SEG/AGU JOINT WORKSHOP

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

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1 AWI

2 JACOBS UNIVERSITY

3 NGI

Photo: David Ball, NRL

- Motivation
- Development of MAiSIE
- First data

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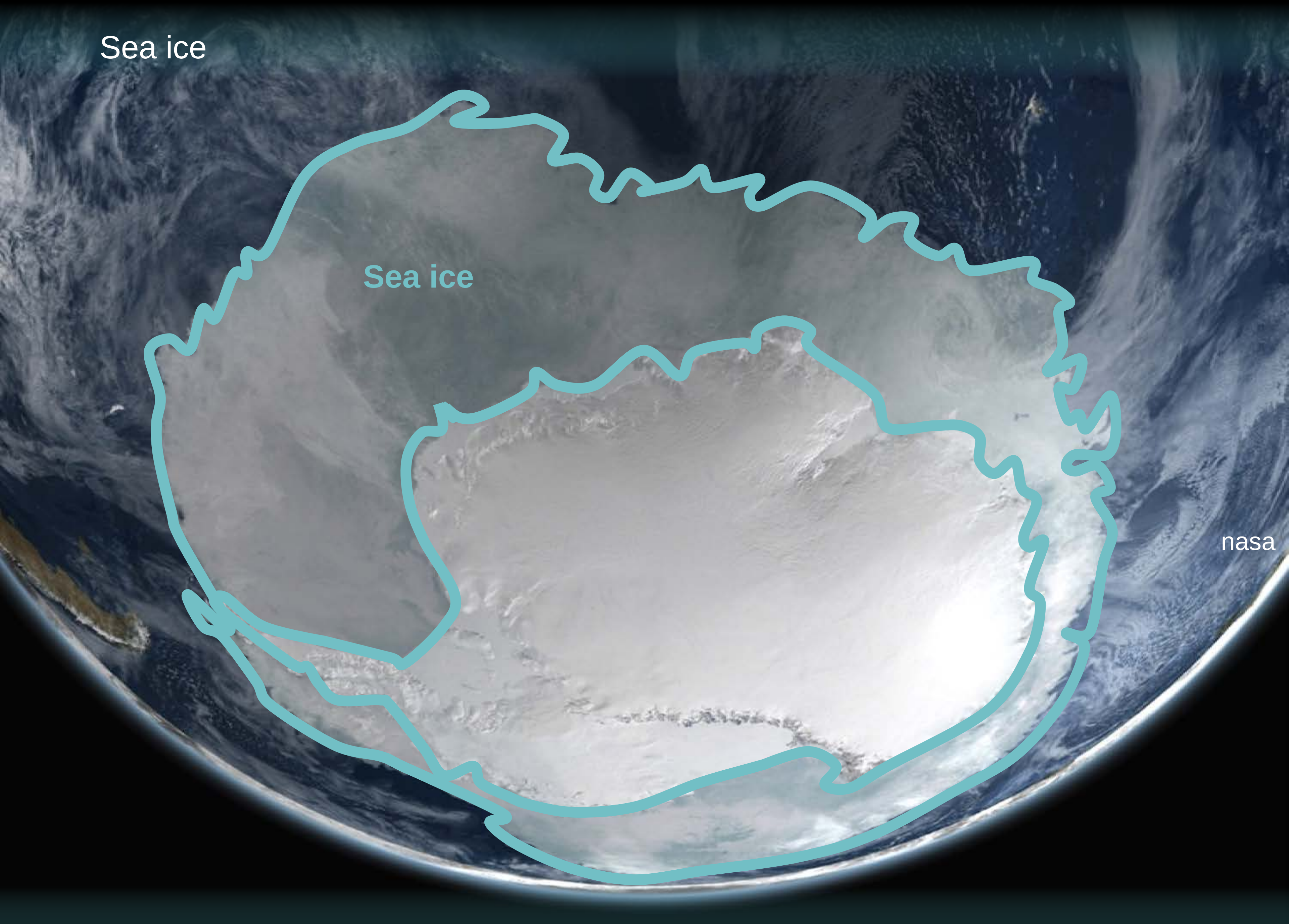
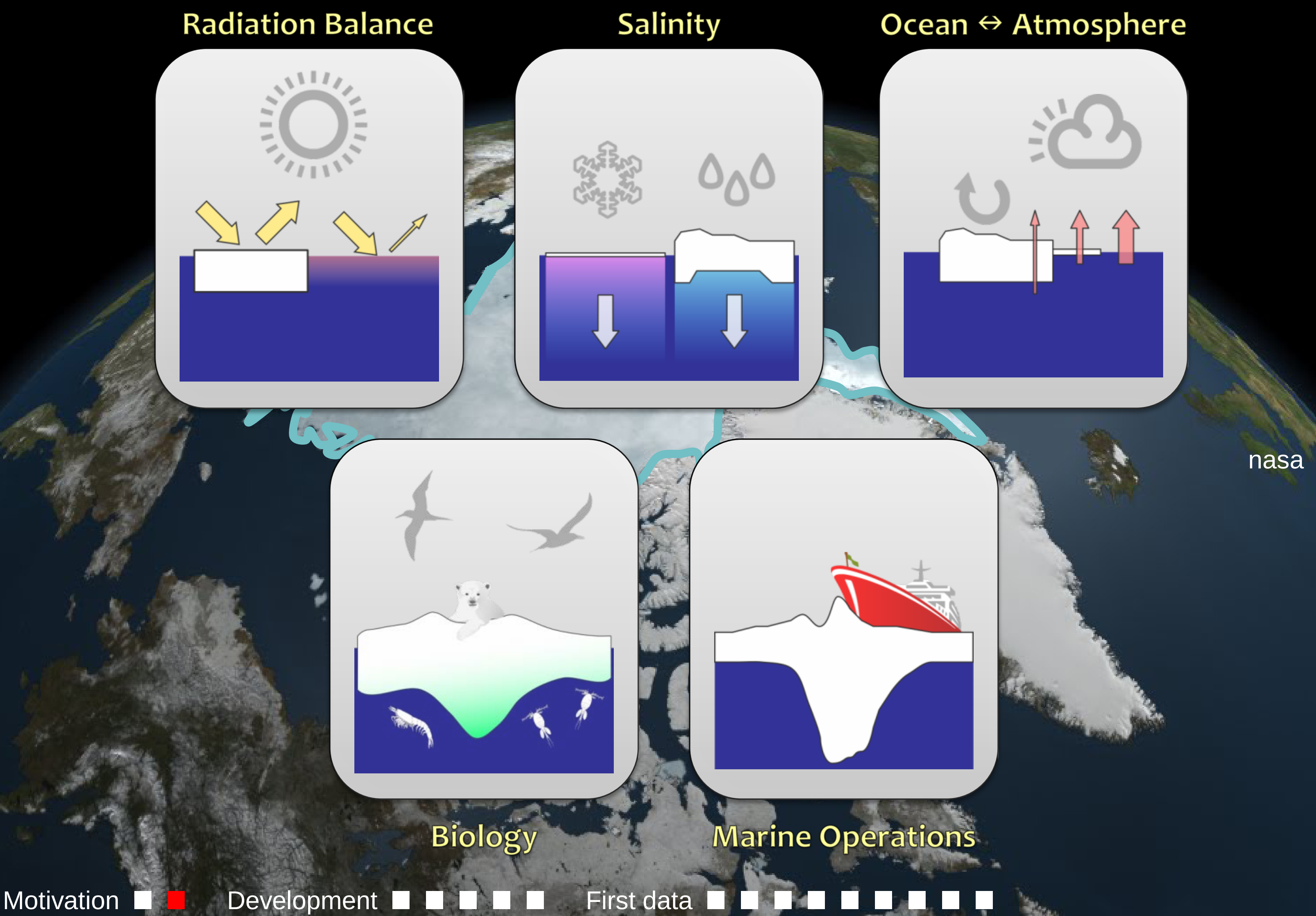
Sea ice

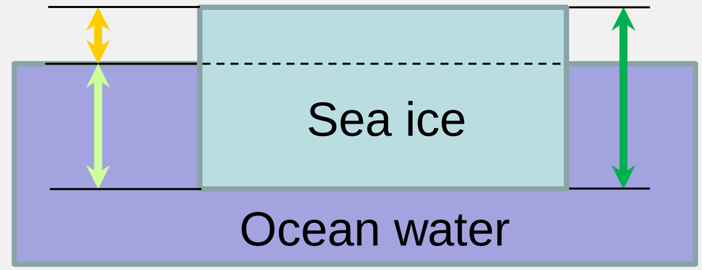


Sea ice

Sea ice

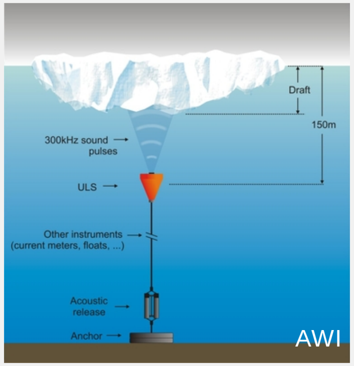

Radiation Balance
Salinity
Ocean ⇔ Atmosphere
Biology
Marine Operations
nasa
Motivation
Development
First data

Sea-ice thickness

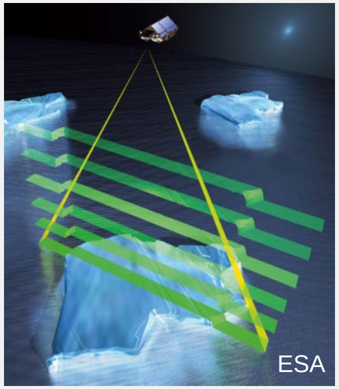


Indirect methods

Draft



Freebord

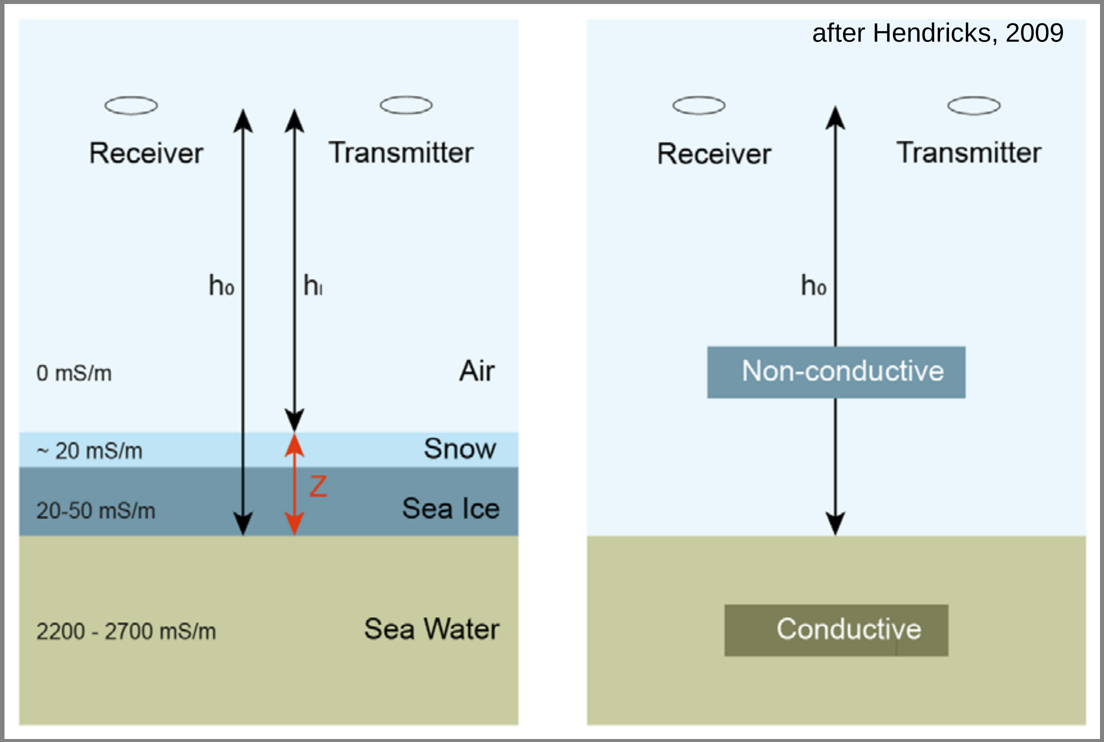


Direct methods

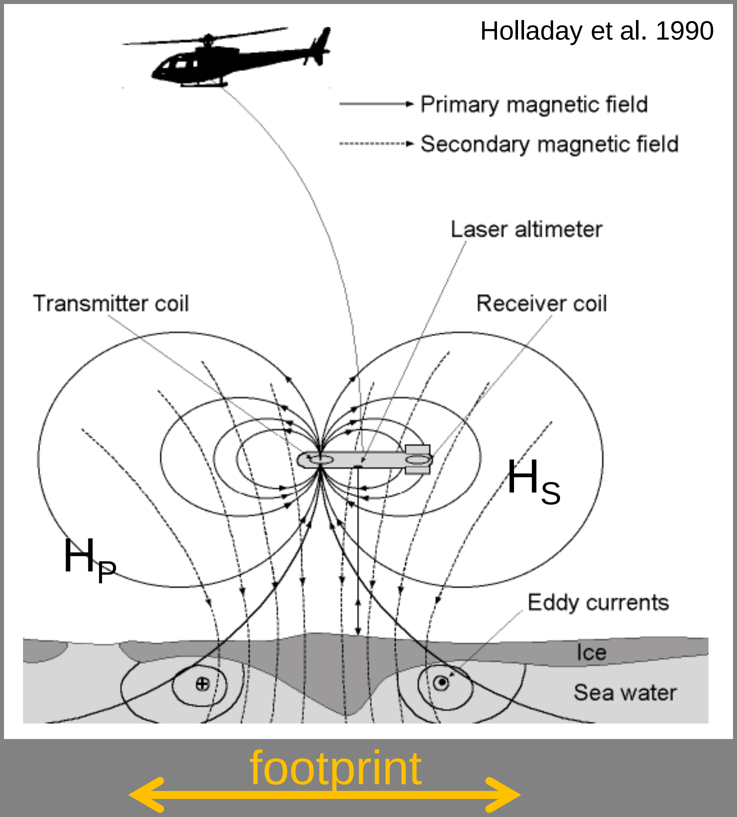
Total ice plus snow thickness

NRL

Airborne Electromagnetics (AEM) - 1D approach



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



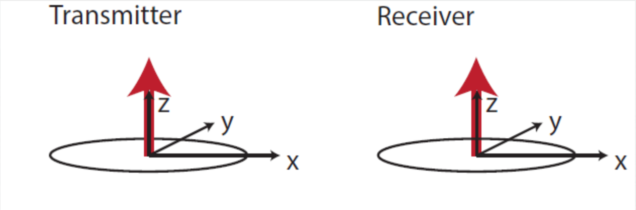
h_l Measured with laser altimeter

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**

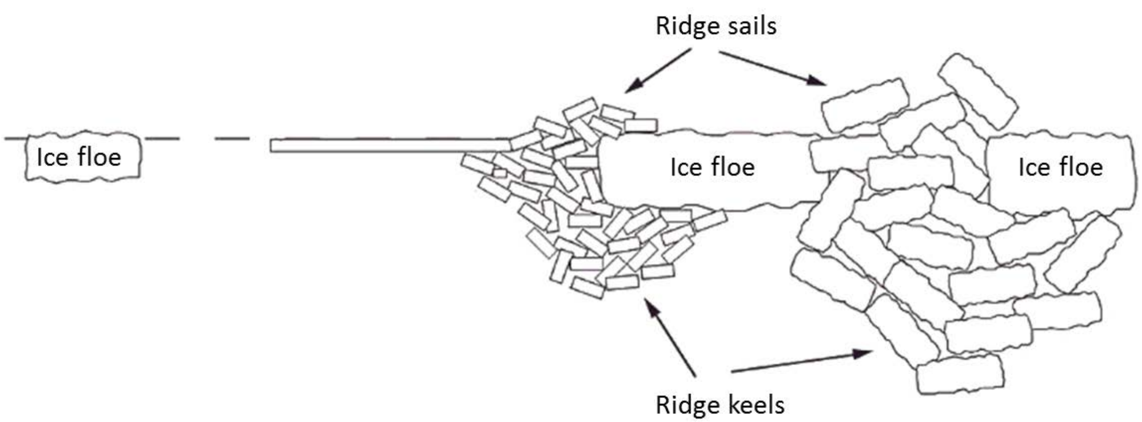
1D approach

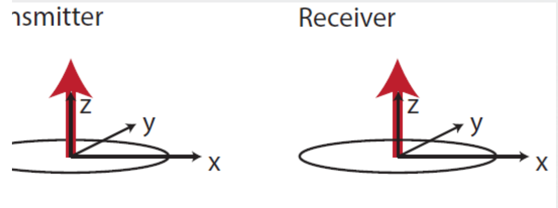
Technical realisation	
	1 transmitter coil 1 receiver coil 1 frequency (4kHz)



1D Assumption	Limitation	Objectives
The sea ice layer is described as a level plate	Ice thickness variability on sub-footprint scale can not be resolved (e.g. pressure ridge)	**More accurate sea ice thickness estimation for deformed ice**
Sea ice is a non-conductive medium	The variable conductivity in the ice layer gives a bias in the 1D ice thickness estimates	**Pressure ridge keel volume estimate** **Platelet-ice thickness**

1D approach





Objectives

More accurate sea ice thickness estimation for deformed ice

Pressure ridge keel volume estimate

Platelet-ice thickness

1D approach

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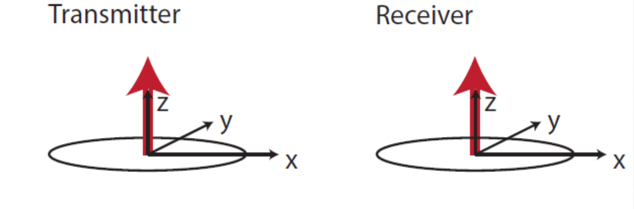

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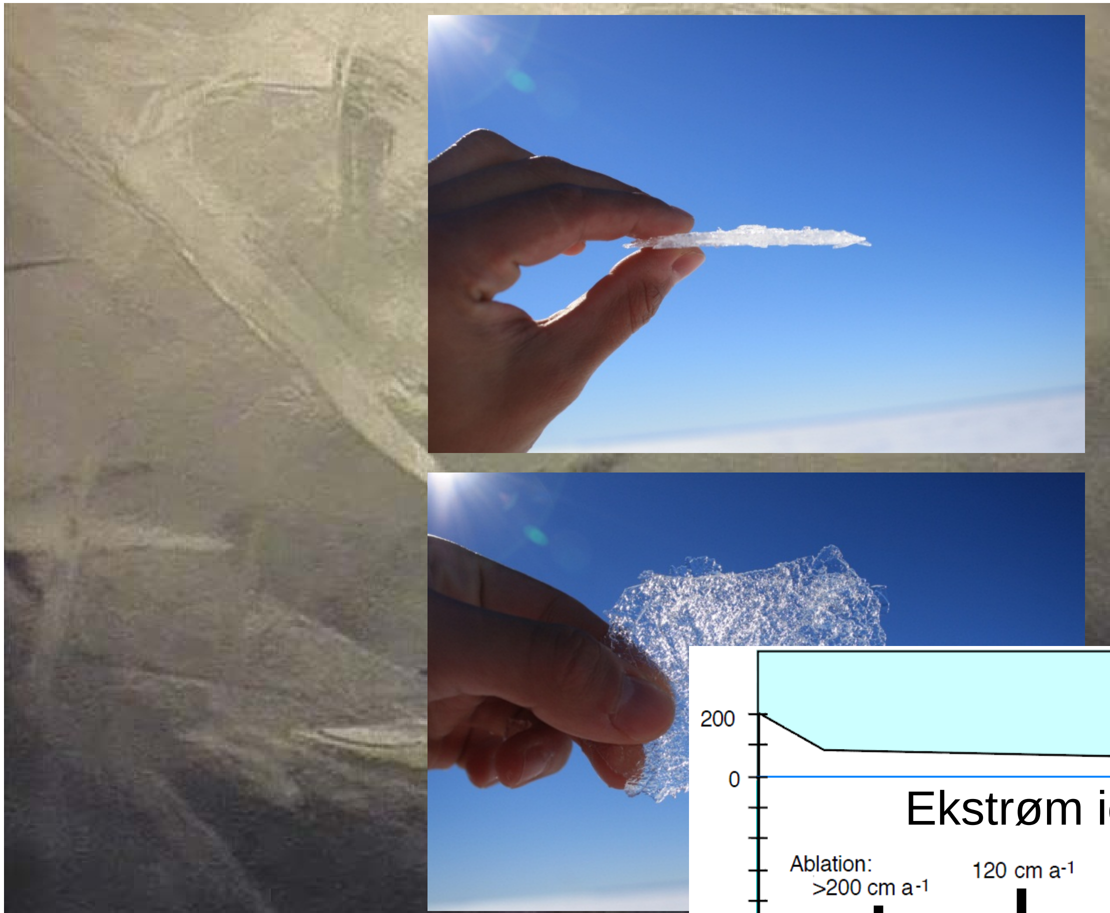
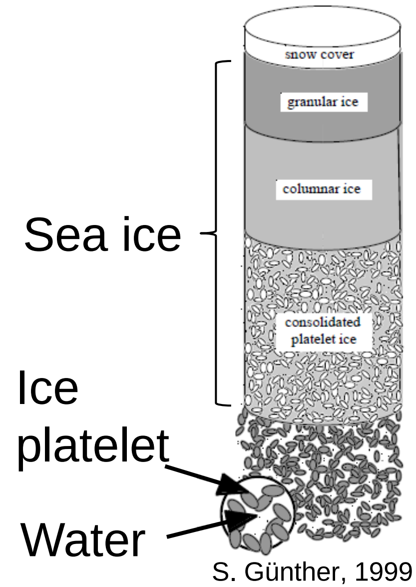
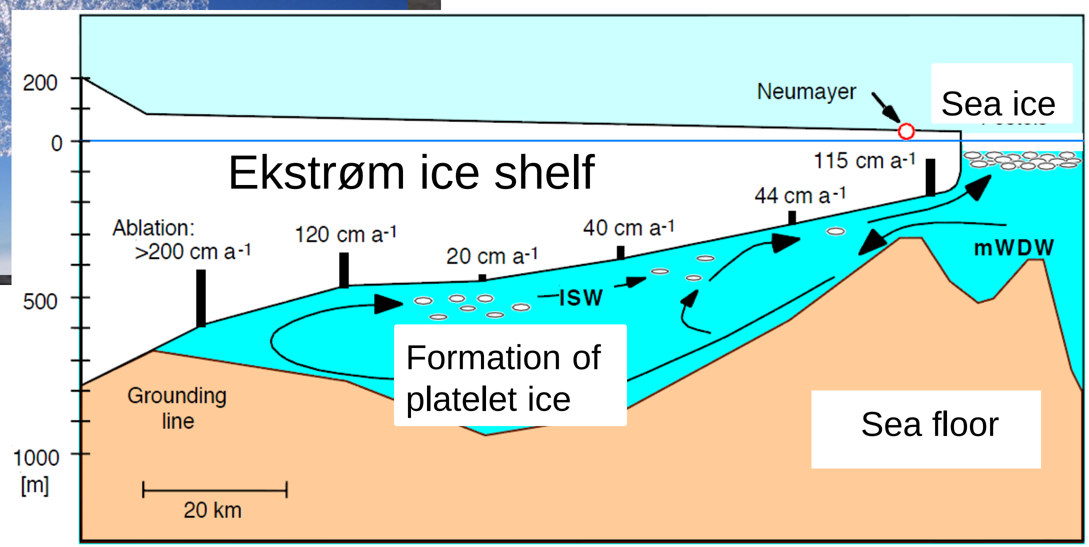
1D approach



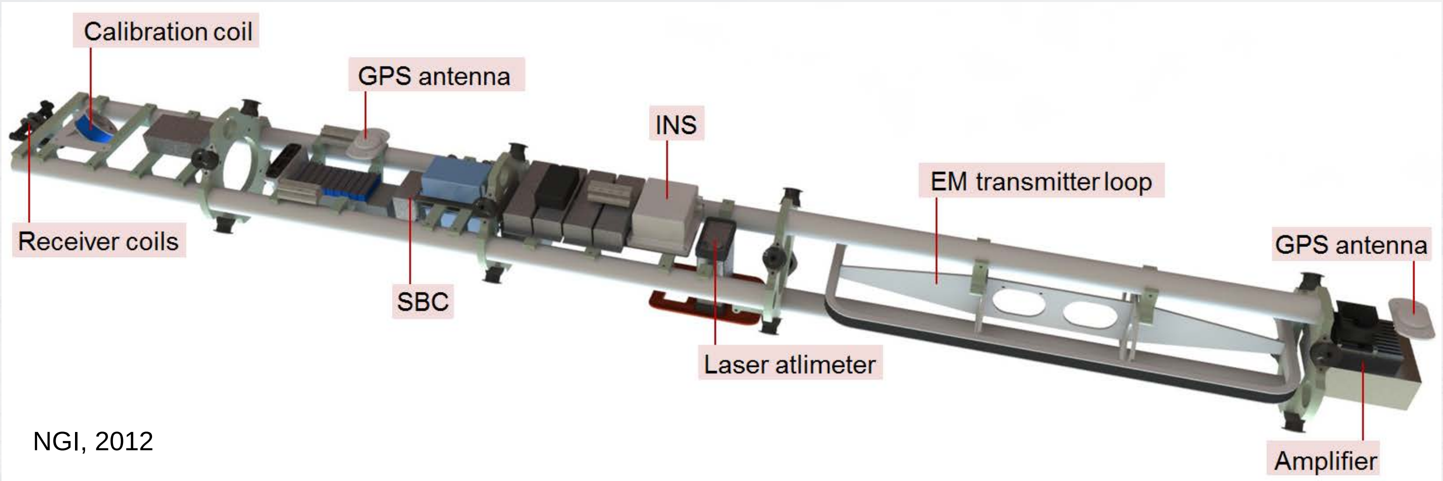




ISW: Ice Shelf Water
mWDW: modified Warm Depth Water

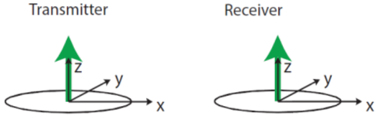
S. Hendricks

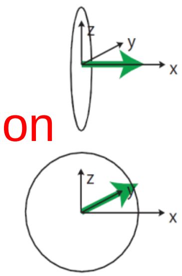
Technical realisation of MAiSIE, the Multi-sensor Airborne Sea-Ice Explorer



NGI, 2012

3 axis receiver





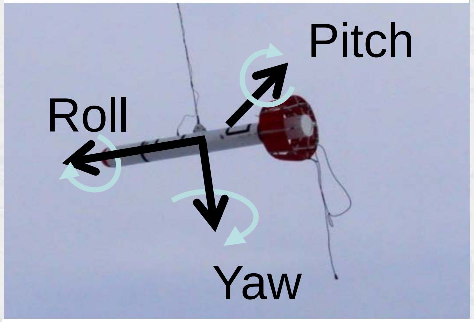
→ 3D information about sea ice

Frequency

Broadband 0.5-8 kHz

→ Variable sounding depth

Attitude



Temperature

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

→ Better control of typical error sources

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

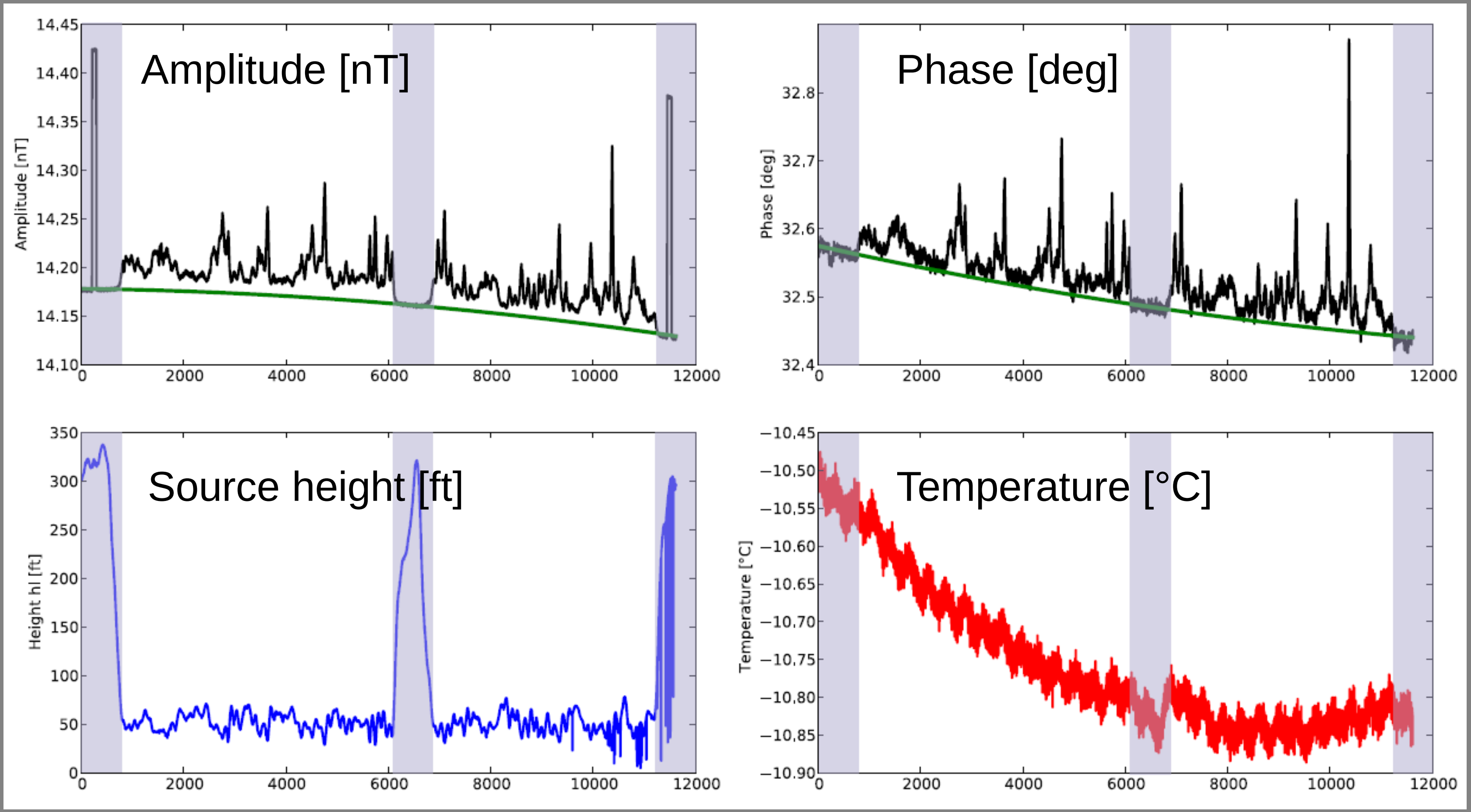
- 2D representation of sea ice → smaller scale than footprint
- One or more ice layers with variable conductivities
- Better control of typical error sources (attitude error, nonlinear system drift)

First tests with MAiSIE

Polarstern cruise
Arctic Ocean
August-October 2012

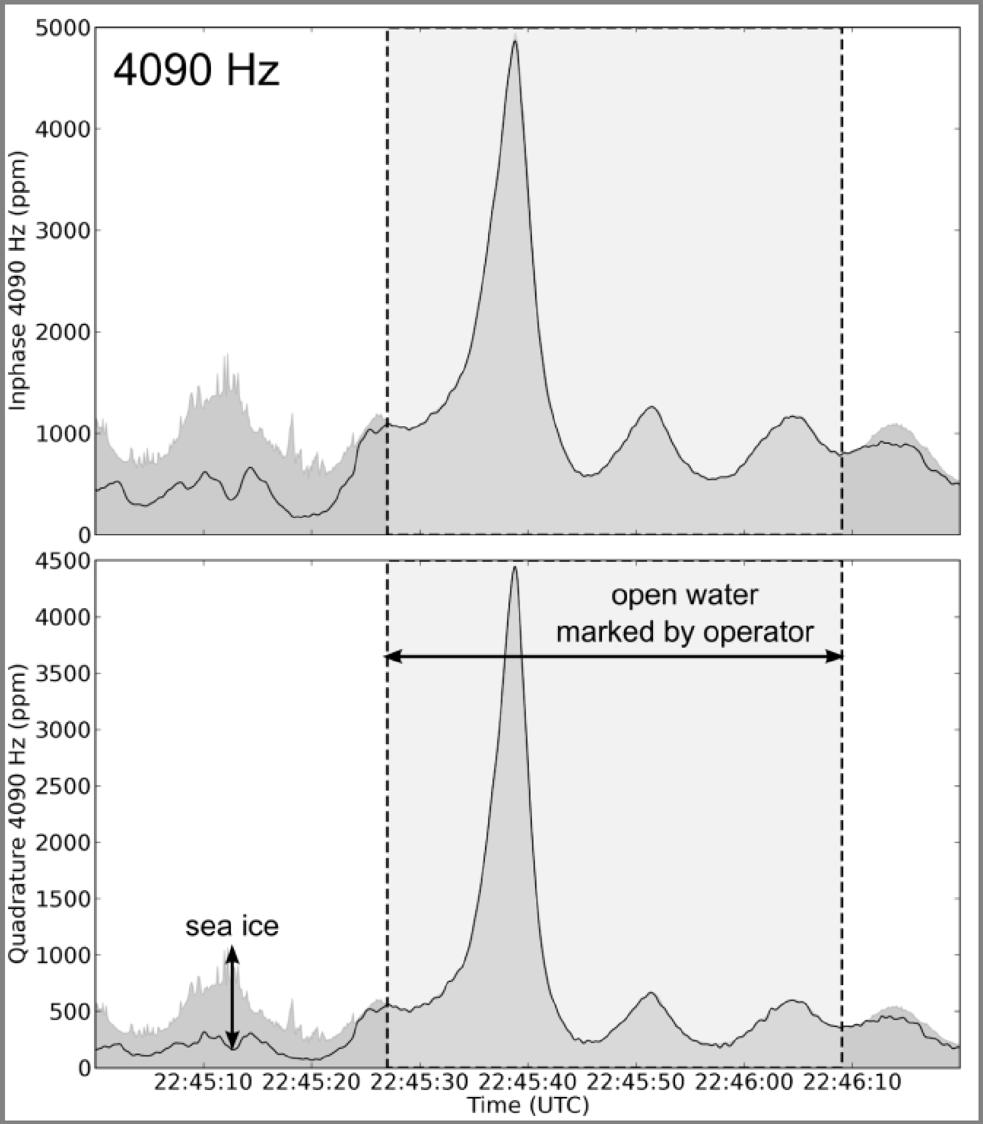
SIZONet campaign
Barrow, Alaska
April 2012

Field campaign SIZONet in Barrow, Alaska (April 2012)



- Raw data, 4090 Hz
- Temperature measurements inside the EM-sensor
  → Improvements of signal quality and drift correction

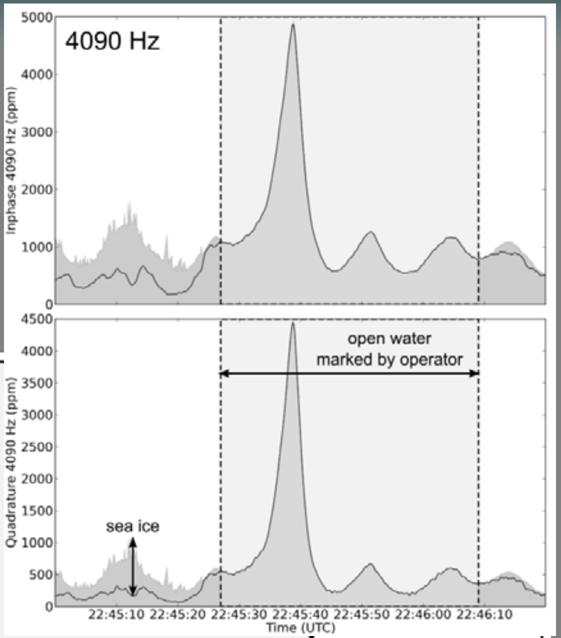
Field campaign SIZONet in Barrow, Alaska - Data quality

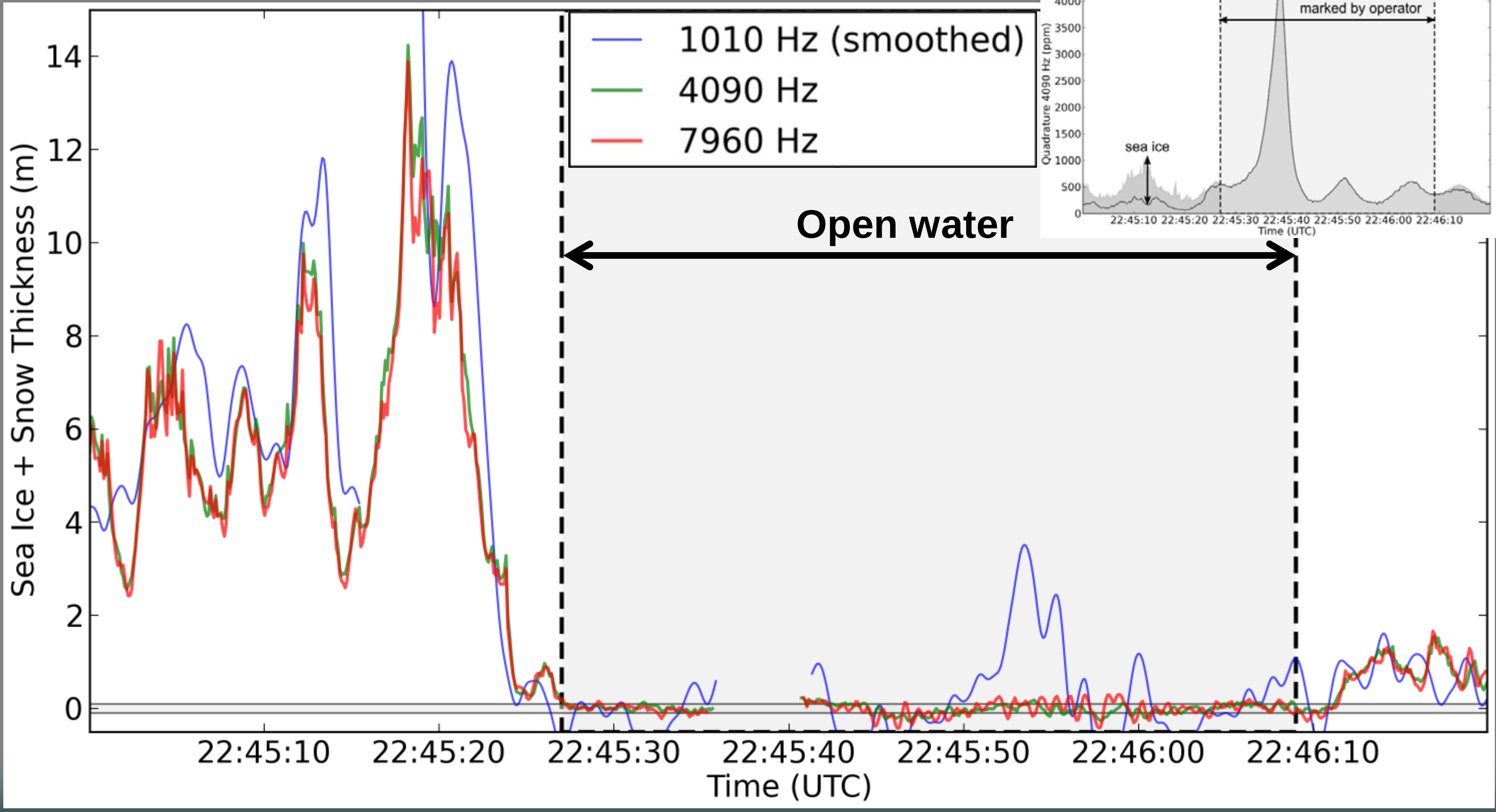


- 4090 Hz
- Drift corrected data
- Comparison of 1D model and data over sea ice and open water
- 1D model: EM response over homogeneous half space, solving of hankel transform after W.L. Anderson, 1970.

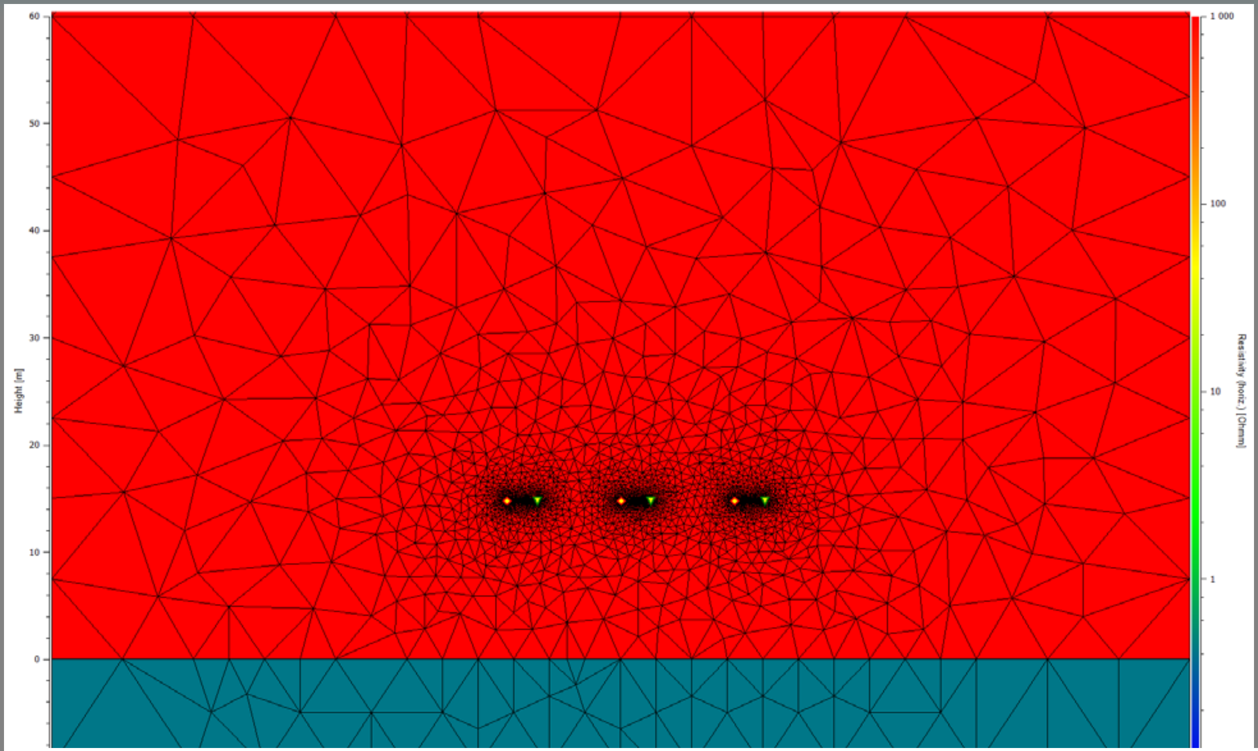
Field campaign SIZONet in Barrow - Data quality

- 1D sea ice thickness for different frequencies over sea ice and open water
- Higher frequencies are within ± 10cm over open water

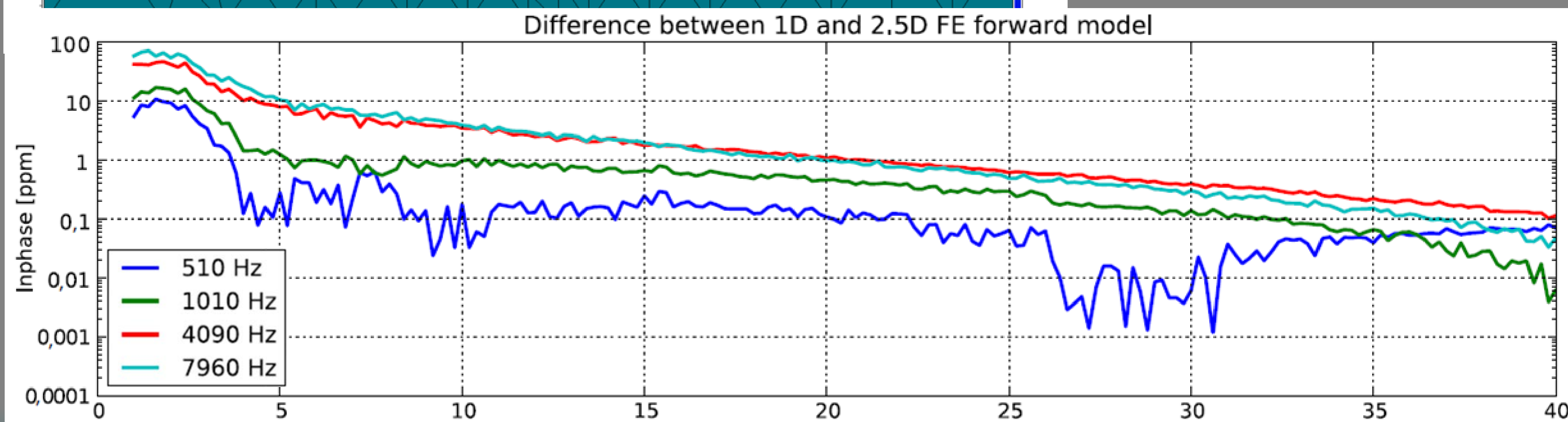




Inversion software NGI “ngi25em”

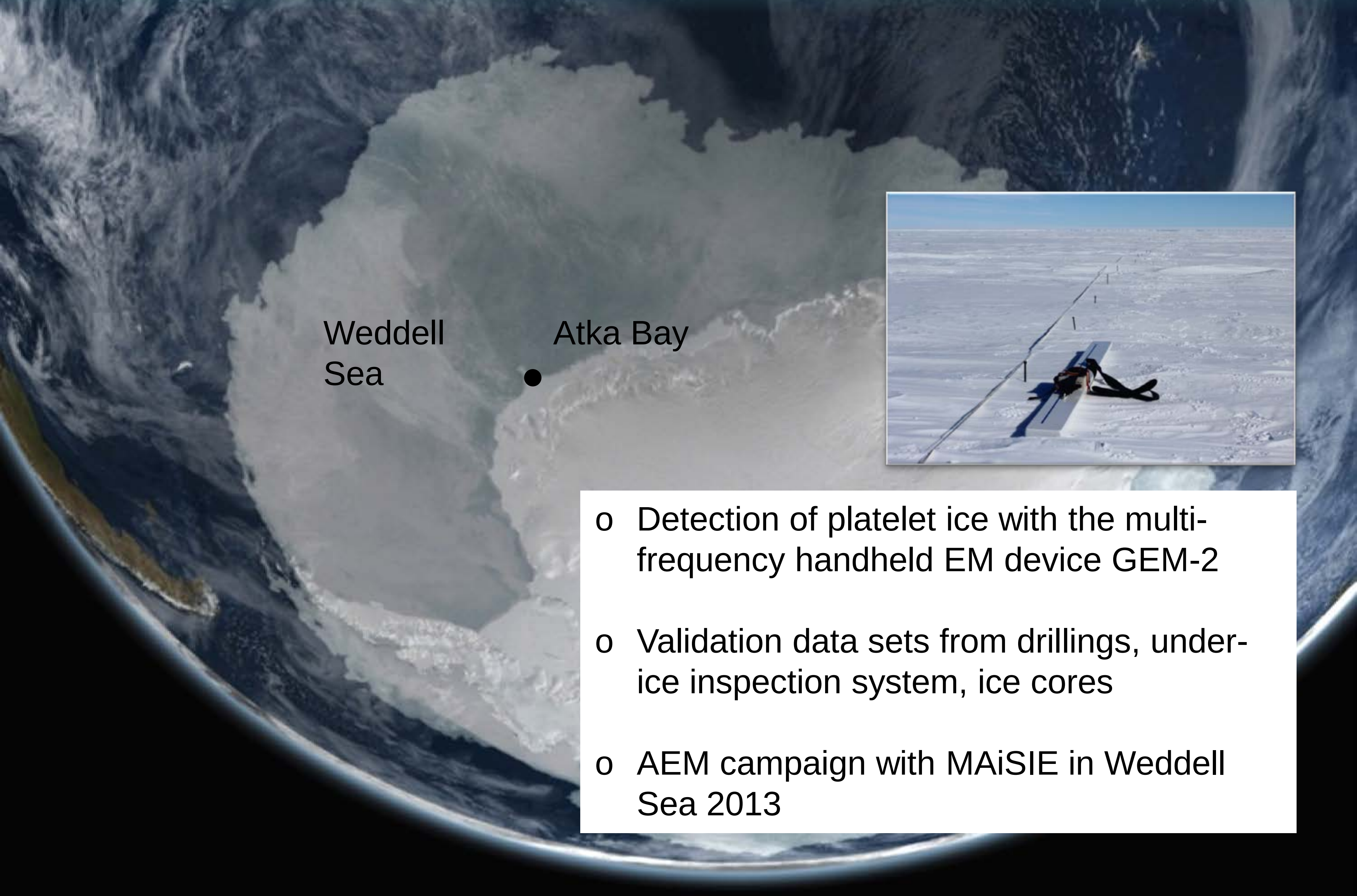


- Adapt “ngi25em” to airborne EM sea ice case
- Mesh for forward model, different positions of receiver and transmitter
- 1D and 2.5 D FE forward model are in good agreement (<10ppm)



NGI, 2012

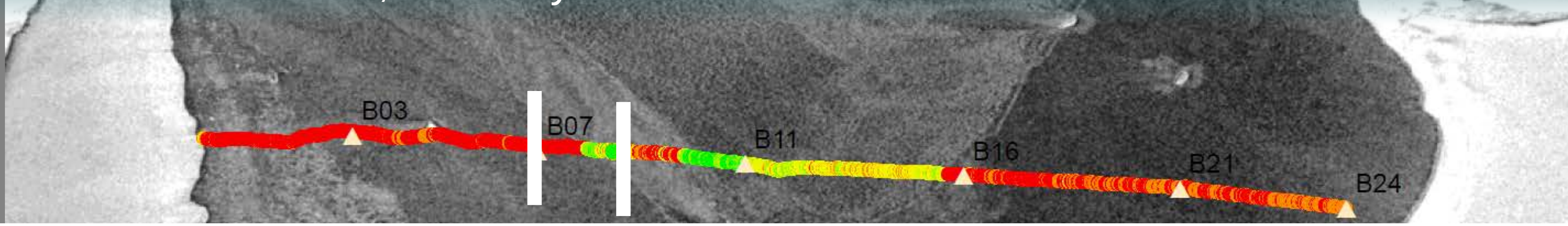
Field campaign SIMBIS, November 2012, Atka Bay, Antarctic

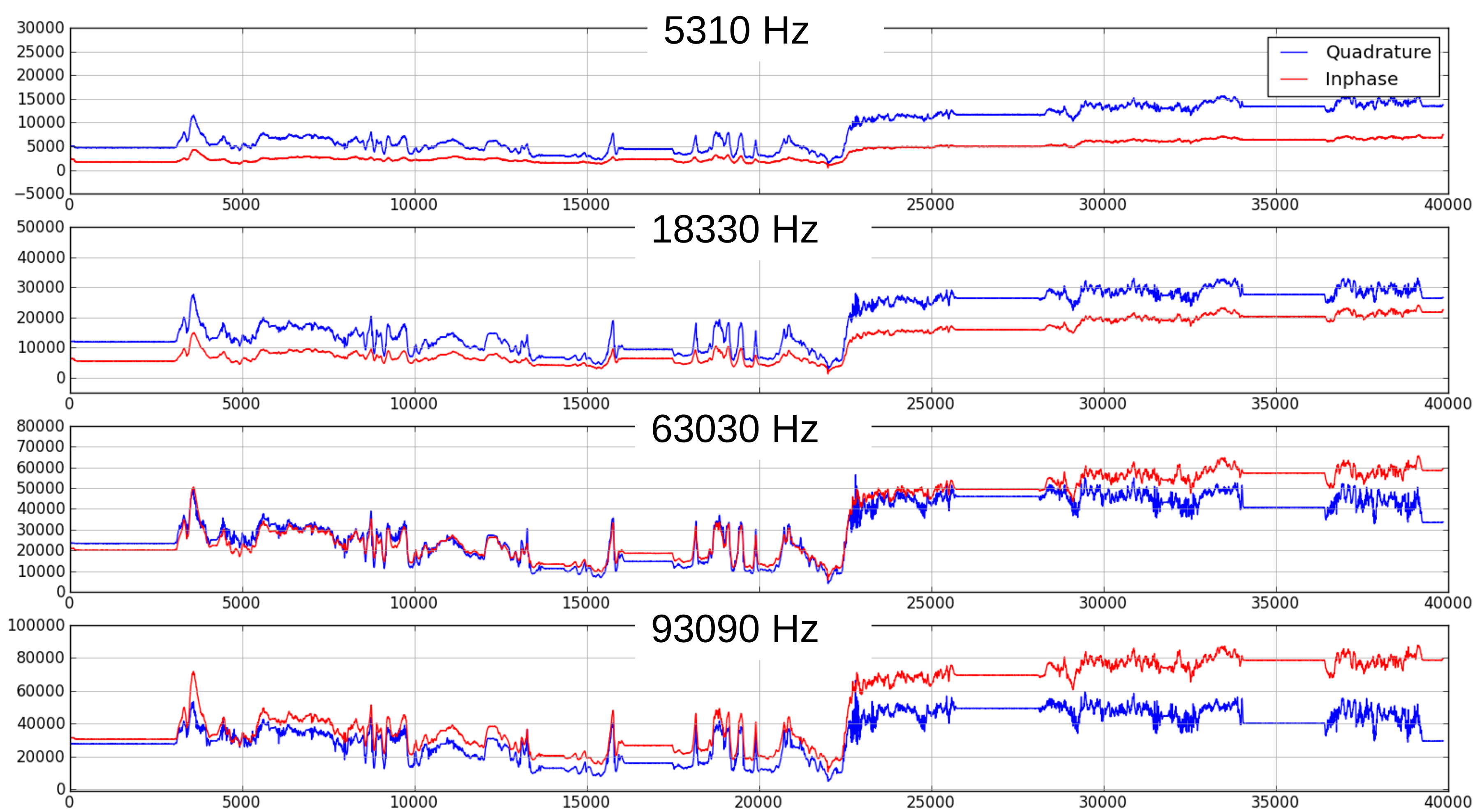


- Detection of platelet ice with the multi-frequency handheld EM device GEM-2
- Validation data sets from drillings, under-ice inspection system, ice cores
- AEM campaign with MAiSIE in Weddell Sea 2013

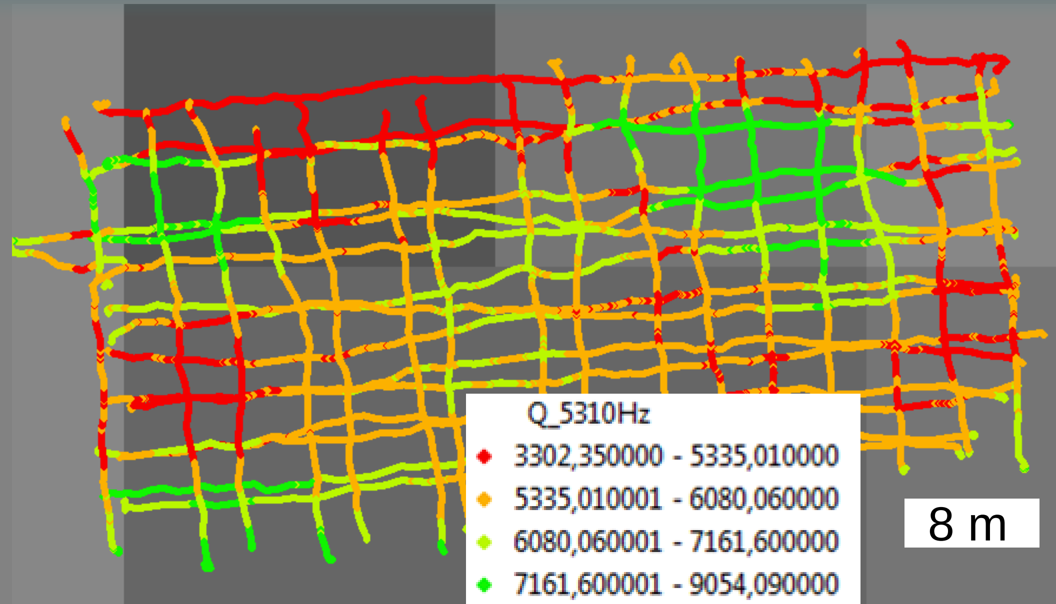
Transect GEM-2, Atka Bay

Transect GEM-2, Atka Bay

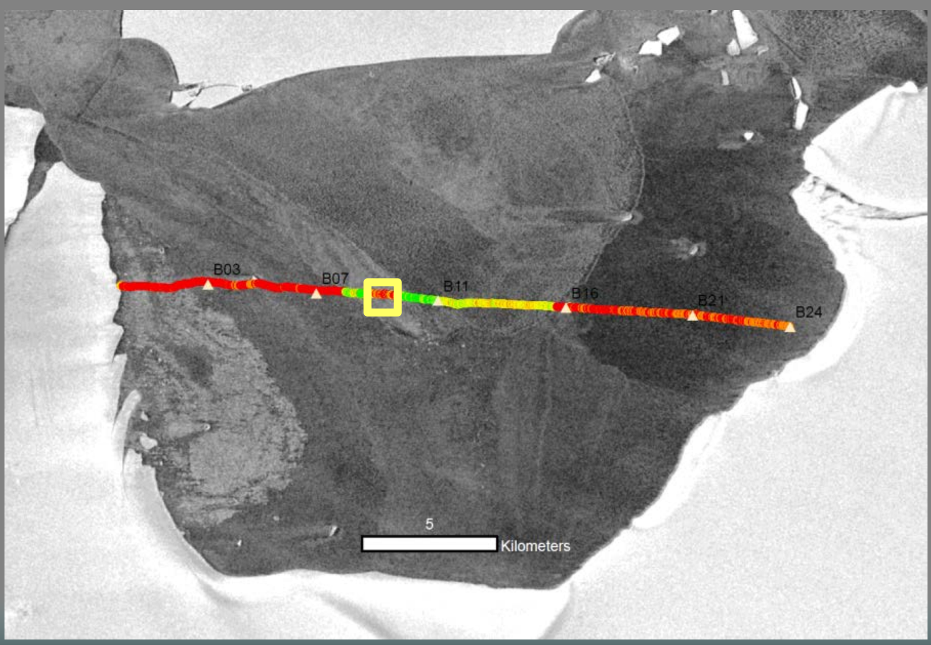




GEM-2, Atka Bay



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



Summary and Outlook

SUMMARY

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

OUTLOOK

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