

THE EARTH SURFACE PLAYGROUND

Investigating the processes that shape the Earth - from the past and from the modern perspective

ENVIRONMENTAL
SEISMOLOGY

GRAIN-SIZE DATA
MODELLING

LUMINESCENCE
FRAMEWORK

SUBITOP PROJECT
MANAGEMENT

CURRENT POSITION

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CURRENT TOPICS

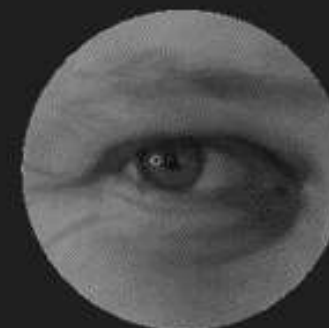
[SUBITOP project management](#)

[Environmental seismology](#)

[Numeric luminescence methods](#)

[Grain-size data handling](#)

A SNAPSHOT



DETECTION, LOCATION, ANATOMIES AND DRIVERS OF ROCKFALLS

INSIGHTS FROM ENVIRONMENTAL SEISMOLOGY

Michael Dietze¹, Jens Turowski¹, Niels Hovius¹

1 - GFZ German Research Centre for Geosciences, Section 5.1 Geomorphology

Rockfalls, rock avalanches, rock slides, landslides?

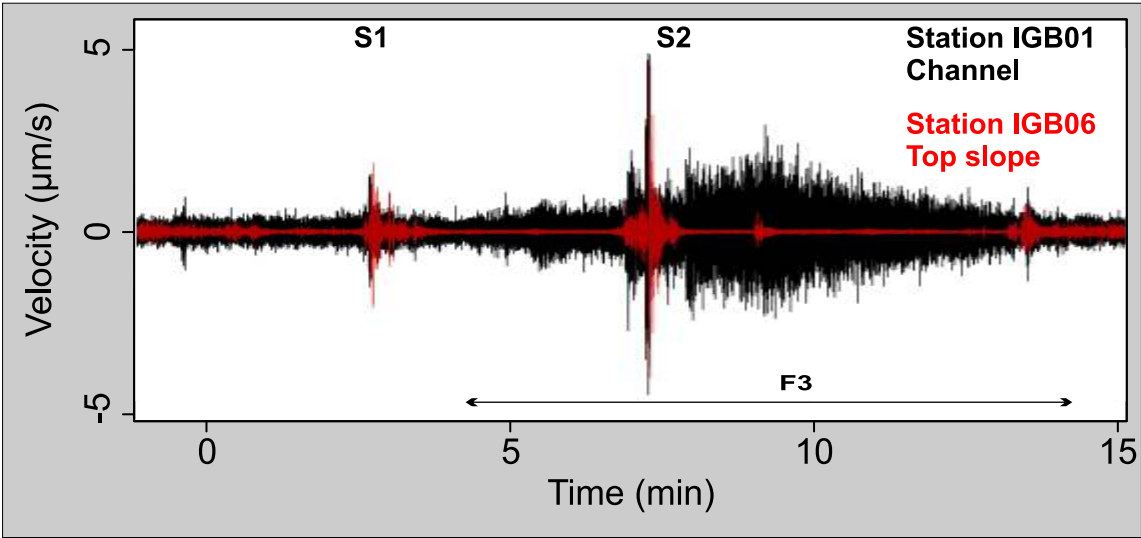


Where? Boundary conditions? Drivers/triggers? Interactions/feedbacks?

When? How long? Coupling/connectivity?

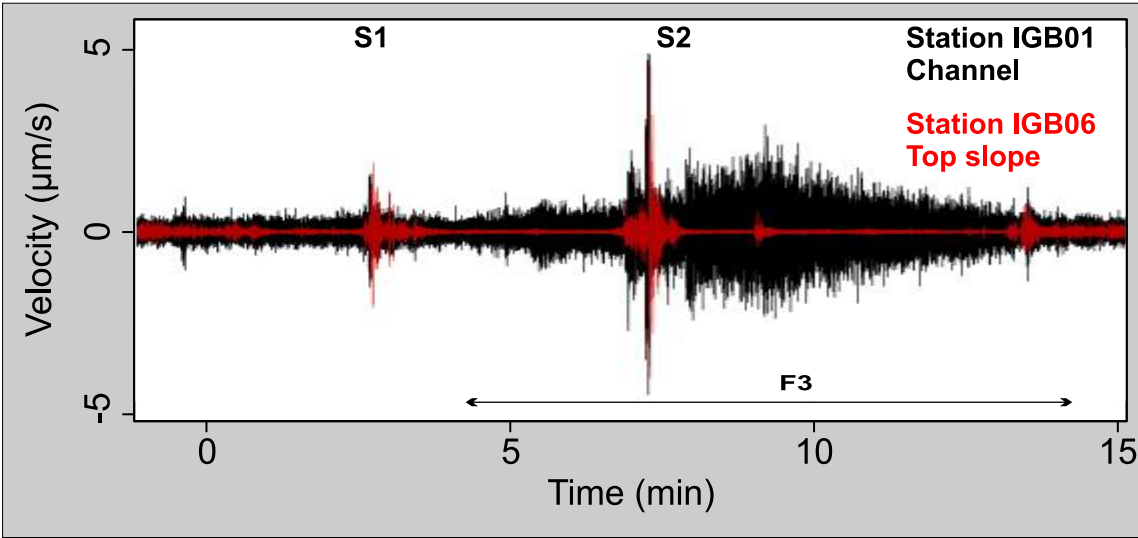
How? How much? Patterns?

Environmental seismology - investigating the signals emitted by Earth surface processes

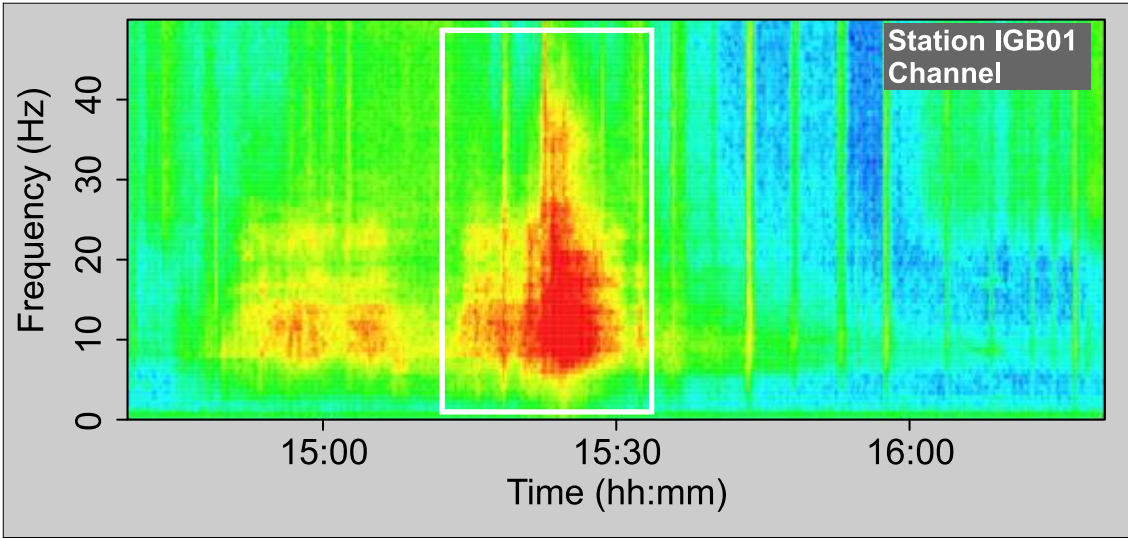


Time series

Environmental seismology - investigating the signals emitted by Earth surface processes

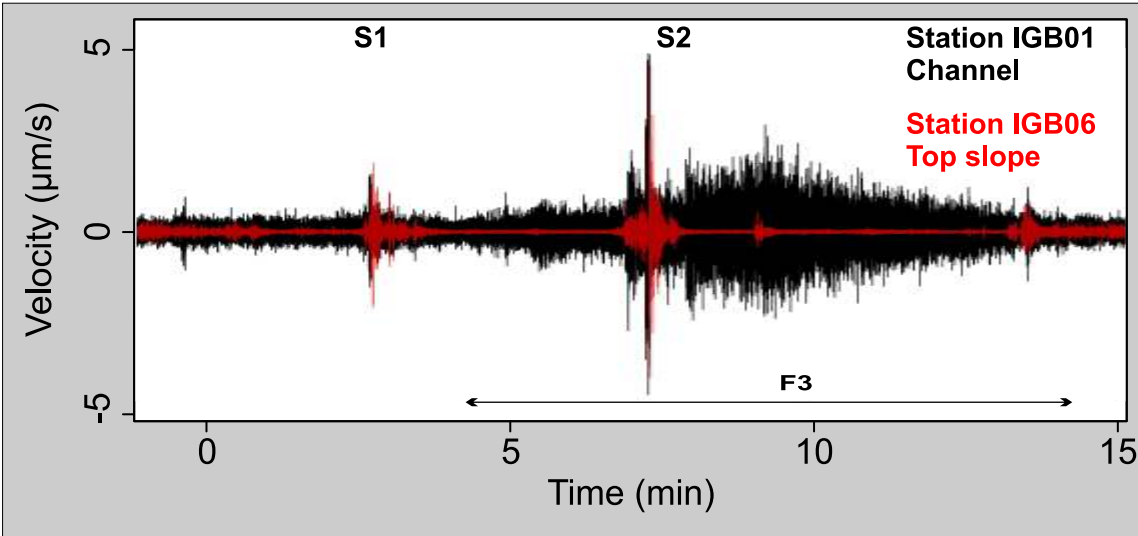


Time series

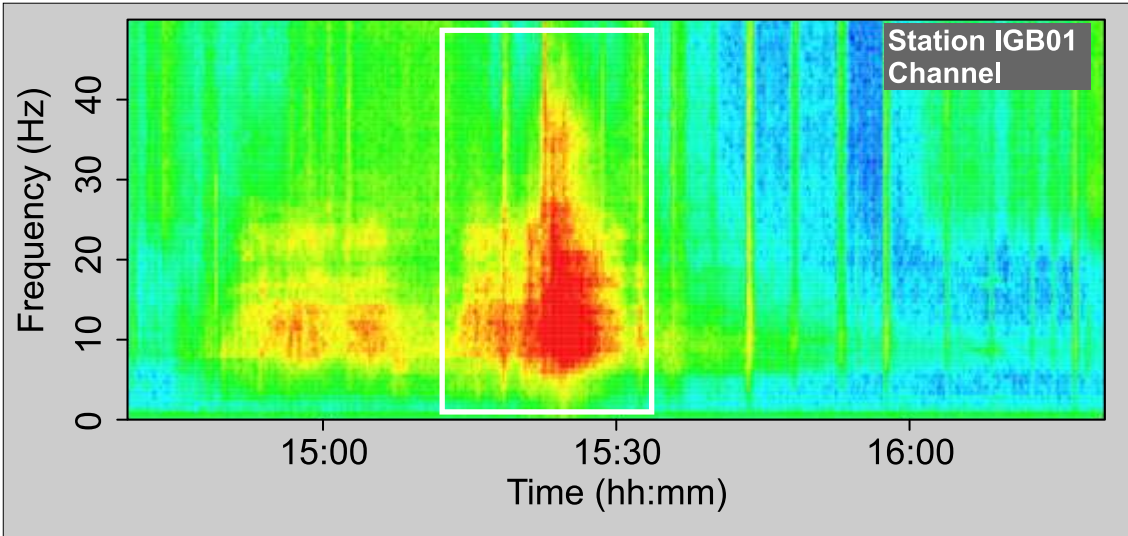


Frequency evolution

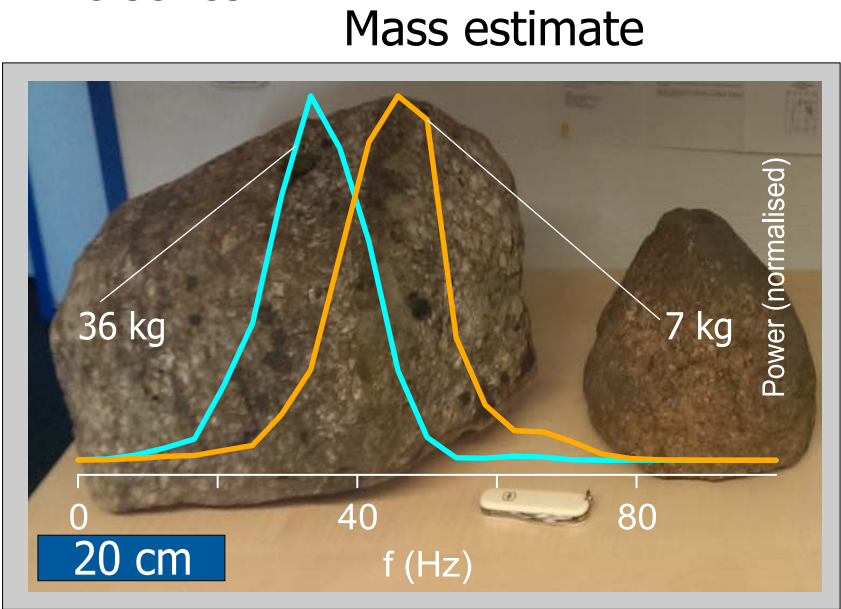
Environmental seismology - investigating the signals emitted by Earth surface processes



Time series

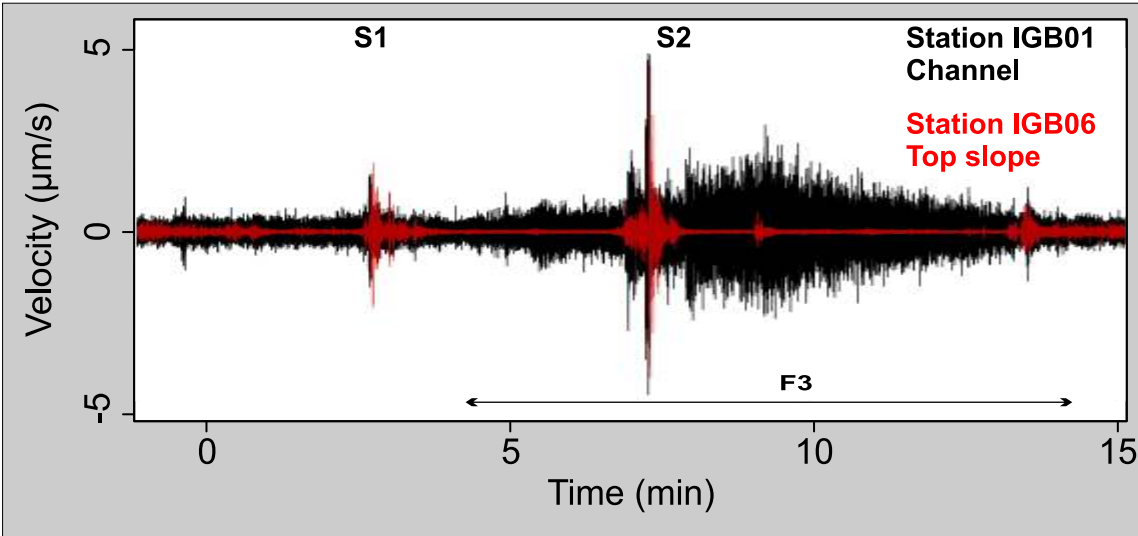


Frequency evolution

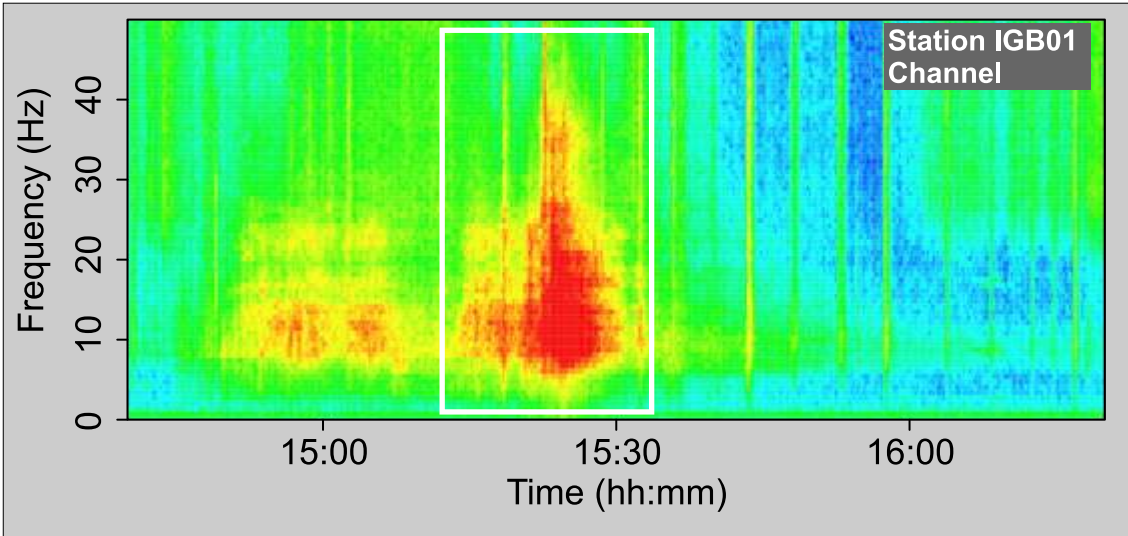


Mass estimate

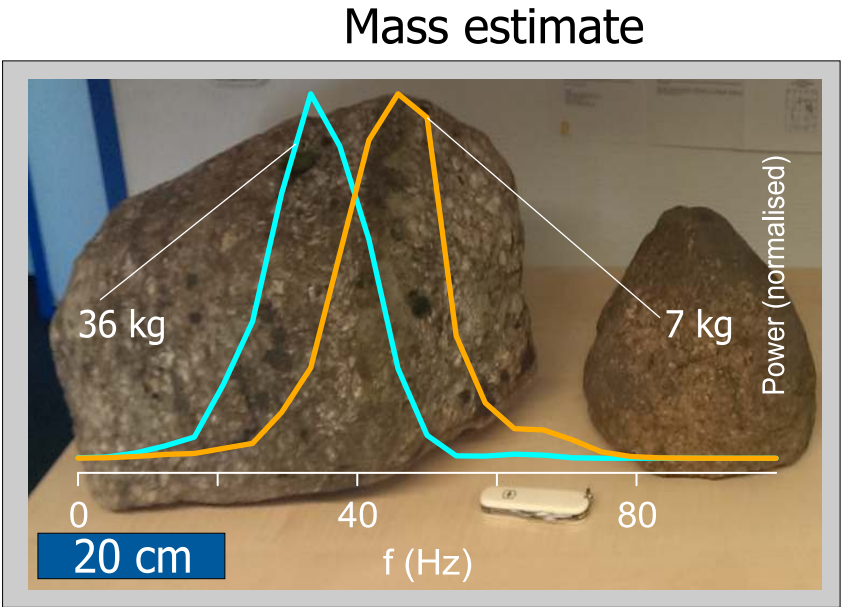
Environmental seismology - investigating the signals emitted by Earth surface processes



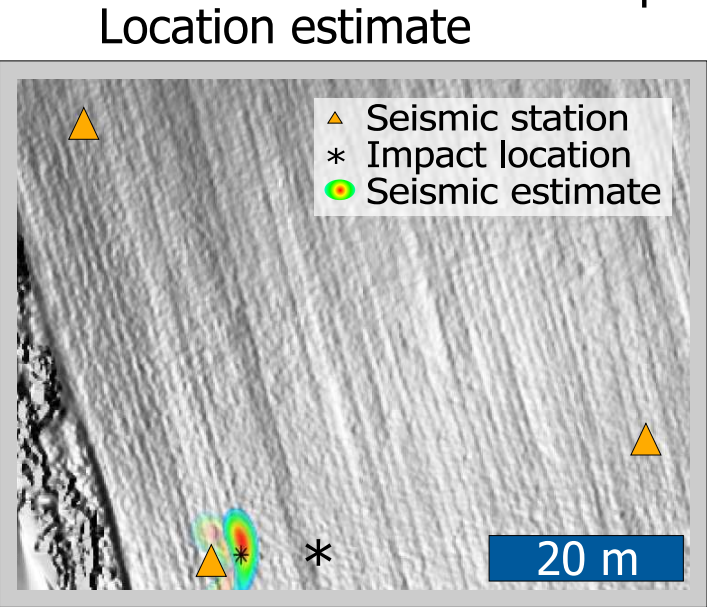
Time series



Frequency evolution

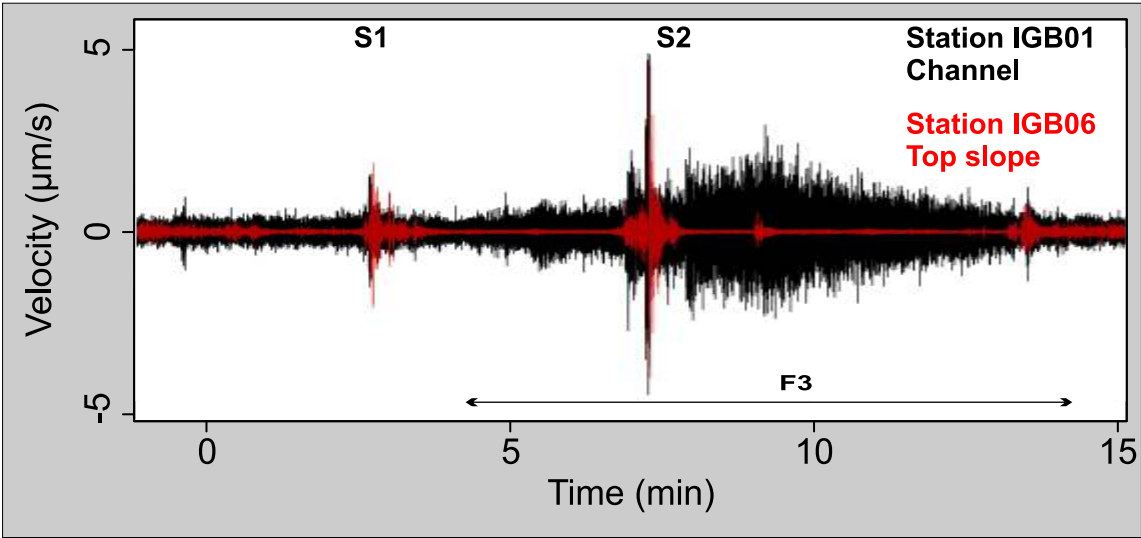


Mass estimate

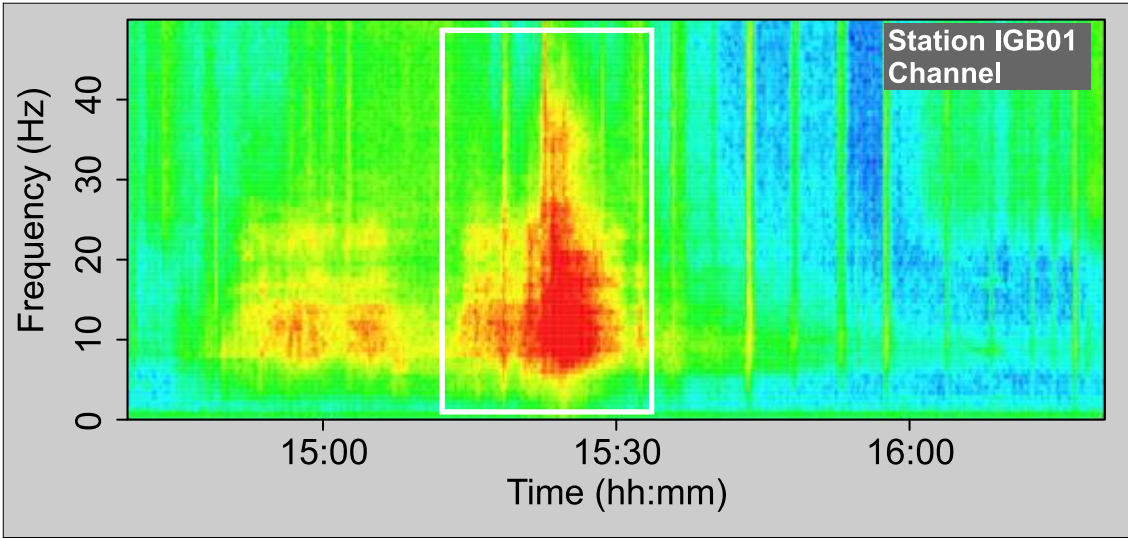


Location estimate

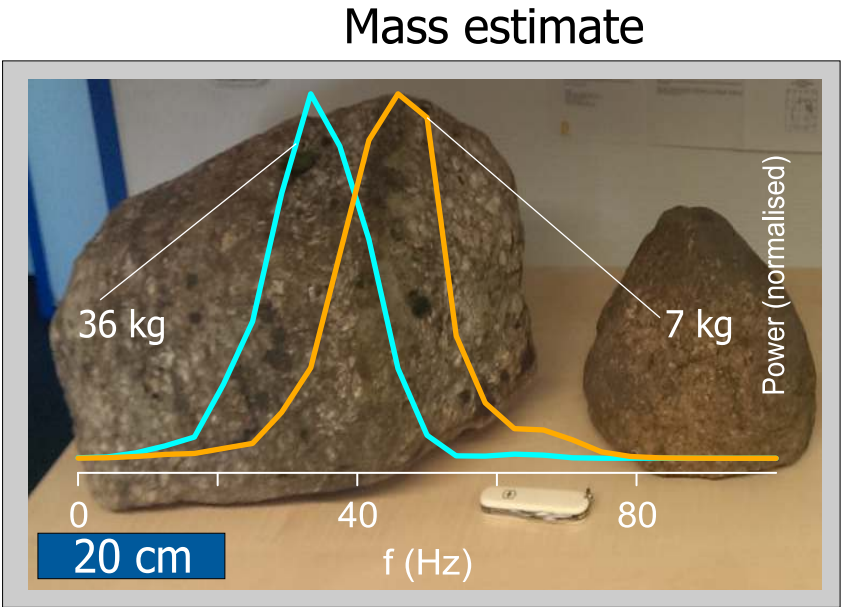
Environmental seismology - investigating the signals emitted by Earth surface processes



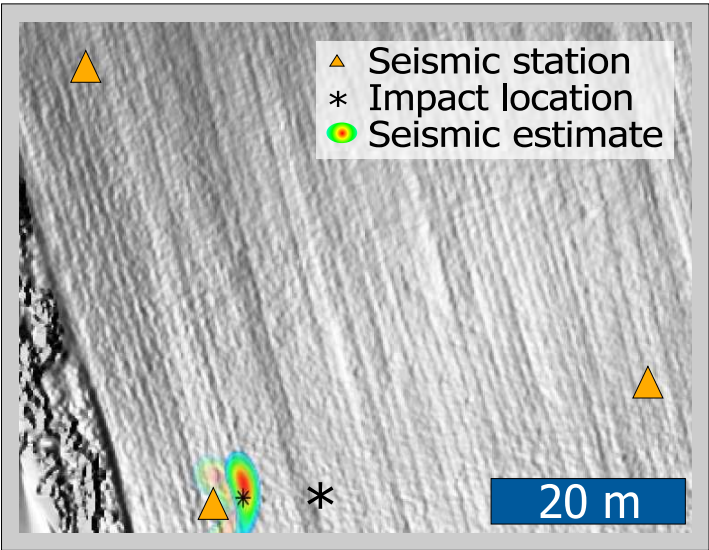
Time series



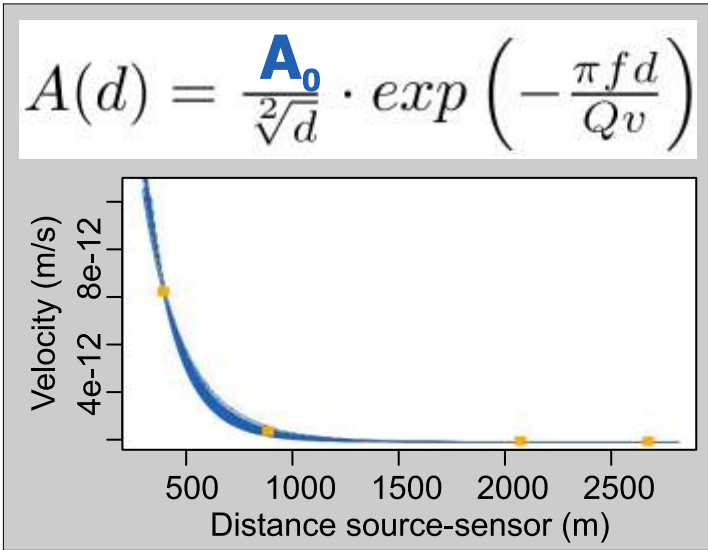
Frequency evolution



Mass estimate

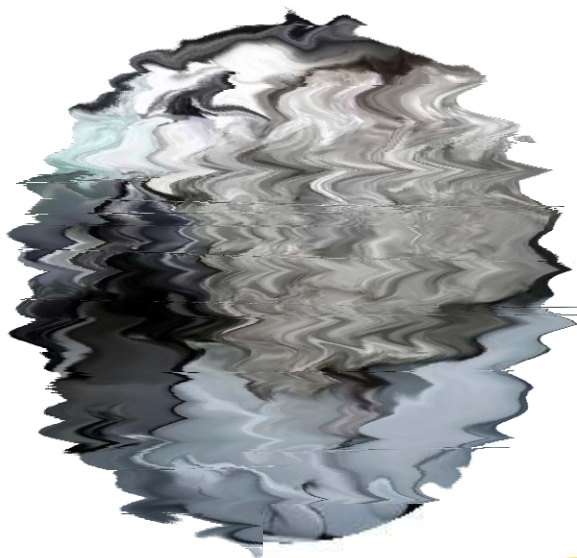


Location estimate



Energy estimate

The scope of this study



Evaluating the potential of environmental seismology to detect rockfalls

How well can seismic methods reproduce lidar-based rockfall events?
What is the lower limit of released volumes that can still be detected?

Insight into individual rockfall events

How do rockfalls initiate and propagate?
What is the range of seismic signatures of rockfalls?



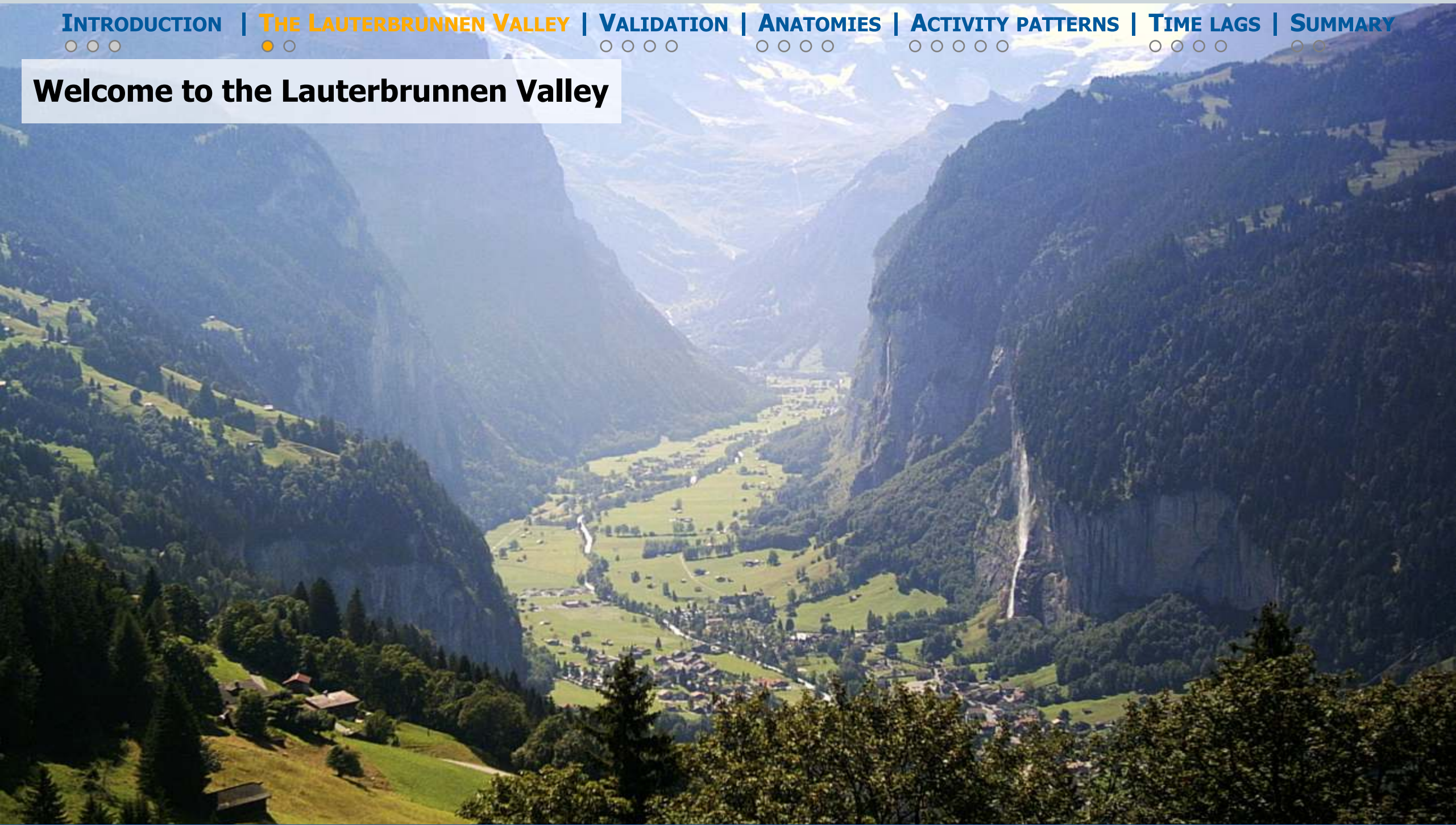
Reveal spatial and temporal patterns of activity

Where do rockfalls occur?
When do rockfalls occur?

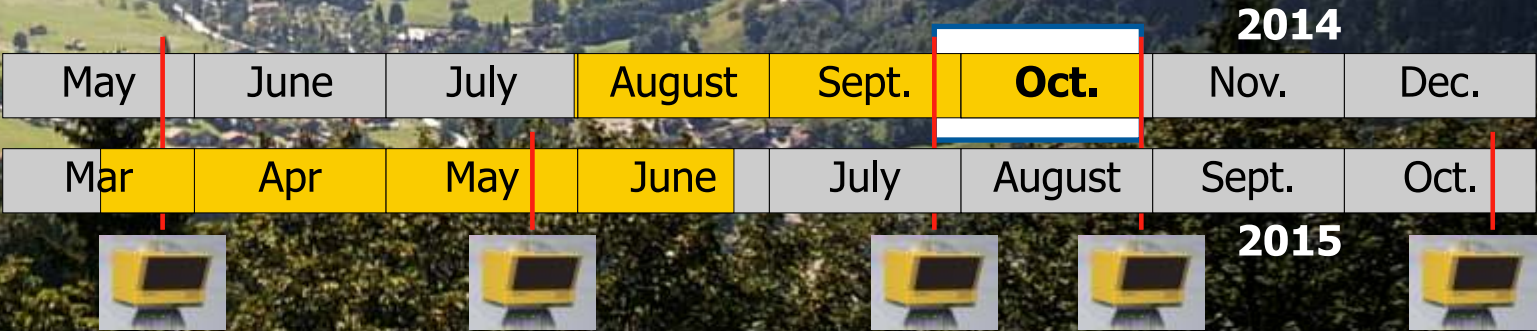
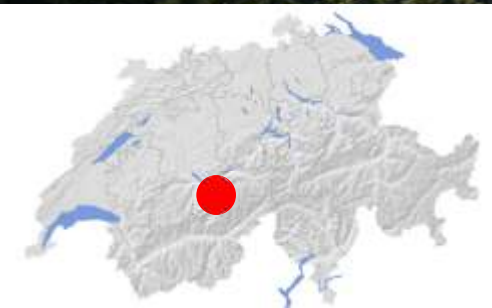
Identify potential drivers of rockfall activity

Which boundary conditions lead to rockfalls?

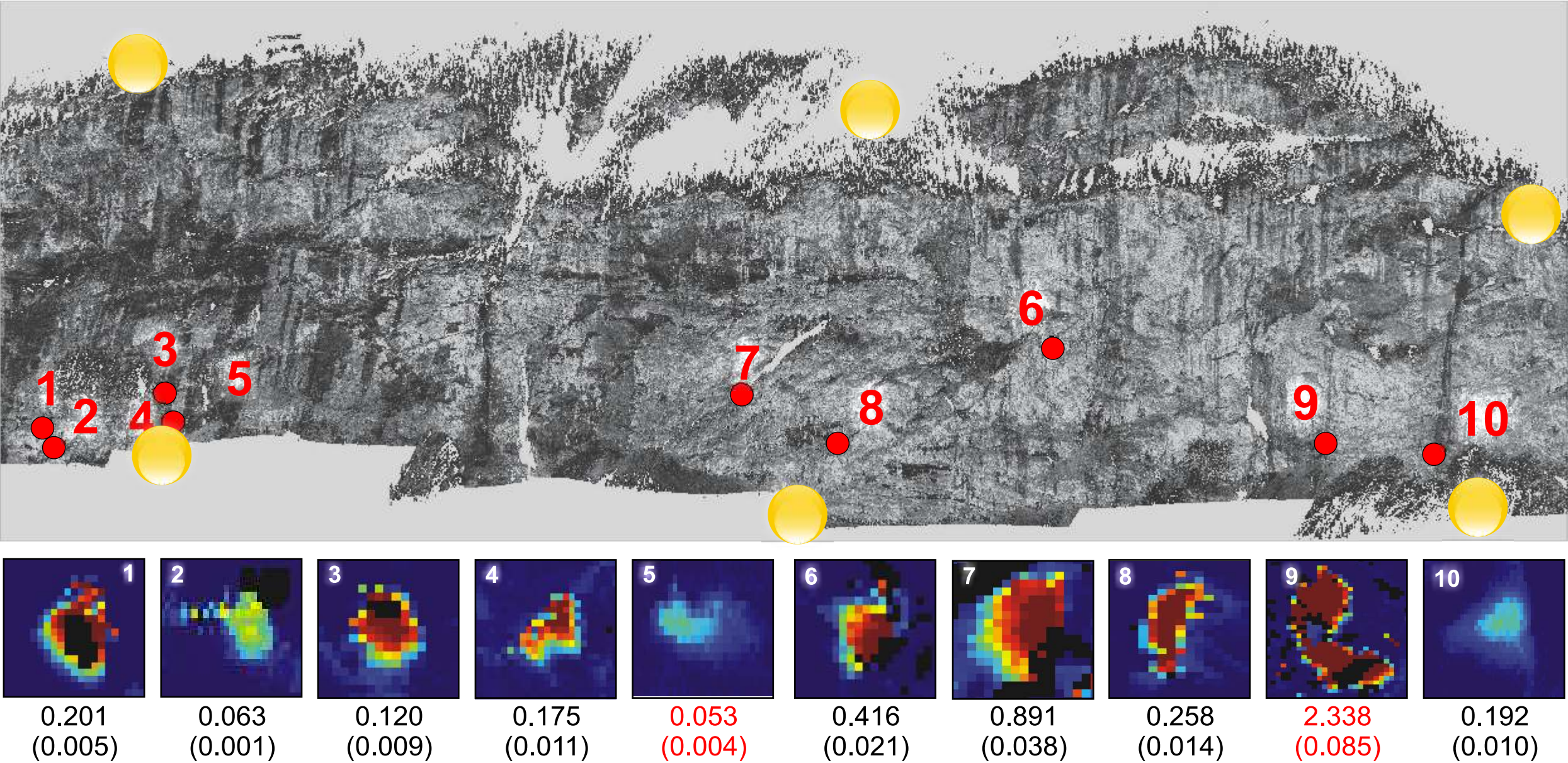
Welcome to the Lauterbrunnen Valley



Welcome to the Lauterbrunnen Valley



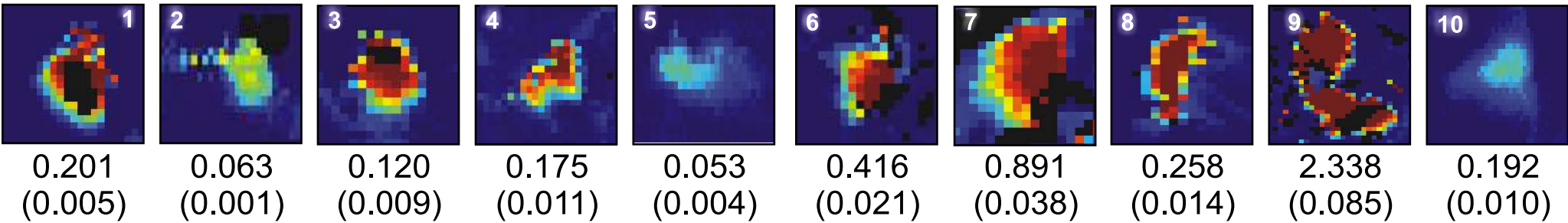
Lidar scans as reference for location and volume (22 September - 28 October 2014)



GFZ Volume (m³) and uncertainty in brackets

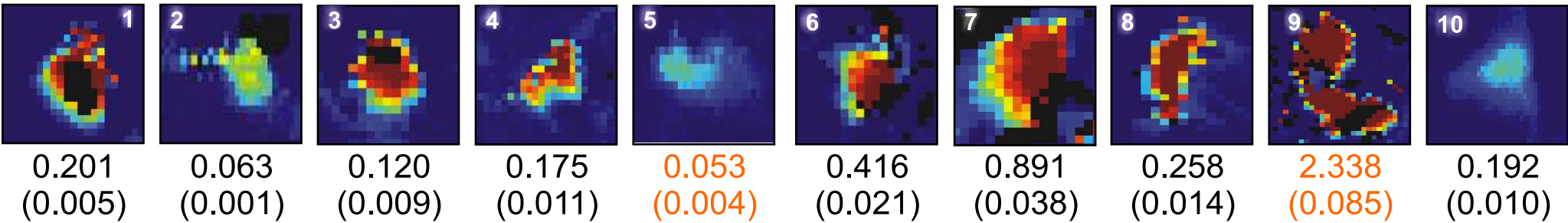
Results - seismic detection and localisation of rockfalls

Lidar-detected rockfall events

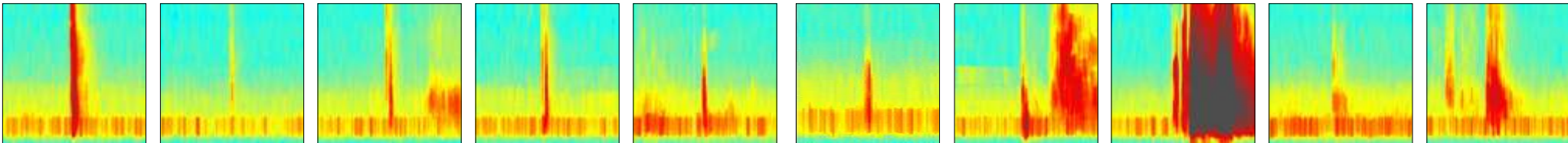


Results - seismic detection and localisation of rockfalls

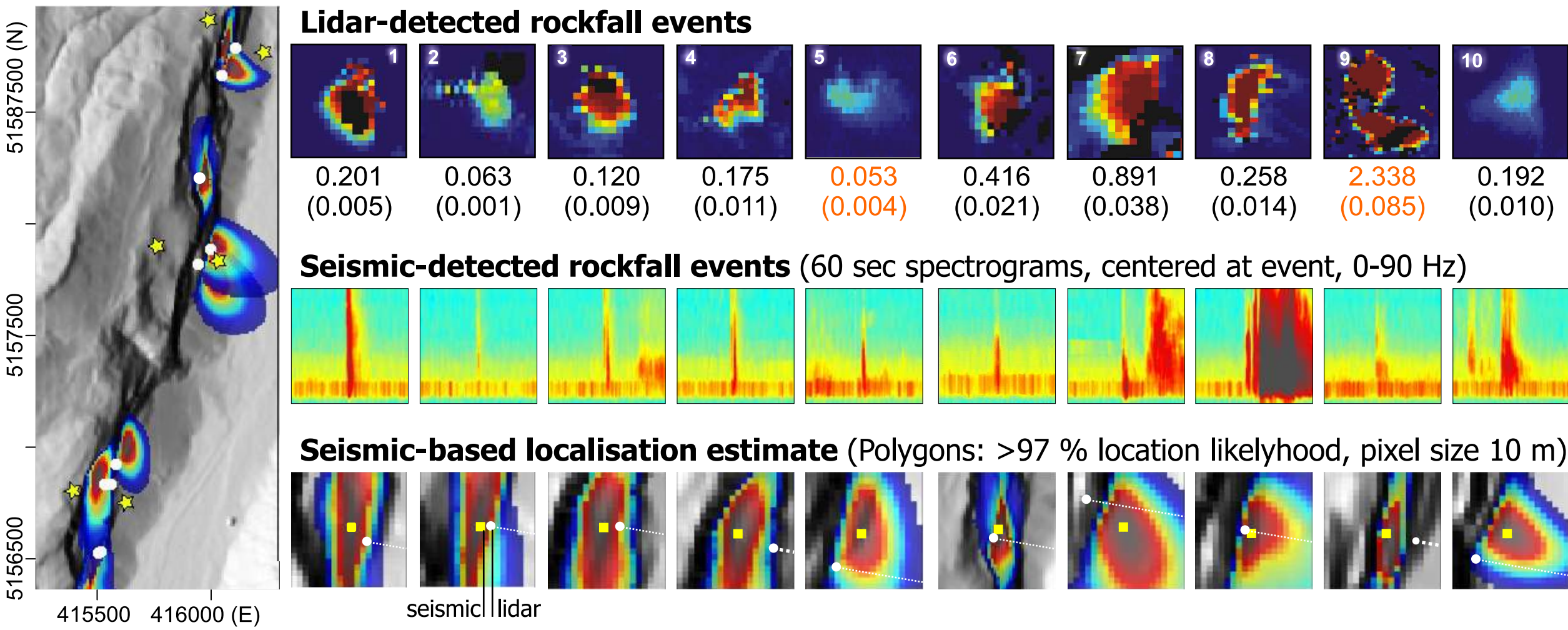
Lidar-detected rockfall events



Seismic-detected rockfall events (60 sec spectrograms, centered at event, 0-90 Hz)



Results - seismic detection and localisation of rockfalls



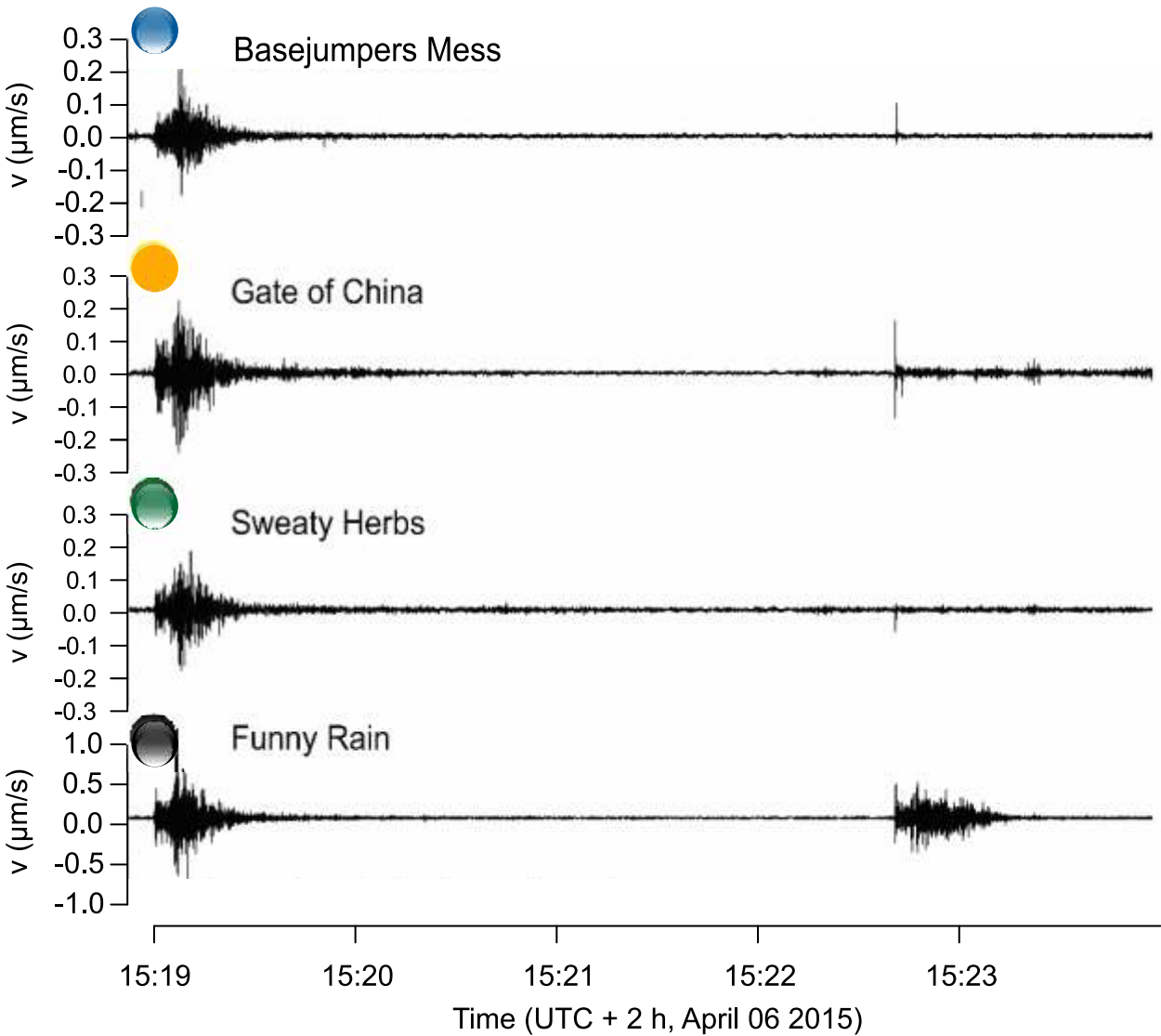
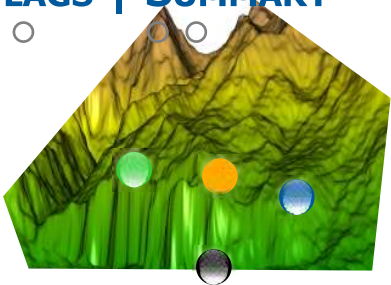
Ten out of ten control events located

Average horizontal deviation: 81 (+59/−29) m

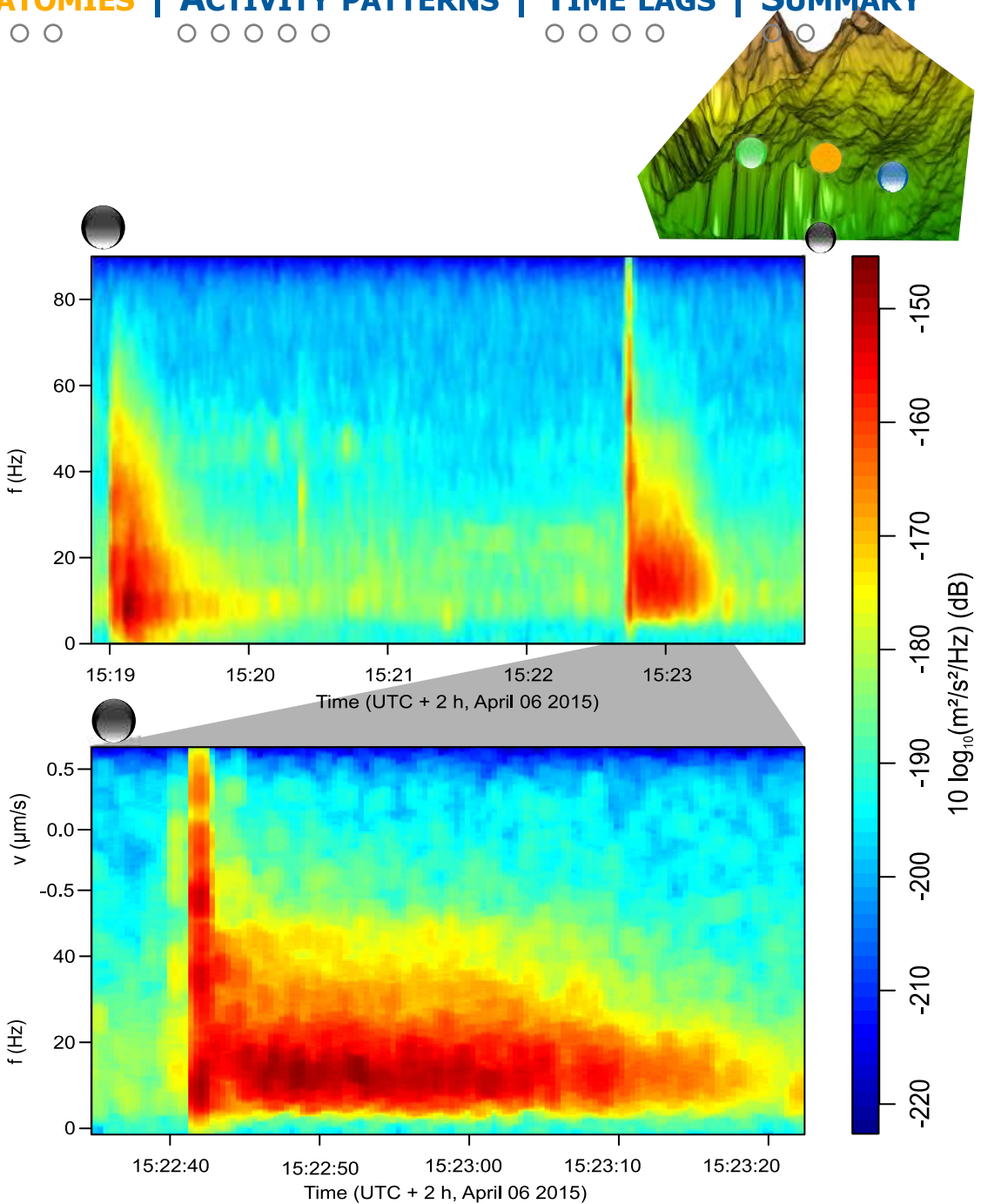
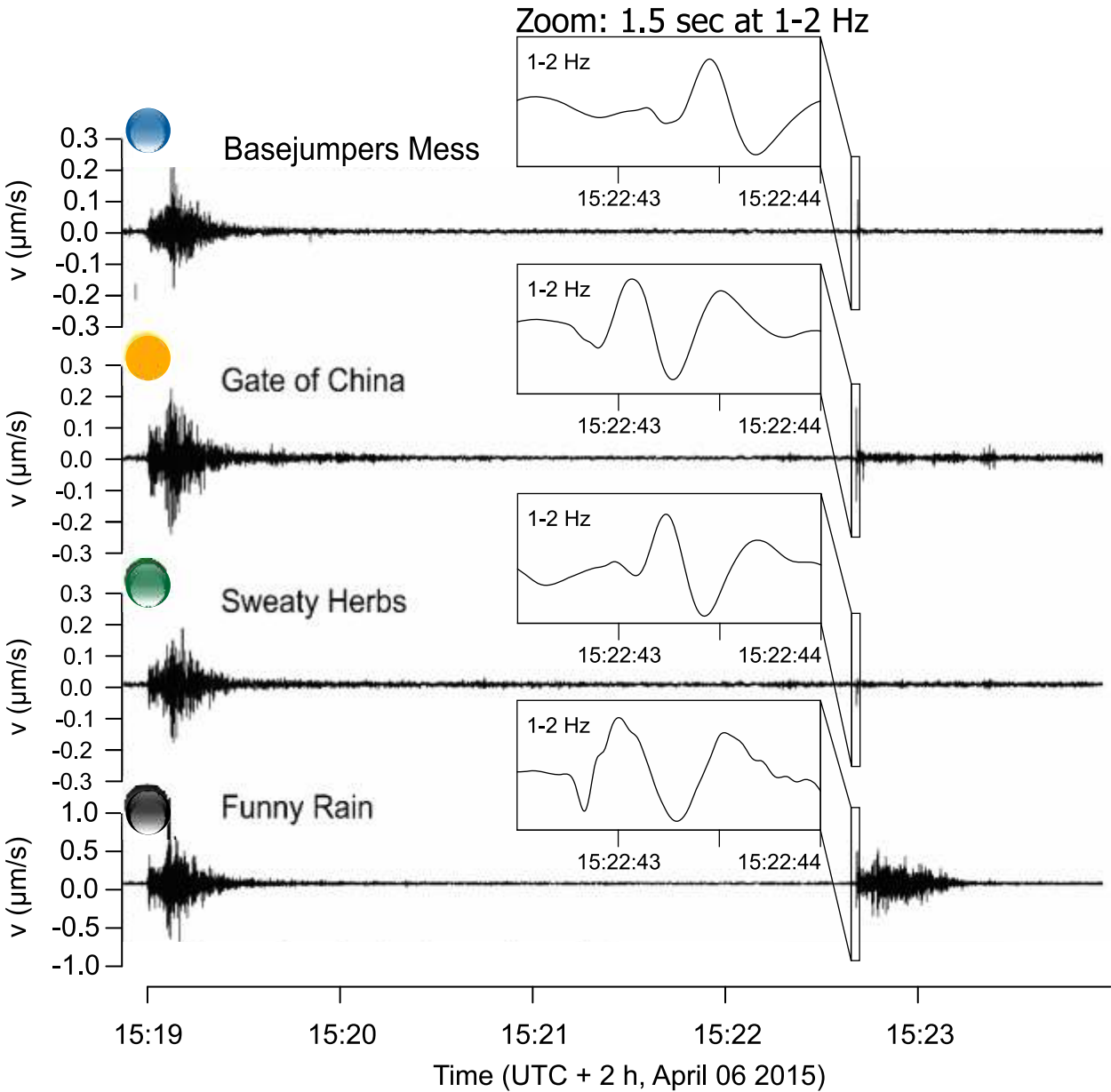
Limitations

- Equivocality for close-by events
- No linkage of volume and energy

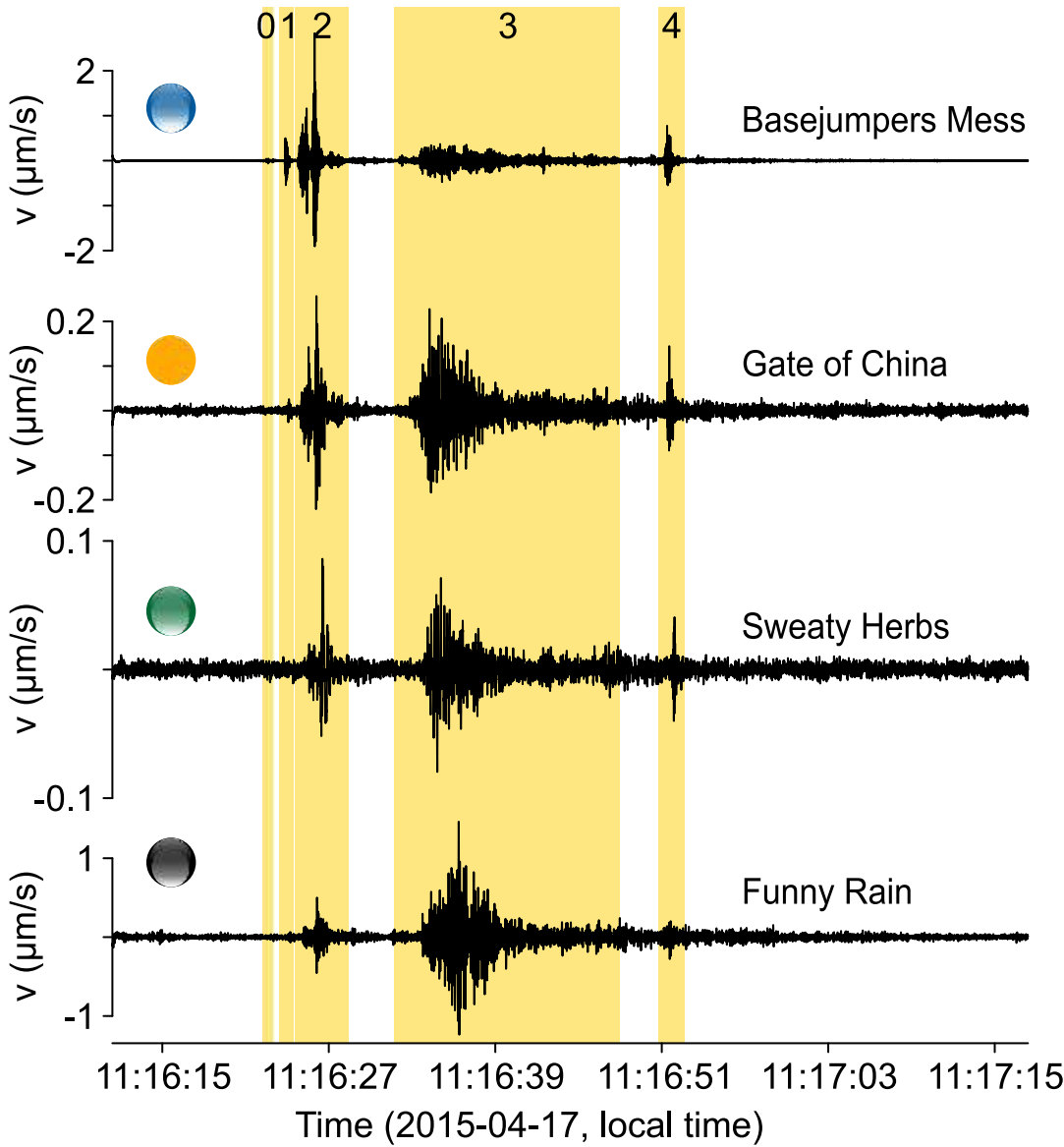
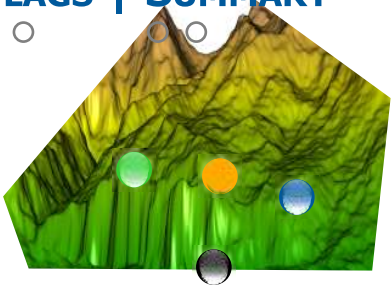
Seismic insights to rockfall evolutions - Example I



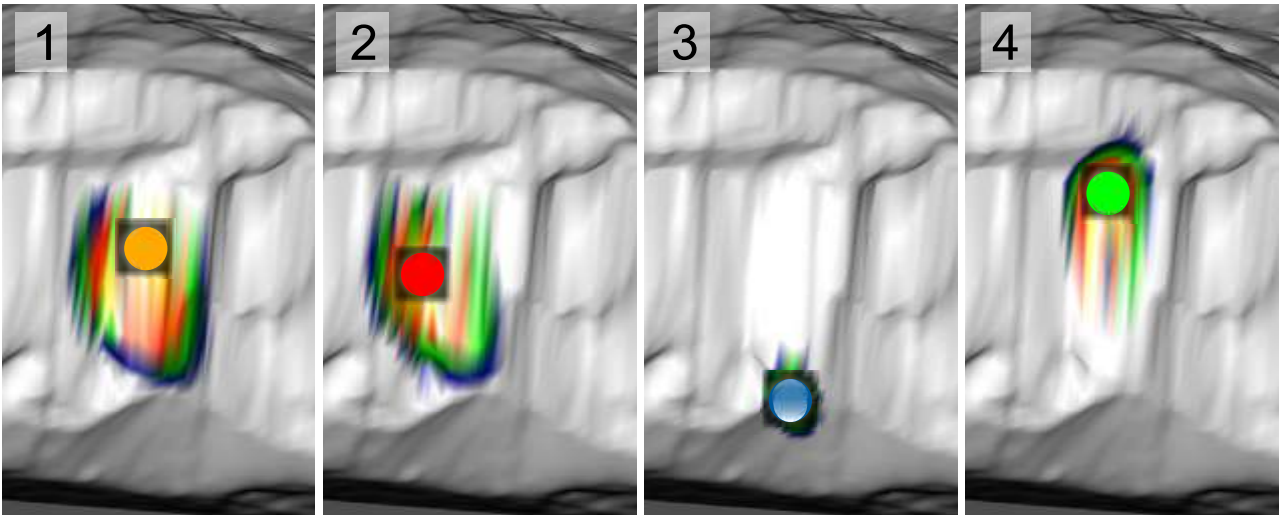
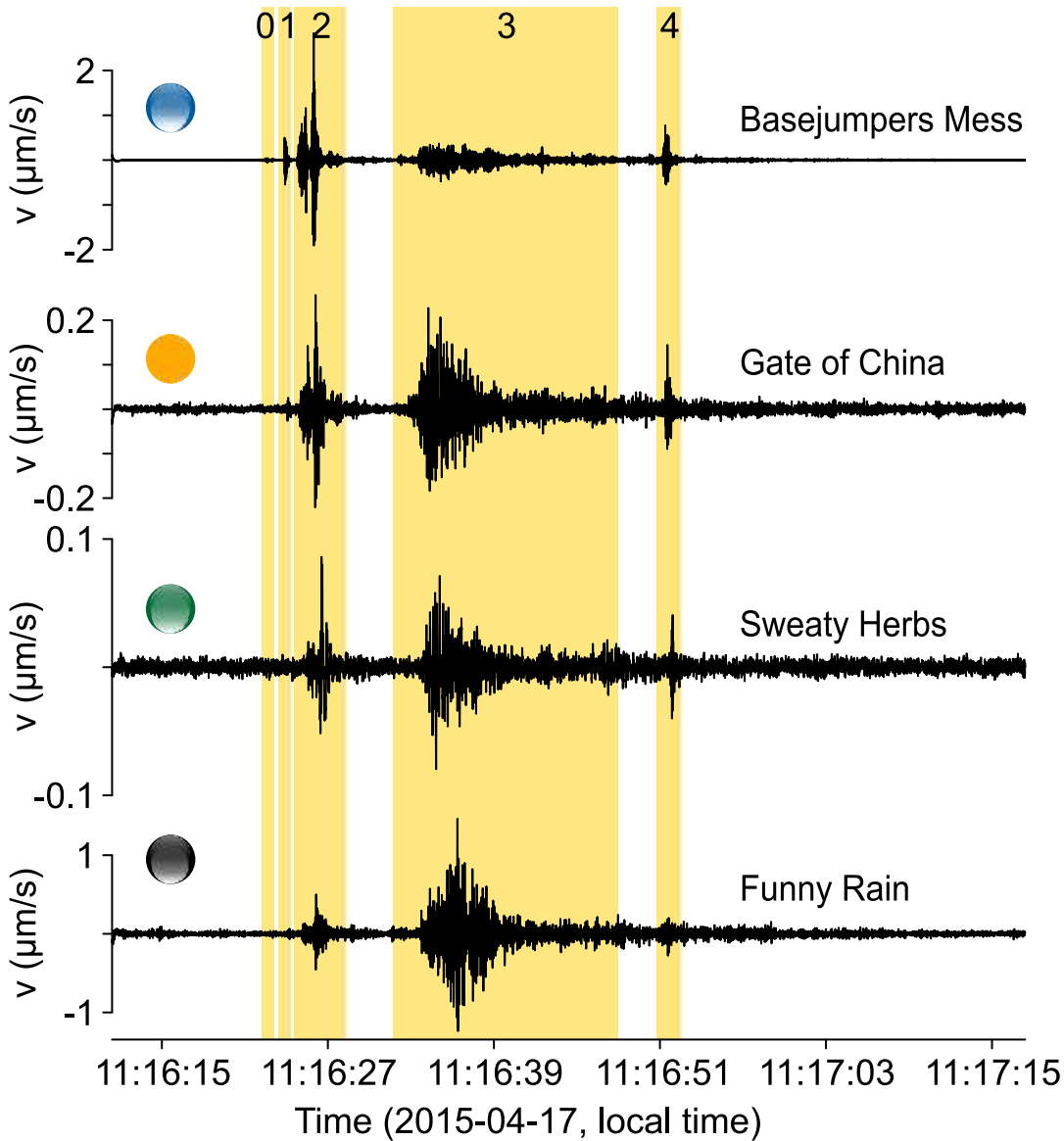
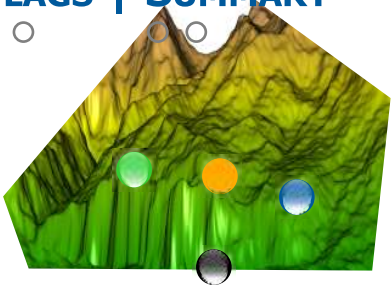
Seismic insights to rockfall evolutions - Example I



Seismic insights to rockfall evolutions - Example II



Seismic insights to rockfall evolutions - Example II

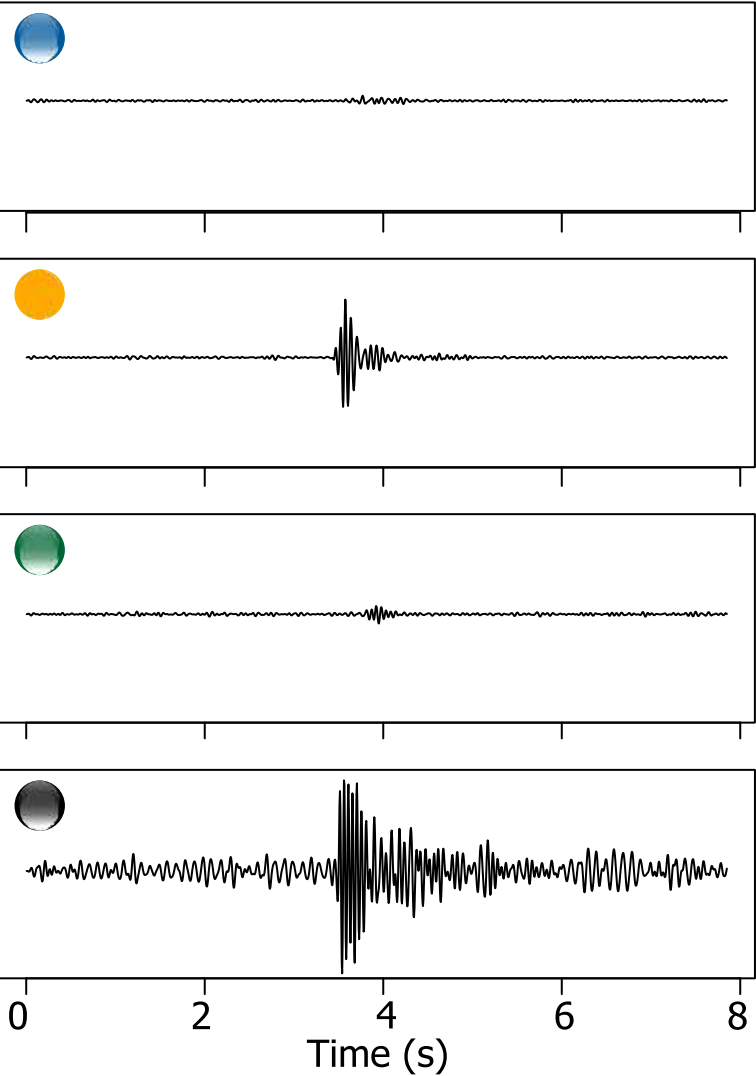


ID	t _{start}	z _{seis} (m)	Δz _{seis} (m)	Δz _g (m)
1	24.4	1184	--	--
2	25.4	1176	8	5
3	32.5	942	234	226
4	51.8	1344	--	--

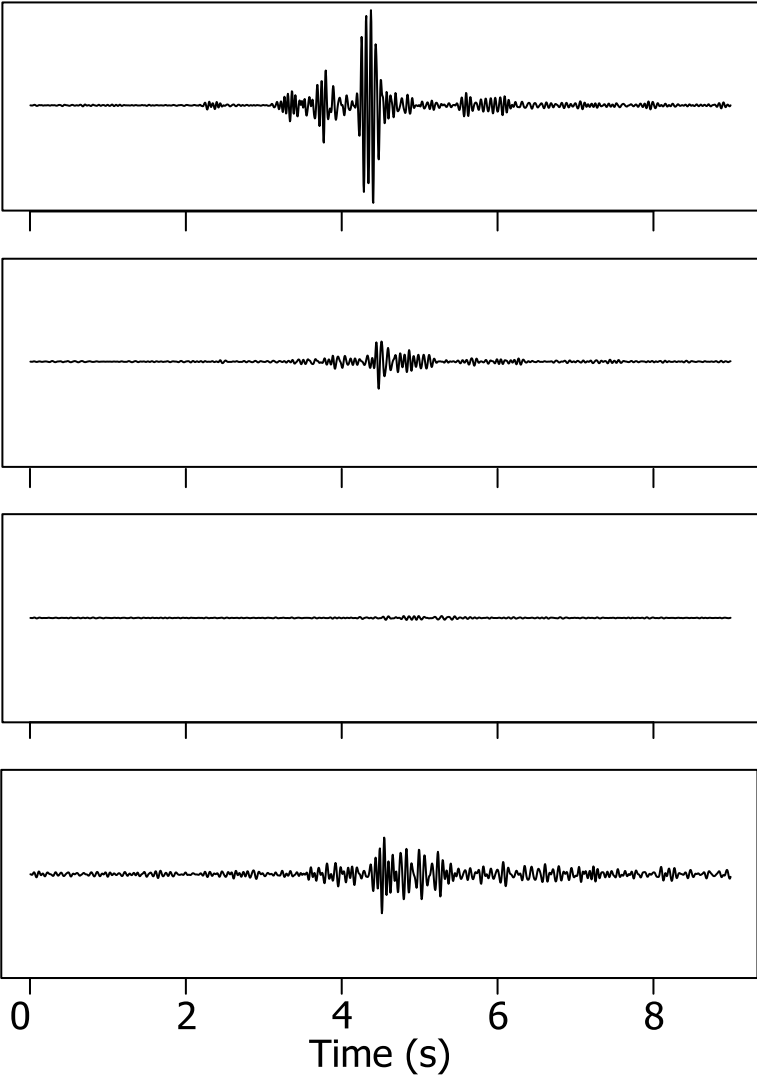
Seismic insights to rockfall evolutions - a synoptic summary



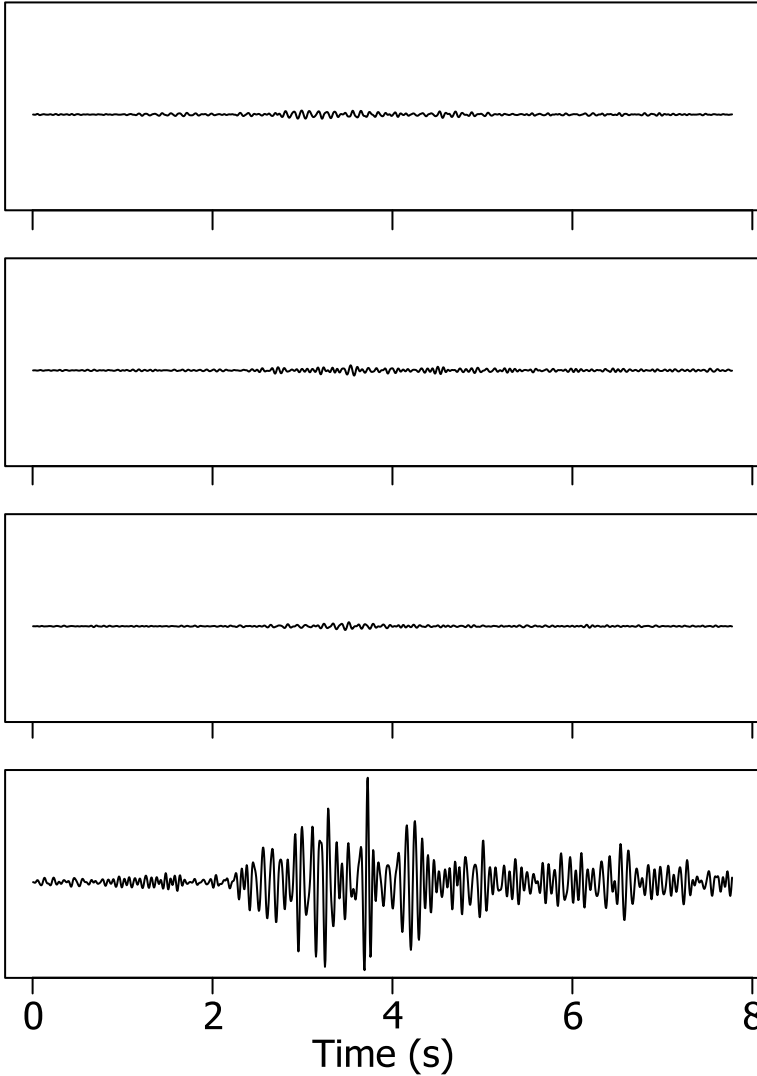
Single impact (39 %)



Multiple impacts (39 %)

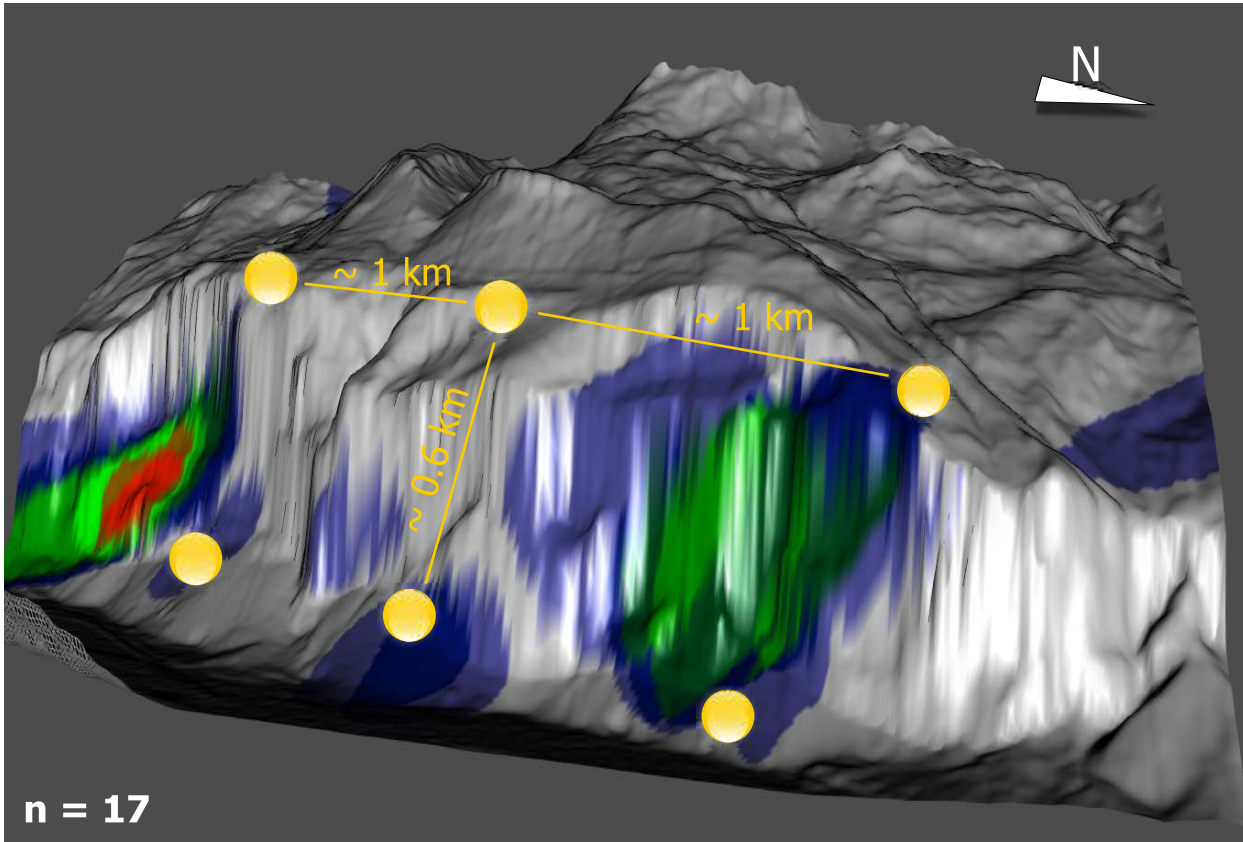


Avalanche-like (22 %)

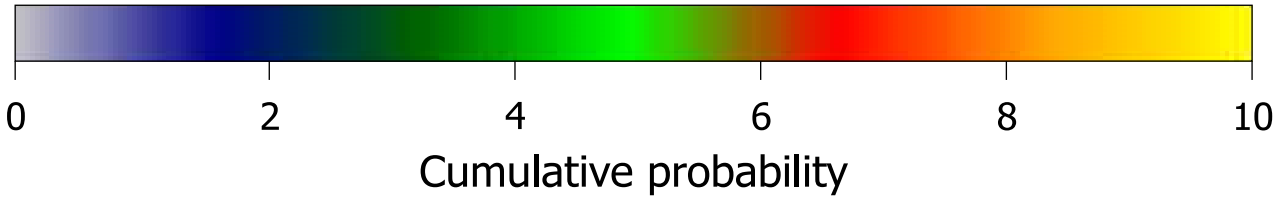
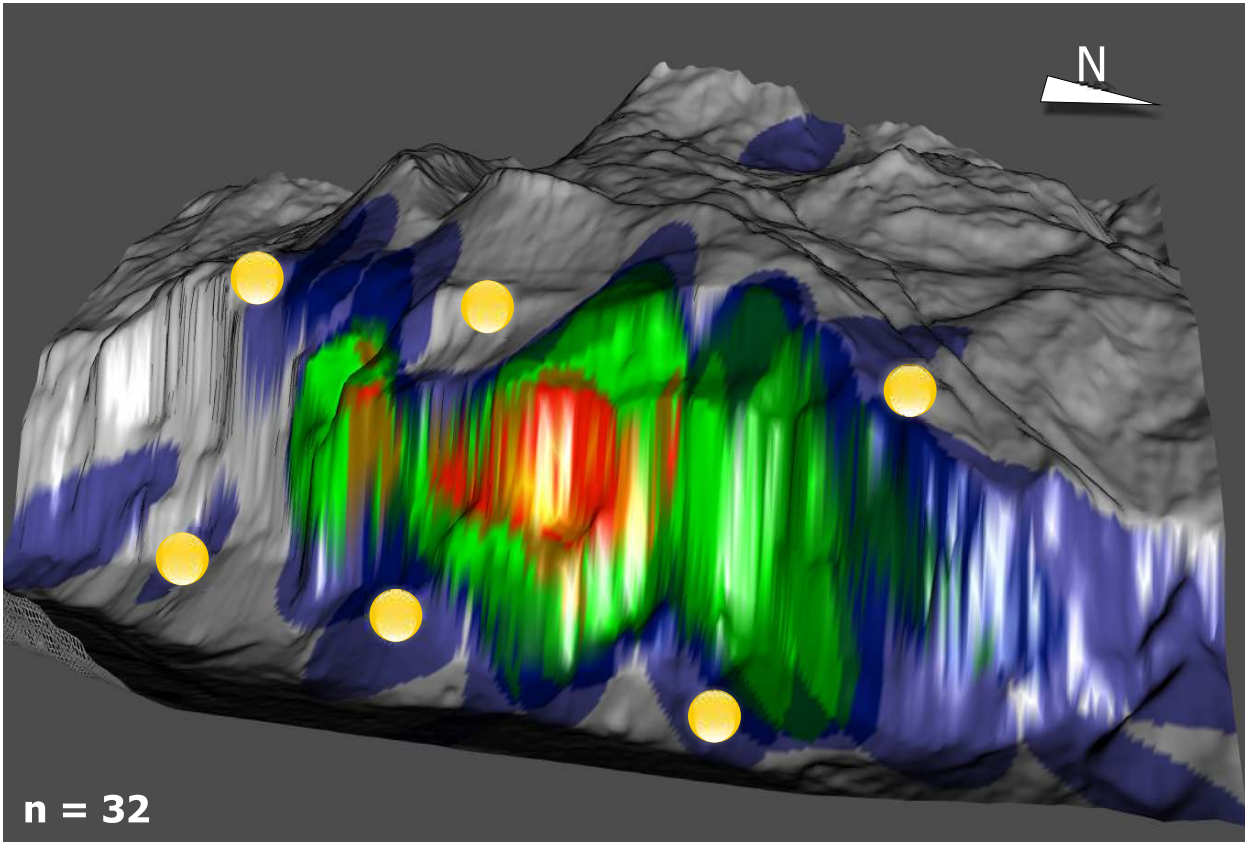


Spatial patterns of rockfall activity

2014 (August-October)

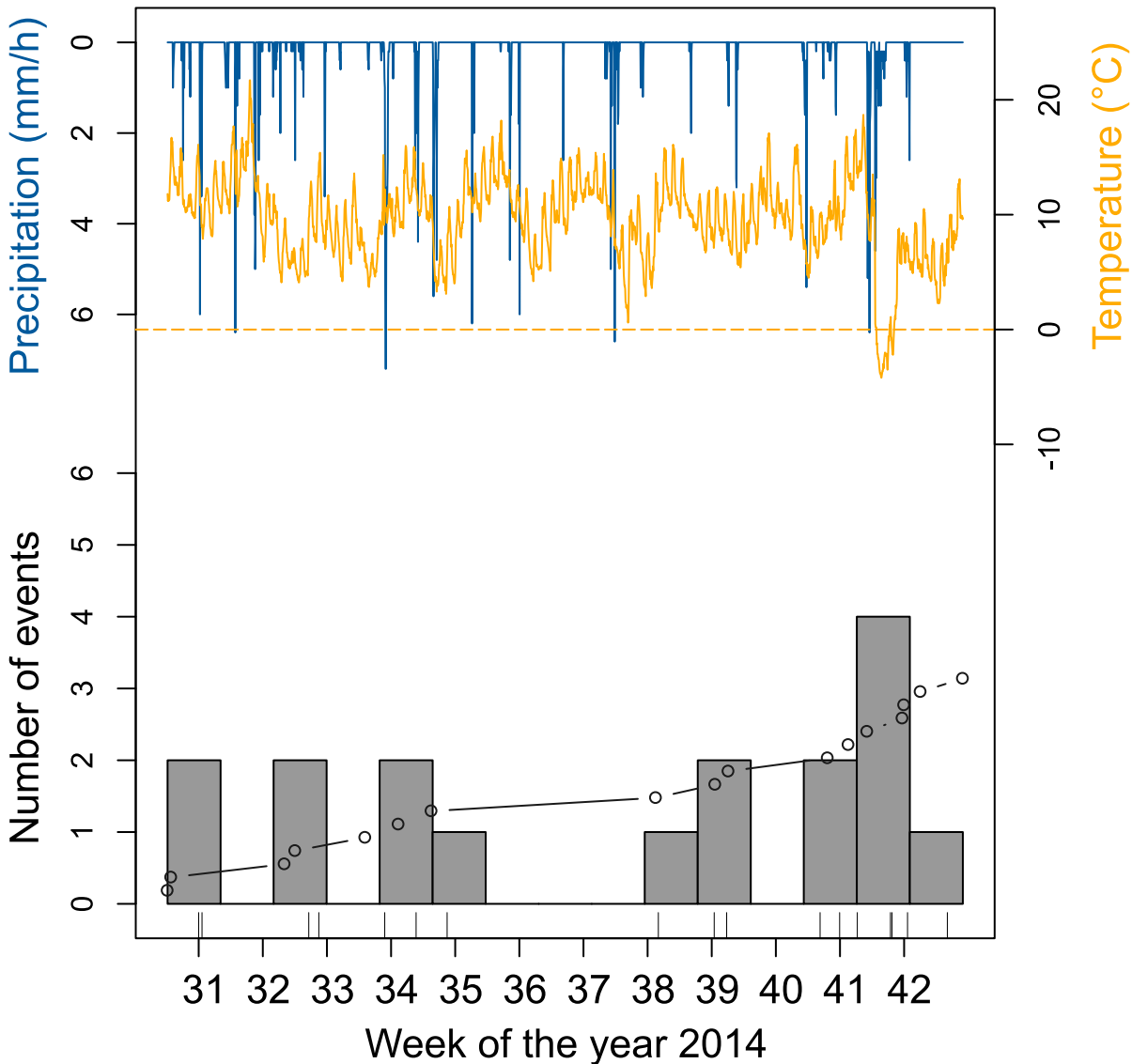


2015 (March-June)

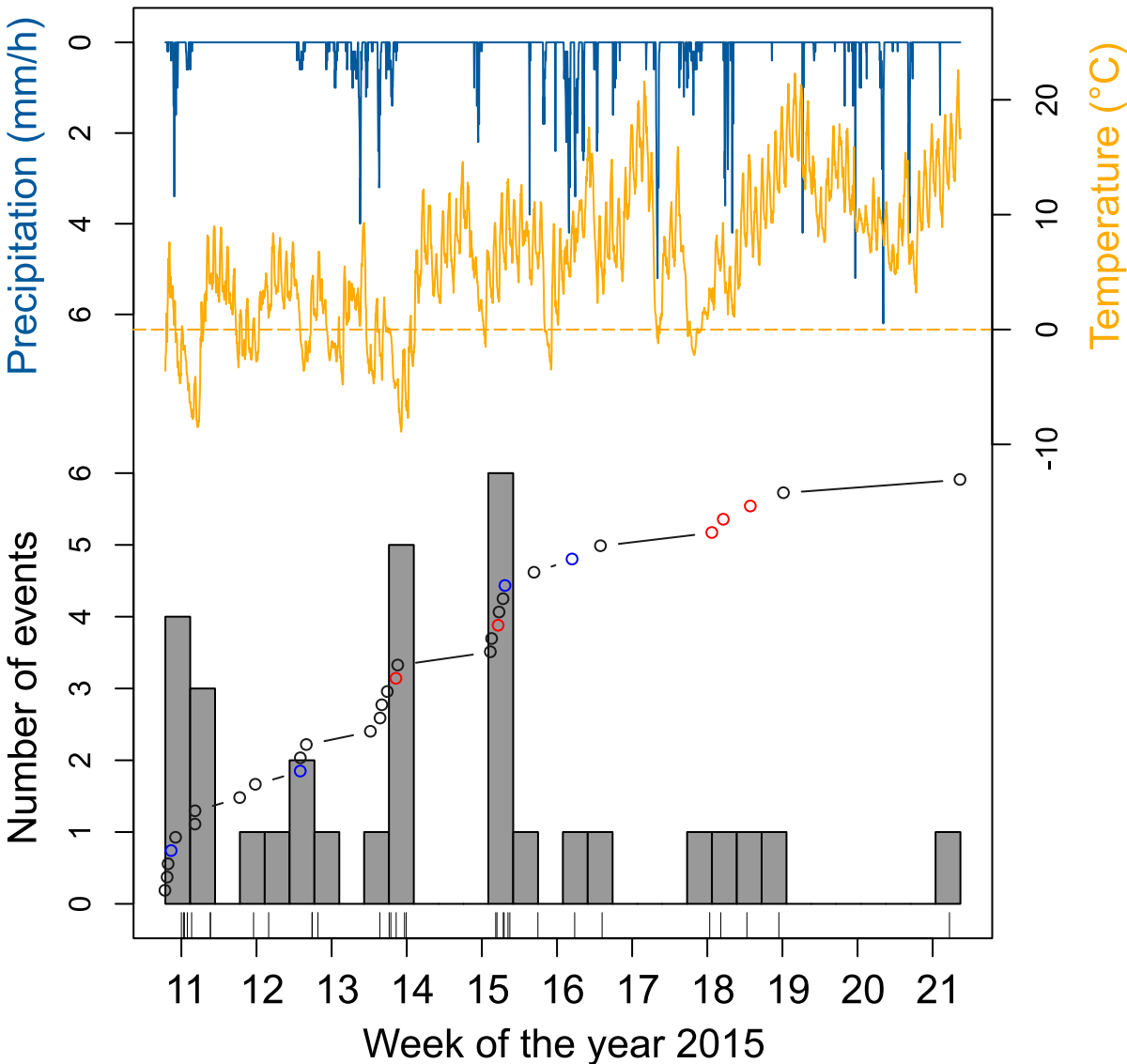


Temporal patterns of rockfall activity

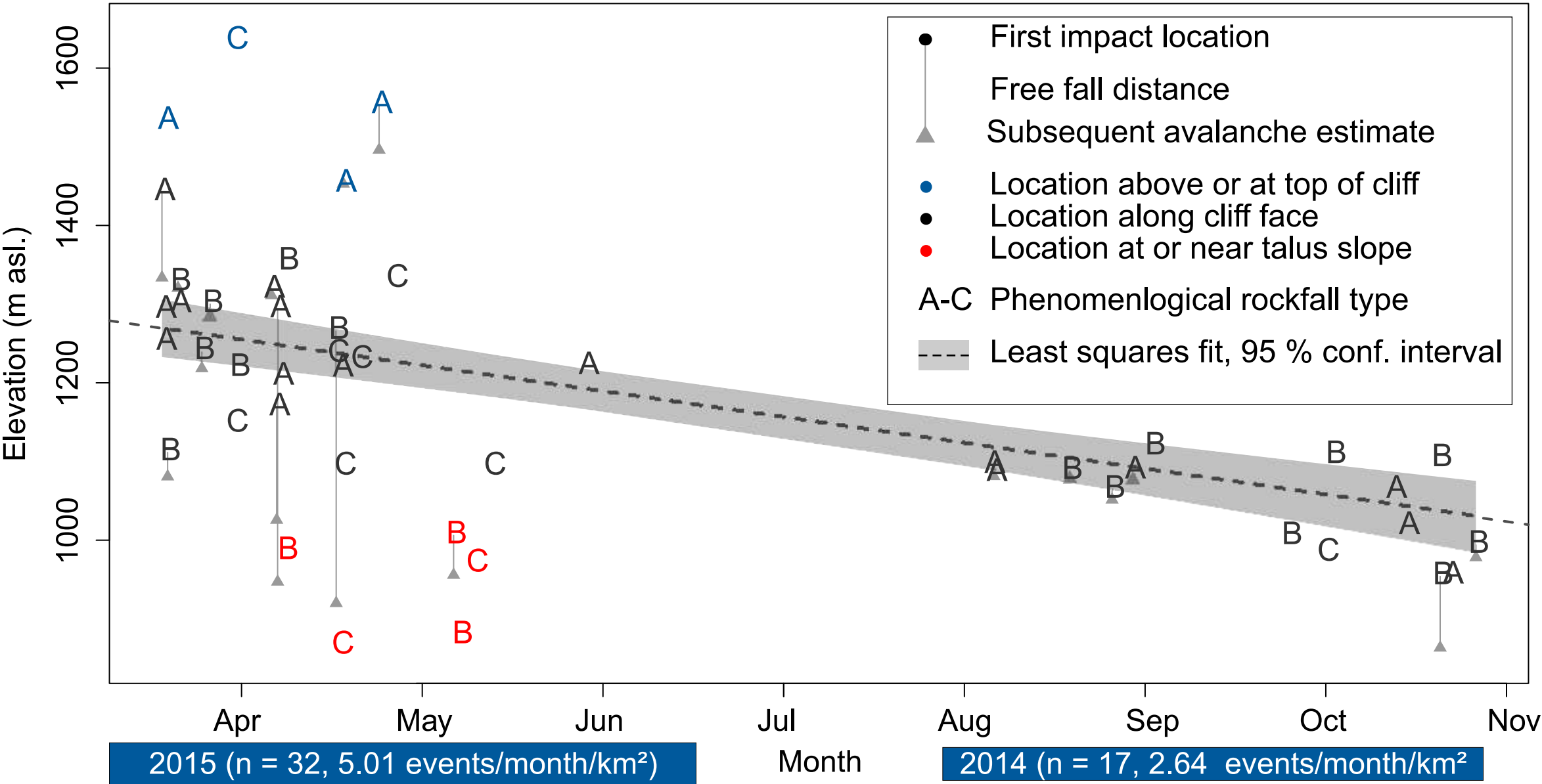
2014 (August-October)



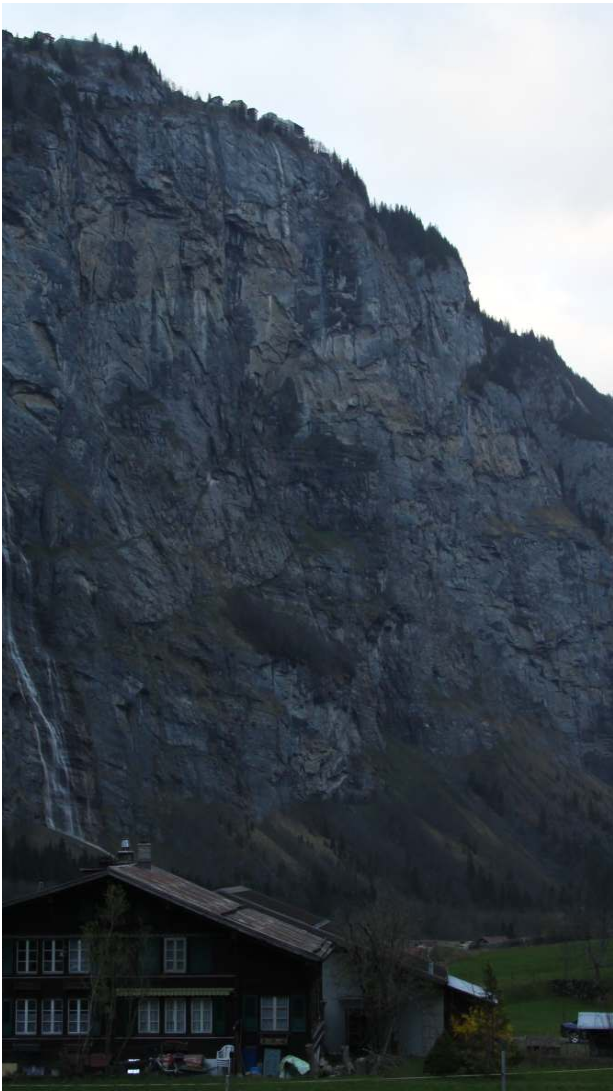
2015 (March-June)



Linking time and space - rockfall activity altitude shifts with the season



Linking time and space - rockfall activity altitude shifts with the season



7 am (April 2014)



8 am

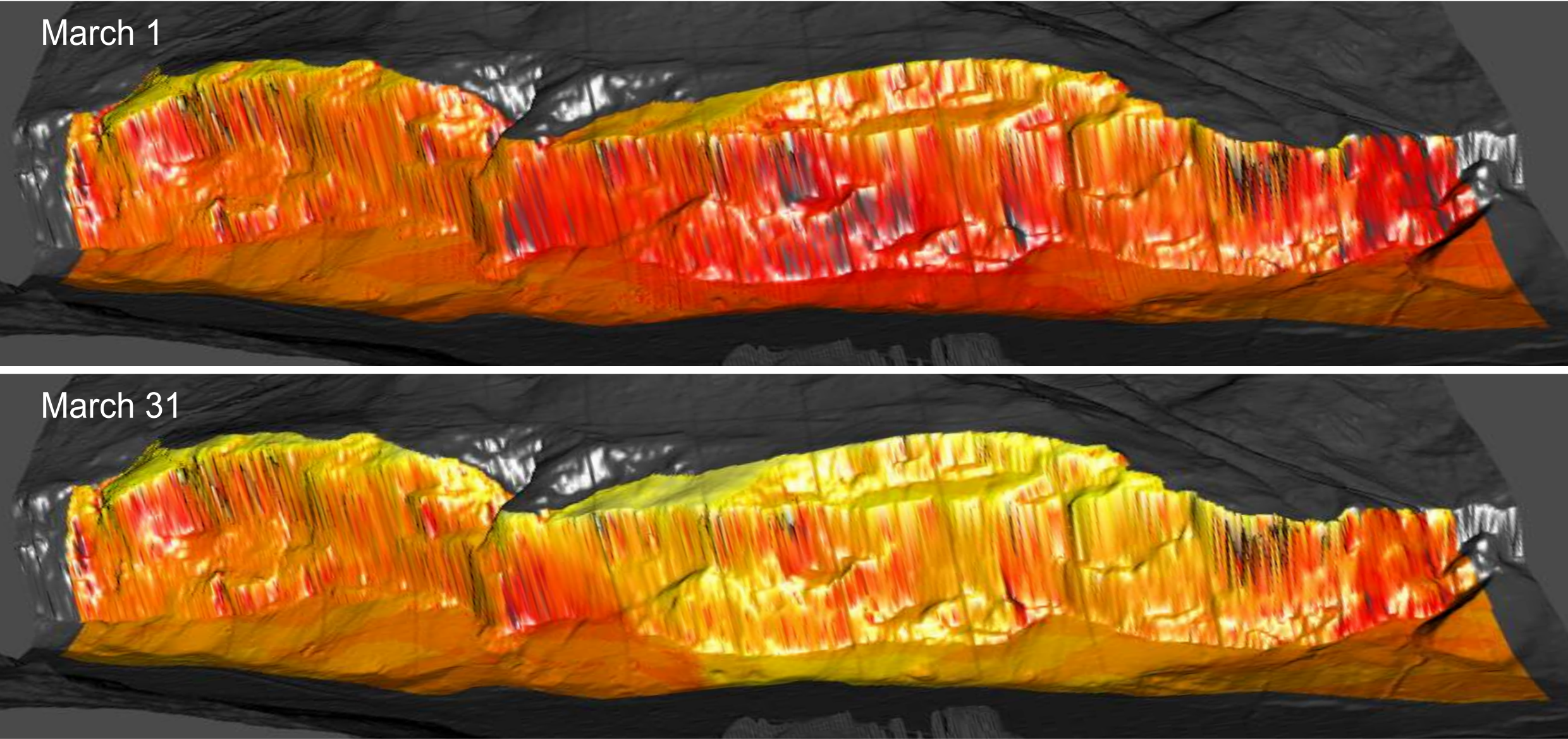


10 am



1 pm

Beyond descriptive ideas - (potential) sunlight exposure modelling



Time lags and driving forces



Earthquakes



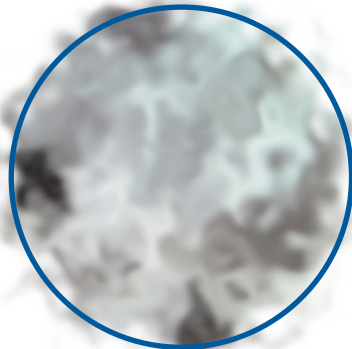
Precipitation



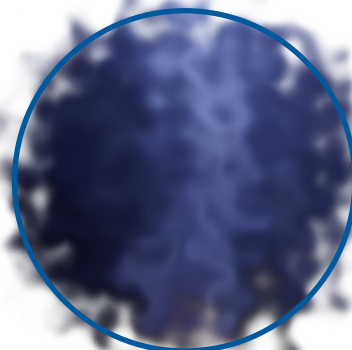
Tremors & eruptions



Human activity



Avalanches



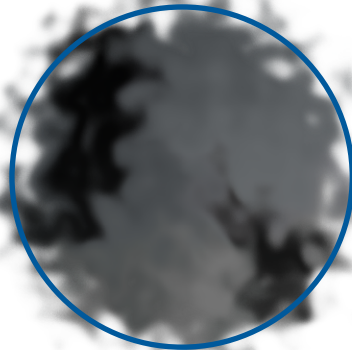
Lightning



Freeze-thaw action

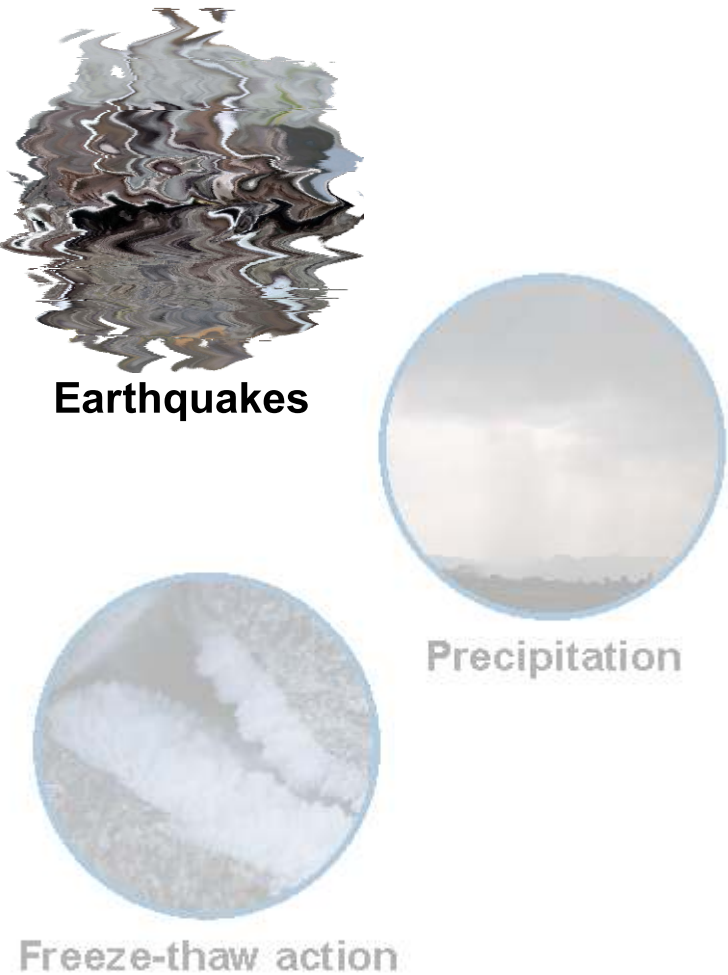


Stream erosion

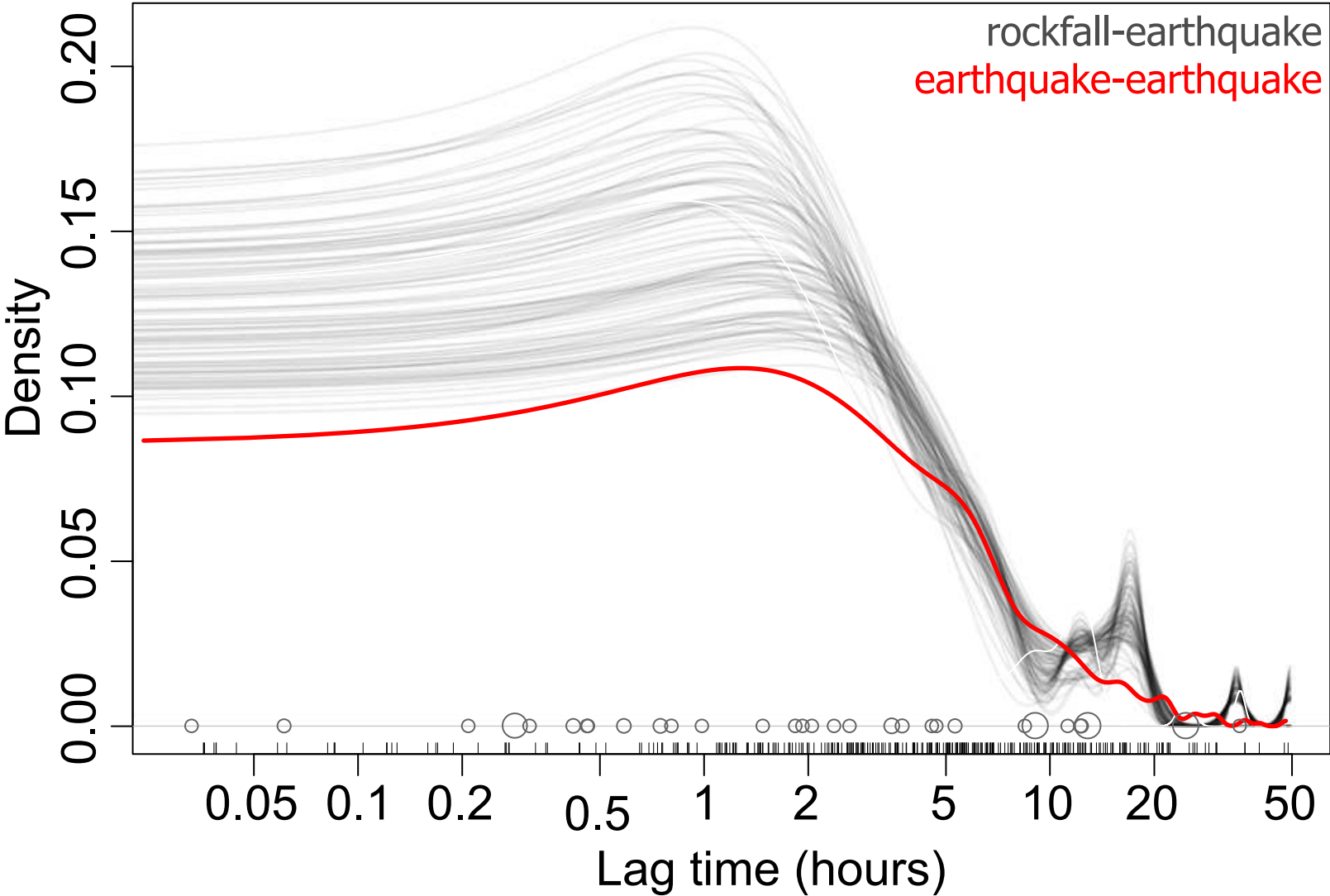


Wind

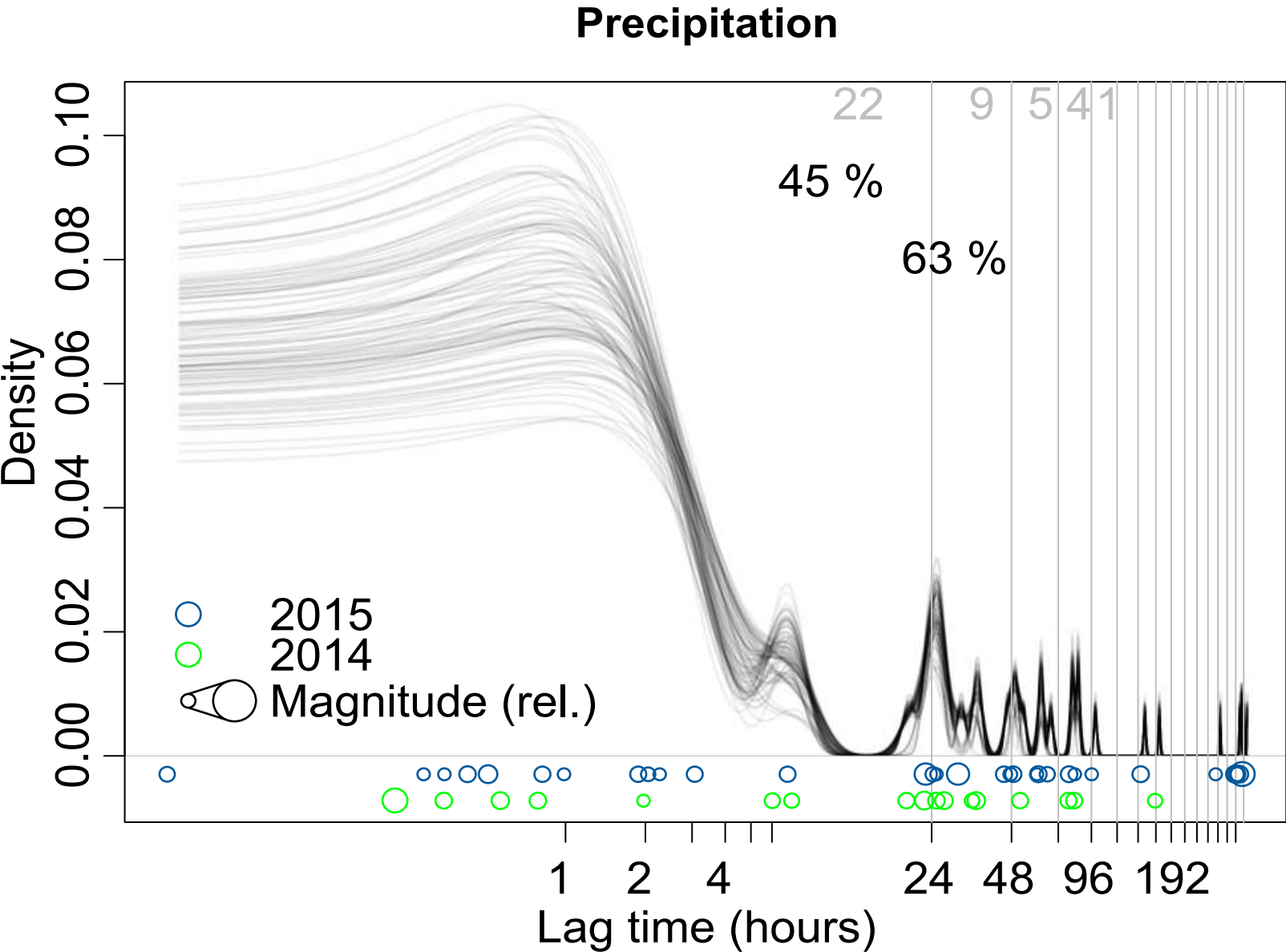
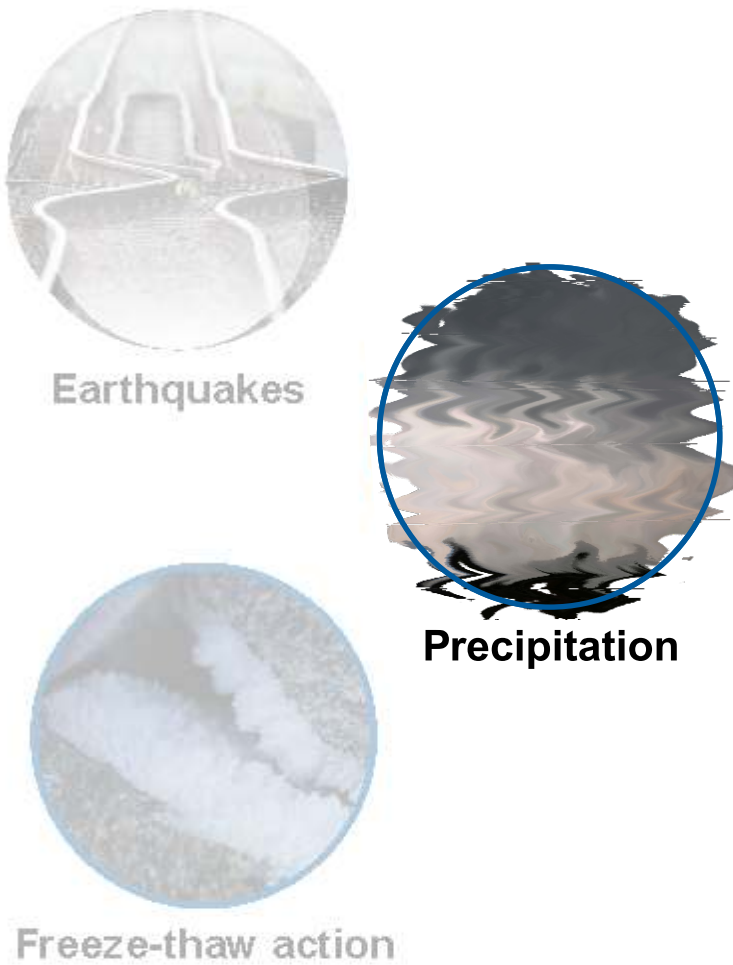
Time lags and driving forces - Monte Carlo-based lag time density estimates



Earthquakes

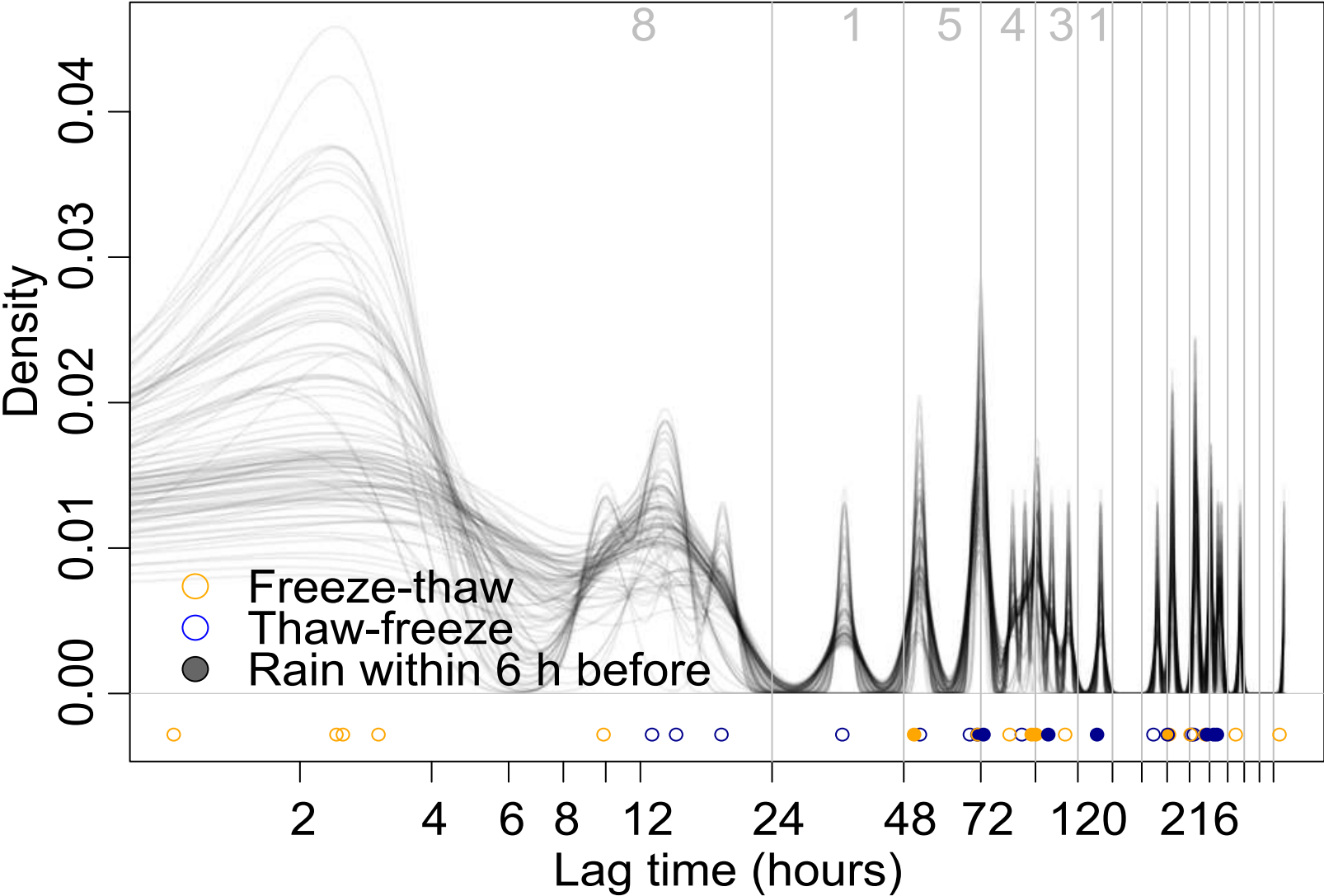
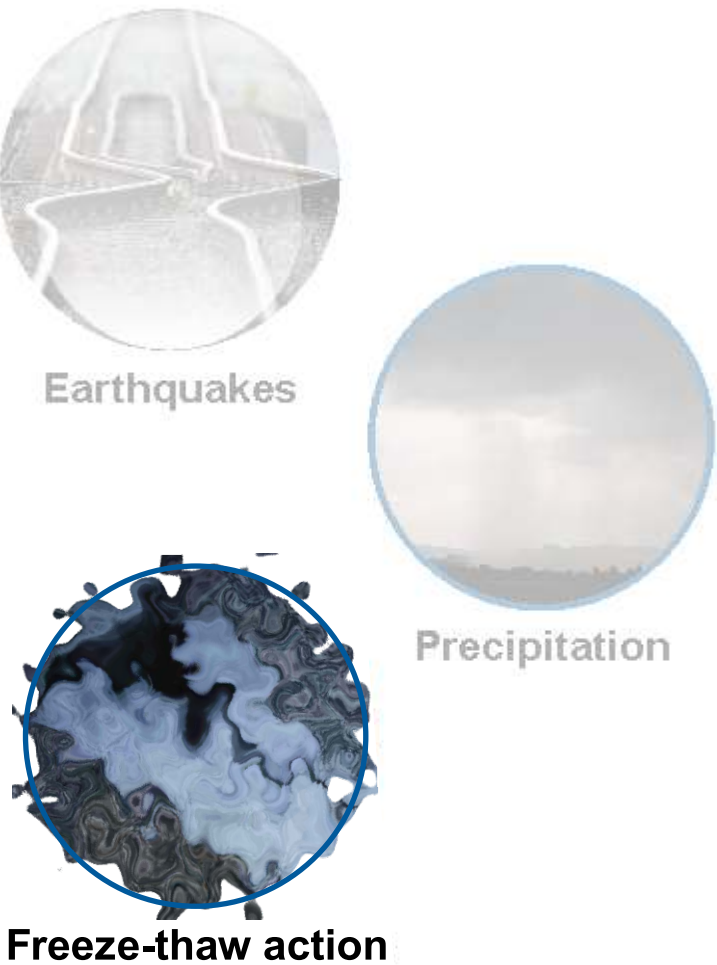


Time lags and driving forces - Monte Carlo-based lag time density estimates



Time lags and driving forces - Monte Carlo-based lag time density estimates

Freeze-thaw transitions



To come to an end...

...and following work

Emerging research

- What happens to the rocks after they landed on the talus slopes? Connectivity studies using seismometers
- How do the links to drivers and the activity patterns change for other time scales? Longer instrumentation
- How generic are the presented relationships and how do we get to larger scales? Case studies in other settings

To come to an end...

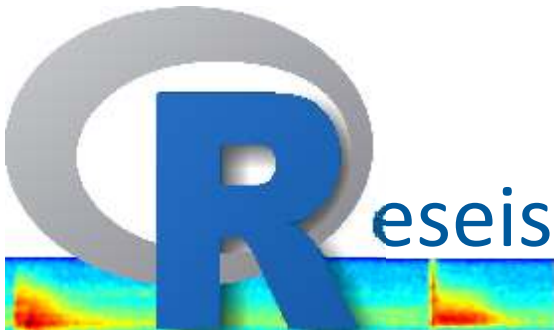
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Notifications

- EGU Galileo conference on environmental seismology
- EGU session on environmental seismology
- EGU session on using **R** for Earth science research



And reach the final words

Evaluating the potential of environmental seismology to detect rockfalls

Seismic monitoring allows quantitatively characterising rockfall events

Insight into individual rockfall events

Three different types of rockfall evolution explain monitored activity

Reveal spatial and temporal patterns of activity

Systematic shift of rockfall activity elevation with month of the year (30-50 m/month)

Identify potential drivers of rockfall activity

Access to lag-time analysis for drivers/triggers, partly directly through seismic data

Done...
Thank you all!



Seismic monitoring allows quantitatively characterising rockfall events

Three different types of rockfall evolution explain monitored activity

Systematic shift of rockfall activity elevation with month of the year (30-50 m/month)

Access to lag-time analysis for drivers/triggers, partly directly through seismic data



Time lags and driving forces

