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Observing ice-bed weakening on a fast flowing glacier with seismic noise interferometry and unsupevised clustering.

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Glacier flow instability often results from changes at the ice-bed interface. However, understanding these processes is challenging due to limited access to the glacier bed. Our study focuses on Kongsvegen glacier in Svalbard, which shows signs of an upcoming rapid flow event. To investigate the potential causes of such acceleration, we installed 20 seismometers along the glacier flowline, from the surface down to 350 m near the ice-bed interface. We combined our seismic monitoring with measurements of surface velocity, basal water pressure, and basal sediment deformation.

First, we performed seismic noise interferometry between stations located along the glacier flowline with inter-station distances ranging from 1 to 12 km. We observed a multi-year decrease in seismic velocity, with a seasonal signal superimposed, showing a melt-season decrease in seismic velocity of 2 to 4%. We compared our observations with 1D models and concluded on the presence of damaged basal ice and/or a weakening of the subglacial sediments. This indicates a mechanical weakening of the ice-bed interface, promoting further glacier acceleration.

Second, we conducted unsupervised clustering of seismic waveforms using a novel approach based on a deep scattering network. Doing so, we observed a yearly increase in surface crevasses concomitant with an increase in basal events, likely indicating stick-slip and/or basal crevasses. This increase is particularly visible during winter, where the number of events steadily increases from year to year. We suggest that, in response to an initial glacier acceleration, new crevasses have opened, providing access pathways for surface meltwater to the base of the glacier, affecting the ice-bed coupling. This mechanism represents a positive hydro-mechanical feedback that fuels further acceleration and crevassing, potentially having wider implications for triggering glacier-wide instabilities, increasing short-term sea-level rise, and local hazards.