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The role of englacial hydrology and hydromechanical processes during an outburst flood cycle from an ice-dammed lake

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In a time of retreating glaciers, outburst floods from ice-marginal lakes are poised to become more prevalent as glaciers thin and tributaries detach. A detailed field-based investigation of the filling and drainage of one such lake, dammed by the 70-km-long Kaskawulsh Glacier in Yukon, Canada, was conducted to characterize the role of the little-studied englacial hydrological system during these events. We deployed a variety of geophysical and hydrometeorological instruments in and around the $\sim$1 km^2 lake to monitor the hydrology and dynamics of the lake—glacier system. By integrating the results from all instruments and surveys, we develop a conceptual model that describes the evolution of various storage reservoirs leading up to, during and following lake drainage.

From the beginning of the instrument record in June 2017, the subaerial lake filled at an average rate of 0.5 m d^{-1} before reaching a maximum volume of 9.9x10^{6}m^3 on 17 August. GPS and timelapse imagery reveal vertical glacier displacements exceeding 25 m near the ice front and 3 m at a kilometer distance, as water is injected beneath a partially floating ice shelf. These data are used to estimate the evolution of the subglacial hydraulic potential, from which a hydraulic seal and likely flood flowpaths are delineated. Abrupt changes in ice-shelf uplift rates, associated with the formation of fractures and faulting, are linked to a redistribution of englacial water. Near the surface, water pressures in multiple boreholes exhibit sudden changes of up to 15 m of head, while at depth, ice-penetrating radar reflection-power measurements indicate fast and slow adjustments in englacial water storage. The onset of drainage begins within six days of a reversal in the subglacial hydraulic gradient near the lake, whereby flow across 55% of the lake catchment area is redirected away from the lake and toward the Kaskawulsh Glacier. Lake outflow discharge appears to increase exponentially over the course of $\sim$19 days, before reaching an estimated maximum of 75-110 m^{3}s^{-1} on 4 September. Radar data collected after the drainage event suggest that the englacial reservoir did not empty entirely, hinting at a possible buffering role for the englacial drainage system.

According to water-balance calculations, the subglacial and englacial reservoirs store approximately 55% and 22%, respectively, of the water in the catchment at peak lake level, compared to 23% in the subaerially exposed lake. In our conceptual model, the subaerial, subglacial and deep/shallow englacial reservoirs connect abruptly in a series of hydromechanical events detected across multiple sensor types. The dynamic coupling of these reservoirs and the abrupt nature of connections between them represent an advance in our conceptual understanding of outburst floods from ice-marginal lakes.