



Long term deformation and seismic observations at the Mont Terri rock laboratory

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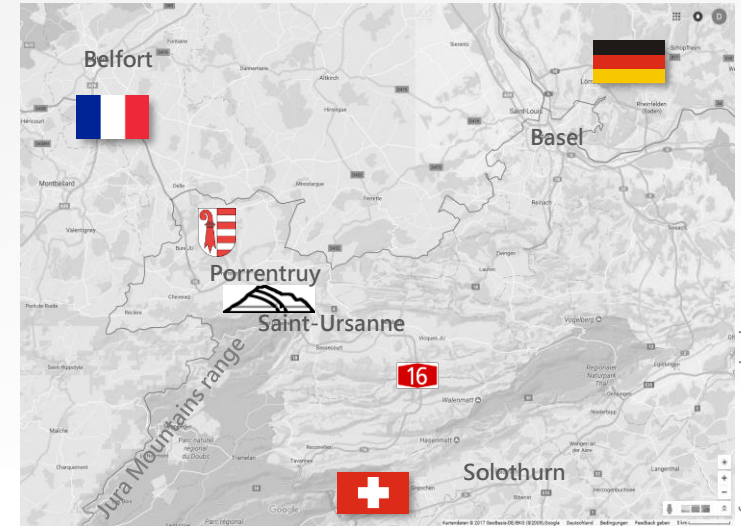
⁴ Lawrence Berkeley National Laboratory, USA

⁵ Edi Meier + Partner AG, Switzerland



Mont Terri rock laboratory

- state-of-the-art underground rock laboratory
- Swiss Jura Mountain Range
- 1200 m galleries + niches
- hydrogeological, geochemical, geotechnical characterisation of Opalinus Clay
- new methods, risk assessment
- > 150 experiments
- investigations on nuclear waste repository + geological storage of carbon dioxide, etc.
- cooperation of 22 partners from 9 countries
- long term commitment
- www.mont-terri.ch



nagra, swisstopo ENSI ETH zürich

nwmo

IR CRIEPI

JAEA

enresa

ANDRA

TOTAL

IRSN

Radioactive Waste Management

SCN-CEN

Chevron

FANC

Bundesamt für die Sicherheit der nuklearen Entsorgung

BCE

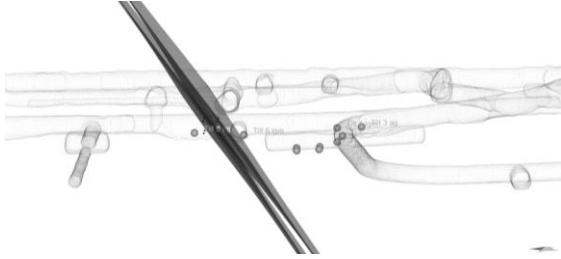
BGR

GRS

HELMHOLTZ

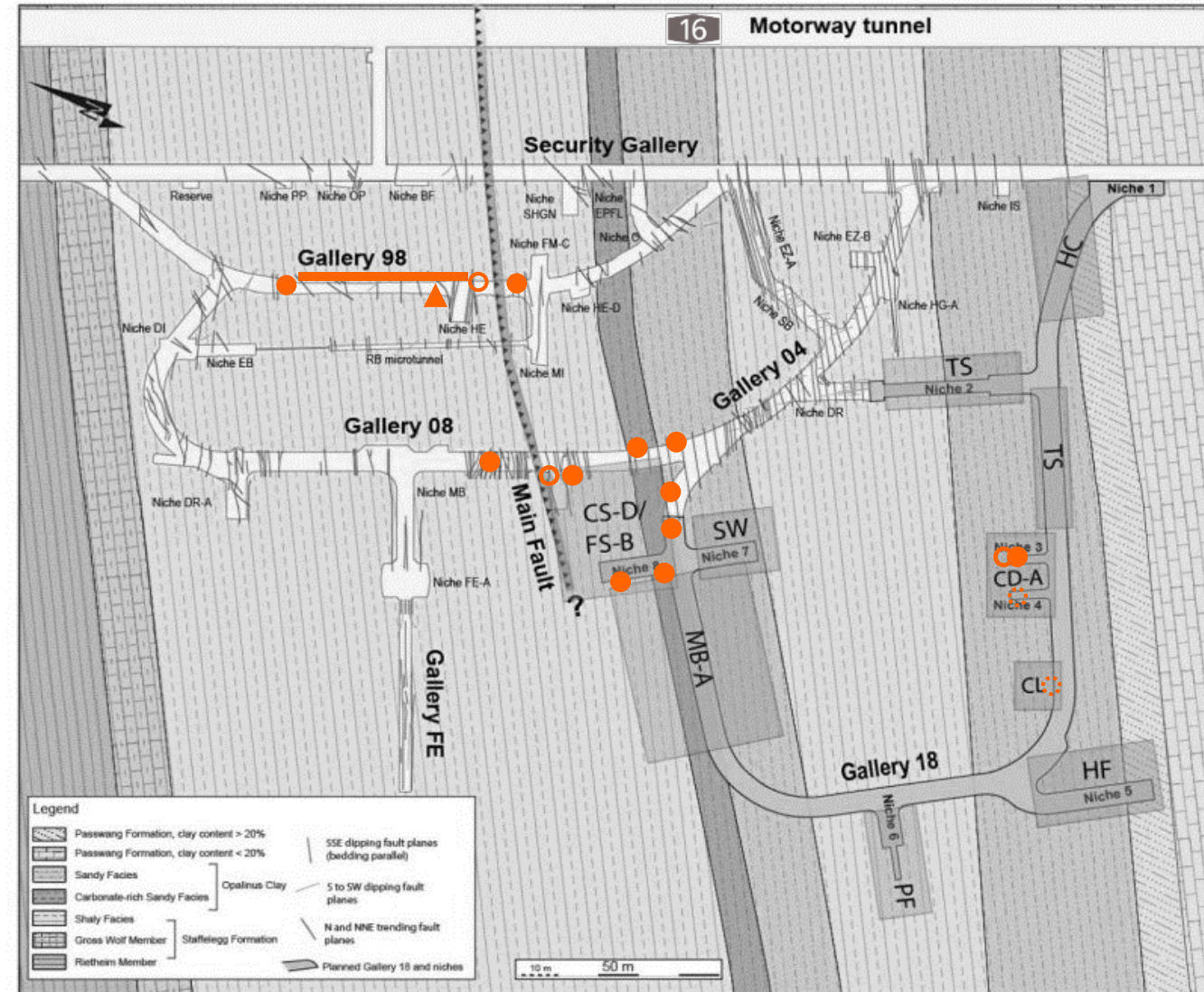
location

- platform tiltmeters
- temporary locations ✱ planned locations
- ▲ triaxial broadband seismometer
- hydrostatic leveling system, HLS



deformation

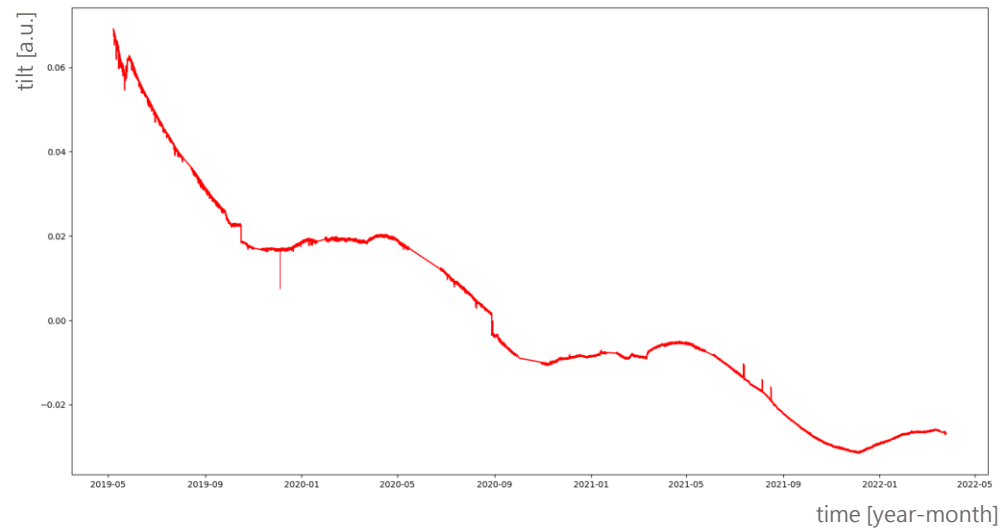
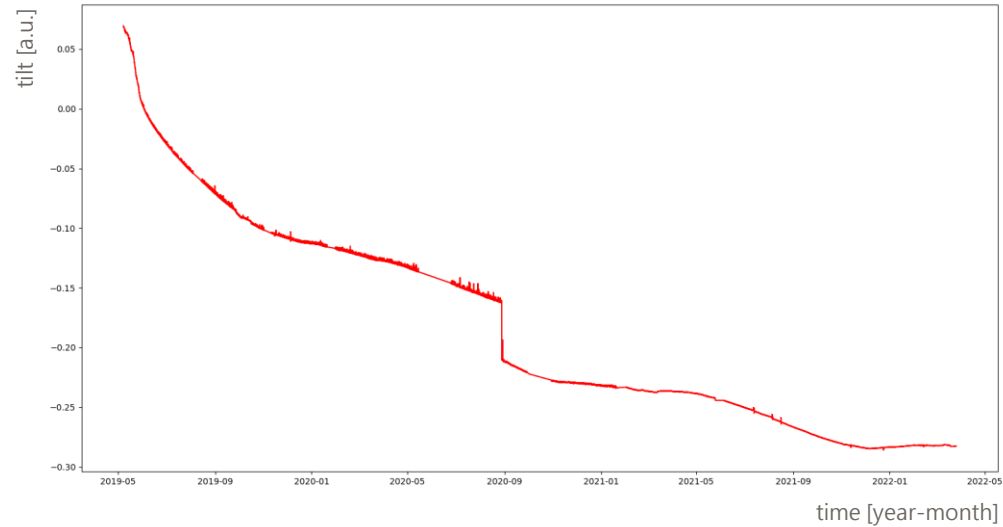
- HLS
- seismometer
- tiltmeter
- quasi continuous time series
- complementation in space + time



floorplan after Raselli et al., 2019, swisstopo



instrumentation

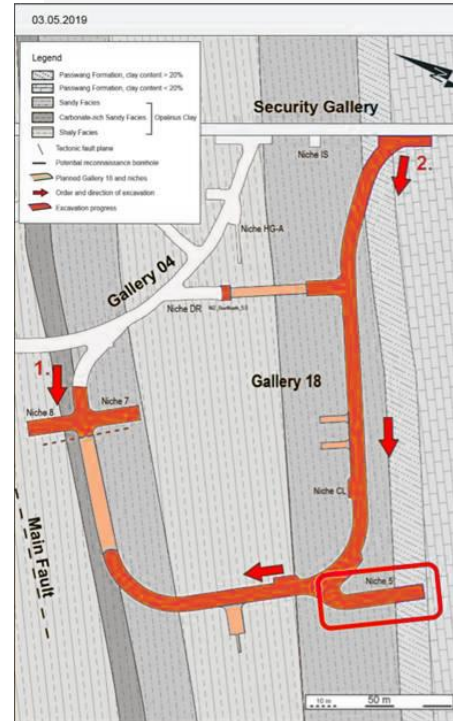
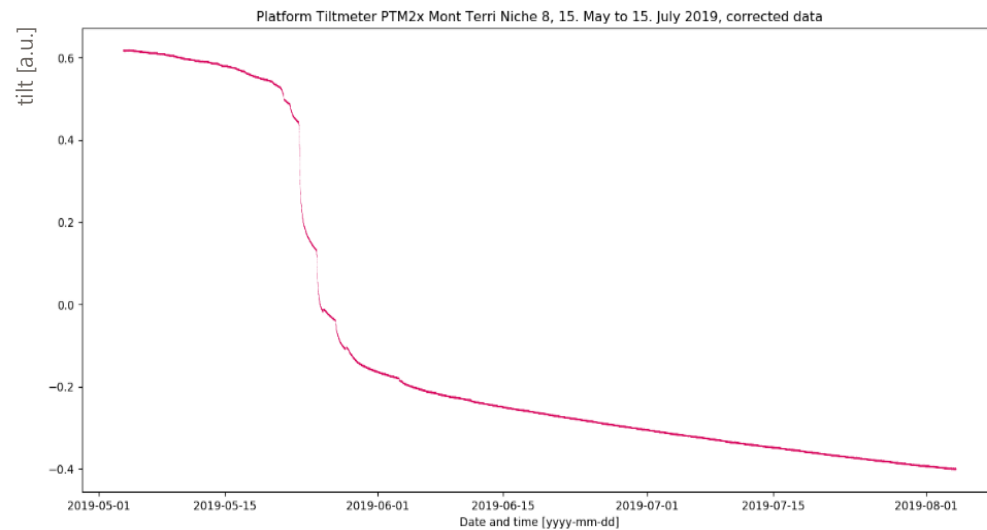
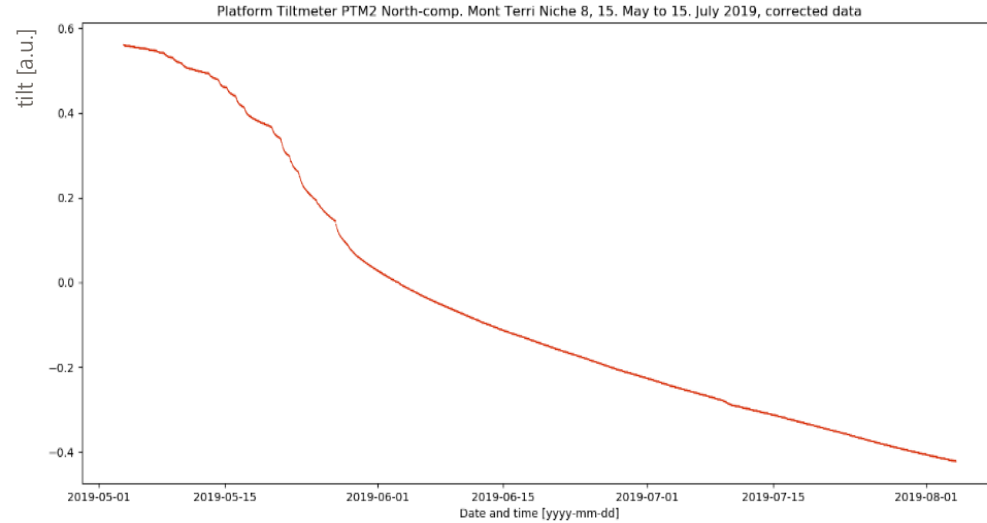


geodetic observation

- > 5/2019
- biaxial instrument
- seasonal variation
- trend



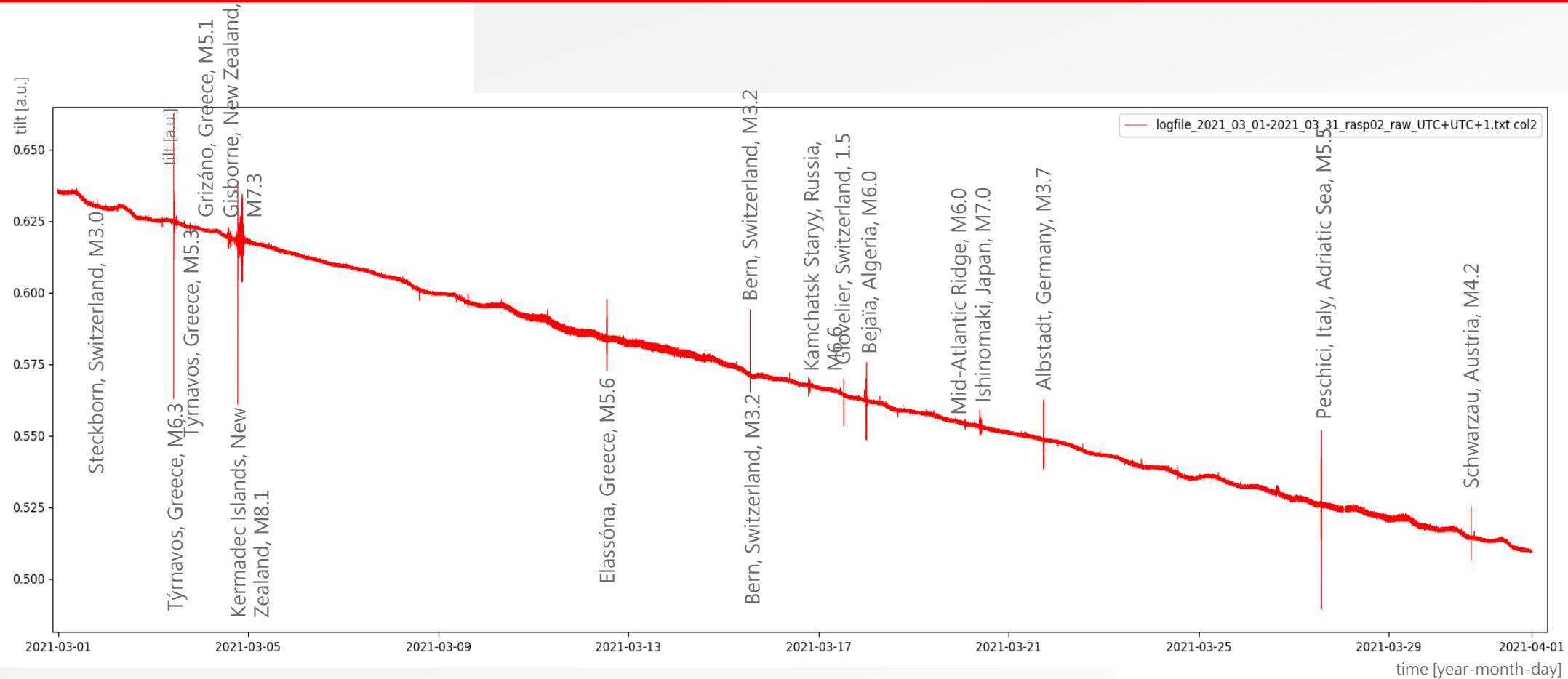
stability of the rock



excavation

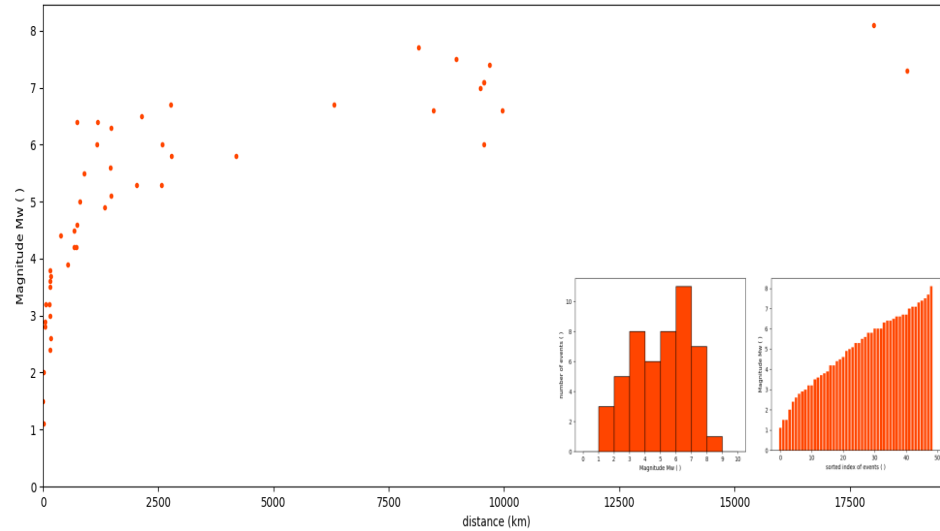
- 5/2019 to 8/2019
- components of two instruments
- 3 weeks during excavation
- 2.5 months after excavation

new Gallery 08



responses on various time scales

- one month, one component
- numerous seismic events + trend

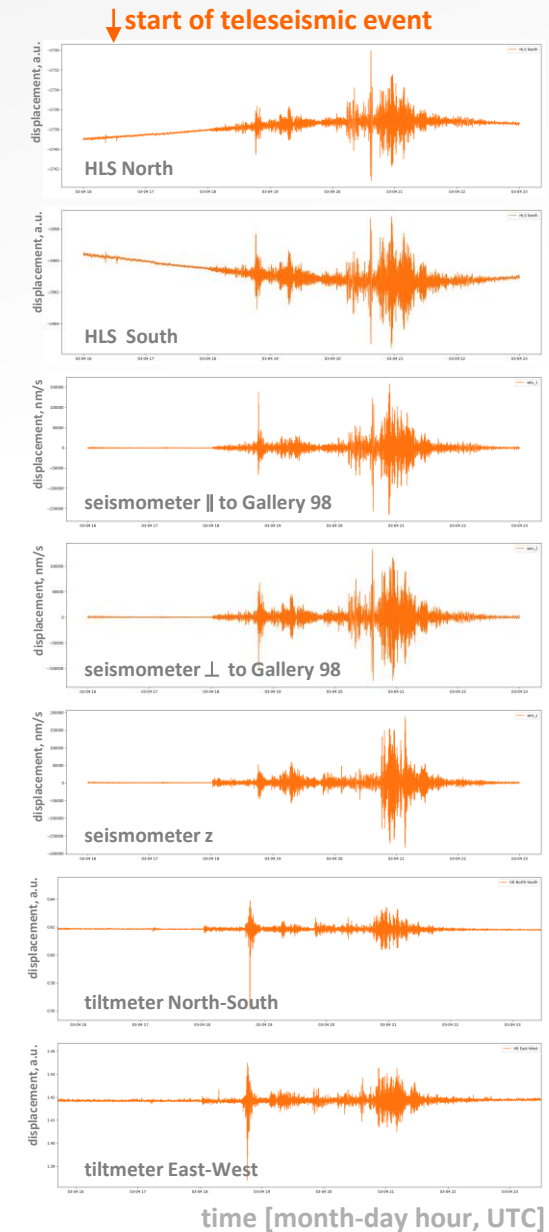


examples of seismic events

- rough estimation, dependent on instrument, location, background noise, distance, dispersion, events
- mutually complementing instruments

teleseismic events

- Kermadec Islands, New Zealand, 2021-03-04, M8.1, 18008 km



comparison

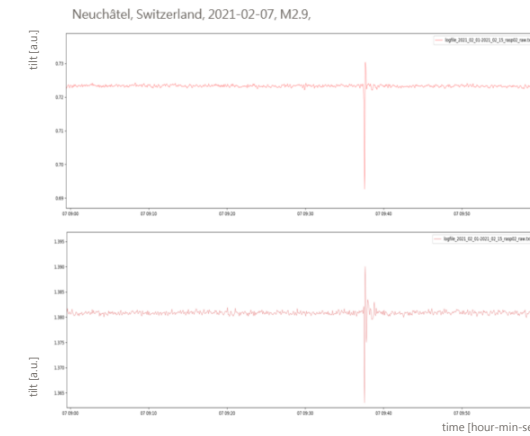
events linked to geothermal activity

- La Wattenau, France,
2020-12-04, M3.6, 151 km



local seismic events

- Neuchâtel, Switzerland,
2021-02-07, M2.9, 39 km



quarry blasts

- Glovelier, Switzerland,
2021-03-17, M1.5, 3.4 km



examples of seismic events

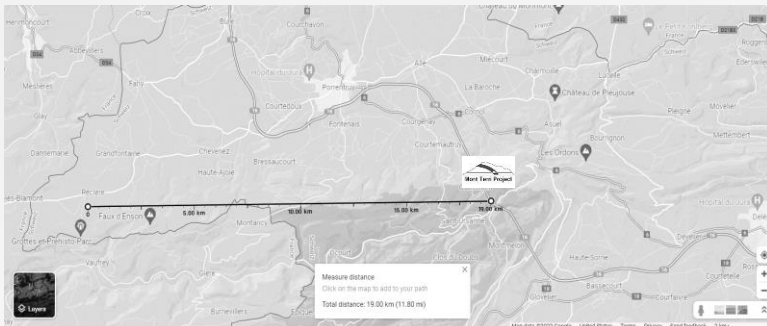
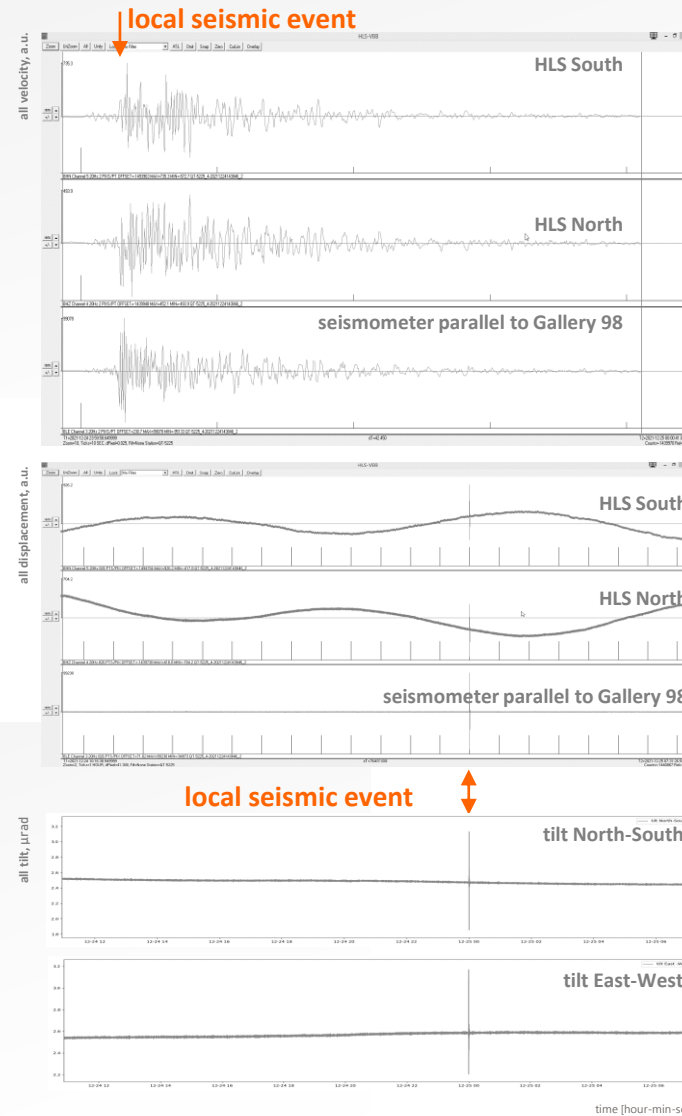
- anthropogenic + natural origin



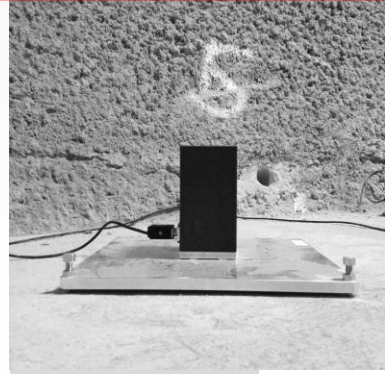
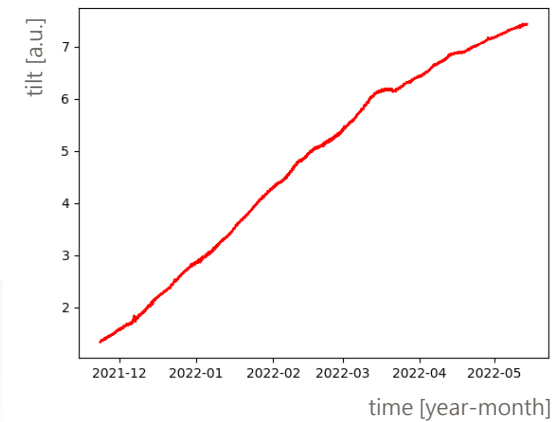
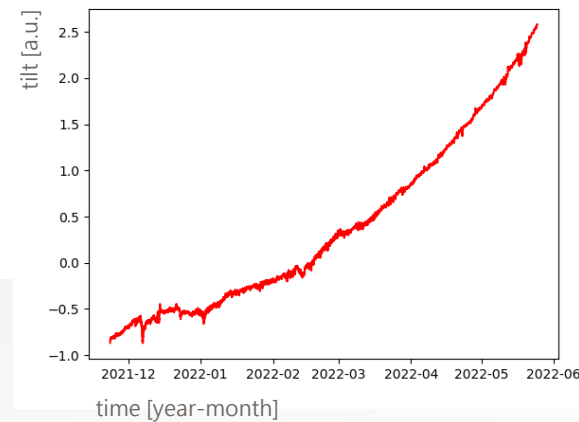
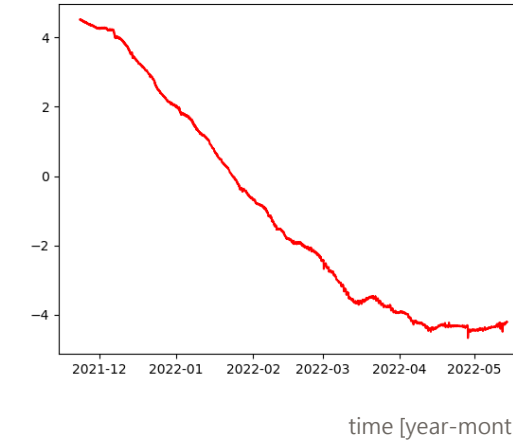
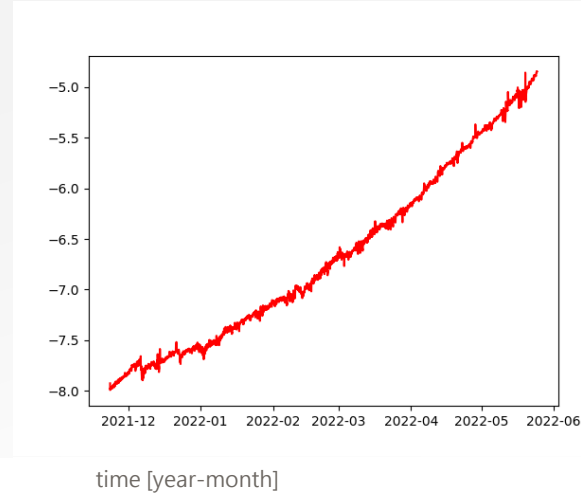
tilt response

local seismic event

- Porrentruy M4.1, JU, Switzerland, depth 4.4 km, distance to Mont Terri 19 km
- date 2021-12-24, time 23:59:56 UTC
- observed by HLS, seismometer, tiltmeters
- Permanent Nanoseismic Monitoring experiment, SM-C

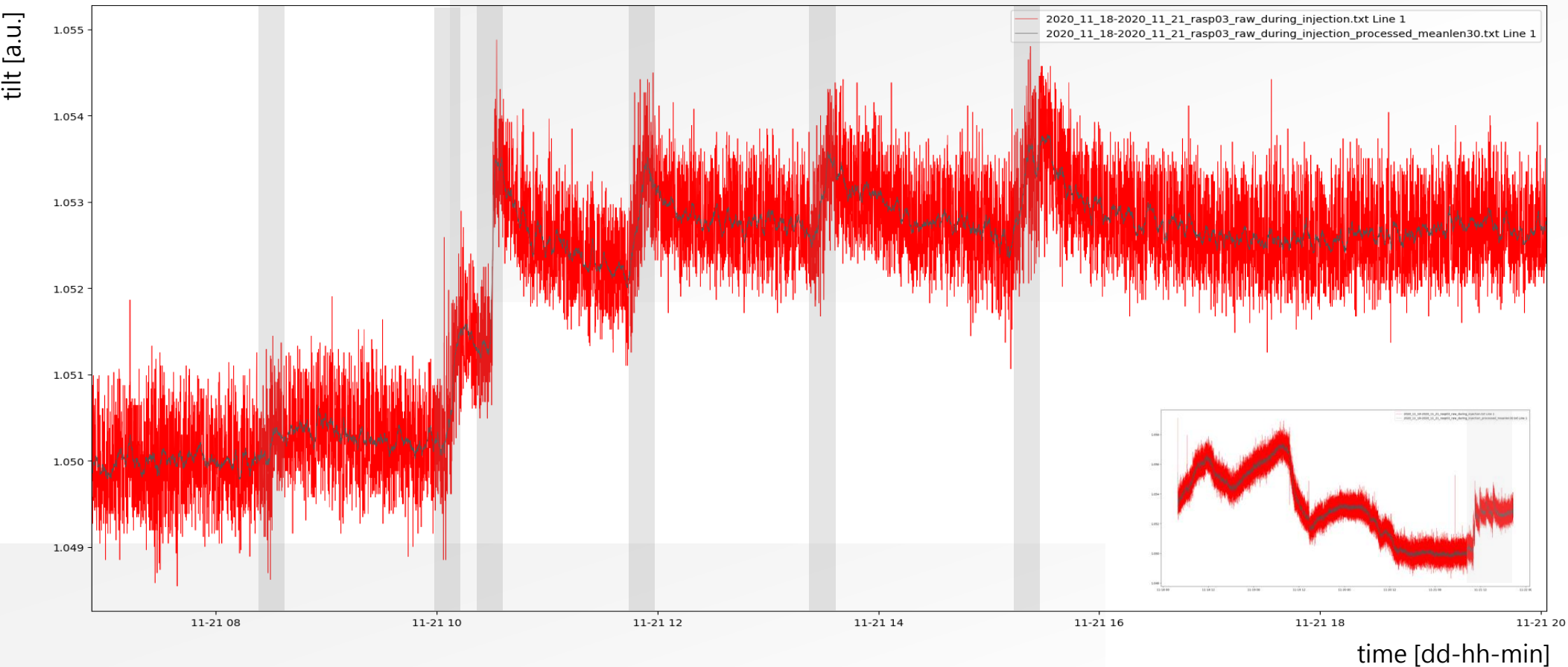


local seismic event



deformation across a fault

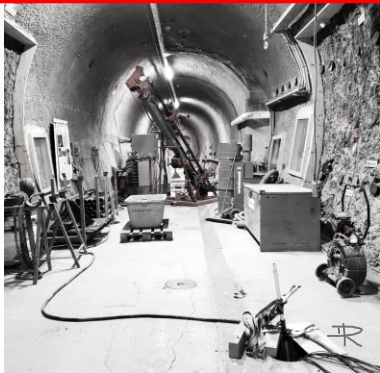
- uniaxial 50 m long HLS
- two biaxial platform tiltmeters, > 11/2021



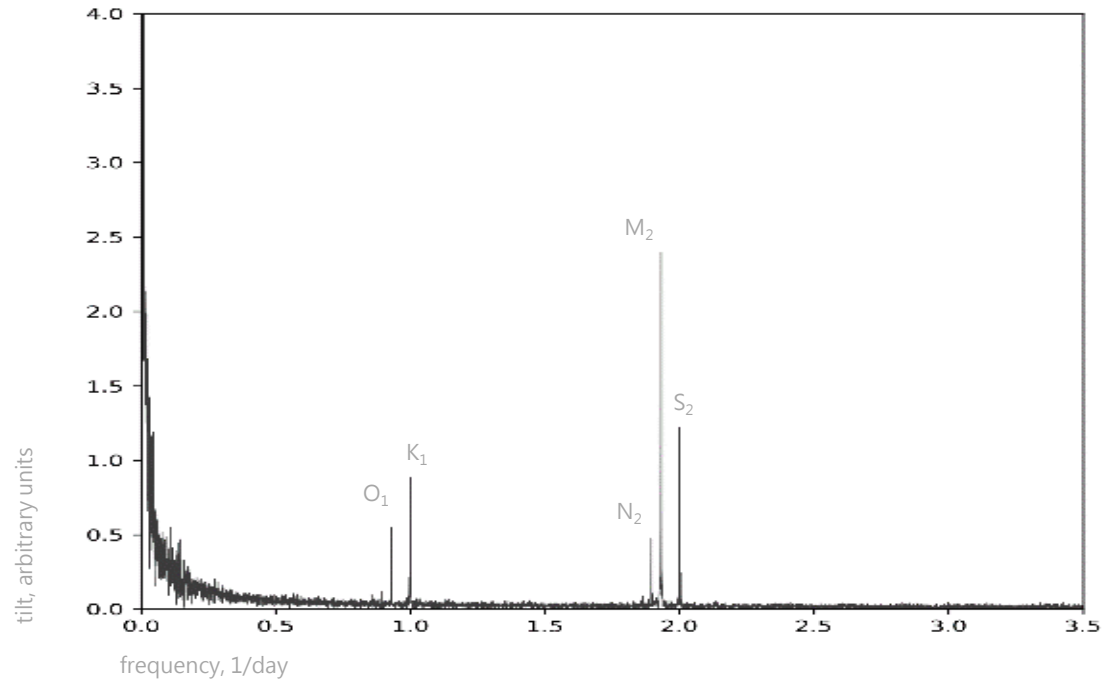
Fault slip experiment, FS-B

- injection period, grey
- North-South tilt component, red
- small response in rock deformation

No.	start date UTC	end date UTC	time duration [s]	injection rate [l/min]	max pressure [MPa]	min pressure [MPa]
1	7:21:26	7:31:12		2.24	6.0	5.4
2	8:21:11	8:31:05		5.91	7.3	5.7
3	10:03:25	10:13:20		9.98	6.7	5.9
4	11:43:40	11:53:11		9.90	6.5	5.8
5	13:25:23	13:34:22		9.44	6.5	5.7
6	15:11:51	15:32:07		10.01	6.5	6.0

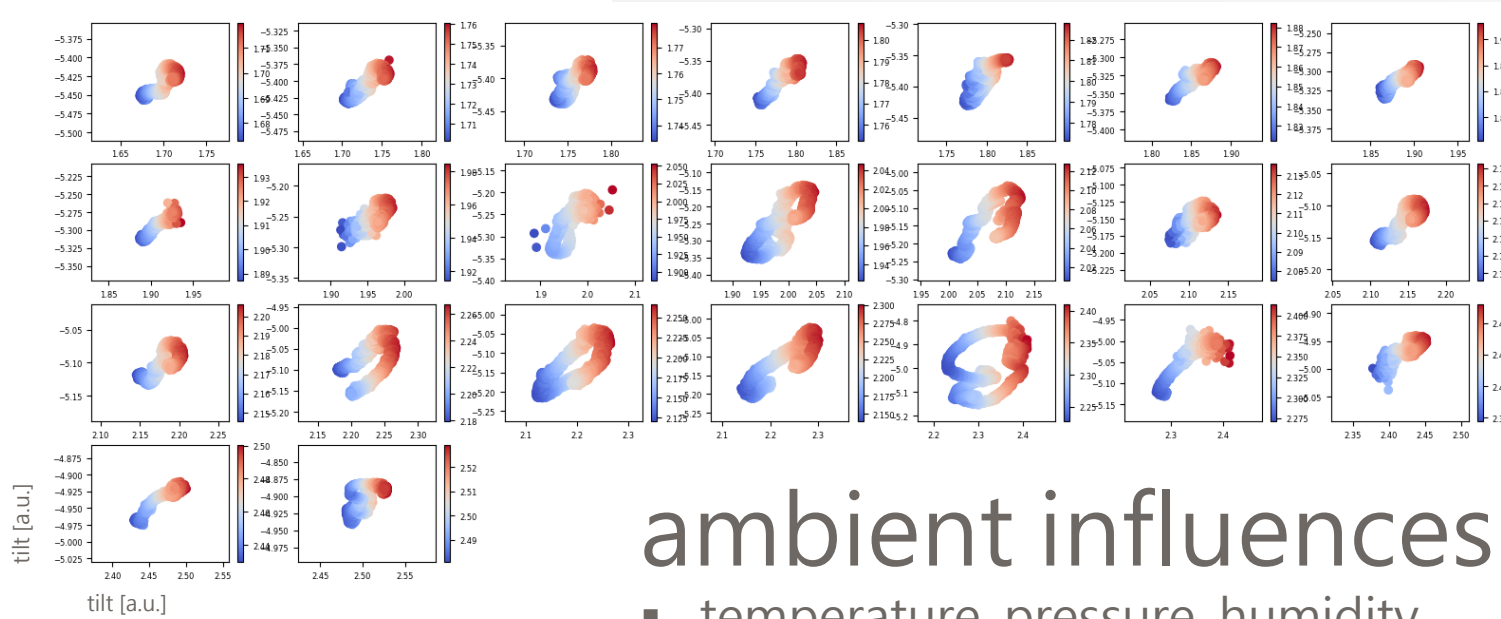


fluid injection



Earth Tides

- hydrostatic leveling system, HLS
- one component, North-South



ambient influences

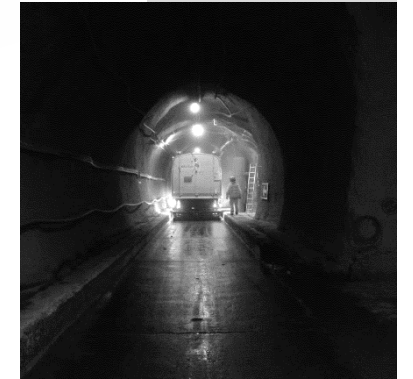
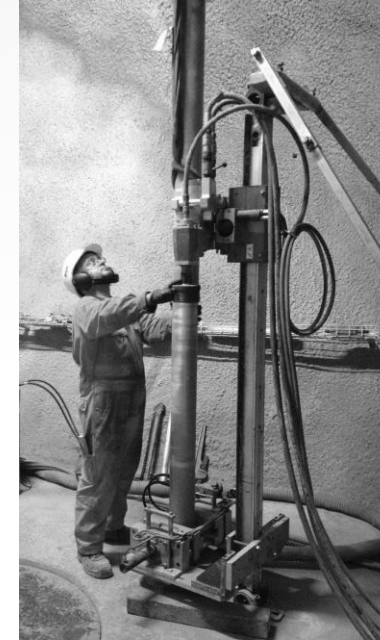
- temperature, pressure, humidity

anthropogenic sources

- drilling, vehicles, people, conducting experiments

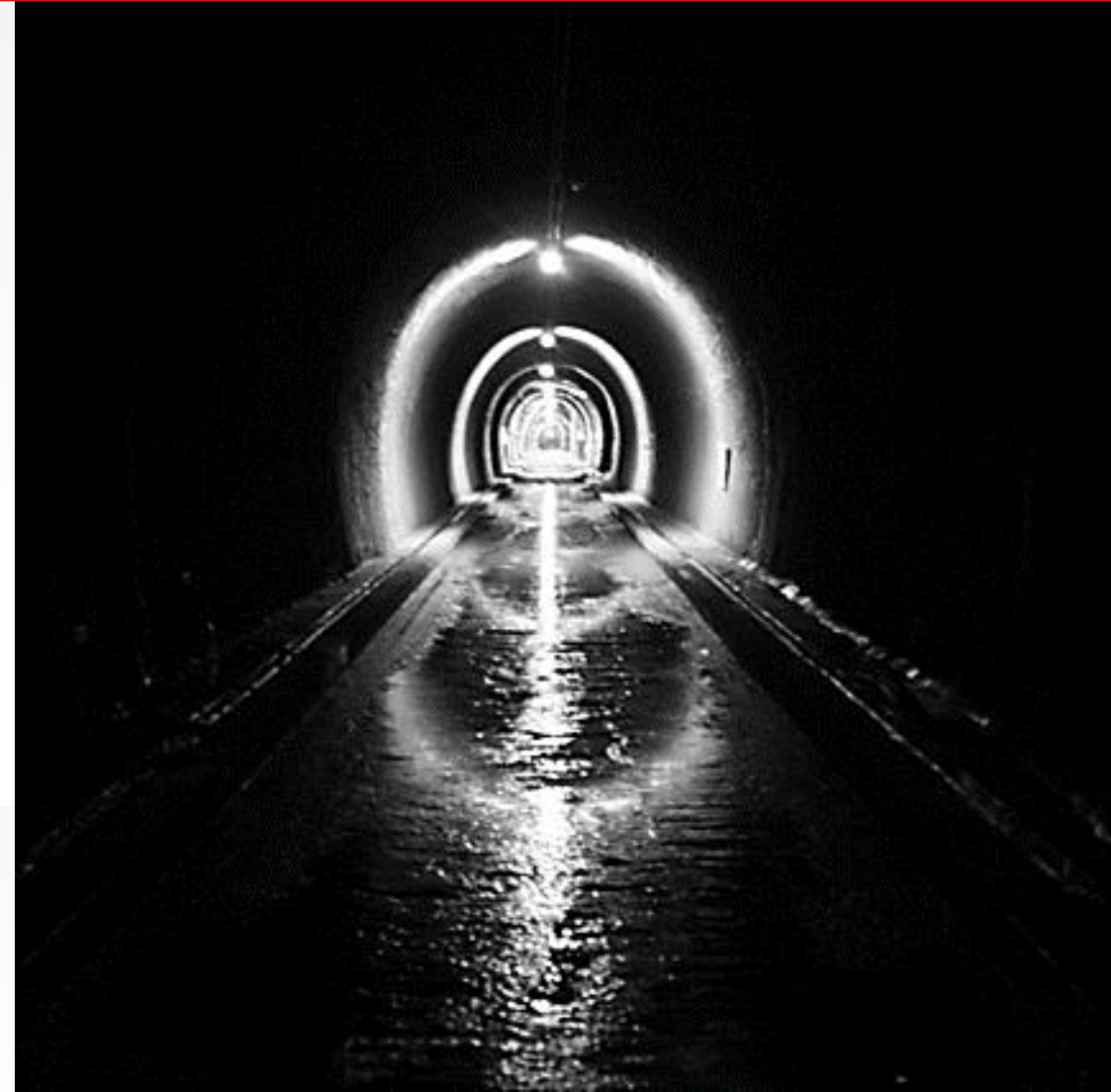
signal vs. noise

- just one part of challenge + potential in long term observations



signals

- BGR: Kristof Schuster
- EPSS: Papp Gábor
- LGM: Erich Lippmann
- swisstopo: Paul Bossart, Christophe Nussbaum
- Mont Terri Consortium



Thank you