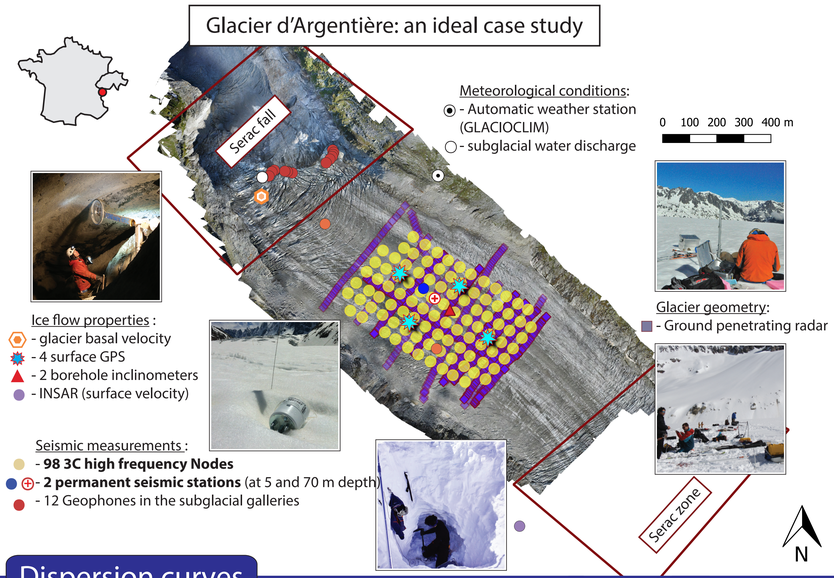
Using dense array seismology to observe glacier dynamics: the RESOLVE-Argentière project

Philippe Roux[1], Florent Gimbert[2], Ugo Nanni[2], Agnès Helmstetter[1], Benoit Urruty[1,2], Stéphane Garambois[1], Andrea Walpersdorf[1], Christian Vincent[2], Albanne Lecointre[1], and Mickael Langlais[1]

Experimental setup

Glacier dynamics regulates the advection of ice towards lower elevations with higher temperature and melt rates, and thus controls the fresh water supply to populations for mountain glaciers and sea level rise for ice sheets.
The **RESOLVE-Argentière** project aims at:
- providing finely resolved observations of glacier process from the use of dense geophysical array.
- using the observations to improve physical laws in theoretical ice-flow models.



Seismic ang glaciological context

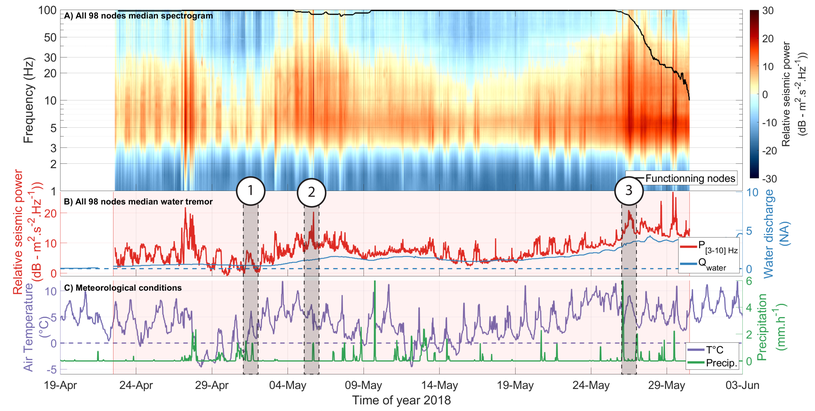


Figure 2: Time series of physical quantities measured during the RESOLVE-Argentiere project. (a) Median seismic power taken over the 98 nodes. (b) Median seismic power assembled from the 98 nodes as averaged in the [3-10] Hz frequency range (red line) and subglacial water discharge (blue line). (c) Surface air temperature (purple line) and precipitations (green line). Numbers refers to Fig. 12

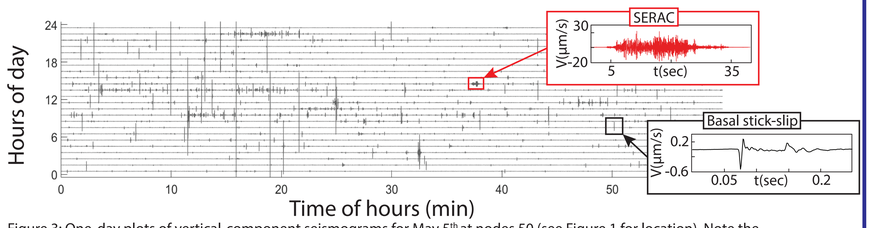


Figure 3: One-day plots of vertical-component seismograms for May 5th at nodes 50 (see Figure 1 for location). Note the numerous impulsive events whose amplitudes are above the background noise.

Event detection and location method

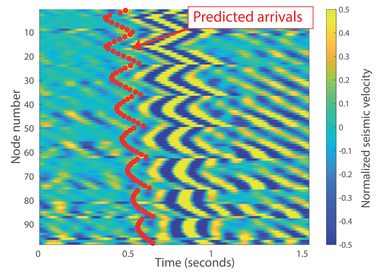


Figure 4: Example of predicted (red) versus observed (colorscale) timedelays

1 → Consider 0.5 seconds-long time windows

2 → Assume a punctual source exists over that time window

3 → Best locate the event based on phase delay minimization from beamforming analysis (Figures 3 and 4)

4 → Consider as « true » seismic sources that are associated with a beamformer value exceeding a certain treshold (Figure 5)

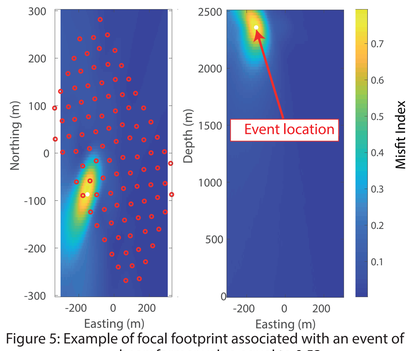


Figure 5: Example of focal footprint associated with an event of beamformer value equal to 0.53

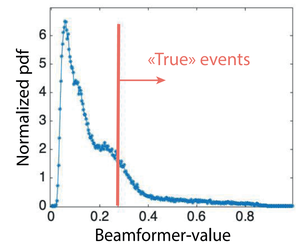


Figure 6: Normalized probability distribution function of the beamformer value

Dispersion curves

Two methods

Subset of manually detected events

Velocity outputs of the beam-forming inversion

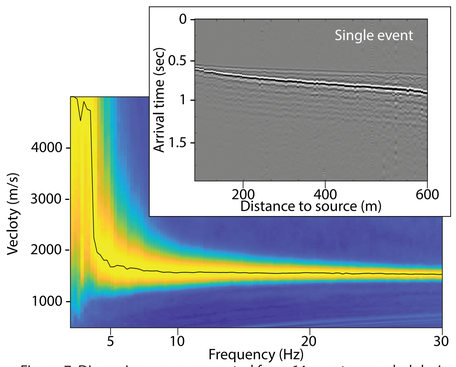


Figure 7: Dispersion curve computed from 64 events recorded during first hour of April 26th. Black line represents the highest probability for each frequency bins.

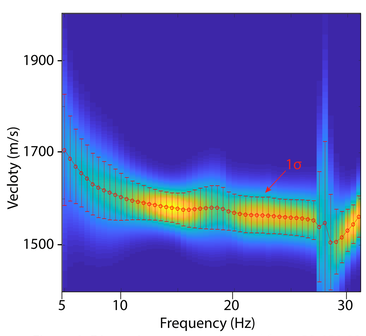


Figure 8: Dispersion curve estimated from 52 650 936 sources located with the beam-forming method.

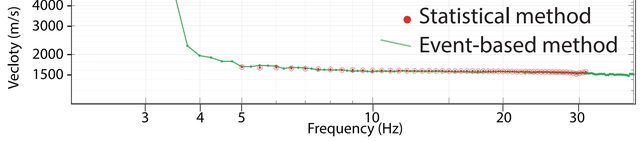


Figure 9: Comparison between the two methods to compute the dispersion curve.

Spatio-temporal dynamics of ponctual sources

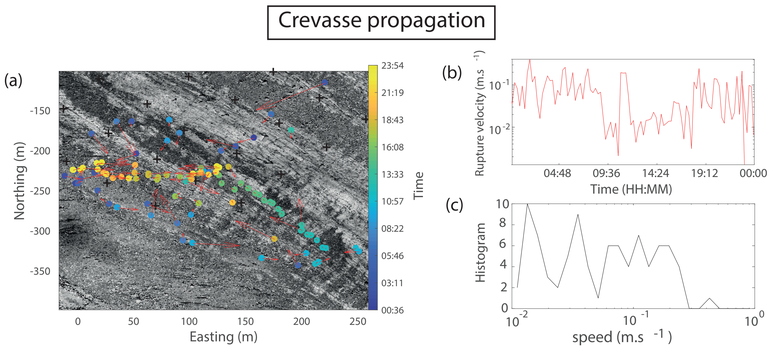


Figure 10: Rupture propagation of a crevasse as observed on April 26 (using 17 Hz frequency waveforms). (a) Localization of rupture events through time (see colorscale). Red arrows indicate velocity vectors. (b) Rupture velocity as a function of time throgout the day. (c) Histogram of rupture velocities.

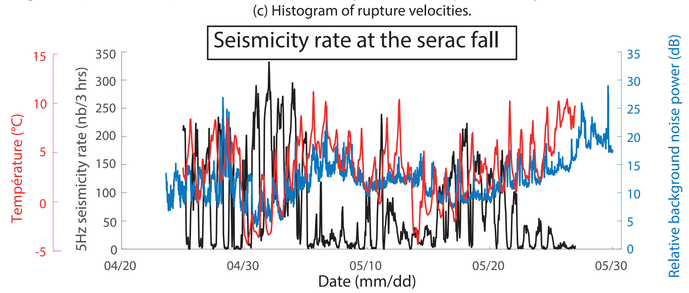


Figure 11: Seismicity rate in the bottom serac fall area (black, using 5-Hz frequency waveforms), air temperature (red) and background seismic noise power (blue) as a function of time.

Seismic amplitudes

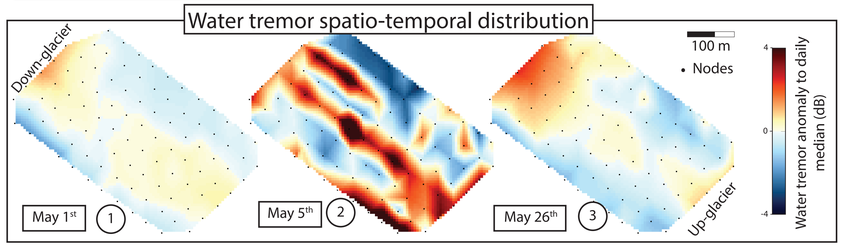


Figure 12. Map view of seismic power daily anomalies in the [3-10] Hz frequency range as interpolated from observations at the 98 nodes. Days with three distinct patterns are presented (see Figure 3 for corresponding time periods). Seismic power anomaly is caclulated as the difference between seismic power at a given node and median seismic power (as calculated over the entire array).

Source or site effect ?

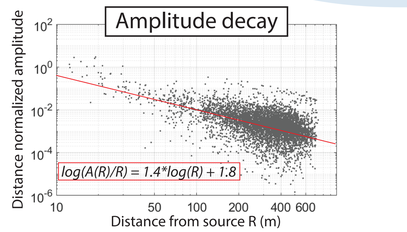


Figure 13. Anelastic attenuation as quantified by evaluating the nomalized amplitude *A(R)/R* for 64 events that occured during the first hour of April 26th. The ration *A(R)/R* is normalized by that observed at the closest distance.

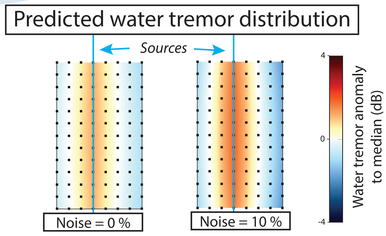


Figure 14. Water tremor anomalies as predicted over the array, under a line source configuration and using observationnaly-constrained wave propagation and attenuation parameters. We consider plane waves, an homogeneous glacier ice and a quality factor Q = 8. Different background are shown.

(2) (3) = source (1) = site ?

Affiliations: [1] University of Grenoble Alpes, CNRS, IRD, Institut des Sciences de la Terre (ISTerre), Grenoble, France.
[2] University of Grenoble Alpes, CNRS, IRD, Institut des Géosciences de l'Environnement (IGE), Grenoble, France.

Financial supports: Université Grenoble Alpes and Obserbatoire des sciences de l'Univers de Grenoble

Visit our website: https://resolve.osug.fr/