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Validation of the enthalpy method by means of analytical solution

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Numerical simulations moved in the recent year(s) from describing the cold-temperate transition surface (CTS) towards an enthalpy description, which allows avoiding incorporating a singular surface inside the model (Aschwanden et al., 2012). In Enthalpy methods the CTS is represented as a level set of the enthalpy state variable. This method has several numerical and practical advantages (e.g. representation of the full energy by one scalar field, no restriction to topology and shape of the CTS). The proposed method is rather new in glaciology and to our knowledge not verified and validated against analytical solutions. Unfortunately we are still lacking analytical solutions for sufficiently complex thermo-mechanically coupled polythermal ice flow. However, we present two experiments to test the implementation of the enthalpy equation and corresponding boundary conditions. The first experiment tests particularly the functionality of the boundary condition scheme and the corresponding basal melt rate calculation. Dependent on the different thermal situations that occur at the base, the numerical code may have to switch to another boundary type (from Neuman to Dirichlet or vice versa). The main idea of this set-up is to test the reversibility during transients. A former cold ice body that run through a warmer period with an associated built up of a liquid water layer at the base must be able to return to its initial steady state. Since we impose several assumptions on the experiment design analytical solutions can be formulated for different quantities during distinct stages of the simulation. The second experiment tests the positioning of the internal CTS in a parallel-sided polythermal slab. We compare our simulation results to the analytical solution proposed by Greve and Blatter (2009). Results from three different ice flow-models (COMIce, ISSM, TIMFD3) are presented.