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

GFZ German Research Centre for Geosciences, Geomorphology Section, Telegrafenberg, Building F 427, D-14479 Potsdam

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CURRENT TOPICS

- SUBITOP project management
- Environmental seismology
- Numeric luminescence methods
- Grain-size data handling

A SNAPSHOT

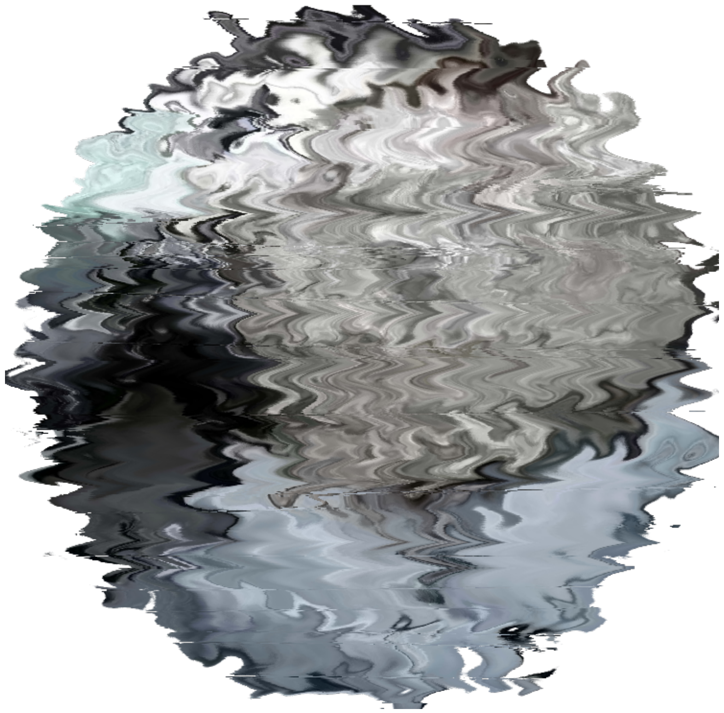
SEISMIC INSIGHT INTO ALPINE ROCKFALL ACTIVITY

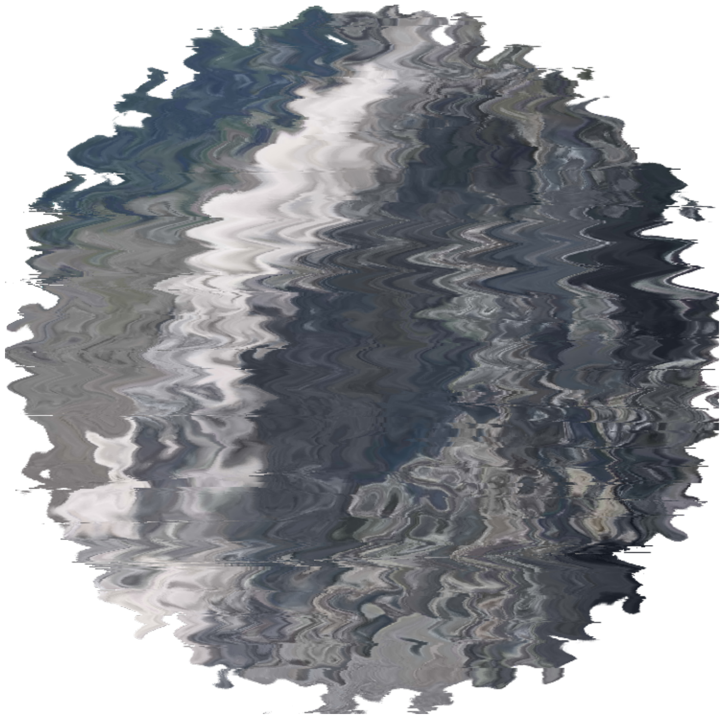
DRIVERS, PRECURSORS AND EVOLUTION

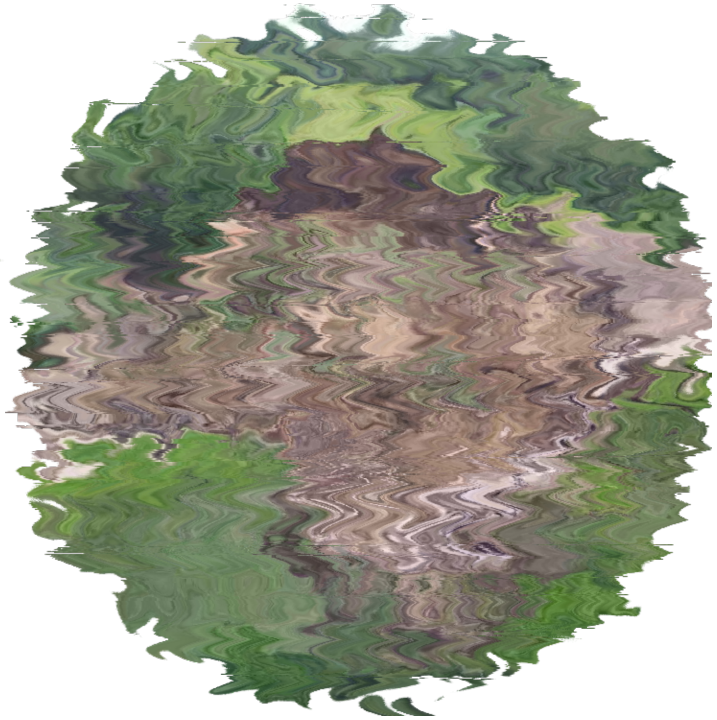
Michael Dietze[1], Jens Turowski[1], Niels Hovius[1]

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

Rockfalls, rock avalanches, rock slides, landslides?







Where?

Boundary conditions?

Triggers?

Interactions/feedbacks?

When?

How long?

Coupling/connectivity?

How?

How much?

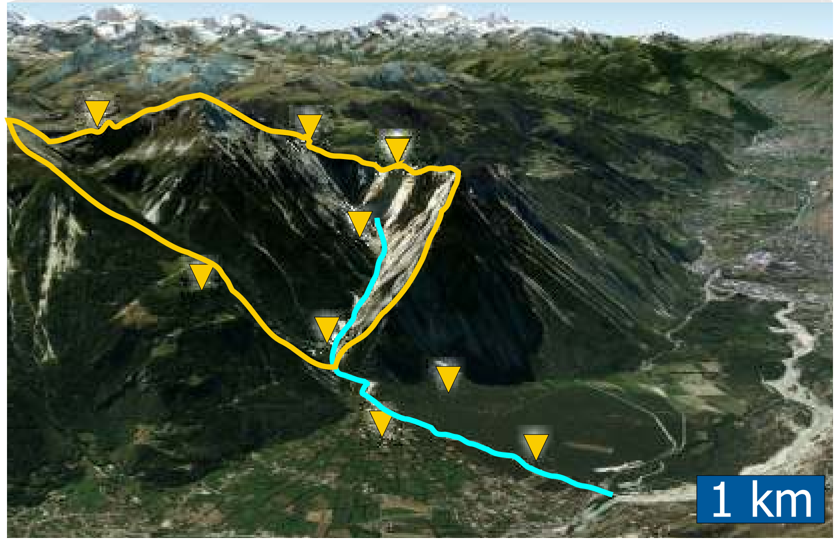
Patterns?

Bridging the gaps with a seismic approach

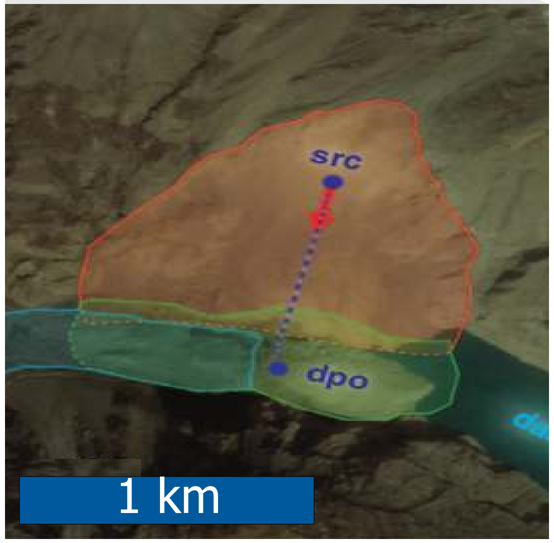
Laboratory scale

Small scale

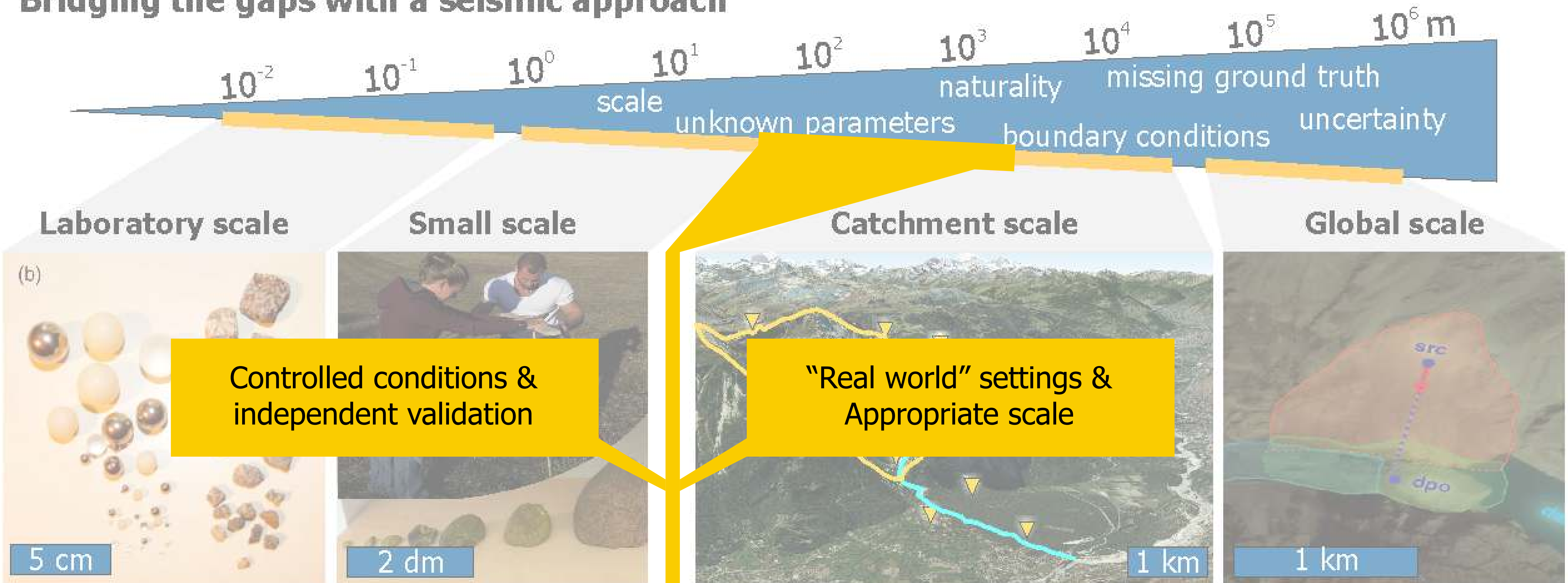
Catchment scale



Global scale



Bridging the gaps with a seismic approach

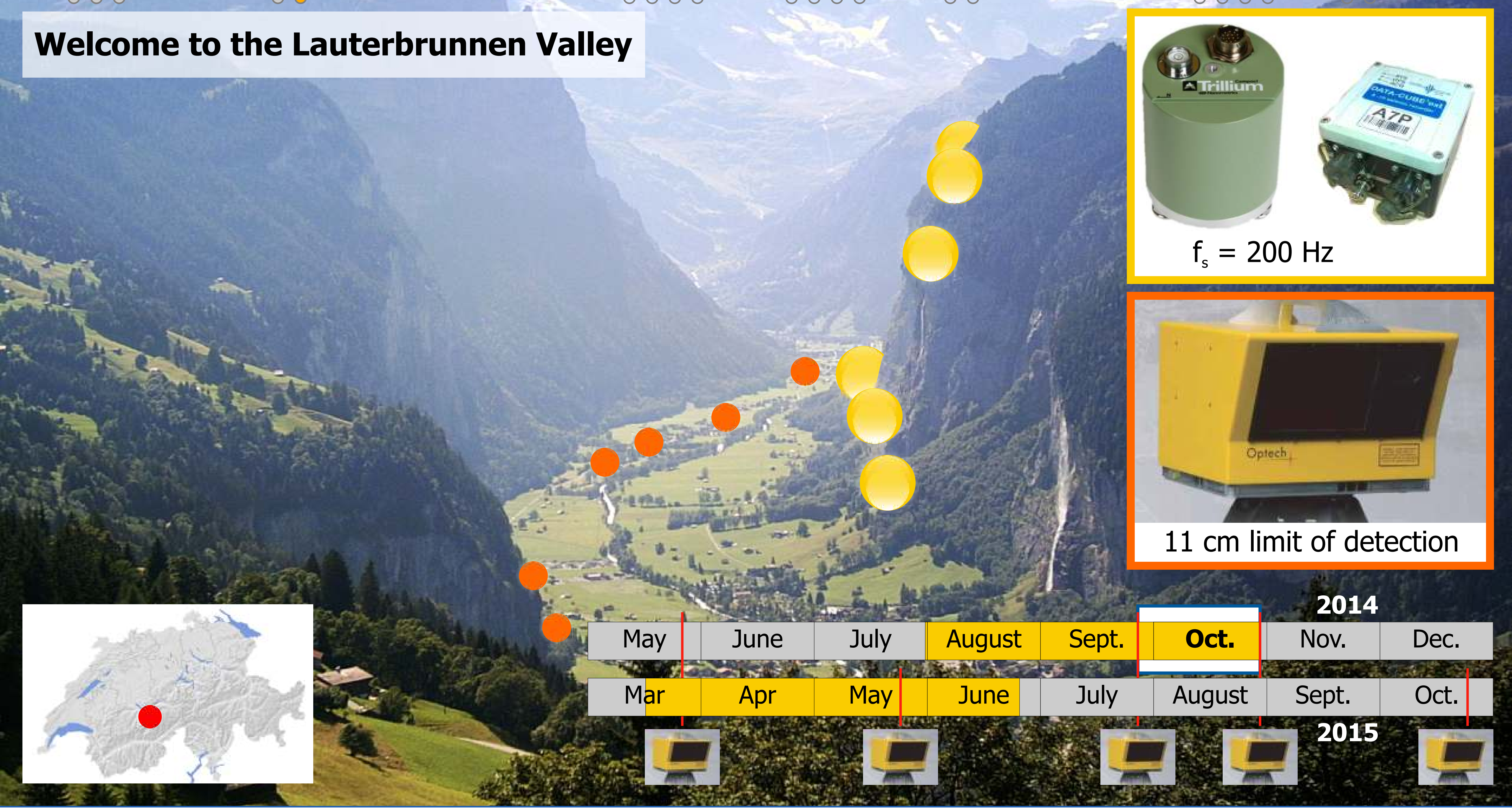


Evaluate the **potential** and **precision** of environmental seismology to detect rockfalls

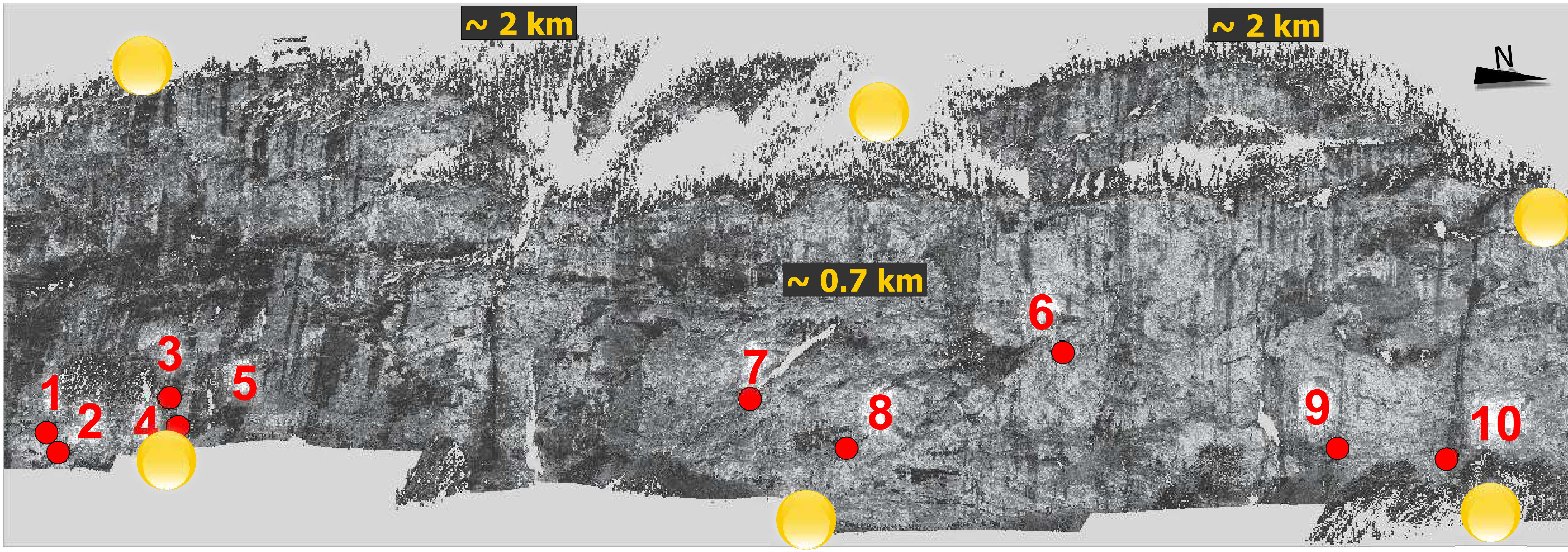
Reveal **activity patterns** in time and space, and identify **triggers** of rockfall activity

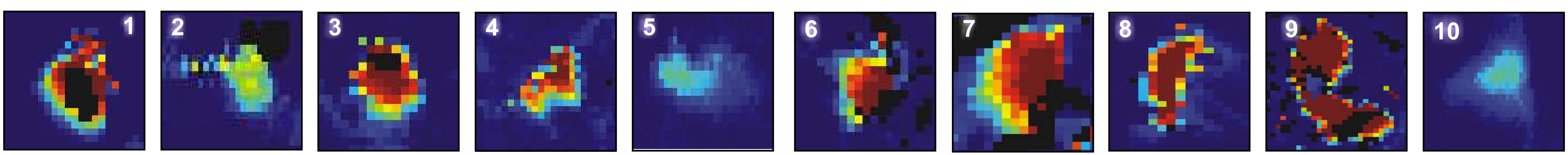
Welcome to the Lauterbrunnen Valley

Welcome to the Lauterbrunnen Valley



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





1	2	3	4	5	6	7	8	9	10
0.201 (0.005)	0.063 (0.001)	0.120 (0.009)	0.175 (0.011)	0.053 (0.004)	0.416 (0.021)	0.891 (0.038)	0.258 (0.014)	2.338 (0.085)	0.192 (0.010)

Volume (m³) and uncertainty in brackets

The seismic signals

Reseis

STA/LTA picking | Location | Description | Linking to drivers

The challenges

Very noisy environment

Very short-duration and low-intensity signals

Rockfall evolution very heterogeneous and diverse

Precluded options

"easy and fix" picking routines

Location algorithms based on first arrival times

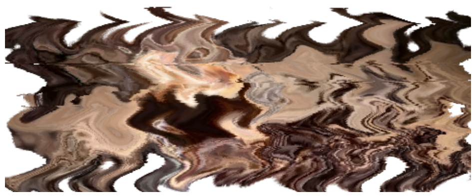
Resulting tasks

Step-wise removal of spurious picks

Signal envelope migration to locate sources

The seismic signals

eseis

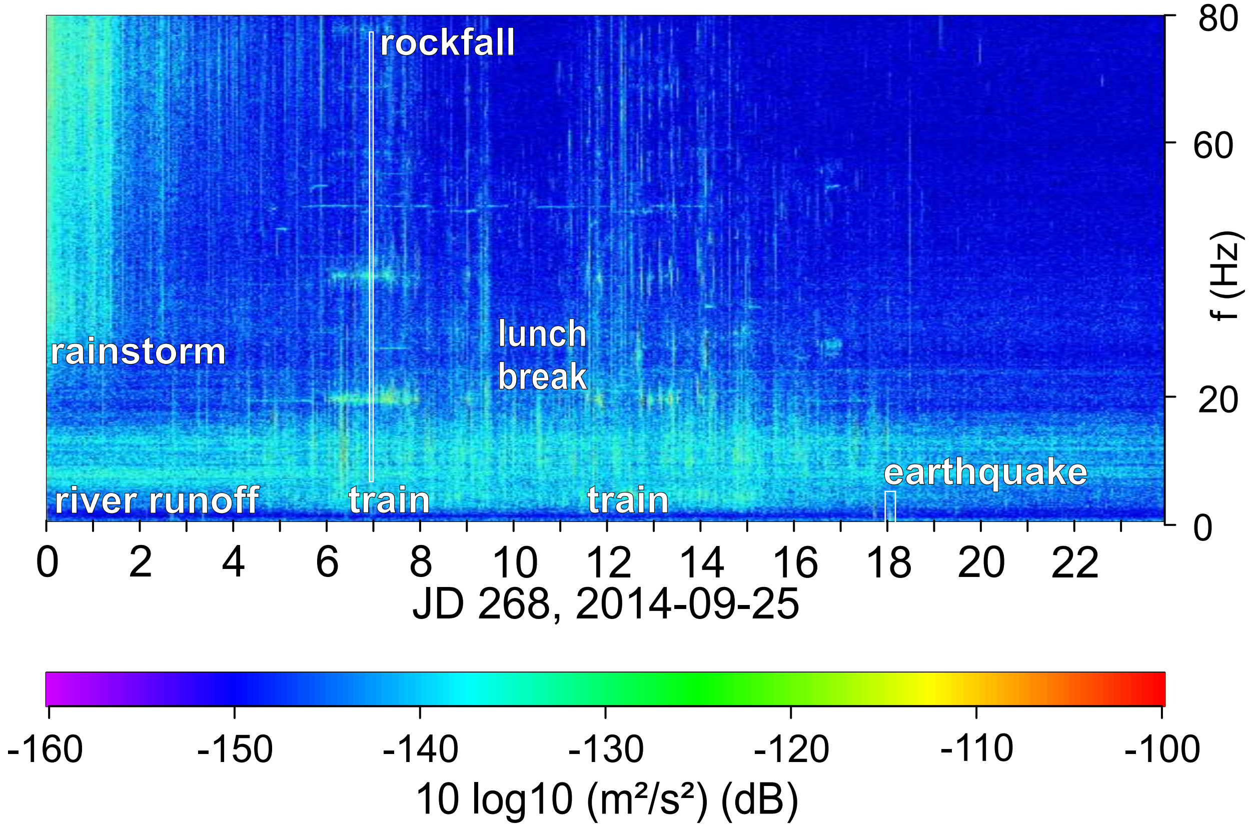


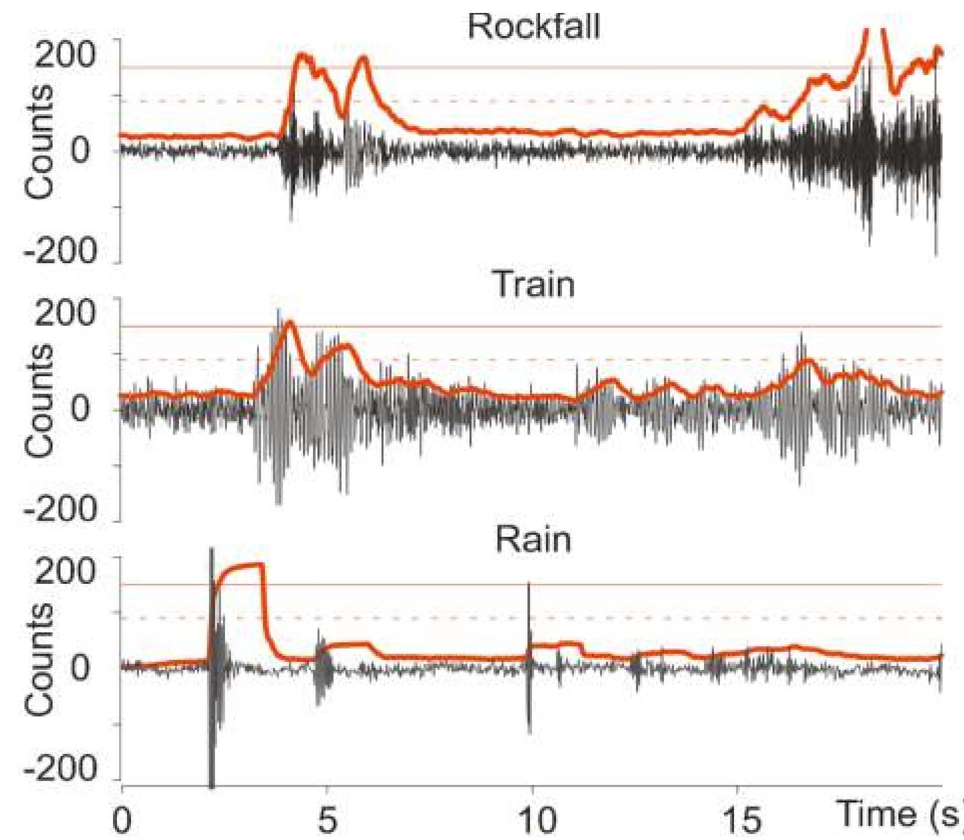
STA/LTA picking

Location

Description

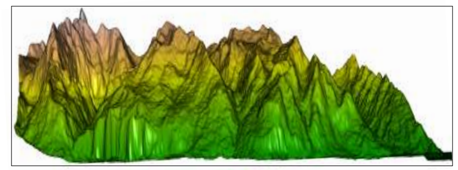
Linking to drivers





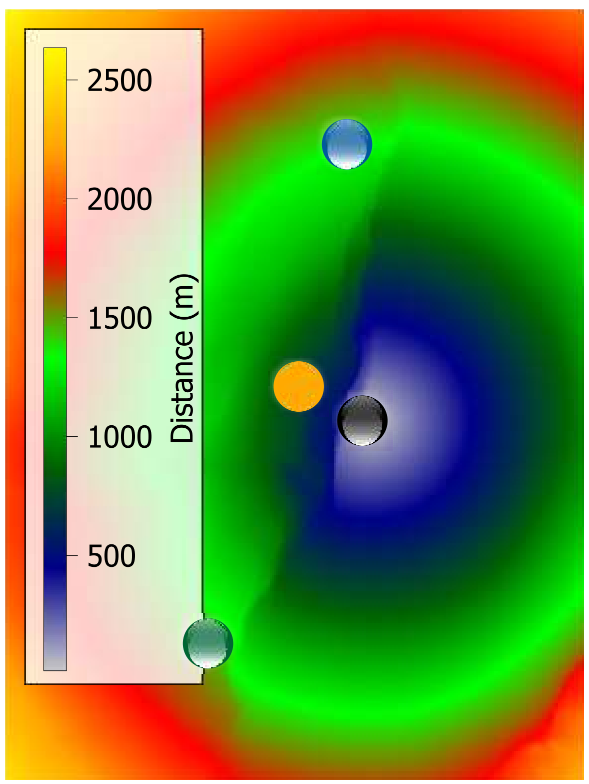
The seismic signals

eseis

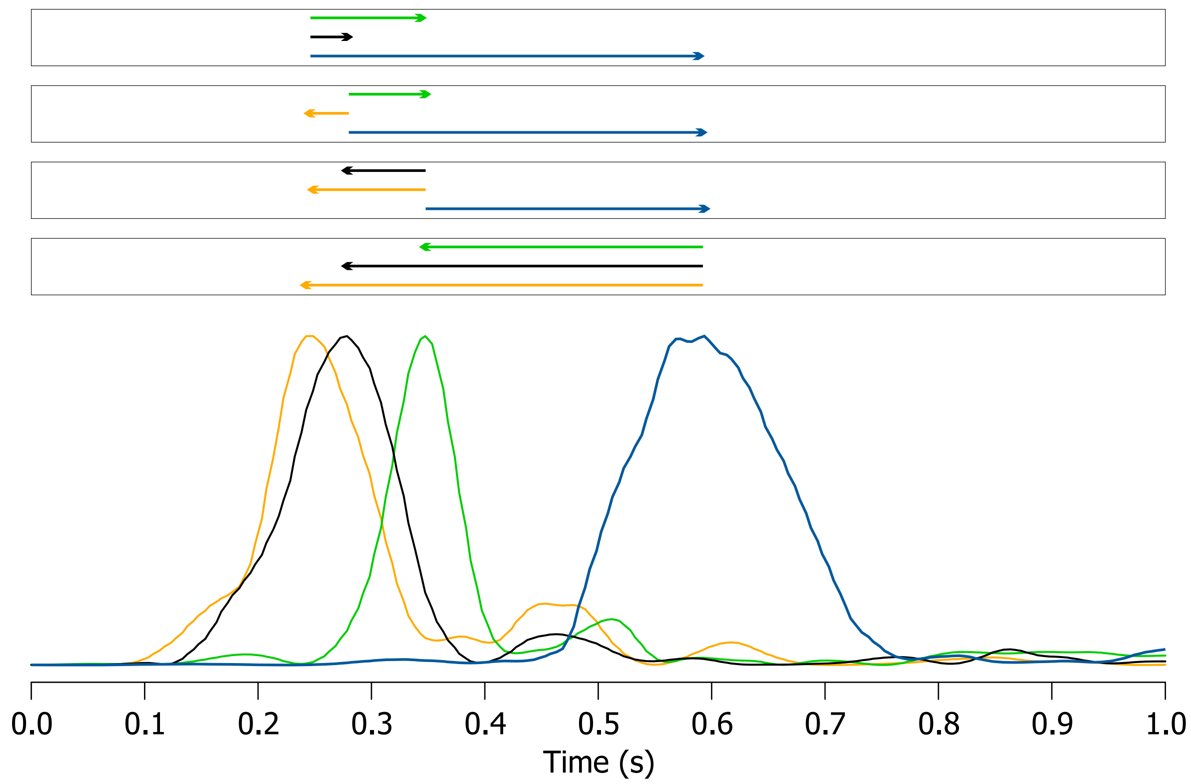


STA/LTA picking | Location | Description | Linking to drivers

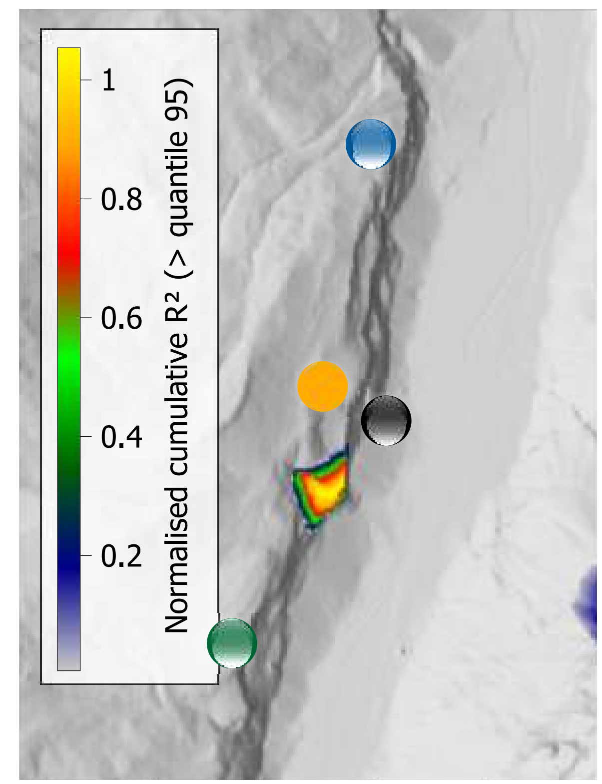
Distance maps



Signal migration



Location map

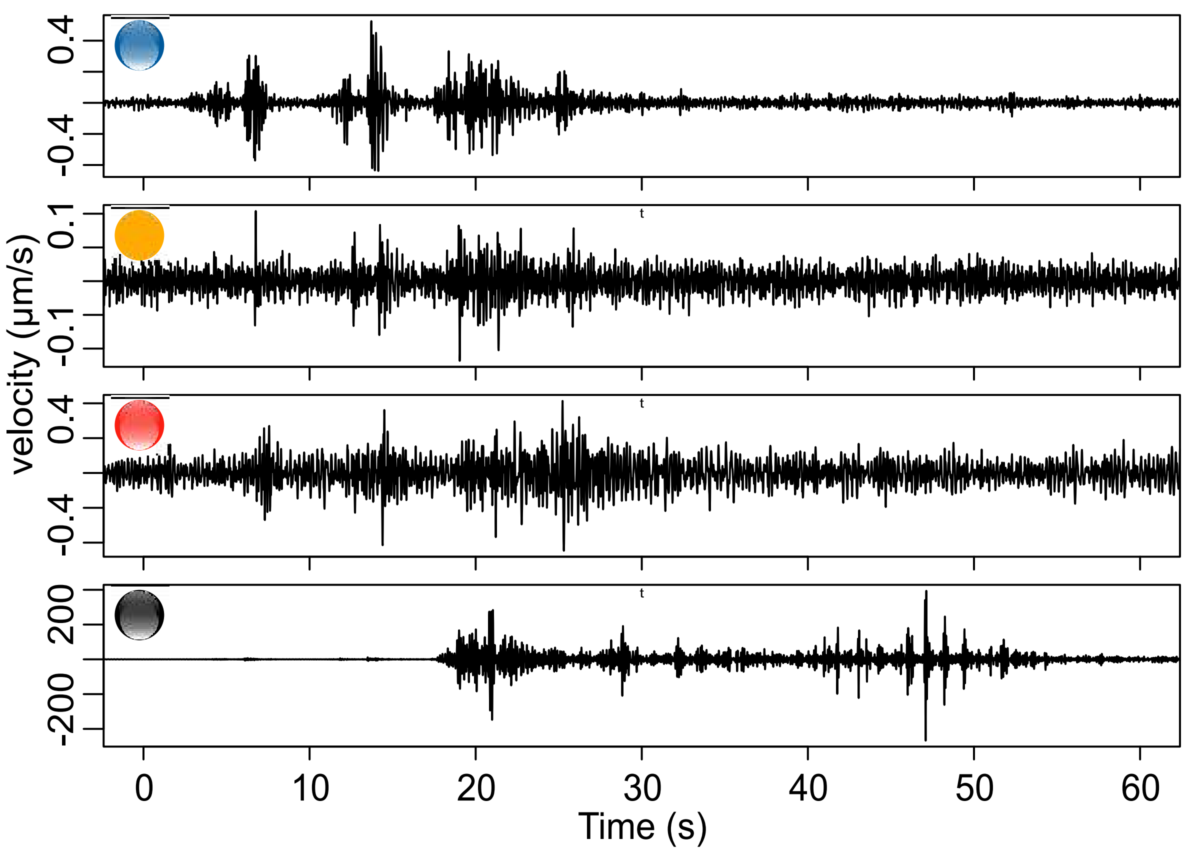


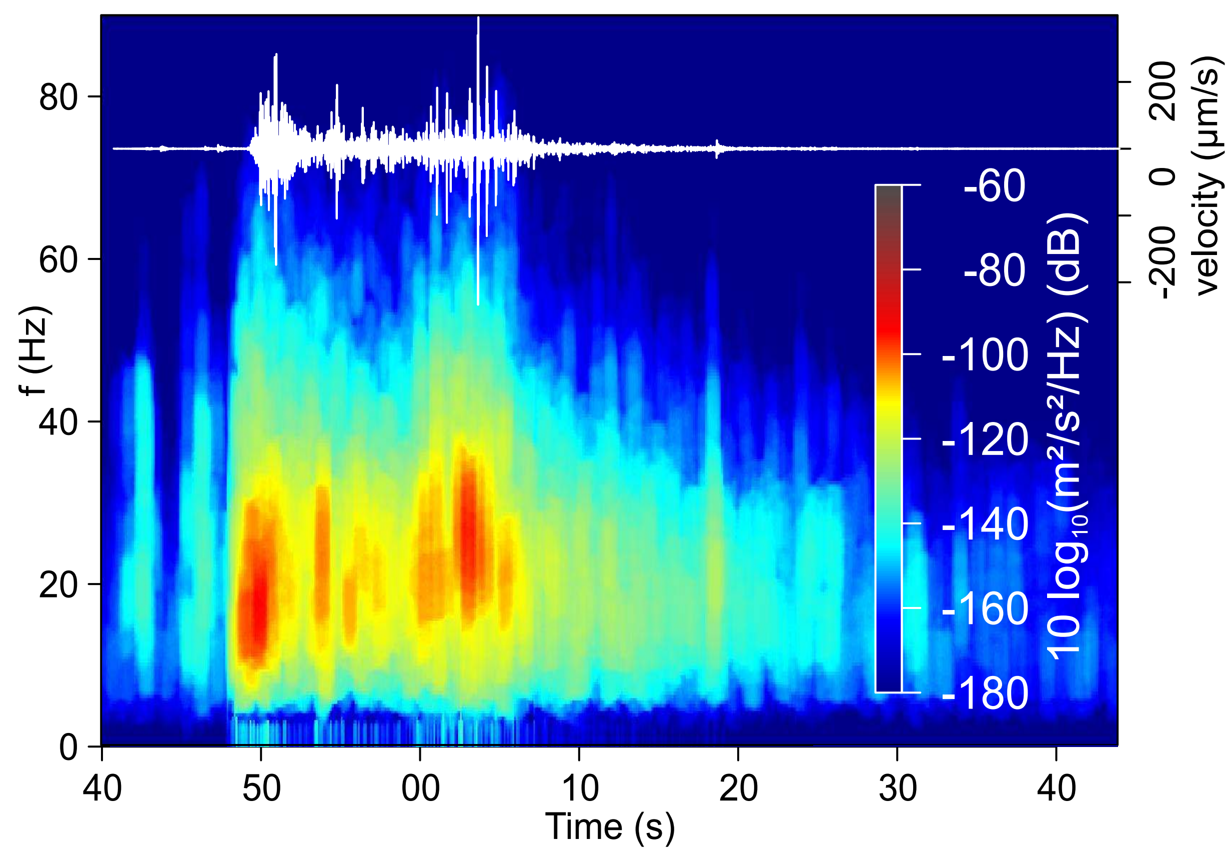
cf. Burtin et al. (2014) ESurf

The seismic signals

Reseis

STA/LTA picking | Location | **Description** | Linking to drivers

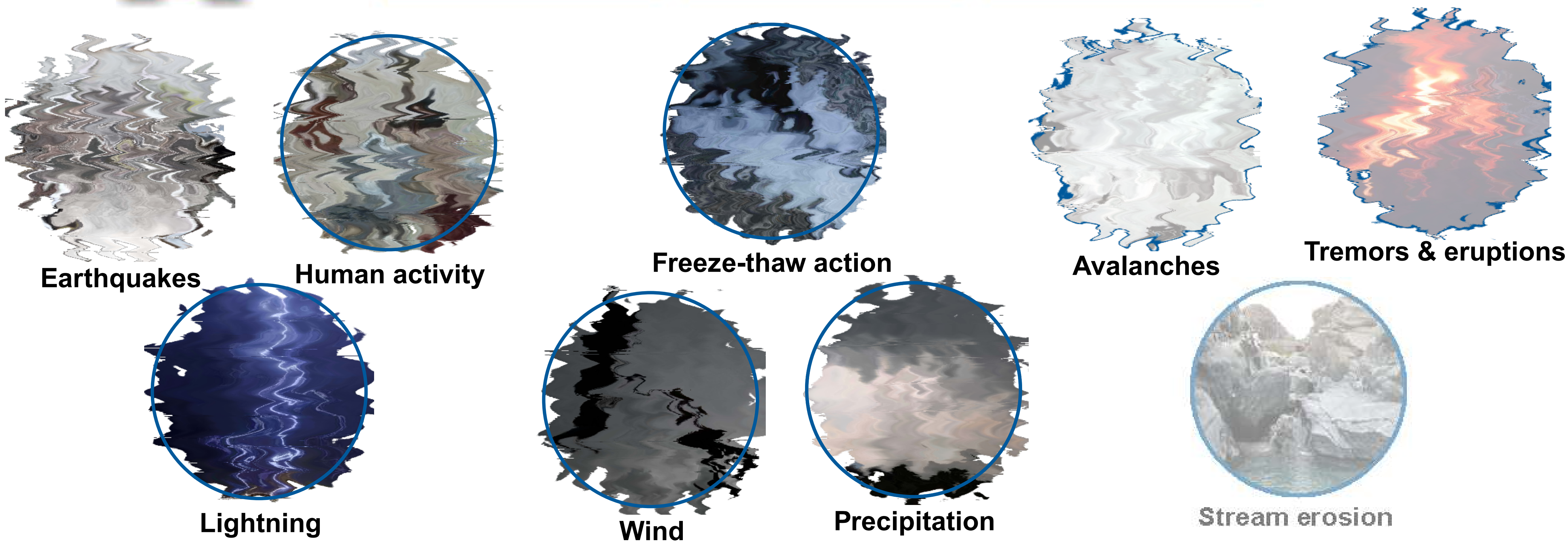




The seismic signals

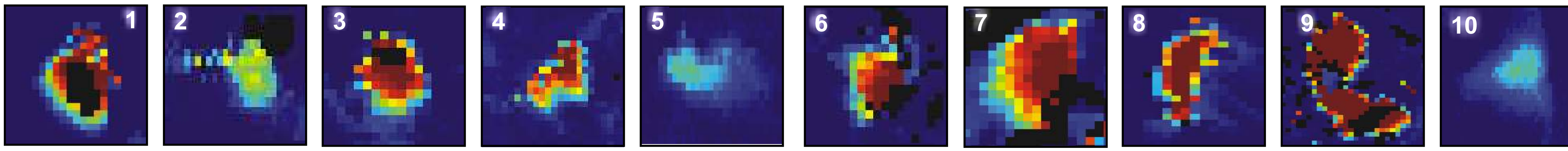
Reseis

STA/LTA picking | Location | Description | **Linking to drivers**



Results - seismic detection and localisation of rockfalls

Lidar-detected rockfall events



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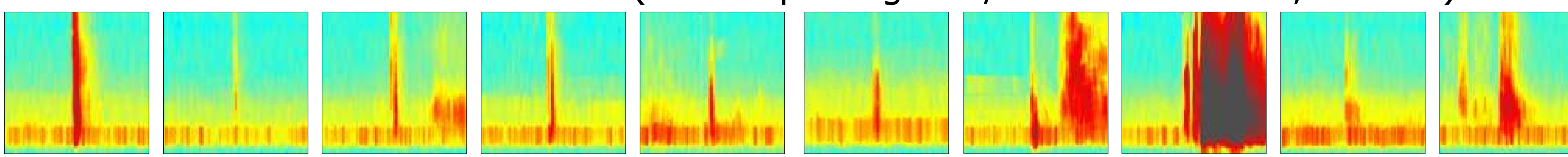
(0.005)	(0.001)	(0.009)	(0.011)	(0.004)	(0.021)	(0.038)	(0.014)	(0.085)	(0.010)

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



STA/LTA picking
STA = 0.5 s
LTA = 180 s
on-value = 5
off-value = 3

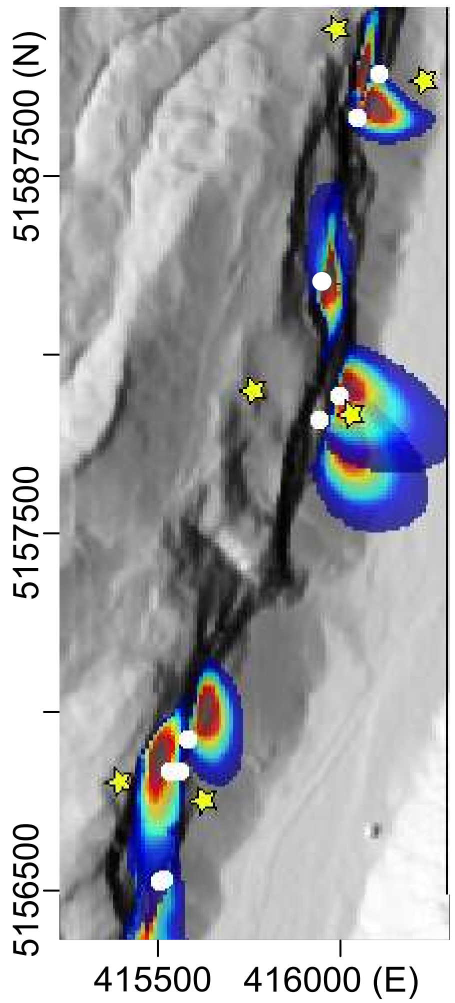
→ **event duration**
t_min = 0.5 s
t_max = 20 s
SNR_min = 6

→ **signal inspection**
train = 455
earthquake = 19
rockfalls = 37

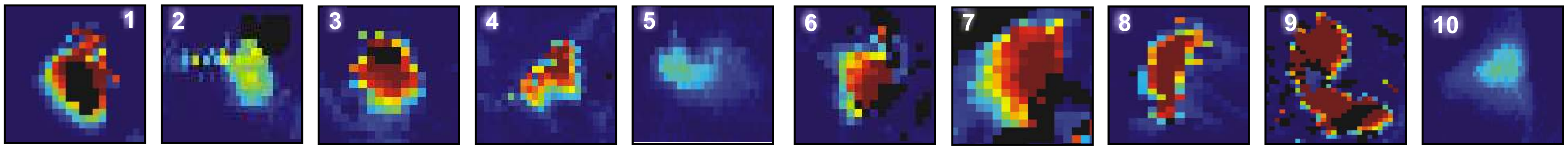
→ **signal location**
other side = 8
out of valley = 19
in AOI = **10**

2175 picks → **511 picks** → **37 picks** → **10 picks**

Results - seismic detection and localisation of rockfalls



Lidar-detected rockfall events



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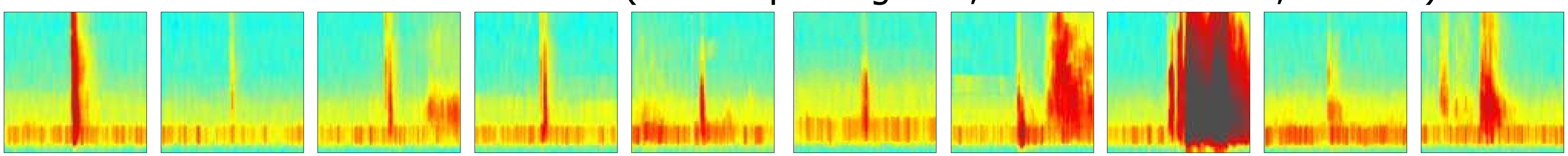
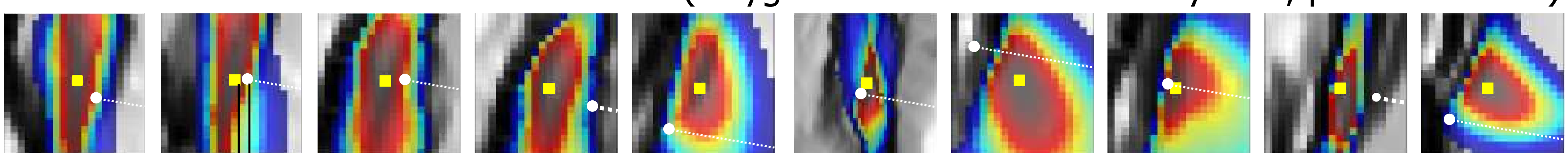


Seismic-based localisation estimate (Polygons: >97 % location likelyhood, pixel size 10 m)



Ten out of ten control events located

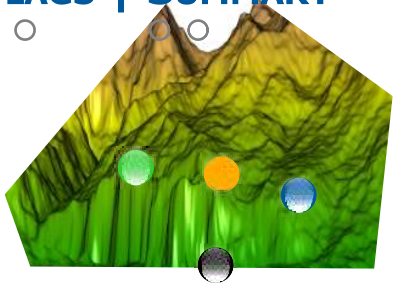
Average horizontal deviation: 81 (+59/−29) m

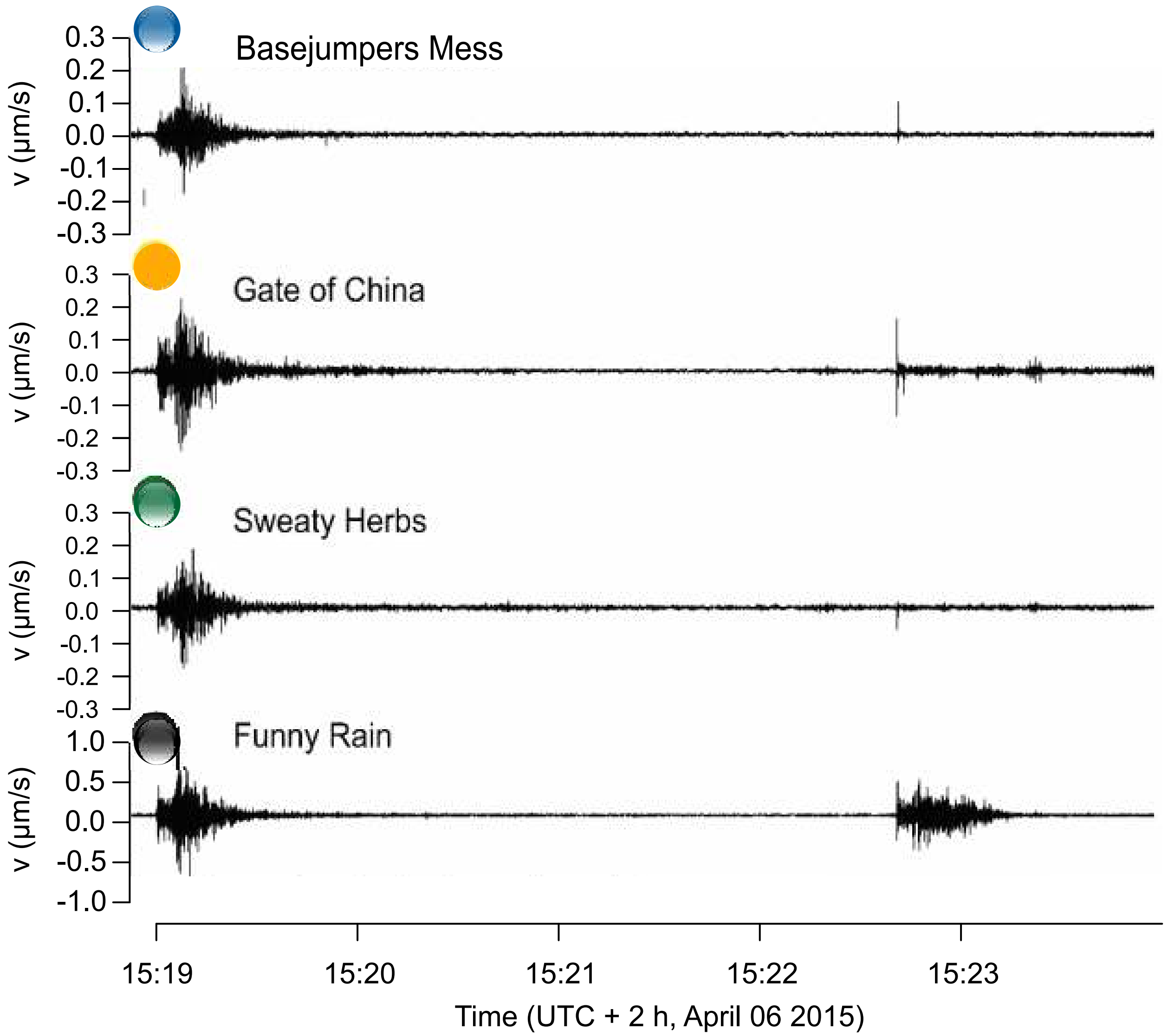
Limitations

Equivocality for close-by events

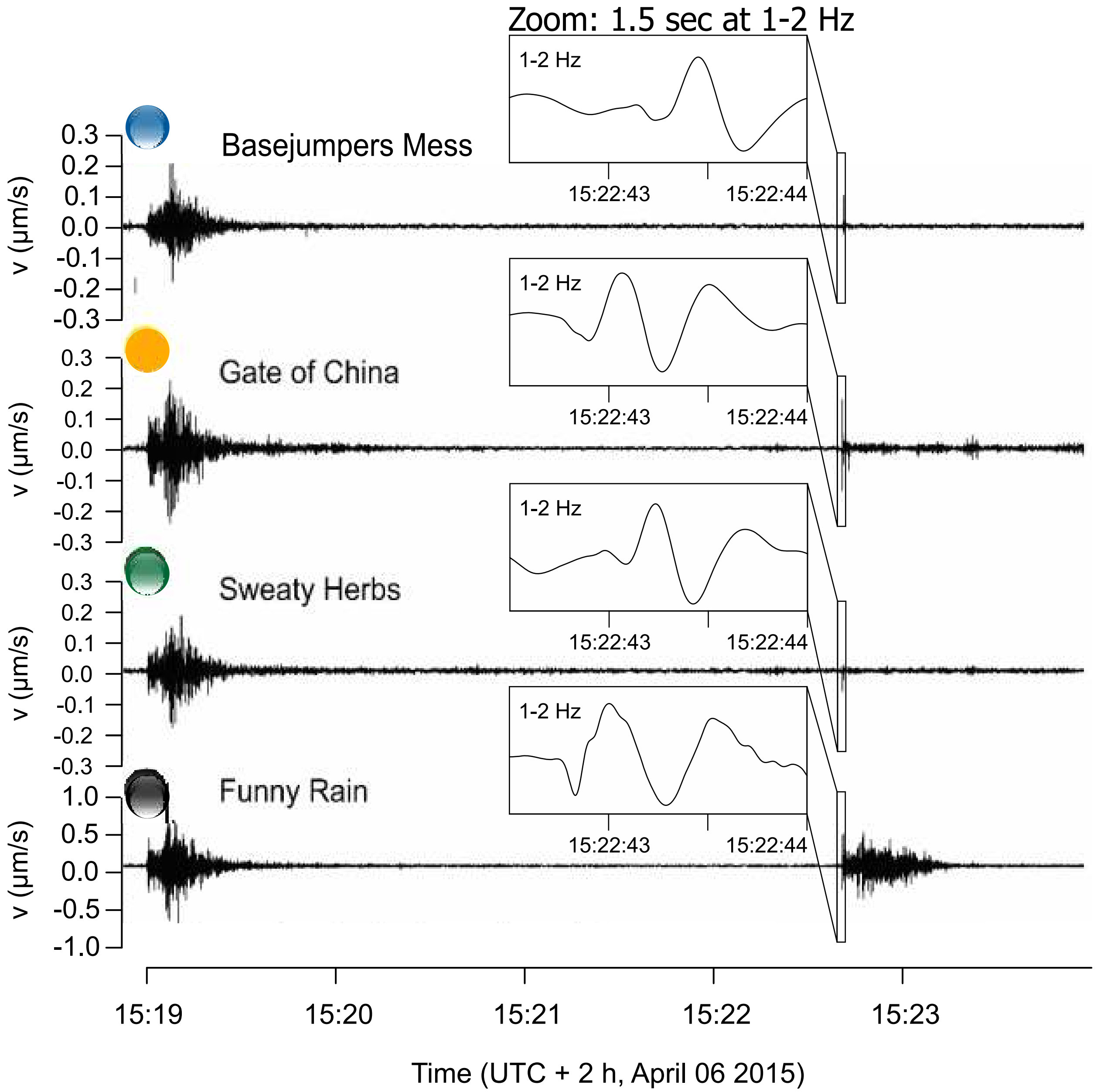
No linkage of volume and energy

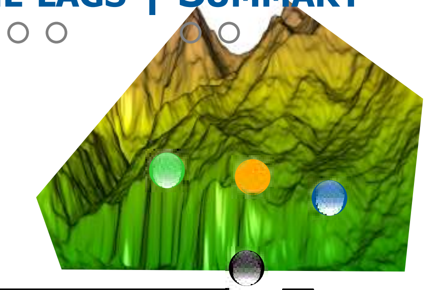
Seismic insights to rockfall evolutions - Example I

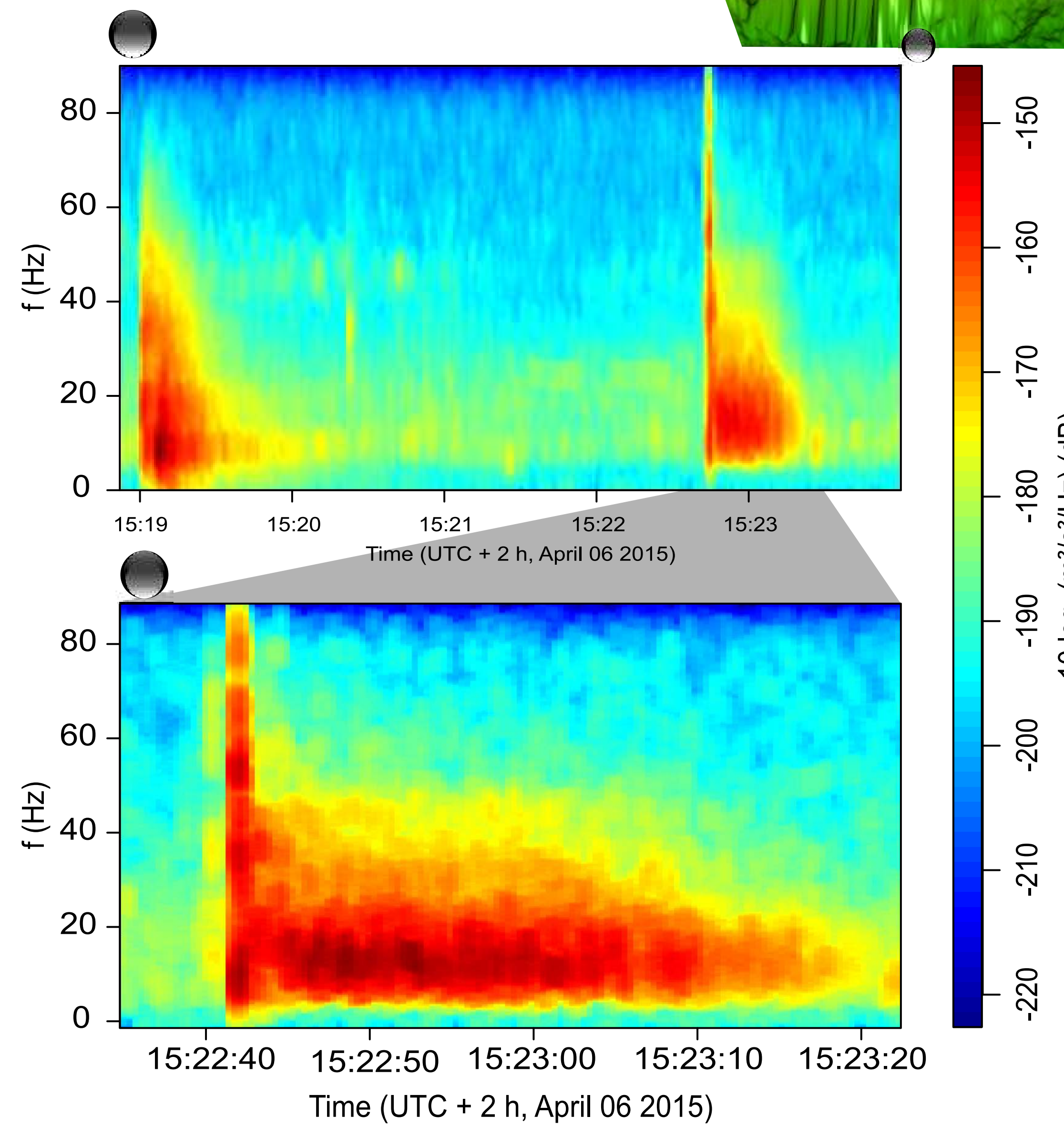




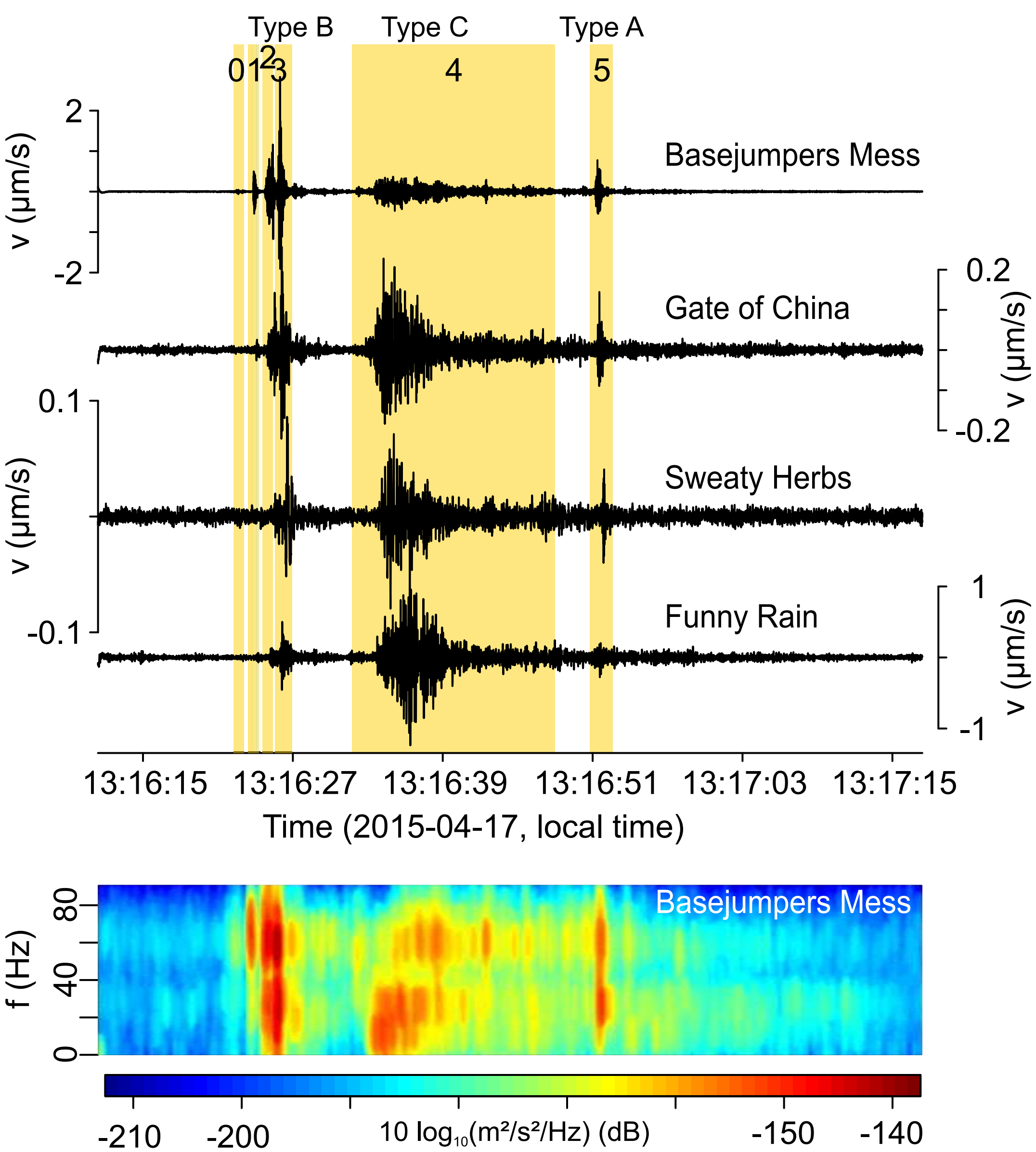
Seismic insights to rockfall evolutions - Example I

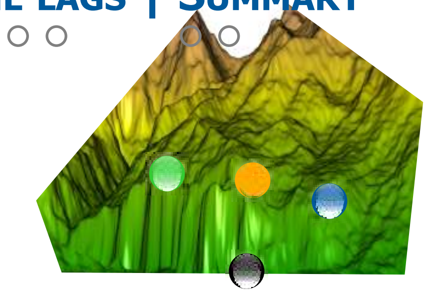




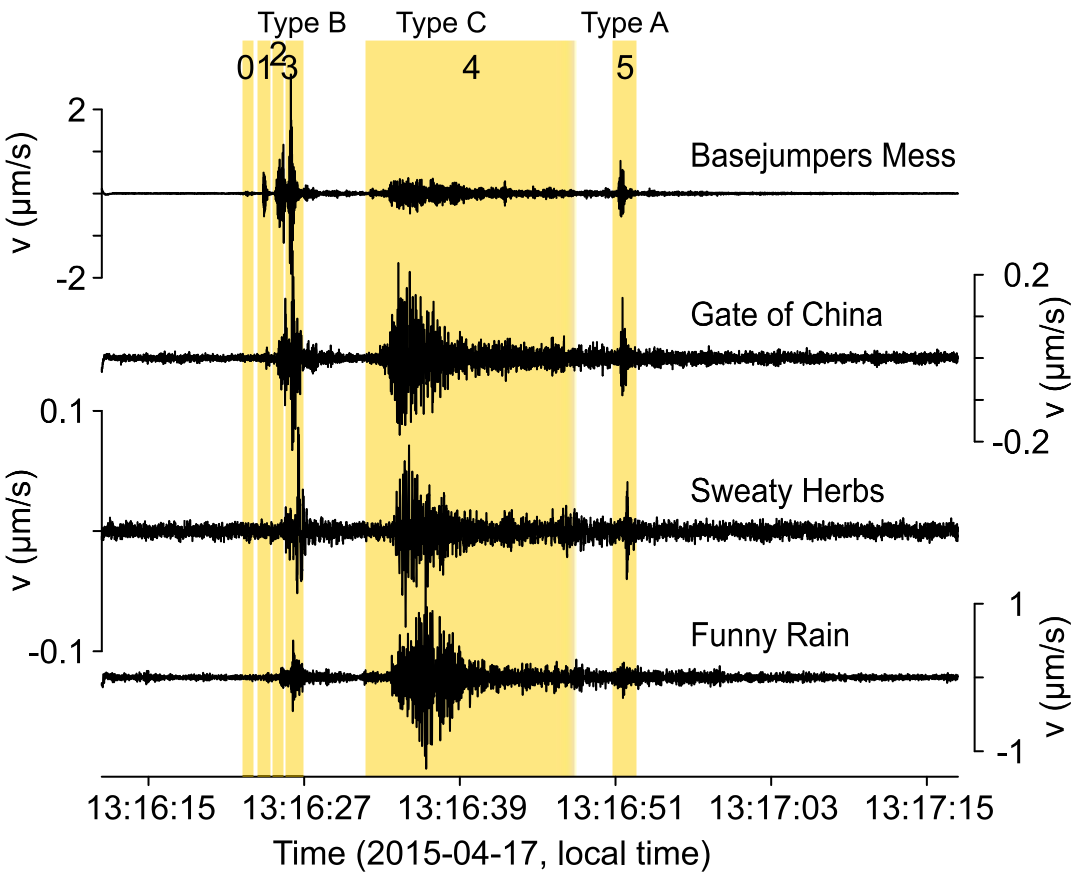


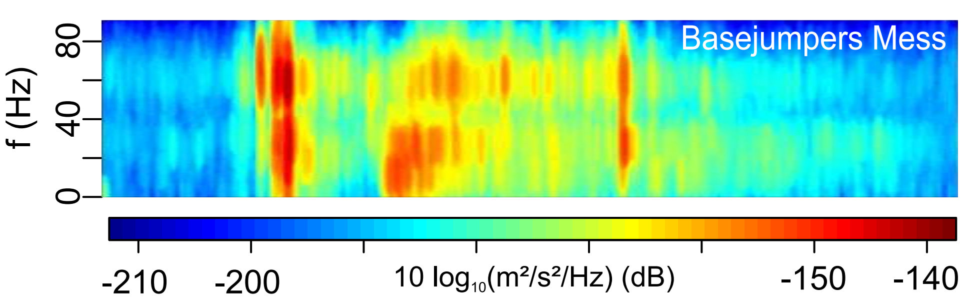
Seismic insights to rockfall evolutions - Example II

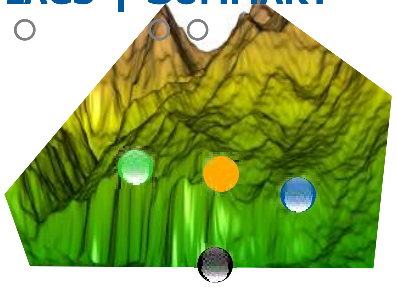


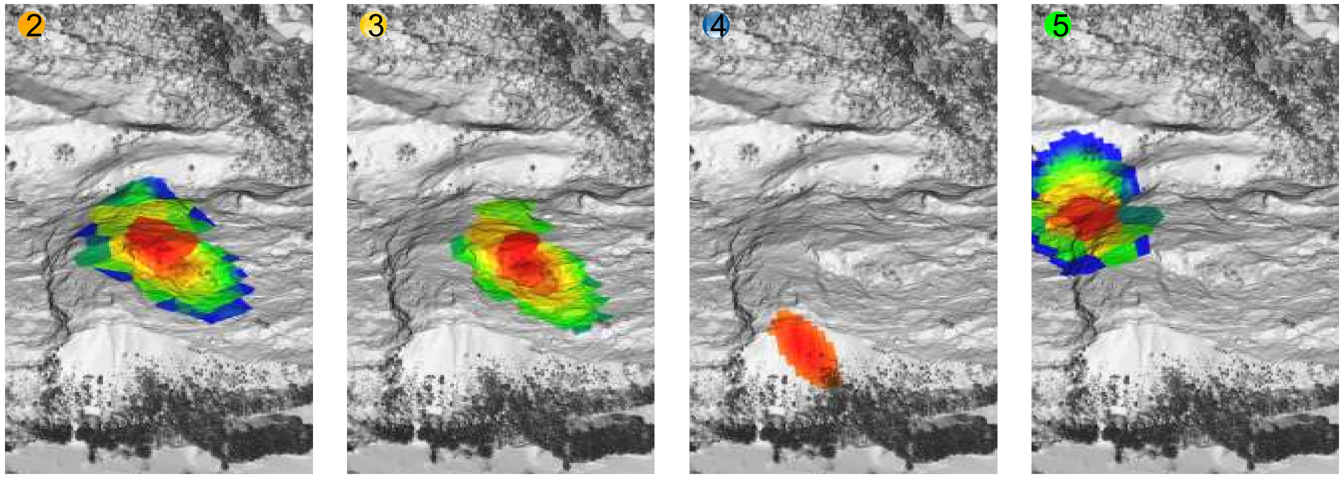


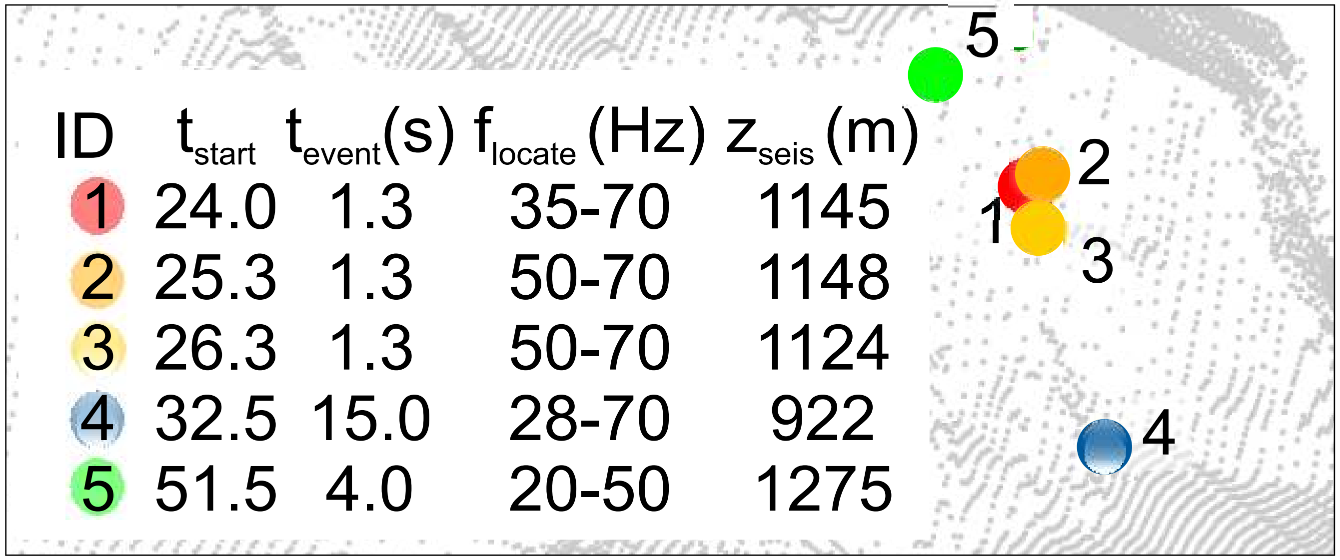
Seismic insights to rockfall evolutions - Example II









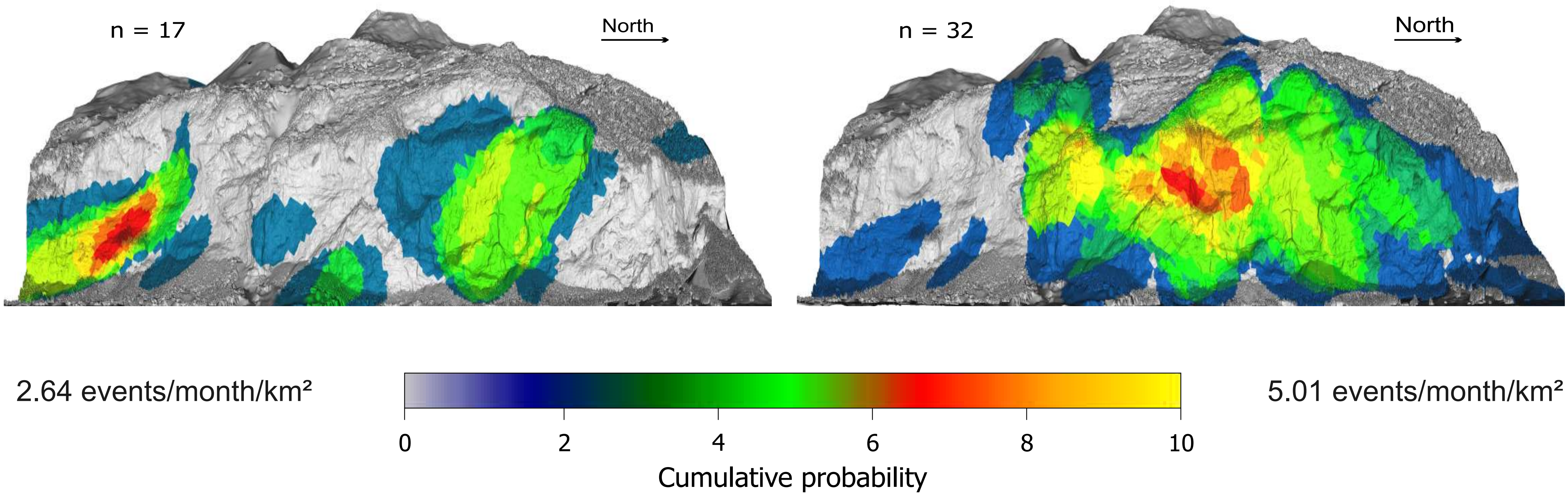


ID	t_{start}	t_{event} (s)	f_{locate} (Hz)	z_{seis} (m)
1	24.0	1.3	35-70	1145
2	25.3	1.3	50-70	1148
3	26.3	1.3	50-70	1124
4	32.5	15.0	28-70	922
5	51.5	4.0	20-50	1275

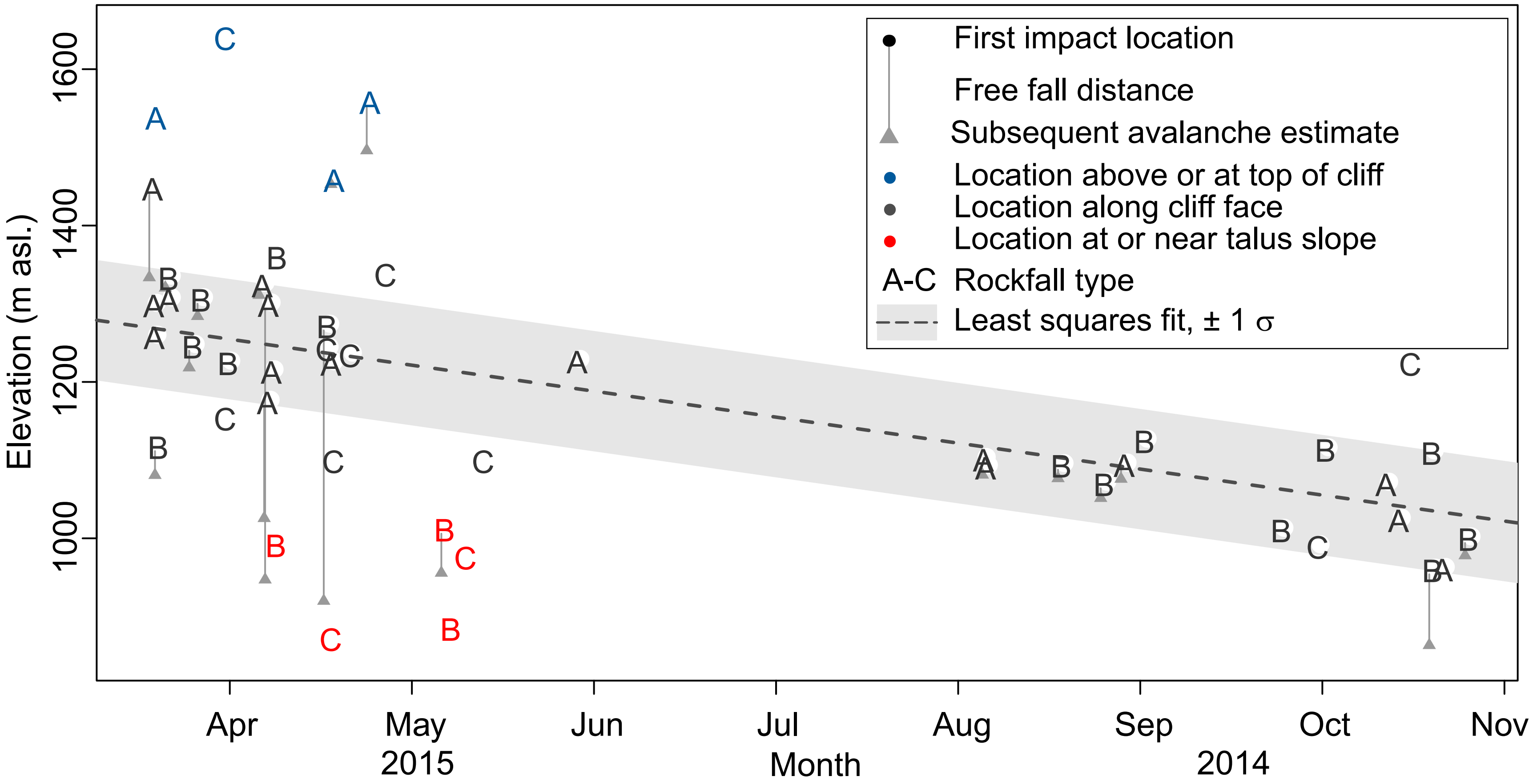
Spatial patterns of rockfall activity

2014 (August-October)

2015 (March-June)



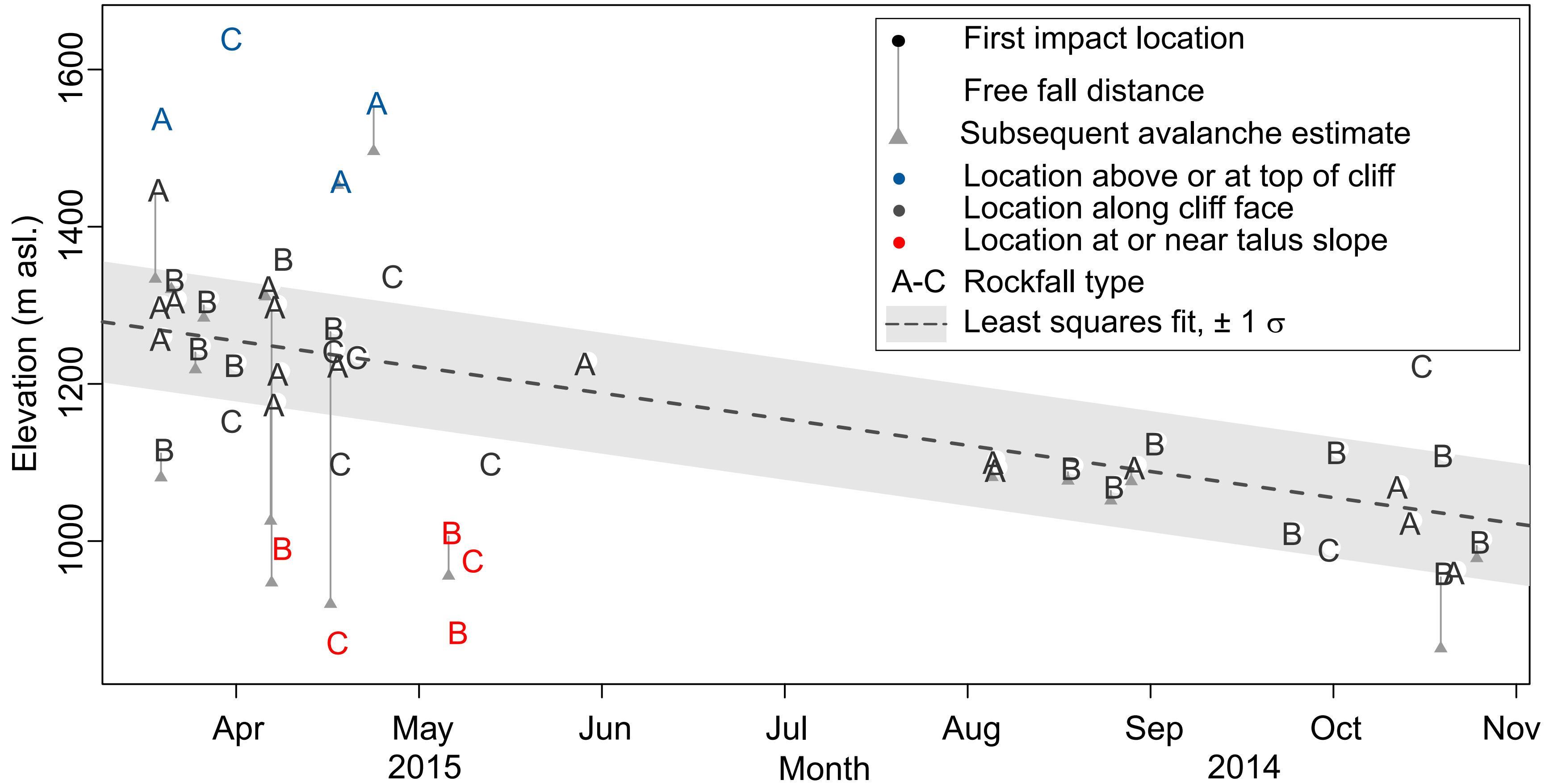
Linking time and space - rockfall activity altitude shifts with the season

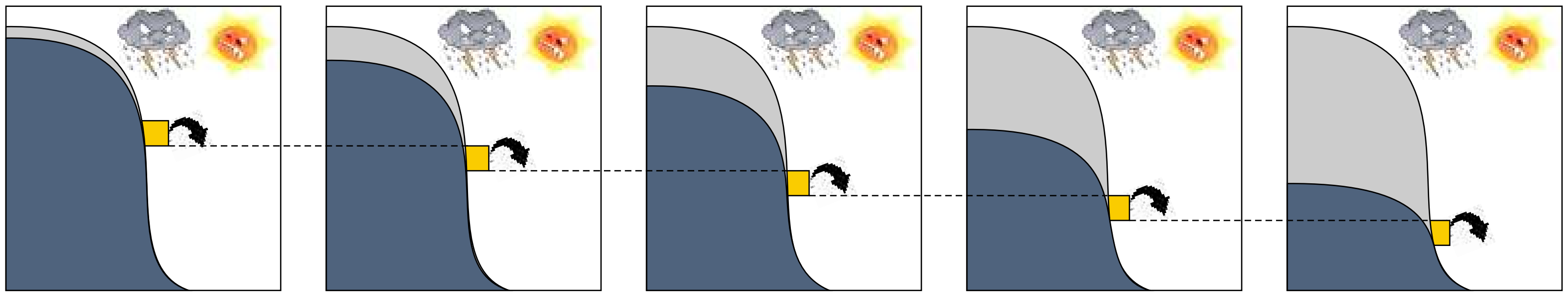


Seasonal trend

33 m per month downward shift in rockfall activity

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





Seasonal trend

33 m per month downward shift in rockfall activity

Underlying mechanism

Continuosly lowering water table

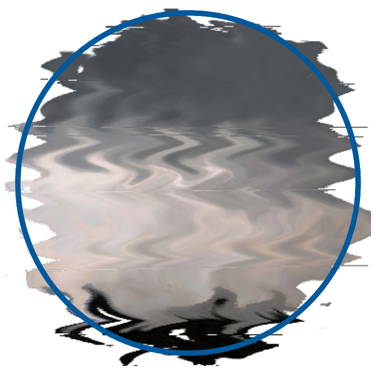
Dry rock is subjective to:

- wetting-drying cycles
- higher temperature amplitudes

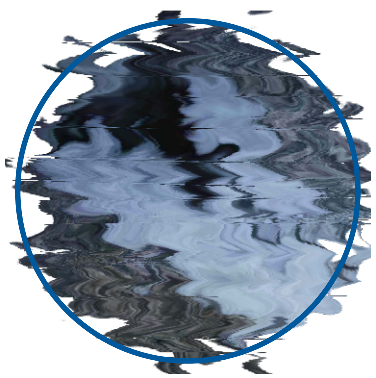
After cliff section is “emptied” it takes months to prepare new rock masses for detachment.

Time lags and driving forces

Earthquakes



Precipitation



Freeze-thaw action

Tremors & eruptions

Human activity

Avalanches

Lightning

Stream erosion

Wind

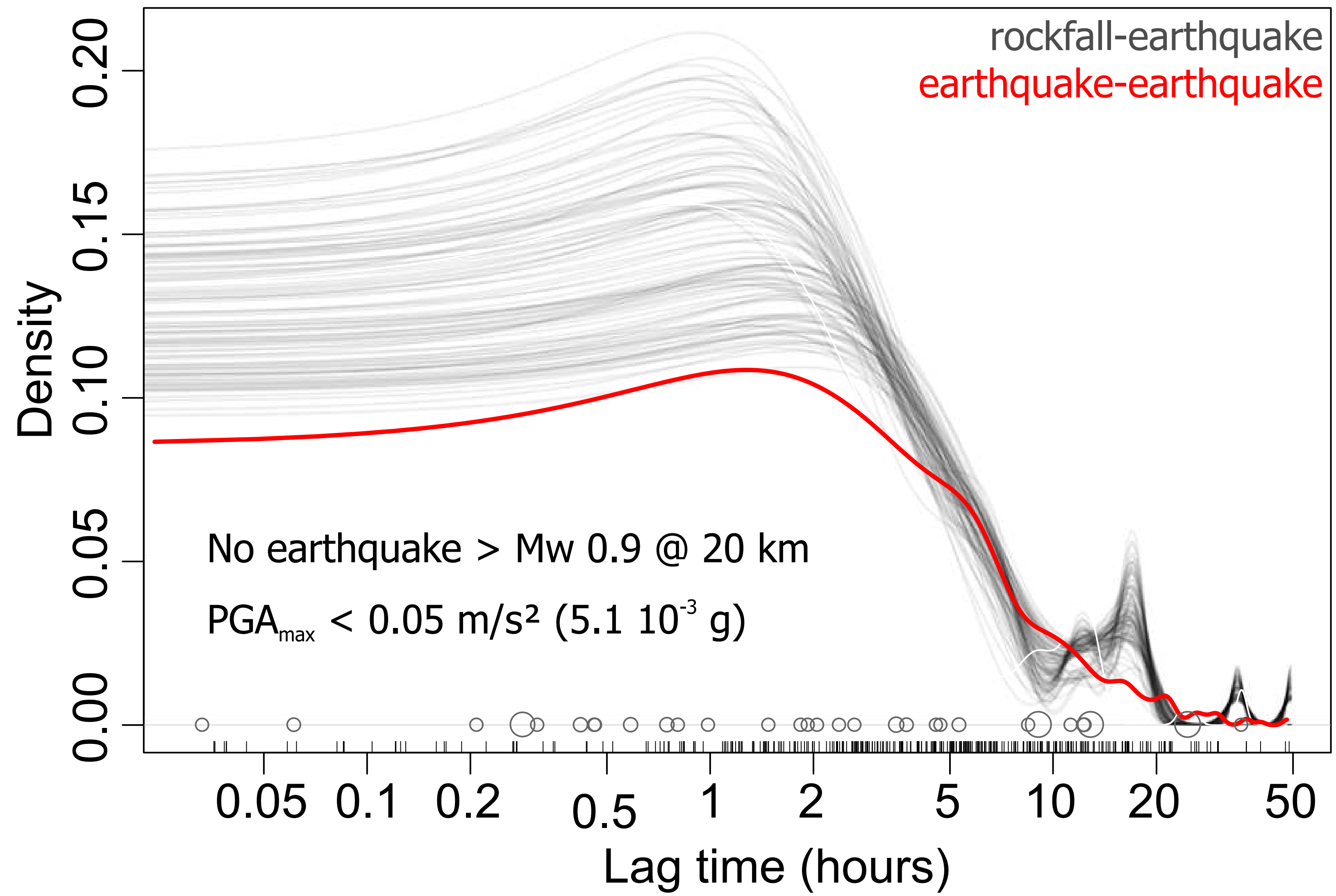
Time lags and driving forces - Monte Carlo-based lag time density estimates

Earthquakes

Precipitation

Freeze-thaw action

Earthquakes



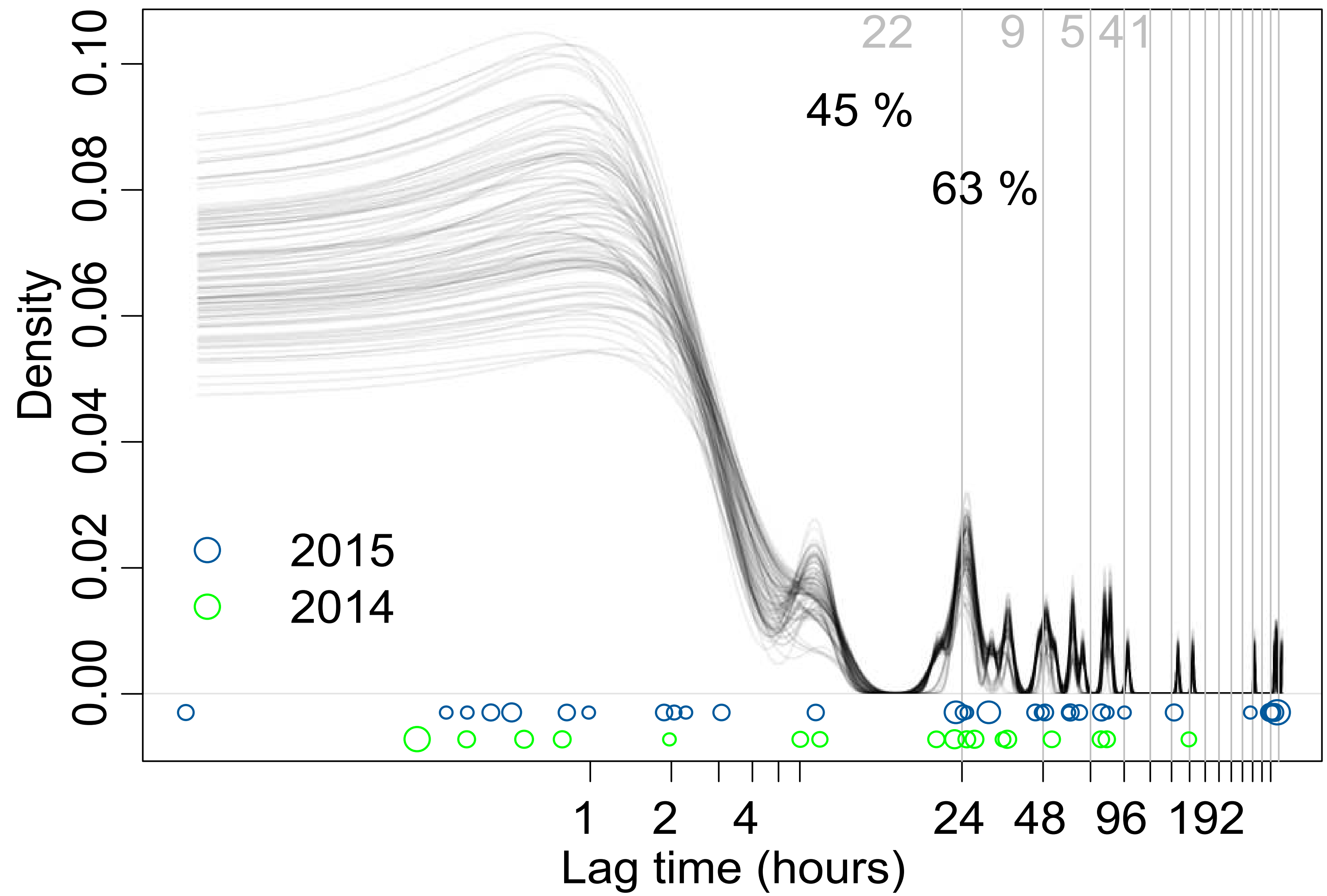
Time lags and driving forces - Monte Carlo-based lag time density estimates

Earthquakes

Precipitation

Freeze-thaw action

Precipitation



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

Earthquakes

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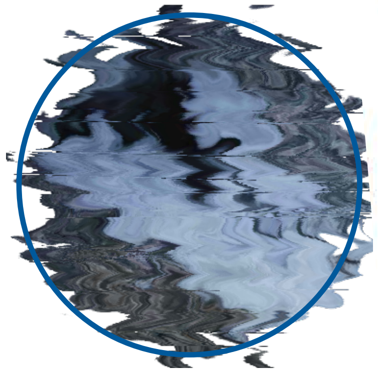
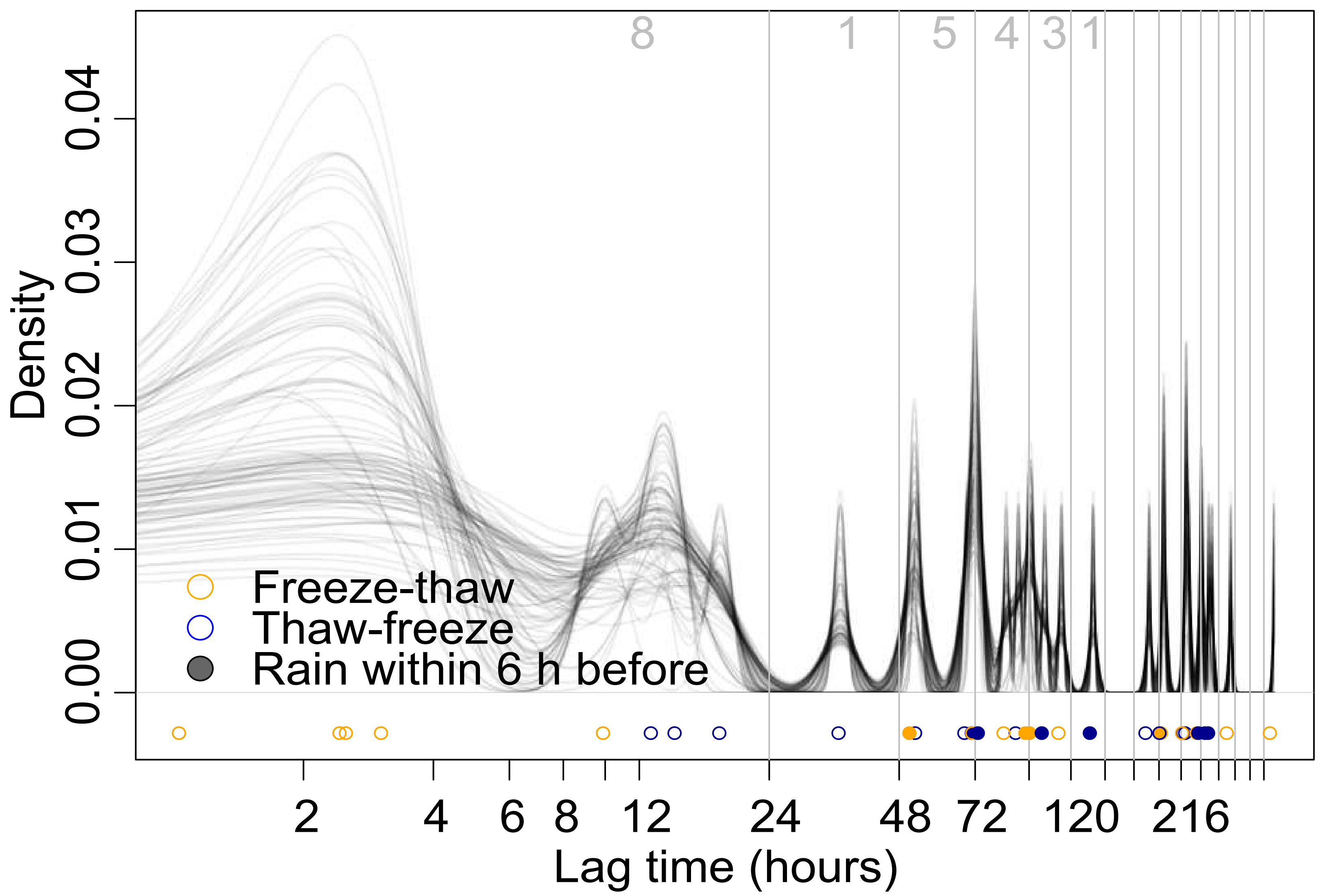
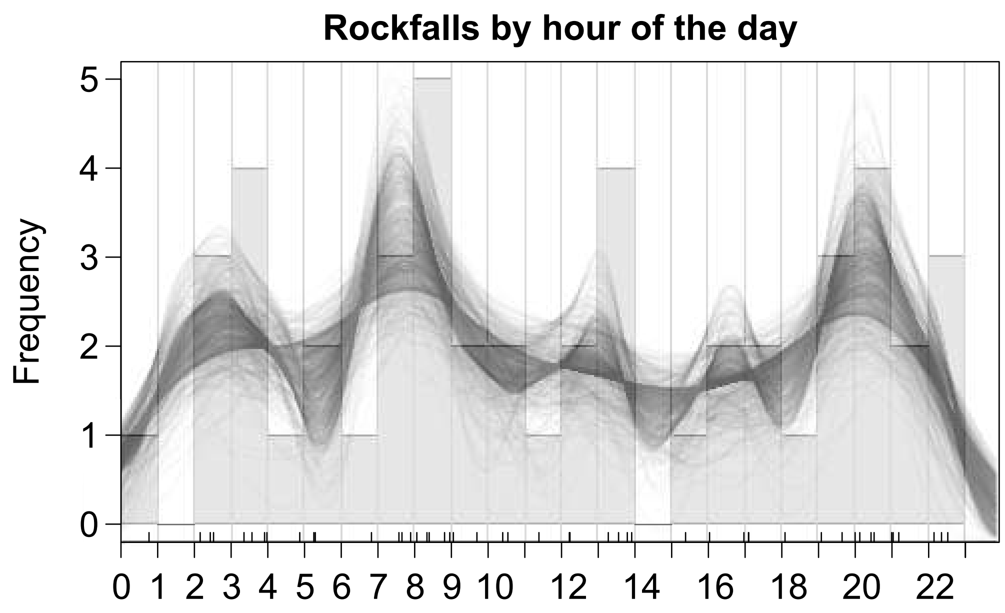


Freeze-thaw action



Time lags and driving forces - The daily cycle



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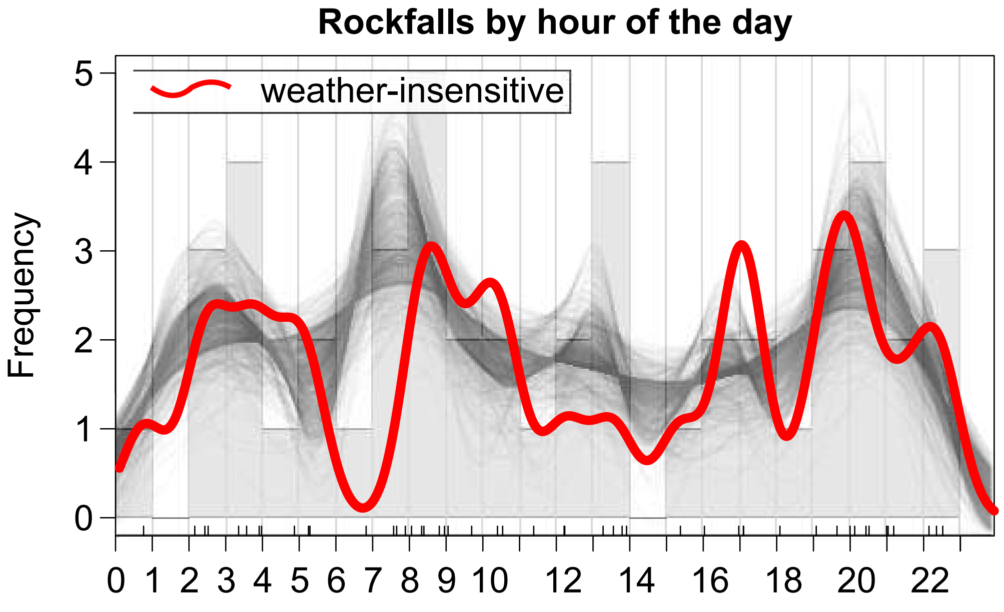
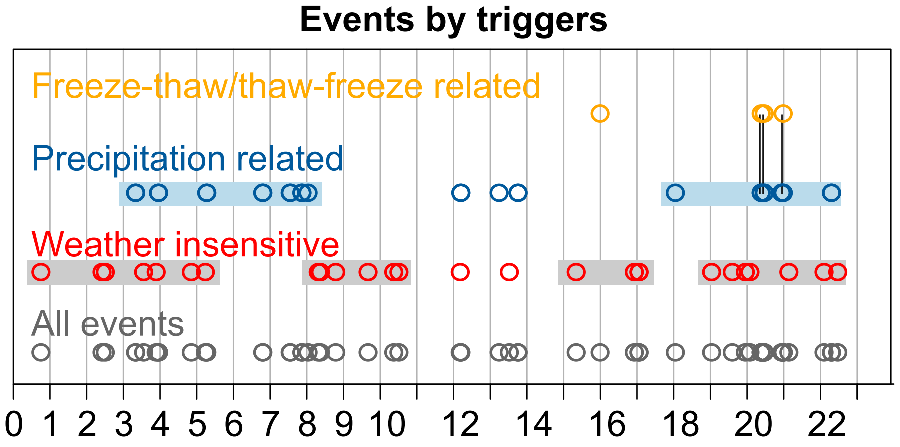
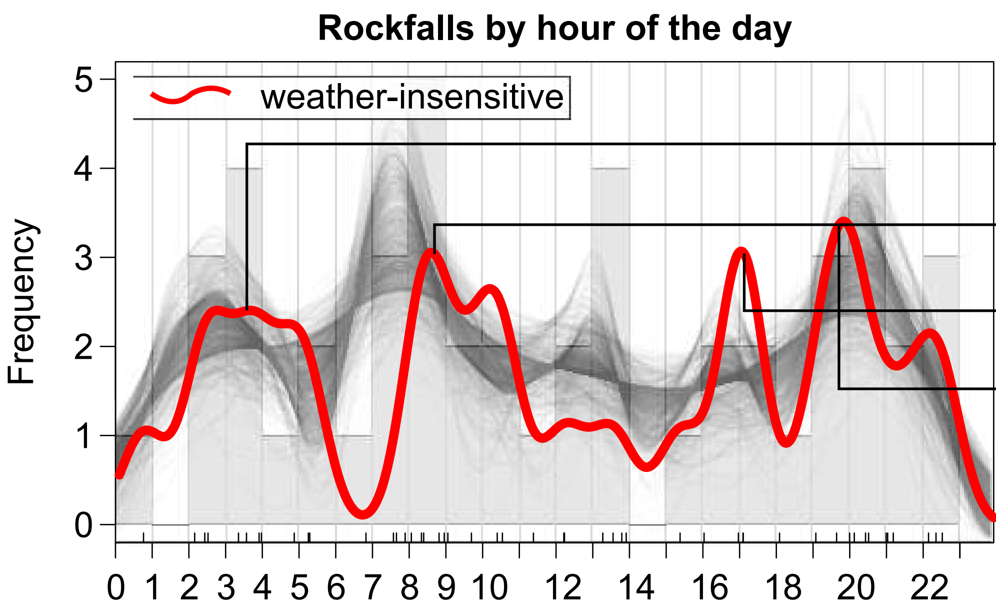




Time lags and driving forces - The daily cycle

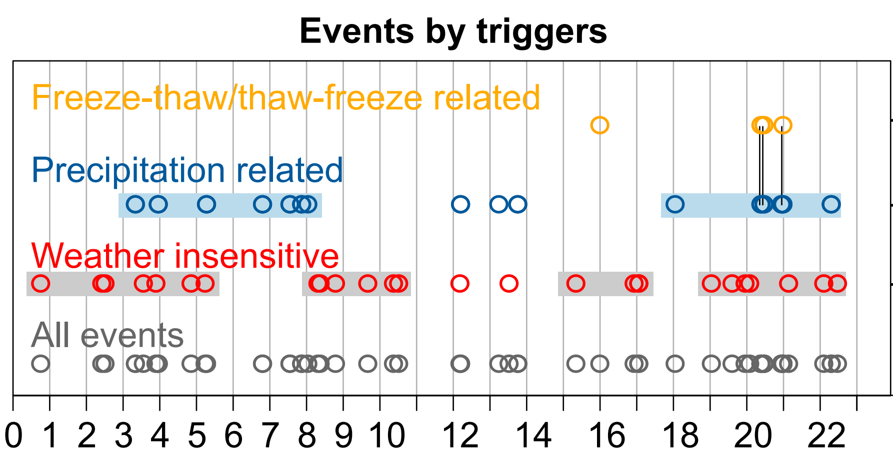


The coldest hours of the day

Highest temperature change rates

Highest temperature change rates

Unknown activity cause



5 (10 %) rockfalls caused by freeze-thaw

19 (39 %) rockfalls caused by rainfall

17 (35 %) rockfalls caused by diurnal forcing

Slides and further information:

www.micha-dietze.de

Done...
Thank you all!

Seismic monitoring detects and locates well below 1 m³ with about 81 m uncertainty

Precise insight to dynamics of individual events provides essential data for other disciplines

Seasonally shifting rockfall activity window (33 m/month)

Precipitation and diurnal forcing dominate rockfall activity