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The skeletal layer of sea ice: X-ray microtomography and modeling

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When columnar sea ice forms on seawater by unidirectional freezing its interface is known to have a lammelar microstructure, consisting of vertically oriented plates with largely horizontal c-axis orientation, parallel within each grain. Away from the interface these plates thicken by lateral freezing, driven by (i) a decrease in temperature and (ii) intermittent convective exchange of brine against seawater. This convection is the main process that drives the desalination of sea ice, and takes place within a layer of a few centimeter thickness that often is called "skeletal layer" (1,2,3). The skeletal layer is not only relevant for convective desalination, but also shapes an important habitat for life near the sea ice bottom (4) and is critical for pollution issues like oil uptake by sea ice (5). As the skeletal layer has high porosity and is, due to its fragile nature, difficult to sample, relatively little is known about its 3-d structure and transport properties like permeability and thermal conductivity. A conceptual model that involves the bridging of plate-like crystals at some distance from the interface, setting the upper boundary of the skeletal layer, has been suggested half a century ago based on thin-section analysis (1,2), but still remains unvalidated. In the present study first different observations of the sea ice skeletal layer are reviewed, followed by an in-depth analysis of the skeletal layer from 3-d microtomographic imaging (XRT) of natural sea ice and laboratory-grown saltwater ice. The XRT images are analysed with emphasis on the process of necking of lamellar ice plates, changes in grain sizes, and the evolution of pore structure and permeability within the skeletal layer. The determined porosity-permeability relationship is used to model and predict the onset of convection and skeletal layer thickness and compare them to previous work (6,7). The present analysis highlights the importance of crystal structure for sea ice property evolution.

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Significance statement

Sea ice, interface, crystal growth and structure, X-ray microtomography

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