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Drainage system structure and evolution at a Greenland outlet glacier

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Coupling between surface melting of the Greenland Ice Sheet and accelerated ice flow, through lubrication of the ice-bed interface, is controlled strongly by the nature of the subglacial drainage system. It is not agreed, however, whether higher melt rates will increase or decrease dynamic mass loss from the ice sheet in a warmer climate. In particular, there is debate as to whether the earlier growth of efficient subglacial channels in warmer summers may lead to a decrease in mean water pressure and ice velocity during years of greater melt. Due to the difficulty of observing the subglacial environment, this debate has focussed primarily on the comparison of ice velocity and melt records. Here, we present results from 43 dye tracing experiments undertaken over the course of the 2010 melt season at Leverett Glacier, an outlet glacier on the western margin of the Greenland Ice Sheet, to obtain a more direct, detailed and independent picture of drainage system structure and evolution beneath the ice sheet.

These observations reveal a seasonal rise in drainage system efficiency which closely resembles that occurring at alpine glaciers, with a rapid transition from an inefficient, distributed drainage system to an efficient channelised system soon after the onset of runoff. The capacity of the drainage system can however be overwhelmed by rising meltwater inputs even following channelisation, leading to englacial water storage and elevated subglacial water pressure. These observations are supported by comparison with differential GPS units located on Leverett Glacier which show a positive correlation between inferred stored water volume and ice velocity throughout the melt season. Since ice velocity continues to respond to changes in discharge following channelisation, this suggests that earlier channelisation of the drainage system in warmer melt years need not reduce summer ice motion relative to cooler years.