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A glimpse beneath Antarctic sea ice: observation of platelet-layer thickness and ice-volume fraction with multifrequency EM

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In Antarctica, ice crystals (platelets) form and grow in supercooled waters below ice shelves. These platelets rise, accumulate beneath nearby sea ice, and subsequently form a several meter thick, porous sub-ice platelet layer. This special ice type is a unique habitat, influences sea-ice mass and energy balance, and its volume can be interpreted as an indicator of the health of an ice shelf.

Although progress has been made in determining and understanding its spatio-temporal variability based on point measurements, an investigation of this phenomenon on a larger scale remains a challenge due to logistical constraints and a lack of suitable methodology.

In the present study, we applied a lateral constrained Marquardt-Levenberg inversion to a unique multi-frequency electromagnetic (EM) induction sounding dataset obtained on the ice-shelf influenced fast-ice regime of Atka Bay, eastern Weddell Sea. We adapted the inversion algorithm to incorporate a sensor specific signal bias, and confirmed the reliability of the algorithm by performing a sensitivity study using synthetic data. We inverted the field data for sea-ice and platelet-layer thickness and electrical conductivity, and calculated ice-volume fractions within the platelet layer using Archie's Law. The thickness results agreed well with drillhole validation datasets within the uncertainty range, and the ice-volume fraction yielded results comparable to other studies. Both parameters together enable an estimation of the total ice volume within the platelet layer, which was found to be comparable to the volume of landfast sea ice in this region, and corresponded to more than a quarter of the annual basal melt volume of the nearby Ekström Ice Shelf.

Our findings show that multi-frequency EM induction sounding is a suitable approach to efficiently map sea-ice and platelet-layer properties, with important implications for research into ocean/ice-shelf/sea-ice interactions. However, a successful application of this technique requires a break with traditional EM sensor calibration strategies due to the need of absolute calibration with respect to a physical forward model.