

We describe and test a two-horizontal-dimension subglacial hydrology model which combines till with a distributed system of water-filled, linked cavities which open through sliding and close through ice creep. The addition of this sub-model to the Parallel Ice Sheet Model accomplishes three specific goals: (1) conservation of the mass of water, (2) simulation of spatially- and temporally-variable basal shear stress from physical mechanisms based on a minimal number of free parameters, and (3) convergence under grid refinement. The model is a common generalization of four others: (i) the undrained plastic bed model of Tulaczyk et al. (2000b), (ii) a standard ``routing'' model used for identifying locations of subglacial lakes, (iii) the lumped englacial/subglacial model of Bartholomaeus et al. (2011), and (iv) the elliptic-pressure-equation model of Schoof et al (2012). We preserve physical bounds on the pressure. In steady state a functional relationship between water amount and pressure emerges. We construct an exact solution of the coupled, steady equations and use it for verification of our explicit time-stepping, parallel numerical implementation. We demonstrate the model at scale by five year simulations of the entire Greenland ice sheet at 2 km horizontal resolution, with one million nodes in the hydrology grid.