CR4.2 Permafrost: Open session

Towards mechanical modelling of rock glaciers from modal analysis of passive seismic data

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What is a rock glacier ?

- Prominent features in alpine permafrost
- Creeping landforms composed of debris (coarse materials and fine matrices), ice, liquid water and air
- Climate indicator, used to assess permafrost spatial limits and their temporal degradation
- Slope movement from cm/yr to several m/yr

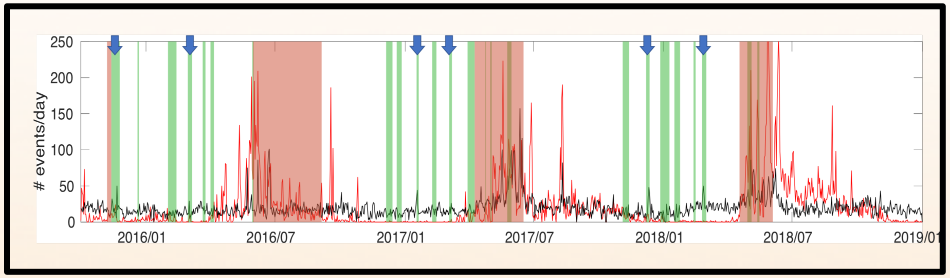
- Destabilization and catastrophic collapses hazards

Laurichard rock glacier (photo EDYTEM)

What can we learn from passive seismology about internal processes inside a rock glacier ?

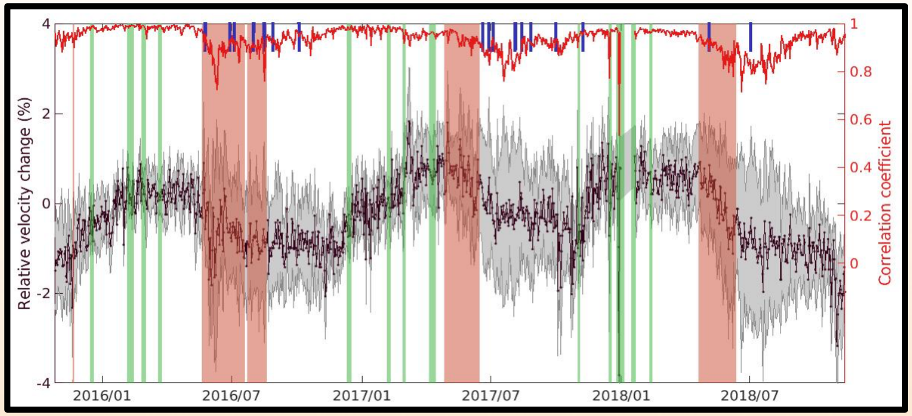
Passive seismic data on rock glaciers

Detection of microseismicity



Quakes
Rockfalls

Ambient noise crosscorrelation



- Burst of microseismic activity during snowfalls, snowmelt, summer (pore pressure increase ?)

- Seasonal variations of the relative velocity change (dV/V)
- The seismic velocity is higher in winter than in summer, probably due to the increase of global rigidity of the medium.

(Guillemot et al. 2020)

First results and open question

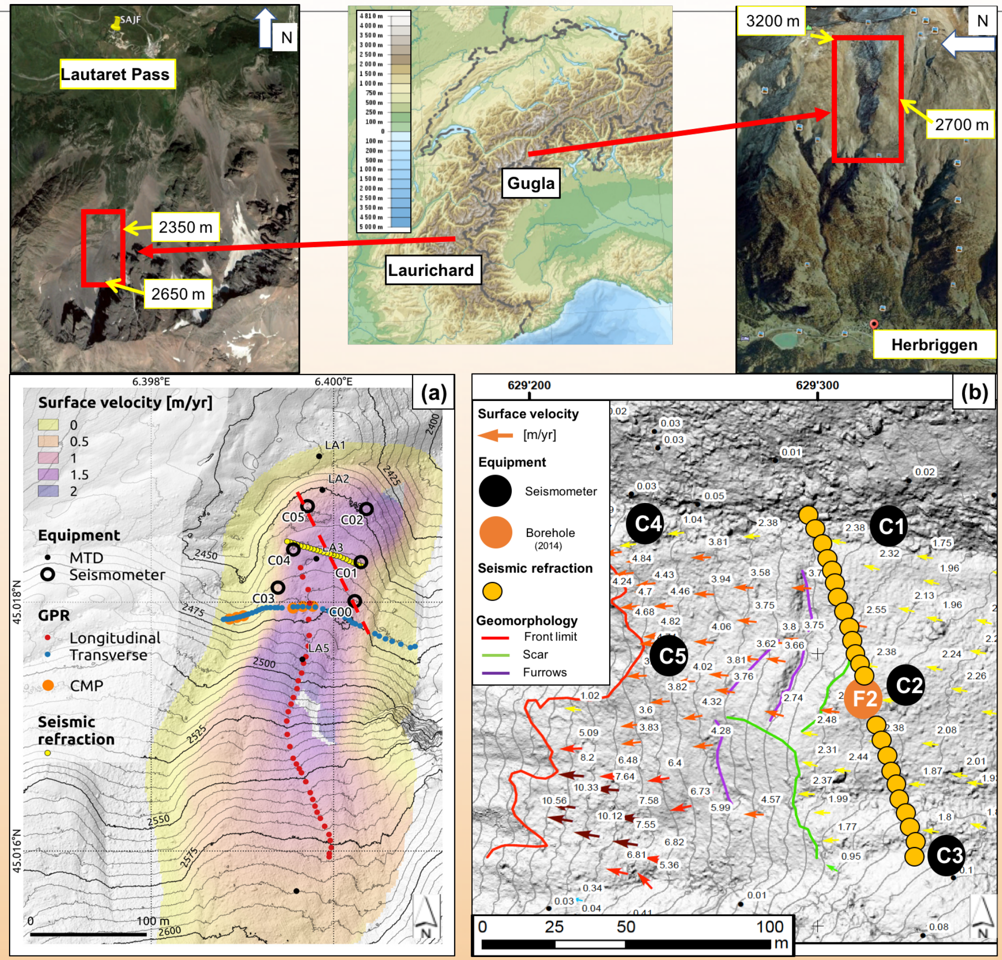
Seismic monitoring of rock glaciers

- Microseismicity
  - Detection and location of rockfalls and quakes (burst of activity during snowfalls, melting periods and summer)
- Ambient seismic noise
  - Intercorrelation
    - Seasonal variations of rigidity of the medium (freeze-thawing of active and permafrost layers), water infiltration during melting periods
  - Frequency content
    - What can we learn about the frequency content of seismic noise on rock glaciers ?

From a previous study (Guillemot et al. 2020)

Two study sites :

Laurichard rock glacier (France)



Gugla rock glacier (Switzerland)

Modal analysis : observations (1/2)

Methodology

Ambient noise recordings

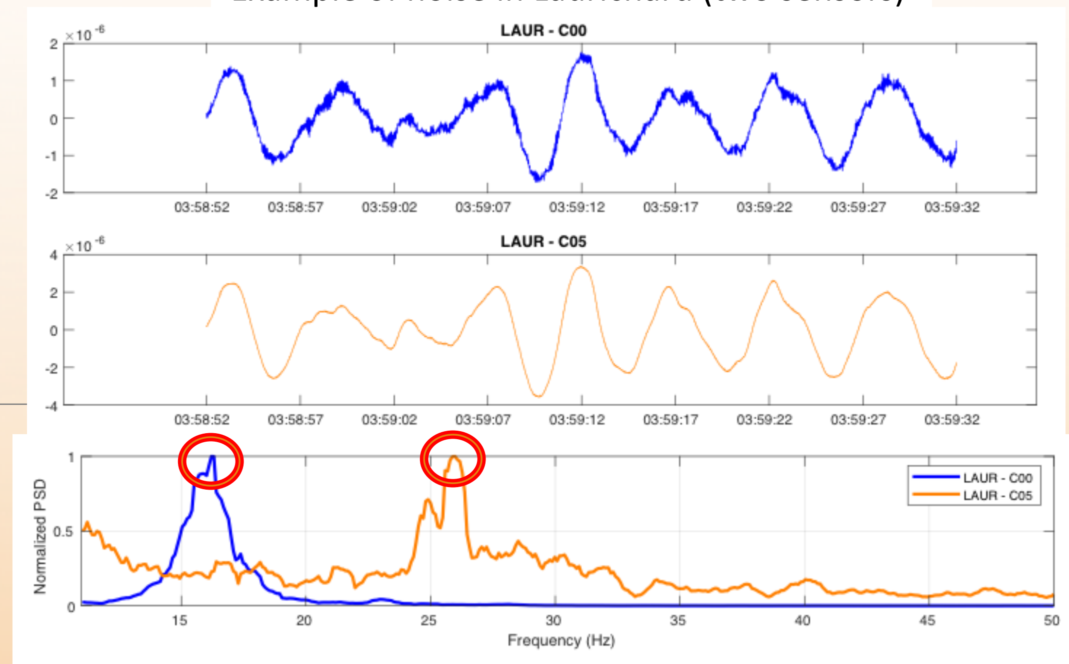
↓ Fourier transform

Frequency content

↓

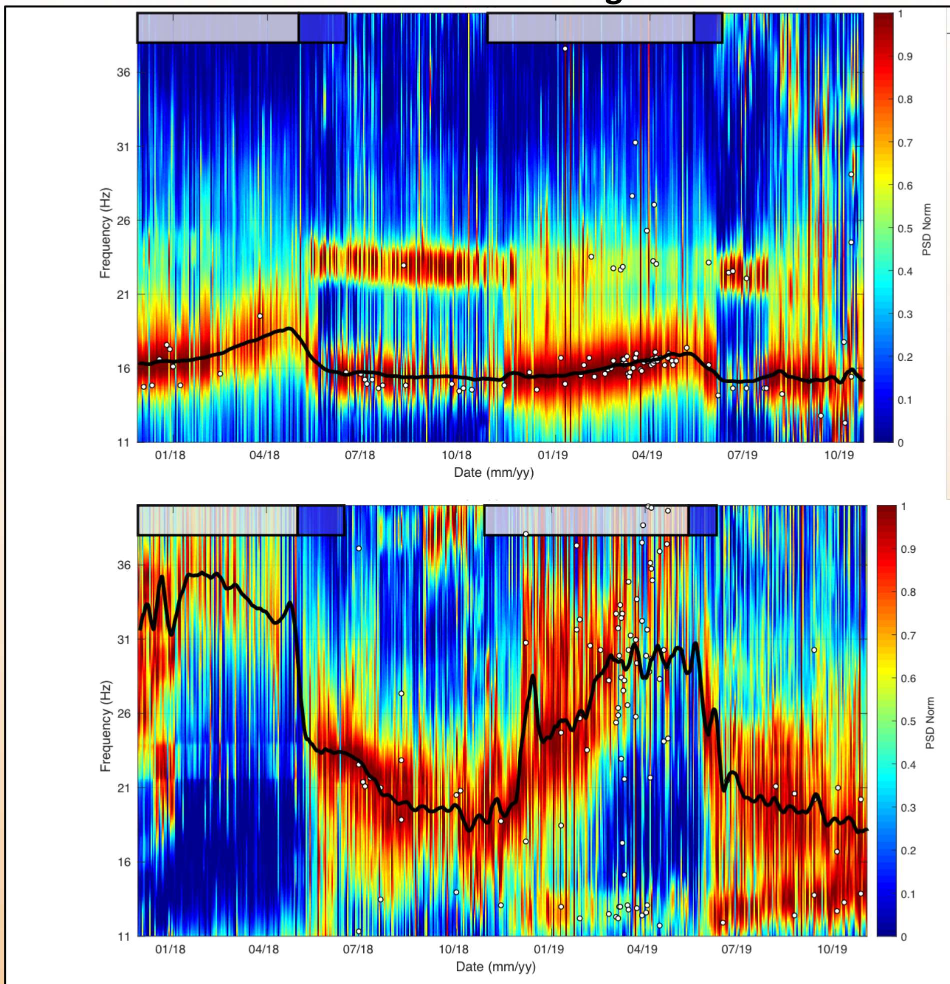
Resonance frequency picking

Example of noise in Laurichard (two sensors)

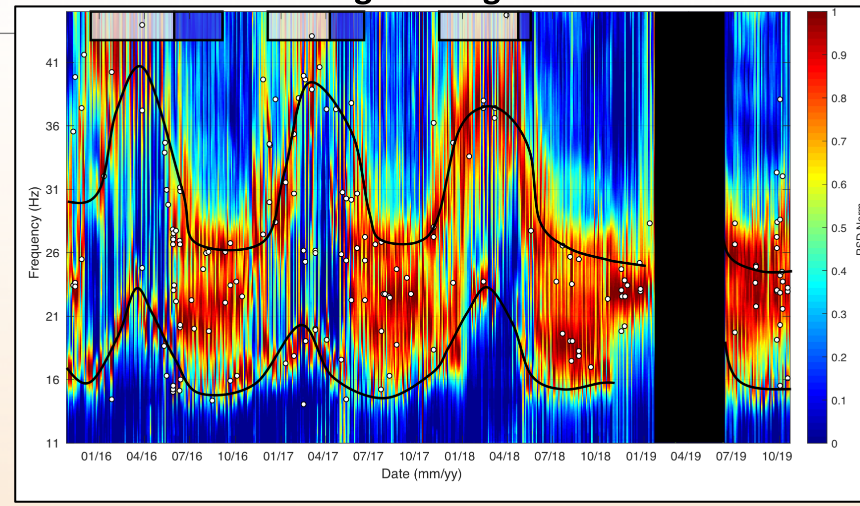


Modal analysis : observations (2/2)

Laurichard rock glacier



Gugla rock glacier



- Resonance frequency tracking of vibrating modes of the rock glacier structure
- Seasonal variations of resonance frequencies (black curves)

→ Mechanical modelling?

Modal analysis : modelling (2/2)

Assumptions

- Rock glacier -> vibrating structure with a specific modal response to seismic sources
- The resonance frequency of these modes is highlighted by peaks in the spectrum

(Guéguen et al. (2017))

- Seasonal variations of these resonance frequencies -> due to freeze-thawing cycles
- Freezing process increases the rigidity of the structure, causing an increase of resonance frequency in winter

(Weber et al. (2018))

Methodology

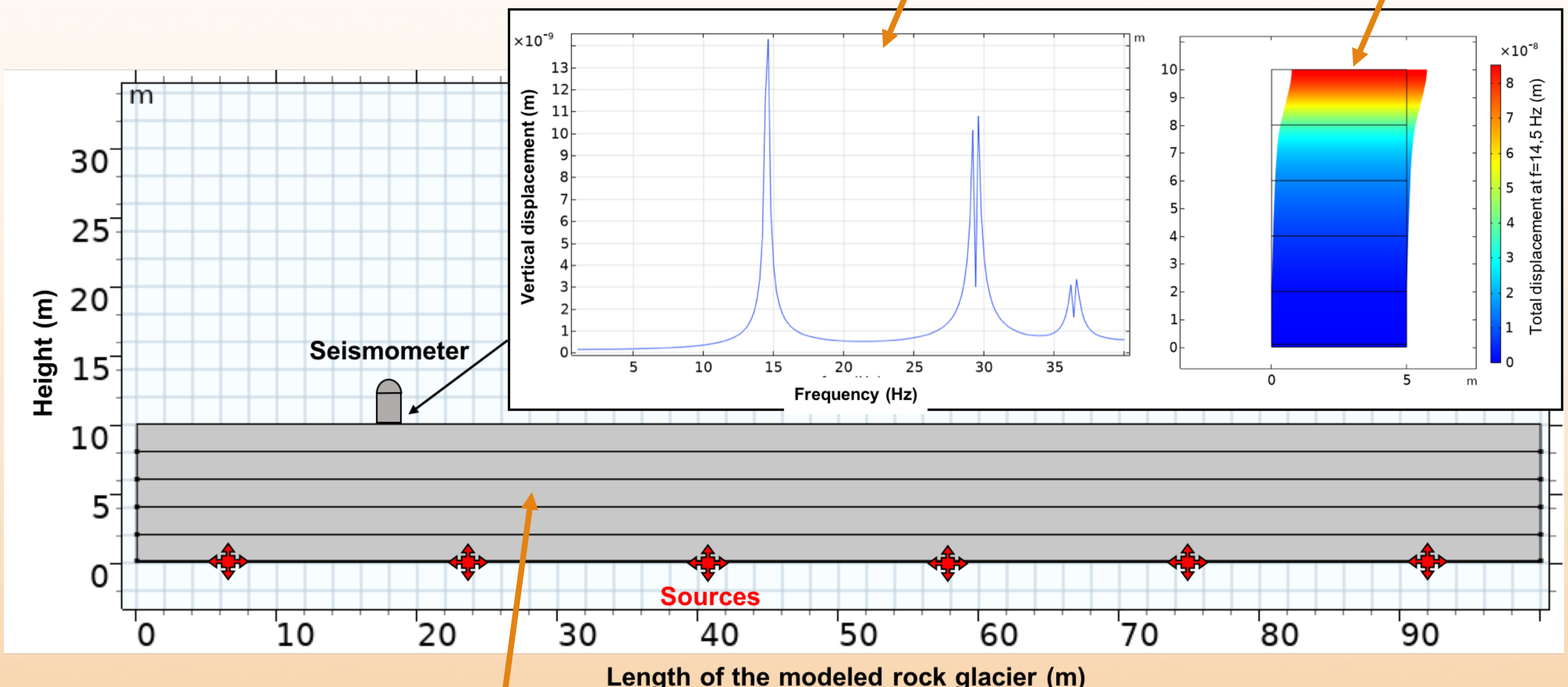
- 2D mechanical modelling of the rock glaciers
- Constrained by geophysics and boreholes (Kneisel et al. (2008))
- Modal response numerically computed by finite-element method

- 3-phases poroelastic modelling of the rock glaciers (rock + water + ice)
- Quantification of the influence of freezing process on elastic parameters of the porous medium
- Modelling of resonance frequency increase due to freezing

Modal analysis : modelling (1/2)

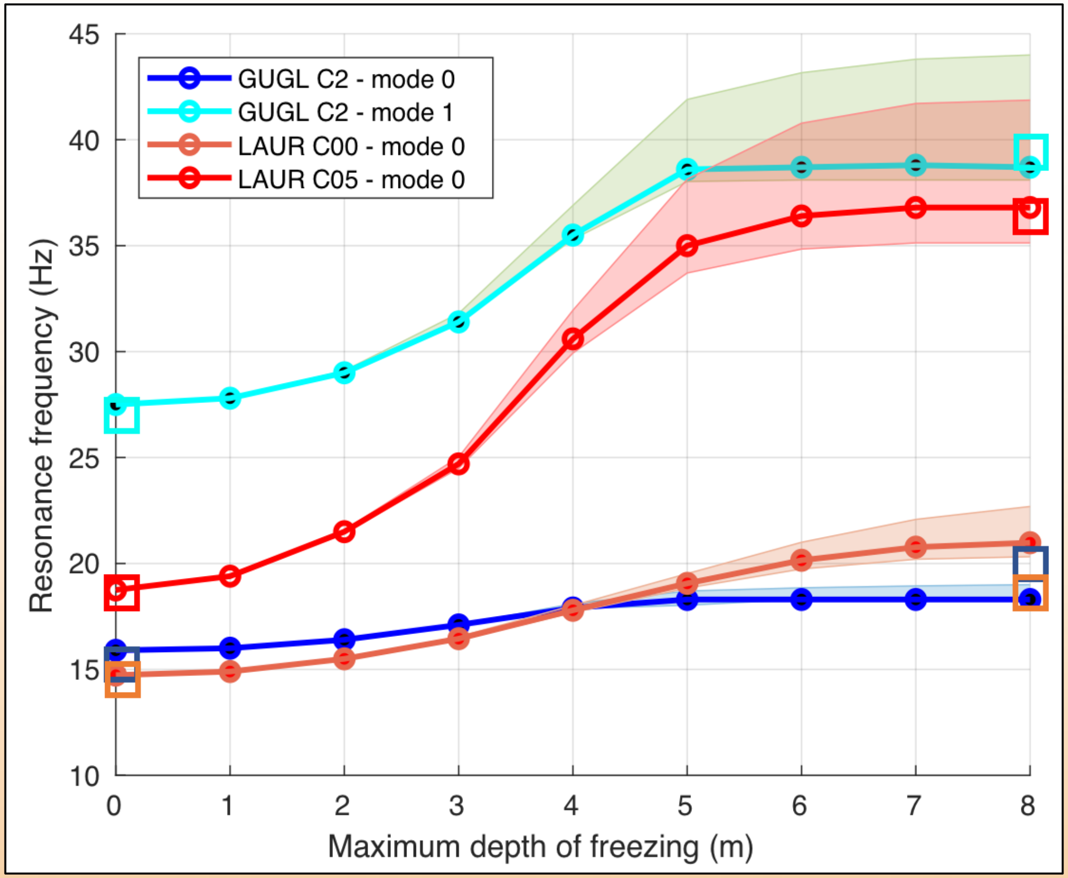
Frequency Response Function from finite-element method

First mode of vibration



2D mechanical model of the rock glacier, constrained by geophysics (GPR, refraction)

Modal analysis : results of the model



Observations

Errorbars :
influence of the porosity
(low-high)

Consistency between observed and modelled resonance frequencies

Conclusions

Seismic monitoring of rock glaciers

Ambient seismic noise

Frequency analysis

- Peaks due to resonance of the rock glacier
- Seasonal variations of resonance frequencies

Mechanical model of the rock glacier

Modal analysis

Seasonal variations of rigidity of the medium (freeze-thawing processes), with precise quantification and location (maximum of sensitivity around 5 m depth)

Thanks for your attention !

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References

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