SEG/AGU JOINT WORKSHOP

Enhanced Sea-Ice Thickness Retrieval with Multi-Frequency Electromagnetic Devices

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Photo: David Ball, NRL
- Motivation
- Development of MAiSIE
- First data
Motivation

Development of MAiSIE

First data
Sea ice

Motivation

Development

First data

Radiation Balance

Salinity

Ocean ↔ Atmosphere

Biology

Marine Operations
Sea-ice thickness

**Indirect methods**

**Draft**
- AWI

**Freebord**
- ESA
- R.Ricker, AWI

**Direct methods**

**Total ice plus snow thickness**
- CDR
- NRL

Motivation  | Development | First data
Airborne Electromagnetics (AEM) - 1D approach

Method is based on the contrast of electrical conductivity between ocean water and sea ice

\( h_l \) Measured with laser altimeter

\( h_0 \) Secondary \( H_S \) to primary \( H_P \) magnetic field (Phase and Amplitude, In-phase and Quadrature) can be related to \( h_0 \)

\( h_0 - h_l \) Sea-ice thickness \( Z \)
### 1D approach

#### Technical realisation
- 1 transmitter coil
- 1 receiver coil
- 1 frequency (4kHz)

#### 1D Assumption
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<th>Limitation</th>
<th>Objectives</th>
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<td><strong>More accurate sea ice thickness estimation for deformed ice</strong></td>
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1D approach

Objectives

More accurate sea ice thickness estimation for deformed ice

Pressure ridge keel volume estimate

Platelet-ice thickness
**1D Approach**

**Technical Realisation**
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**Platelet-Ice thickness**
1D approach

ISW: Ice Shelf Water
mWDW: modified Warm Depth Water

Motivation
Development
First data
2D approach

Technical realisation of MAiSIE, the Multi-sensor Airborne Sea-Ice Explorer

3 axis receiver

Frequency

Attitude

Temperature

→ 3D information about sea ice

Broadband 0.5-8 kHz

→ Variable sounding depth

→ Better control of typical error sources

Measurements inside the EM-Bird (receiver, amplifier, …)
Summary MAiSIE

Existing AWI systems

- 1 frequency (4 kHz)
- 1 component receiver
- GPS
- 1D processing

MAiSIE

- Broadband 0.5 - 8 kHz
- 3 component receiver
- GPS, INS, temperatures, space for laser scanner
- 2.5D FE inversion
Summary MAiSIE

Existing AWI systems

- 1D representation of sea ice
- One sea ice layer
- Underestimation of sea-ice pressure ridges

MAiSIE

- 2D representation of sea ice → smaller scale than footprint
- One or more ice layers with variable conductivities
- Better control of typical error sources (attitude error, nonlinear system drift)
First tests with MAiSIE

SIZONet campaign
Barrow, Alaska
April 2012

Polarstern cruise
Arctic Ocean
August-October 2012
Field campaign SIZONet in Barrow, Alaska (April 2012)

- Raw data, 4090 Hz
- Temperature measurements inside the EM-sensor
  \rightarrow Improvements of signal quality and drift correction
Field campaign SIZONet in Barrow, Alaska - Data quality

- 4090 Hz
- Drift corrected data
- Comparison of 1D model and data over sea ice and open water

Field campaign SIZONet in Barrow - Data quality

- 1D sea ice thickness for different frequencies over sea ice and open water
- Higher frequencies are within ± 10cm over open water
Inversion software NGI “ngi25em”

- Adapt “ngi25em” to airborne EM sea ice case
- Mesh for forward model, different positions of receiver and transmitter
- 1D and 2.5 D FE forward model are in good agreement (<10ppm)
Field campaign SIMBIS, November 2012, Atka Bay, Antarctic

- Detection of platelet ice with the multi-frequency handheld EM device GEM-2
- Validation data sets from drillings, under-ice inspection system, ice cores
- AEM campaign with MAiSIE in Weddell Sea 2013
Transect GEM-2, Atka Bay

TerraSAR-X 15.11.2012

Motivation

Development

First data
Upcoming field campaign November 2012 in the Antarctic Transect GEM-2, Atka Bay

Motivation

Development

First data
Grid over ridge structures
GEM-2 data processing (any experiences?)
AEM campaign in 2013
Summary and Outlook

AEM MAiSIE multi-frequency and multi-component datasets
- Barrow 2012
- Central Arctic Ocean 2012

GEM-2 multi-frequency dataset (platelet ice, ridge)
- Atka Bay 2012

Hardware
- MAiSIE hardware changes: Reducing drift und noise

Data analysis
- Correcting for pitch, roll and yaw
- Completion of inversion software
- Processing of existing AEM data sets
- Processing of GEM-2 data set

Campaigns
- AEM campaigns 2013 (Barrow and Weddell sea)
Thank you