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Models for polythermal ice sheets and glaciers

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The dynamics of ice-sheets and glaciers depend sensitively on their thermal structure. Many ice masses are polythermal, containing both cold ice, with temperature below the melting point, and temperate ice, with temperature at the melting point. The temperate ice is really an ice-water mixture, with water produced at grain boundaries by dissipative heating. Although the water content is typically small, it can have an important effect on ice dynamics; water content controls ice viscosity, and internal meltwater percolation affects hydrology. Locations where this may be important are in the enhanced shear layer at the base of fast-flowing outlet glaciers, and in the shear margins of ice streams.

In this study, we present a simplified model to describe the temperature and water-content of polythermal ice masses, accounting for the possibility of gravity- and pressure-driven water drainage according to Darcy's law. The model is based on the principle of energy conservation and the theory of viscous compaction. Numerical solutions are described and a number of illustrative test problems presented. The model is compared with existing methods in the literature, including enthalpy gradient methods, to which it reduces under certain conditions. Based on the results of our analysis, we suggest a modified enthalpy method that allows for drainage under gravity but that can be relatively easily implemented in ice-sheet models.