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ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
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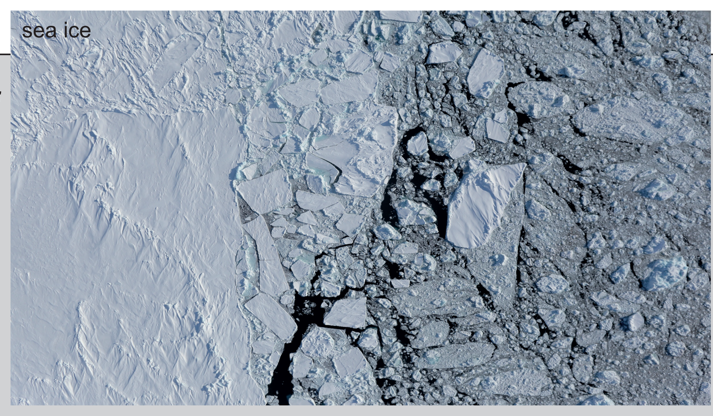
Multi-Frequency Electromagnetics for Sea-Ice Thickness Retrieval

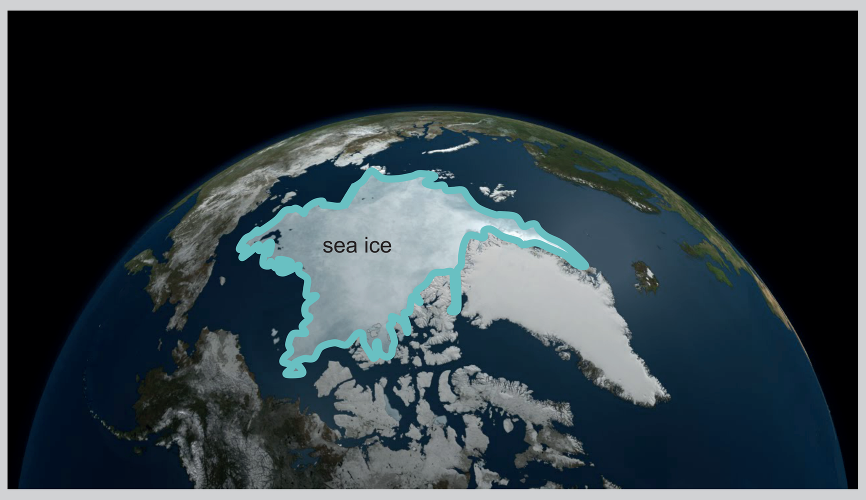
Motivation



The characterization of the state of the **sea-ice cover** is of great importance for the evaluation of the polar climate system. Satellite data show a rapid reduction of summer **sea-ice extent** in the Arctic, which culminated in a new record minimum in September 2012. In the Antarctic results of average September sea-ice extent show a small positive average trend over the last three decades.

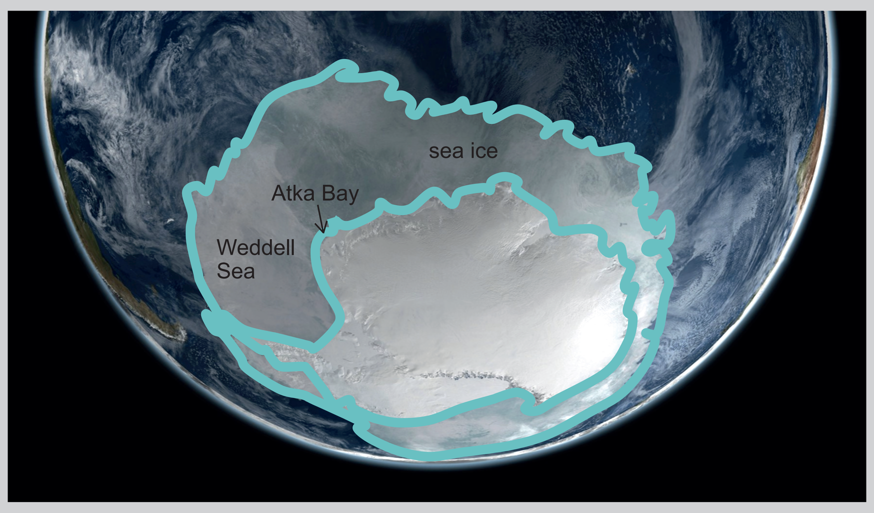
Different types of sea ice can be found in both Polar Regions depending on the growth history, the season and environmental conditions. In Antarctica, a special sea-ice type is present below the solid sea ice. This **porous sub-ice platelet layer** contributes significantly to the total sea-ice mass and energy balance of Antarctic landfast sea ice and forms a unique habitat for planktonic organism. Little is known about the platelet-layer thickness and its large-scale distribution in the Antarctic.

In general, **high resolution sea-ice thickness data** are sparse, but important for validation of high spatial coverage satellite data. One method to measure sea-ice thickness with high resolution is frequency domain electromagnetic (FDEM) induction sounding.



Arctic summer sea ice

Antarctic winter sea ice

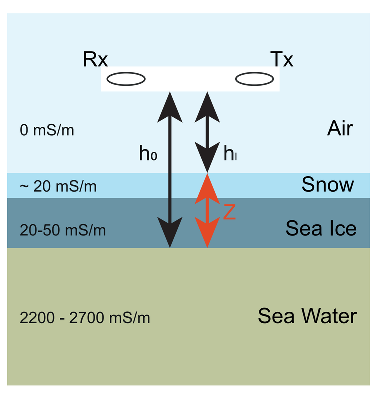


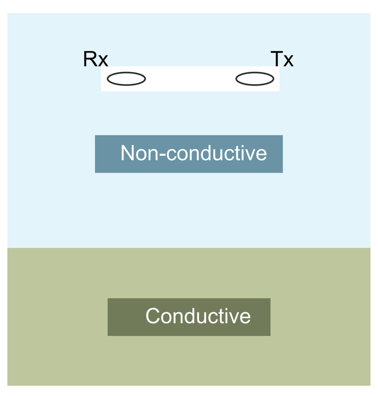
GEM-2 and Sea Ice

Standard assumptions ...

The sea-ice layer is described as a **level plate**

Sea ice and snow are non-conductive, whereas sea water is conductive





... and their limitations

Ice thickness **variability on sub-footprint scale** cannot be resolved (e.g. sea- ice pressure ridges)

Non negligible **conductivity** in the ice layer gives a bias in the 1D ice-thickness estimates. It is not possible to resolve for platelet-ice, flooded ice or internal conductive ice structures

Environmental conditions

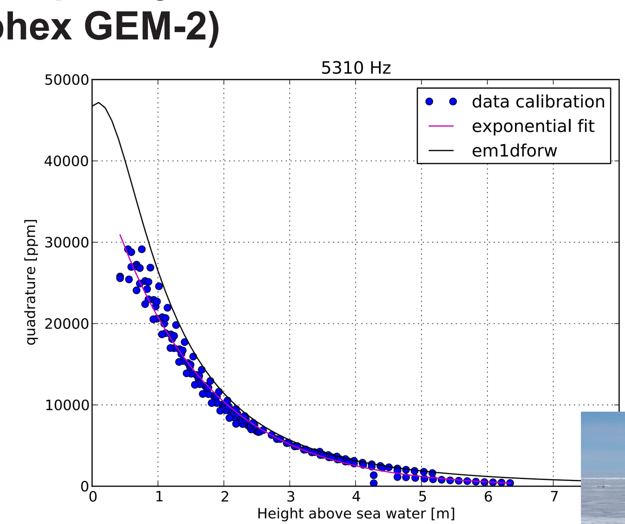
The measurements are acquired in a very **conductive environment** (ocean water: 2700 mS/m)

The environmental temperature can reach from **-30 up to +10°C**

➡ Problems with temperature dependent drift of the instrument

State of the art single-frequency sea-ice thickness retrieval (Geonics EM-31 / Geophex GEM-2)

Exponential representation of one frequency (here quadrature, 5310 Hz) at one location in different heights



Objectives

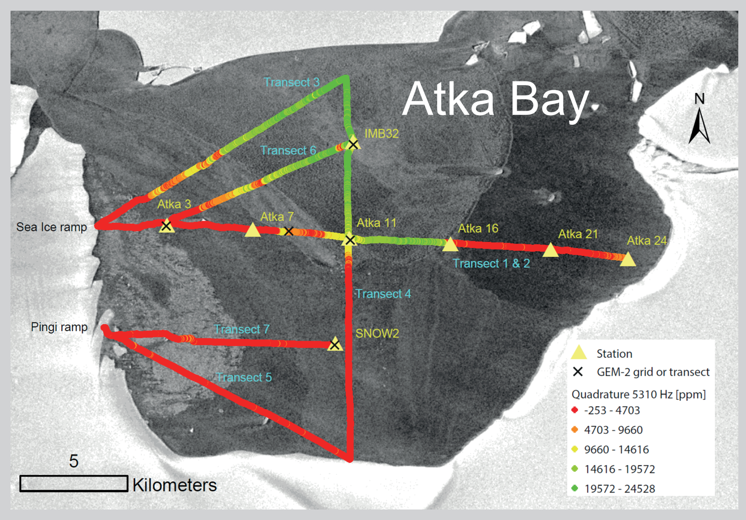
These standard assumptions are not valid for platelet ice and pressure ridges. With the processing of multi-frequency GEM-2 data we overcome the limitations of a homogeneous half-space model.

Data and Results

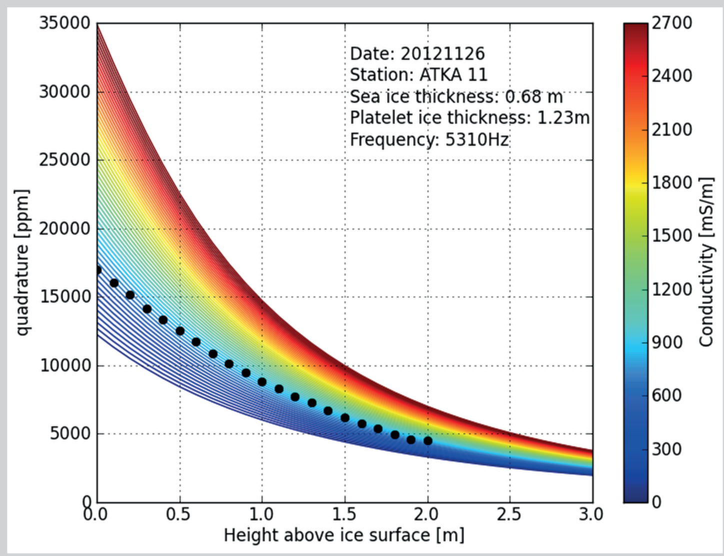
Sub-ice platelet layer

Comprehensive data set from the Atka Bay, Antarctica, November 2013 to January 2013

➡ Porous sea-ice layer is located below the solid sea ice



From comparison of calibration data with model data, the sub-ice **platelet layer conductivity** can be estimated (700-1000 mS/m) for different frequencies and components (here 5310 Hz, quadrature). With Archie's law, the porosity of the platelet-ice layer can be estimated:



$$\sigma = a\,\sigma_b\,\emptyset^m \qquad \emptyset = 57\,\%$$

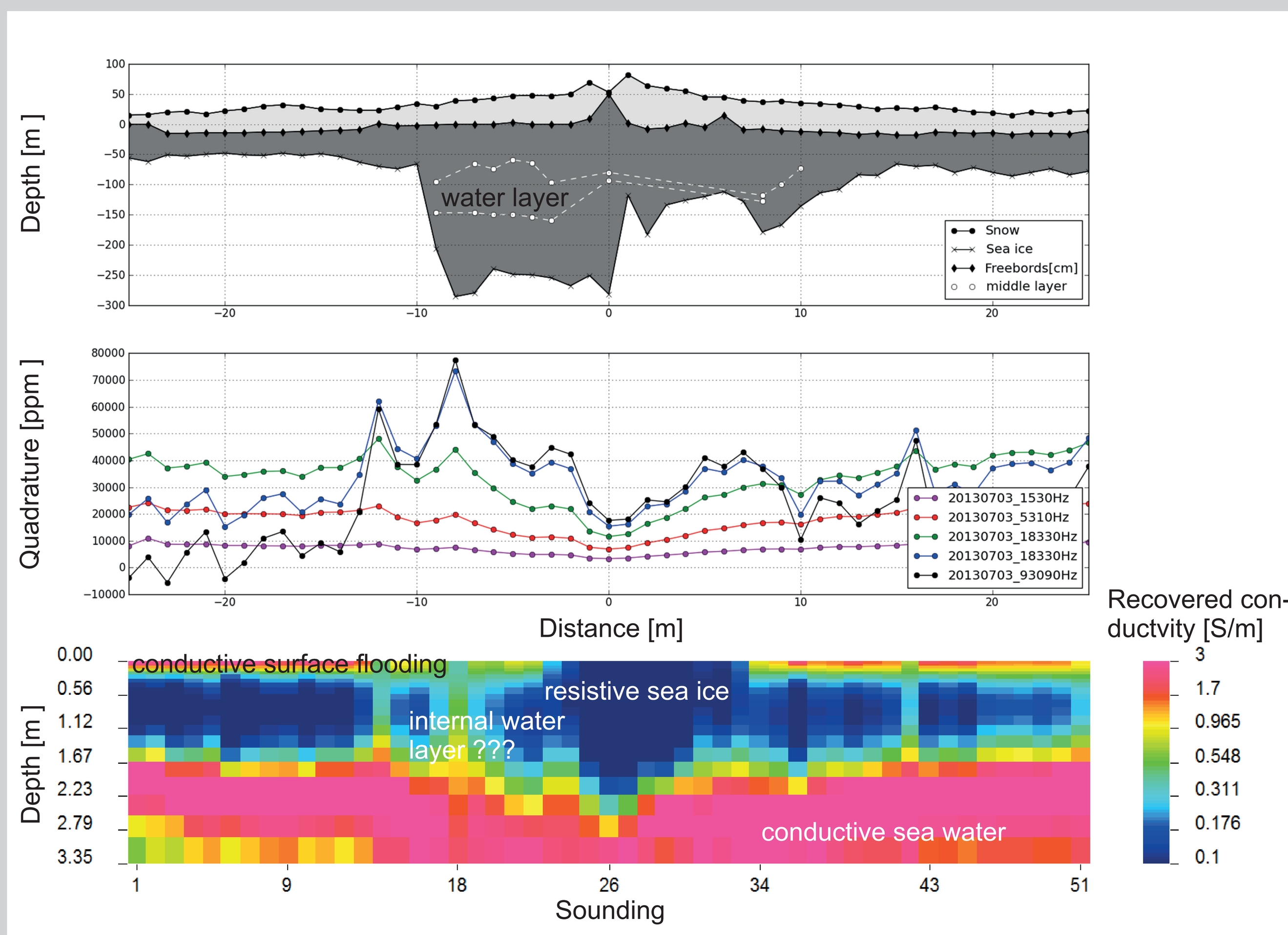
- σ Bulk conductivity of sea ice (here 1 S/m)
- σ_b Brine conductivity (here 2.7 S/m)
- $\emptyset$ Porosity (relative volume fraction of fluid)
- m Constant (1.552.2), depends on the solid phase of porous media (here 1.75)
- a Empirical scaling parameter (here 1)

The porosity of the sub-ice platelet layer is an unknown parameter, but important for the sea-ice mass balance of Antarctic landfast sea ice.

Pressure ridges

Pressure ridge ground truth data set from the Weddell Sea, June-August 2013

➡ Sea-ice thickness varies on sub-footprint scale



Data from drillings, one cross-section

Raw GEM-2 data acquired over the cross-section

1D Inversion EM1DFM from UBC (University of British Columbia)

Conclusion and Outlook

It is important to account for conductive layers inside or at the top of complex sea-ice features. The existing assumptions of conductive sea water and layered resistive sea ice should no longer be used, especially not for multi-frequency applications.

⬇

This work is the first step to replace traditional homogeneous half-space sea-ice thickness retrieval algorithms, by more detailed 1D/2D inversion schemes of multi-frequency FDEM data.

Furthermore, the data lays the foundation for future larger scale airborne electromagnetic surveys with the multi-frequency device MAiSIE (Multi-Sensor Airborne Sea-Ice Explorer).

Upcoming working tasks:

Absolute calibration of the instrument by correction the data for drift and zero-measurements and adjusting gain and phase during the post-processing

Processing the promising dataset with a suitable inversion algorithm (2D, inversion for thickness only)

References

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