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Observational constraints from englacial layers on fast flow initiation of a West-Antarctic ice stream

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The physical processes governing the organization of ice flow into fast flowing ice streams are of major interest with respect to predictions of future ice sheet mass loss. A variety of elements have been proposed that might explain ice flow acceleration. On the one hand observations of contemporary ice streams suggest that fast ice flow is favored by overdeepenings in bed topography and sediment beds. On the other hand, dynamic processes involving either thermo-mechanical feedbacks within the ice and at the ice-bed contact, or subglacial hydrology have been proposed, which would hold implications with respect to the ability of ice streams to self-organize in space and change spontaneously over time. While basal topography and lithology are reasonably well known, dynamic feedbacks remain challenging to constrain with direct observations, and therefore theoretical predictions of the key physical processes controlling fast flow initiation are, to date, largely untested in the real world. In this study we seek to fill this gap in the context of thermo-mechanical feedbacks, which are particularly relevant in the onset region of ice streams. These feedbacks come in two basic forms: either ice becomes less viscous at higher temperatures, or sliding between ice and bed is temperature dependent. Here our focus is on the latter: first, we briefly review recent theoretical work developed by one of the authors (Mantelli and Schoof, 2019) that describes from first principles an instability inherent to ice flow across transitions from frozen to molten beds commonly encountered in the onset region of ice streams. This instability relies on the physics of subtemperate sliding, which the theory predicts to occur in extended portions of the ice sheet across basal thermal transitions. Informed by this finding, we turn the attention to a major Antarctic ice stream - Institute Ice Stream in the Weddell Sea sector- and attempt to characterize the transition from basal no slip to basal sliding observationally. To do so, we follow two lines of evidence: (i) we perform an inversion for bed slipperiness with the Ice Sheet System Model (ISSM), as constrained by the current geometry and velocity field of the ice sheet in the Institute Ice Stream region; (ii) we apply a novel Layer Optimized Synthetic Aperture Radar processing (Castelletti et al, IEEE, 2019) to selected flight lines of the BAS-PASIN 2010/2011 radar survey, and compare the architecture of englacial layers in this region to model predictions. Our results so far are consistent with the hypothesis that the onset region of Institute Ice Stream is characterized by a spatially extended transition from basal no slip to basal sliding, and the observed layer architecture is compatible with an extended region of subtemperate sliding.