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An Observationally-Validated Theory of Viscous Flow Dynamics at the Ice-Shelf Calving-Front

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An analytical theory is developed for ice flow velocity in a boundary layer couplet at the calving front. The theory has simple quantitative characteristics that relate ice front velocity to thickness, strain-rate and shelf width, matching one set of empirically-derived relationships (Alley & others, 2008) and implying that these relationships predict ice velocity rather than calving rate. The two boundary layers are where longitudinal and transverse flow fields change fromthe interior flow to patterns consistent with the calving front stress condition. Numerical simulations confirm the analytical theory. The quantitative predictions of the theory have low sensitivity to unmeasured parameters and to shelf plan aspect ratio, while its robustness arises from its dependence on the scale invariance of the governing equations. The theory provides insights into calving, the stability of ice shelf calving fronts, the stability of the grounding line of laterally-resisted ice-streams, and also suggests that the calving front is an instructive dynamical analogue to the grounding line.