is much larger this method is useless for calibration of the radar, instead it is possible to use leads in the sea ice for the range calibration. This is possible because water and very thin ice will act as a mirror reflecting both laser and radar at the surface.

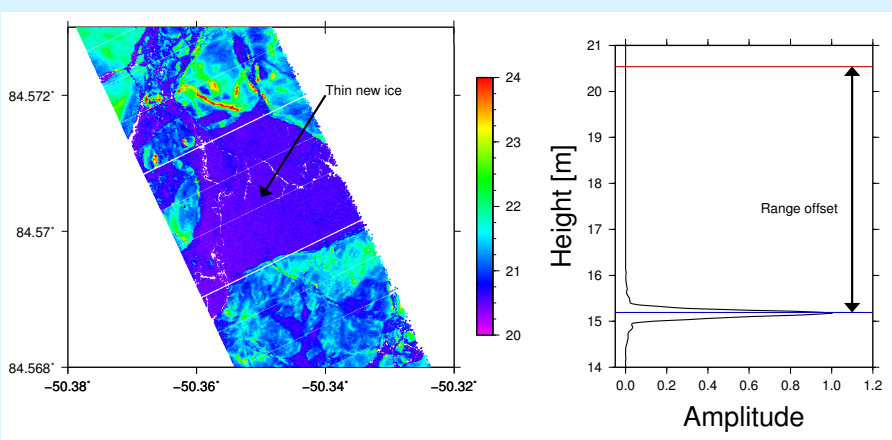

Figure 2: Using a lead to determine the radar range offset.

Accumulation layers in inland snow

Layers are formed in the snow pack by the changing seasons and is detectable several meters down. Below is examples the T05, T12, and T21 sites north-east of Kangerlussuaq on the so called EGIG line. The layers can be used to estimate the yearly accumulation at the site by combination with a density profile.

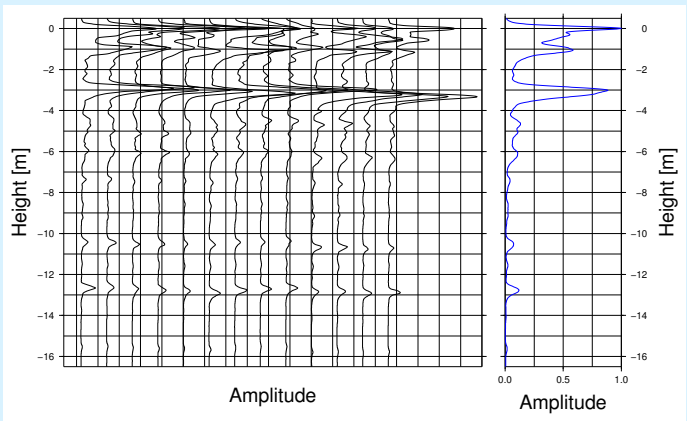

Figure 3: Annual layers in the Greenlandic inland ice, at the T21 site. The blue curve on the right is the average of the individual waveforms shown in black.

The snow conditions at the T21 site, situated at 2700 meters above sea level, enables the radar to penetrate several meters into the snow pack. Previous summer events is easily detectable down to 15 meters below the surface.

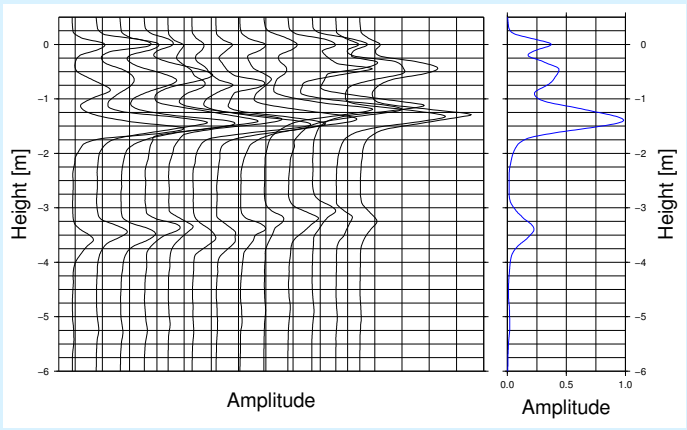

Figure 4: Annual layers in the Greenlandic inland ice, at the T12 site. In the plot the surface and four events show up.

The T12 site is situated at 2300 meter above sea level and the snow properties has clearly changed. The layering is now only detectable down to 6 meters below the surface.

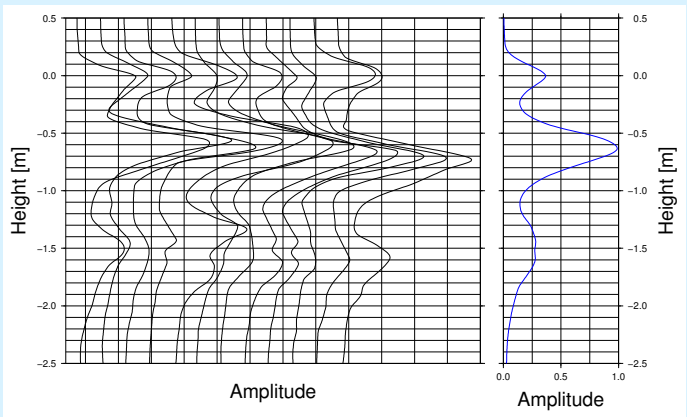

Figure 5: Annual layers in the Greenlandic inland ice, at the T05 site.

Further down the EGIG line we find the T05 site at 1900 meter above sea level. The more extreme summer temperatures here block the radar and layers are only detectable down to 3 meters below the surface.

Conclusion and Future Work

These first tests indicates that the radar can be used to estimate the snow accumulation. Future work will need to further validate the results with collected in-situ data and improve the retracking of the radar data. The in-situ data is also needed to convert the apparent depths to true depths and convert the measurements into water equivalents.

Ongoing work is trying to apply the same method to sea ice site, in order to evaluate the snow depth on sea ice.