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Characterization of seismic signals and their sources in alpine glacier ice

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The presentation gives an overview of past and current efforts to study glacial ice deformation via passive seismic measurements. The first systematic observations based on an array of sensors installed on the glacier itself was undertaken on Athabasca Glacier, Canada, in 1970. Based on this study as well as on some others that followed it, it was concluded that most seismic energy is radiated by the opening of crevasses. Although some signals observed on land-based sensors were hypothesized to be related to basal slip, most sources of icequakes were believed to be constrained to shallow depths. The frequency of occurrence of these shallow icequakes was observed to correlate closely with fluctuations in flow velocity and thus with deformation. More recently, on Unteraargletscher, in the Swiss Alps, icequakes were shown to occur also at intermediate depths as well as near or at the bed. This shows that brittle deformation of glacier ice is not restricted to any particular depth. Three-component seismograms recorded during the Unteraargletscher investigation as well as during recent field work on Gornergletscher, Switzerland, allow for a more detailed characterization of the fracture processes inside the glacier. High-precision relative location techniques applied to clusters of icequakes originating from the same fracture are used to study possible relations to the hydraulic regime inside and at the base of the glacier. Whereas most of the observed signals seem to be compatible with a tensile source, some of the recently observed seismograms suggest the occurrence also of shear failure in ice, which up to this point was believed to fracture under tensile stress only. A comparison of the observed signals with synthetic seismograms calculated for different source types is being undertaken to clarify this issue.