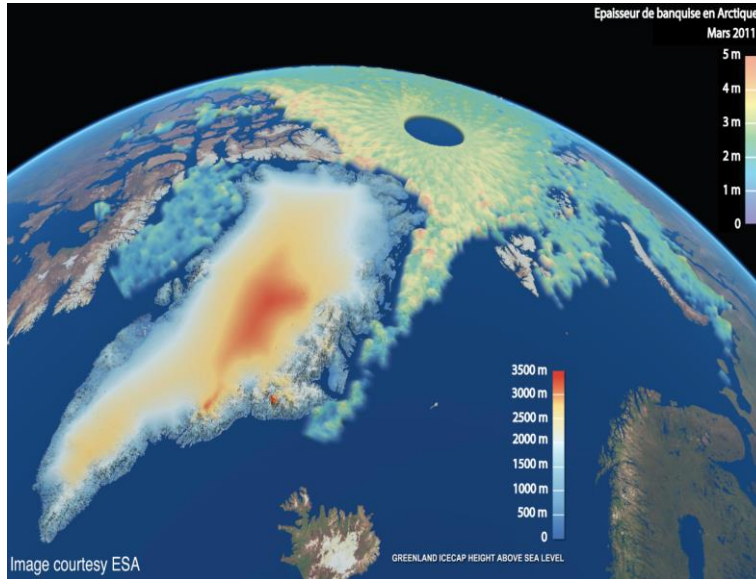


Environnemental Seismology (in Moutaineous Areas)



Florent Gimbert
IGE Grenoble

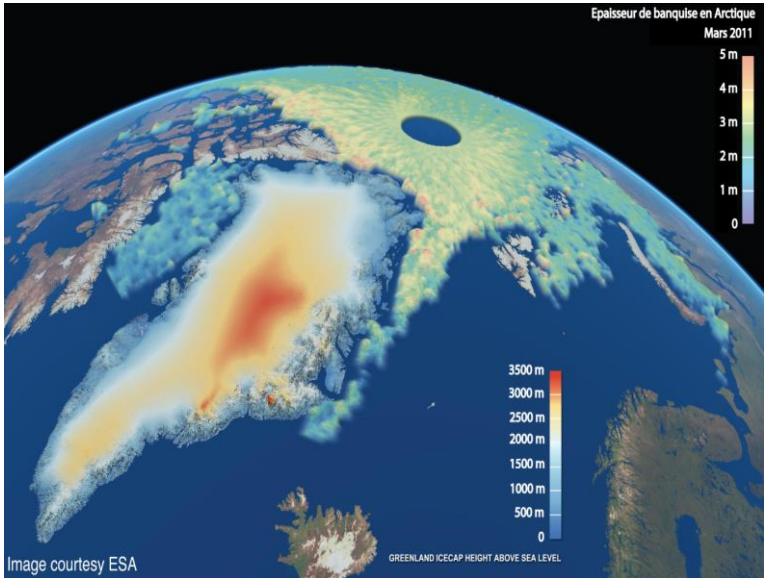


Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Larose et al., 2015

Seismic source

Wave propagation

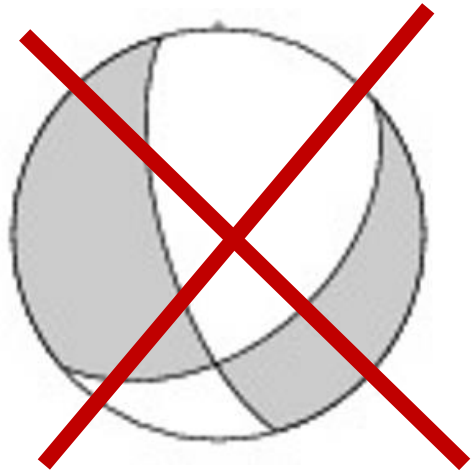


Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Larose et al., 2015

Seismic source

Wave propagation



?

Complex radiation patterns

Often high frequency (>1 Hz) signals

Heterogeneous ground structure

...

Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Larose et al., 2015

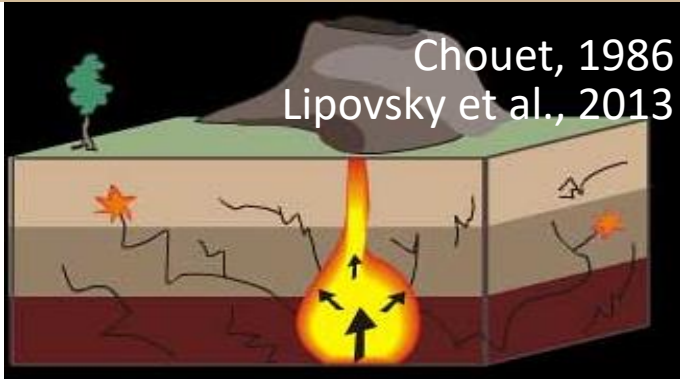
Seismic source



Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Larose et al., 2015

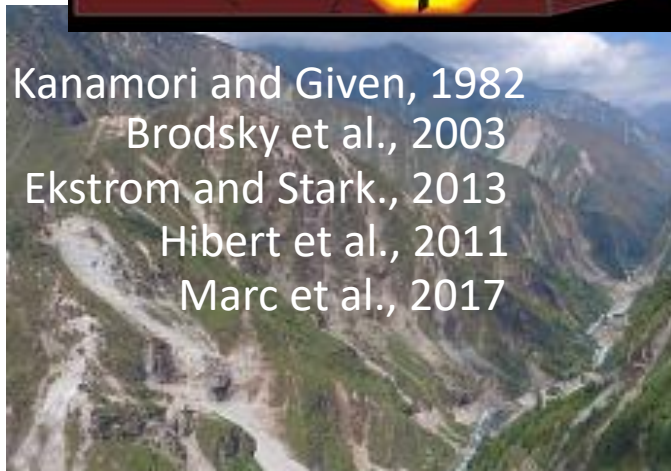
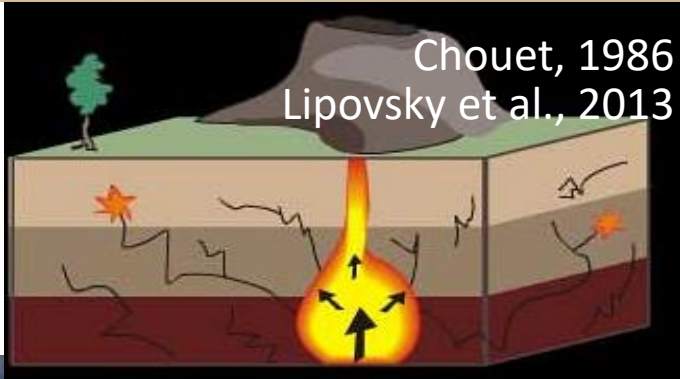
Seismic source



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Larose et al., 2015

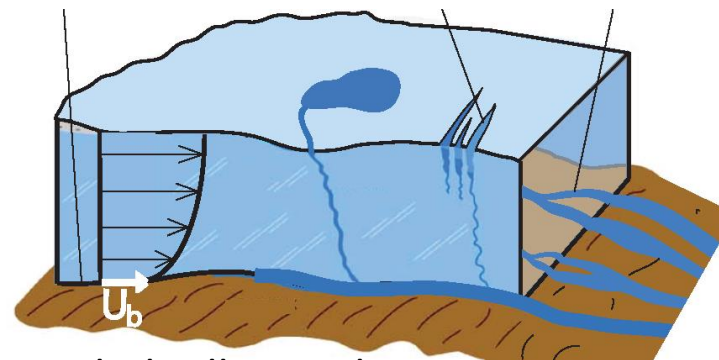
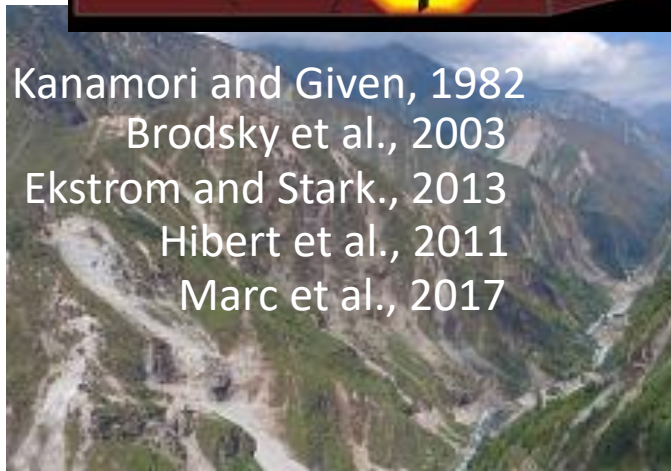
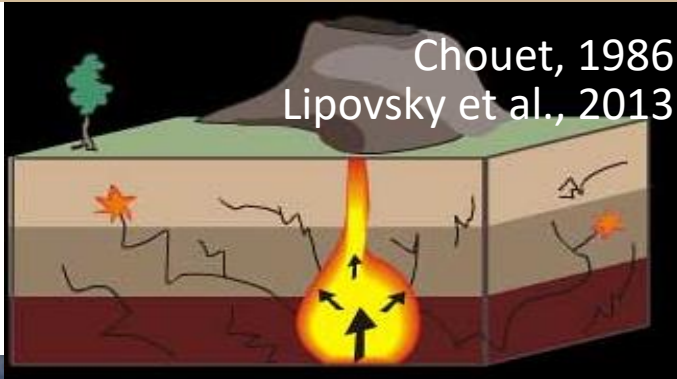
Seismic source



Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Larose et al., 2015

Seismic source



Bindschadler et al., 2003
Lipovsky et al., 2013
Roesli et al., 2014
Helmstetter et al., 2015
Gimbert et al., 2016

Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Seismic source

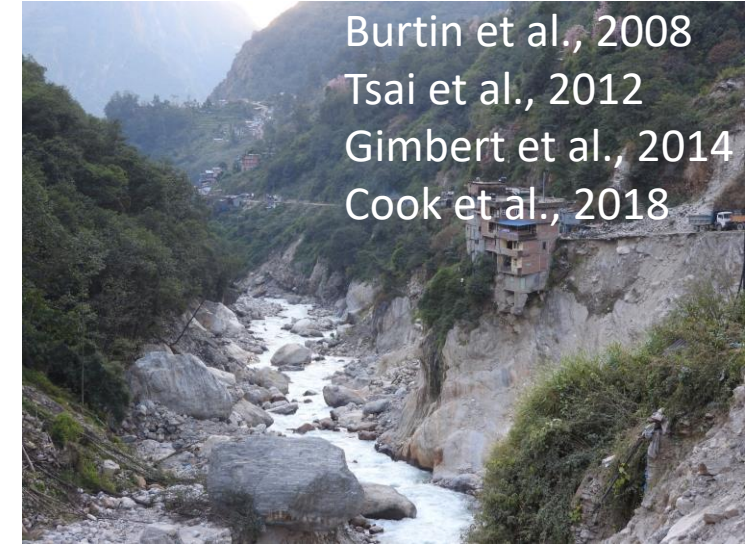
Larose et al., 2015



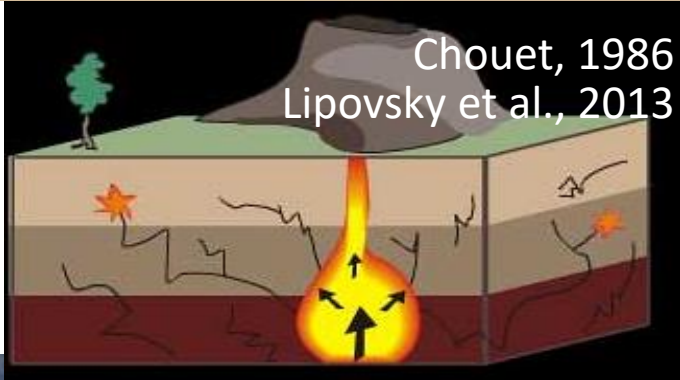
Longuet-Higgins, 1950
Hardhuin and Hebers, 2013



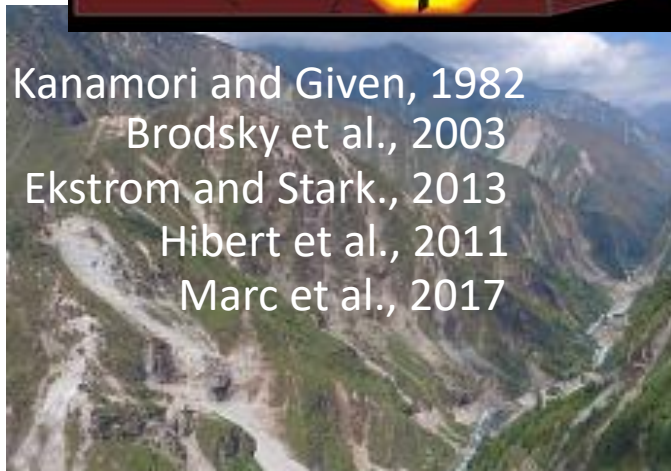
Ekstrom et al., 2006
Bartholomaus et al., 2012
Sergeant et al., 2016; 2019



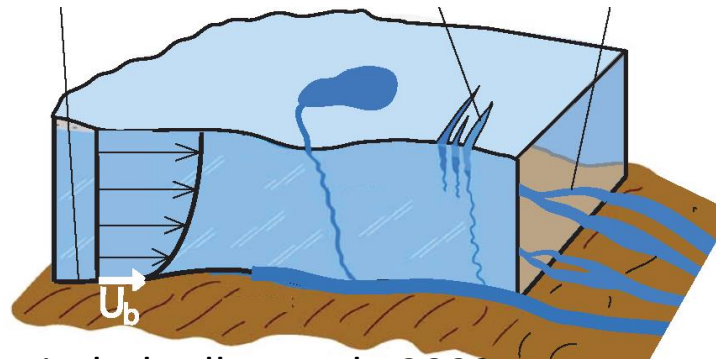
Burtin et al., 2008
Tsai et al., 2012
Gimbert et al., 2014
Cook et al., 2018



Chouet, 1986
Lipovsky et al., 2013



Kanamori and Given, 1982
Brodsky et al., 2003
Ekstrom and Stark., 2013
Hibert et al., 2011
Marc et al., 2017

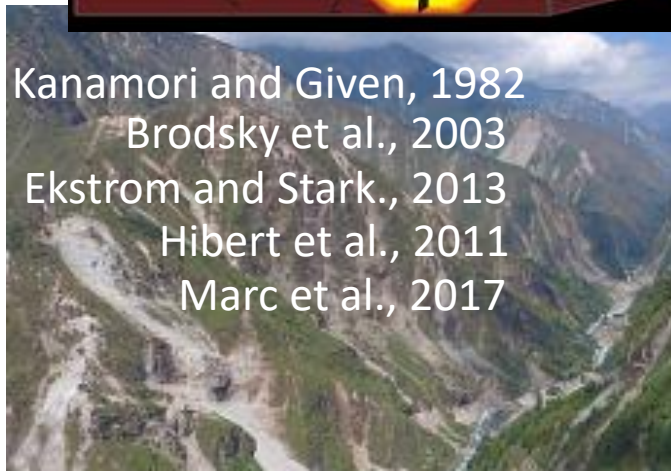
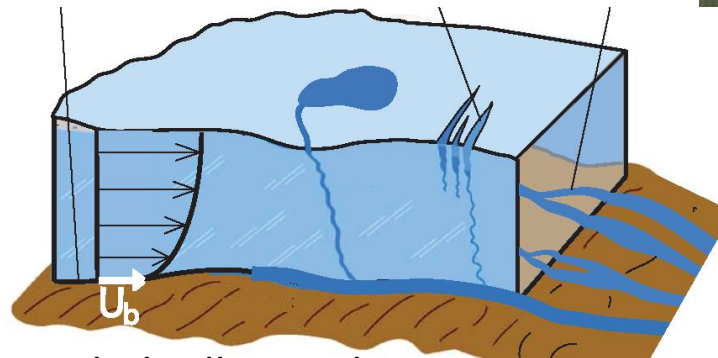
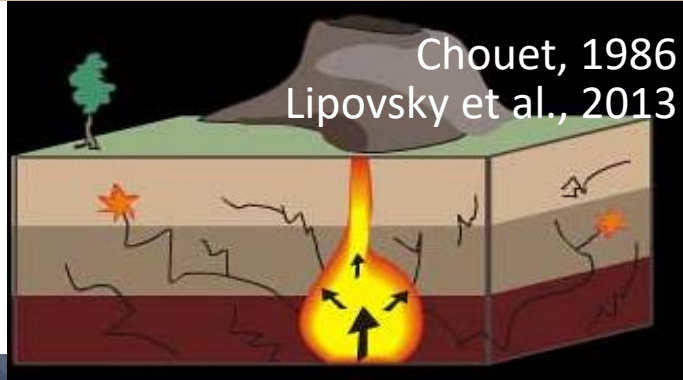
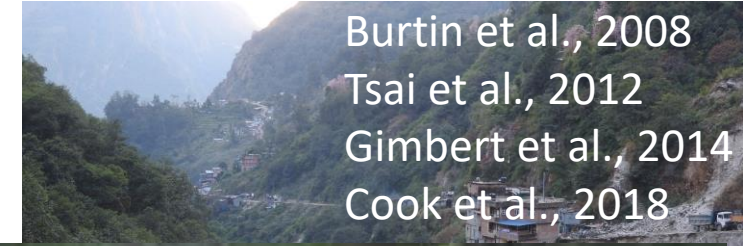


Bindschadler et al., 2003
Lipovsky et al., 2013
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Helmstetter et al., 2015
Gimbert et al., 2016

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Seismic source

Larose et al., 2015



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Seismic source

Larose et al., 2015



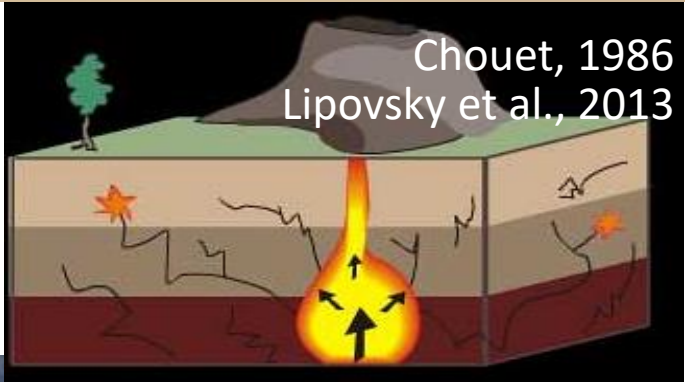
Longuet-Higgins, 1950
Hardhuin and Hebers, 2013



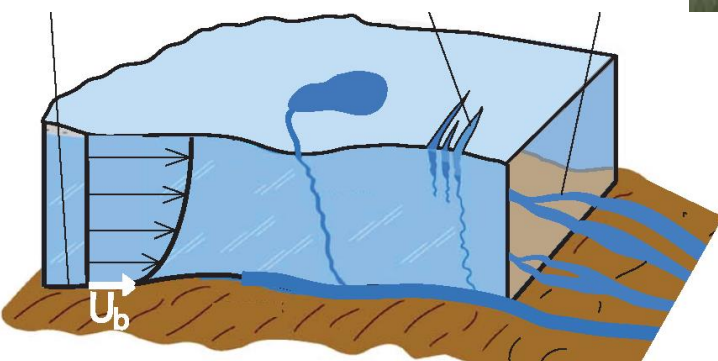
Ekstrom et al., 2006
Bartholomaus et al., 2012
Sergeant et al., 2016; 2019



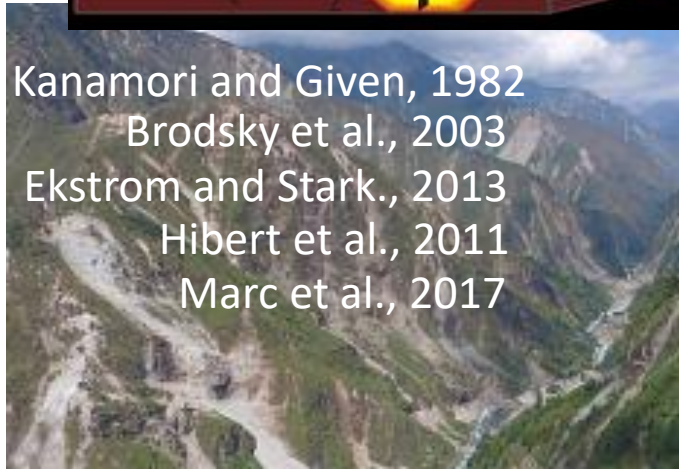
Burtin et al., 2008
Tsai et al., 2012
Gimbert et al., 2014
Cook et al., 2018
Kean et al., 2015
Farin et al., 2019



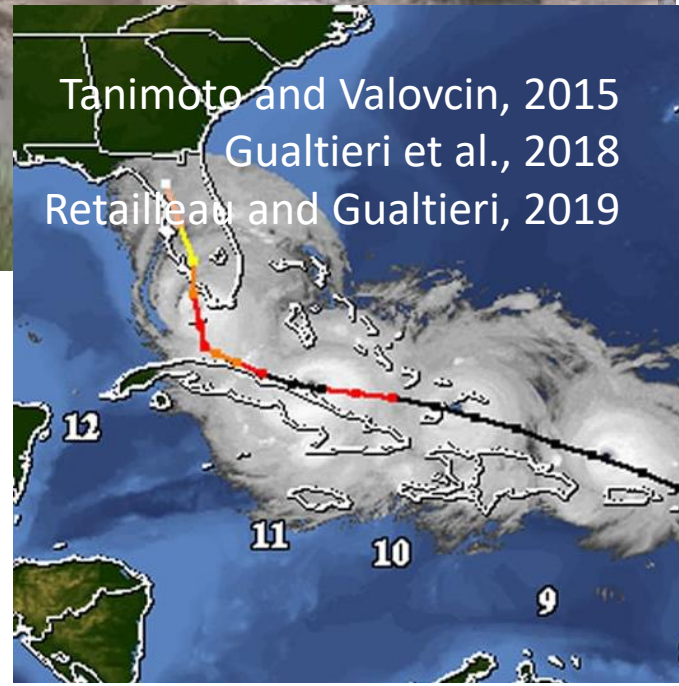
Chouet, 1986
Lipovsky et al., 2013



Bindschadler et al., 2003
Lipovsky et al., 2013
Roesli et al., 2014
Helmstetter et al., 2015
Gimbert et al., 2016



Kanamori and Given, 1982
Brodsky et al., 2003
Ekstrom and Stark., 2013
Hibert et al., 2011
Marc et al., 2017



Tanimoto and Valovcin, 2015
Gualtieri et al., 2018
Retailleau and Gualtieri, 2019

Environmental seismology consists in studying the mechanical vibrations that originate from or have been affected by external causes.

Seismic source

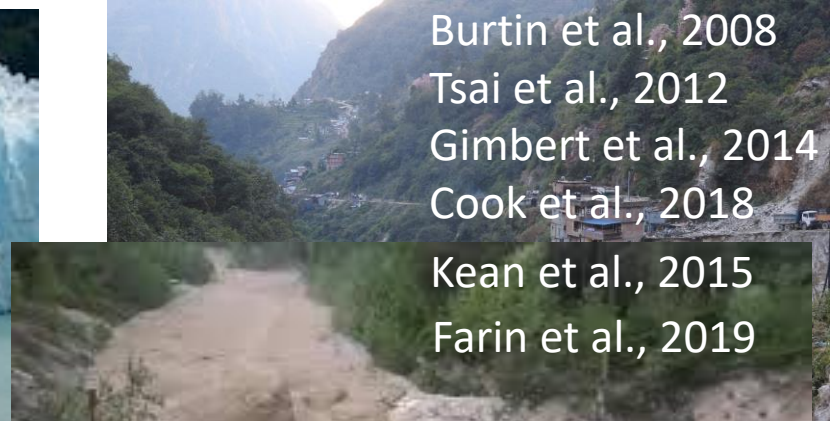
Larose et al., 2015



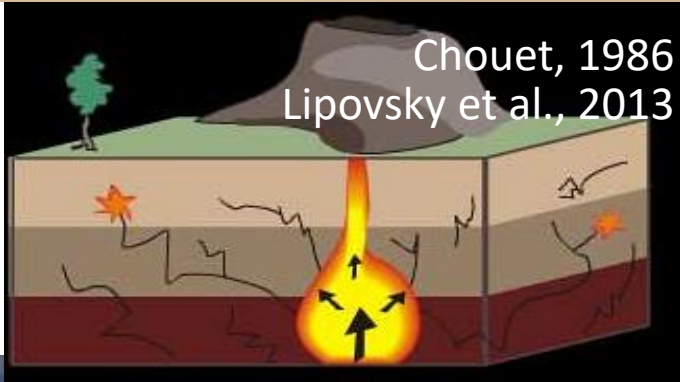
Longuet-Higgins, 1950
Hardhuin and Hebers, 2013



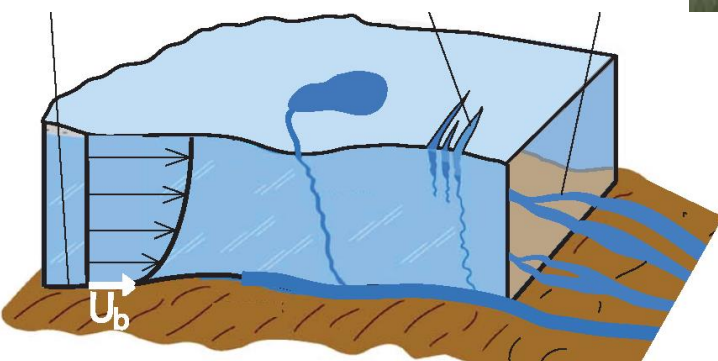
Ekstrom et al., 2006
Bartholomaus et al., 2012
Sergeant et al., 2016; 2019



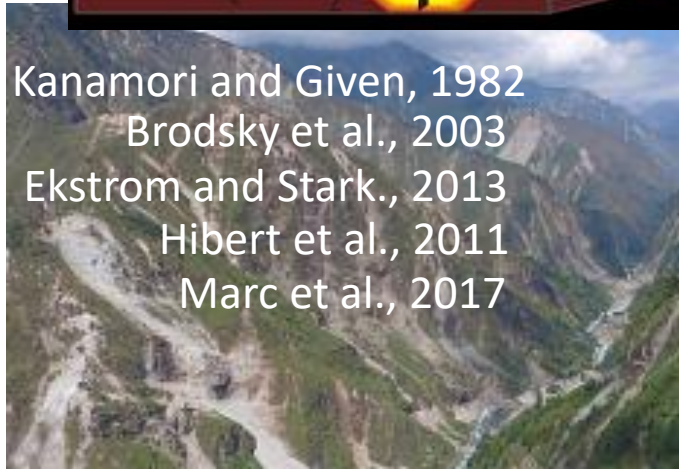
Burtin et al., 2008
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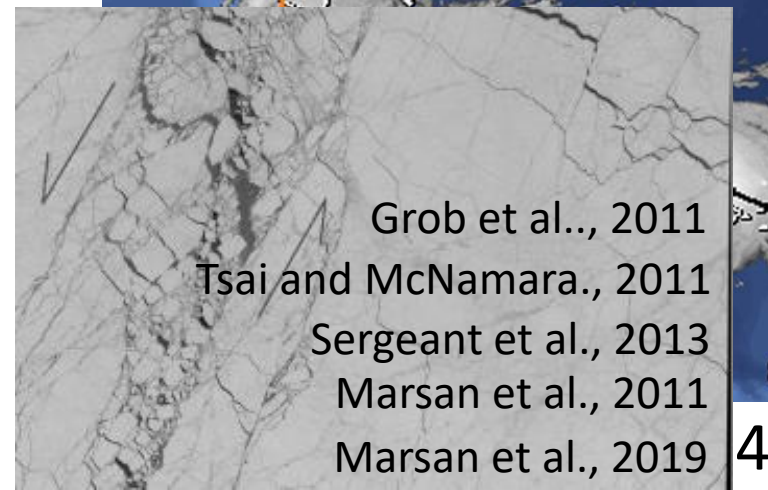
Bindschadler et al., 2003
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Helmstetter et al., 2015
Gimbert et al., 2016



Kanamori and Given, 1982
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Marc et al., 2017



Tanimoto and Valovcin, 2015
Gualtieri et al., 2018
Retailleau and Gualtieri, 2019

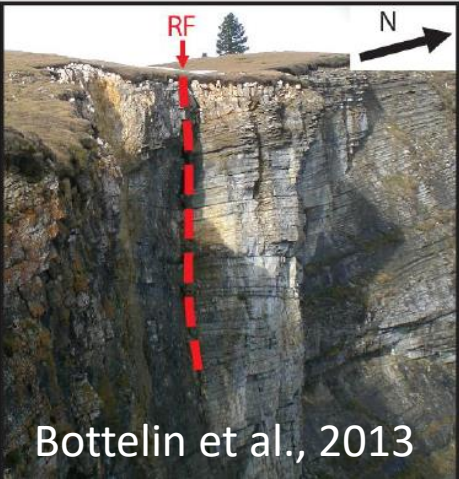


Grob et al., 2011
Tsai and McNamara., 2011
Sergeant et al., 2013
Marsan et al., 2011
Marsan et al., 2019

Environmental seismology consists in studying the mechanical vibrations that **originate from** or have been affected by external causes.

Larose et al., 2015

↙
Wave propagation



Bottelin et al., 2013

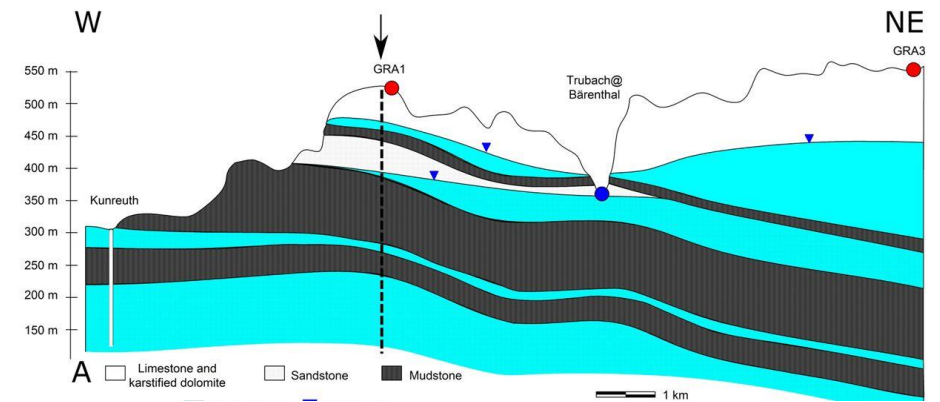
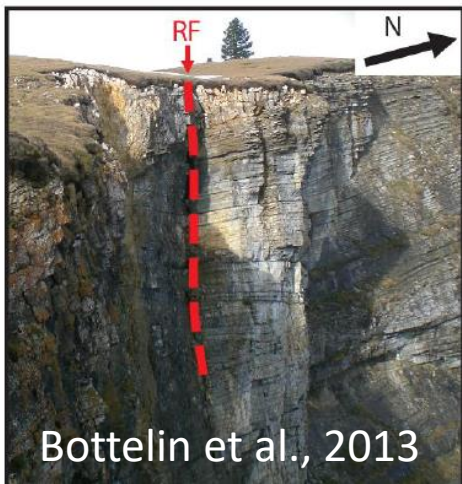
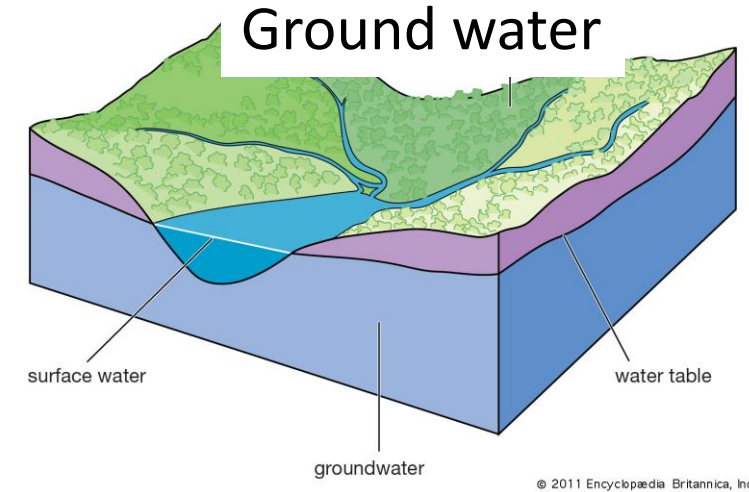


Environmental seismology consists in studying the mechanical vibrations that **originate from** or have been affected by external causes.

Larose et al., 2015



Wave propagation



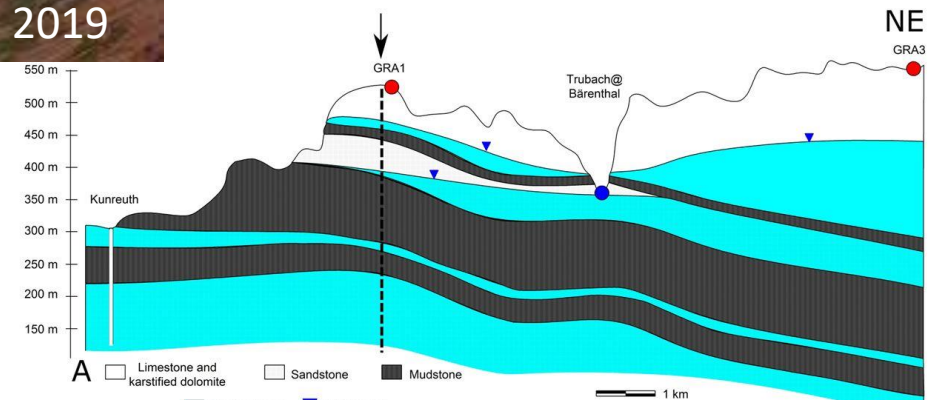
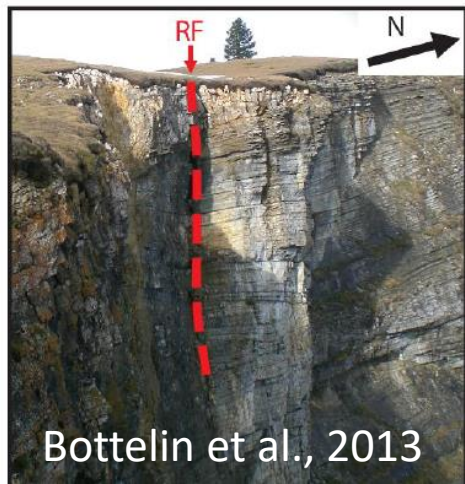
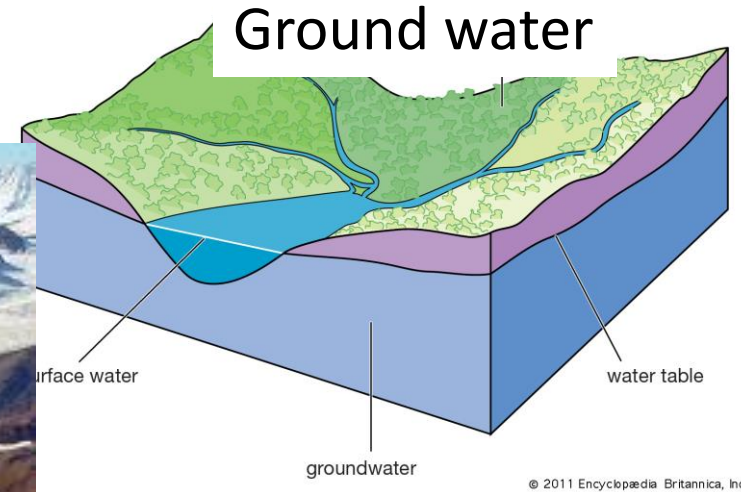
Lecocq et al., 2017

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Larose et al., 2015



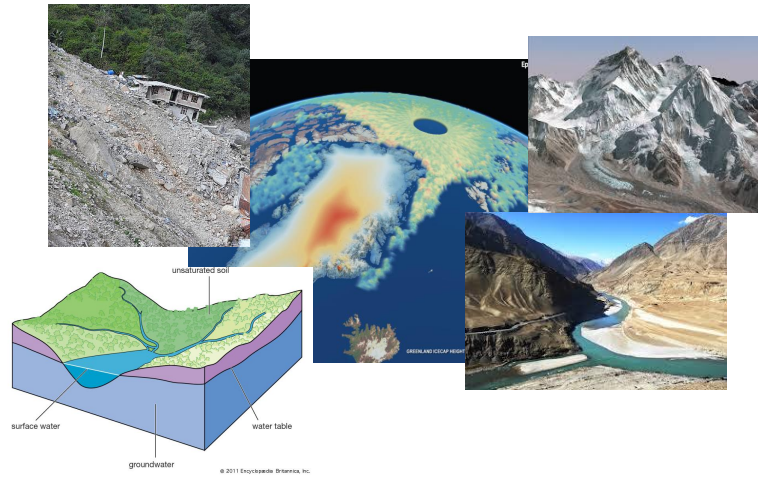
Wave propagation



Lecocq et al., 2017

Environmental Seismology

How are seismic observations helpful to answer key scientific questions in the respective fields (geomorphology, glaciology, climate, natural hazards, etc...)?

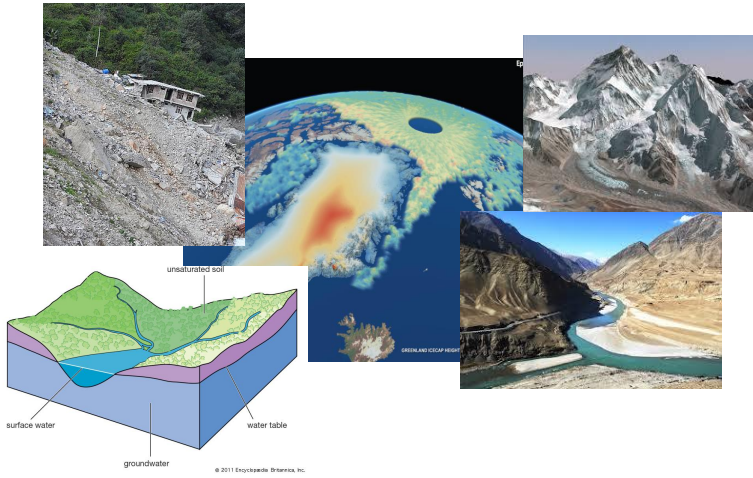


Environmental Seismology

How are seismic observations helpful to answer key scientific questions in the respective fields (geomorphology, glaciology, climate, natural hazards, etc...)?

1- Can we provide new understanding on unknown physical processes?

2- Can we provide deliverables/numbers?



Environnemental Seismology

How are seismic observations helpful to answer key scientific questions in the respective fields (geomorphology, glaciology, climate, natural hazards, etc...)?

1- Can we provide new understanding on unknown physical processes?

Glaciology

Subglacial hydrology

using source analysis (Bartholomaus et al., 2015; Gimbert et al., 2016, Nanni et al., 2019; The RESOLVE project)

Glacier fracturing

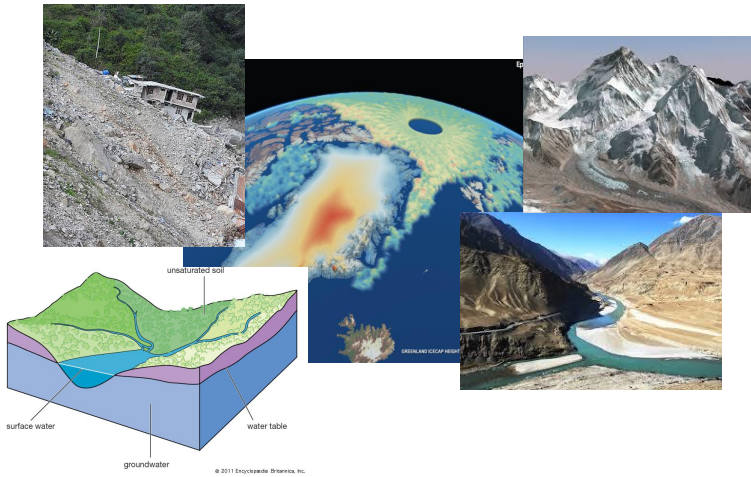
using source analysis (The RESOLVE Project)

2- Can we provide deliverables/numbers?

Geomorphology

River sediment transport

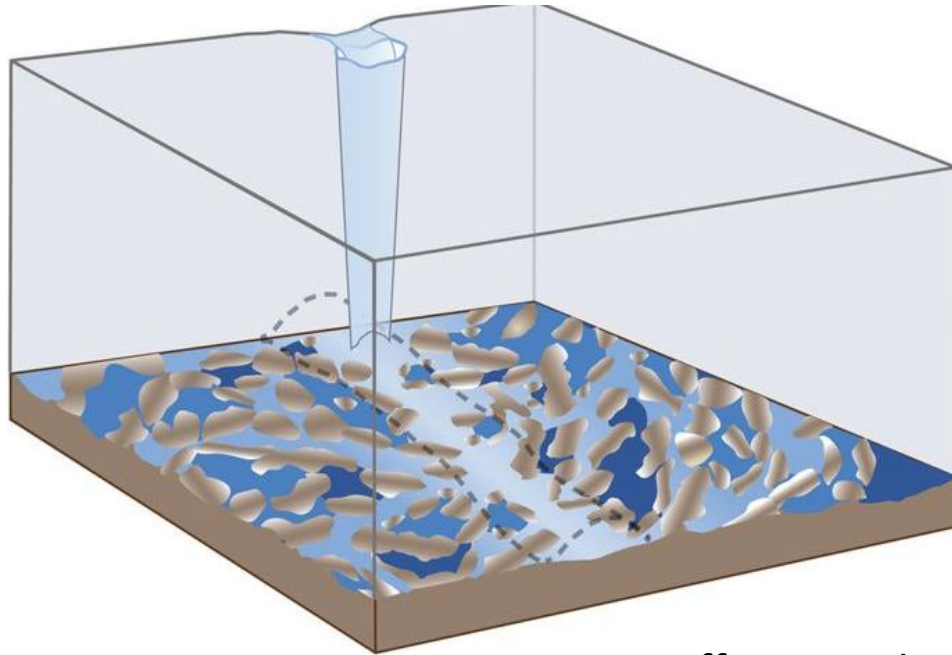
using source analysis (Burtin et al., 2008; Tsai et al., 2012; Gimbert et al., 2014; Bakker et al., 2019)



1- Can we provide new understanding on unknown physical processes?

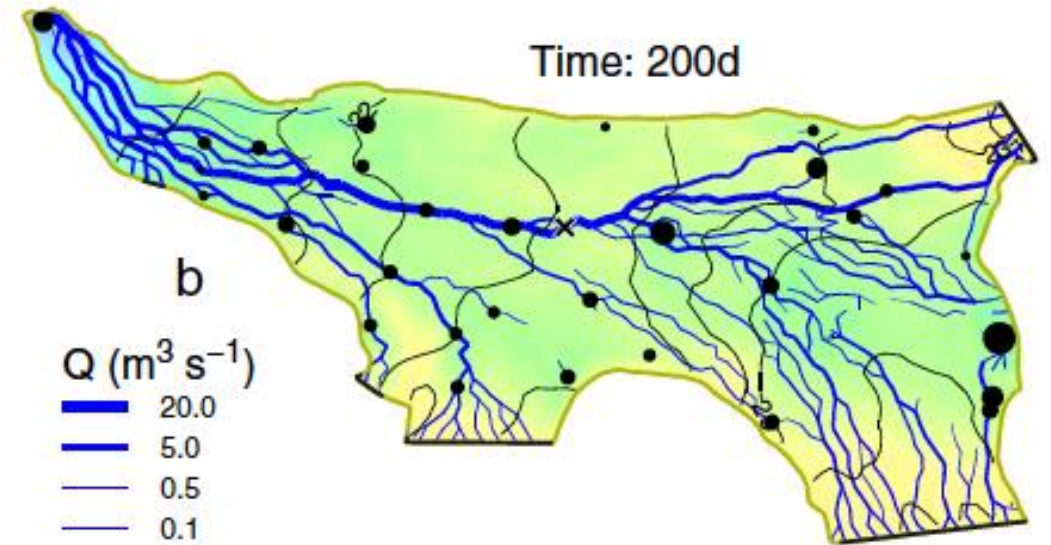
The example of subglacial hydrology

Conceptualization



Hoffman et al., 2016

Glacier scale numerical modelling



Werder et al., 2013

What is the geometry (cavity structure, channel size and number) of the subglacial hydrology network?

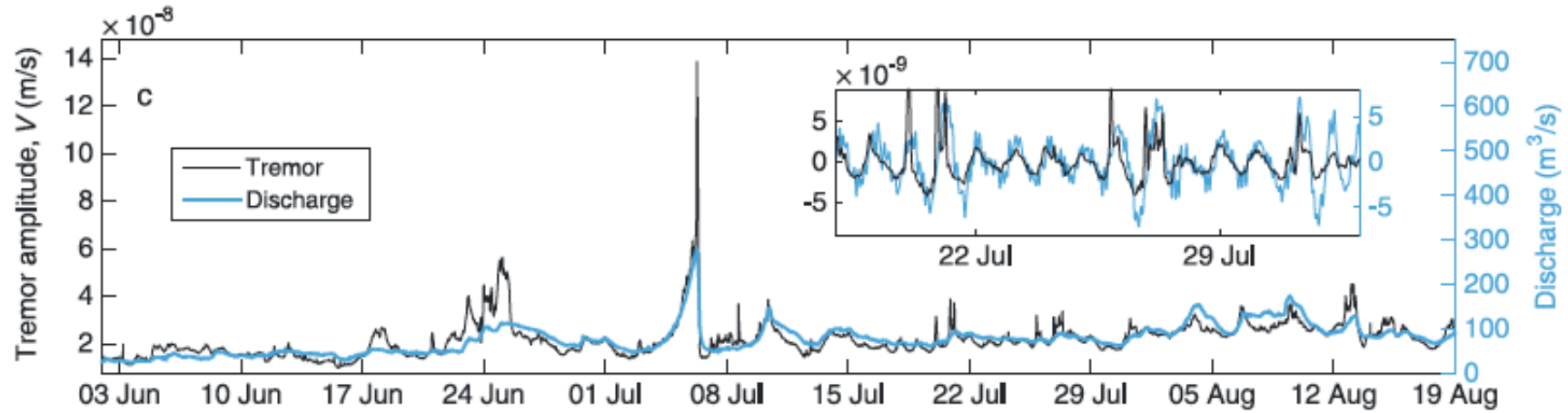
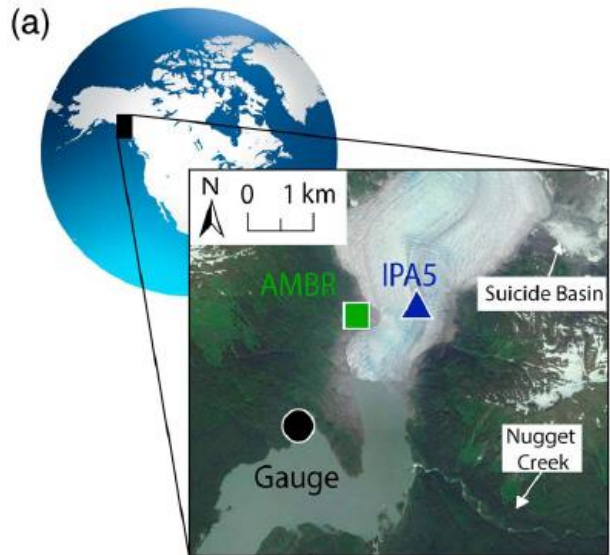
How does the geometry evolve with changing sliding velocity?

How about water pressure?

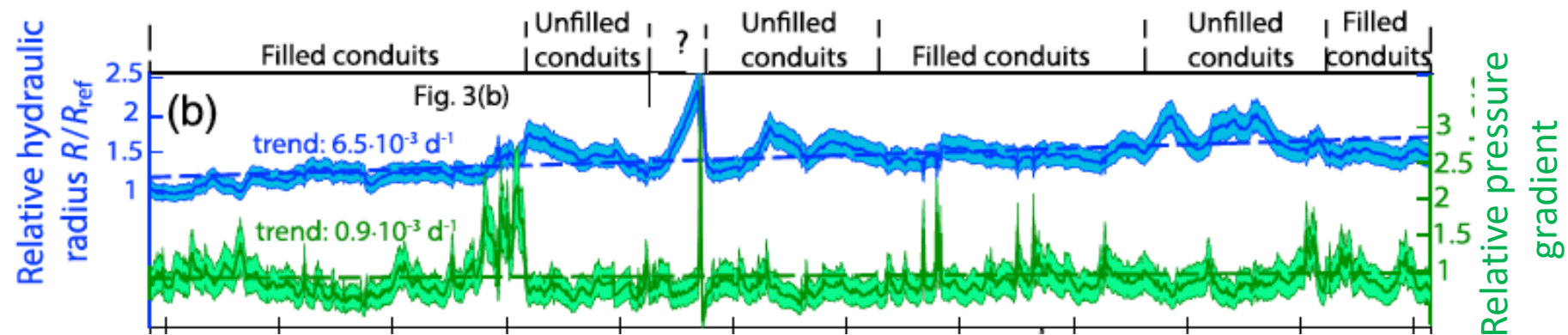
1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology

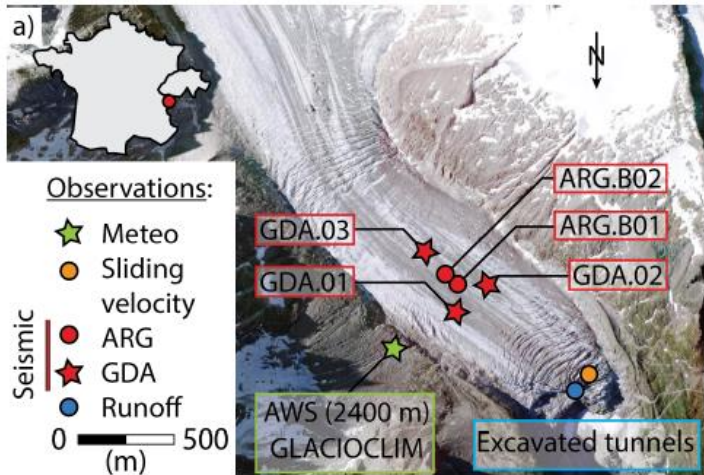
using source analysis (Bartholomaus et al., 2015; Gimbert et al., 2016, Nanni et al., 2019; The RESOLVE project)



Bartholomaus et al., 2015



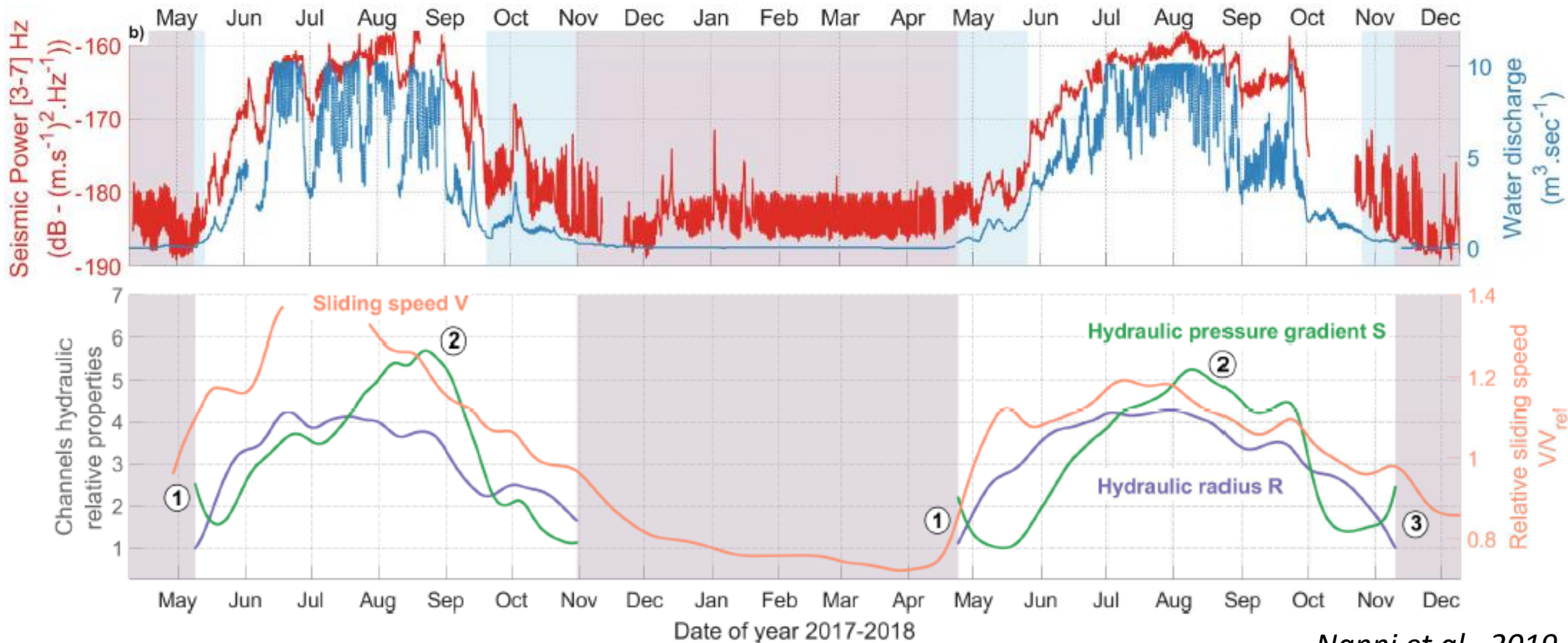
Gimbert et al., 2016



1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology

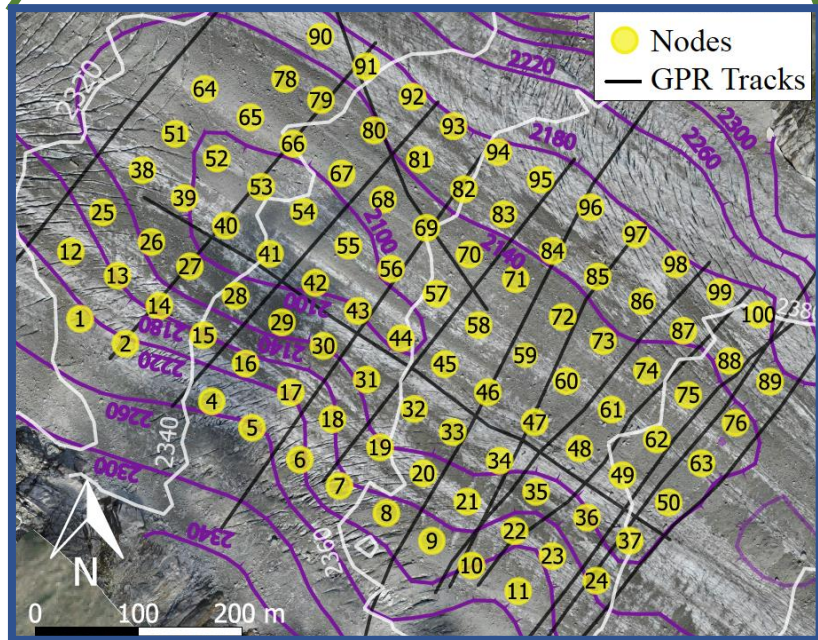
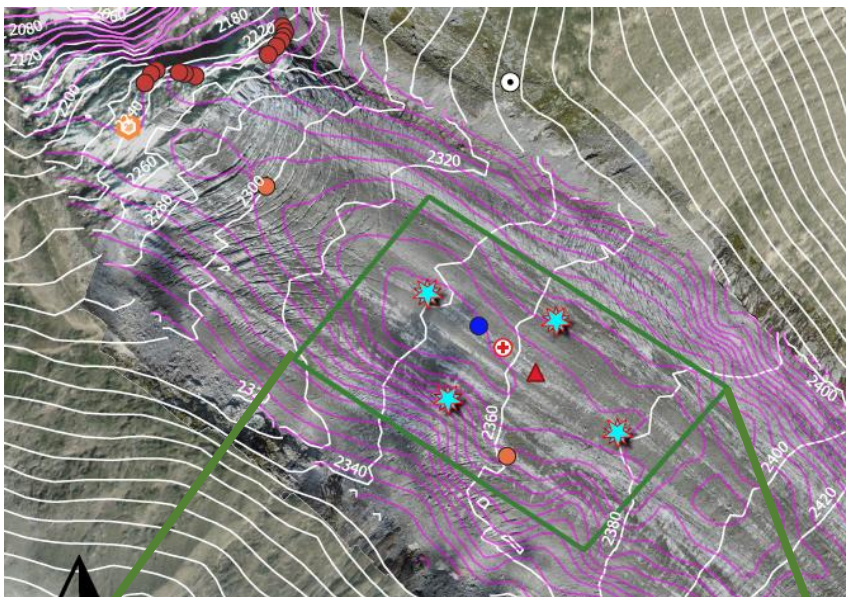
using source analysis (Bartholomaus et al., 2015; Gimbert et al., 2016, Nanni et al., 2019; The RESOLVE project)



1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology

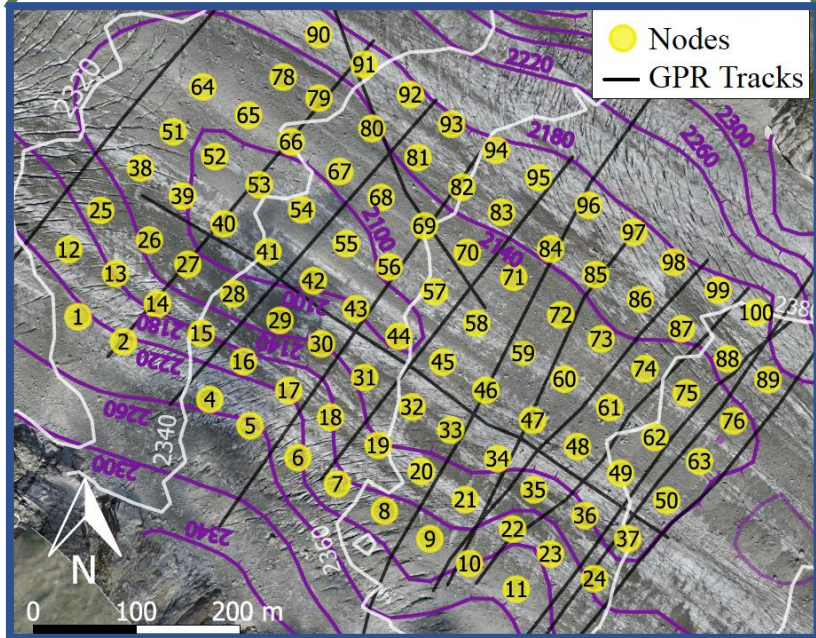
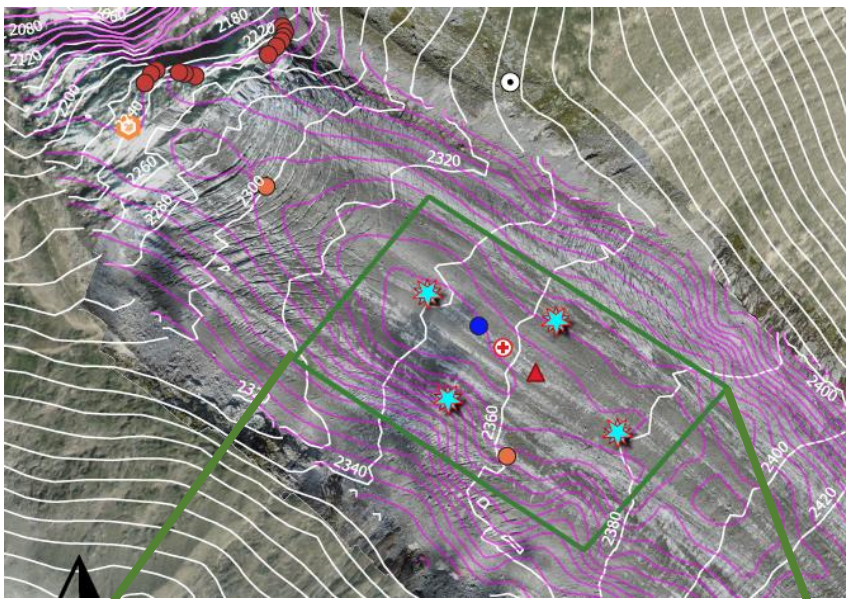
using source analysis (Bartholomaus et al., 2015; Gimbert et al., 2016, Nanni et al., 2019; The RESOLVE project)



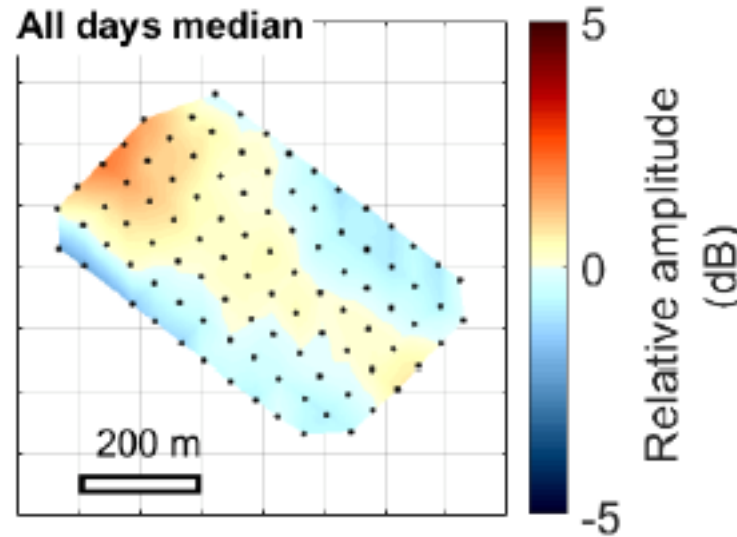
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The example of subglacial hydrology

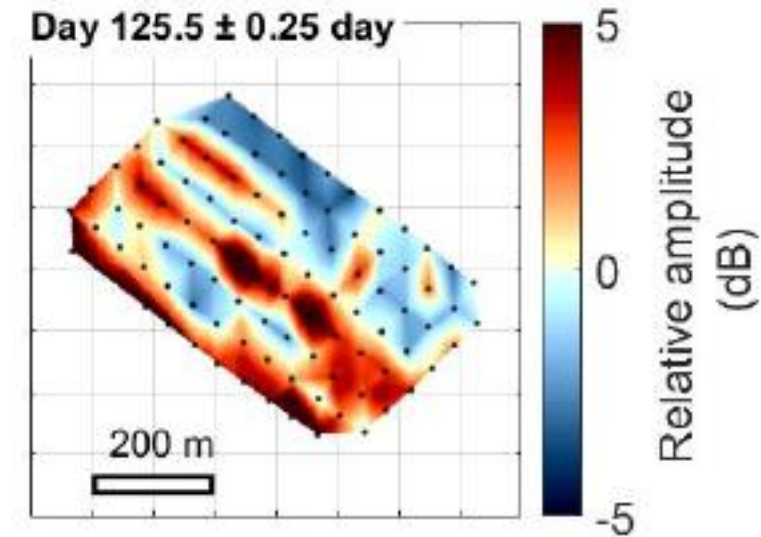
using source analysis (Bartholomaus et al., 2015; Gimbert et al., 2016, Nanni et al., 2019; The RESOLVE project)



a) Freq: [3-9] Hz
All days median



a) Freq: [3-9] Hz
Day 125.5 ± 0.25 day

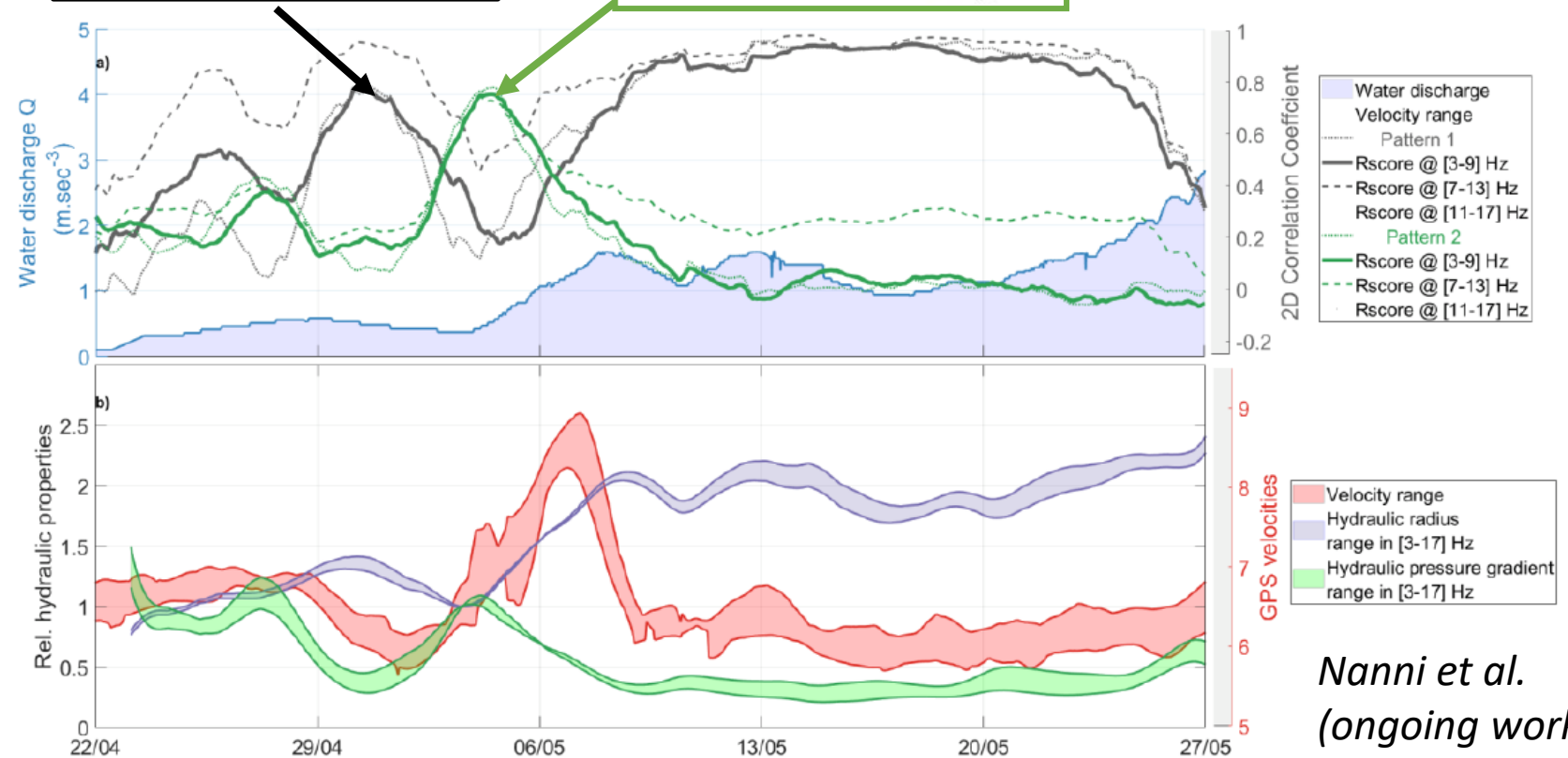
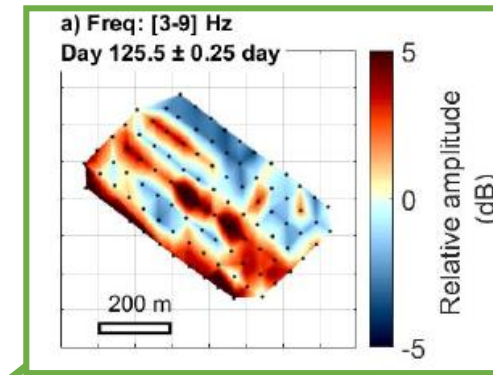
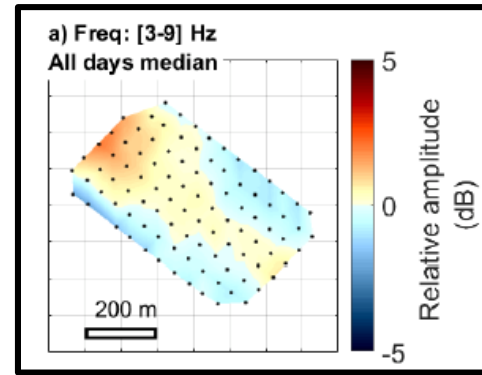
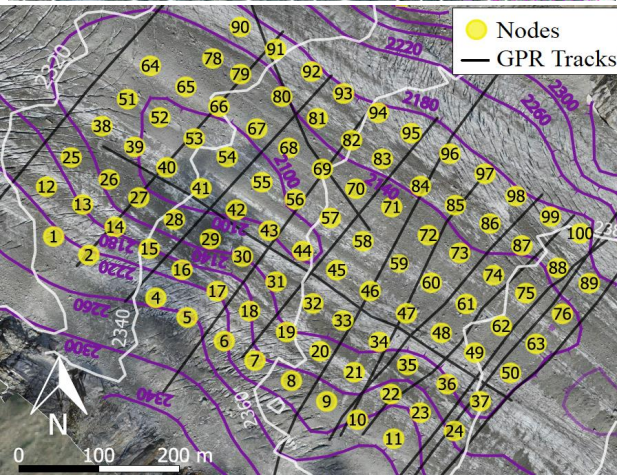
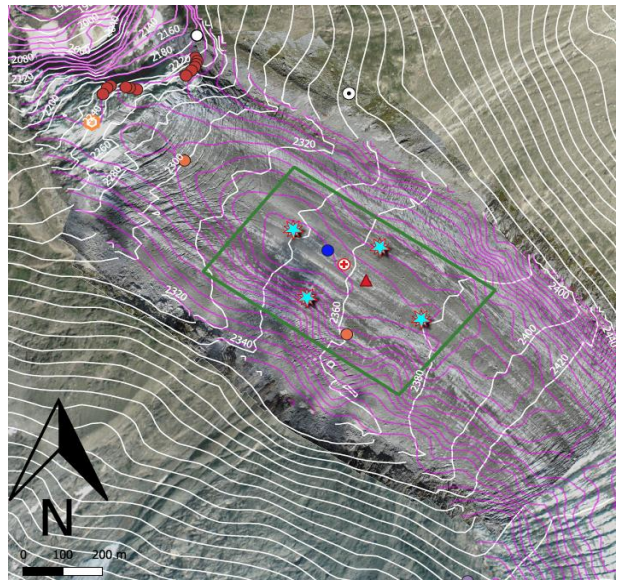


Nanni et al. (ongoing work)

Subglacial channel network ?

1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology

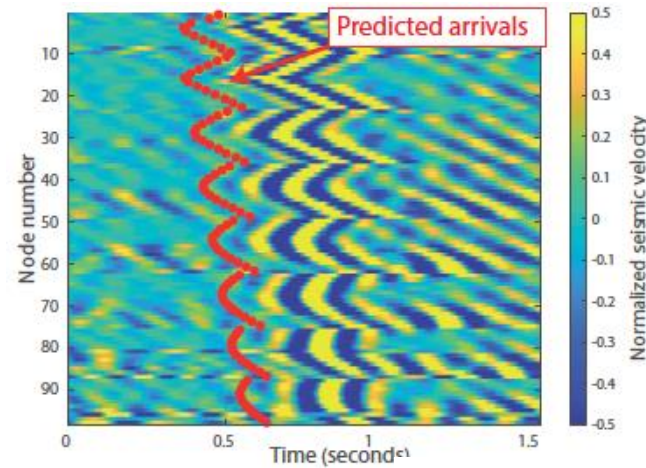
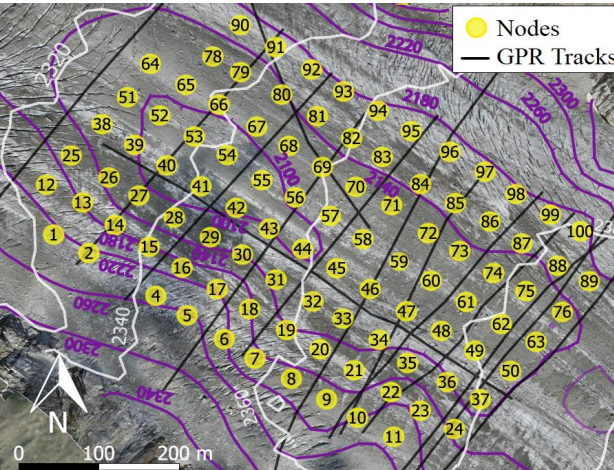
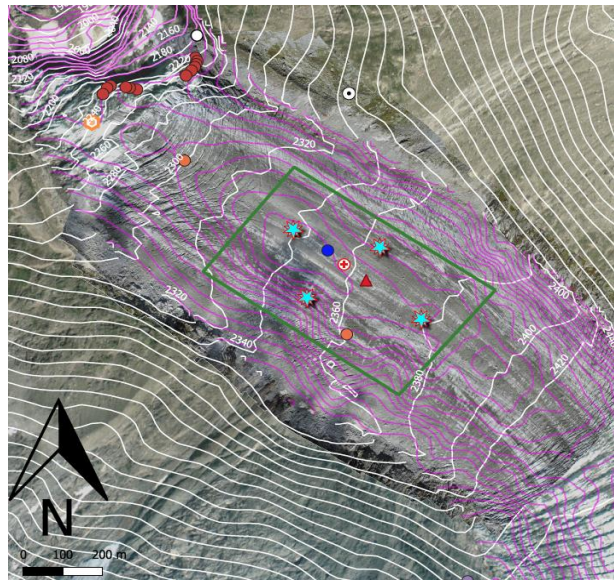


Nanni et al.
(ongoing work)

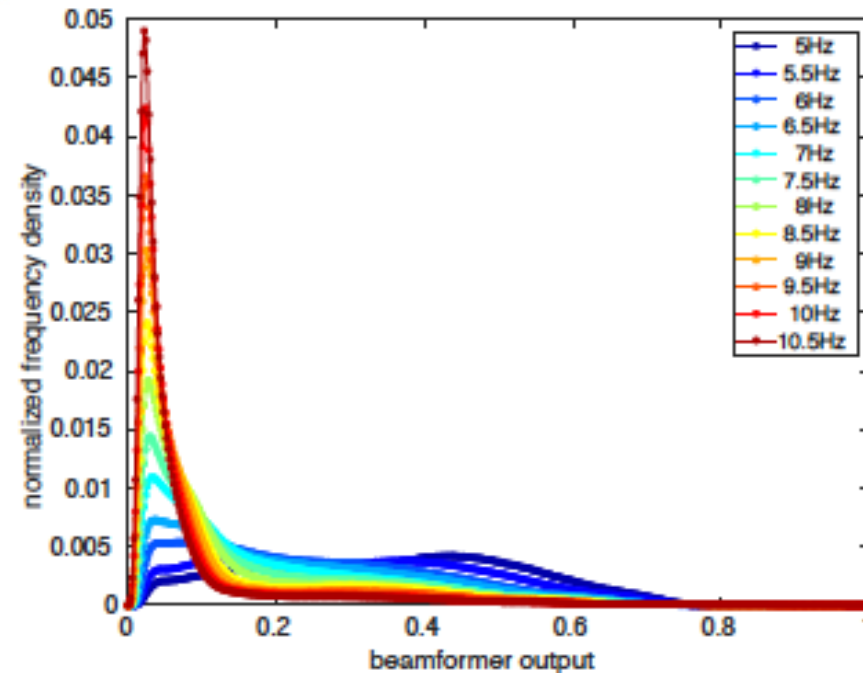
1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology

Using the phase of the signal

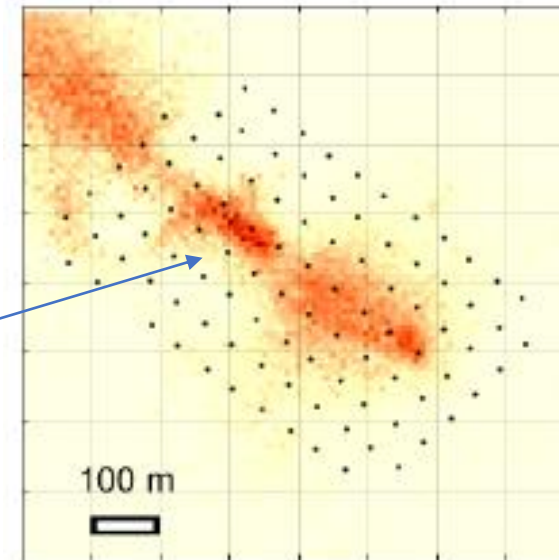
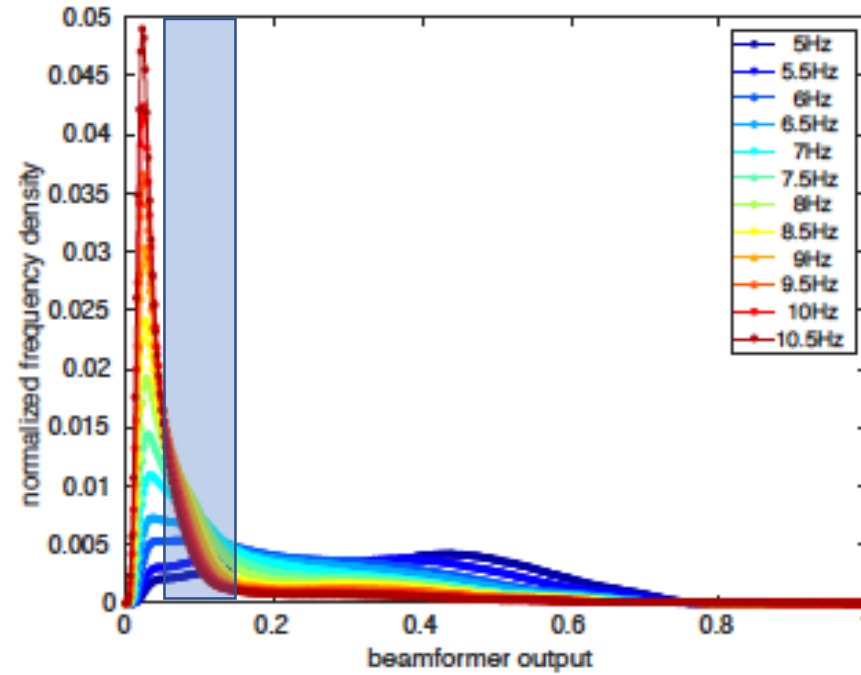
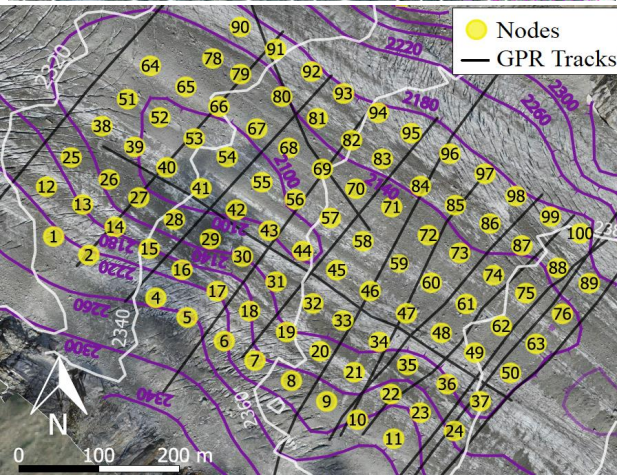
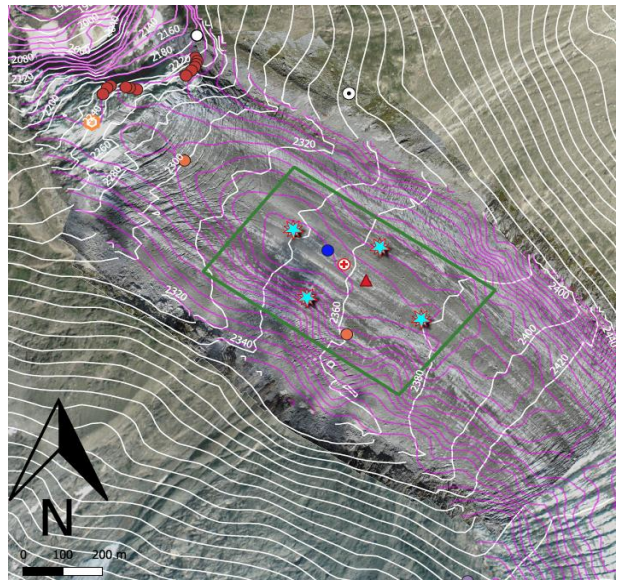


- 1 → Consider 0.5 seconds-long time windows
- 2 → Assume a punctual source exists over that time window
- 3 → Invert event location (x,y,z) and phase velocity based on phase delay minimization from beamforming analysis (Figures 3 and 4).



1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology

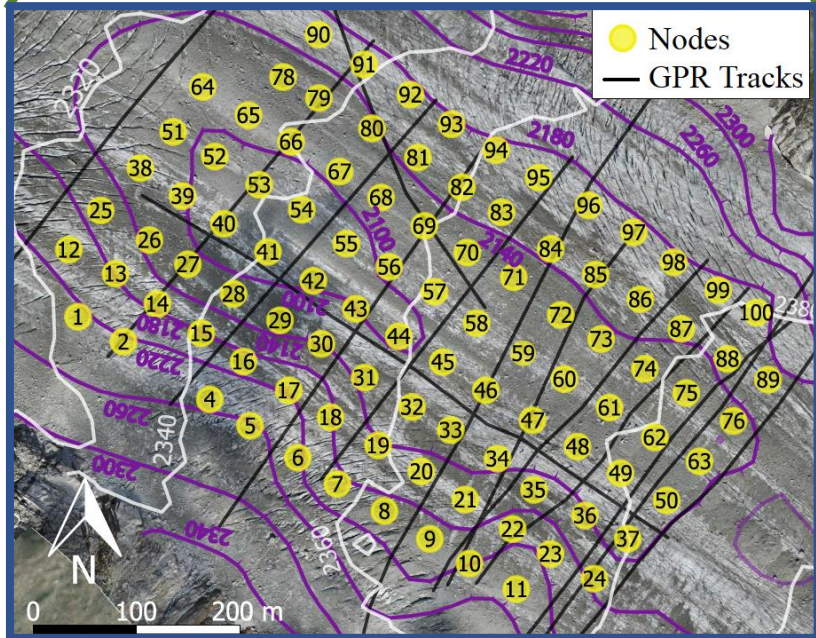
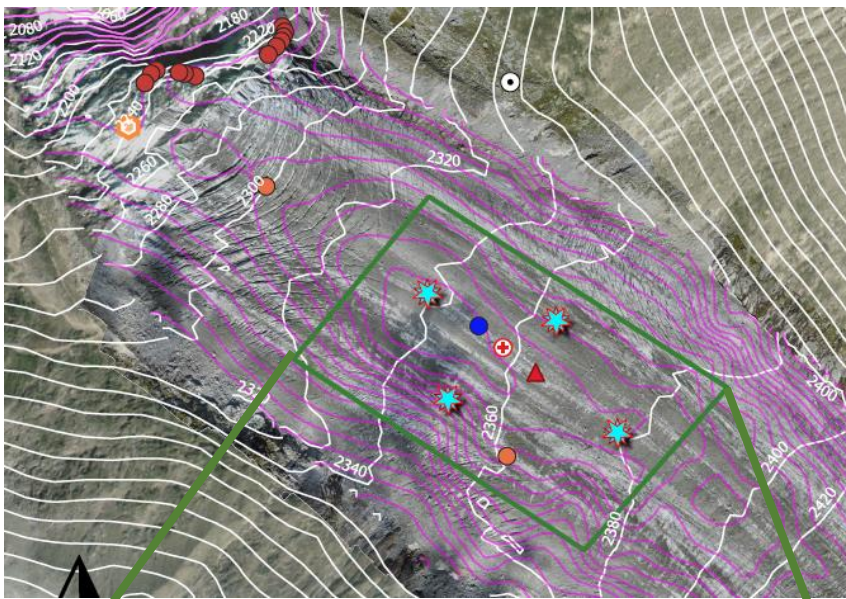


Subglacial channel ?

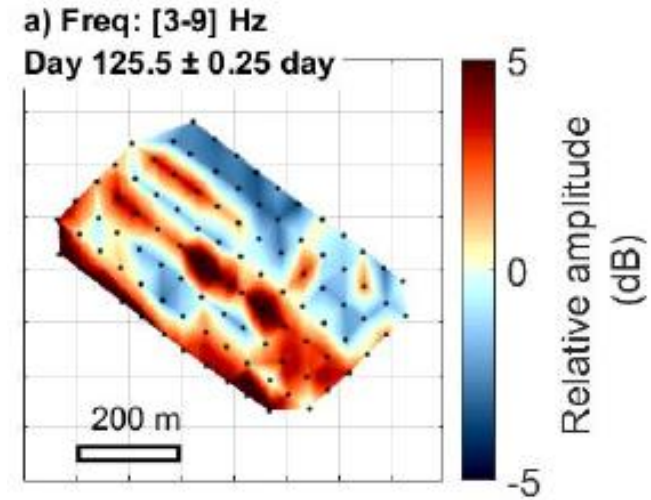
*Nanni et al.
(ongoing work)*

1- Can we provide new understanding on unknown physical processes?

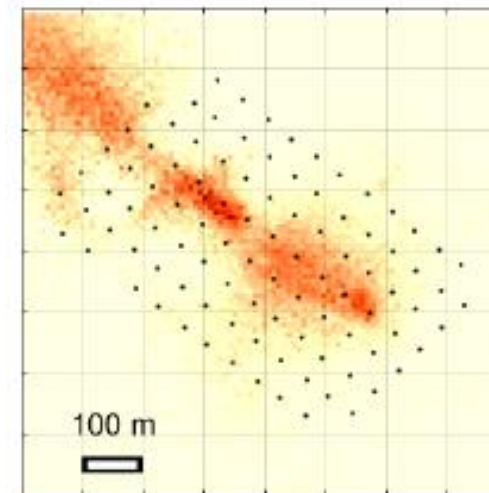
The example of subglacial hydrology



AMPLITUDE



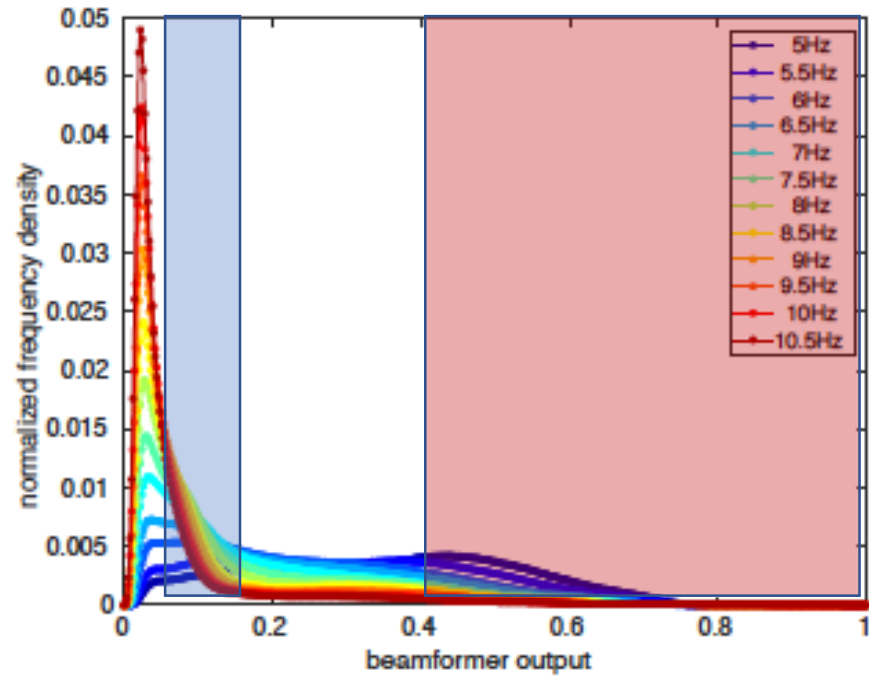
PHASE



Nanni et al.
(ongoing work)

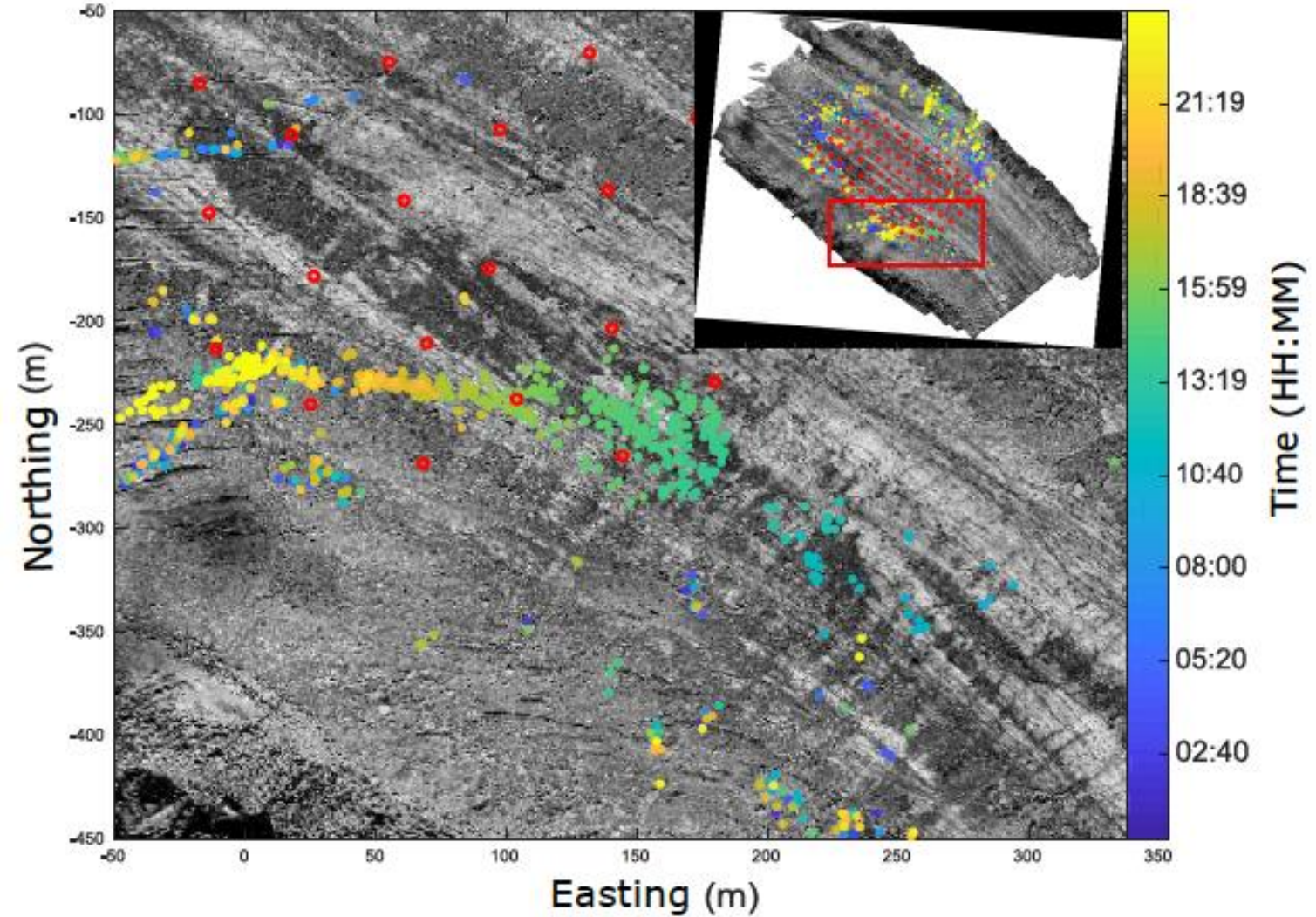
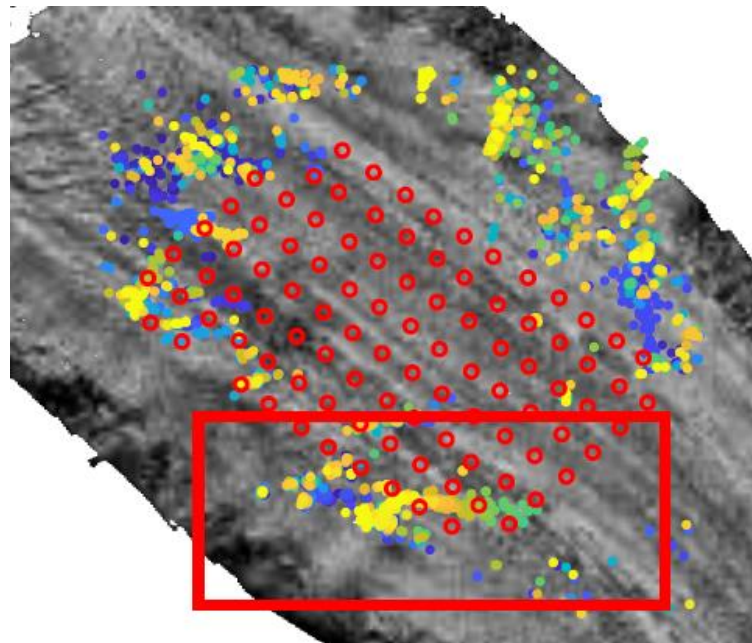
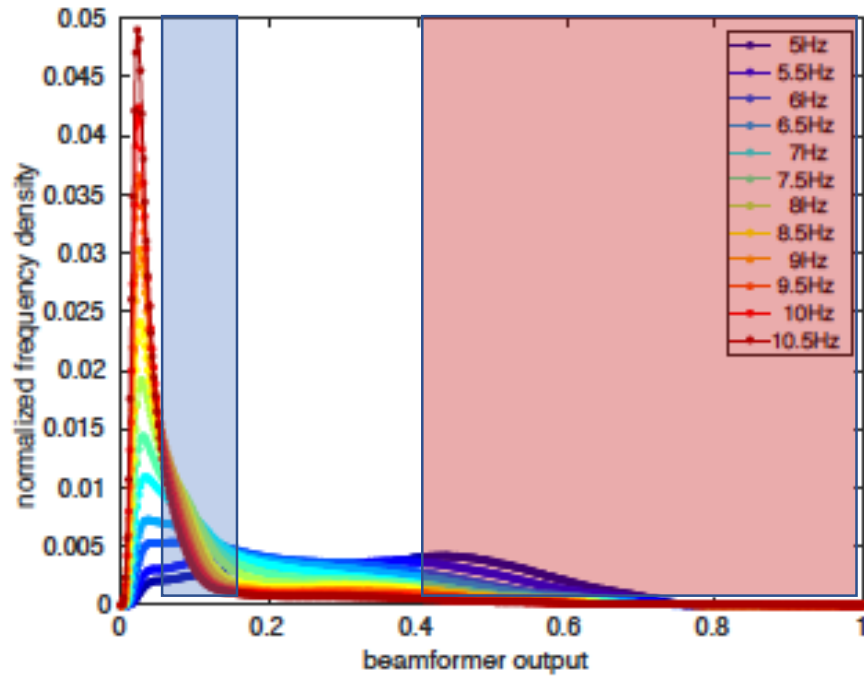
1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology



1- Can we provide new understanding on unknown physical processes?

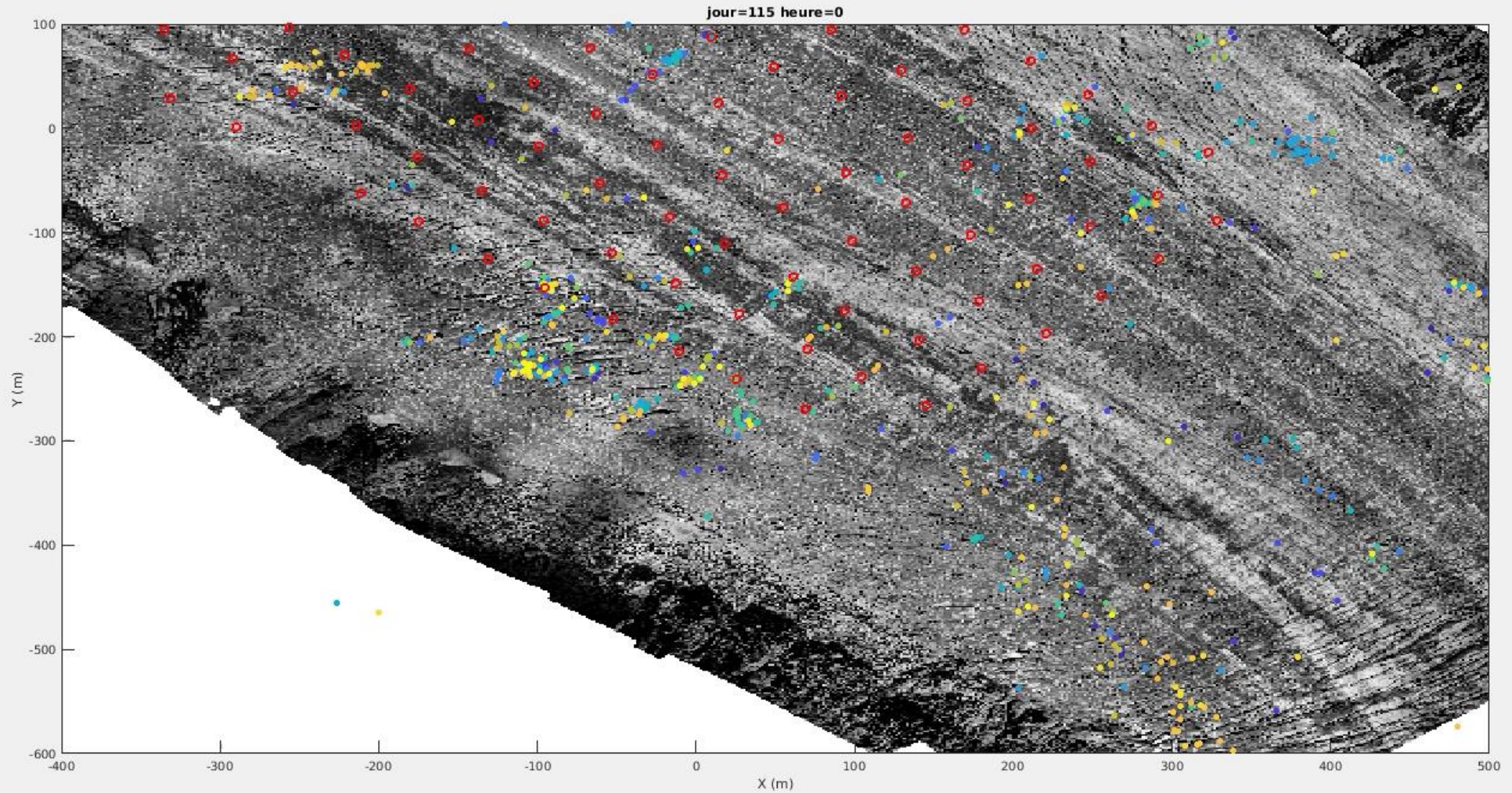
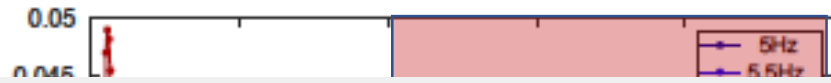
The example of subglacial hydrology



Urruty et al. (ongoing work)

1- Can we provide new understanding on unknown physical processes?

The example of subglacial hydrology



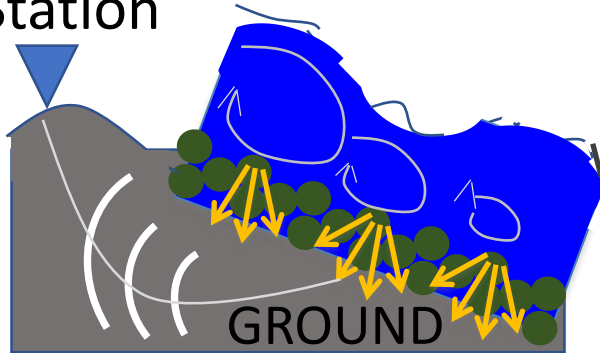
Urruty et al. (ongoing work)

2- Can we provide deliverables/numbers?

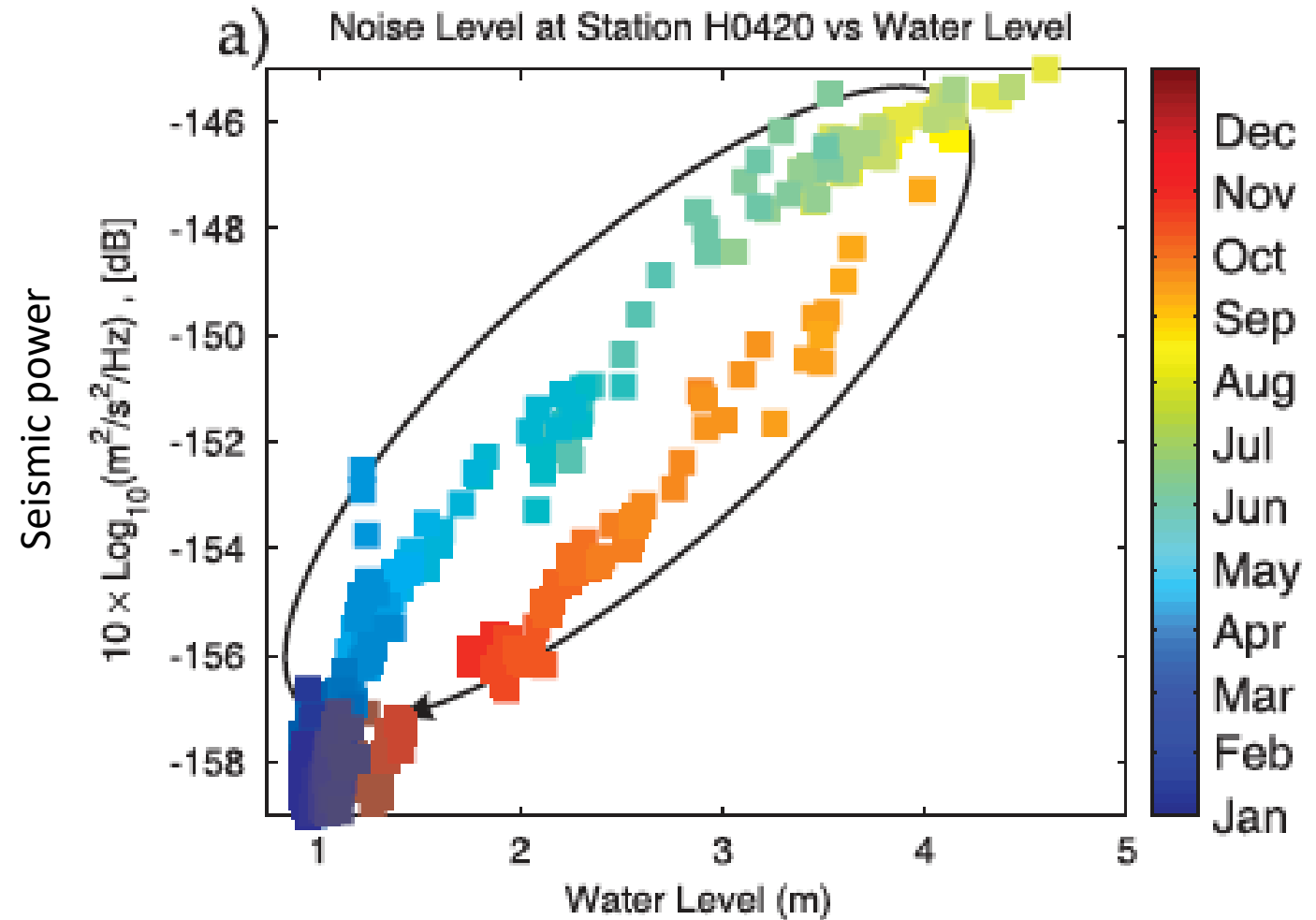
Geomorphology

River sediment transport

Seismic
Station



using source analysis (Burtin et al., 2008; Tsai et al., 2012; Gimbert et al., 2014; Bakker et al., *subm.*)

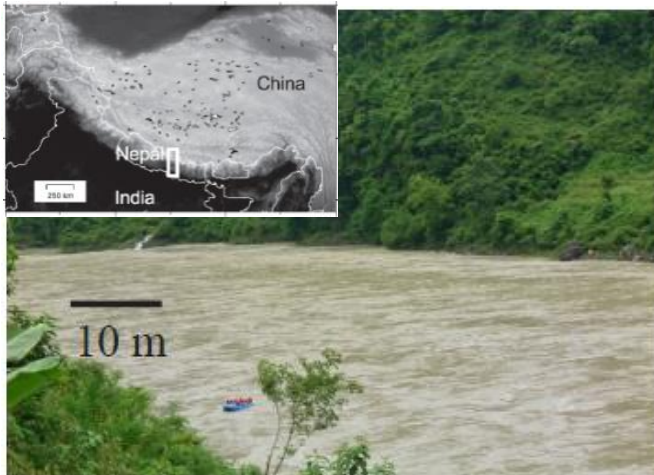
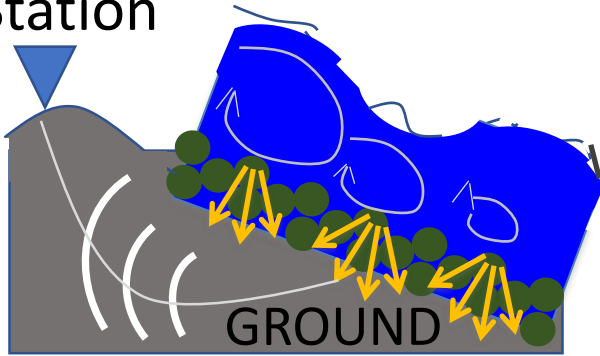


2- Can we provide deliverables/numbers?

Geomorphology

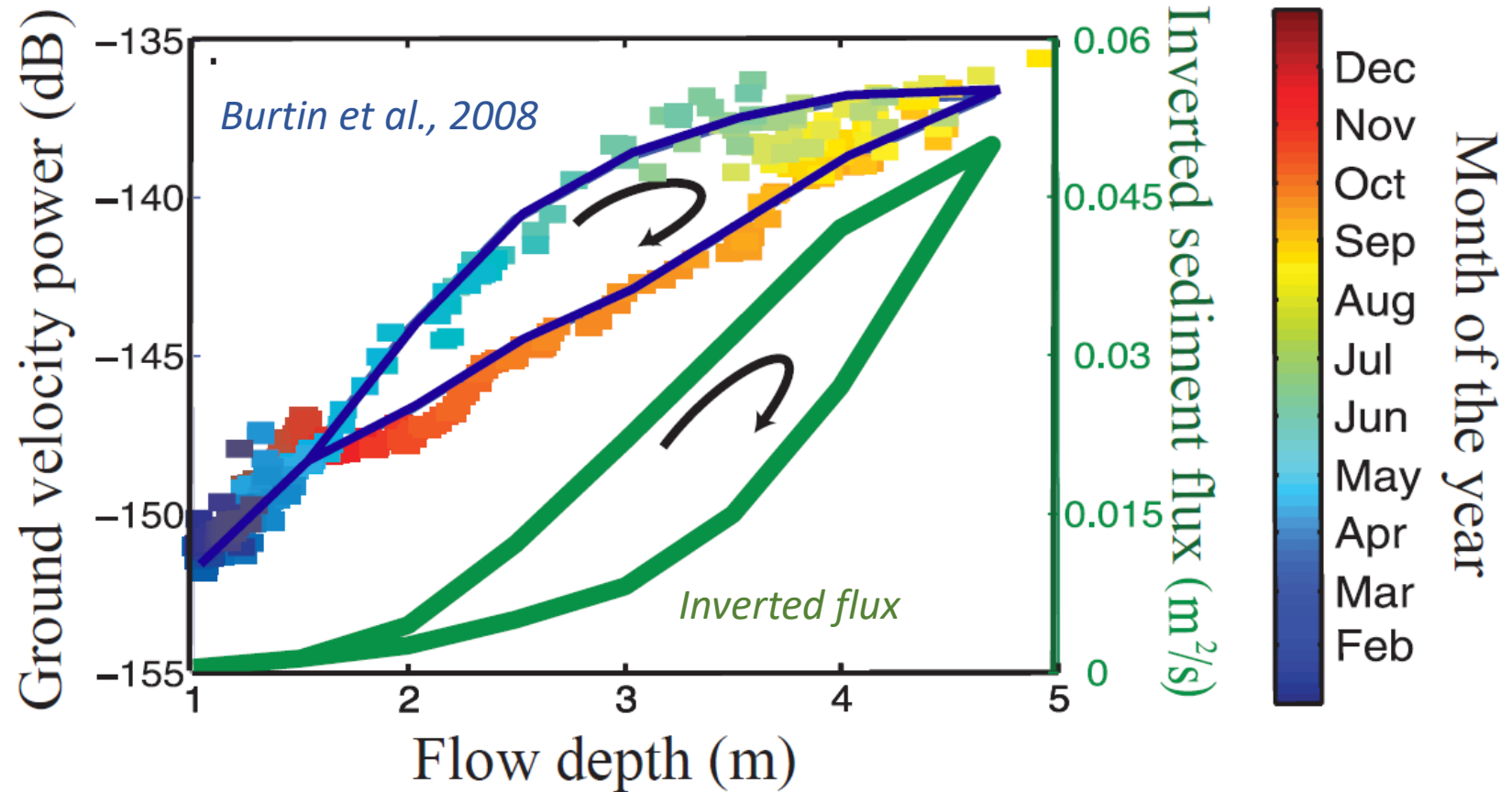
River sediment transport

Seismic
Station



Trisuli River (Nepal)

using source analysis (Burtin et al., 2008; Tsai et al., 2012; Gimbert et al., 2014; Bakker et al., *subm.*)

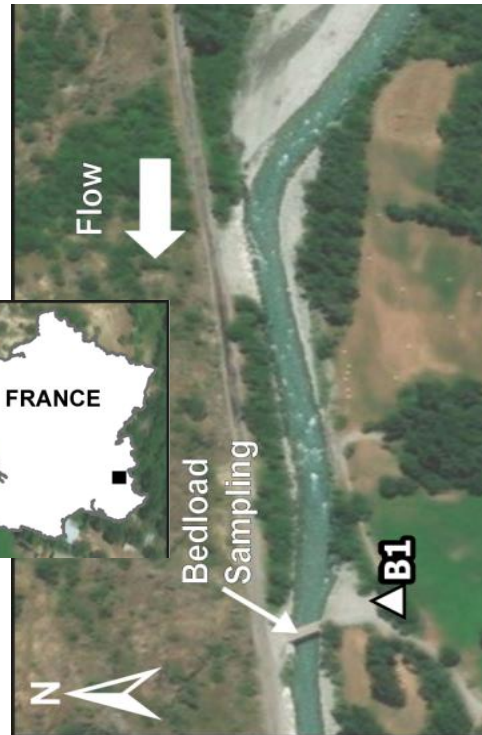
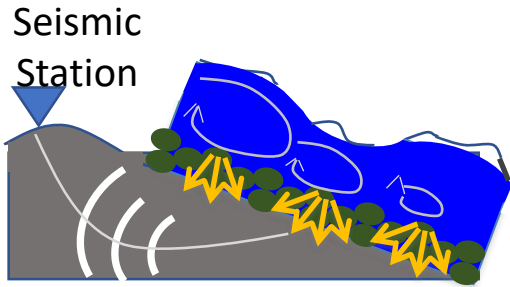


Tsai et al., 2012

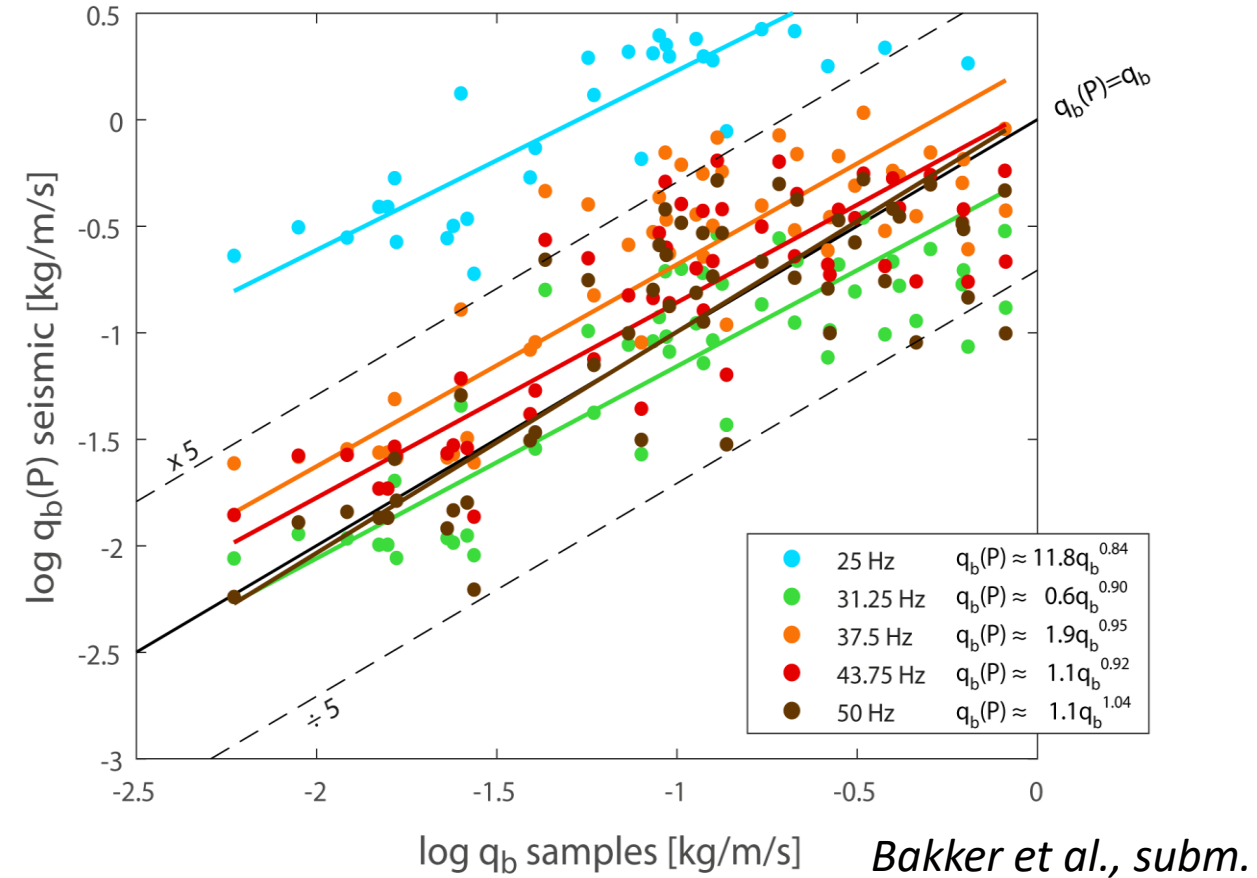
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Geomorphology

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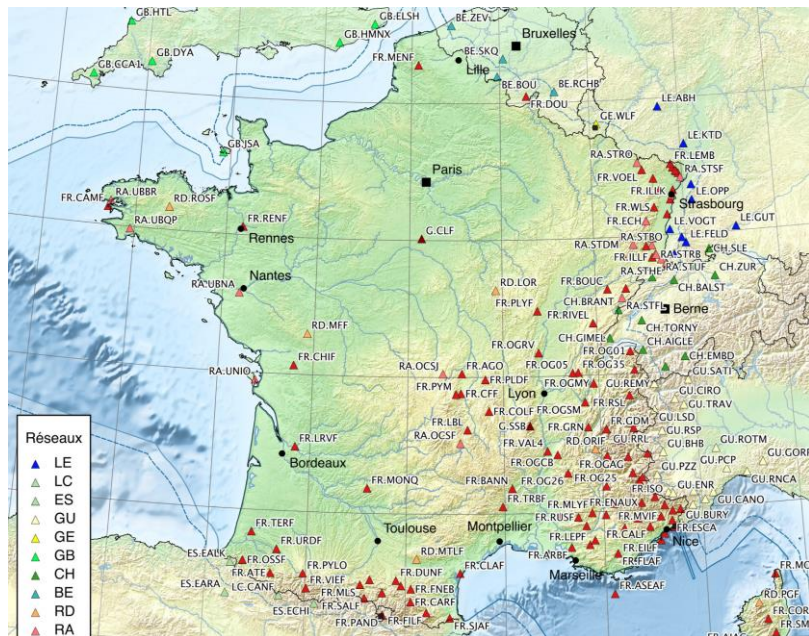


Sediment flux inversions yield reliable results
(no need of calibration, just need appropriate source
and wave propagation description)

Sismologie environnementale et RESIF

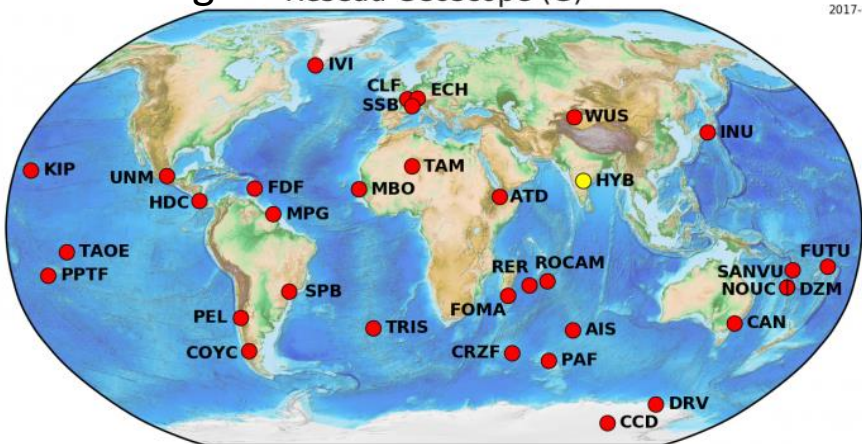
Observations de terrain

En France



A l'étranger Réseau Geoscope (G)

2017-01-24



● stations en temps réel (ou légèrement différé) ● stations temporairement interrompues

Parc instrumental

Nodes (100 SISMOB)



Exemples d'activités en cours et futures sur les glaciers:

Cet hiver

Glacier d'Argentière (F. Gimbert; A. Helmstetter) et de l'Astrolabe (Terre Adélie, PI: G. Barruol, IPGP)

Futur proche à lointain

- projet ANR Franco-Allemand avec l'Astrolabe comme site pilote (PI: D. Zigone, IPGS)

- projet ERC SYNERGY sur l'instrumentation/l'exploration de l'Antarctique de l'Est (co-PI: G. Barruol, IPGP avec glaciologues, océanographes et biologistes)

Diffusion de données



Réseau Sismologique et Géodésique Français

FDSN and EIDA Webservices

These services allow retrieval of seismological data and metadata.

- Service URL for getting data : <http://ws.resif.fr/fdsnws/dataselect/1>
- Service URL for getting metadata : <http://ws.resif.fr/fdsnws/station/1>
- Service URL for getting waveform quality : <http://ws.resif.fr/eidaws/wfcatalog/1/>