Interfacial stresses at the grounding line of the Whillans Ice Plain control the initial stick-slip rupture speed

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Each day, as many as two slip events occur beneath the Whillans Ice Plain over a region ~100 km long (Bindschadler et al., 2003; Wiens et al., 2008; Winberry et al., 2009; 2011; Walter et al., 2011). Recent studies have established that the rupture velocity varies systematically with loading over the tidal cycle and therefore cannot be controlled solely by the material properties (Wiens et al., 2008). Total slip, recurrence time and nucleation location also covary with rupture velocity and the tidal cycle (Winberry et al., 2009; Walter et al., 2011; Winberry et al., 2011). Typically individual rupture fronts initiate at two distinct nucleation regions that vary with the tide (Winberry et al., 2009; Pratt et al., 2014); events that begin at low tide nucleate closer to the grounding line than those that begin at high tide. Surprisingly, the low tide events rupture almost an order of magnitude fast initially (first ~100 s) within ~40-50 km of nucleation (~1,000 m/s) compared to high tide events (~400 m/s), even though typically the low tide events occur with significantly less time elapsed between events. Further, events occurring during high tide have an average rupture speed (when averaged across the Ice Plain) that is faster than low tide events, the low tide events tend to have significantly higher initial rupture speeds.

We attribute this behavior to local stress configurations that are spatially and temporally heterogeneous and utilize laboratory measurements of stick-slip sliding on plastic blocks to mimic the WIP behavior. Basal interfacial stresses are known to control rupture speed in numerous laboratory analogue experiments. We hypothesize a similar control on the WIP behavior and show that laboratory experiments can explain most of the rupture speed behavior. We propose a mechanism where the nucleation of faster initial rupture near the low-tide initiation point can be explained by locally high shear to normal stress ratios (τ/σ) caused by flexure near the grounding line. This is an effect caused not by lowering of the ice column, but by the flexural forebulge created in the upwards direction further inland from the Ross Sea during low tide. A momentary reduction in normal stress (upwards ice motion) would cause a temporary increase in the interfacial stress (τ/σ), which is possibly an instability, and may be the cause of the high initial rupture speeds observed near the grounding line during the low tide events. The central conclusion of this study is that the observed systematic variations in rupture velocities are governed by the applied stresses and may provide insight into grounding line stability.

- Ice-ocean interaction *(Surfin' USA)*
    - everywhere else (*Promised Land)*