M. Hoppmann[1], P. A. Hunkeler[1], S. Hendricks[1], T. Kalscheuer[2], R. Gerdes[1,3]
[1]Alfred-Wegener-Institute, Bremerhaven, Germany , [2]Uppsala University, Sweden, [3]Jacobs University Bremen, Germany
Contact: Mario.Hoppmann@awi.de or Stefan.Hendricks@awi.de

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

Session CR6.1/OS1.25
EGU2016-4084
Board X3.280

A glimpse beneath Antarctic sea ice:

observation of platelet-layer thickness and ice-volume fraction with multi-frequency EM

I. The story in short

Ice platelets form and grow in supercooled Ice Shelf Water in coastal Antarctica.

↓

Masses of platelets rise and accumulate below sea ice to form sub ice platelet layers. These accumulations have significant impacts on sea ice properties and the associated ecosystem.

↓

But: in-situ observations are limited to drillhole measurements and ice cores.

↓

In this study, we recorded and inverted the first multi-frequency EM induction sounding dataset on a sea ice regime with an underlying platelet layer.

↓

The obtained thickness results agreed well with drillhole validation datasets within the uncertainty range.

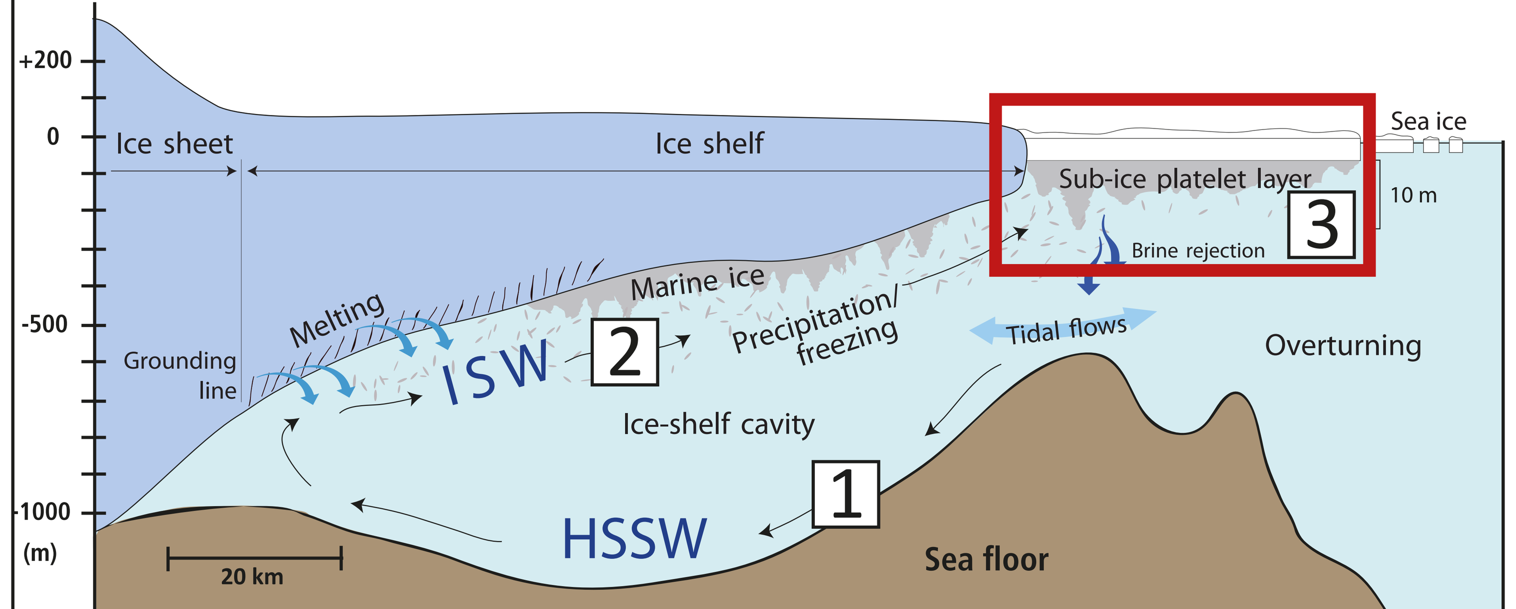
↓

Ice-volume fractions were calculated from inverted conductivities, yielding plausible results.

↓

Conclusion: inversion of multi-frequency EM data is a suitable approach to map sub-ice platelet properties.

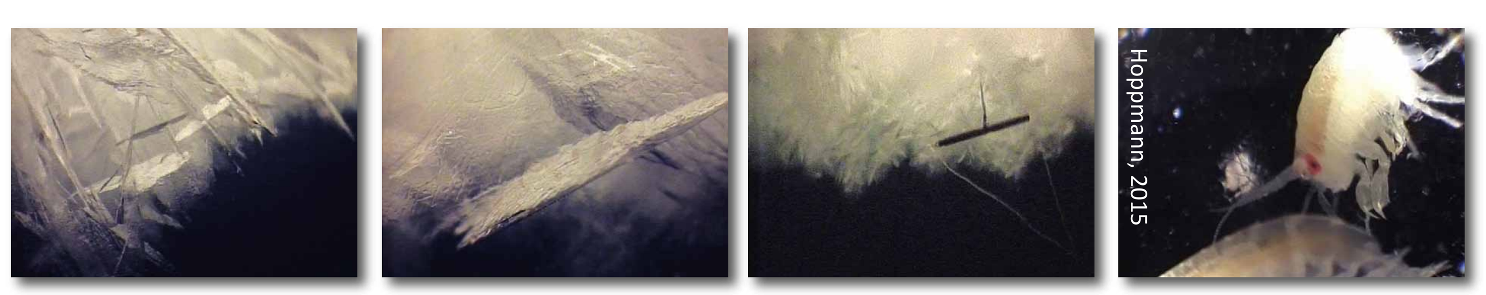
II. Background: platelet-layer formation and importance



1 High Salinity Shelf Water (HSSW) enters the cavity and melts the base of the ice shelf. Very cold, less saline Ice Shelf Water (ISW) is formed.

2 The ISW rises and becomes supercooled (the freezing point depends on pressure!). Supercooling is relieved through formation of ice platelets.

3 The crystals float upwards, while continuing to grow. They eventually accumulate beneath coastal sea ice, forming a sub-ice platelet layer (red box).



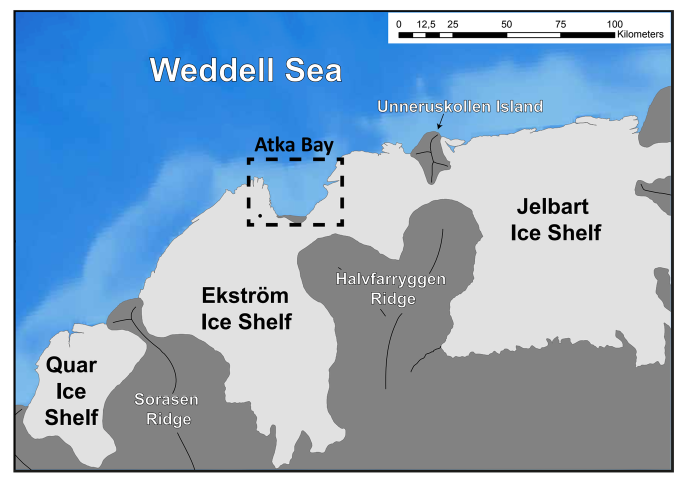
The platelet layer

- consists of individual crystals (platelets) up to 20 cm in diameter.
- is unconsolidated and porous, with interstitial water between the platelets.
- hosts a unique ecosystem (phytoplankton, crustaceans, fish, anemones, ...).
- reflects ocean/ice-shelf interaction, which is difficult to observe directly.
- contributes to coastal sea-ice mass and energy balance, especially fast ice.

The challenge: Find an efficient method to determine platelet-layer volume on larger scales.

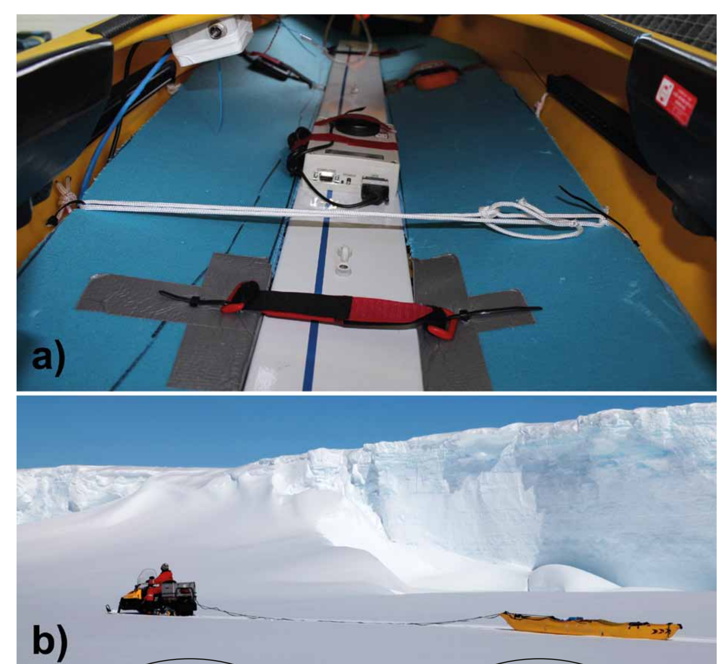
III. Ingredients

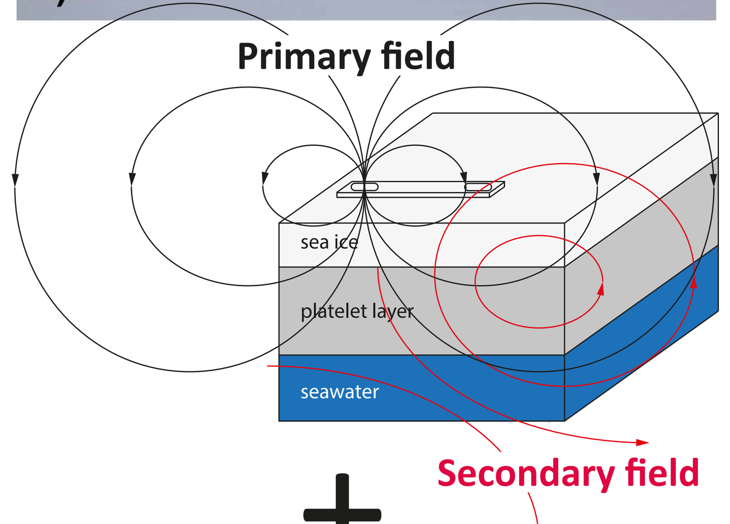
1. A study area with sea ice and an underlying platelet layer.



+

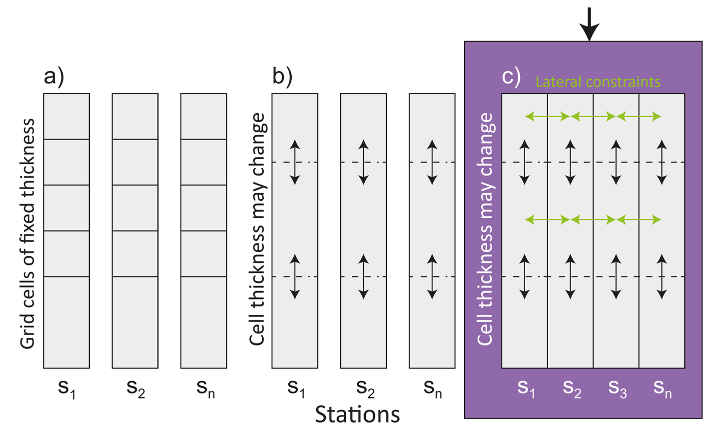
2. A multi-frequency EM instrument, a) mounted in a kayak, b) pulled over sea ice



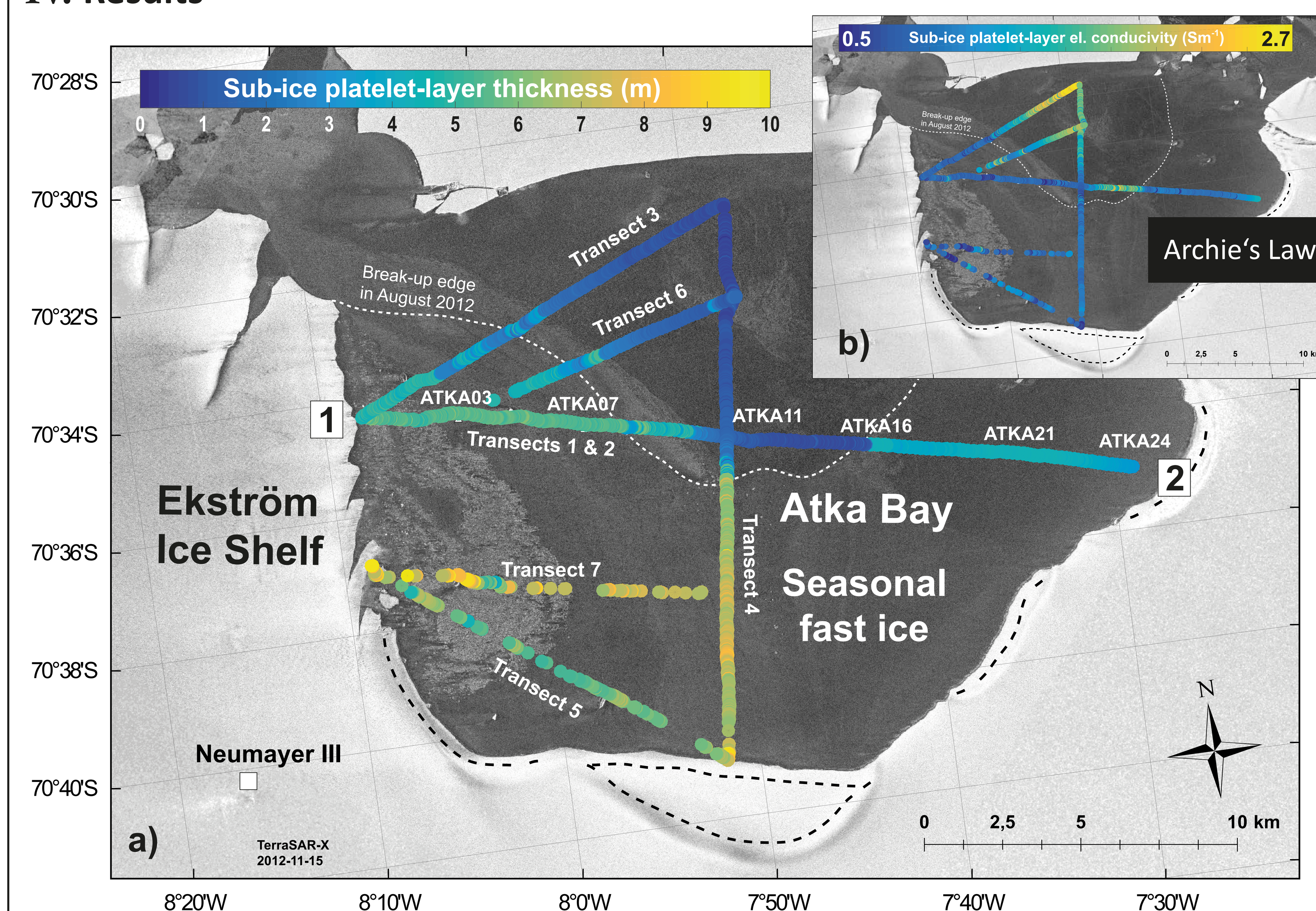


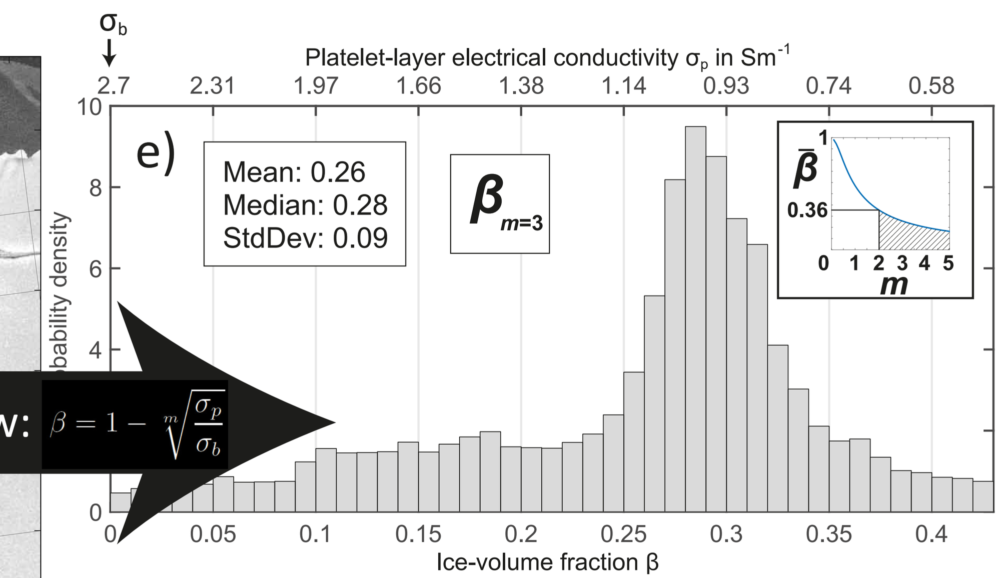
+

3. A suitable geophysical inversion which models the subsurface until it fits to the EM data. We used a laterally-constrained Marquardt-Levenberg inversion from the EMILIA software package (Hunkeler, 2015).

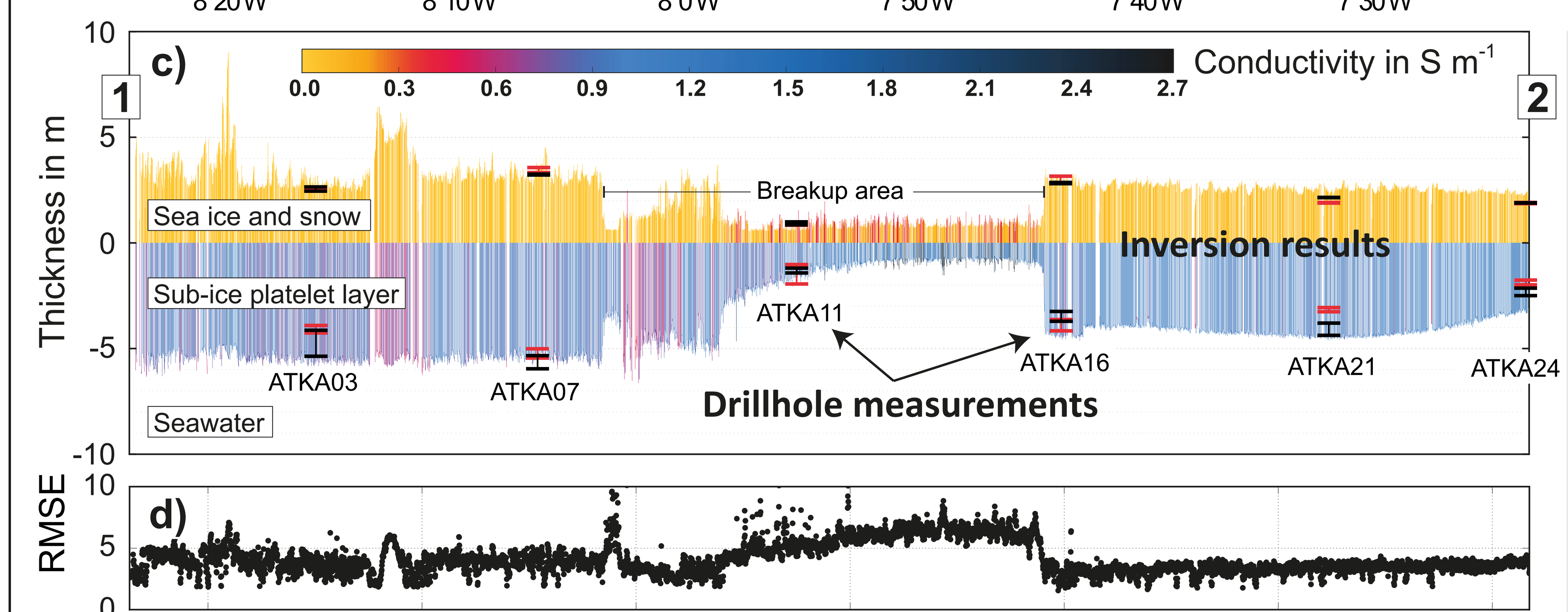


IV. Results





a) Platelet-layer thickness and **b)** conductivity resulting from inversion from multi-frequency EM data recorded on the landfast sea ice at Atka Bay, eastern Weddell Sea, in December 2012.
c) Inversion results of sea-ice and platelet-layer thickness and -conductivity of a profile between points 1 and 2 indicated in a), along with results from drillhole measurements. The RMSE, a measure of the fit quality between inversion and measured data, is given in **d)** (lower values are better).
e) Distribution of ice-volume fractions β in the platelet layer, which is needed for calculation of the ice volume. It is derived from inverted electrical conductivities via Archie's Law, here shown for a cementation factor m = 3.



- The inversion results for thickness show good agreement with drillhole measurements (c), and show a generally plausible pattern (a).
- The inversion results for conductivity are also in a plausible range (b), with a possible indication of surface flooding (red colors in breakup area in c).
- A thinner (younger) platelet layer is less consolidated and has a lower ice-volume fraction (a,b).
- A cementation factor m>2 yields plausible values for ice-volume fractions (β<0.36) (e).
- The RMSE is suffiently low for an inversion with four free parameters (sea-ice and platelet layer thickness and -conductivity) (d).

Results taken from „Hunkeler, P. A., M. Hoppmann, S. Hendricks, T. Kalscheuer, R. Gerdes (2016), A glimpse beneath Antarctic sea ice: Platelet layer volume from multifrequency electromagnetic induction sounding, Geophys. Res. Lett., 43, 222–231, doi:10.1002/2015GL065074"

The authors thank Stephan Paul, Uwe Baltes, Johan Hermansson and the Neumayer III wintering crew of 2012 for their support. This work was funded by the POLMAR graduate school and the German Research Council by grants to SPP1158, NI 1092/2 and HE2740/12.

V. Take-home messages

1. **We present the first EM-based platelet-layer thickness and conductivity dataset.**
2. **Multi-frequency EM data inversion enables platelet-layer volume estimates: platelets at Atka Bay contribute about 50% to the annual sea-ice volume, and represent >25% of Ekström Ice Shelf meltwater volume.**
3. **Platelet layer properties allow conclusions about ice and ocean processes, such as ice shelf melt, currents, primary productivity estimates, ...**