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The Role of Ice Longitudinal Shear Stresses and Subglacial Till Dynamics in Shear Flow Instability of an Ice Flow

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A significant portions of the ice discharge in the great ice sheets is drained through ice streams, with subglacial till acting as a lubricant. The known importance to ice stream dynamics of horizontal friction in shear margins suggests a critical role of longitudinal shear stresses.

The effects of subglacial till dynamics and longitudinal shear stresses on the stability of an ice sheet flow are studied using a model of a vertically averaged ice sheet overlying a till covered bed. The ice model encompasses viscous constitutive law and includes longitudinal shear stresses. The till is represented through evolution of void ratio due to changes in available melt water. The till and ice are coupled through the ice velocity field and void ratio.

We first analyze the linear stability of the problem. We show that there is an unstable solution and that the wavelengths corresponding to the most unstable modes agree with the observed width of ice streams. The results also indicate that the till dynamics play a crucial role in this instability and that ice longitudinal shear stresses affect the stability characteristics at short wavelengths. We then extend the discussion into the nonlinear regime of the solution. We solve the full nonlinear problem numerically and compare it to the studied analytic solution, and then address non-linear properties of the full solution.