Geophysical Research Abstracts
Vol. 21, EGU2019-14486, 2019
EGU General Assembly 2019

From diurnal to seasonal dynamics of the subglacial hydrology revealed by cryoseismology

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Subglacial hydrology strongly modulates glacier basal sliding, and thus likely exerts a major control on ice loss and consequent sea-level rise. Subglacial water pressure and subglacial channel size are two key properties which determine how glacier and ice cap sliding evolves with melt water supply. Quantifying those properties, however, is challenging as they do not simply scale with water input and remains poorly constrained due to lacking observations. Recent work shows that seismology is a valuable tool to fill this observational gap as seismic recordings are sensitive to subglacial channel flow. Theoretical work has established a link between seismicity and changes in hydraulic radius and water pressure gradient within subglacial channels. This link can be leveraged when proglacial water discharge measurements exist. The applicability of this framework over relevant glaciological periods (diurnal and seasonal) and its implications for subglacial hydraulic processes remain to be explored: this is the objective of this study.

On the Argentière glacier (French Alps), we explore the temporal evolution of the hydraulic radii and basal water pressure gradients of subglacial conduits over two complete melt seasons (spring 2017 to winter 2018). For this glacier continuous water discharge measurements are available, and changes in subglacial hydrology properties are well reflected by changes in glacial basal sliding speeds measured in-situ at the ice bed. On seasonal timescales, we observe a non-unique relation between channel size and water pressure gradient. Basal water pressure gradients are high at the very beginning of the melt season with limited channel size. This is consistent with significant glacier sliding acceleration observed at that time. When pressure gradients decrease until mid-May, channels reach their maximum sizes within about two months (early May to late June). Subsequently, both quantities concomitantly evolve through the summer with channel radii remaining at their maximum sizes and decreasing starting end of August. On diurnal scales we observe a pronounced hysteresis between seismic power and water discharge in early spring, in fall and during storm events. This hysteresis is caused by rapidly increasing basal water pressure gradients peaking up to 6 hours before the daily surface melt water supply. During the rest of the season the diurnal hysteresis is less significant, therefore daily runoff fluctuations mainly cause hydraulic radius fluctuations. We conclude that on-glacier seismology allows studying subglacial hydraulic processes through a complete melt season from diurnal to seasonal timescales.