Ambient seismic noise monitoring of active landslides and rock columns prone to failure

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1. Problematic

Ambient noise monitoring, a technique widely used today.

Civil engineering

Example of a structure – Autocad

Volcanology

Piton de la Fournaise
Volcano – Reunion Island

Earthquakes

San Andreas fault line - California

What about landslides and rock columns?
1. Problematic

Ambient noise monitoring

Rock column

Active landslide

Fundamental frequency

Relative velocity changes

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1. Problematic

- **Rockfall**
  - Limestone
  - Seismic sensor

- **Earthflow**
  - Clay

(Levy et al., 2011)

(Mainsant et al., 2012)
2. Landslides monitoring

Ambient noise monitoring applied to landslides:

- Ambient noise
- Daily cross correlation
- Processing of $dV/V$
- Characterize the changes

 piping image:

- Seismic sensor
- Acquisition system

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2. Landslides monitoring

The «Pont-Bourquin» landslide:

Geology:
• Upper part: black shales
• Middle part: flysch
• Lower part: gypsum dolomite

Characteristics of the landslide:
• 100 m long
• 30-50 m wide
• Fast displacements (around 5m a year)
• Evolves sometimes in earthflow (2007 and 2010)

Equipped with:
• 8 seismic sensors 1C
• 2 extensometers
• 1 weather station
• 1 piezometer

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2. Landslides monitoring

The case of « Pont-Bourquin »:

Daily dV/V (%) – Sensors 2–6 – Bandwidth [10–12Hz]

NO DATA

Earthflow

Weekly rainfall (mm)

Weekly Temperature (°C)

Pillon road

20 m

Seismic sensor
Electrodes
Extensometer
Piezometer

Weather station

Pont-Bourquin landslide - Switzerland

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3. Rock columns monitoring

Ambient noise monitoring applied to prone to fall rock columns:

- Ambient noise
- Spectral analysis
- Fundamental frequencies of the column
- Characterize the changes

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3. Rock columns monitoring

The « Les Arches » site:

Limestone beds

Altitude (m)

1880
1870
1860
1850
1840
10 m

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3. Rock columns monitoring

The case of « Les Arches »:

(Daily frequency variations due to thermal forcing)

(Bottelin et al., 2013)
3. Rock columns monitoring

The case of « Les Arches »:

Yearly variations with increase of the fundamental frequency during winter

(Bottelin et al., 2013)
4. Conclusion

No activation

- Rock column
  - Daily and yearly $f_0$ fluctuations
  - Landslide
    - Seasonal $dV/V$ fluctuation

Activation

- Rock column
  - Drop of $f_0$ before activation
  - Landslide
    - Drop of $dV/V$ before activation

1: $F_0$ and $dV/V$ seem to be precursors to landslide and rock column activation

2: Clear dependance of the seismic properties of the soil to the environmental conditions (temperature and hydrology)

Perspectives

Isolate variations due to mechanical changes from variations due to environmental fluctuations

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Thank you for your attention

Questions?
Landslide monitoring

Ambient noise monitoring applied to landslides:

Ambient noise

Frequency equalization + Amplitude normalization

Daily cross correlation + Reference correlation

Stretching method

Doublet method

Daily $dV/V$ and DC estimation
Rock columns monitoring

Ambient noise monitoring applied to rock columns:

Ambient noise

Windowing  Clipping  Apodisation

Spectral Analysis (FFT)

Spectral Analysis (PSD)