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Conditions for initiation of surface water drainage to the base of a polar ice sheet

S. Tulaczyk

Department of Earth and Planetary Sciences, University of California, Santa Cruz, CA 95064

An analytical model of downward fracture propagation from ice surface is developed based on the assumption that the rate of propagation is controlled by water flux rate in the fracture [Alley et al., 2005]. The model is first developed for temperate ice and then parametrized to represent growth of water-filled fractures in cold ice. Model results support the conjecture that water-filled fractures may propagate to the bed in a marginal zone of the Greenland ice sheet. Because of non-linear dependence of fracture growth rates on depth, fracture propagation is blocked only by a shallow 'thermal barrier', extending from the ice surface down to ˜10-100 m depth. The ability of a water-filled fracture to reach the bed is only weakly dependent on ice temperature at greater depths (100s-1000s of meters). As the upper layer of ice warms, either due to climate warming and/or advection of an ice column from the accumulation to the ablation zone, the shallow thermal barrier may be removed, enabling development of a connection between supraglacial and basal water systems. Because conductive response times for ice depths of ˜10-100 m are relatively short (˜1-100 years), the lag time between climate warming and increased surface water supply to the bed should be comparably short.