Ice crystal growth in different environments: an approach from micro to macro scales

Starting from a small-scale level we consider snowflakes and other natural ice crystals which are created under different environmental conditions. They are out-of-equilibrium growth shapes and these are the result of a nonlinear growth dynamics and a variational principle. A special role during the pattern formation is played by kink solutions that represent the different state of affairs at the phase boundaries. The mechanisms of kink formation give an insight into the dynamics of phase transitions. In this sense the phase field model of Kobayashi describes the shape of ice crystals due to supercooling and the strength of anisotropy. In addition, the impact of salt on the growth process is considered. This pattern formation is different from a reaction–diffusion system according to Alan Turing and the earlier thermodynamic approaches. We modify Kobayashi's phase field model and supplement with the influence of salt in order to describe a fine network of microscopic brine channels and cavities filled with brine that are formed during the freezing process in sea ice. The phase transition at the microscopic level, which leads to the formation of brine channels, is coupled to a phenomenological approach, the 'theory of porous media' (TPM), on the macro scale driven by the divergence of heat flux. The aim of these studies is to gain insight into the small-scale coupled physical processes of freezing and melting sea ice and their connections to the size and distribution of the enclosed brine channels.