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Controls on crevasse water transmission to the bed of an ice sheet from remotely sensed datasets

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Surface meltwater is transmitted to the bed of the Greenland Ice Sheet via supraglacial lake drainages, moulins, and crevasses. Of these, comparatively little research has been performed on the melt infiltration occurring in crevasse fields, which are widespread in fast-flowing, marine-terminating sectors of the ice sheet. Here, we explore the relationships between crevassing, incidence of surface meltwater, and glacier dynamics at a fast-flowing, marine-terminating sector of West Greenland. Data were collected at high spatial resolution from unmanned aerial vehicle (UAV) surveys on Store Glacier, Greenland, in July 2018. Crevasses and surface water were identified using an object-based machine learning classifier, and strain rates and subsequent stress fields were derived from feature-tracked velocities. Contemporaneous observations of crevasses and surface water on a larger regional scale were made using ArcticDEM and Sentinel-2 data processed in the Google Earth Engine cloud-based geospatial analysis platform, while stress fields are derived from MEaSUREs velocity data. We find that, whilst previous studies have focussed on relationships between crevassing and stress regime through yield criterion such as the Von Mises stress, we can additionally link the observed spatial distribution of surface meltwater over crevasse fields to the mean stress (defined as the arithmetic mean of the maximum and minimum stress). Crevasse fields existing in tensile mean stress regimes were less likely to exhibit ponded meltwater through a melt season, which we interpret as meltwater being able to continuously drain into the englacial system. Conversely, crevasse fields in compressive mean stress regimes were more likely to exhibit ponded meltwater, which we interpret to be as a result of englacial conduit closure. We show that in these compressive regions, water transfer takes place via intermittent drainage events (i.e. hydrofracture), as envisaged in linear elastic fracture mechanics (LEFM) models. Hence, stress regime can inform spatially heterogeneous styles of crevasse drainage across the ablation zone of an ice sheet: a continuous, low-intensity mode in extensional regimes, in contrast to an episodic, high-intensity mode in compressional regimes. These processes may have distinctly different impacts on basal processes, including subglacial drainage efficiency, diurnal variability, and cryo-hydrologic warming.