A Model for Subglacial Flooding Along a Pre-existing Hydrological Network During the Rapid Drainage of Supraglacial Lakes

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As presently happening on the Greenland Ice Sheet, large numbers of supraglacial lakes may form and drain rapidly in the future on the West Antartic Ice Sheet. Vertical discharge of water during such events may find a pre-existing film of water potentially within a system of linked cavities. Here, we present a theoretical model for subglacial flooding applied specifically to such circumstances. Given the short timescale of events, we treat the ice and bed as purely elastic and assume that fluid flow is fully turbulent. We evaluate the effect of initial thin film thickness, w_i, on the rate of flood propagation and along-flow profiles of field variables. We find that floods propagate much faster, particularly in early times, for larger w_i. For w_i = 10 and 1 cm, for example, floods travel about 68 and 50% farther than in the fully coupled ice/bed scenario after 2 hours of drainage, respectively. Irrespective of the magnitude of w_i, we also find that there exists a region of positive pressure gradient. This reversal of pressure gradient draws water in from the farfield and causes the thin film to narrow, respecting mass continuity. While the general shape of the profiles appear similar, greater conduit opening is found for larger w_i. For w_i = 10 and 1 cm, for example, the elastostatic conduit opening at the point of injection is about 1.39 and 1.26 times that of the fully coupled ice/bed scenario after 2 hours of drainage. The hypothesis of a pre-existing thin film of water is consistent with the spirit of contemporary state-of-the-art continuum models for subglacial hydrology. Using this framework also results in avoiding the pressure singularity, which is inherent in classical hydrofracture models applied to fully coupled ice/bed scenarios, thus opening an avenue for integrating the likes of our model within continuum hydrological models. Furthermore, we foresee that the theory presented can be used to potentially infer subglacial hydrological conditions, particularly the initial thin film thickness, given accurate observations of ice surface displacement during drainage events.

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