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Studies of Austfonna ice cap (Svalbard) using radar altimetry with other satellite techniques

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Austfonna - largest ice cap in the Eurasian Arctic

Austfonna - 8120 km$^2$, Vestfonna - 2500 km$^2$
ETONBREEN: RECENT CHANGES
FROM SPOT

Etonbreen + Basin 03:
continuous rapid retreat


<table>
<thead>
<tr>
<th>Period</th>
<th>Change, km²</th>
<th>Rate, km²/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/04/1987-28/07/1988</td>
<td>-0.75</td>
<td>-0.58</td>
</tr>
<tr>
<td>28/07/1988-29/07/1991</td>
<td>-3.04</td>
<td>-1.01</td>
</tr>
<tr>
<td>29/07/1991-19/07/1993</td>
<td>-1.42</td>
<td>-0.72</td>
</tr>
<tr>
<td>19/07/1993-28/03/1998</td>
<td>-2.25</td>
<td>-0.48</td>
</tr>
</tbody>
</table>

Data quality control:
Non-blank values of backscatter and range in Ku band, heights more than -1 m above the geoid.

Number of observations:
- 25-31
- 20-24
- 15-19
- 10-14

Eastern coast - few data (altimeter locked), central part - OK

Number of observation decreases in summer (melting)
Orbit changes across track are much larger than distance between 18 Hz measures (1500 m vs 400 m)

Use of latitude or longitude for study of temporal changes is misleading

Solution:
Choosing one cycle as reference and referring data for each cycle to the nearest reference point

Location of 18 Hz ENVISAT points for cycles 10 to 36. Track 20.
Height: good relation to DEM, temporal variability low on top, high on slopes

Backscatter: low values for ice, low temporal variability

Haight (Ku) Backscatter (Ku)
SNOW DEPTH

GR ratio: linear relation to snow depth

ENVISAT: maximal values NE, GPR - NE and SE

NPI Ground Penetrating Radar (GPR) snow depth (2004) and interpolated map. Courtesy of A. Taurisano, NPI
TEMPORAL VARIABILITY ALONG THE TRACK

Backscatter: high values in summer near the ice edge (melting), low values in winter on top

dTB - strong melting signal in summer
Mean height (mm relative to reference ellipsoid) in Ku band for track 853.

Opposite changes (swinging mode) before and after top of AID. No real seasonal signal, but something intriguing is evident...

Anomalies in mm (from median values for cycles 11 to 31) of height in Ku band for track 853.
Artefact related to changes in orbit over topography!

INFLUENCE OF ORBIT CHANGE ON ALTIMETRIC MEASURES

Anomalies of Height in Ku band, color scale is the same as previous slide.
SLOPE AND TOPOGRAPHY INFLUENCE

Sloping and hilly terrain: complicated radar echo

Simulation of radar return echo at various time steps for different topography

CASE 1: Flat surface

CASE 2: Sloping from SW to NE

CASE 3: Sloping from SW to NE with noise

CASE 4: Hilly terrain

CASE 5: Hilly terrain at the sea border

Nadir line (shortest distance in theory)

Case 2: first echo comes not from the nadir point

Shortest distance in reality
SLOPE AND CURVATURE INFLUENCE

Comparison of measured height in Ku band vs NPI DEM

Altimeter locked

Overestimation on slopes

Theoretical line (Measured = DEM)

Good agreement, topography influence is low
SLOPE AND CURVATURE CORRECTIONS

Altimeter X and Y position

DEM

DEM subset in +/−20 km direction from X and Y

Approach: for a given DEM subset approximate (least square solution)

\[ H_{\text{dem}} = ax^2 + by^2 + cx^y + dx + ey + f \]

Coefficients \((a, b, c, d, e, f)\)

Slope and curvature values for a given DEM subset

Three ERS-1 and ERS-2 tandem pairs from SPRI

DEM SOURCE 3: SPOT STEREO

Austfonna (Etonbreen region): stereo pairs for 1987 (SPOT1) and 1991 (SPOT2) from the ISIS project 0506-778
ITERATIVE APPROACH: SIMULATED AND MEASURED RA DATA

Correcting errors due to DEM inclination plane