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Thermodynamic treatment of morphogenesis of brine channels in sea ice

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Sea ice is a very variable biotope with respect to extension,thickness, porosity or texture. Therefore the basic understanding of brine channel formation in sea ice is important for the interplay between the microbial colonization and their natural habitat. The early phase of brine channel formation in sea ice is considered. The first structures emerging during sea-ice formation are determined by the phase instability of the ice-water system in the presence of salt. We apply a Ginzburg-Landau type approach to describe the phase separation in the two-component system (ice, salt). The free energy density involves two order parameters: one for the hexagonal ice phase with low salinity, and one for the liquid water with high salinity. A gradient dynamics minimizes the free energy with respect to the conservation of the salinity. The resulting model equations are solved numerically in one and two dimensions. The numerical solution shows a short-time behavior of structure formation where the freezing is assumed and a large-time broadening of the structure. A stability analysis provides the phase diagram where brine channels can be formed. In thermodynamics the parameters determine the supercooling or superheating region and the specific heat respectively. The size of the brine channels depends on the salinity and the temperature. With the help of realistic parameters the brine channel distribution is calculated and found in agreement with the measured samples.