Student Project:

Exploring the effects of a heterogeneous medium on icequake source inversion

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Icequakes are earthquakes that occur at glaciers. They can be caused by numerous glacier processes, from surface crevassing to sliding of ice into the oceans. Such icequakes can be used to provide observational constraint of critical processes that affect the stability of glaciers and control how fast ice might flow into the oceans, promoting sea-level rise.

One useful tool for interrogating the physical processes that generate icequakes is earthquake moment tensor inversion, where one inverts for the direction and mechanism of strain release of the earthquake/icequake. To date, studies have typically approximated these icequakes as being generated within a homogeneous medium, that is a structure where the seismic properties don't vary spatially. However, recently collected datasets are now allowing us to observe icequake signals in sufficient detail that we now need to start accounting for the effect of varying properties of the medium surrounding an icequake.

One particularly exciting dataset for which this is the case is a dataset collected from a crevasse field at Gornergletscher, Switzerland. Fibreoptic sensors and seismic nodes were deployed to provide 100s measurements of the seismic wavefield, directly above the crevasses. Sometimes these crevasses are filled with water and at other times they are filled with air. In each case, these cracks will likely have significant effects on the energy that propagates from the icequake source at the tip of the crack. Such crevasse fracturing caused by the presence of water is hypothesized to be a key cause of the disintegration of glaciers and ice shelves.

The student will investigate the effect of a heterogeneous medium surrounding these crevasse icequakes sources. To do this they will use full-waveform inversion techniques developed by the Seismology and Wave Physics group at ETH Zurich. This will include forward modelling the wavefield using the state-of-the-art full-waveform propagation software, Salvus, and the possibility of working with Distributed Acoustic Sensing data.

Key aims of the project include:

- Developing expertise in running full-waveform propagation software.
- Varying the properties of the medium, simulating the effects of (empty and fluid filled) crevasse fractures on wave propagation.
- Use the forward models to invert for icequake source mechanisms.
- Gain exposure to Distributed Acoustic Sensing data.

This project would ideally suit students with a strong numerical background, passionate about applying their skills to real-world problems that will have global significance for society. Some experience working with Python is essential, although the student will benefit from mentoring from the supervisors to develop their coding skills further. Assuming that the project is successful, it would be possible to extend this project to a Master thesis, especially if the student would like to explore the scientific implications of the initial project findings.

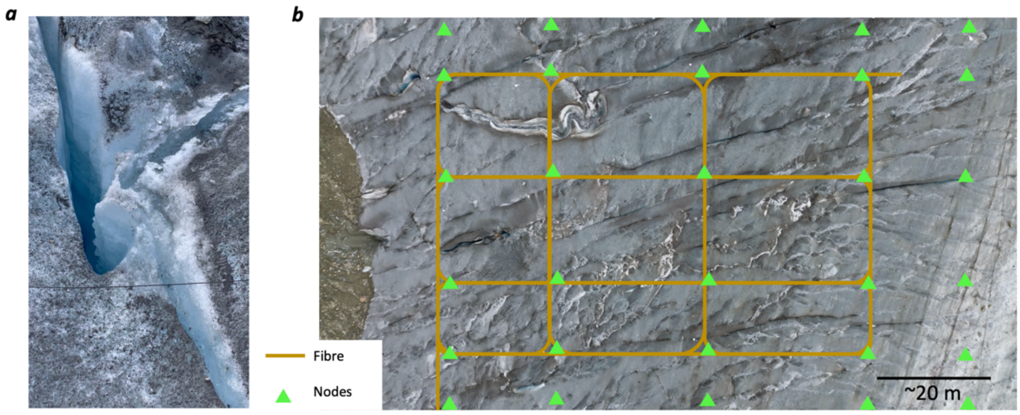

Figure 1 – a. Example of crevasse. b. Crevasse field where the real-world data relevant to this project was collected (Gornergletscher, Switzerland).

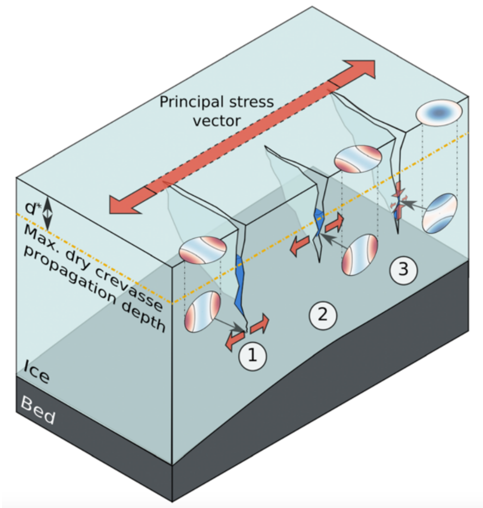

Figure 2 – Hypothesized mechanisms that generate crevassing icequakes (Hudson et al. (2020)).

Relevent Publications:

Afanasiev, M., Boehm, C., Van Driel, M., Krischer, L., Rietmann, M., May, D. A., et al. (2019). Modular and flexible spectral-element waveform modelling in two and three dimensions. Geophysical Journal International, 216(3), 1675–1692. https://doi.org/10.1093/gji/ggy469

Hudson, T. S., Brisbourne, A. M., White, R. S., Kendall, J. M., Arthern, R., & Smith, A. M. (2020). Breaking the Ice: Identifying Hydraulically Forced Crevassing. Geophysical Research Letters, 47(21). https://doi.org/10.1029/2020GL090597

Hudson, T. S., Brisbourne, A. M., Walter, F., Gräff, D., White, R. S., & Smith, A. M. (2020). Icequake Source Mechanisms for Studying Glacial Sliding. Journal of Geophysical Research: Earth Surface, 125(11). https://doi.org/10.1029/2020JF005627

Walter, F., Clinton, J. F., Deichmann, N., Dreger, D. S., Minson, S. E., & Funk, M. (2009). Moment tensor inversions of icequakes on Gornergletscher , Switzerland. Bulletin of the Seismological Society of America, 99(2), 852–870. https://doi.org/10.1785/0120080110