Thermodynamic and Fluid-Dynamical Processes in Sea Ice

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Abstract

In this thesis, new experimental and modelling approaches are used to study the growth of sea ice and the associated loss of salt into the underlying ocean. It is shown that in winter salt is only lost from sea ice by so-called gravity drainage and that the bulk-salinity and solid-fraction fields are continuous across the ice–ocean interface during ice growth. The concept of an effective distribution coefficient is therefore not warranted in the context of sea ice. It is further shown that so-called brine expulsion does not lead to any net loss of salt from sea ice, and that flushing with melt water during summer is the only other process that has any impact on the salinity evolution of sea ice.

These results are obtained theoretically, using the so-called mushy-layer equations and an enthalpy-based numerical model. The numerical model allows the study of sea-ice growth and its interaction with radiative processes, melt ponds, oceanic heat and salt fluxes, internal density changes, and surface heat fluxes on a single domain.

The theoretical predictions are confirmed by laboratory and field experiments, using a new instrument developed in this study, which allows the *in situ* measurement of the salinity distribution in growing sea ice with a very high temporal and spatial resolution. The instrumental technique is based on impedance measurements, and solid fraction profiles measured with the instrument in artificial sea ice in laboratory experiments are in very good agreement with theoretical predictions. During several field campaigns in the Arctic the salinity distribution of newly forming ice was measured and compared with results from traditional coring methods. It is shown that the latter are inaccurate, because significant amounts of brine are lost from the lower parts of the cores. The instrument also allows the direct measurement of the total salt flux from growing sea ice and provides new insight into the interior structure of general mushy layers.

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