# Ambient seismic noise monitoring:

# an online application for decision makers;

example of various applications for different slopes configurations.

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**From: M. Le Breton, N. Bontemps, A. Guillemot, L. Baillet, E. Larose Landslide Monitoring Using Seismic Ambient Noise Interferometry: Challenges and Applications, Earth Science Review (in revision, 2020)**

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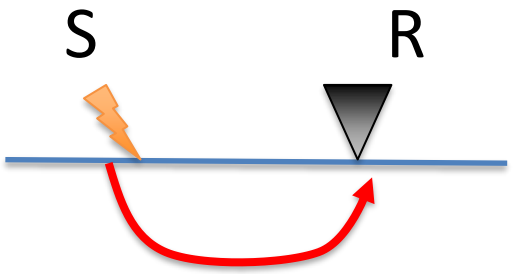
# Main conclusions

- Ambient noise correlation method has been applied on 9 landslides to date => insights.
- Large drop of seismic velocity (below -5%) before observed before two earthflow failures (Pont-Bourquin & Montevecchio)
- Slow-motion of a deep-seated landslide was correlated with a lower seismic velocity (below -1.2%) (Maca, Peru)
- The velocity slowly recovers (several days/weeks) after a motion or failure event
- **Seismic velocity monitoring can provide precursor on earthflows, but can also help to monitor reconsolidation after a failure**
- Seismic velocity is also reduced by higher groundwater elevation and by snowmelt.

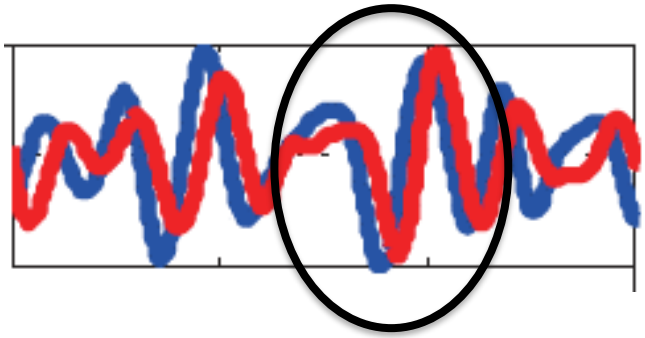



Time of flight

Seismic velocity $v = \sqrt{\frac{rigidity}{density}}$

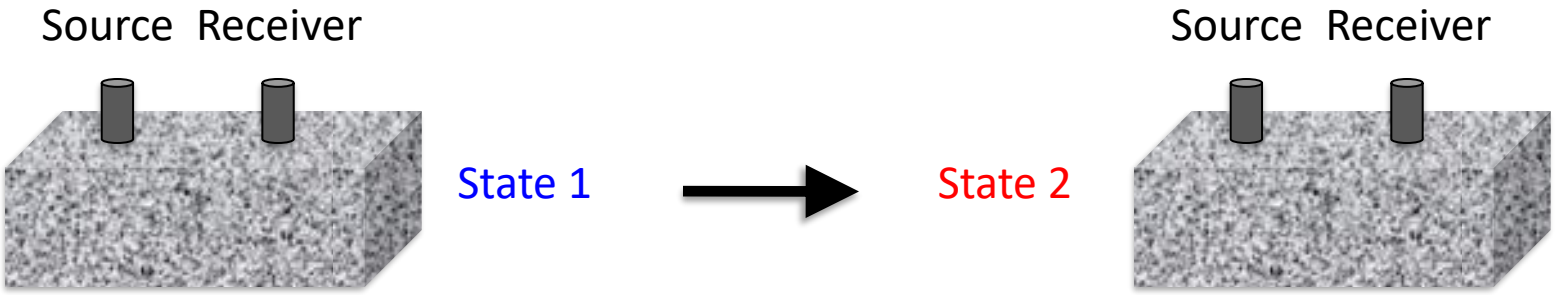
- dV/V <0
  - > Increase of  density (water content)
  - > decrease of stress (acousto-elasticity)
  - > **decrease of rigidity (fracturation/damage)**

# X-correlations-> 2 kinds of changes

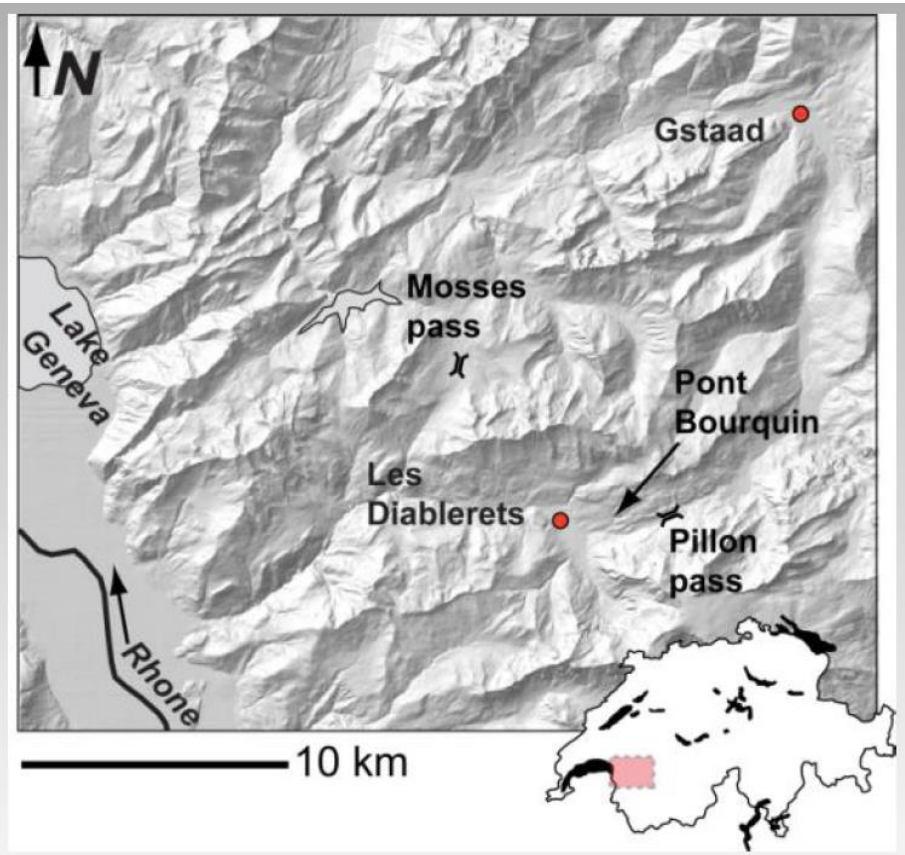


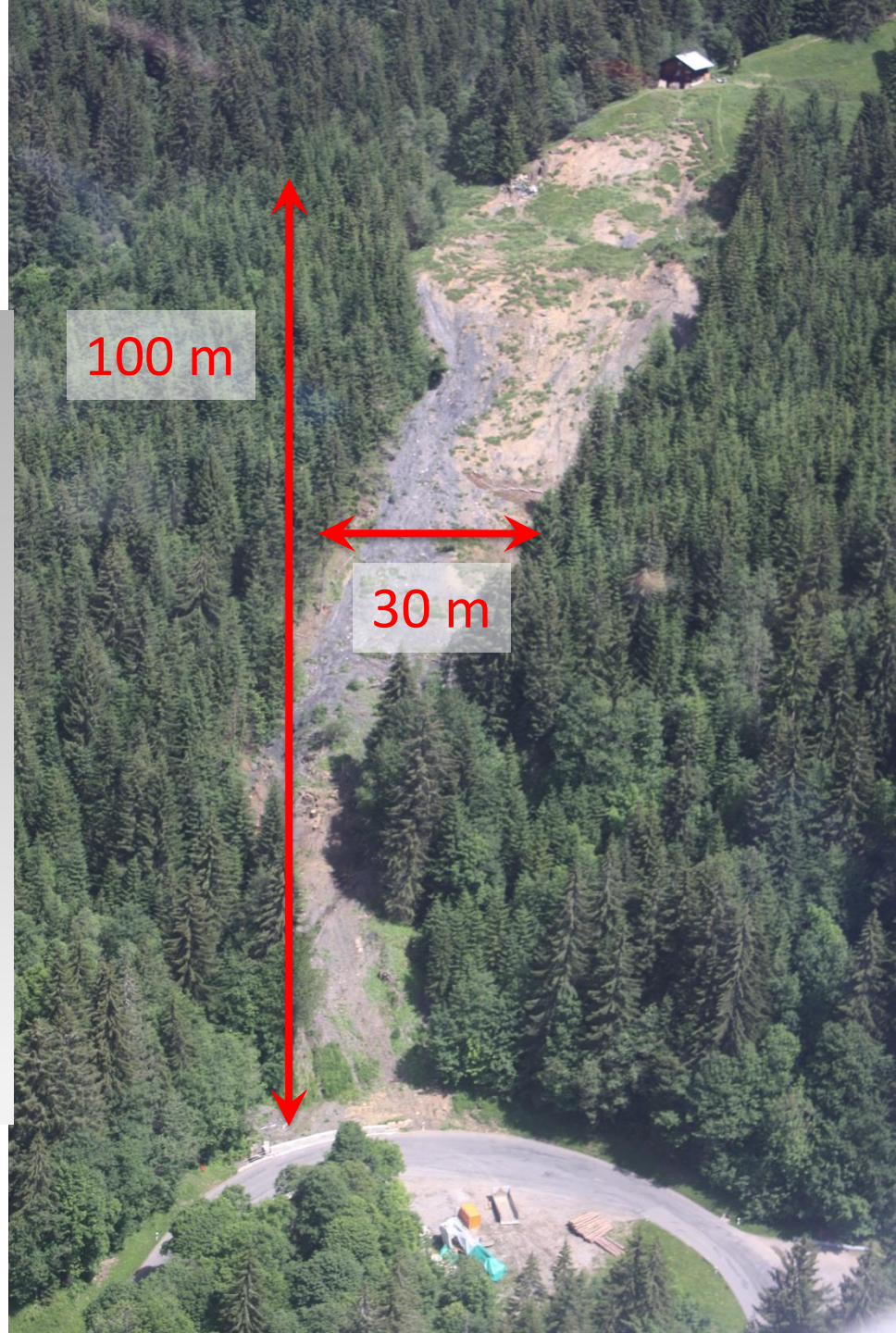
1) Relative velocity changes dV/V=-τ/t
   => global macroscopic change

2) Waveform decorrelation
   => Change of structure, geometry
   => fluid injection…



# Les Diablerets (Suisse)

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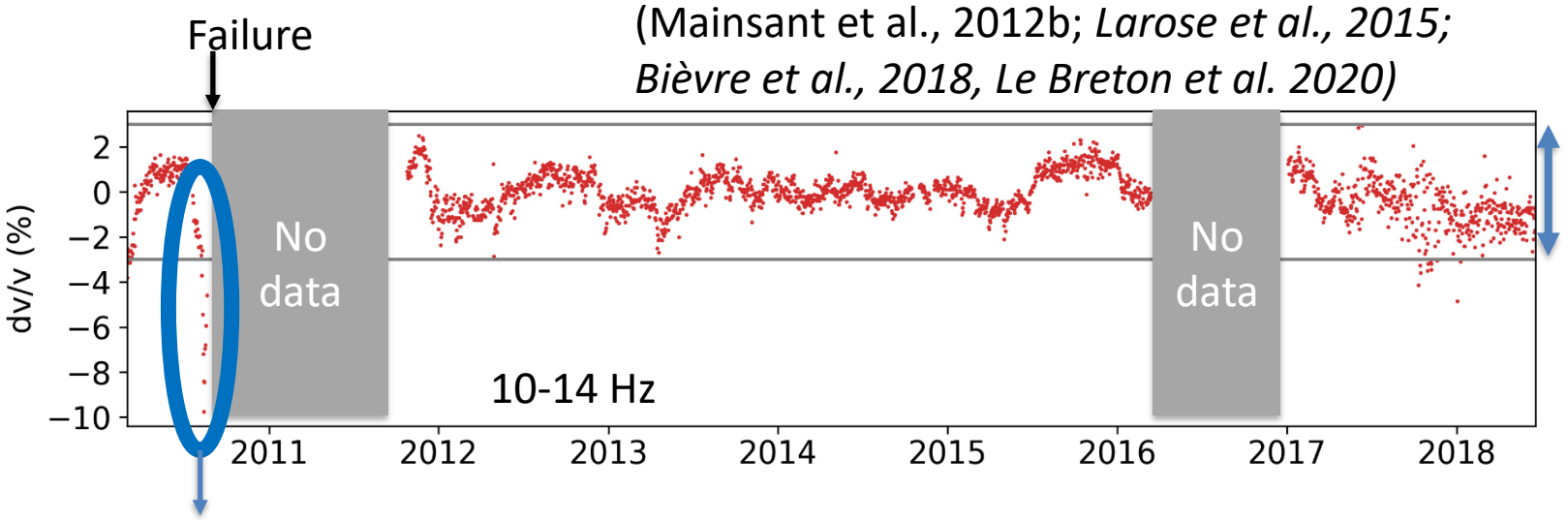


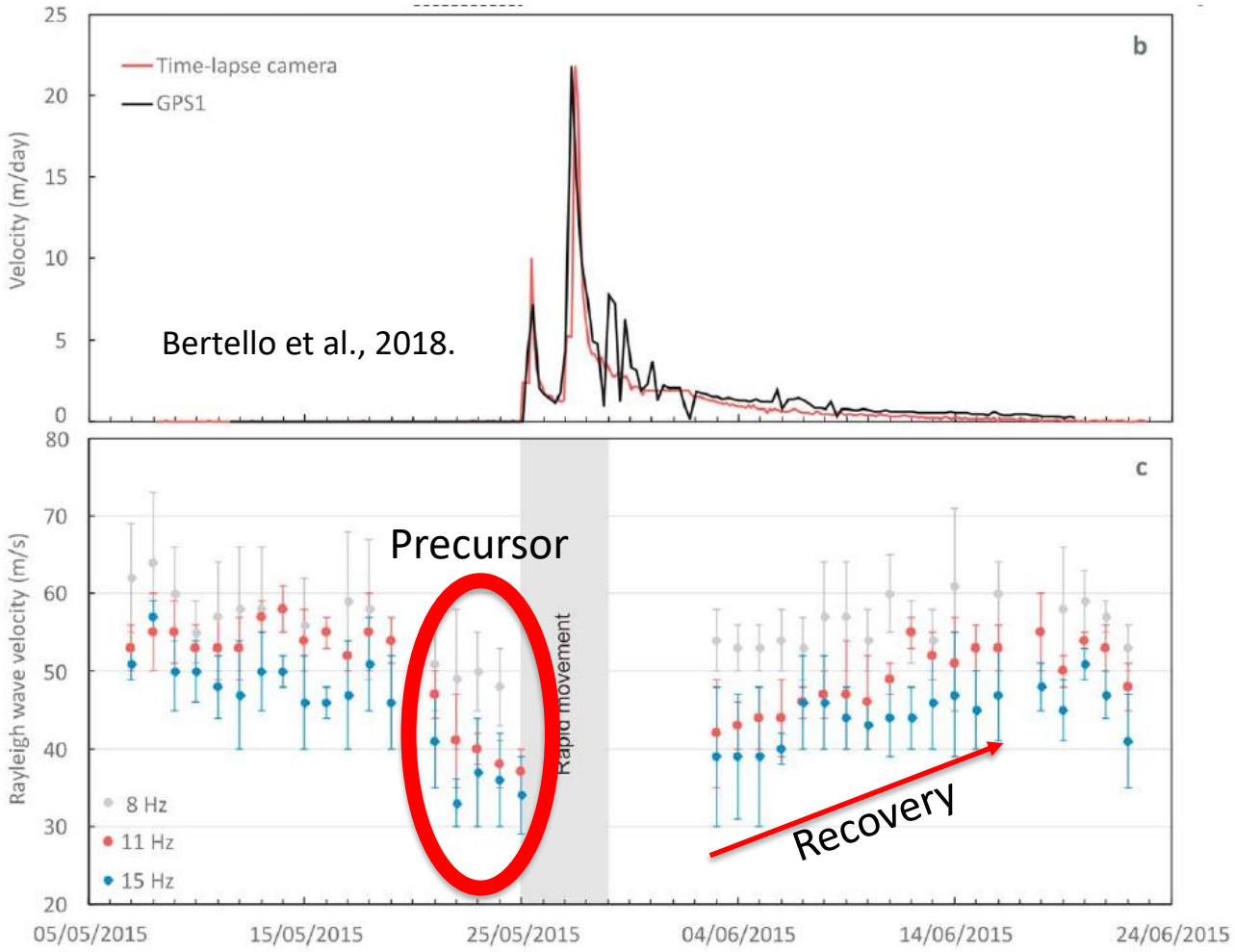

Precursor drop of dv/v observed five days before a major failure
No other major failure since 2010, and no major drop of dv/v

-> Is dV/V a systematic indicator for failure ?
-> What happens after the failure ?
-> role of rainfalls? Earthquakes ?

# Montevecchio landslide, Italy


Bertello et al., 2018.

# Montevecchio landslide, Italy




=> 4 days before the failure : dv/v dropped

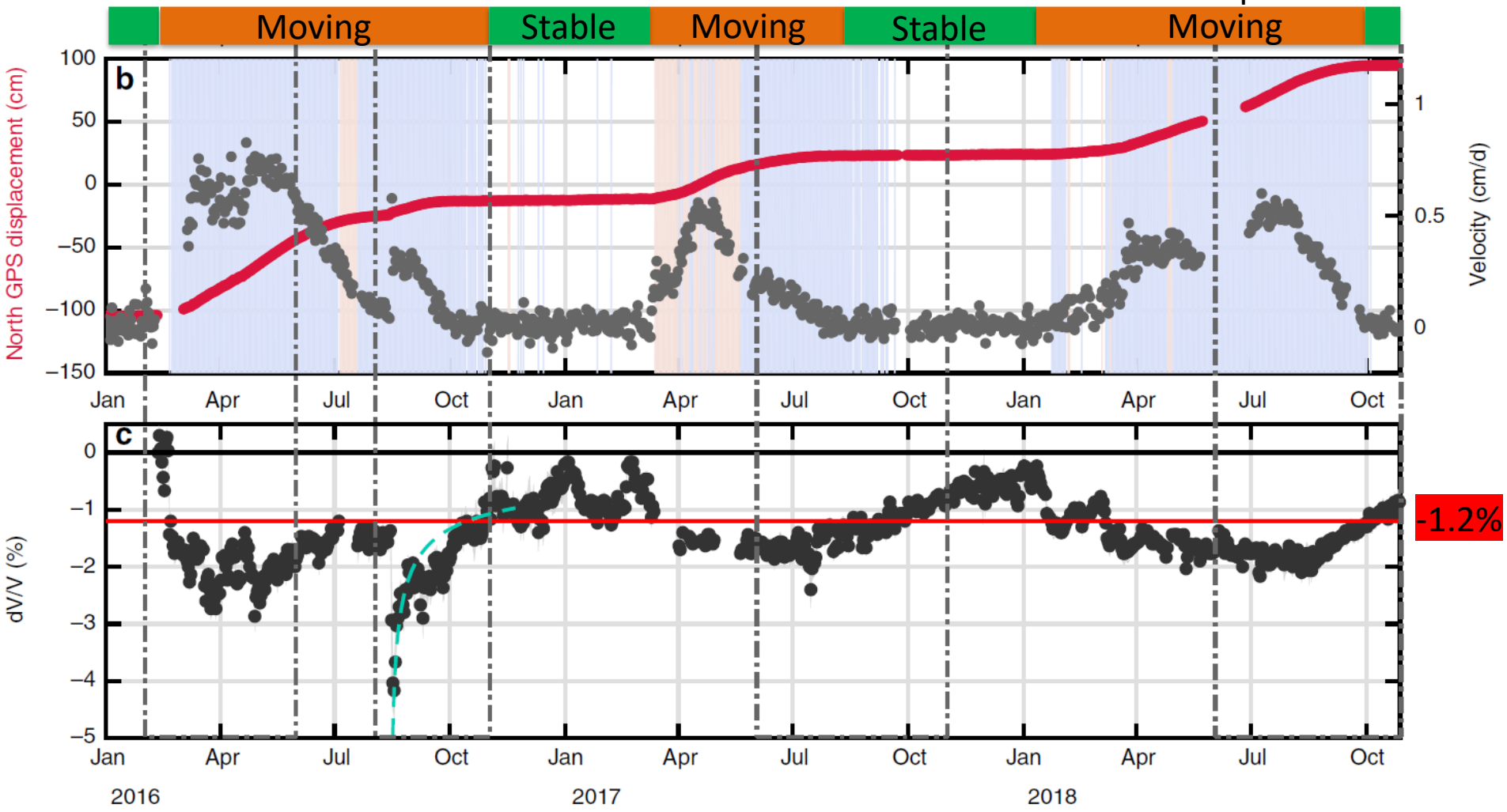
=> After the failure : dv/v slowly recovers

# Maca landslide, Peru


Bontemps et al. 2020

# Maca landslide, Peru

Bontemps et al. 2020



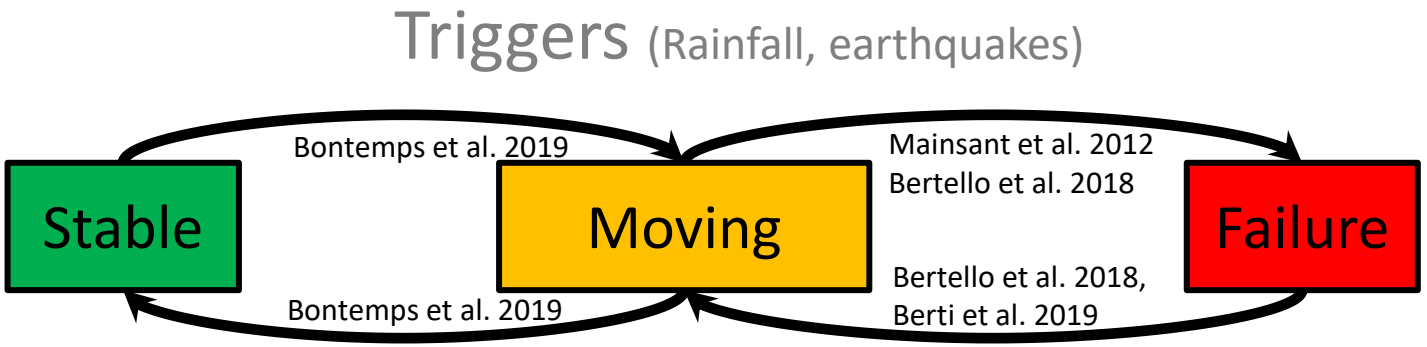

⇒ The landslide moves when the dv/v < 1.2%

⇒ Motion is triggered by Earthquake + Rainfall

⇒ dv/v slowly recovers after the failure

# Synthesis : three states of stability observed

The transition between states happens when the dv/v crosses a threshold




*Le Breton et al. 2020*

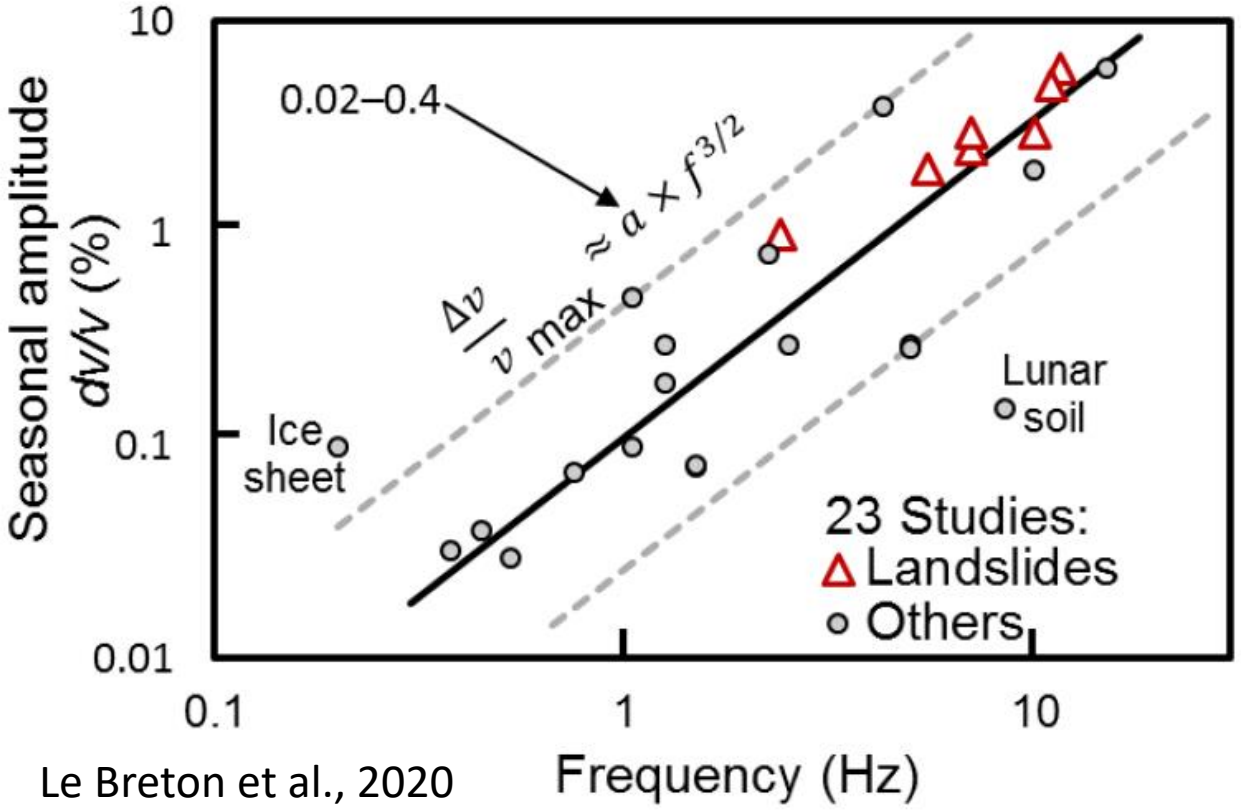
dv/v, an indicator of landslide stability…

⇒ Before failure (precursor)

⇒ But also after the failure (recovery)

Question : is the dv/v also influenced by the environment ?

# Seasonal amplitude of the dv/v



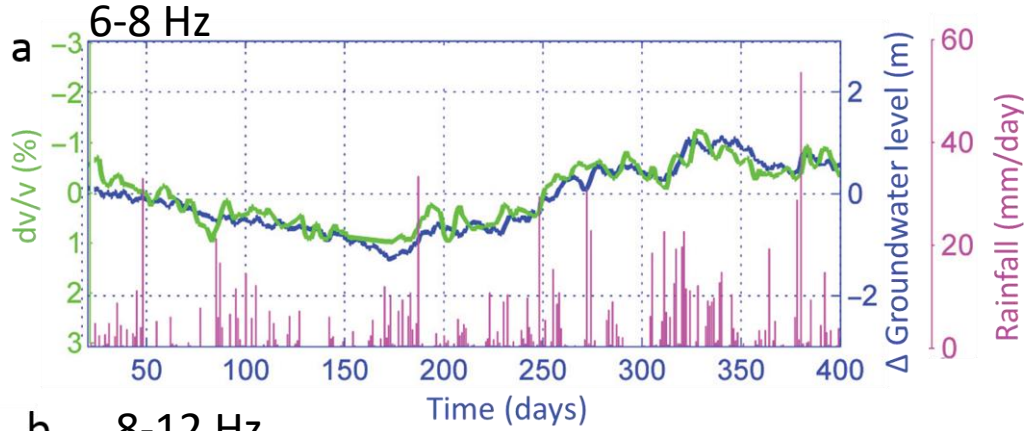

Le Breton et al., 2020

⇒ Dv/v fluctuates seasonaly, not only on landslides

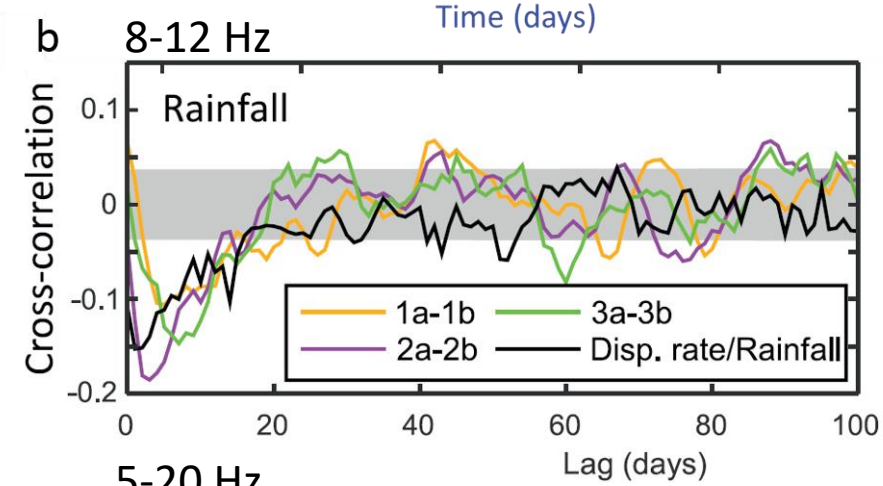
⇒ Fluctuation amplitude depends on frequency (proxy to investigation depth)

⇒ The same processes may occur on landslides or on stable grounds

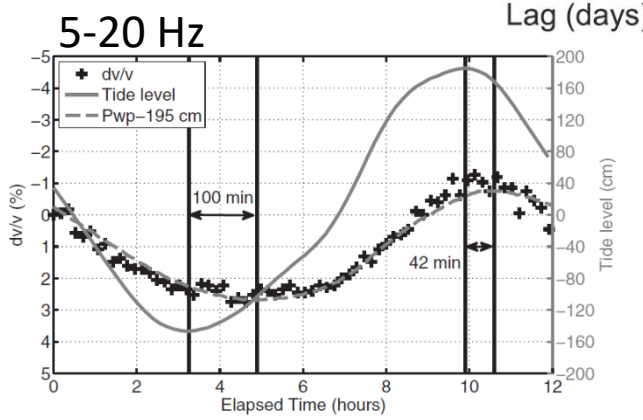
# Influence of groundwater




Yearly negative correlation between groundwater and dv/v, on Utiku landslide (Voisin et al. 2016)



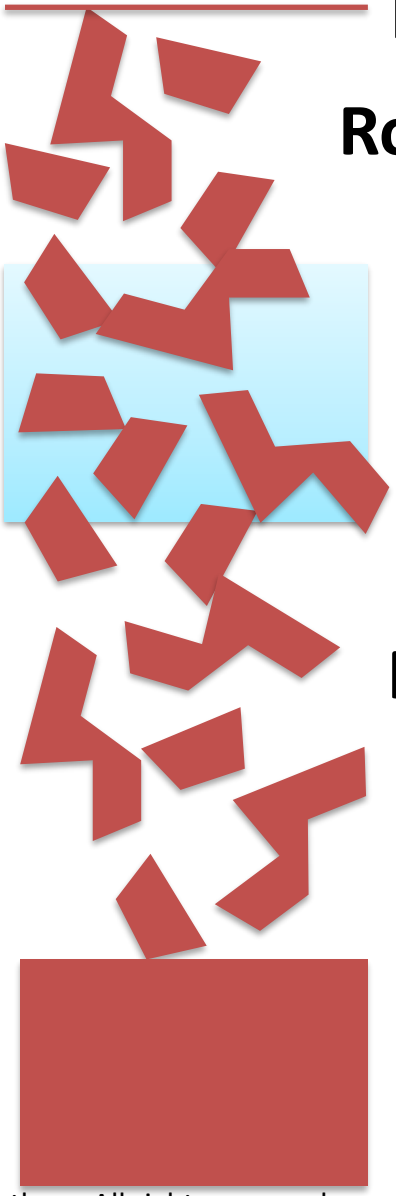

Rainfall is correlated with a negative peak of dv/v, on Pont-Bourquin landslide (Bièvre et al. 2018)




Groundwater level is negatively correlated, on a 12-hour periods, created by tides, on a coast (Planès et al., 2017)

**=> Groundwater elevation has a major (negative) influence on the dv/v**

# Rocky Glacier « Gugla » – Wallis (CH)

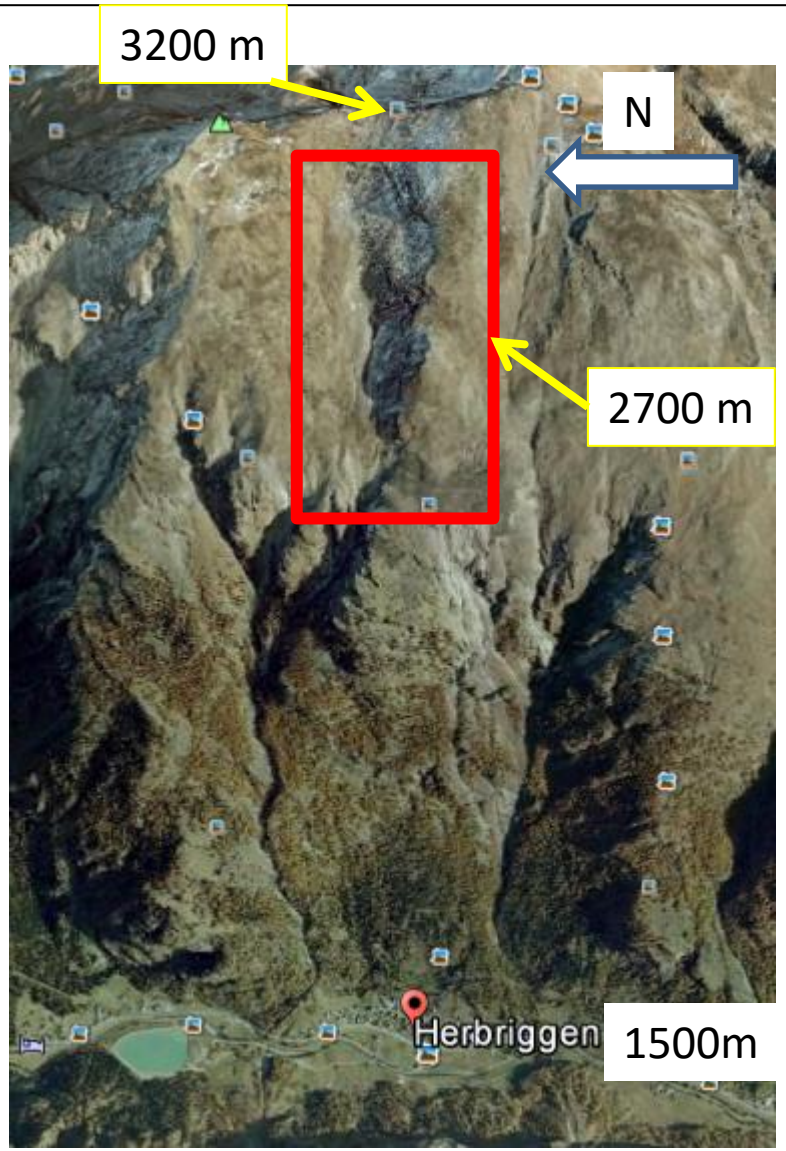


**Rock+sand+clay**

**Ice**

**Rock+sand+clay**

**bedrock**

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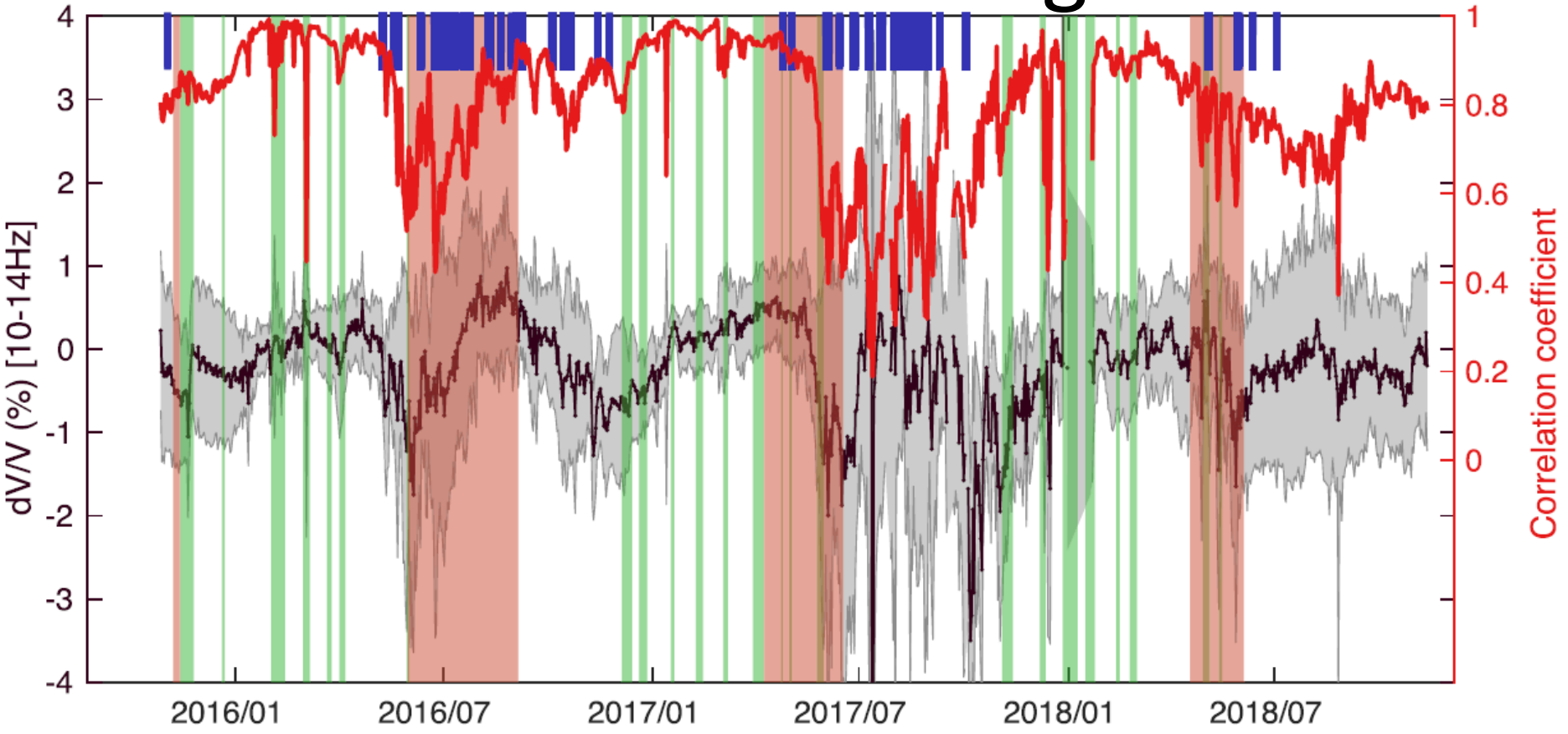
Guillemot et al., 2020

# Permafrost monitoring

Guillemot et al., 2020




Intense periods of :

- Snow melting
- Snowfall
- Rainfall

=> Large drops of correlation coefficient occured during intense snow melting + rainfall

# Online monitoring application

In partnership with Geolithe and Geolithe Innov, engineers-consultants in geology, geophysics and geotechnical science, an online monitoring application is now available:

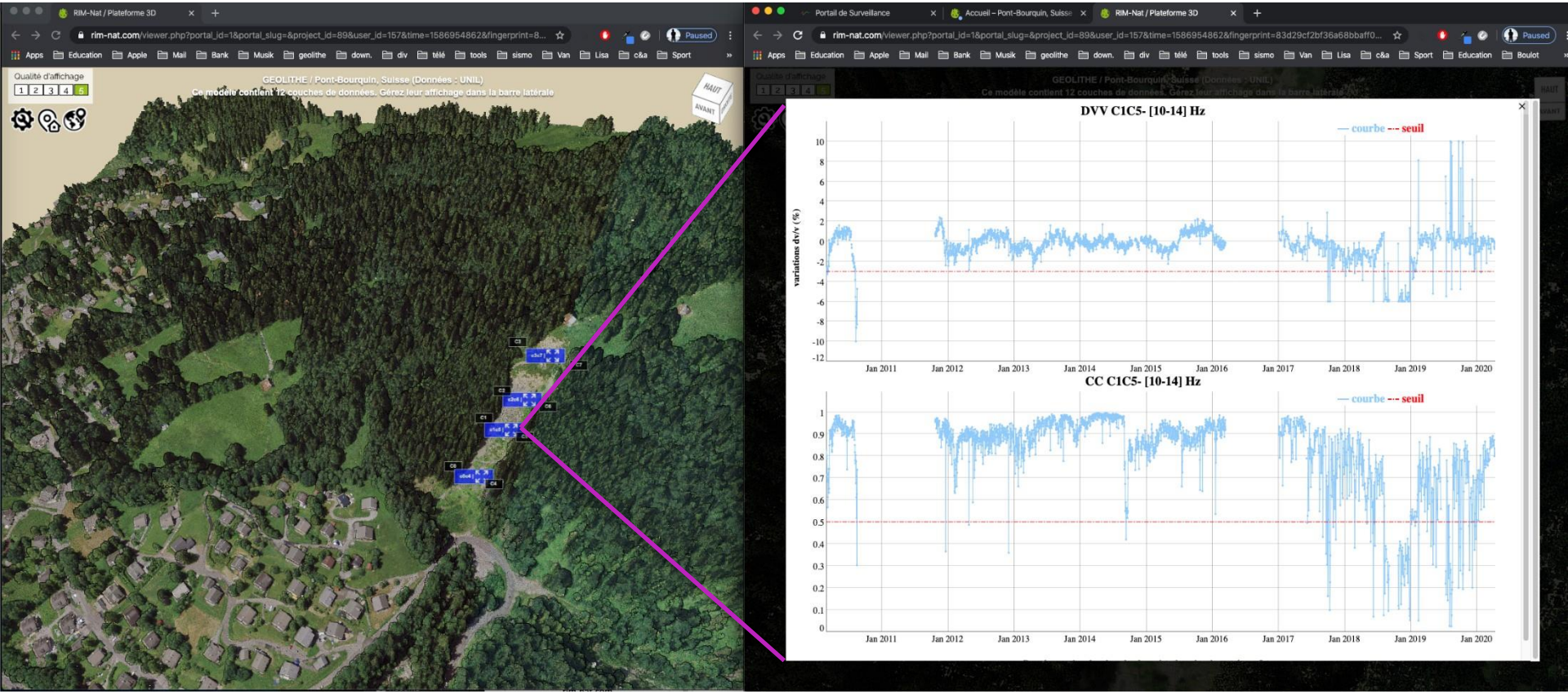
- Interactive visualization of data for comparison
- Updated data every day/hour
- Alert by email/sms
- Possibility to map sensors and visualize data on 4D model with Rimnat®

https://app.surveillance-geolithe.fr
https://rim-nat.com

# Online software for processing and visualization


https://app.surveillance-geolithe.fr

# Visualization of the data on a DEM




https://rim-nat.com

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