The Cryosat land ice validation experiment CryoVex2004
Part I: ASIRAS vs. laser altimeter measurements

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Introduction:
The purpose of the CryoSat altimeter mission was to determine trends in the ice masses of the Earth over a period of ~3 years. Although the launch failed in October 2005 the scientific objectives of the CryoVex validation experiments are still unfurnished.

For redundant calibration purposes the German aircraft Polar 4 is equipped with a laser scanner, the ASIRAS instrument (Airborne SAR Interferometric Radar Altimeter System), a single-beam laser and two DGPS receivers.

The primary goal of CryoVex2004 was to provide coincident laser and interferometric radar altimeter measurements, in order to understand the penetration of CryoSat radar signal into polar sea ice and continental ice caps and to quantify uncertainty in the CryoSat measurements.

Processing:
For calibration and validation of ASIRAS a precise digital elevation model (DEM) of the measured profile is required. This DEM is calculated from the airborne Laser Scanner (ALS) data, which is measured with the Regl – LMSQ280 instrument. The reference DEM (ALS-DEM) is calculated on a 1x1 m grid using a trigrid delauny triangulation.

After DGPS and ALS L1 pre-processing, it is necessary to calibrate the measurement system. This includes corrections for possible time shifts and inevitable installation inaccuracies (squint angles) in the aircraft (see red box). This procedure is required for each device.

After applying corrections to the ALS and the Single Beam Laser (LD90) the calibration of the ASIRAS with the ALS-DEM is possible. For calibrating the ASIRAS and LD90 a couple of runway over flights were flown.

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During CryoVex 2004 two campaigns took place. Flights were performed in Svalbard across Austfonna (Figure 1), on the Greenland Ice Sheet along the EGRG line (Figure 3) and on Devon ice cap (Canadian Arctic, Figure 2).

For calibrating the system runway over flights and corner reflector cross flights were performed. We will demonstrate the extensive calibration processing flow (Figure 4) and focus at squint angle and time shift problems between the instruments.

Concept of the determination of squint angles:

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Concept of the determination of time shifts:

In defining squint angles cross flights over hangar buildings determine the squint angle correction. In defining squint angles cross flights over hangar buildings are performed. To minimize the distance between hangar edges determined in each cross flight a Newton approximation is applied, see Figure 6. Figures 7,8 are showing overlaid hangar buildings before and after applying the squint angle correction.

The obtained values are used as correction constants in the processing flow.

Validation of ASIRAS:
Flight activities during the CryoVex 2004 campaigns included over flights of corner reflectors (Figure 12). An example for the Austfonna kecap is shown in Figure 11. In Figure 13 a strong corner reflector response is visible in the power echo. The surface response echo is strongly disturbed and divided into two peaks, which results in a high uncertainty of tracking the surface. In this case the smaller, first peak was taken and the peak to peak difference is determined to 1.67 m. The ground team measured the corner reflector height above the snow surface with 1.56 m, which yields a penetration depth of the radar echo at Cry-3 of 0.11 m.

Calibration of ASIRAS:
In order to calibrate the ASIRAS instrument runways were chosen as target assuming no penetration for both the radar and the laser. The true color image at the right hand side of Figure 10 shows an overflight over the runway in Resolute Bay at May 2, 2004. The difference plot of ASIRAS and ALS-DEM subtrack surface elevation (Figure 10, left hand side box 2 and histogram) shows an constant offset of ~85 cm, due to unknown instrument characteristics (e.g. cable length). It is likely that the energy of the radar return is affected by echoes reflected from rough snow beside the runway. This as well as high roll affects the radar waveform and therefore reduces the quality of the retracted surface elevation.

The flow chart in Figure 4 shows the content of the whole processing scheme. In the following calibration/validation box two main tasks are of special importance:

- Determination of device dependent time shifts
- Determination of squint angles of ALS (airborne laser scanner) and LD90 (single beam laser)

In defining time shifts a cross correlation of profile intervals of GPS-derived parameters and true instrument parameters (e.g. pitch rate, vertical velocity, rate of change in elevation ) are performed. Second method, a Newton approximation between ALS-DEM and derived elevation, is used only for ASIRAS and LD90 (see Figure 5).

Figure 7 shows the Ilulissat runway before and after time shift correction. In defining squint angles cross flights over hangar buildings are performed. To minimize the distance between hangar edges determined in each cross flight a Newton approximation is applied, see Figure 6. Figures 7,8 are showing overlaid hangar buildings before and after applying the squint angle correction.

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