Airborne EM Sea Ice Thickness Sounding

Forward Modelling & Hardware Developments

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Airborne Sea Ice Thickness Sounding

- Frequency: 4.09 kHz
- Coil Spacing (HCP): 2.77 m
- Sample Interval: 10 Hz

Diagram showing a helicopter with antennas and a 3D model of the electromagnetic parameters:
- Air
- Snow
- Sea Ice
- Sea Water
- Non-conductive
- Conductive

Point Spacing: 3-4 m

Tow-Cable & Power-Transfer

Wireless Communication

ca. 20 m

10 - 15 m
## Limitations of 1D Approach

<table>
<thead>
<tr>
<th>1D Assumption</th>
<th>Reality</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layers of sea ice and snow can be described as level plates</td>
<td>Common ice deformation zones show high ice thickness variability on sub-footprint scale</td>
<td>1. <strong>Estimate</strong> misinterpretation of local 1D ice thickness</td>
</tr>
<tr>
<td>Sea ice is a non-conductive medium</td>
<td>Young Pressure ridges consists of blocky structures with significant brine inclusion</td>
<td>2. <strong>Bias of mean sea ice thickness on longer profiles</strong></td>
</tr>
</tbody>
</table>
Comsol Multiphysics
  – Finite Elements

Forward Modelling of Inphase/Quadrature

Interpretation with 1D Approach
  ▶ Apparent 1D ice thickness vs. specified (true) ice thickness
Model Validation

- Numerical 1D Solution vs. 3D Halfspace model

- Variable vertical offset between coil plane and halfspace interface
  - Small systematic bias

\[
\frac{H_s}{H_p} = -r^2 \int_0^\infty \lambda R_1 \cdot e^{-2\lambda h_0} \cdot f(\lambda r) d\lambda
\]
Porosity of Blocky Ice Structures

- Relevant parameter for EM
  - DC conductivity

- Ridge parameter: Porosity
  - Blocksize
  - Percolation

- Result of random geometries very close to Archies Law (First-year sea ice)
Mean Thickness (m)

- Center profile: 3.07
- Average Footprint: 3.11
- 3D Model: 3.09

Result of forward model

Simulated 3D ice draft
Part II  New Developments towards Range Improvements
### Basler BT67 (DC3-Turbo)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude Bird</td>
<td>50</td>
<td>ft</td>
</tr>
<tr>
<td>Altitude Airplane</td>
<td>200</td>
<td>ft</td>
</tr>
<tr>
<td>Cable length</td>
<td>225</td>
<td>ft</td>
</tr>
</tbody>
</table>
Airborne EM : Maiden Voyage

3D Forward Model
Developments
Conclusion
• **Airborne EM (towed system)**
  – State of the Art for regional sea ice thickness surveys
  – Significant range improvements with utilizations of airplanes

• **1D Interpretation**
  – Underestimation of maximum sea ice thickness: up to 50%
  – Mean sea ice thickness: Conserved quantity

• **Outlook**
  – Porosity information of ridges desirable
  – *Ideas for EM parameter changes welcome!*