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Surface Nuclear Magnetic Resonance Tomography on a First-Year Sea Ice Pressure Ridge

A. Nuber (1), L. Rabenstein (1), J. A. Lehmann-Horn (1), H. Eicken (2), A. Mahoney (2), and S. Hendricks (3)
(1) ETH Zurich, Institute of Geophysics, Zurich, Switzerland, (2) University of Alaska Fairbanks, Fairbanks, USA, (3) Alfred-Wegener-Institute, Bremerhaven, Germany

The porosity of the keel of a sea ice pressure ridge is one of the critical parameters required to understand the mass budget and evolution of the Arctic sea ice cover. Sea ice pressure ridges are built when drifting ice floes collide due to convergent forces, i.e. due to ocean currents or winds. The resulting ice fragments enclose water-filled cavities in the keel of the ridge. The determination of the keel porosity using drilling yields limited and potentially inaccurate information because of the small footprint and errors involved. Since the porosity within the keel equals its liquid water content, surface-NMR can be applied, a method which is directly sensitive to unbound hydrogen protons.

This study shows the results of the first application of surface-NMR on sea ice to determine ridge porosity. A surface-NMR tomography, using seven coincident soundings, was performed on a first-year sea ice pressure ridge on landfast ice off Barrow, Alaska, in April 2011. The inversion indicated a water content in the ridge's shallower part of 31 $\pm$ 7%, and of 49 $\pm$ 7% in its deeper part. The error range of 7% results from noise, but also from the uncertainty and the simplification implicit in the assumed ridge geometry. The obtained values are much higher than the values obtained from drilling: 10% and 27% respectively. Hence, ridge porosities obtained from direct measurements may result in substantially underestimated ridge melt rates and overestimated total ice volume.

The algorithm employed for forward modelling and inversion of surface-NMR data has been extensively tested in a preceding modelling study. It has been shown that the main challenge in deriving subsurface liquid volume fractions from surface-NMR on sea ice is due to the high electric conductivity values of the ocean of up to 3 S/m. Hence, the geometry of the sea ice pressure ridge and the associated electric conductivity distribution of the subsurface need to be represented accurately in the forward modelling and inversion. The geometry of the ridge in our case study was obtained from direct borehole measurements and helps constrain, in conjunction with representative data from the literature and the analysis of an ice core, the conductivity distribution of the subsurface. Nevertheless, a mismatch of around 30 nV (maximum amplitude around 200 nV) in the imaginary part of some sounding curves remains unexplained, giving rise to further research.