The failure of fracture mechanics: (Or can fracture mechanics be used to predict when melt ponds will drain?)

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One of the discoveries in glaciology over the past decades with far reaching consequences is the realization that melt water can accumulate in ponds or lakes on the surface of ice sheets and ice shelves and then suddenly drain all the way to the ice sheet (or shelf) base. Although these sporadic drainage events have little influence on the mass balance of ice sheets, they can have profound consequences for the dynamics of the ice sheet/shelf. For instance, the explosive disintegration of Antarctic Peninsula ice shelves has been blamed, at least in part, on the increased fragmentation of the ice caused by the hydrofracturing events that preceded melt lake drainage. Linear elastic fracture mechanics (LEFM) provides the theoretical framework which has long been invoked to explain how melt water assisted fractures can penetrate through up to one kilometer of sub-freezing ice. In the most common interpretation of LEFM, the availability of melt water is the primary limiting factor in explaining when fractures will propagate through the entire ice thickness. However, if melt water truly limits when a lake drains one would expect some threshold size beyond which lakes cannot exist.

Instead, observations indicate that the size distribution of surficial lakes on Greenland follows an exponential distribution, where nearly all of the measured lakes have sufficient melt water volume that they ought to drain (by LEFM standards). The question we ask is why don't these lakes drain? In this presentation we argue that fracture is a random process and that the exponential size distribution of observed lakes can be explained using extreme value statistical. In this theory, the probability that a lake will drain is determined from the probability that a lake intersects with a pre-existing fracture. To make predictions using this theory we also need to know something about the size distribution of fractures. We explore a class of statistical thermodynamic models of fracture of disordered media as a means of making quantitative predictions of surficial drainage events.

Under very general assumptions, we show that this approach can explain the exponential distribution of melt lake sizes.