Spatial Heterogeneity in Ice-bed Interactions Revealed by Variable Seismic Coupling and Basal Seismicity on the Whillans Ice Plain, West Antarctica

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The Whillans Ice Plain (WIP) moves by stick-slip motion with periods of little to no motion followed by a brief rapid surge, or slip event. Previous work has found that sliding motion initiates in one of two regions of the WIP depending on tide height: in the middle of the ice plain during high tide (Site A), and near the grounding zone during low tide (Site B). The persistence of these two slip initiation areas suggests that these two locations have different basal conditions than the surrounding ice plain. In order to investigate spatial variability in bed properties, we combine 3 GPS and 4 passive seismic datasets collected on the WIP over 4 months between 2008-11 for a comprehensive analysis of ice dynamics and seismicity during the stick-slip cycle. Using continuous GPS (15 sec interval), we calculate seismic coupling, or the percent of total ice motion that occurs during slip events, at >40 locations. We find Site A is highly coupled (~80- 90%) and surrounded by less coupled ice (55-75%). This suggests that Site A has a stronger bed and accumulates a greater shear stress between slip events than the surrounding ice, which responds to shear stress by creeping. Visual inspection of high frequency seismic data (>1Hz) in both the time and spectral domain reveals ~10s-100s of tiny earthquakes during slip events at 11 locations near Site A. Seismicity is scarce in the surrounding areas during slip, and at all seismic sites during the inter-slip periods. Site B has lower coupling (<55%) and few basal microearthquakes. This result confirms elevated basal stress near Site A and suggests that it occurs as isolated small regions of high friction. S-P times of the microearthquakes change over weeks, suggesting different rupture patches evolve over short timescales. The pattern of GPS-derived coupling shows mesoscale variability in bed strength (~10s of km) while microseismicity with varying S-P times indicates small-scale bed variability within the initiation area (~100s of m).

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