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Extension of marine ice-sheet flux conditions to effective-pressure-dependent and hybrid friction laws

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Marine ice sheets are complex systems with a highly non-linear behavior. There remains a large uncertainty about how various physical processes such as the basal friction and the subglacial hydrology affect the dynamics of the grounding line (GL). One possibility to better understand their mechanical behavior consists in adopting a boundary-layer analysis close to the GL. Specifically, one can derive a so-called flux condition, which is an analytical expression for the amount of ice that flows through this GL per unit time. In turn, this flux condition can provide useful information about the grounding-line dynamics, including the presence of hysteresis (Schoof, 2007b).

Several studies have introduced hybrid friction laws to model friction between the grounded part of the ice sheet and the bedrock (Schoof, 2005, Gagliardini et al., 2007). These friction laws behave as power-law friction laws far from the GL and plastically closer to it. Recent experiments have shown that these models are more realistic than the usual power-law friction (Zoet and Iverson, 2020). In parallel, sophisticated models for the subglacial hydrology have been developed (Bueler and van Pelt, 2015).

In this presentation, we show that the flux conditions previously derived for the Weertman friction law (Schoof, 2007a) and the Coulomb friction law (Tsai et al., 2015) can be extended to a flux condition for the general Budd friction law, with two different simple effective-pressure models for the subglacial hydrology. Using asymptotic developments, we provide a justification for the existence and uniqueness of a solution to the boundary-layer problem. Finally, we generalize our results to hybrid friction laws, based on a parametrization of the flux condition.