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Monitoring of an Alpine landslide using dense seismic observations:
Combining Distributed Acoustic Sensing (DAS) and 1000 autonomous nodes

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Motivation

Develop new seismic strategies for landslide characterization & monitoring
→ To provide new tools for the assessment and mitigation of landslide risks

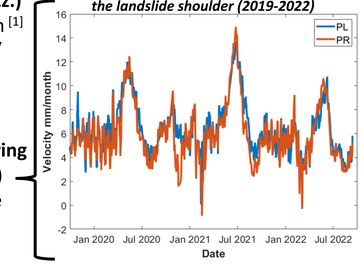
1. **Characterization of the landslide body**
   → Assemble a subsurface structural model
2. **Monitoring landslide dynamics over time**
   → Study landslide movement & driving mechanisms over time
3. **Integrating different observables**
   → Exploit complementarity of different data types

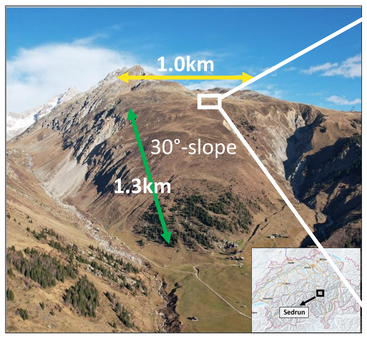
The 'Cuolm da Vi' landslide

Active landslide above Sedrun (Centr. Switz.)
- Area: ~1.3 x 1.0 km & Depth: 100-200m [1]
- Surface deformation rates of 5 – 30 cm / year[1]
  → Strong seasonal variation

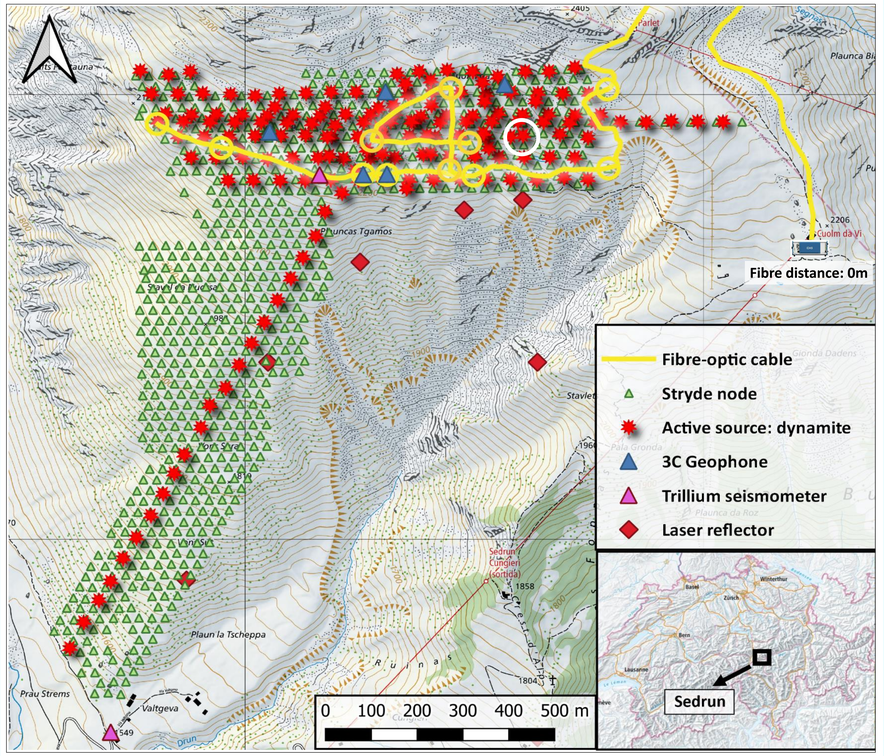
Long-term surface and/or remote monitoring
- For 20 years: 8 laser reflectors (see map)
- Repeated drone surveys → digital image correlation[2]

Displacement rate of two laser reflectors on the landslide shoulder (2019-2022)





Field deployment & data set



Stryde nodal array
Configuration
- 1046 Stryde nodes (1C)
- Hexagonal grid: 28m spacing
- 100 nodes co-located with stretch of fibre-optic cable

Acquisition
- June-July 2022
- 30 days continuous (500Hz)

Fibre-optics (DAS & DSS)
Configuration
- Trenched fibre: 6500m long
- Long-term installation (>1 yr.)

Distributed Acoustic Sensing
- Summer 2022 → 21 + 10 days
- Spring 2023 → 5 months

Distributed Strain Sensing
- Full year monitoring (2022-23)

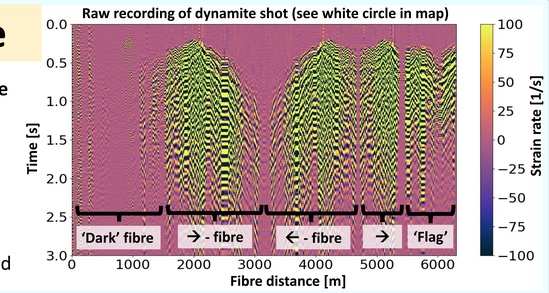
→ Monthly 24h-measurements

Active sources
Configuration
- 163 active dynamite shots
- June-July 2022
- Shot grid on shoulder
- Two shot lines

Recorded by
- Nodal array (1046 nodes)
- DAS (6500 channels)

Data example

Raw DAS-recording of an active source
- First 1500m: 'dark fibre'
  → low signal, but low noise
- Self-deployed cable:
  → (very) high SNR for most channels
- Challenge: complex wavefield



Research outline

Characterization	Dynamics & Monitoring
Goal: *Structural subsurface model*	**Goal:** *Monitor driving mechanisms over time*
Data: DAS + nodal array → *Obtained summer 2022*	**Data:** Distributed Acoustic & Strain Sensing → *Long-term acquisition: ongoing*
Methods ➢ Tomography from: ○ Active shots (Vp) ○ Ambient noise (Vs) ➢ Localization of micro-seismic energy	**Methods** ➢ Absolute strain data (DSS) over time ➢ Development of micro-seismic energy ➢ Monitoring subsurface changes in Vs (dv/v) and decoherence

Seismic landslide monitoring

Data integration
Goal: *Exploit complementarity DAS-, DSS- and nodal array data*
Data: Field + synthetic data
Methods: Joint processing, inversion and interpretation

Key points

This unique data set covers a wide range of spatial and temporal scales that allows:

- **Detailed subsurface characterization of a large alpine landslide structure**
- **Continuous monitoring of the driving parameters, processes and mechanisms**

References

[1]: Amann, F. (2006). *Großhangbewegung Cuolm Da Vi (Graubünden, Schweiz) Geologisch-geotechnische….*
[2]: Bickel, V., Manconi, A., & Amann, F. (2018). Quantitative Assessment of Digital Image Correlation …..

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