Geophysical Research Abstracts
Vol. 14, EGU2012-13434-2, 2012
EGU General Assembly 2012

Response of ice motion to tidally influenced subglacial hydraulic systems

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Numerous studies using ground-based and satellite techniques show evidence for active water drainage beneath much of Antarctica. Along ice streams, data indicate hydraulically conductive flow paths with water moving between the overlying ice and underlying bed. Furthermore, data from sites near grounding lines show that flow of ice streams is tidally influenced. For some ice streams, areas of water drainage and tidally influenced flow overlap. These are areas known to be underlain by subglacial deformable till. Field studies, lab experiments, and theory all demonstrate that subglacial water is essential for the weakening of basal till. Weakening of till is critically dependent on effective pressure. Changes in tidal height alter the pressure of a subglacial hydraulic system. Thus, it is possible that changes in water pressure weaken basal till and aid ice slip.

Here, we show how tides affect subglacial till using mathematical and numerical models of subglacial water flow. Tides modulate effective pressure that, under certain circumstances, aids in till failure and slip. The critical parameter for tidal influence on slip is the compressibility of the water system. The compressibility is linked to the amount of water stored along the ice–bed interface. Observations show two starkly different tidally-modulated behaviors. In one case, Rutford Ice Stream has a smoothly varying displacement with the tides. Whillans Ice Stream, however, shows discrete stick-slip events. We show how both of these types of behaviors can be related to hydraulic weakening of the slip interface and discuss implications of this phenomenon.