Research Perspectives

Dynamics of glacial and paraglacial floods
From local processes to regional monitoring with seismology

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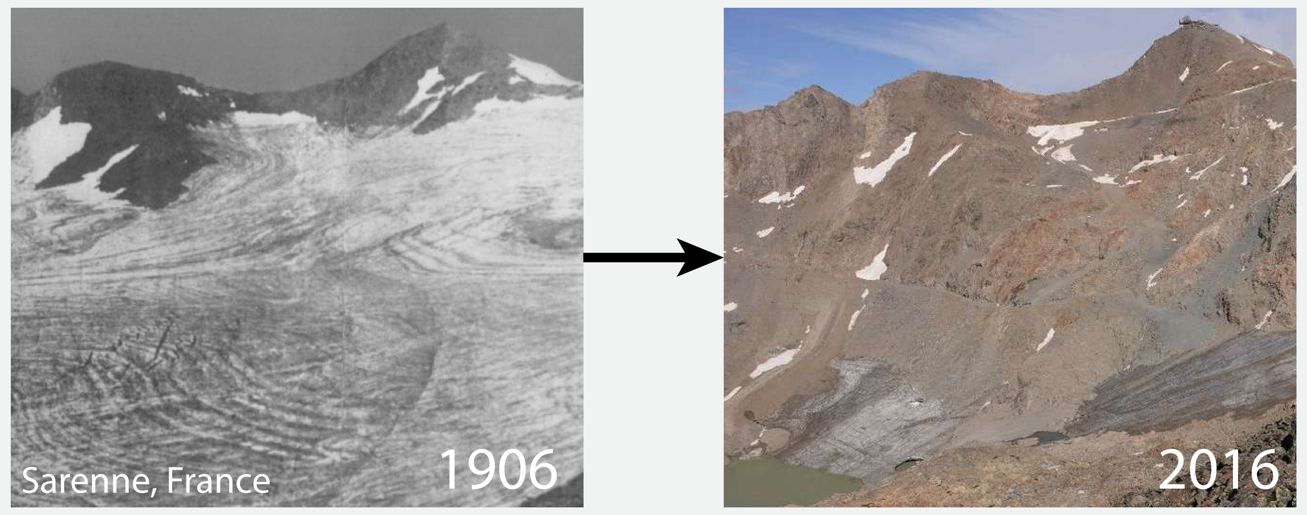
From glacial to paraglacial landscapes

Glacier retreat causes profound changes in continental surfaces



As glaciers melt, long-term water storage is reduced and a cascade of thermo-mechanical and hydrological changes is triggered, from the top of the mountains to the bottom of the water sheds.
But these changes not only happen gradually but can cause hazards

Cascading hazards: initiation and propagation processes

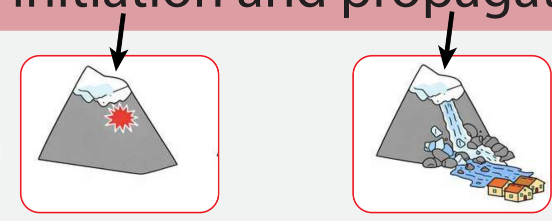
Glacial and paraglacial floods are one of the most devasting hazards

A combination of extreme precipitations, extreme snow depth, extreme melt and subglacial water pocket has caused a 300 000 m³ debris flow and burried a village.

A rock-ice avalanche caused a 20 millions m³ debris flow travelling 10s of km, destroying 2 hydropower facilities and causing more than 200 casualties

What controls the initiation and propagation of such events ?

$Time_{characteric}$: sec-min
$Distance_{characteric}$: m-10s m

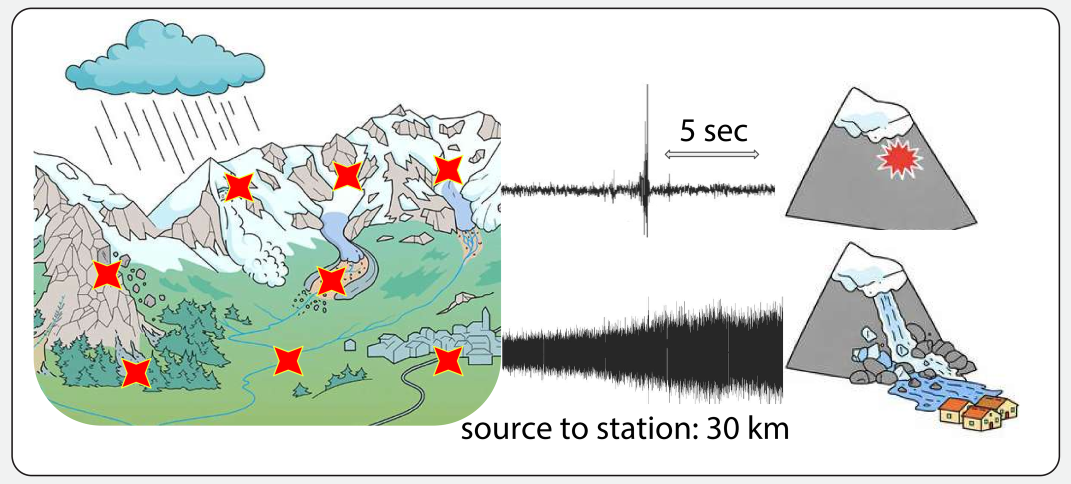


$Time_{characteric}$: min-h
$Distance_{characteric}$: km-10s km

Satellite imagery does not offer the temporal resolution and in-situ observation is spatially limited for emerging & far-range processus

Using seismology to investigate data scarse environnements

Environmental seismology is an emerging field that consists of investigating surface processes through the vibration their produce and to use the tools and methods developped for earthquakes.

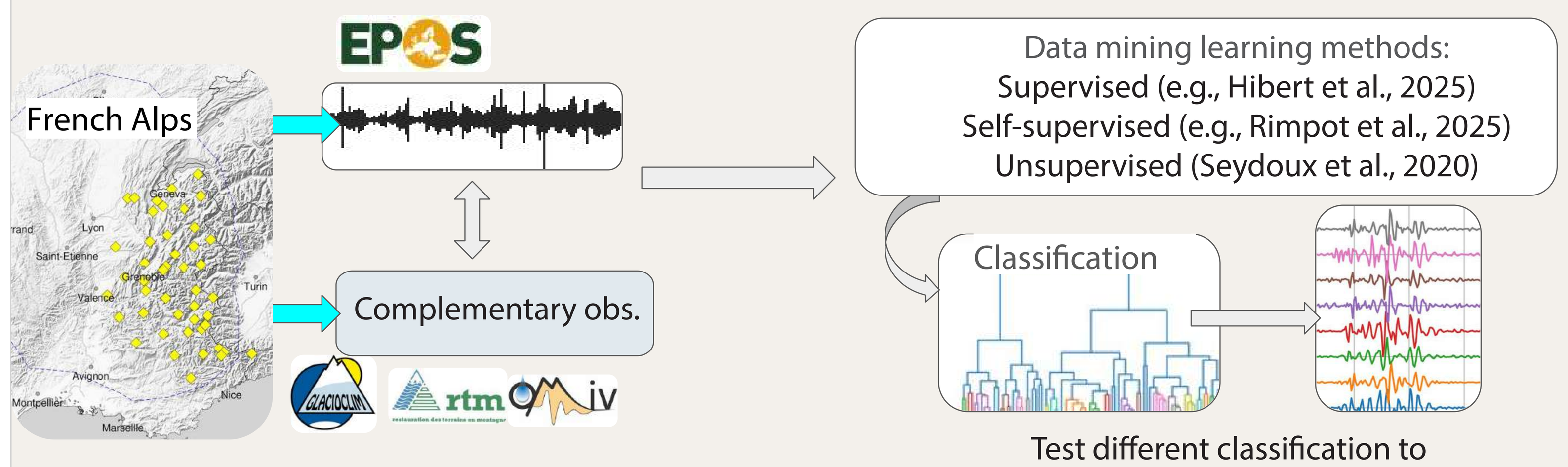


Seismic observations offer high temporal resolution (<1 s), have a large spatial sensitivity (> 100 km), instruments can be installed in non-vulnerable places and are sensitive to various processes

Detection and characterization of key seismic signatures

How to identify the seismic signatures of theses hazards ?

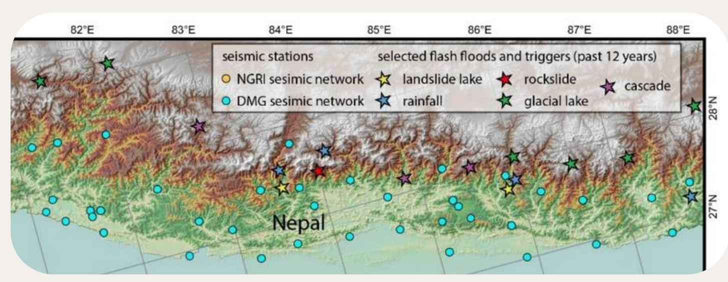
In order to explore seismic signals originating from various sources and in remote areas with little to non in-situ observations, we will first develop an hybrid approach in a well-instrumented area.



Test different classification to identify signals families

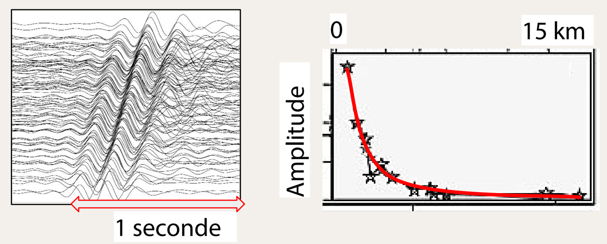
In the well-instrumented area, we will test the capicity to detect events from the near-field (m) to the far-field (>100 km); we will explore the sensitivity to site effect conditions; we will test the influence of instrumental and geomorphological specificities.

We will then test combinations of detection approaches & developp a foundation model able to be transferred to data-scarse regions

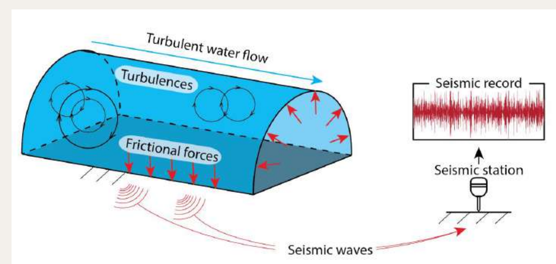


Evaluation of physical properties

We will **combine** location methods based on the phase coherence of the seismic signal and methods based on the spatial decay of the seismic amplitude.



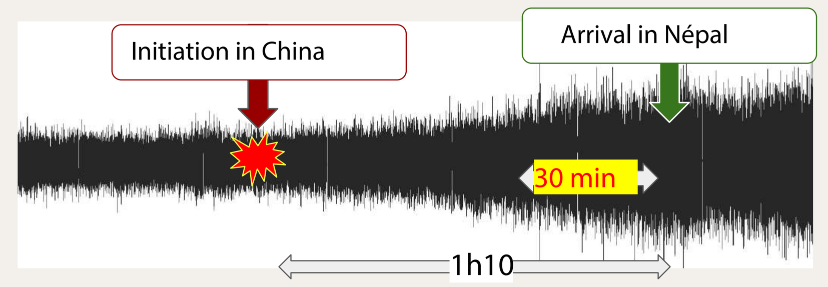
We will then combine empiric models and theoretical models to retrieve key properties: **rupture sizes, runout distances, flow rheology, velocities ...**



Morpho-climatic influences and monitoring strategies

Seismic records allow retro-analysis of events for more than 40 years. This provides key records to investigate the effect of warming on glacial hazards and potential non-linear trends.

Towards early-warning ?



Seismic signal recorded in Nepal (KKH, Z component) during the Rasuwagadhi glacial flood in July 2025.

Case study and perspectives

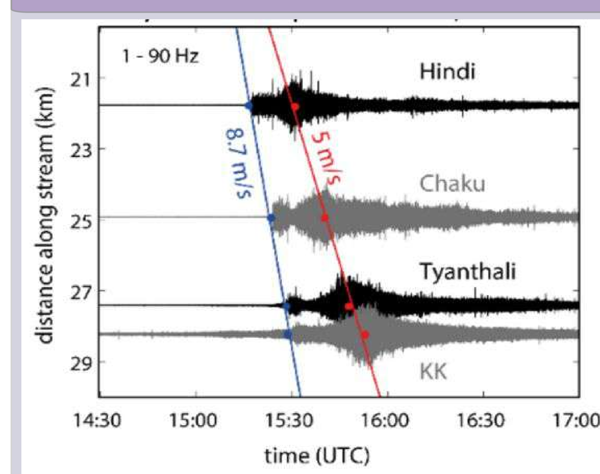


Fig. 2. Seismic record of GLOF, blue and red lines show propagation of a water wave and a slower sediment pulse. Cook et al., 2018

First study site: the Bhote Koshi catchment, Nepal.

Since 2016, more than 20 seismic stations have been installed in the largest catchment of Nepal. Key glacio-fluvial events, such as the 2016 GLOF, have been recorde as well as numerous landslides, making an ideal area to test our seismic based approach.

Perspective: Callejon de Huaylas, Perou.

This valley, in the Cordillera Blanca, hosts numerous proglacial lakes, and recent events (Vallunaraju) have demonstrated the presence of related hazards.
We will investigate the national seismic records and potential deployments.