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Dense seismic array observations of spatial and temporal channels in subglacial hydrology in an Alpine Glacier

♫ Listen to a 1 min audio summary

Welcome to our online presentation.

We propose a different format than the traditionnal oral presentation with more detailed and interactive materials ( ).

Challenges

Investigating the spatial organisation of the **drainage system** through time is a challenge for both the glaciological and the seismological communities.

This study aims at bringing new insights on the subglacial hydrology spatial dynamics using **dense array seismic observations** and combining phase and amplitude approaches to locate subglacial water flow.

Outcomes

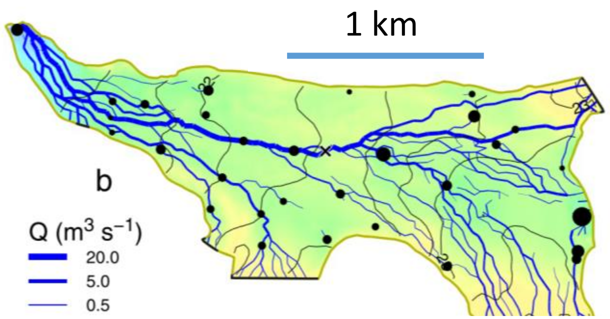
The phase-driven approach shows an evolution in noise sources that represents the **transition** from a **distributed** drainage system toward the development of one main subglacial **channel**.

The amplitude-driven approach shows spatial pattern that are representative of the **subglacial water pressure**.

We are capable of investigating **subglacial water flow properties** in **space** and in **time.**

Jump to the end

Challenges in subglacial hydrology and seismological opportunities



Subglacial drainage system as modelled by Werder et., (2013)

Subglacial hydrology strongly modulates glacier basal sliding, and exerts a major control on ice loss and sea-level rise.

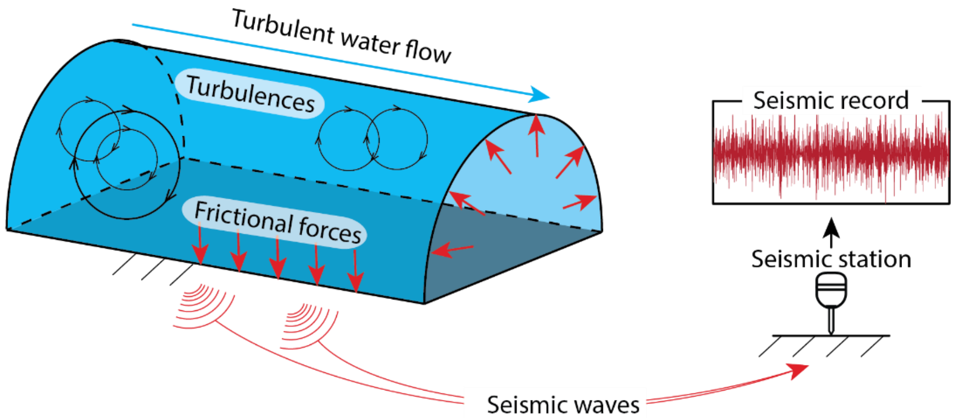
The subglacial drainage system of hard-bedded glacier is considered to be composed of a widespread inefficient drainage system with slow and pressurized water flow (**cavities**) and of a localized efficient drainage system with faster and less pressurized water flow (**channels** melted into the ice).

The **limited** direct and **spatialized observations** make difficult to assess the physical processes involved in its development.

Recent work shows that **seismic noise** analysis may be used to retrieve the **physical properties** of subglacial water flow (e.g. Vore et al., 2019; Lindner et al., 2020; Nanni et al., 2020).

The capability to investigate the drainage system **spatial** organisation and evolving **properties** remains to be demonstrated.

A major challenge lies in the seismic source of the subglacial channel flow that is a **continuous** source of noise distributed in space and likely strongly **varying** in time.



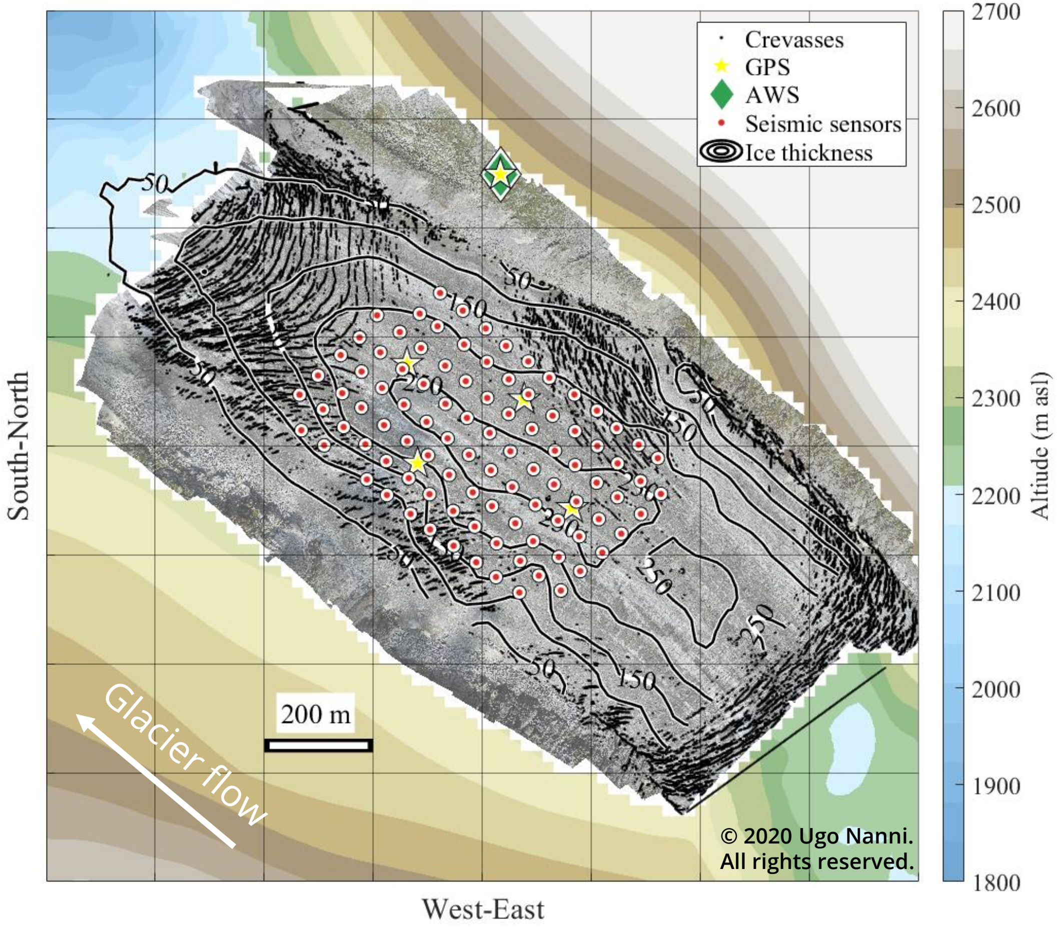
Schematic representation of subglacial channel-flow-induced seismic noise from Nanni et al., (2020)

Dense seismic array and complementary measurements

We use the setup of the [RESOLVE-Argentière] experiment that consists in a **one-month deployment of 98 seismic** stations on the glacier d'Argentière (French Alps) at the onset of the melt season.

This site is ideal to study **subglacial hydrology** and its link with glacier dynamics.

In this location subglacial water flow strongly influence **glacier dynamics** (Vincent and Moreau., 2016; Gimbert et al., in review) and generate a continuous seismic noise (Nanni et al., 2020) which is expected to be both **spatially continuous** outside and inside of our seismic array.



Monitoring setup with aerial view of the field on top of the surface elevation.

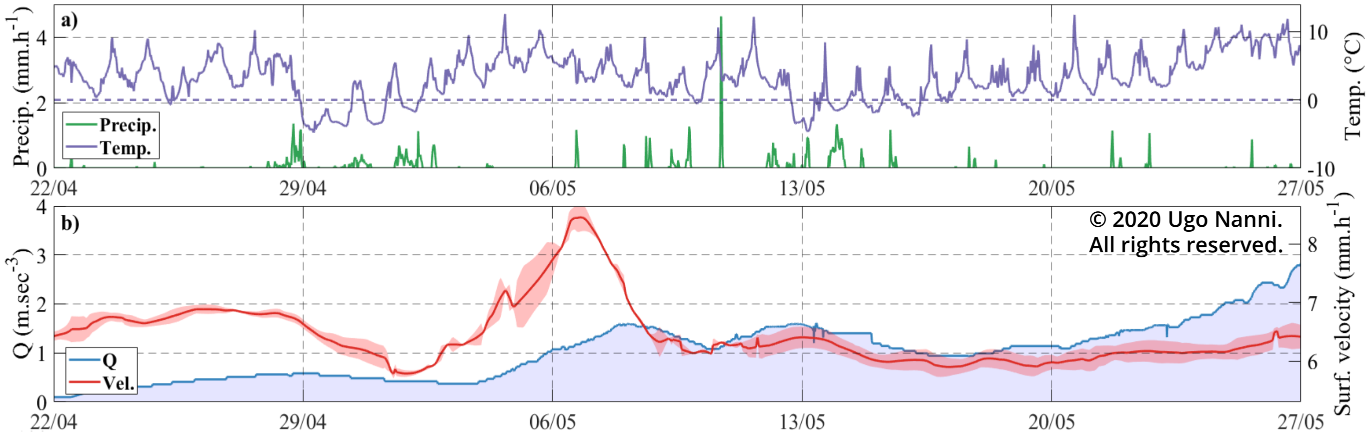
Go for a 30 sec trip on the field

Go for a quick heli-ride

Seismological and glaciological context

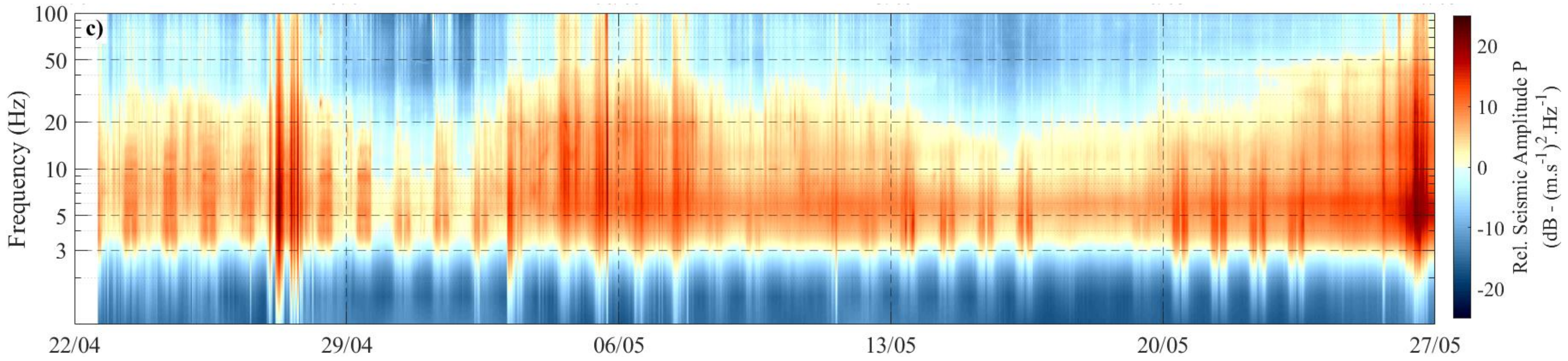
The early spring period is the **onset of the melt season**, when the subglacial hydrology network strongly evolves.

Water discharge increases from 0.1 to 3 $m^3.sec^{-1}$ because of increasing **surfaced melt** driven by c. 5°C increase in surface temperature.



The glacier surface **velocity** shows a clear peak as Q reaches its first peak. As Q reaches its higher values, surface velocity is however near its minimum.

The median **seismic power** over the 98 nodes shows variations with discharge that are most pronounced in the **[3-7] Hz** frequency band.
<u>We focus on this band to study subglacial hydrology.</u>



♫ ♫

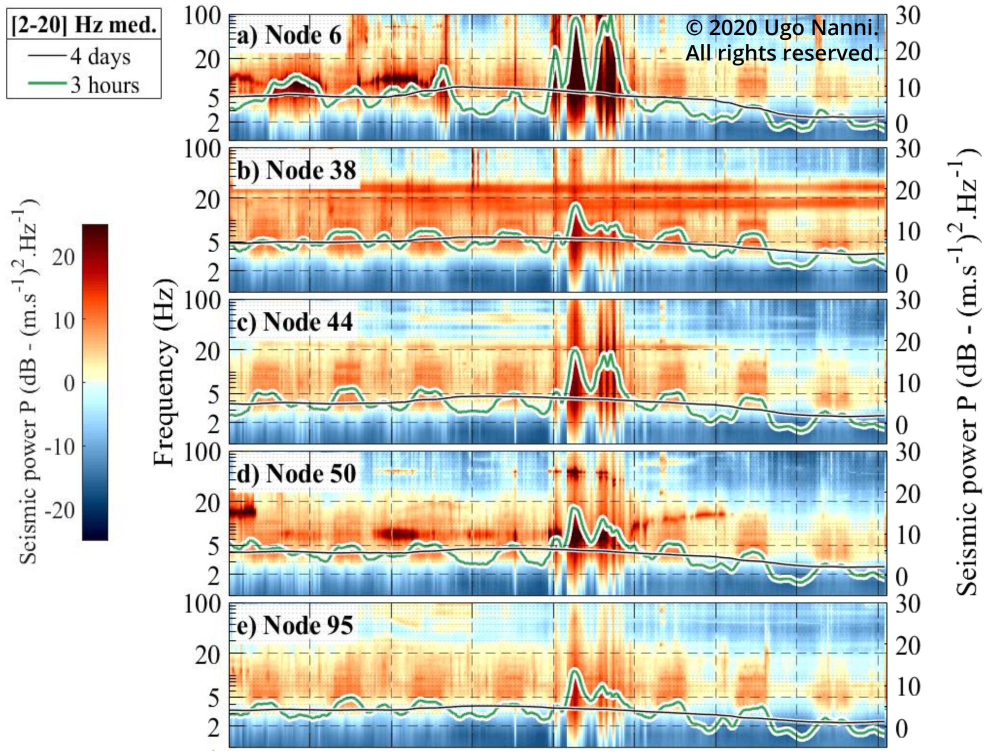
[Listen to the sound of subglacial water flow]

Timeseries of physical quantities measured at Glacier d'Argentière.

Seismological methodology: amplitude and phase analysis

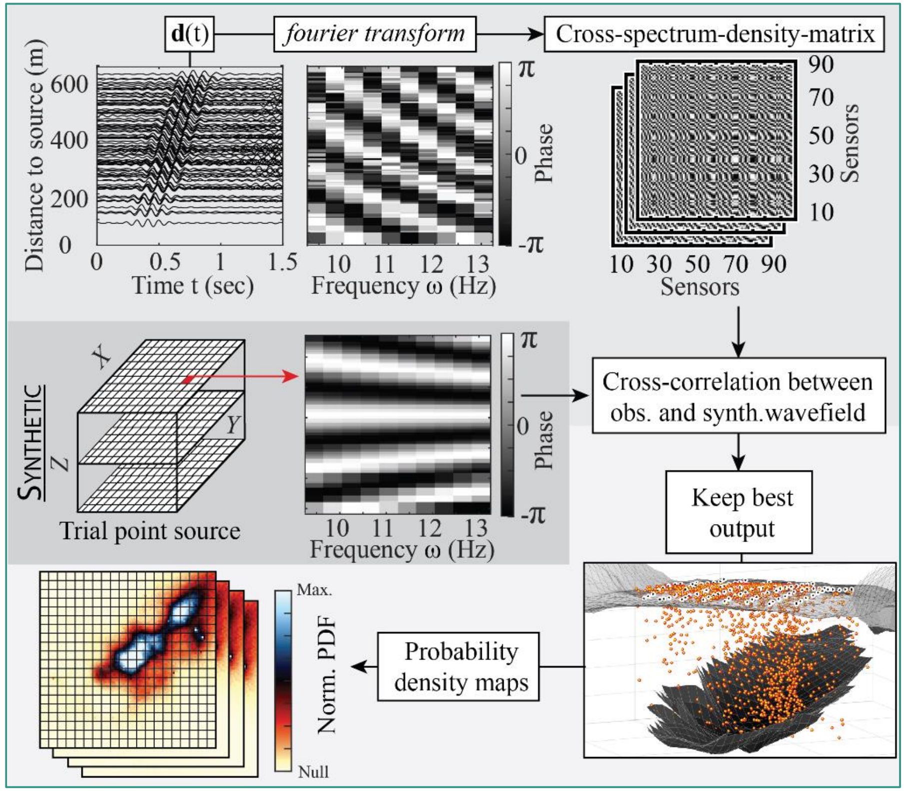
<ins>Amplitude analysis</ins>:
Investigate **spatial heterogeneity** in the amplitude.

The closer to the sources the higher the amplitude.



<ins>Phase analysis</ins>:
We **recursively** match the phase delays of a model-based **synthetic** wave field ("trial source") to the phase delays **observed** between the sensors over the array.

We use here a probabilistic approach to locate up to **29 sources per second** and then stack sources over time.



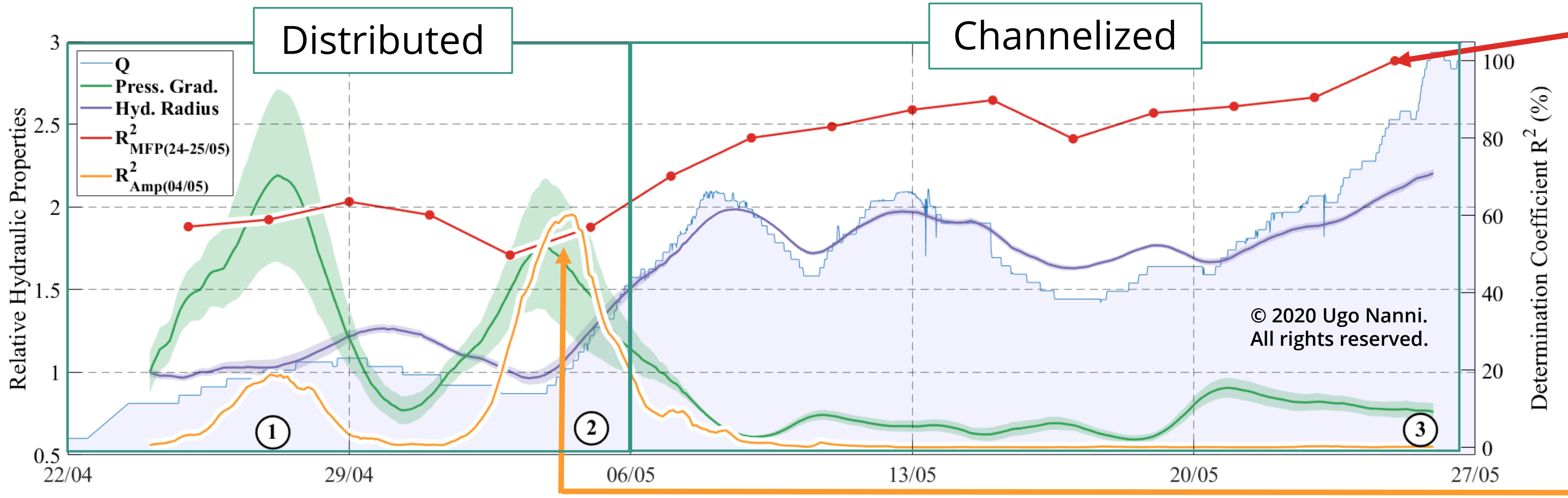
Spatial seismic properties and inversion of hydraulic properties

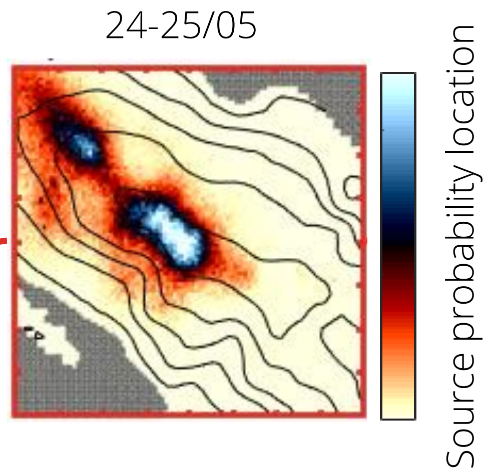
We selected **one pattern** from the phase and amplitude outputs and compared its **temporal evolution** to hydraulic properties.

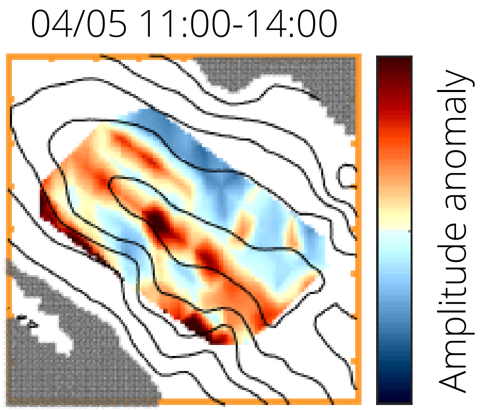
Temporal evolution is evaluated from **2D cross-correlation** of the selected pattern to the other temporal windows.

The amplitude anomalies suggest **two main channels** at the centre of the glacier with a similar orientation as the highest probability of location.

Hydraulic properties are inverted from the seismic and discharge measurement (Nanni et al., 2020)







Amplitude anomalies are sensitive to change in **pressure conditions**.

Phase's source location is sensitive to **channels size** development.

Ongoing work, perspectives and opportunities …

Take home message(s)

Dense seismic observations:
- **Directly map** spatial evolution of subglacial hydrology
- Capture distributed and channelized systems

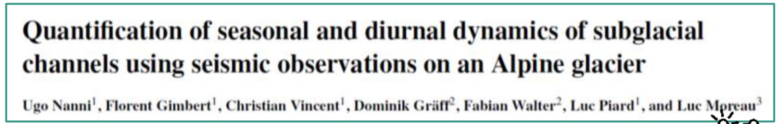
→ Easily deployable in remote areas (Greenland, Antarctic …)

Subglacial hydrology:
- **Cavity-channels** transition occurs in less than 4 days
- Main channel located at the minimum of **hydraulic potential**
- New constrains for subglacial hydrology **models**

→ One of the first direct observation

Papers on this study and the RESOLVE-Argentière experiment soon to be out …

About me :
- Finishing my Phd in September after 3 years in Grenoble
- Looking to further investigate glacier processes using passive/active seismic
- Looking to test our approaches on **new glaciological context**
- **Looking for future collaborations**


Quantification of seasonal and diurnal dynamics of subglacial channels using seismic observations on an Alpine glacier

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About my work

SAUSSURE

Some of our projects

Looking forward to further discussing with you !!

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Have a look at our drawings about glaciology