# Intermediate-depth & Basal icequakes at Greenland's fastest outlet glacier

← *Evidence for englacial thrust faulting?*

Patterns in basal stick-slip? →

QR to abstract

**Objective**

Constrain and understand fast ice stream dynamics with passive seismology. Investigate processes such as englacial brittle deformation and frictional basal sliding.

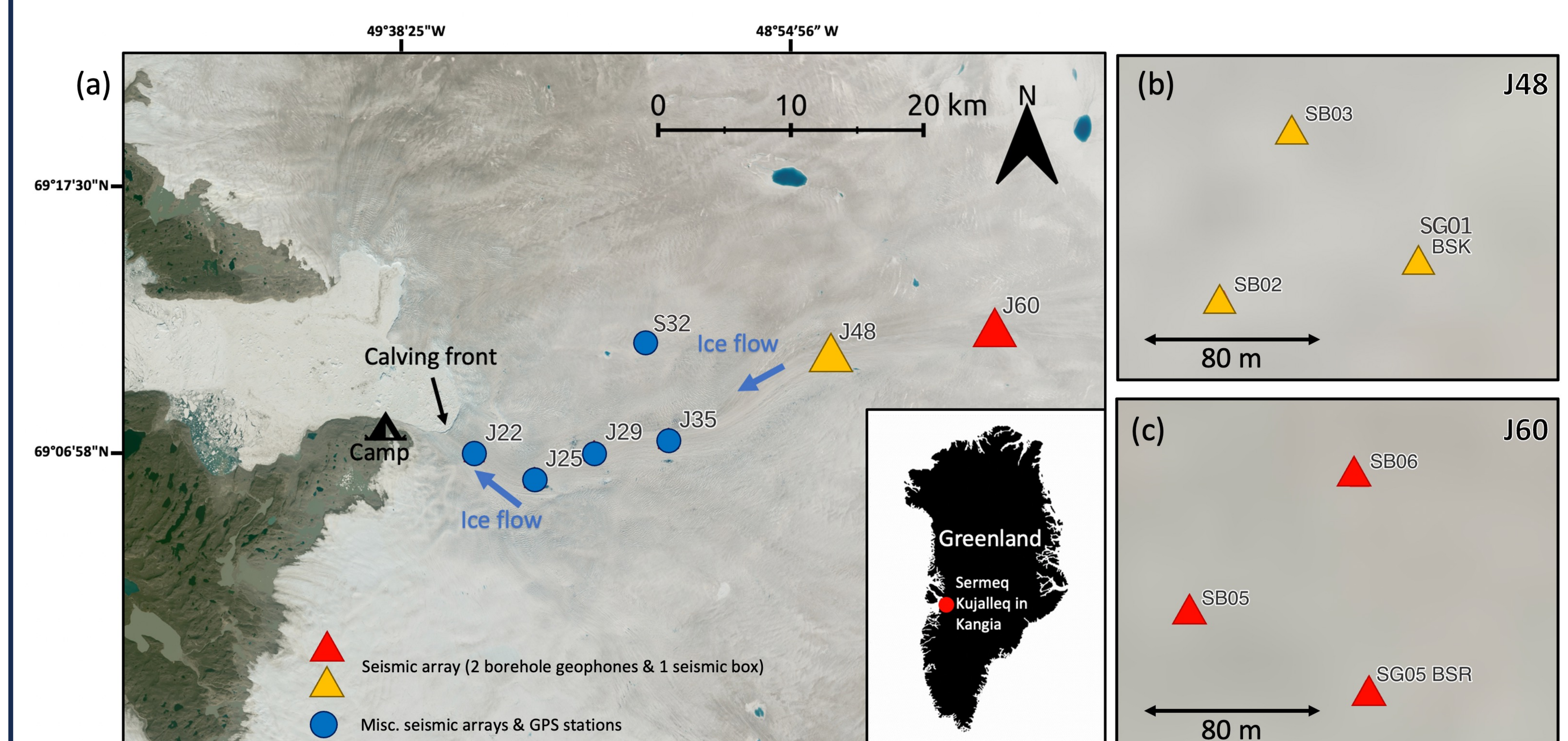


*Fig. 1. Total deployment in summer season 2022 on SKK, Greenland. Array J48 recorded from May – September, Array J60 from July – September.*

**Background**

- **Sermeq Kujalleq in Kangia (SKK)** (also known as Jakobshavn Isbrae) → Extremely fast ice flow of up to 40 m/d at the calving front. → Largest contributor to solid ice discharge from the Greenland ice sheet.
- Within the **COEBELI project**: Two large field campaigns in 2022 and 2023, combining multiple types of field measurements (various seismic arrays, GPS, terrestrial radar, long range drone) and modelling.

## Intermediate-depth Icequakes

**J60** *Englacial 200 – 420 m depth*

- Traditional glacier flow laws assume non-Newtonian viscous fluid, neglecting the possibility of elastic and brittle deformation.
- We detected icequakes occuring within the ice, suggesting englacial dislocations, possibly stick-slip (caused by thrust faulting?).

**Stacks of 2 intermediate-depth "clusters"** *→ Good P wave match, S wave out of phase*

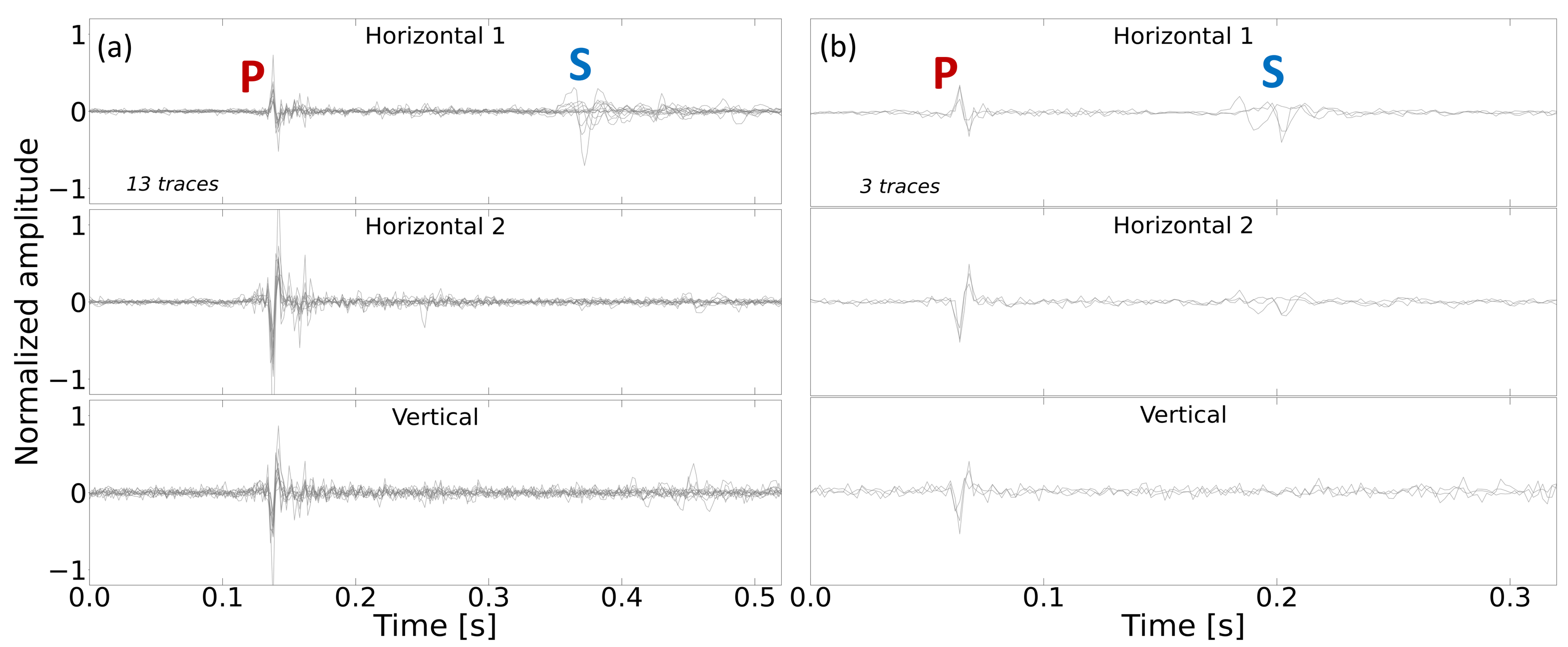


*Fig. 2 Two example event stacks of intermediate-depth events from borehole station SB05. The borehole sensors are not geographically oriented, hence the naming of the horizontal components.*

**Individual locations of all icequakes** *→ Horizontally spread, but similar depth per "cluster"*

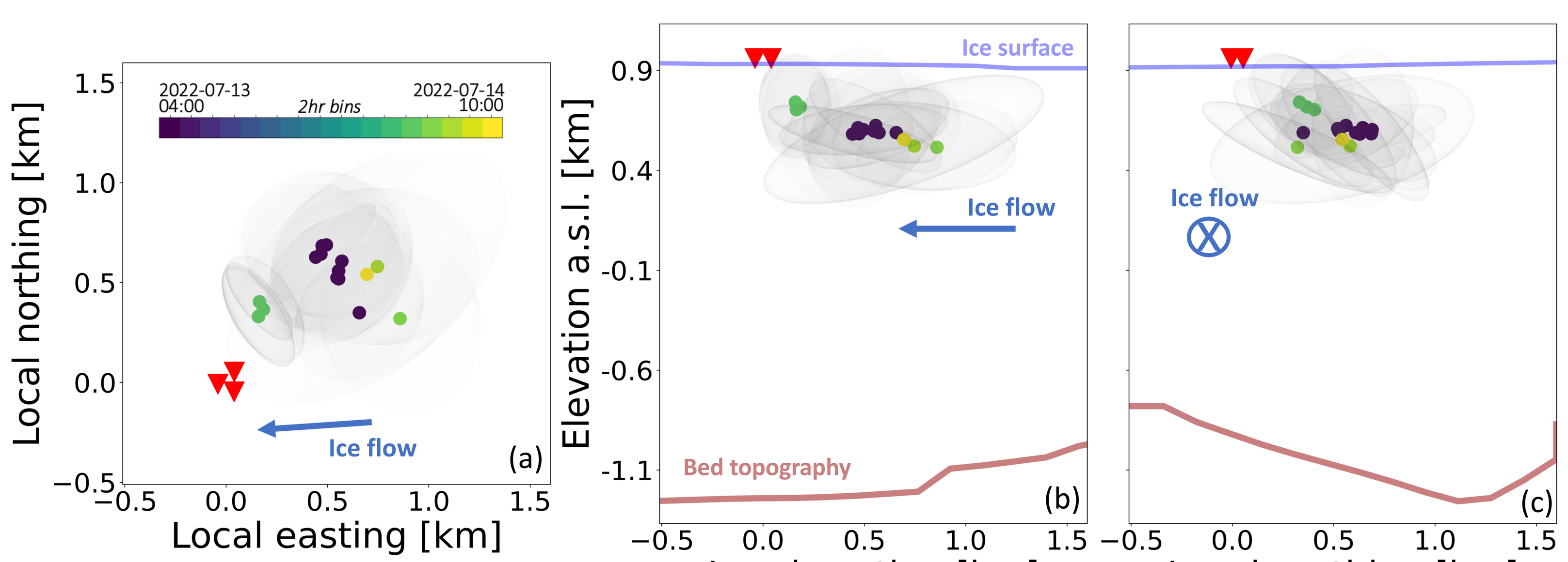


*Fig. 3 Locations of all icequakes in stacks of Fig. 2. Individually located with NonLinLoc and coloured according to event time within 2 hour bins. The grey ellipses represent the location error. (a) Top view, the cluster of 3 icequakes closest to the array correspond to the events from Fig. 2b. (b) Side view E-W (c) Side view S-N.*

**Spectogram and particle motion** *→ Similar frequencies as basal stick-slip events*

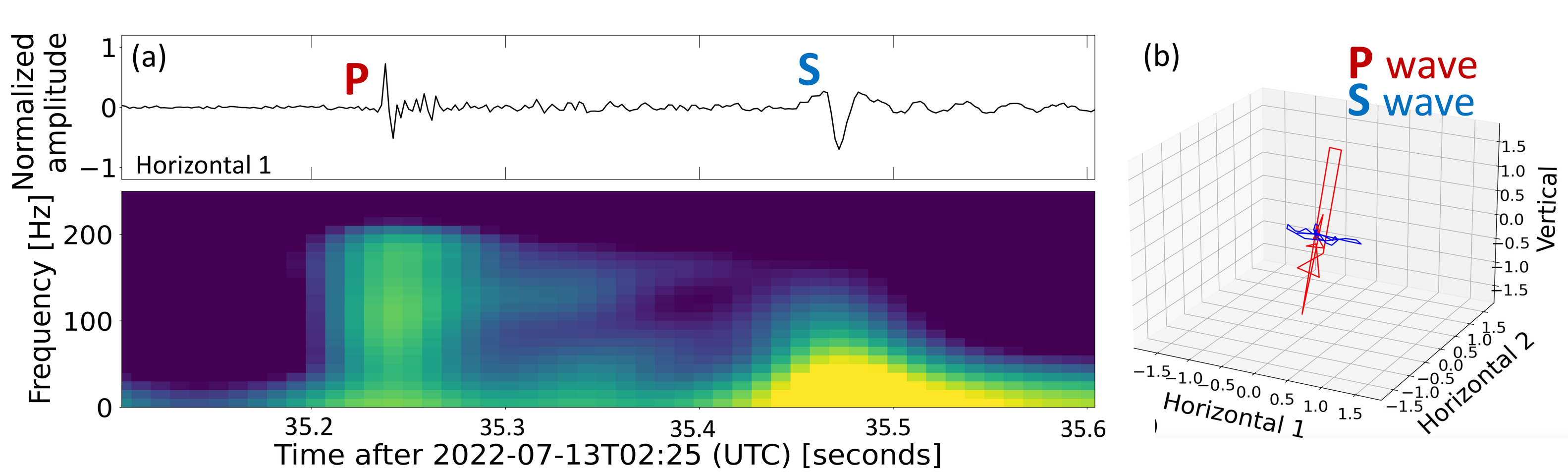


*Fig. 4 (a) Spectogram of one icequake event from the stack in Fig 2a. (b) Particle motion P and S wave of waveform in Fig. 4a.*

**Outlook**

- Find more clusters/events through search- and template matching algorithms.
- Source mechanism analysis → Hydro-fracturing? Stick-slip caused by thrust faulting?
- Analyse activity of intermediate-depth icequakes over time and space.

## Basal icequakes

**J48** *> 2000 m depth*

- To what degree does basal friction control the flow regime of fast flowing outlet glaciers?
- Basal (stick-slip) icequakes observed at SKK can give us insight into the frictional regime of fast outlet glaciers.

***Stack of basal cluster*** *→ Striking correlation!*

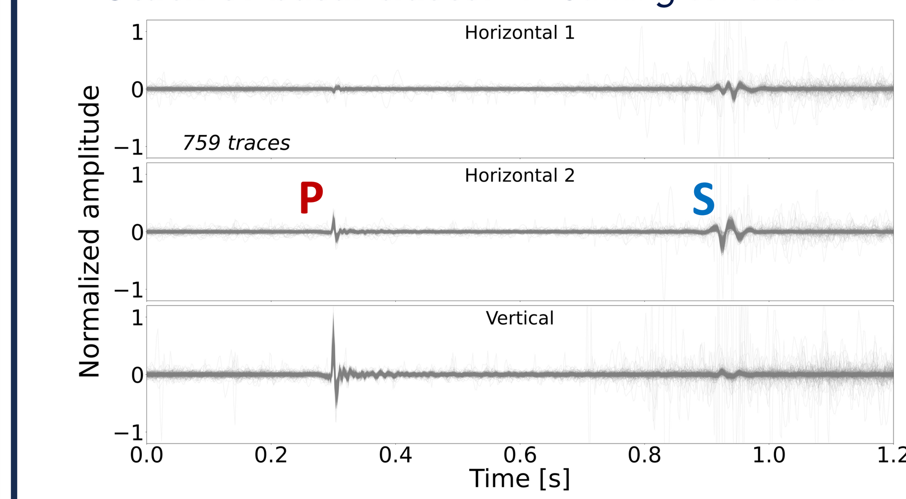


*Fig. 5 Stack of basal icequakes from station SB02, detected with template search. The borehole sensors are not geographically oriented, hence the naming of the horizontal components.*

***Location of basal cluster*** *→ Clearly constrained at depth, located with picks on mean cluster waveforms*

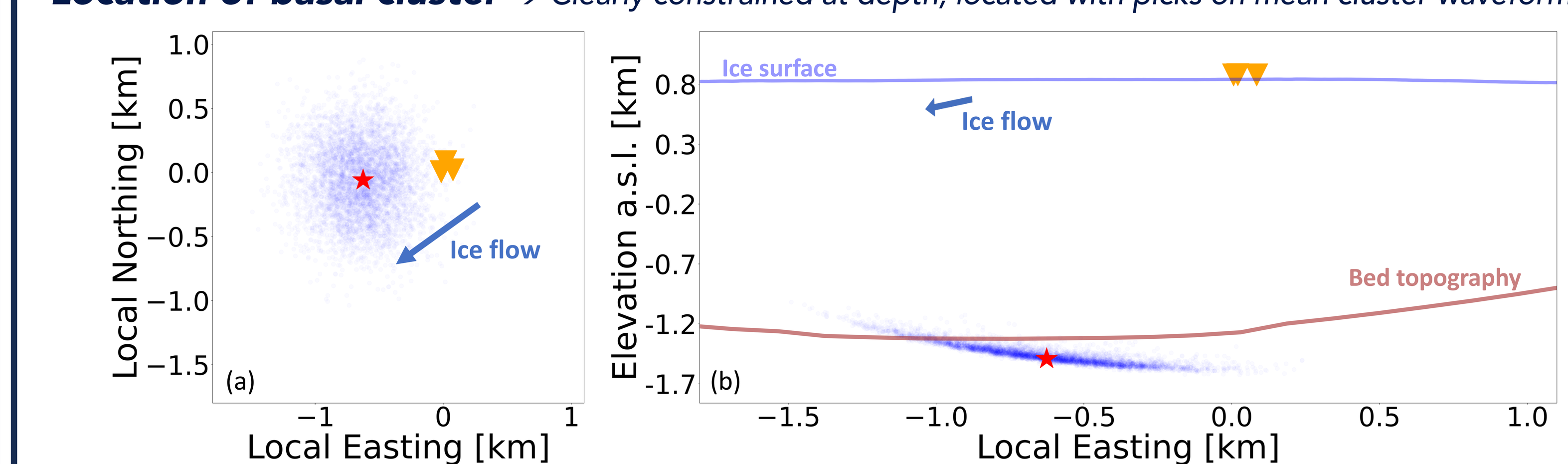


*Fig. 6 Location of basal icequake cluster from mean cluster waveforms. (a) Top view (b) Side view S – N. The red star represents the most probable hypocenter and the blue dots are the power spectral density clouds, a representation of the error.*

***Cluster activity over time*** *→ Alternating active & inactive phases. Amplitude fluctuations during active phases*

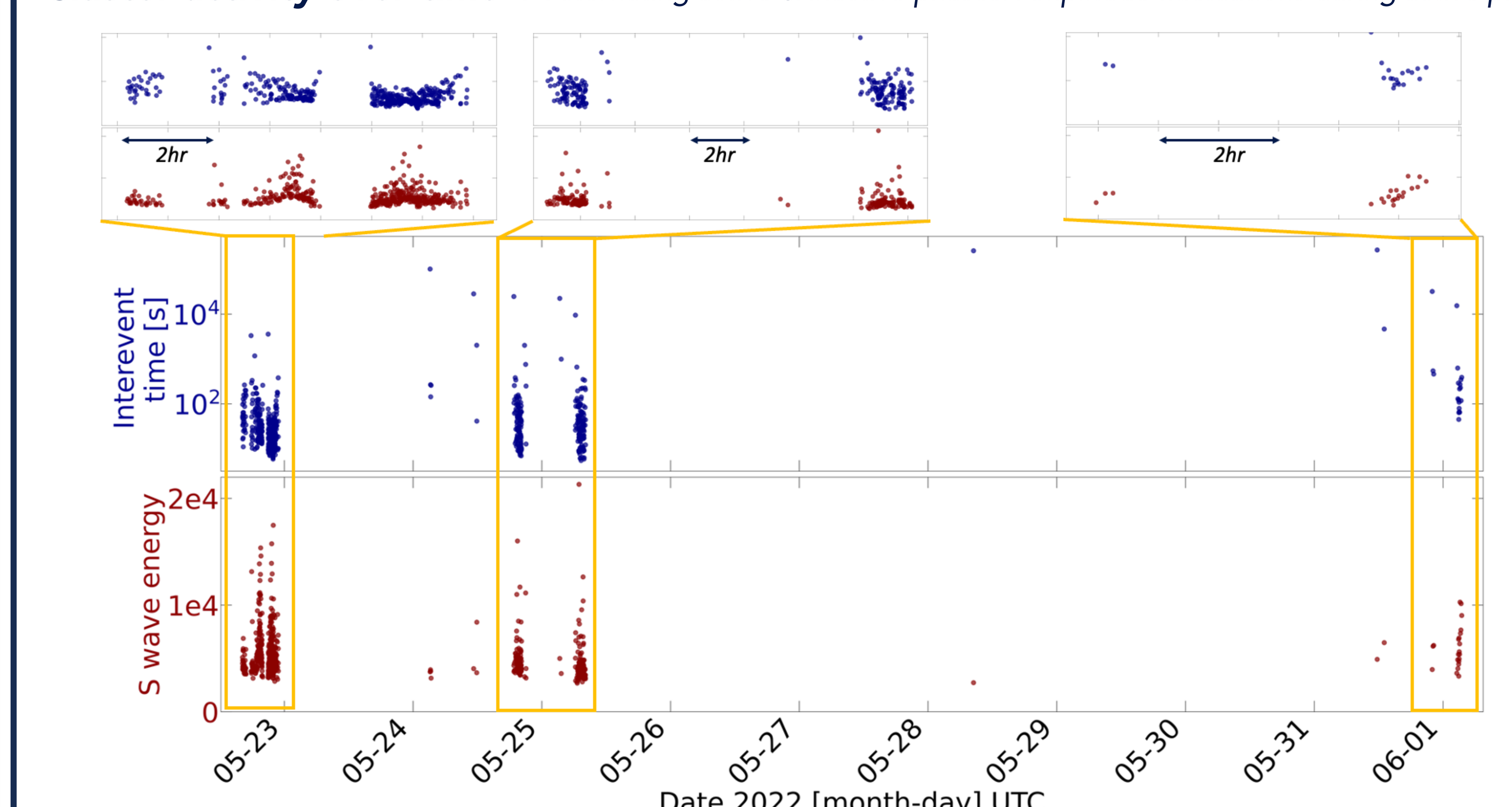


*Fig. 7 Cluster activity over time. The S wave energy is calculated by integration over the S wave of each individual icequake. The interevent time is the time between consecutive icequakes. At the top: zoomed snippets of the active phases.*

**Spectogram and particle motion** *→ Both agree with known basal P & S wave characteristics*

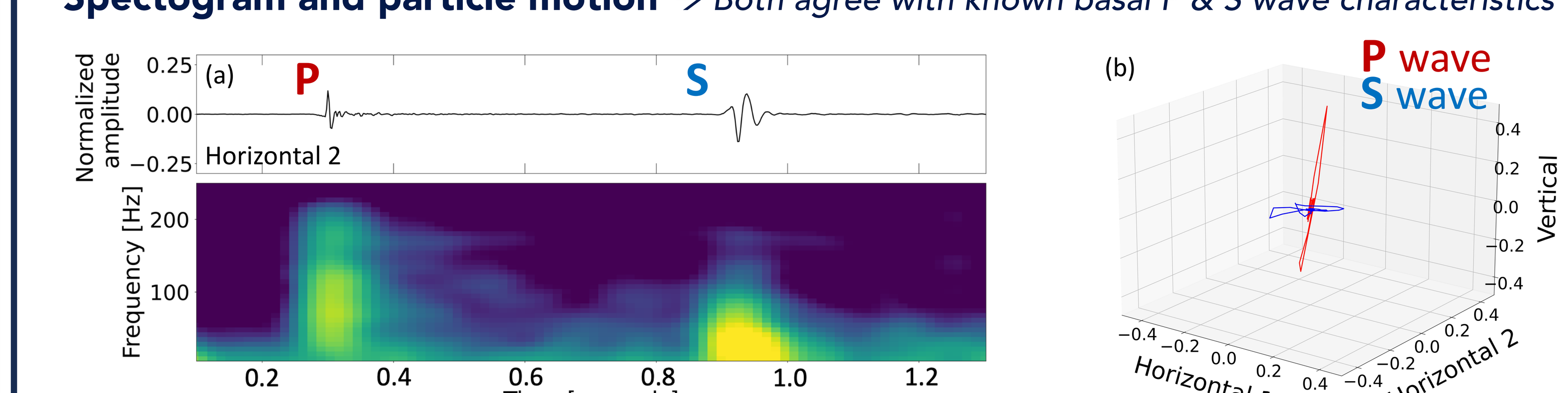


*Fig. 8 (a) Spectogram of mean waveform basal cluster taken from the horizontal 1 component of station SB02. (b) Particle motion of P and S wave from waveform in Fig. 8a.*

**Outlook**

- Find more clusters/events through search- and template matching algorithms.
- Analyse activity over time vs. ice flow velocity.
- Source mechanism analysis (double couple source?)
- Possible shear wave splitting → anisotropy analysis?


**Ana Nap**[1], Fabian Walter[2], Adrien Wehrlé[1], Martin P. Lüthi[1], Janneke van Ginkel[2,3], Andrea Kneib-Walter[1] & Hugo Rousseau[1]

[1]Glaciology and Geomorphodynamics Group, University of Zürich, Zürich, Switzerland [2]Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmersdorf, Switzerland [3] Swiss Seismological Service, ETH Zürich, Zürich, Switzerland

ana.nap@geo.uzh.ch


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**References:**

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**Lomax A., et al.. (2000)** Probabilistic Earthquake Location in 3D and Layered Models. *Modern approaches in Geophysics.*

**Nap, A. et al. (2023).** Self-sufficient seismic boxes for monitoring glacier seismology. *Seismica.*