University of Stuttgart
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Institute of Mechanics, Structural Analysis
and Dynamics of Aerospace Structures
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Announcement – HiWi/ Master's Thesis

Mathematical modeling and numerical implementation of mushy layer theory and its comparison with theory of porous media applied to sea ice freezing

Motivation: Sea ice forms as a temperature-driven solidification of salty seawater. The resulting material is a composite of ice crystals and a saline interstitial liquid (brine). Understanding the coupling and transport (heat, salt, brine flow) behavior in this *mushy* porous medium is essential for predicting brine rejection, permeability evolution, and larger scale ice-ocean interactions.

Tasks: Develop mathematical models and numerical implementations that describe sea-ice freezing using classical mushy-layer theory and compare it with existing in-house developed two-phase theory of porous media (TPM) approach. Validate model behavior on representative freezing scenarios and identify regimes where one formulation is preferable.

Procedure:
- Derive governing equations for mushy layer model.
- Identify constitutive relations (permeability vs porosity, effective thermal conductivity, phase relations).
- Implement reduced test problems (solidification front, steady mushy column, brine drainage).
- Perform parametric studies: initial salinity, cooling rate, porosity–permeability laws.
- Compare results of both theories: porosity fields, brine fluxes, temperature/salinity profiles, and computational cost.

Requirements: Background in continuum mechanics, phase-change modeling, and numerical PDE solvers using at least one of the main solver tools (MATLAB, Python, etc.).


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