Half-full or half-empty? Informing a model of subglacial lake drainage with observations of surface motion

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Since 2005, approximately 130 new subglacial lakes have been discovered from observations of surface uplift and subsidence; these are commonly referred to as "active lakes". In contrast to the ~160 lakes detected by radar sounding ("RES" lakes), which are typically in mountainous terrain near the ice divide and have residence times spanning millennia, active lakes are typically located beneath fast flowing ice streams far from the divides, have short residence times, and, when surveyed with radar, do not exhibit basal reflections consistent with RES lakes. While the connection between RES lakes and ice dynamics has not been observed, discharge from active lakes has been shown on multiple occasions to temporarily accelerate the flow of ice downstream. We have developed a numerical model that can reproduce the timing and magnitude of observed subglacial lake drainage events in Antarctica based on earlier theoretical work and informed by lake-volume estimates inferred from of ice surface displacements detected by satellite radar and laser altimetry. We find that the overall pattern of filling and drainage is similar to that for ice dammed lakes in alpine regions via channels thermally eroded into the ice that then creeps shut as water pressure declines. However Antarctic lake drainage is better simulated by invoking a channel mechanically eroded into the underlying sediment. Our model predicts that maximum lubrication immediately downstream of the lake should occur when the lake nears its high stand and outflow via a distributed system dominates. The majority of outflow however, occurs via a channelized system, peaking while the lake is half-empty. The amount of lubrication available per unit outflow is sensitive to the geometry of the water system as well as the strength and composition of the surrounding sediments. We explore how this sensitivity is expressed through a variety of environments throughout lower Whillans and Mercer Ice Streams.