

Environmental seismology

indispensable tool to constrain
drivers, precursors and evolution of mass wasting processes

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Rockfalls, rock avalanches, rock slides and landslides



Where?

Boundary conditions?

Interactions/feedbacks?

Coupling /connectivity

When?

How much?

Triggers?

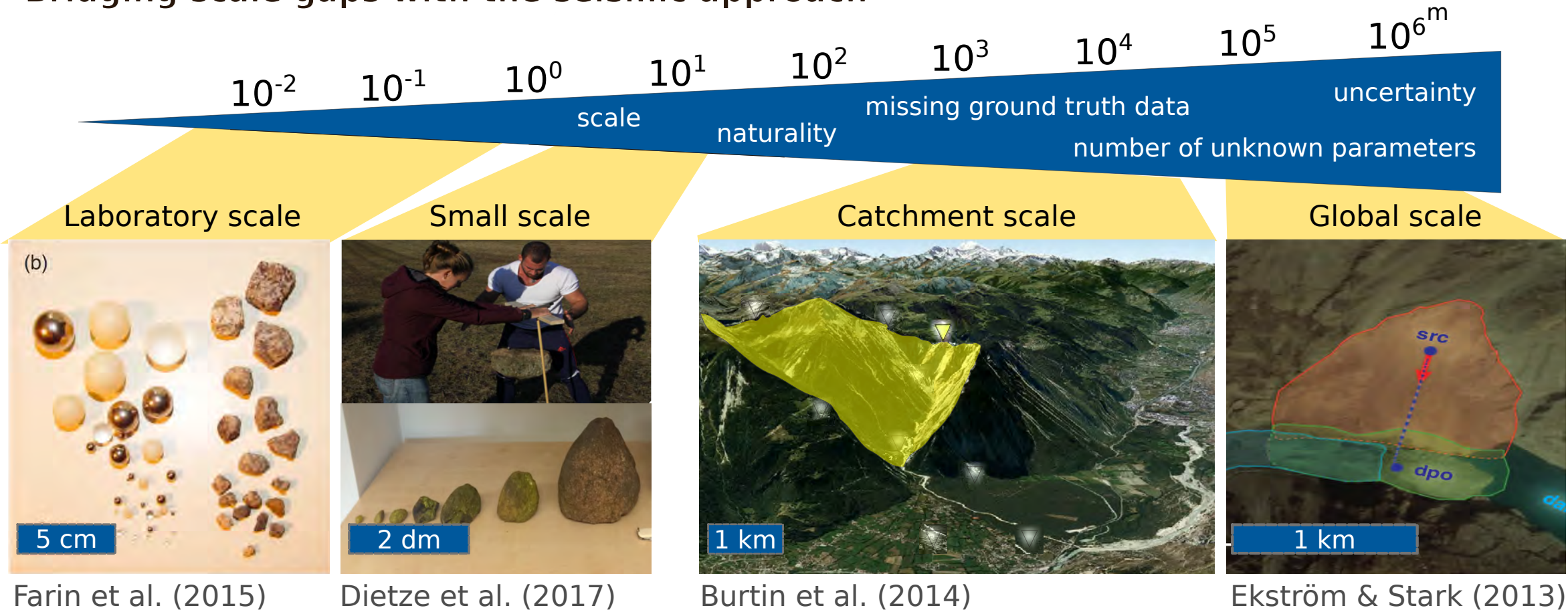
Patterns?

How?

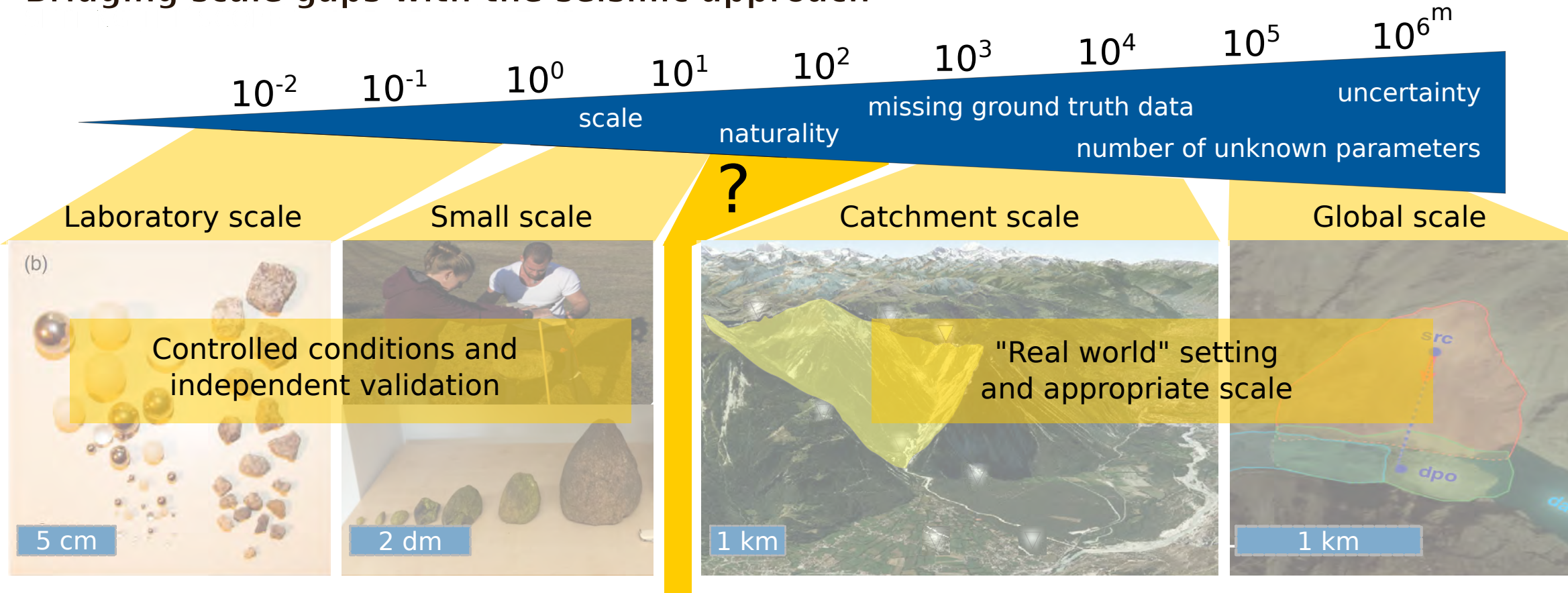
How long?

Drivers?

Bridging scale gaps with the seismic approach

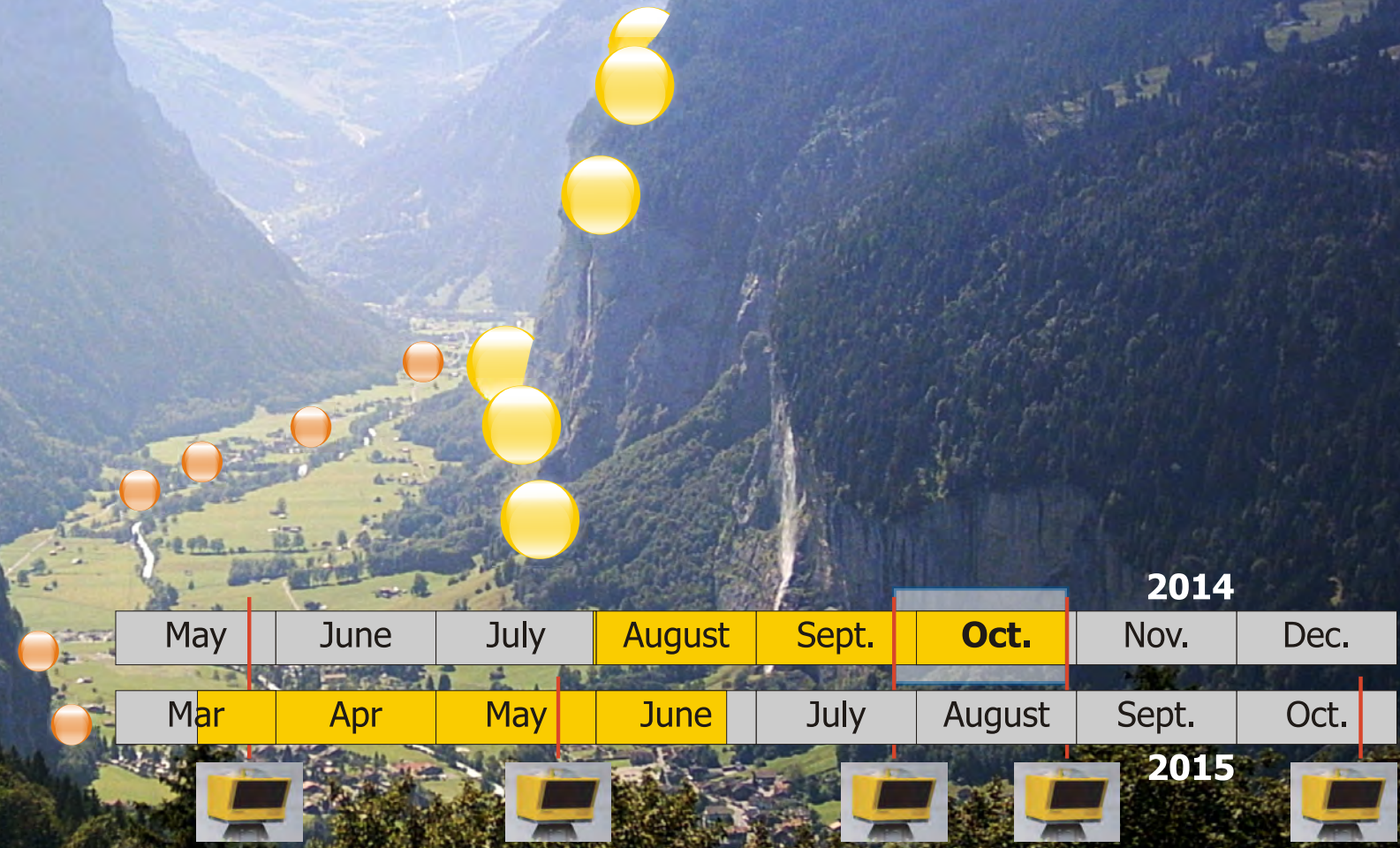


Bridging scale gaps with the seismic approach

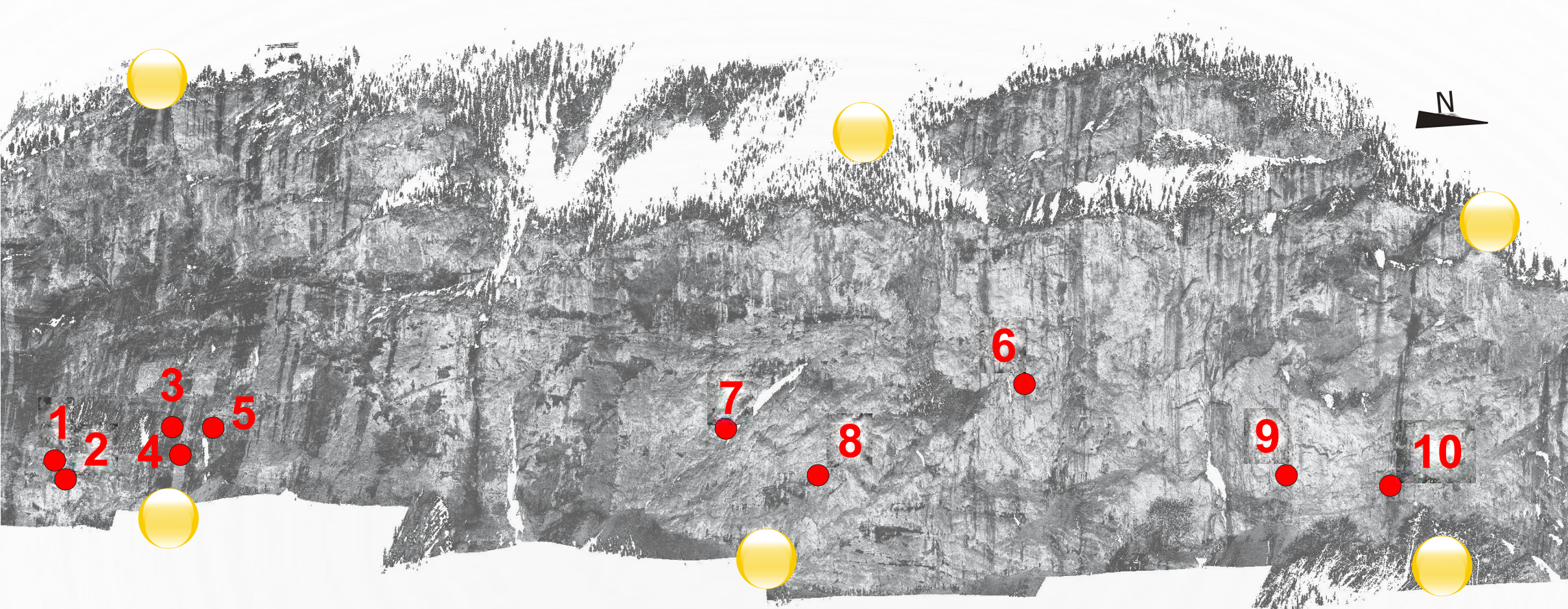


Evaluate the **potential and precision** of environmental seismology to detect rockfalls
Reveal **activity patterns** in time and space, and identify **triggers** of rockfall activity

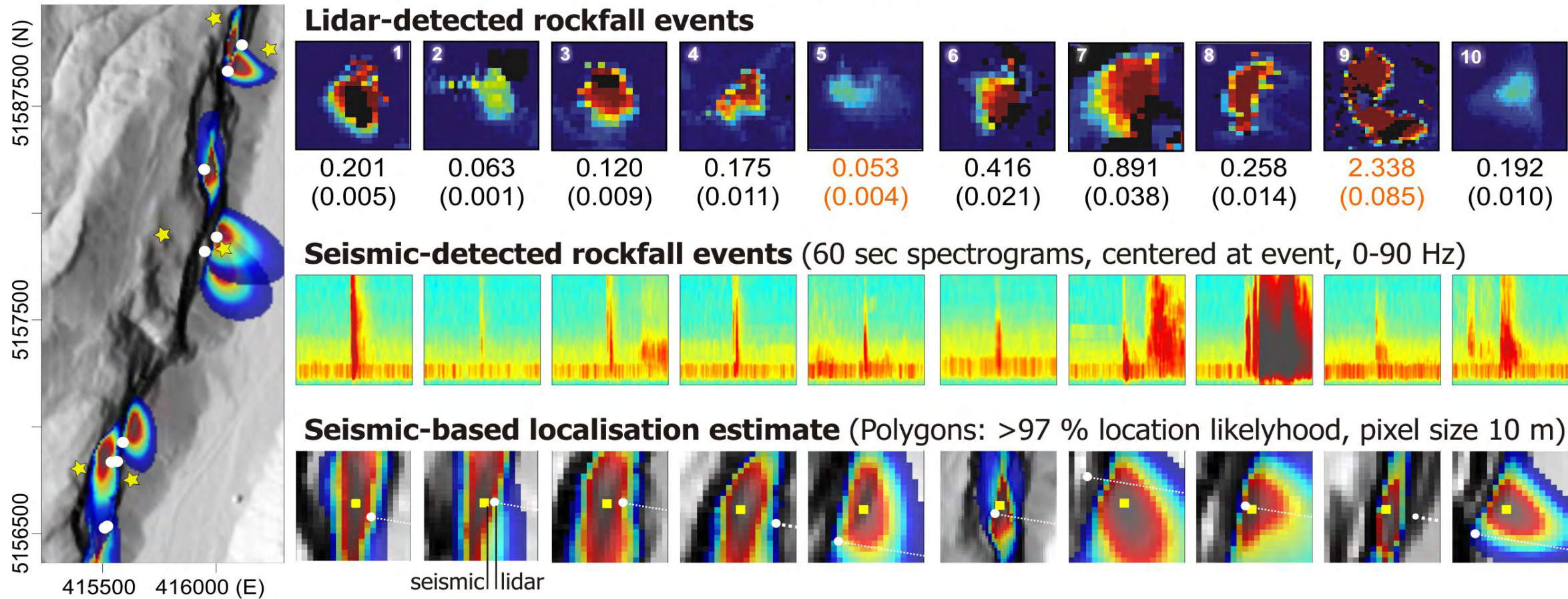
Welcome to the Lauterbrunnen Valley



Results - TLS-based rockfalls as reference for seismic approach validation



Results - seismic detection and location of rockfalls



2175 STA/LTA picks > 511 events after rejection criteria > **455** trains, 19 earthquakes, 37 rockfalls > **10** in AOI
 Ten out of ten events located | Average location deviation 81 (+59 / -29 m)

Application in a retrospective way - spatio-temporal patterns



Earthquakes



Volcanism



Snow avalanches



Rainfall



Human action



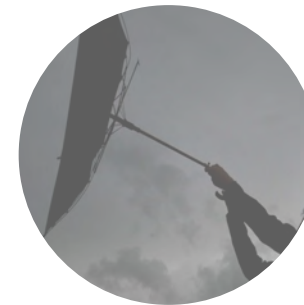
Lightning strike



Freeze-thaw/
thermal forcing



Fluvial activity



Wind

Application in a retrospective way - rockfall trigger analysis



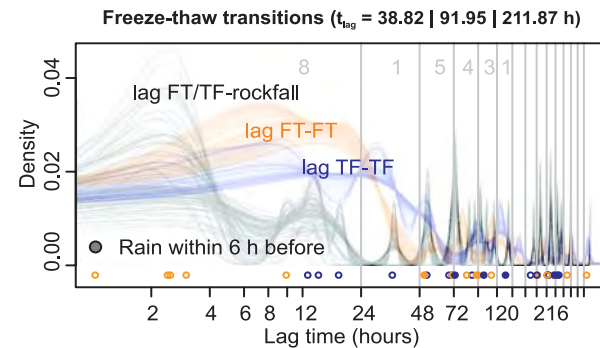
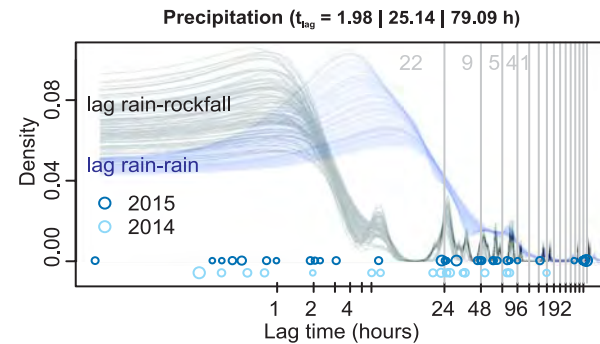
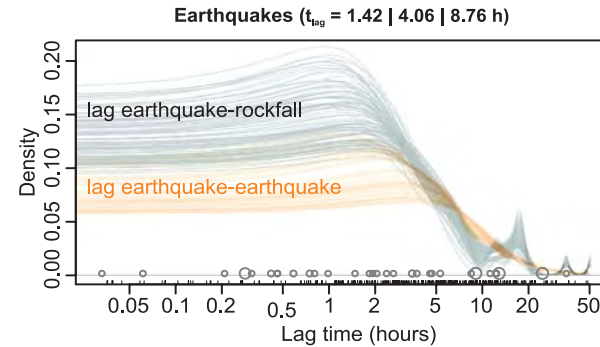
Earthquakes



Rainfall



Freeze-thaw/
thermal forcing



Application in a retrospective way - rockfall trigger analysis



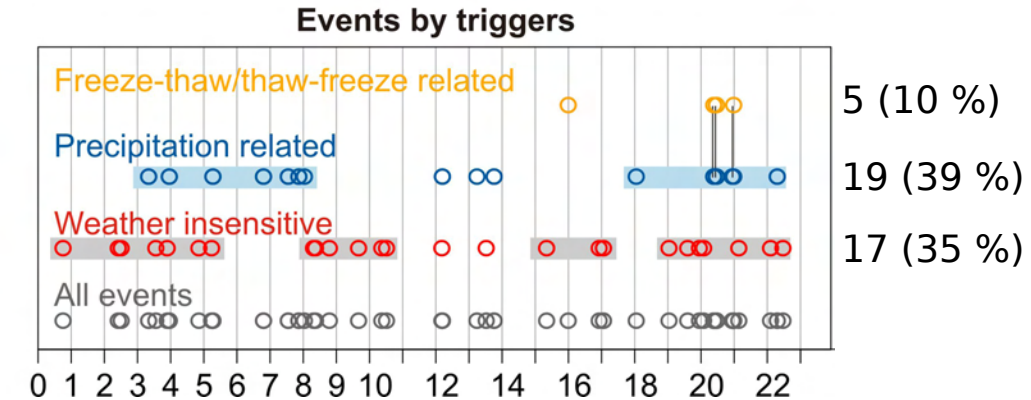
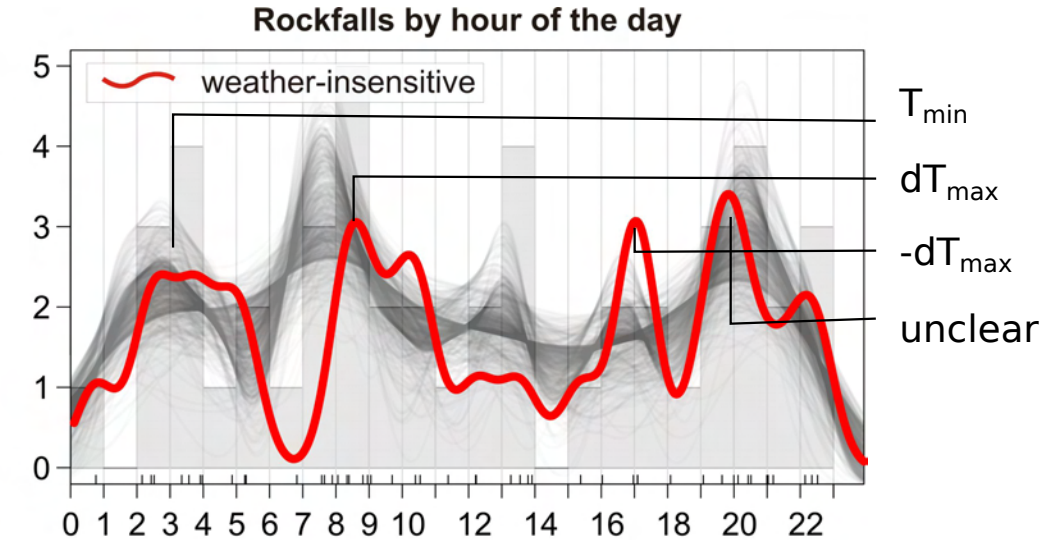
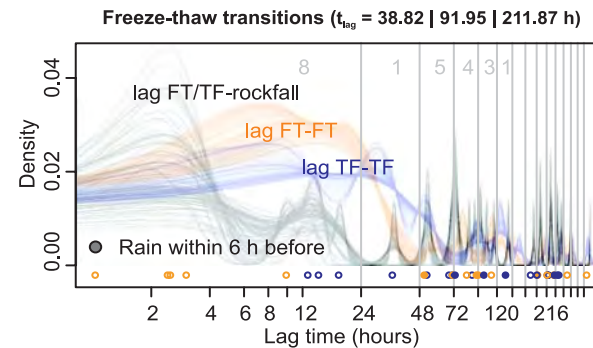
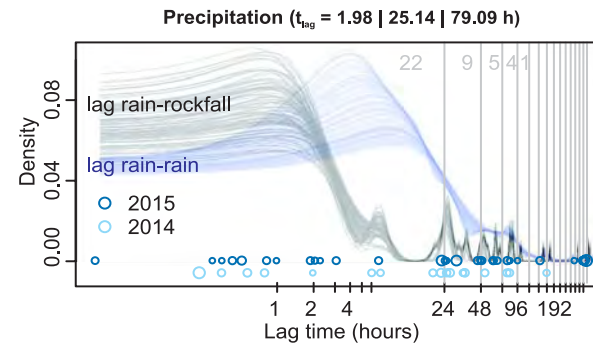
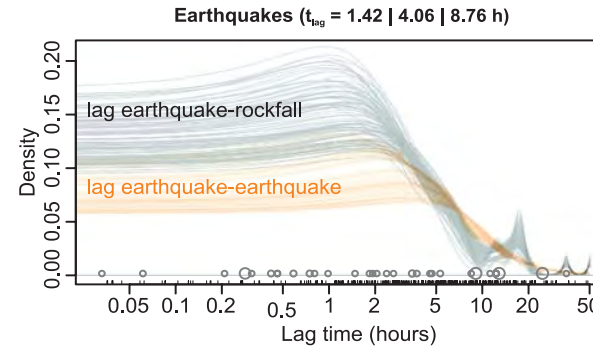
Earthquakes



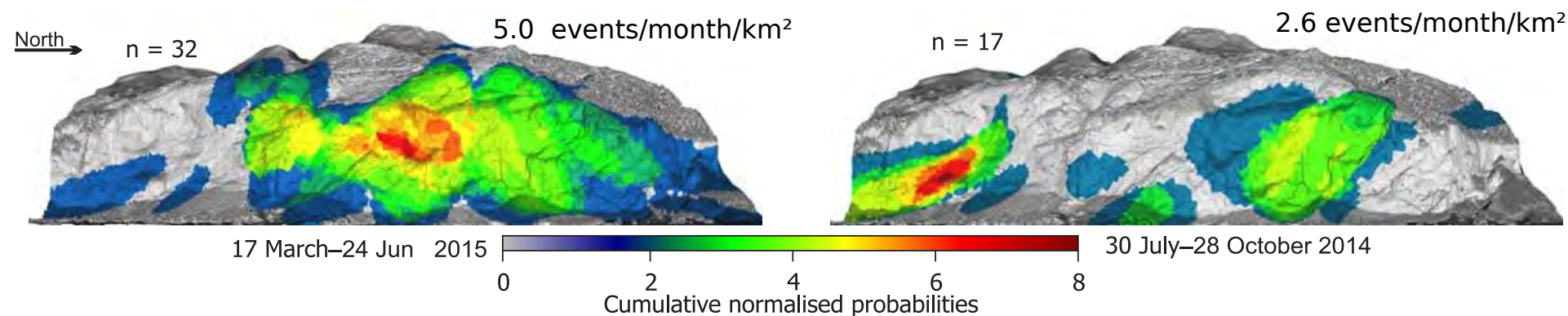
Rainfall



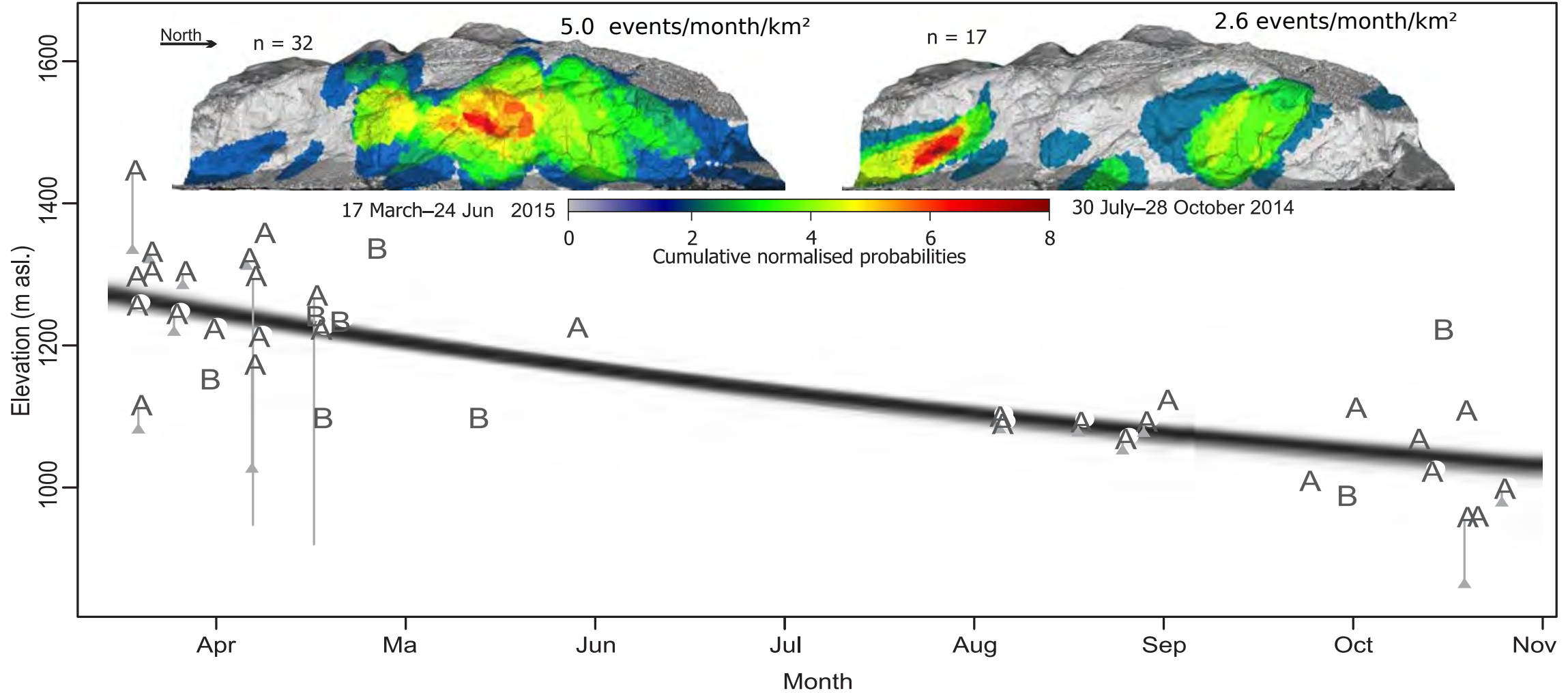
Freeze-thaw/
thermal forcing



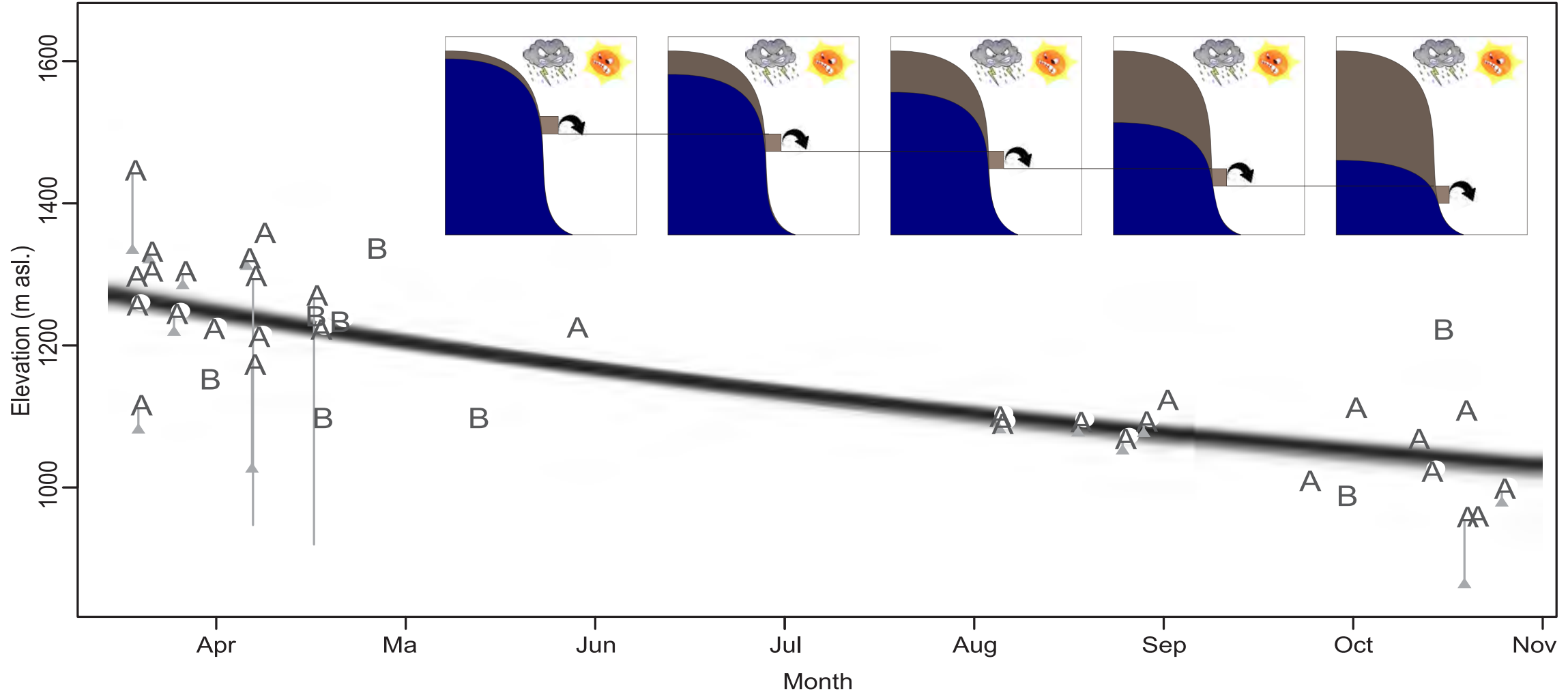
Application in a retrospective way - spatio-temporal patterns



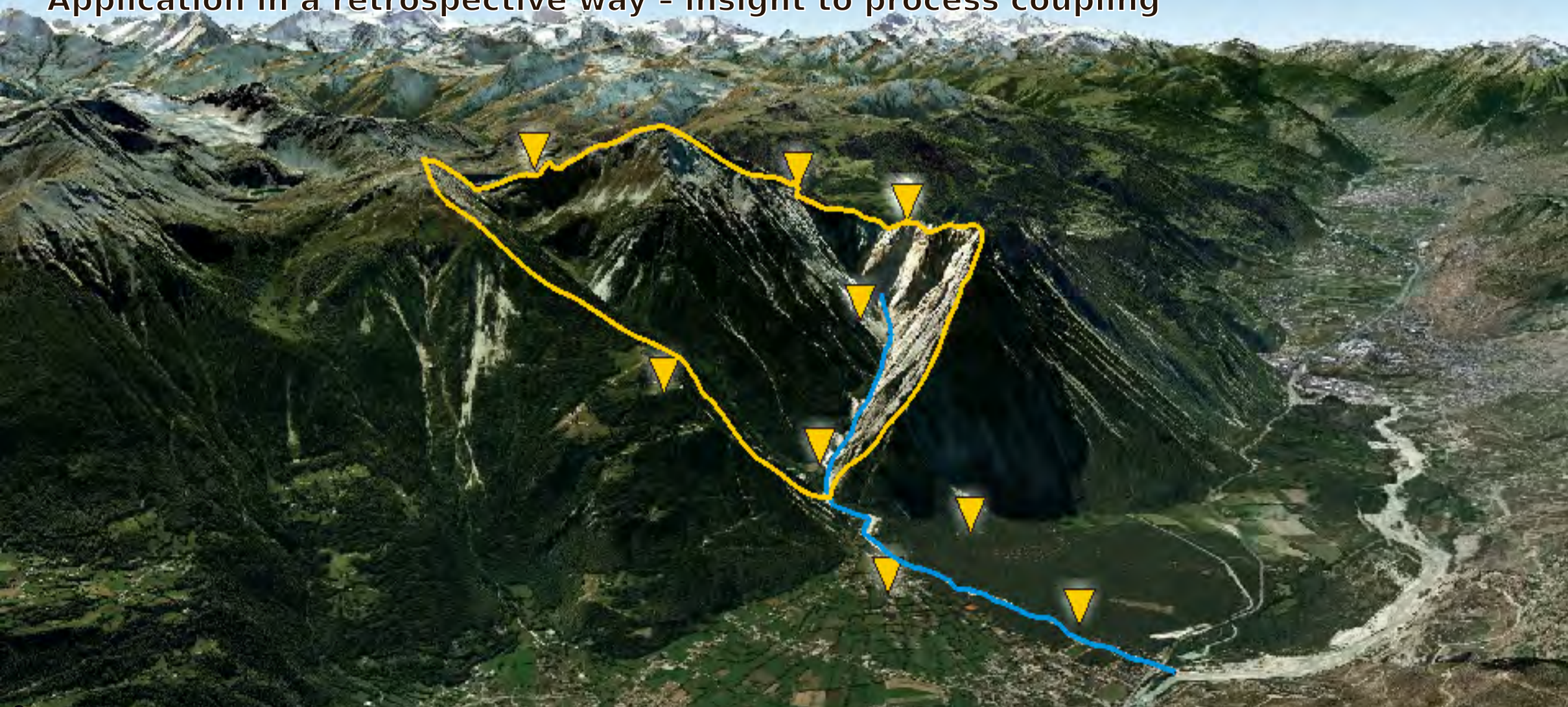
Application in a retrospective way - spatio-temporal patterns



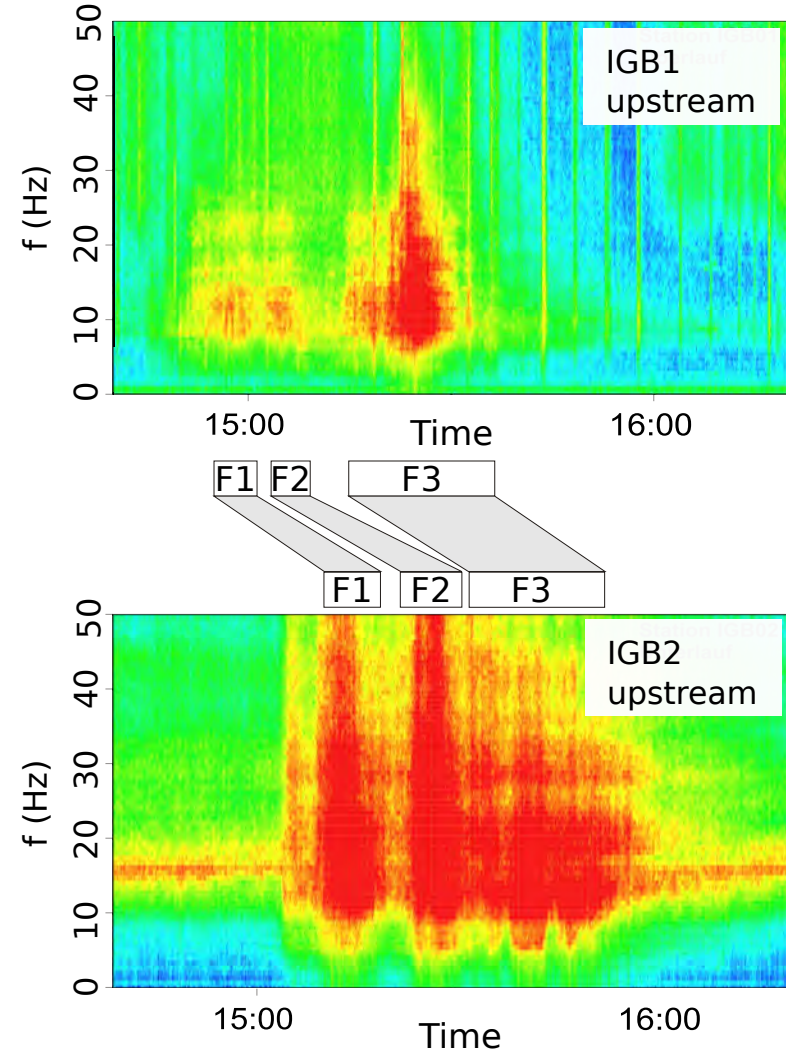
Application in a retrospective way - spatio-temporal patterns



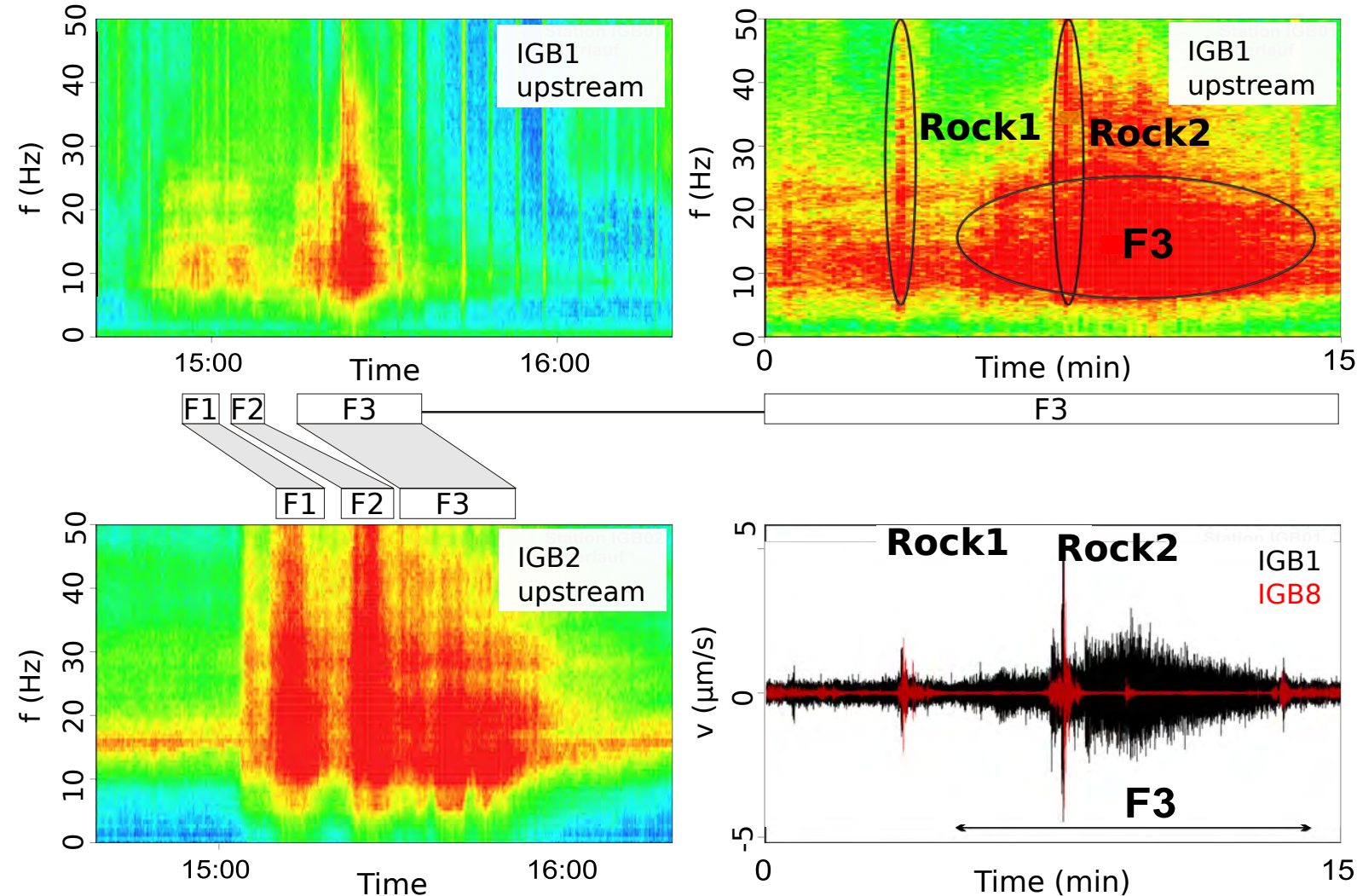
Application in a retrospective way - insight to process coupling



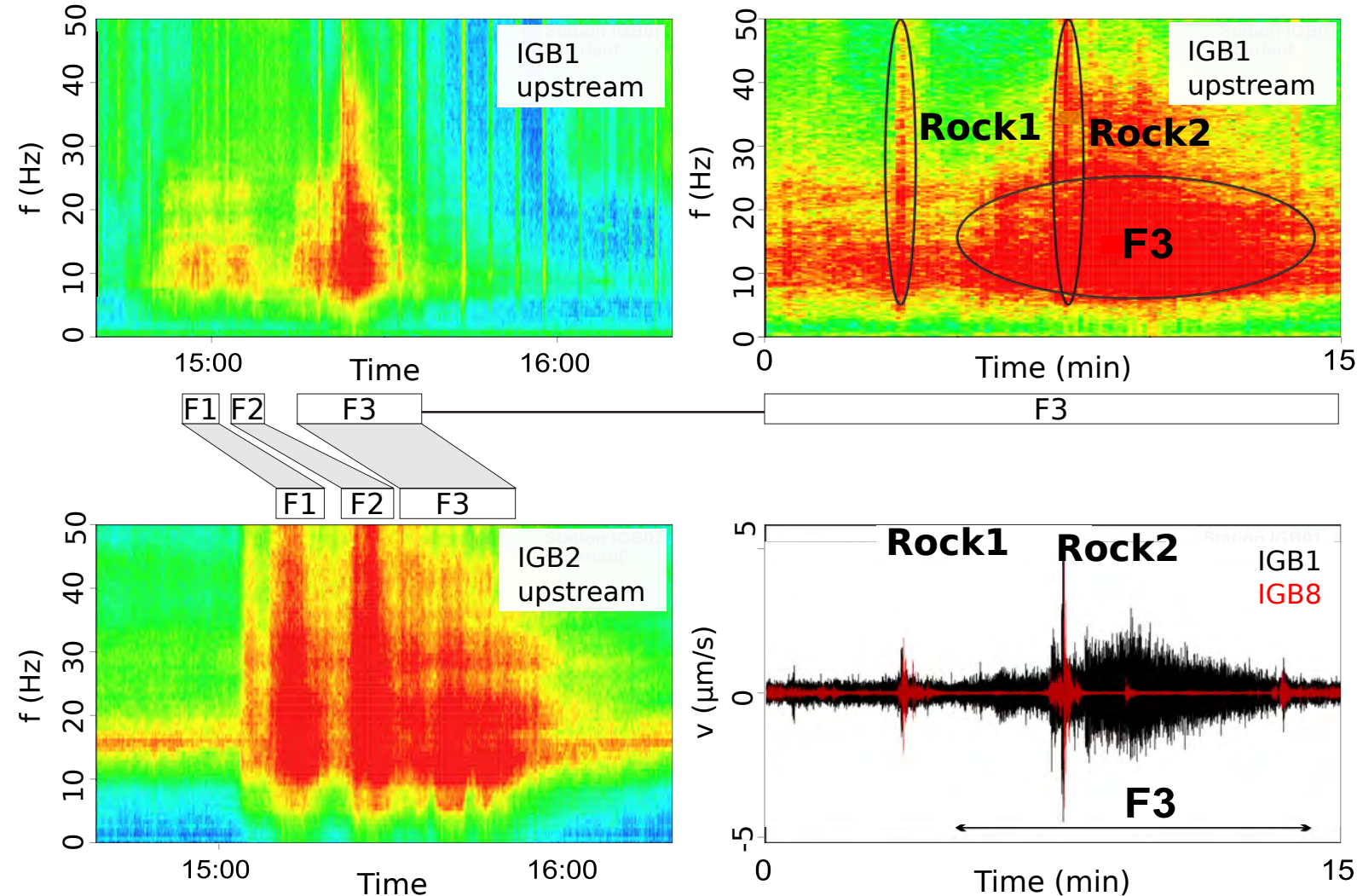
Application in a retrospective way - insight to process coupling



Application in a retrospective way - insight to process coupling



Application in a retrospective way - insight to process coupling

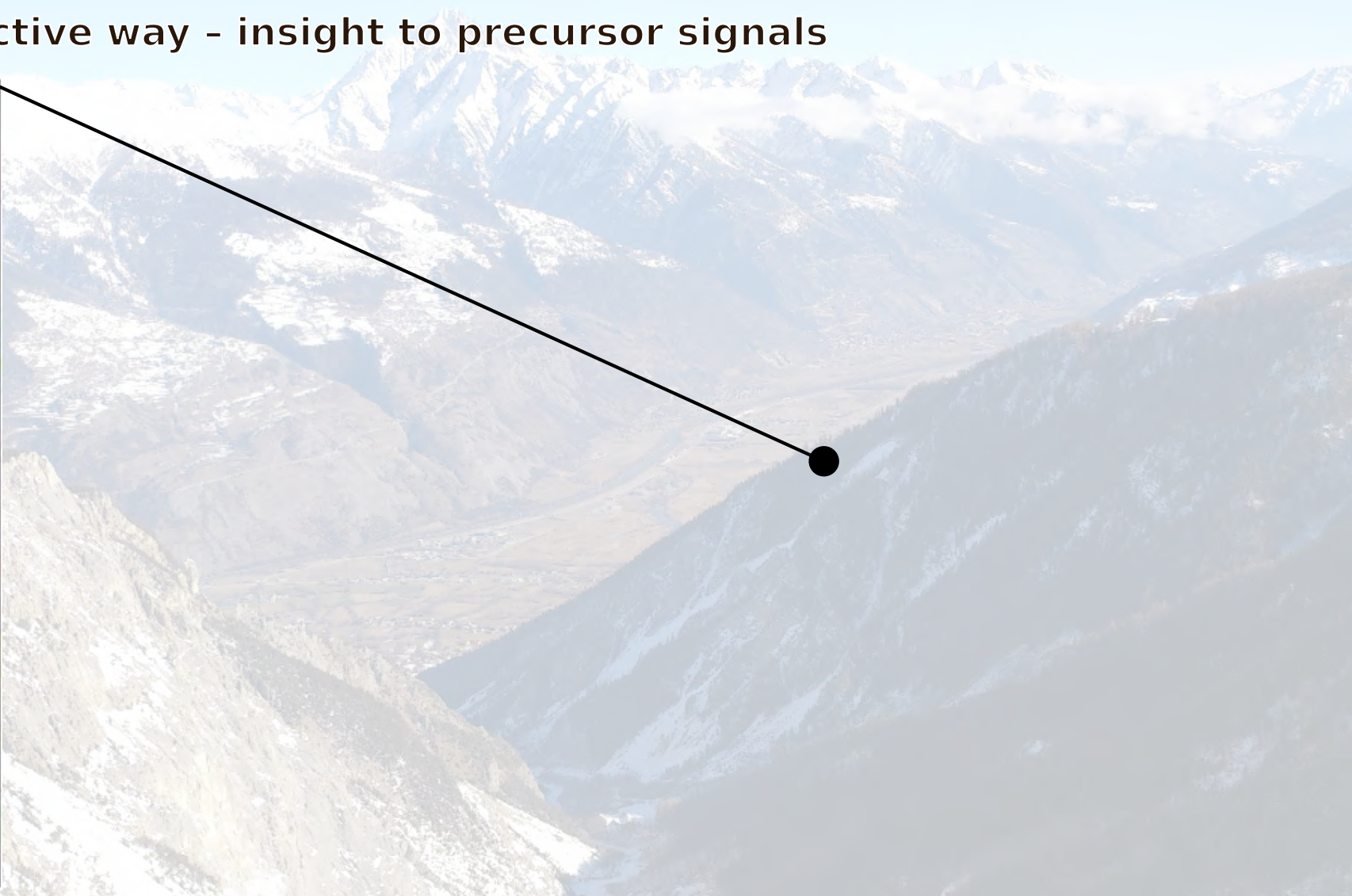


Burtin et al. (2014)

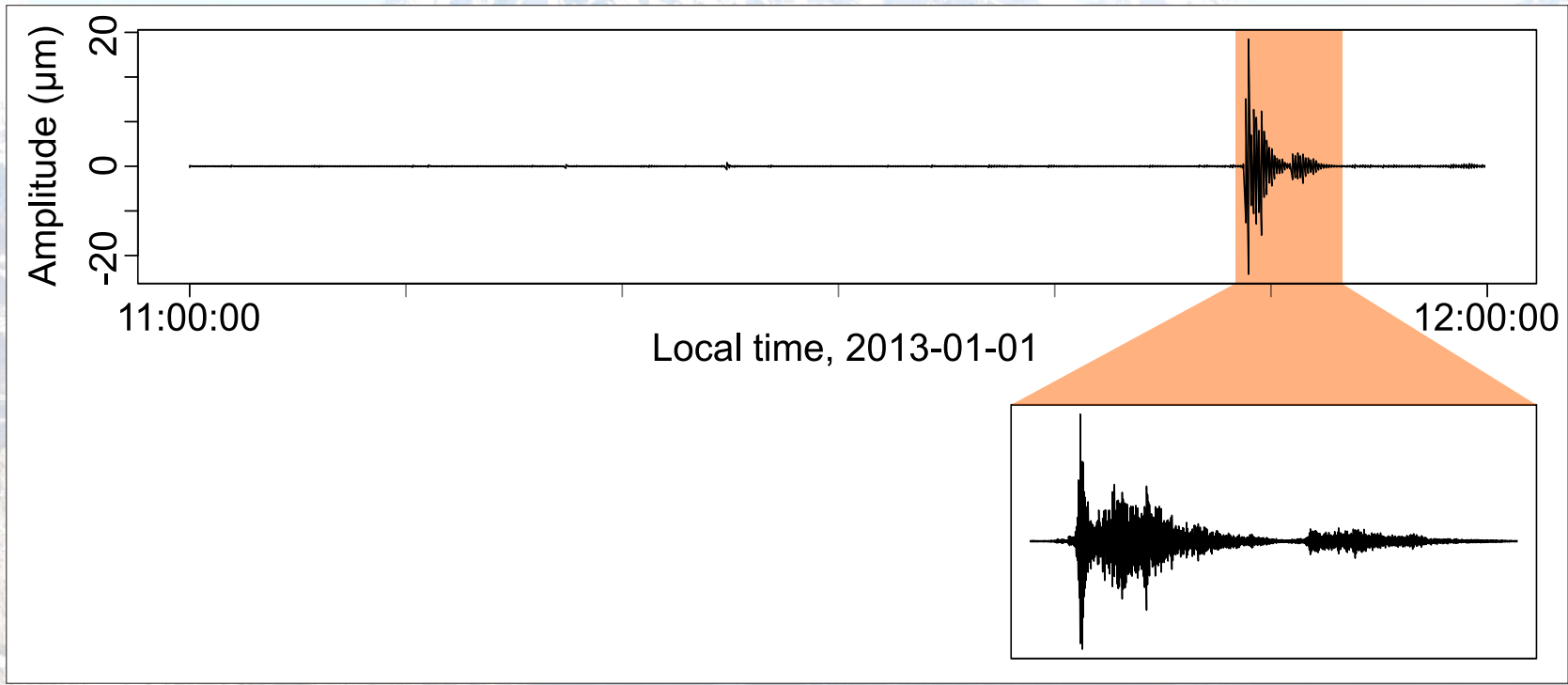
Application in a prospective way - insight to precursor signals



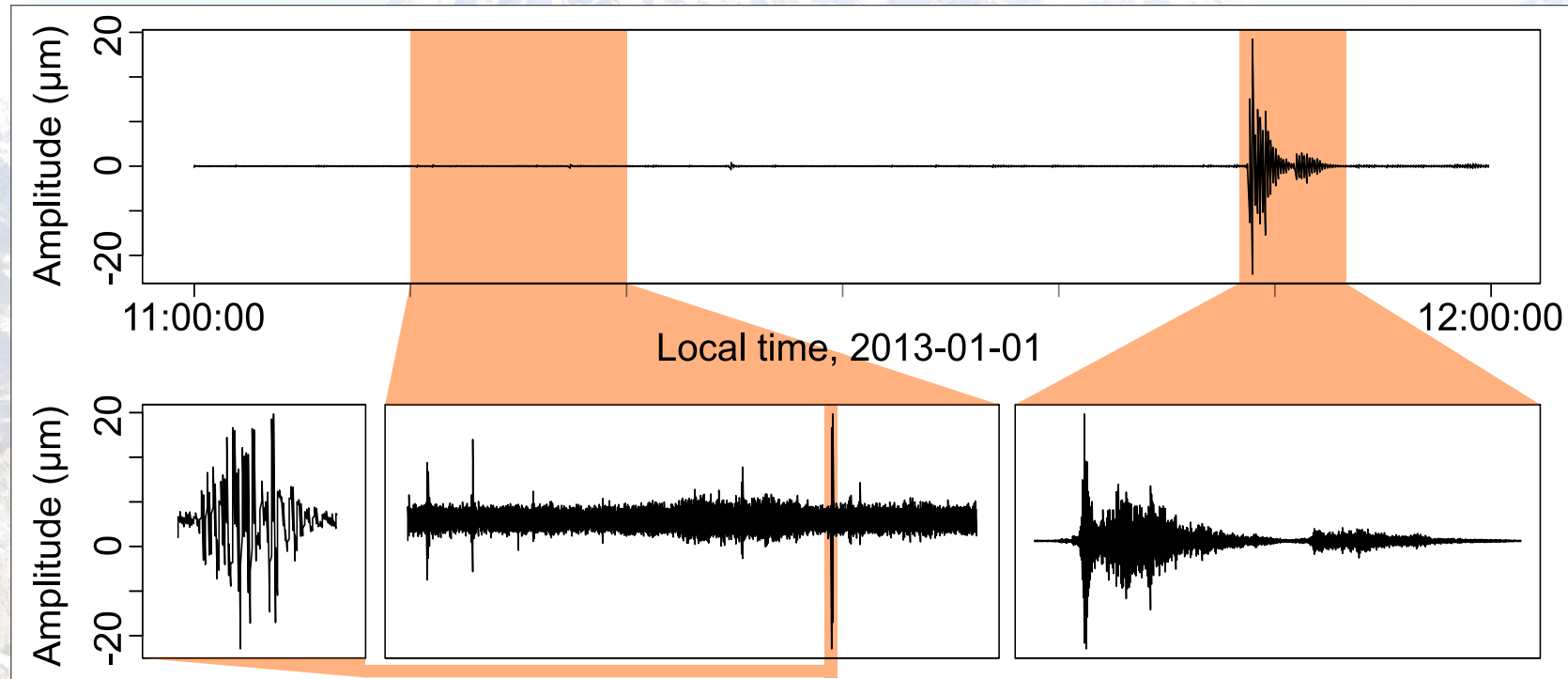
Application in a prospective way - insight to precursor signals



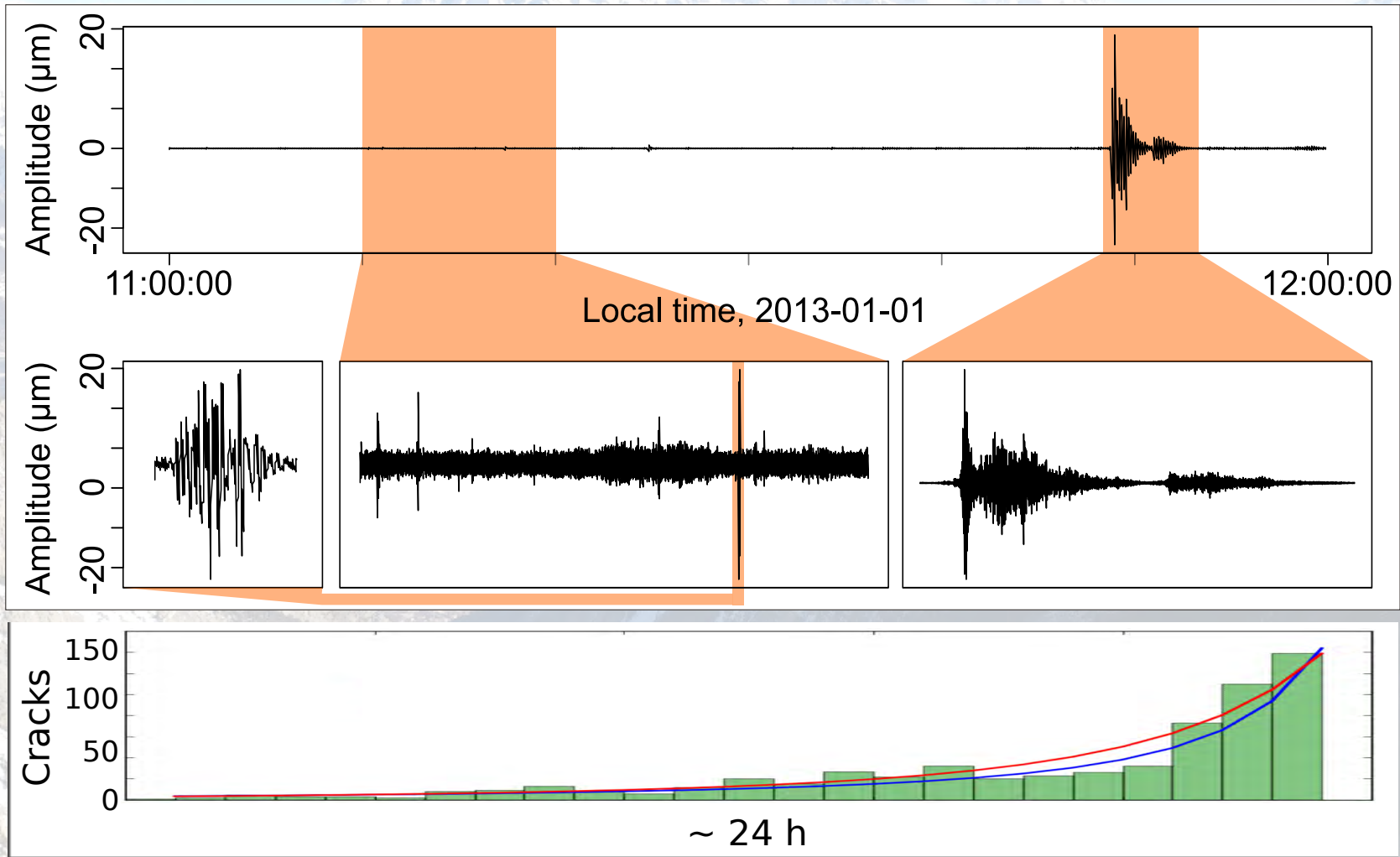
Application in a prospective way - insight to precursor signals



Application in a prospective way - insight to precursor signals



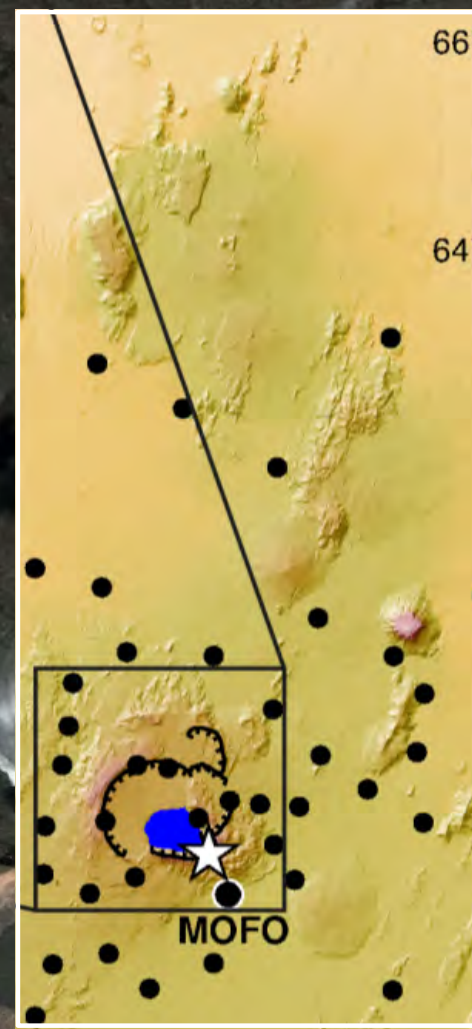
Application in a prospective way - insight to precursor signals



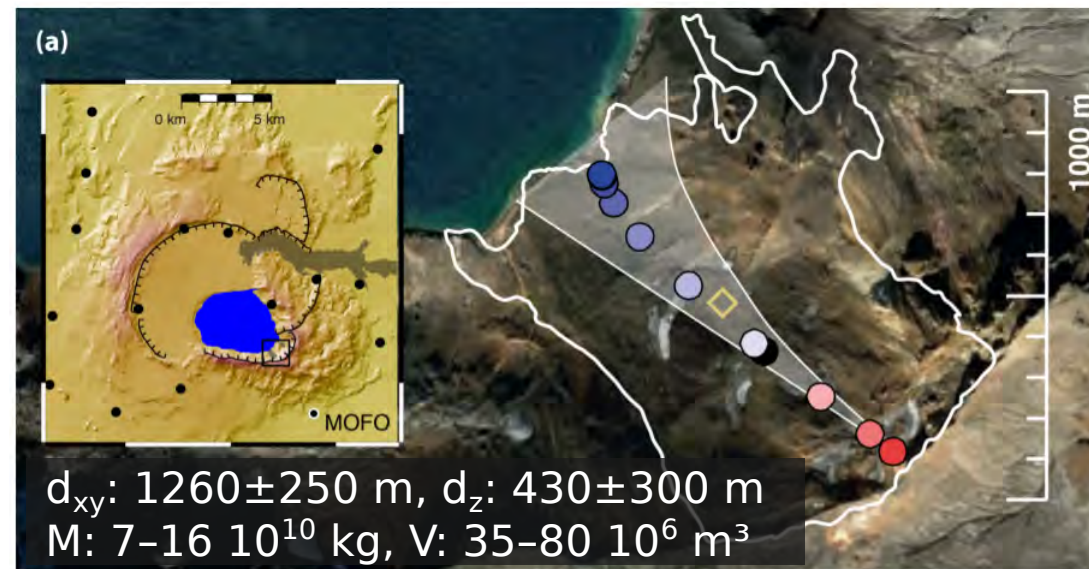
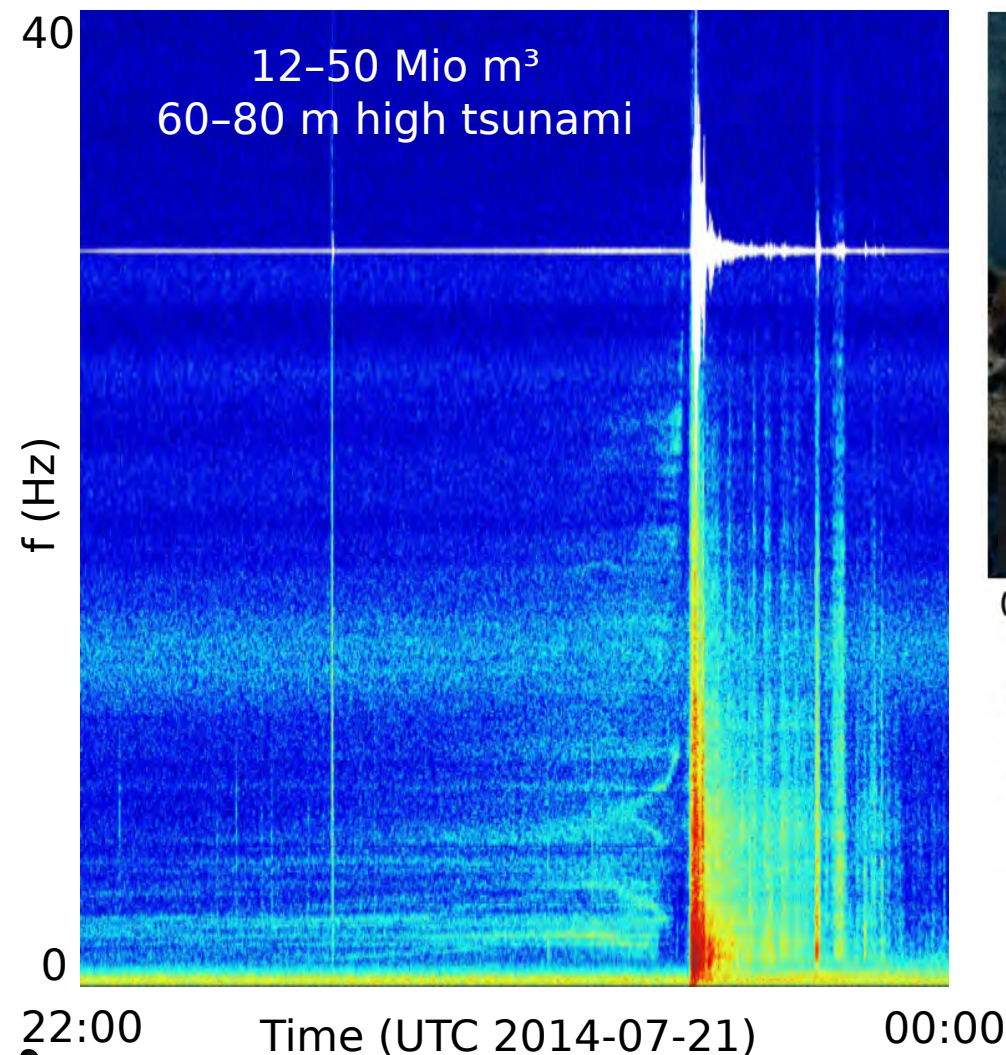
Application in a prospective way - precursor signals and anatomy of a larger event



Application in a prospective way - precursor signals and anatomy of a larger event



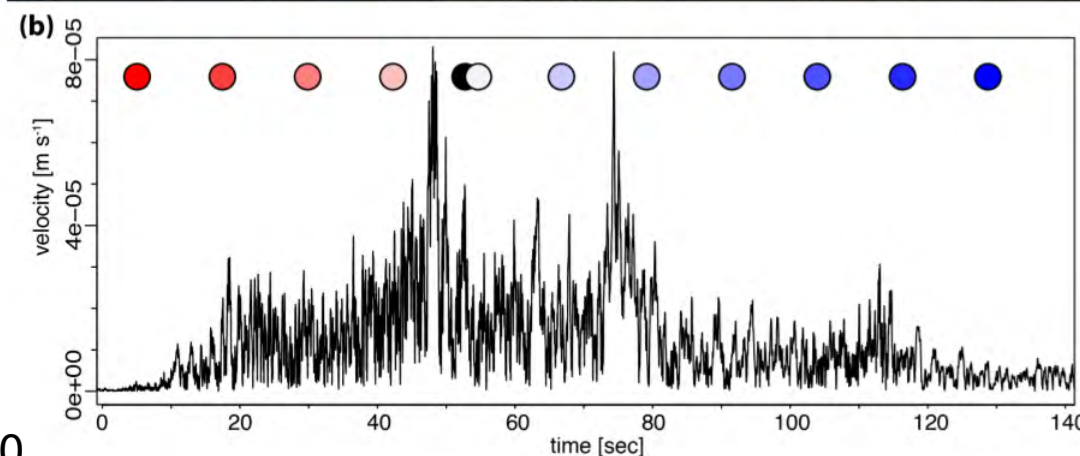
Application in a prospective way - precursor signals and anatomy of a larger event



f = 0.02-0.05 Hz
0.02-0.08 Hz
0.04-0.08 Hz

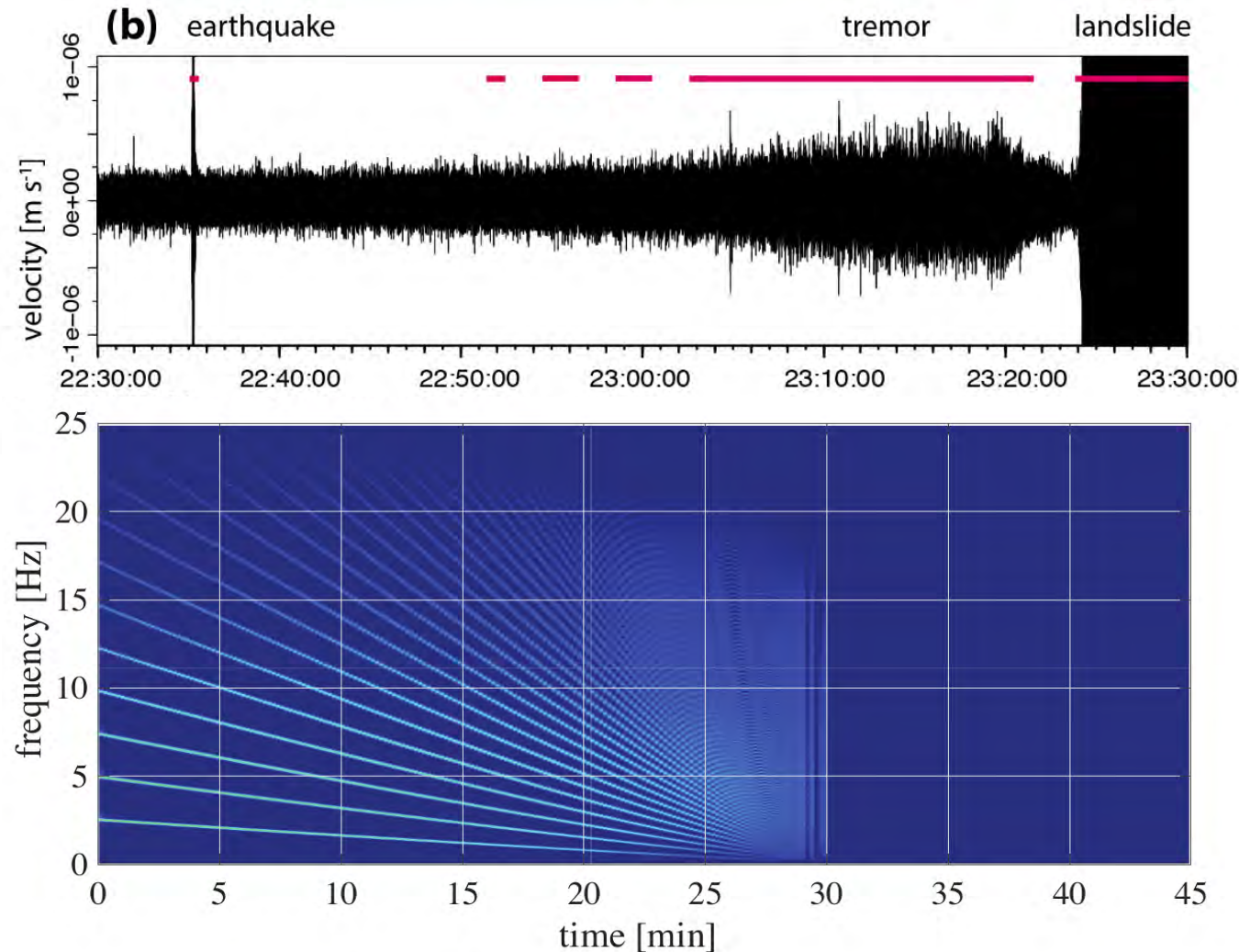
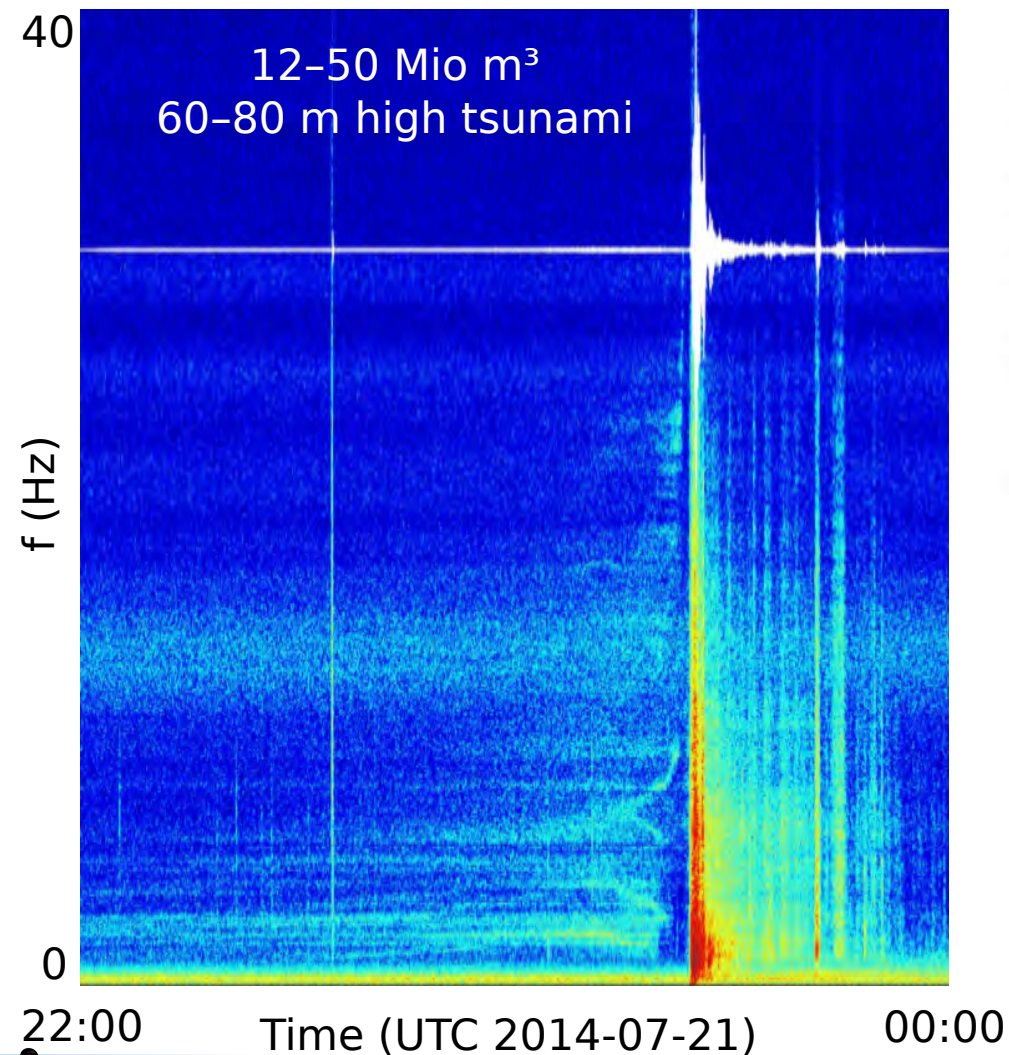
v (1D model) after Mitchell et al. (2013).

Inversion after Ekström & Stark (2013), Chao (2016)

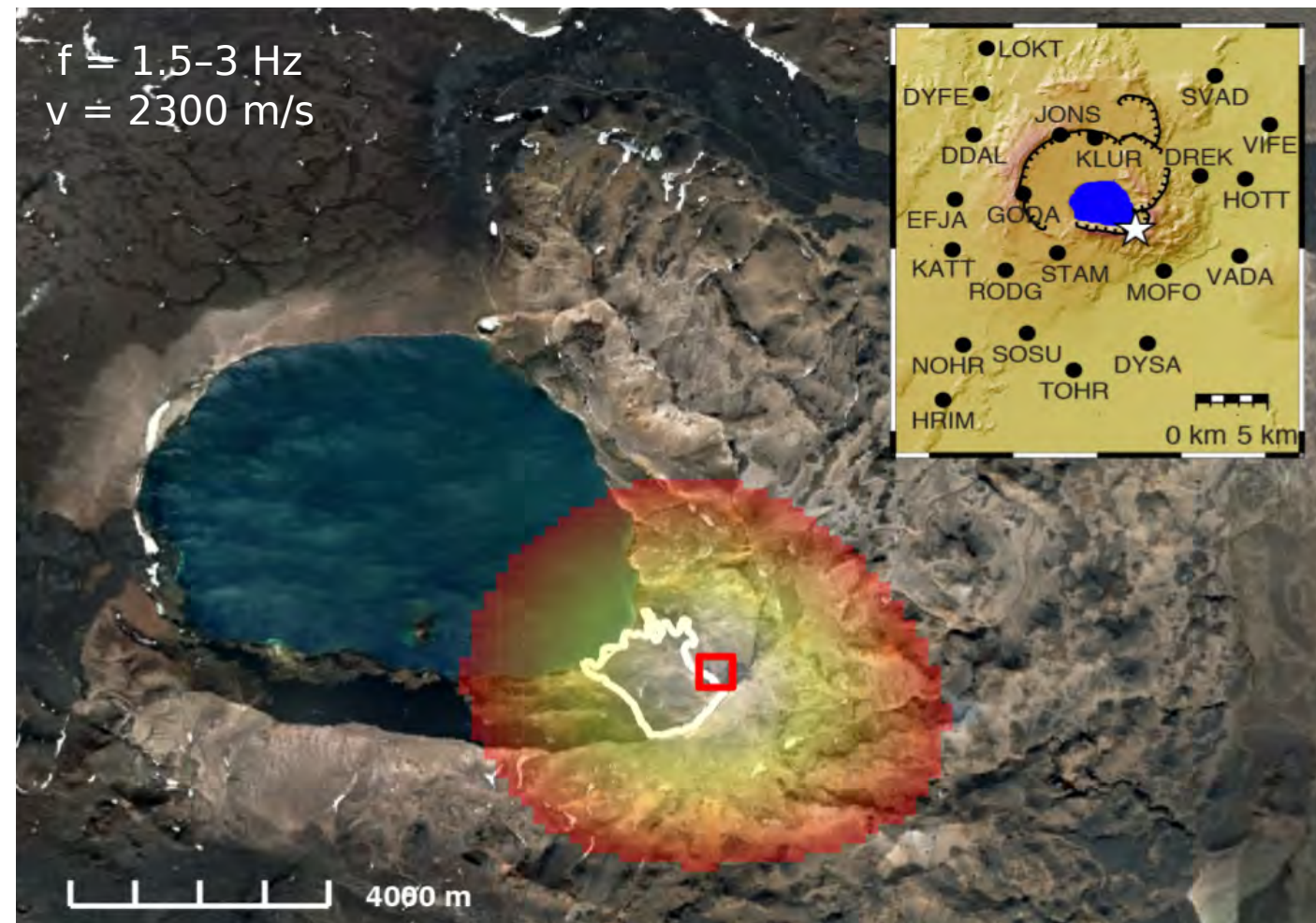
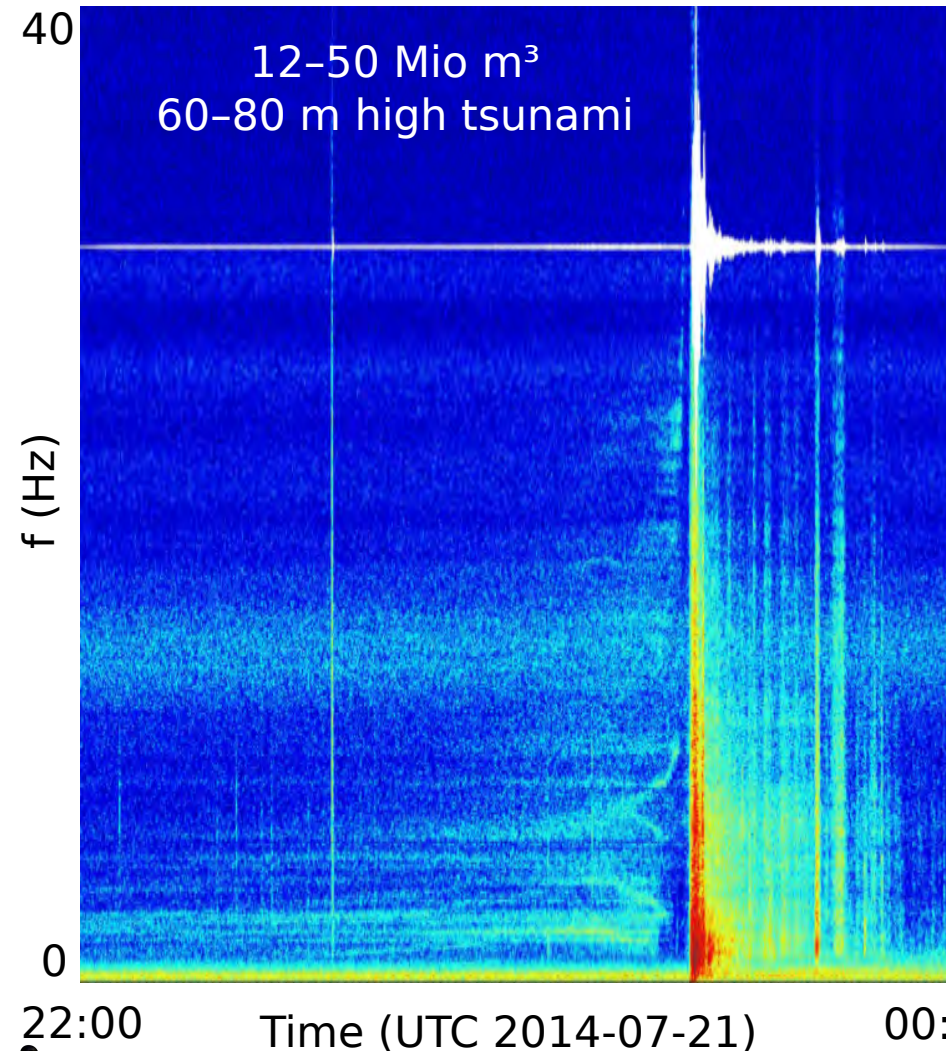


BHE component
f = 1-45 Hz
envelope
MOFO station

Application in a prospective way - precursor signals and anatomy of a larger event



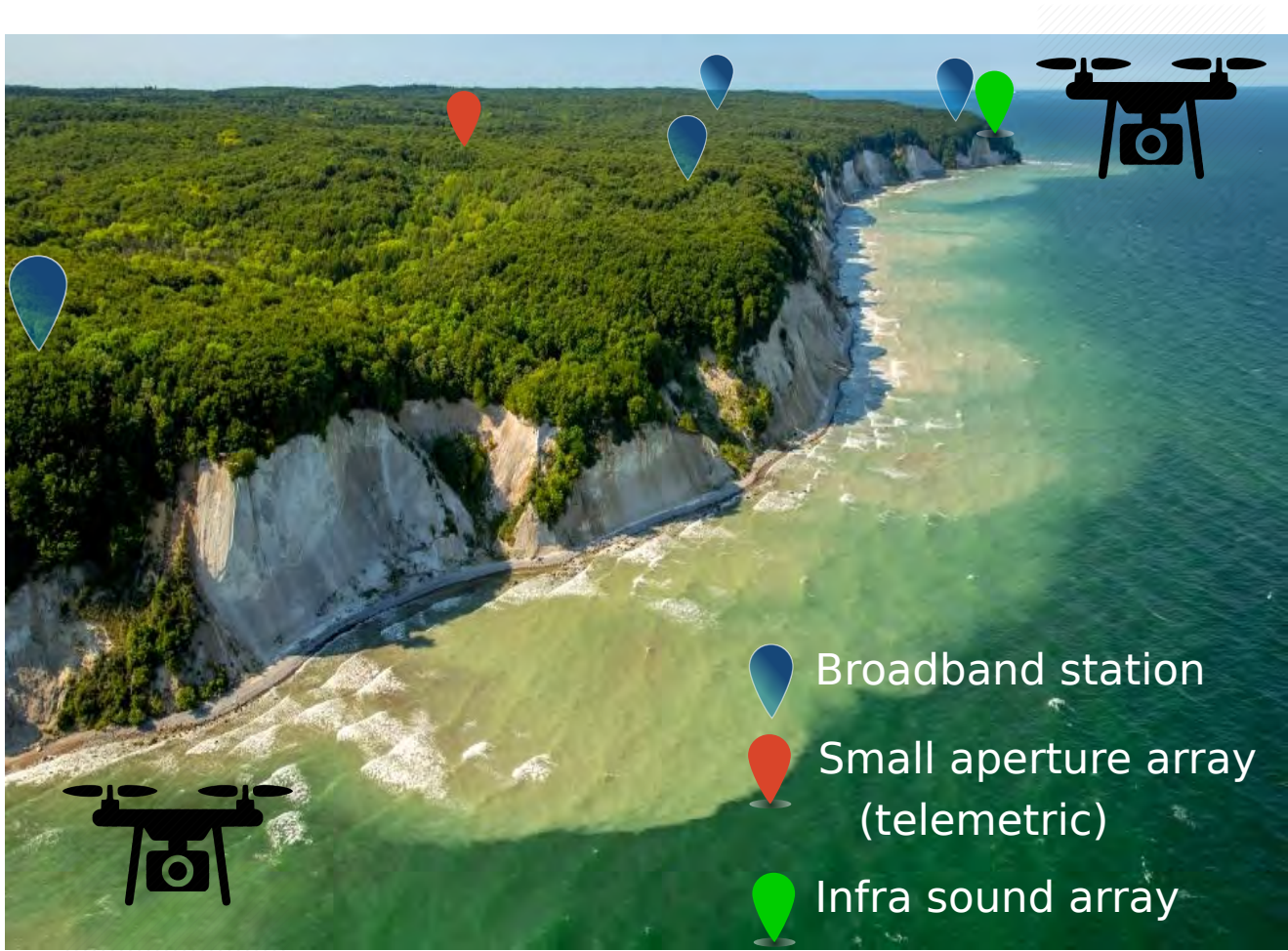
Application in a prospective way - precursor signals and anatomy of a larger event



Application in a prospective way - repid response actions to cliff coast collapses



Application in a prospective way - repid response actions to cliff coast collapses



Events

- Location
- Timing
- Duration
- Mode of failure
- Volume
- Anatomy

Warning

- Inform authorities
- Close beach parts (precursor signals)

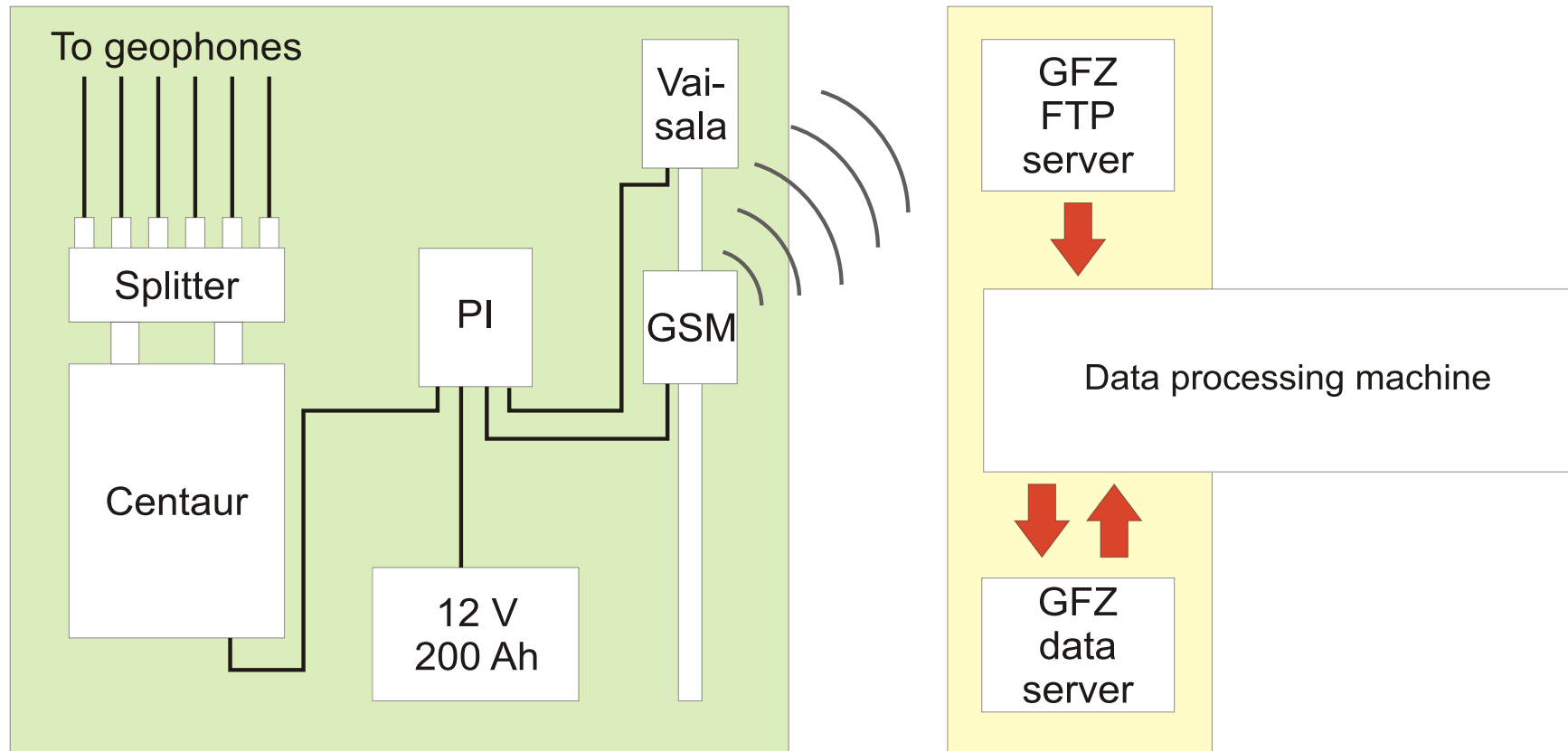
Patterns

- Spatial activity
- Temporal activity
- Magnitude-freq.
- Coastline evolution

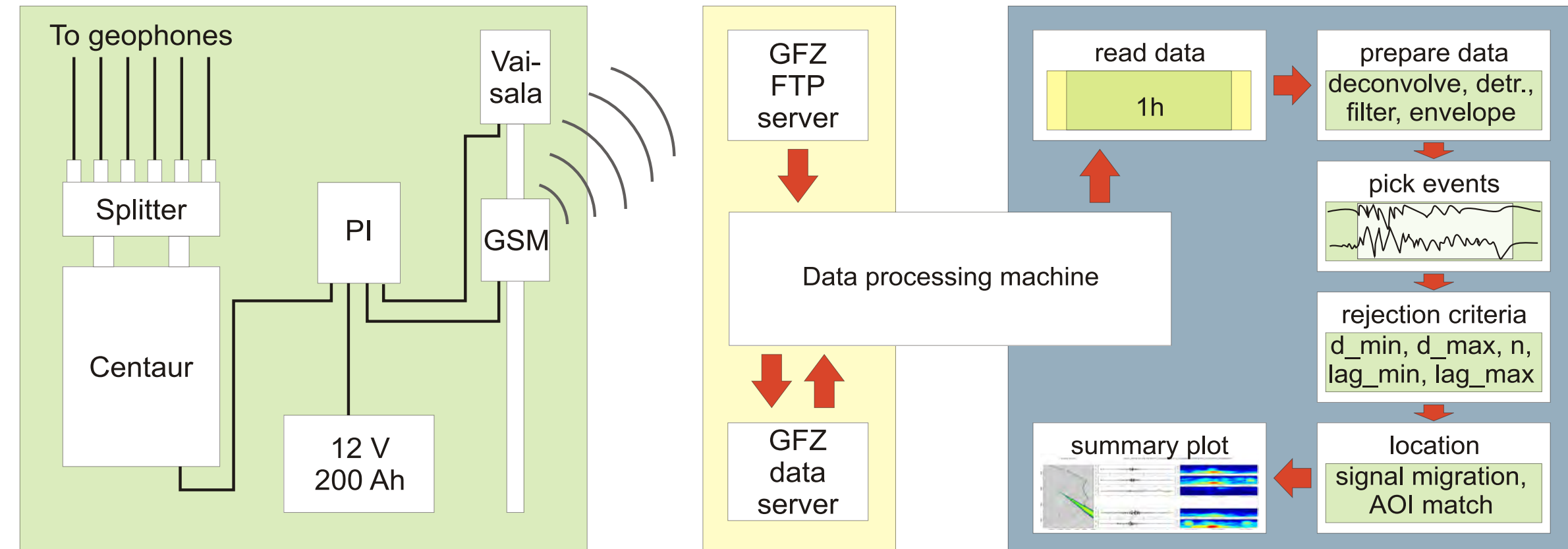
Triggers

- Time lags
- Intensity
- Duration
- Long time series

Application in a prospective way - rapid response actions to cliff coast collapses



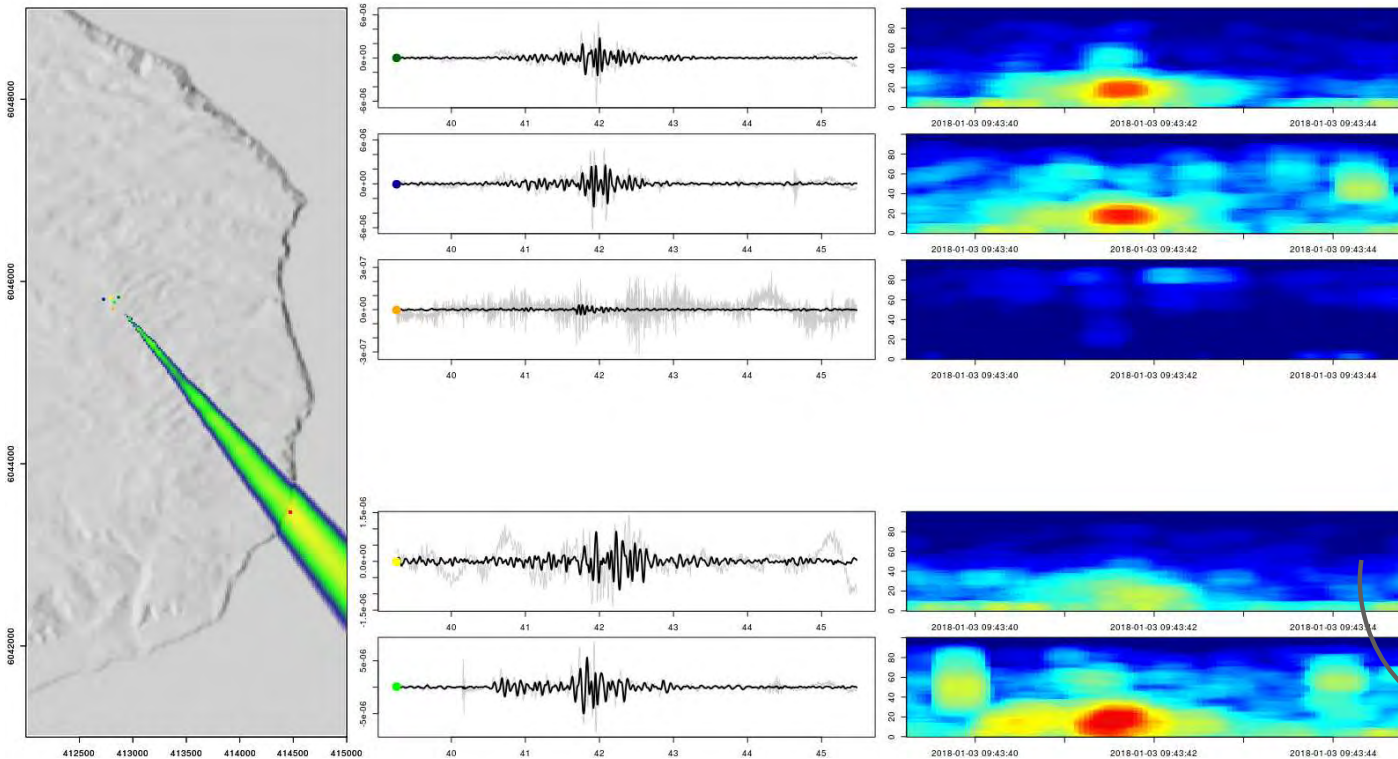
Application in a prospective way - rapid response actions to cliff coast collapses



Application in a prospective way - rapid response actions to cliff coast collapses

Event found

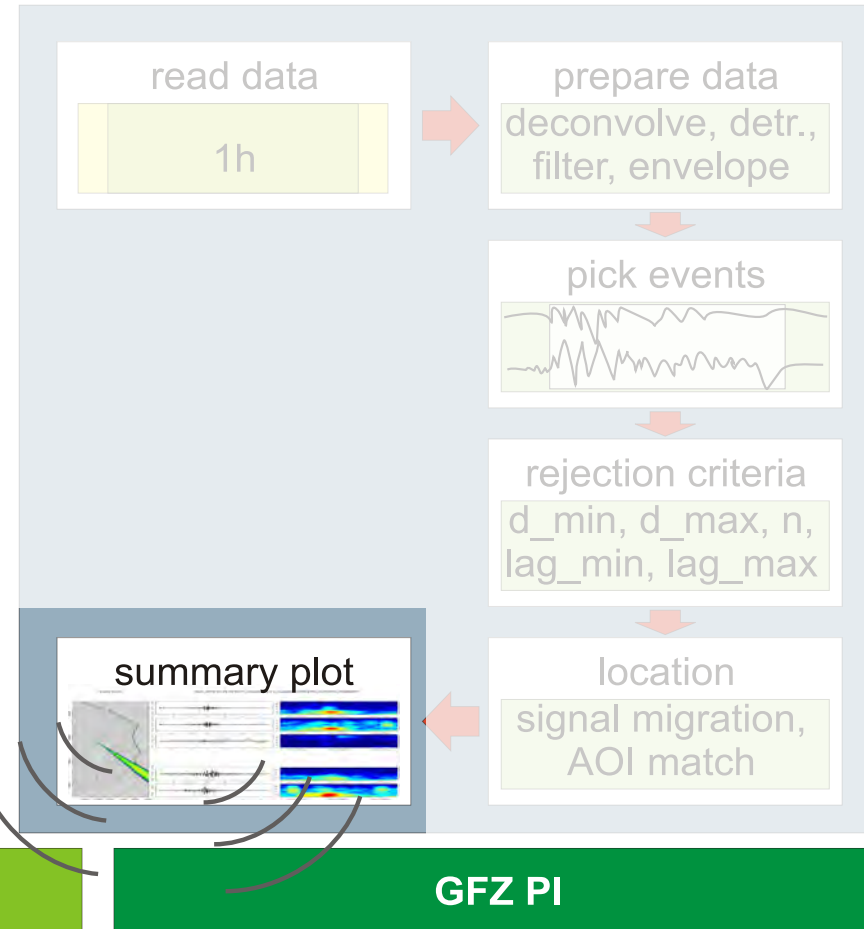
Start: 2018-01-03 09:43:41 | Duration: 2.2 s | Location (UTM 33N): E 414470, N 6043470



public, stake holders

NP staff

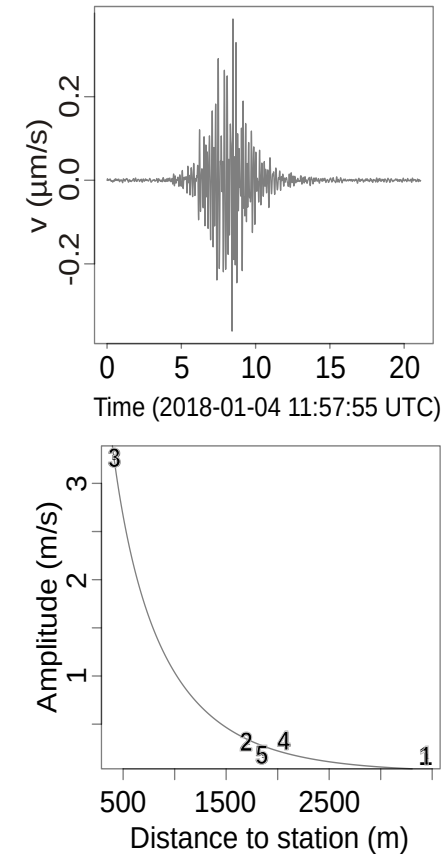
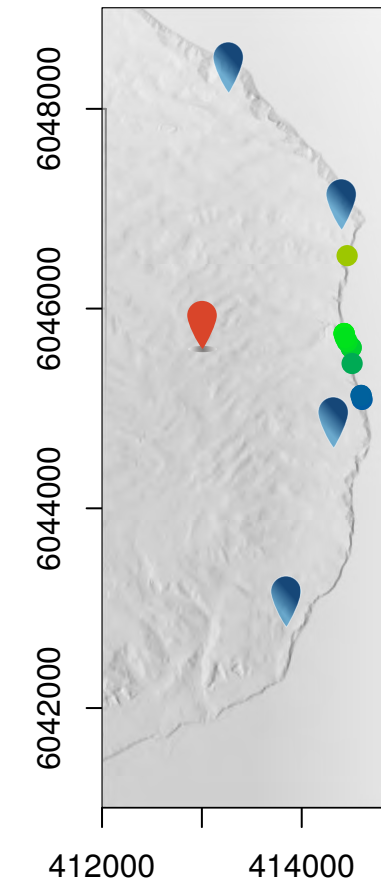
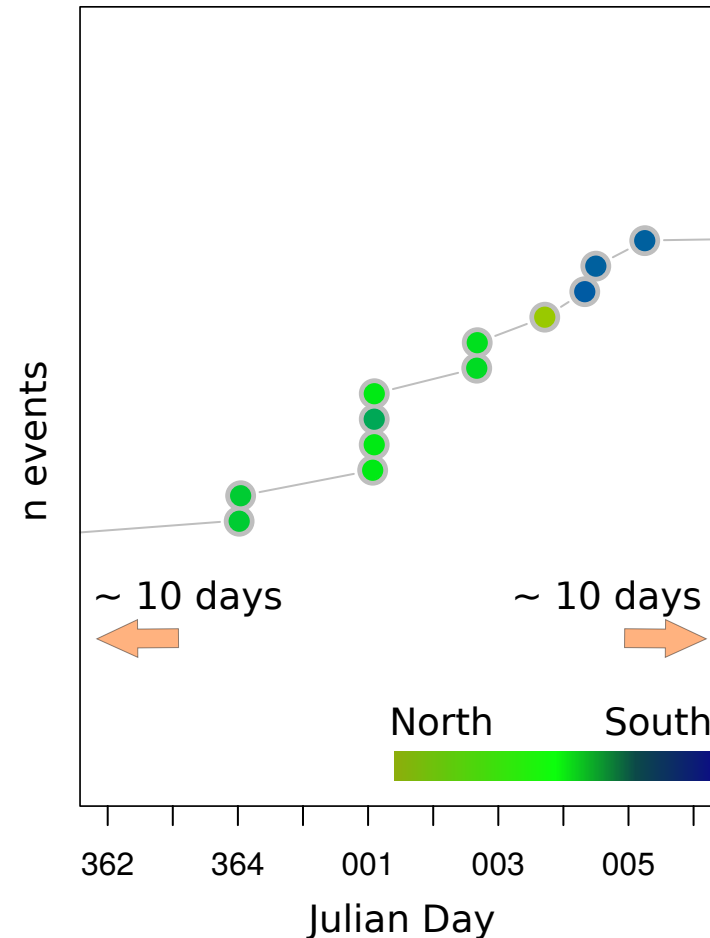
GFZ PI



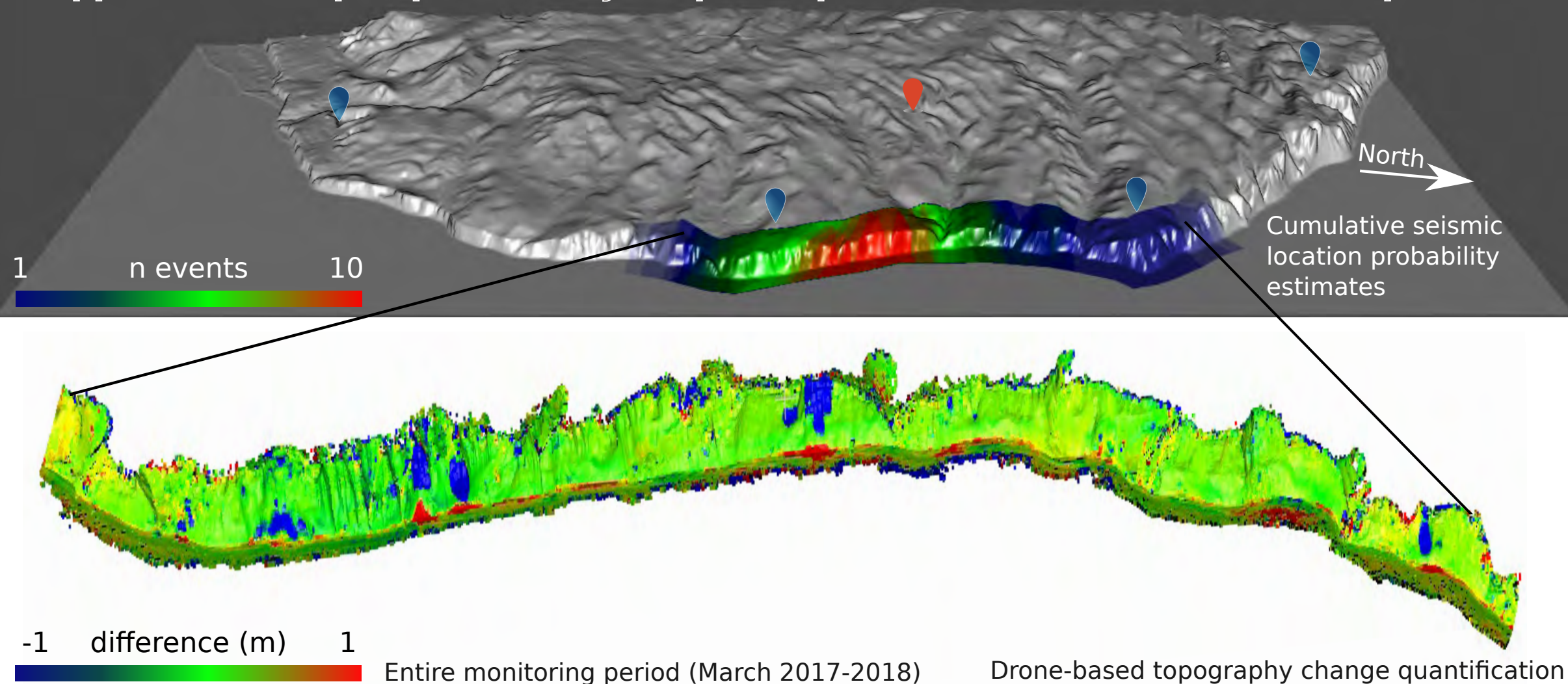
Application in a prospective way - repid response actions to cliff coast collapses



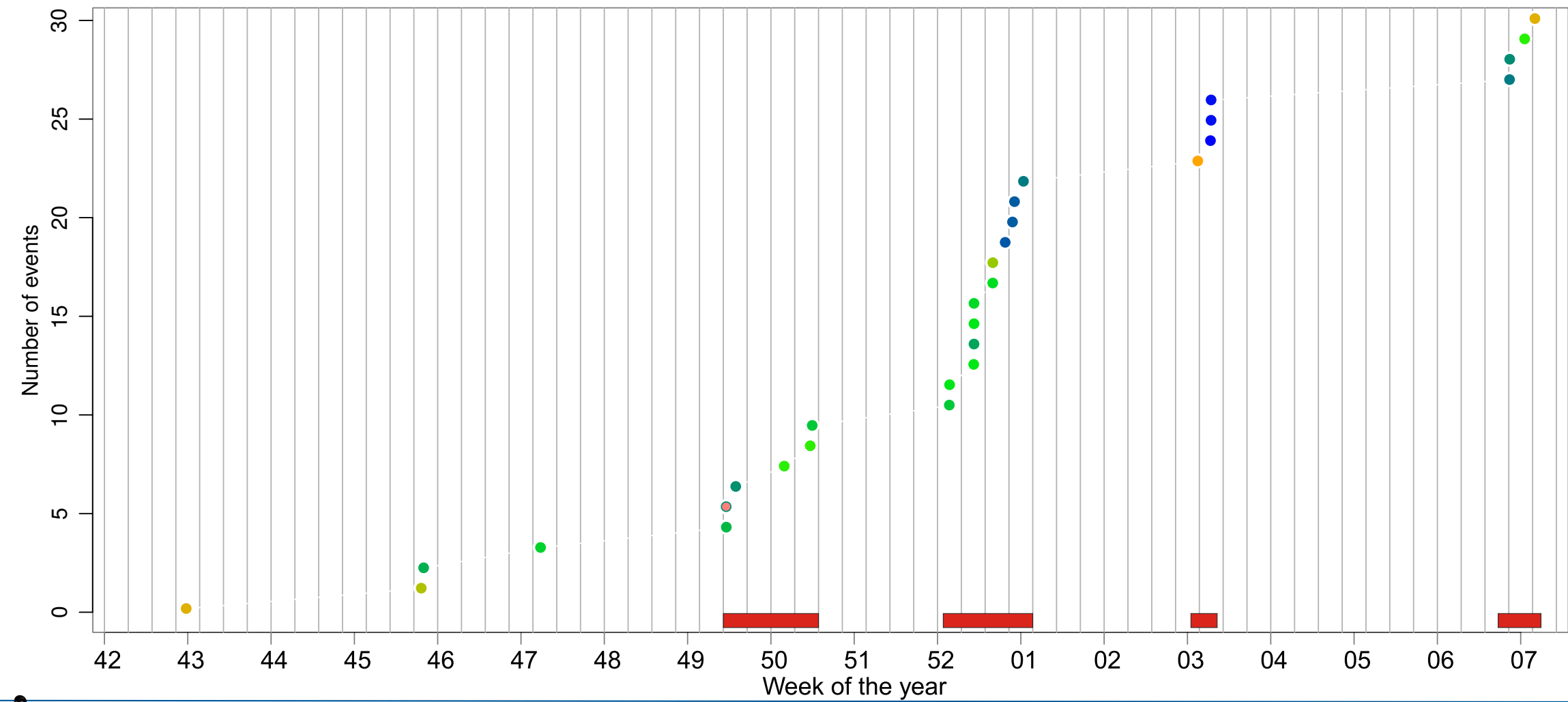
Application in a prospective way - repid response actions to cliff coast collapses



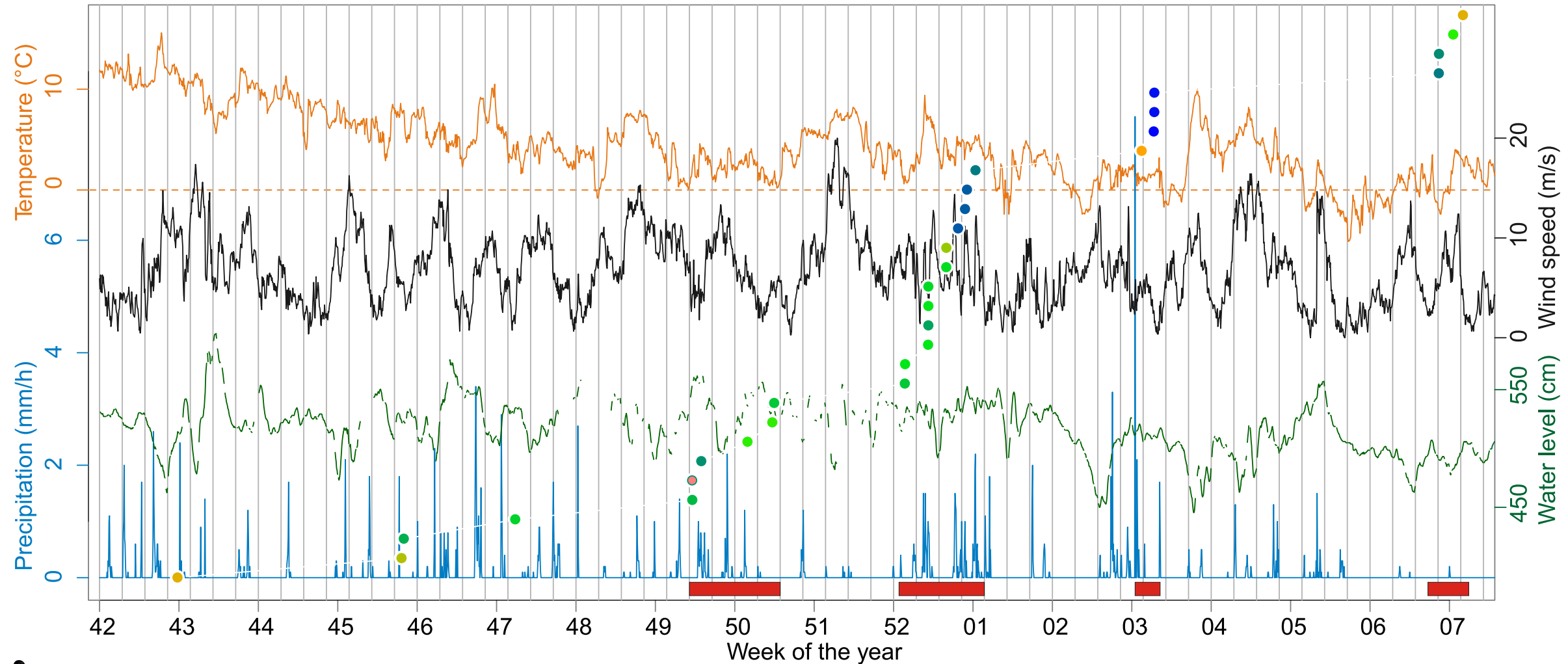
Application in a prospective way - rapid response actions to cliff coast collapses



Application in a prospective way - rapid response actions to cliff coast collapses

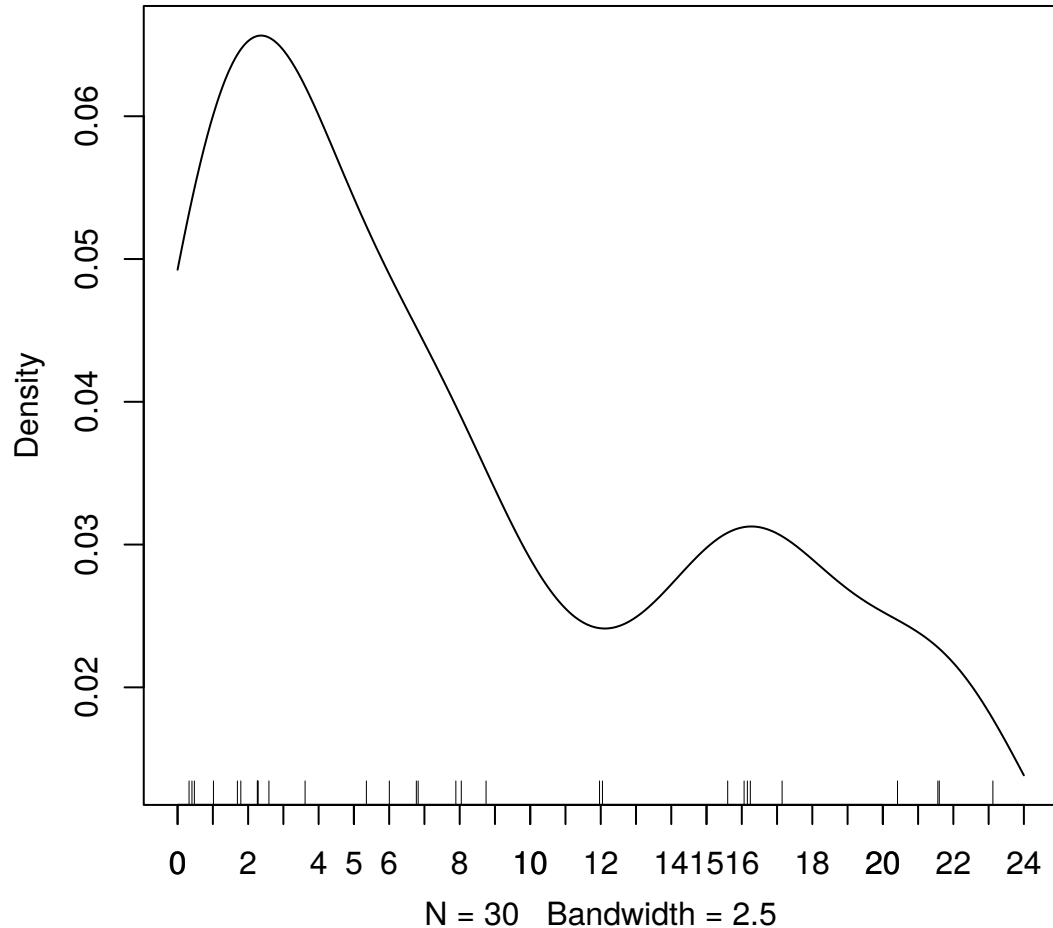


Application in a prospective way - rapid response actions to cliff coast collapses

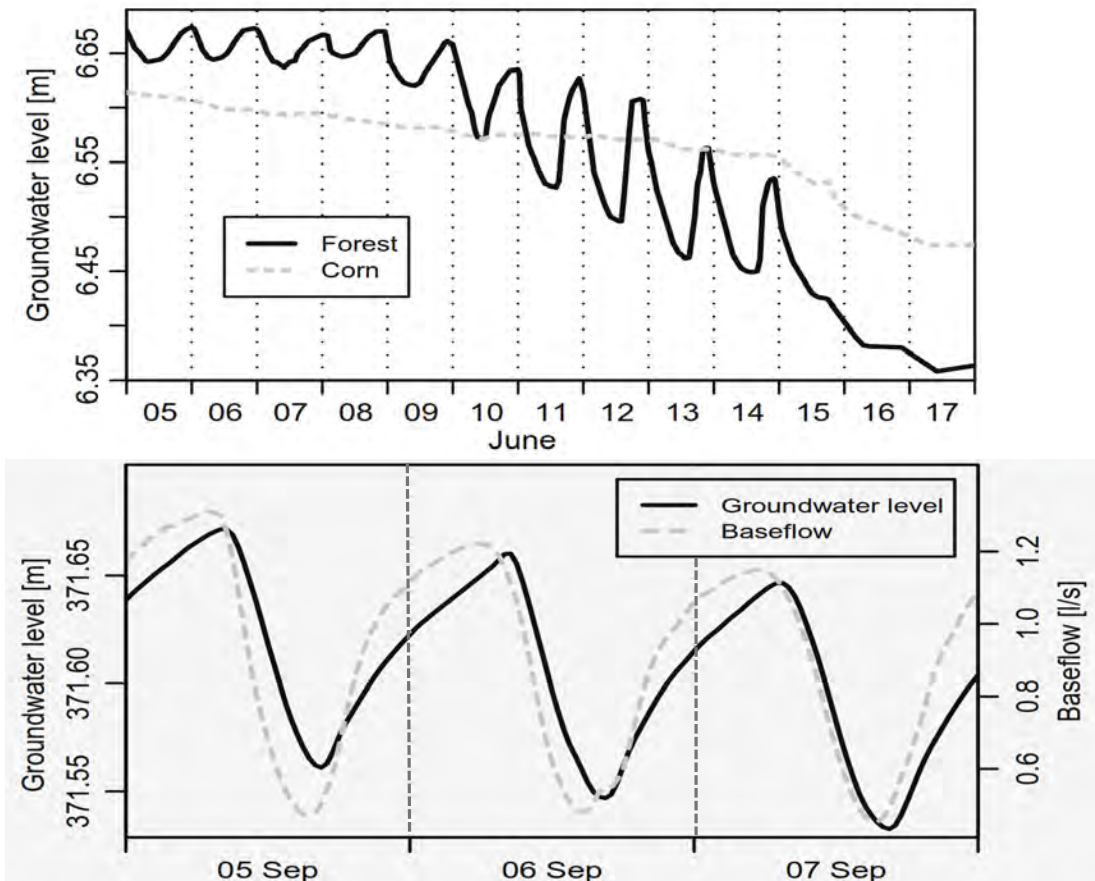


Application in a prospective way - rapid response actions to cliff coast collapses

Collapses by the hour of the day



Seasonal and diurnal groundwater dynamics



A few summarising statements

Environmental seismology provides a highly **scalable** approach to **holistic** Earth surface processes investigation, beyond the proof-of-concept phase, applicable in low energy systems.

Precise **time** and **location** information (across wide process range) and process **anatomy** allows **catchment-wide** studies of **triggers** (drivers) and **interaction**.

Continuous monitoring and almost real time data processing allows **rapid response** actions (event characterisation) and even **early warning** studies (event anticipation).

Environmental seismology can and should become a **standard tool** for Earth surface dynamics research. What are these other researchers looking for? At which (skill, theory,...) level should environmental seismology feed into other disciplines?

Thank you...
slides at www.micha-dietze.de

Acknowledgements to GeoX for the support.