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Hydraulic controls on glacier and ice cap flow

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The supply of surface meltwater to the beds of glaciers and ice caps can have a profound impact on their flow. This is a key ingredient in assessing how the dynamics of glaciers will change under a warming in climate, which will often lead to longer melt seasons and more intense surface water input to the bed. Classical glacier hydraulics theory suggests that high water supply rates should be associated with the formation of an efficient, channelized drainage system at low water pressure, and consequently with slow ice flow. Direct observations paint a much more complicated picture, with significant spatial and temporal variations in subglacial water pressure and surface velocity.

Here we show how spatially extended models for drainage through a system of connected cavities and channels can describe a wide range of responses to surface water input. After a ‘spring event’ transient early in the melt season, channelization driven by an increase in water input can indeed lead to slow-down, but whether this occurs crucially depends on four factors: i) the relative magnitude of background water flow to seasonal surface water supply ii) how concentrated surface water supply is trough discrete moulins iii) the temporal variability of water input, iv) the capacity of the drainage system to store water. Contrary to classical notions, we find that concentrated, highly temporally variable water input typically leads to significant localized speed-up (when averaged over diurnal cycles), especially when background water supply is small. We also show that the storage capacity of the drainage system plays a crucial role in damping the magnitude and spatial extent of this speed-up, in particular in more extensive drainage systems such as those expected to form under ice caps.