The hum of our environment

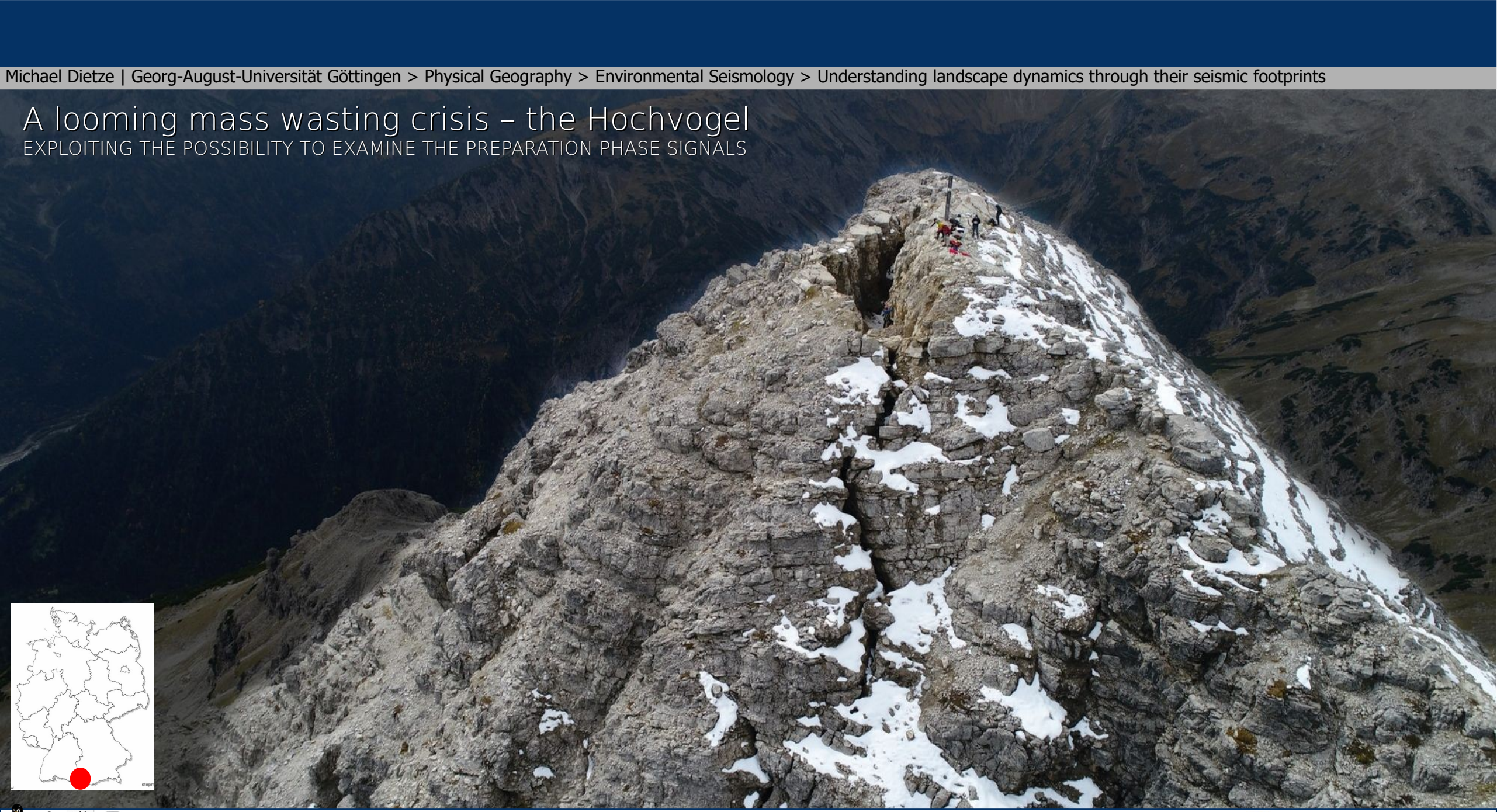
Understanding landscape dynamics through their seismic footprints

Picking on the elephant – seismic signals of the surface expression of deep deformation

Michael Dietze, Georg-August-Universität Göttingen (& Deutsches GeoforschungsZentrum Potsdam)
… and a large number of friends, colleagues, collaboratours, enthusiastic referees

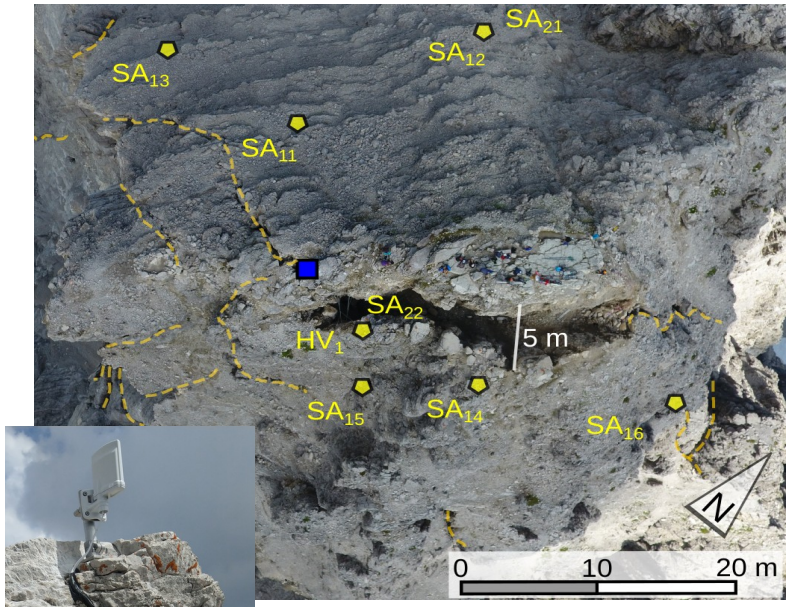
A looming mass wasting crisis – the Hochvogel

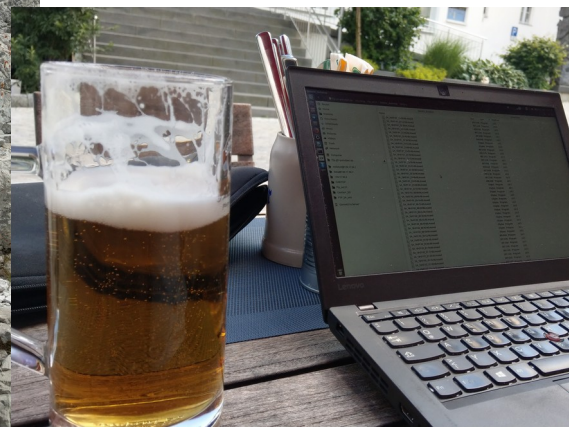
EXPLOITING THE POSSIBILITY TO EXAMINE THE PREPARATION PHASE SIGNALS

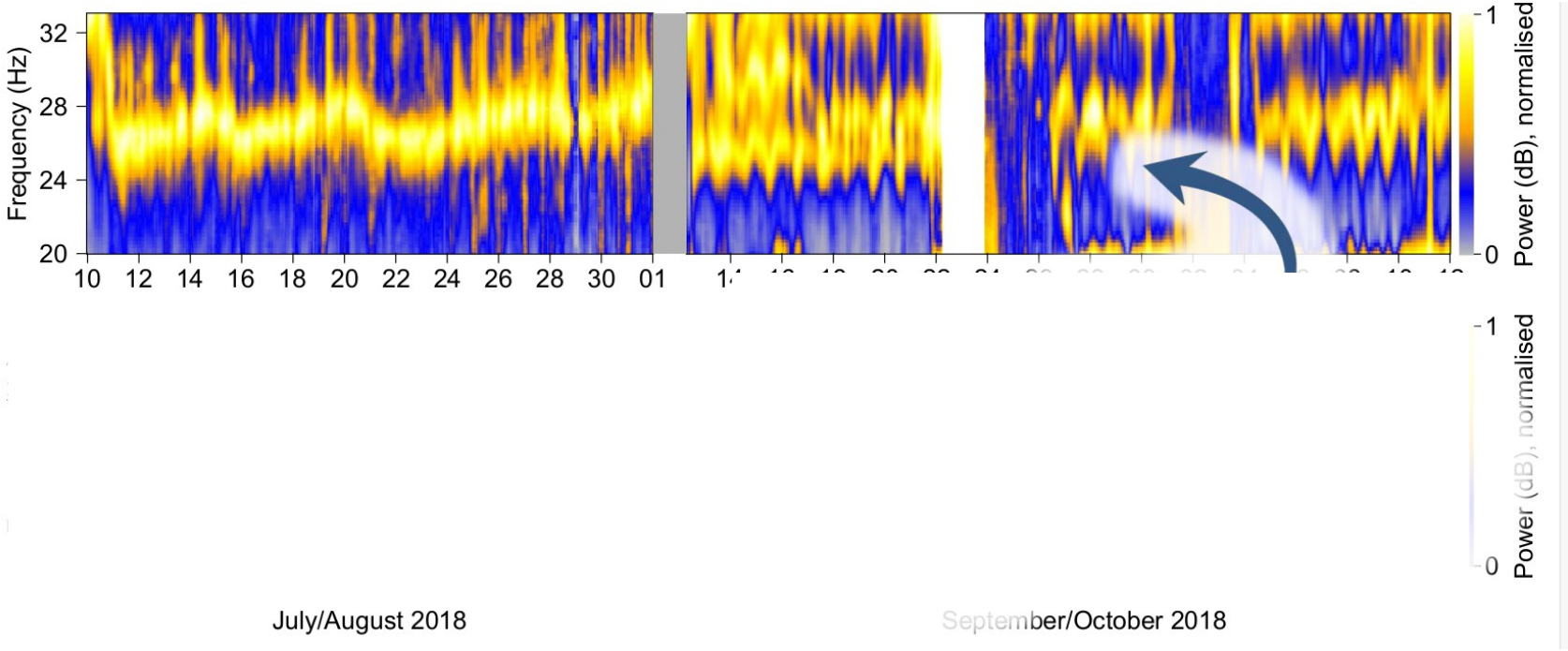


Live view of the seismic signals of rock deformation

24/7 MONITORING OF ROCK MECHANIC STATE EVOLUTION: CYCLIC STRESS ACCUMULATION

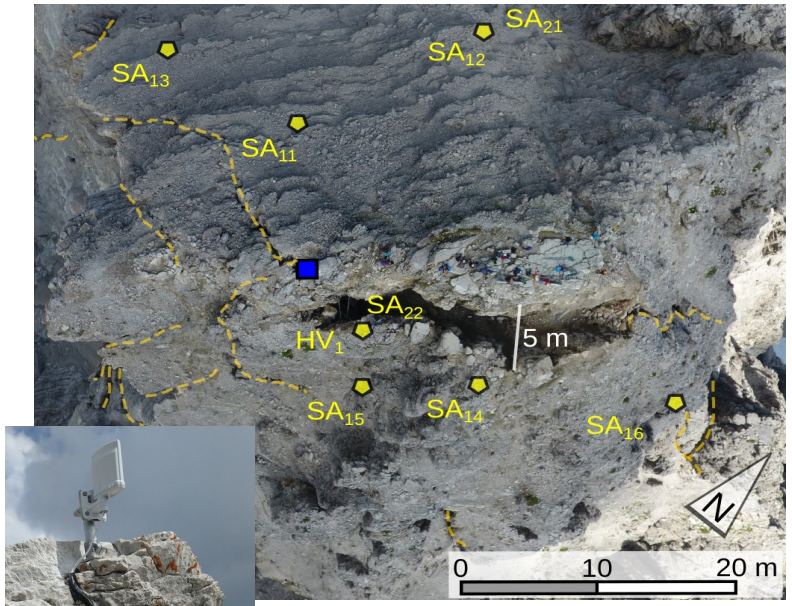


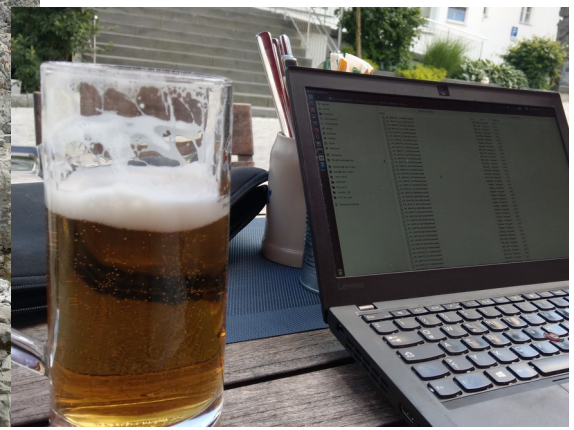


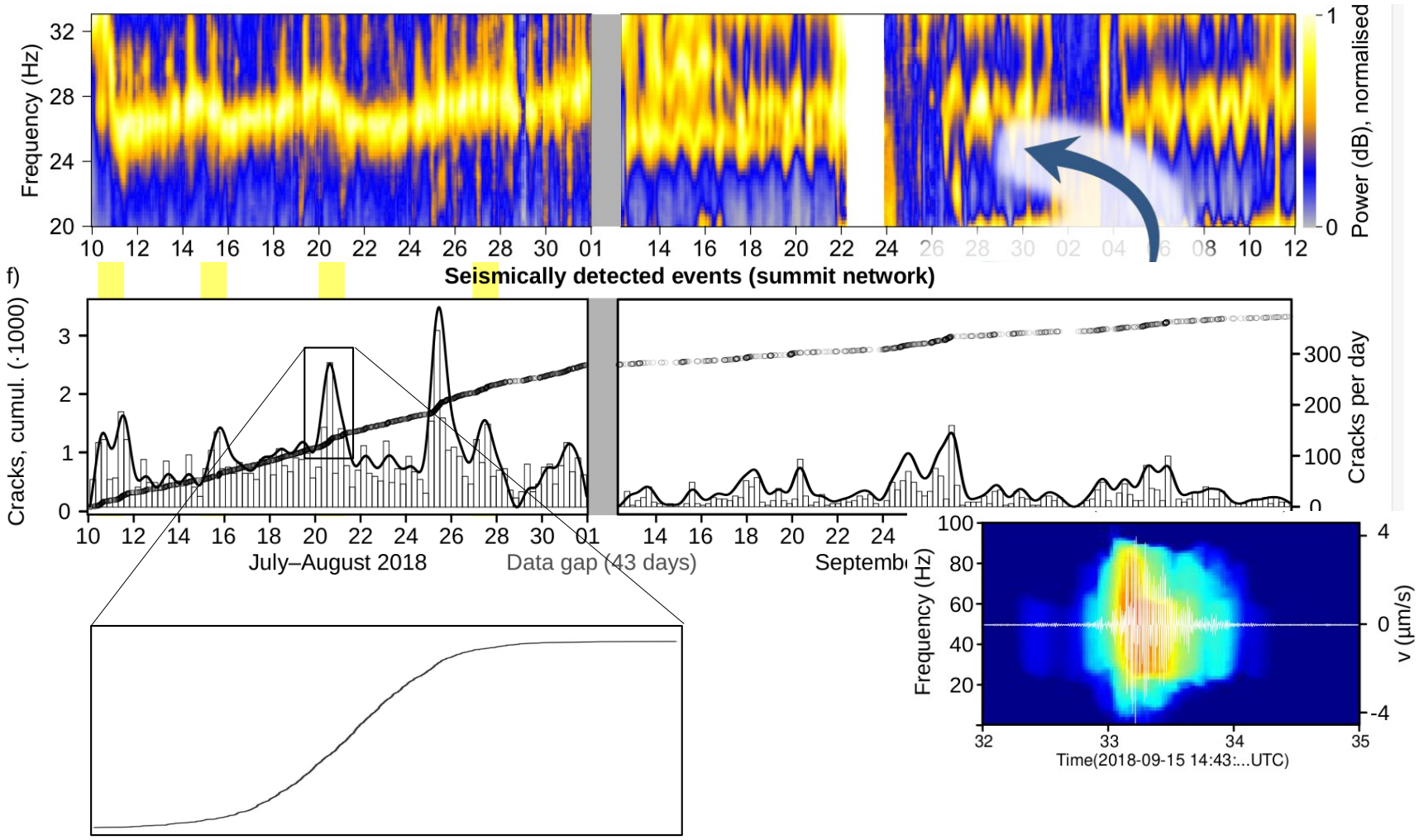


Live view of the seismic signals of rock deformation

24/7 MONITORING OF ROCK MECHANIC STATE EVOLUTION: CYCLIC STRESS ACCUMULATION AND RELEASE



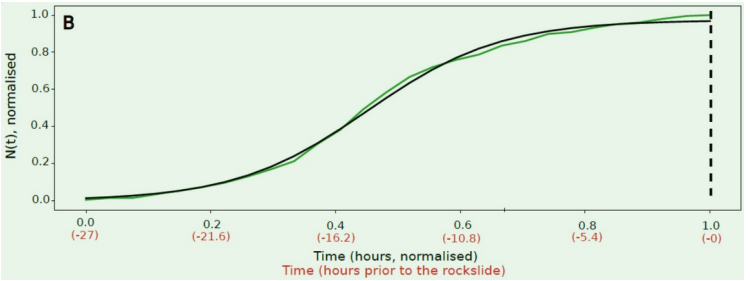


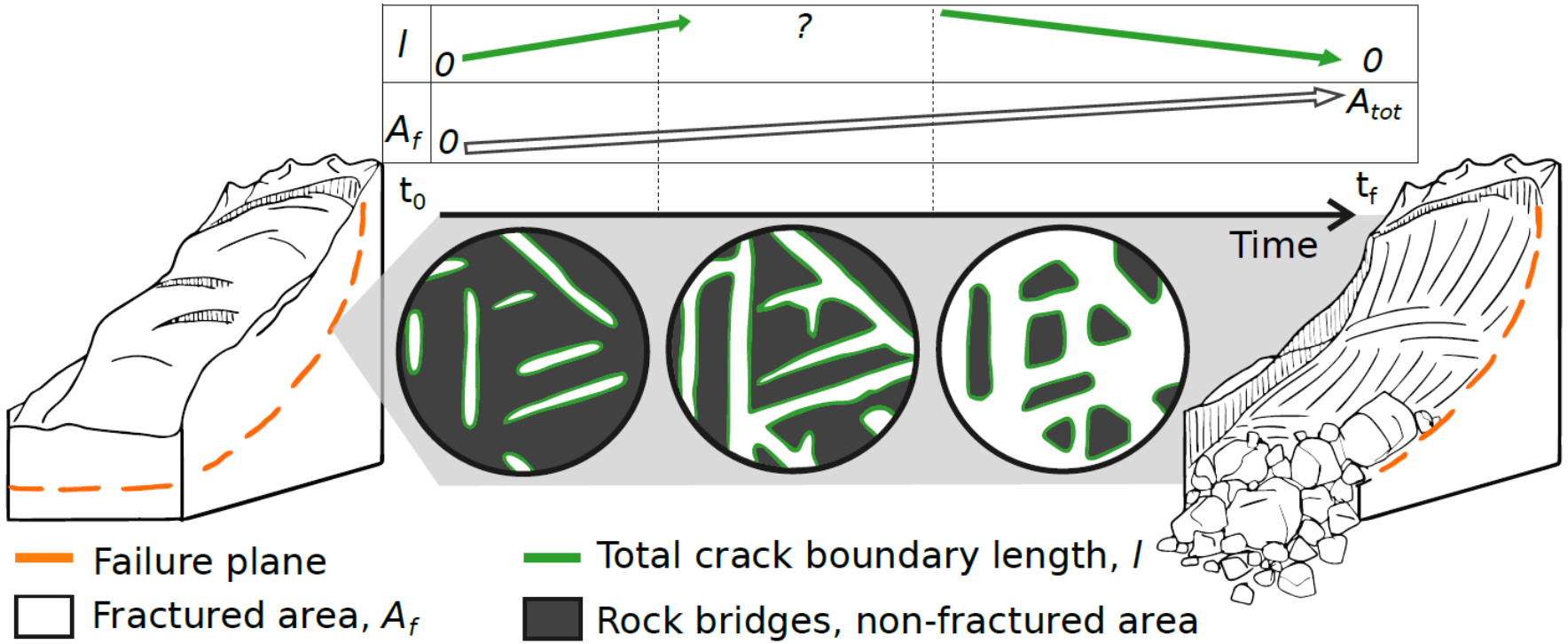


What drives the temporal evolution of crack emission rate?

GROWTH OF A SHEAR PLANE CAUSES SIGMOIDAL CRACK RATE PATTERN DUE TO GEOMETRIC EFFECT

$$N(t) \quad \frac{A_{tot}}{1+\exp\left(\frac{-t}{\tau}+b\right)}$$





When millions of cubic metres start to move

OR ABOUT THE PURE NECESSITY TO UNDERSTAND THE PREPARATION PHASE

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Mass wasting in central Europe (almost) always affects society

BRINZAULS, GRISON (CH), SITS RIGHT BELOW A MIO M³ ACTIVE ROCK SLIDE, WHILE MOVING ON A LANDSLIDE

Mass wasting in central Europe (almost) always affects society

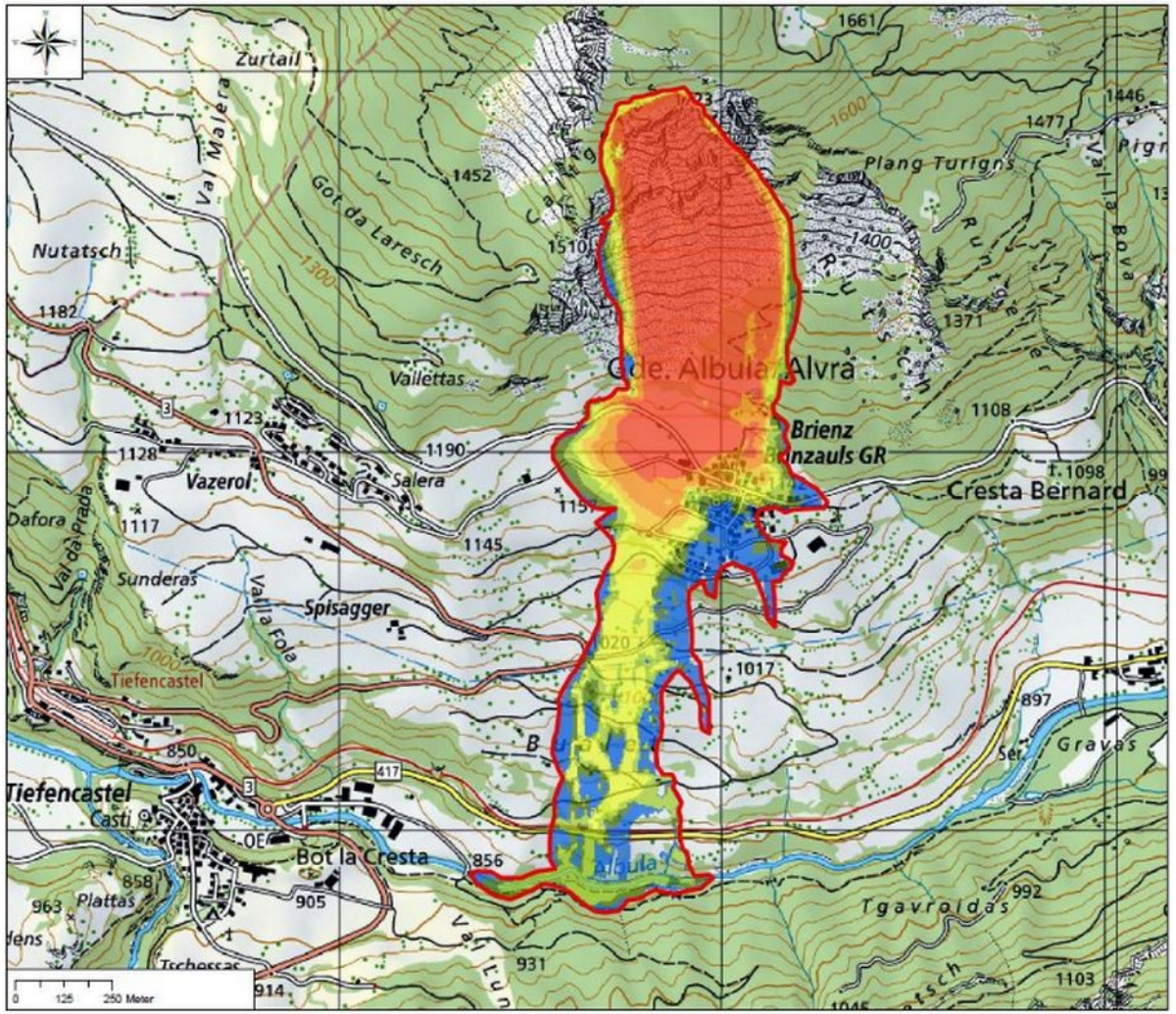
BRINZAULS, GRISON (CH), SITS RIGHT BELOW A MIO M³ ACTIVE ROCK SLIDE, WHILE MOVING ON A LANDSLIDE

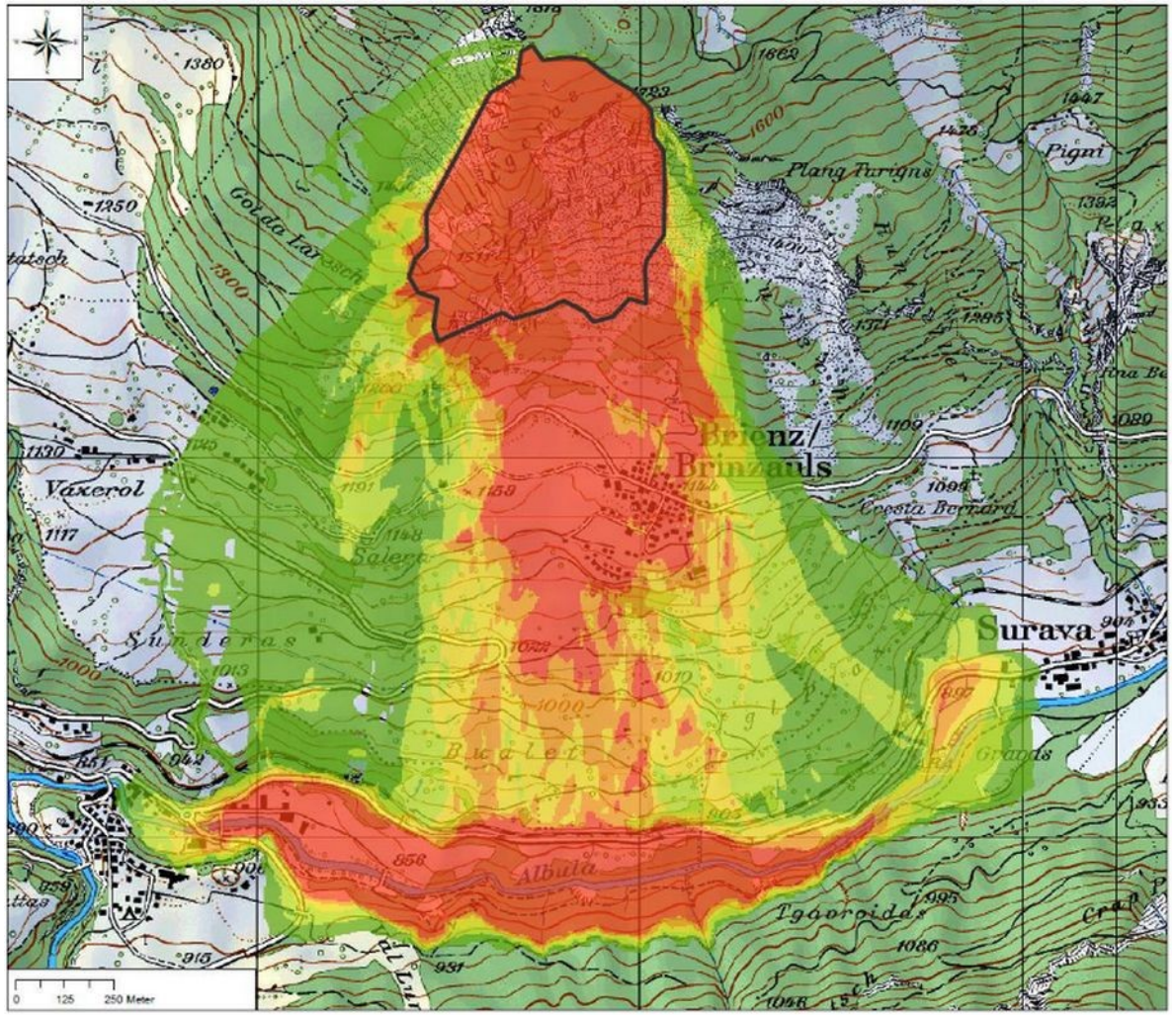
1) Towards real time rapid mass wasting detection, independent of visibility conditions

2) Understanding activity patterns and drivers

Szenarios of mass wasting impact

CONNECTIVITY OF STEEP ROCK SLIDE, SLOW MOVING LANDSLIDE AND THE ALBULA RIVER



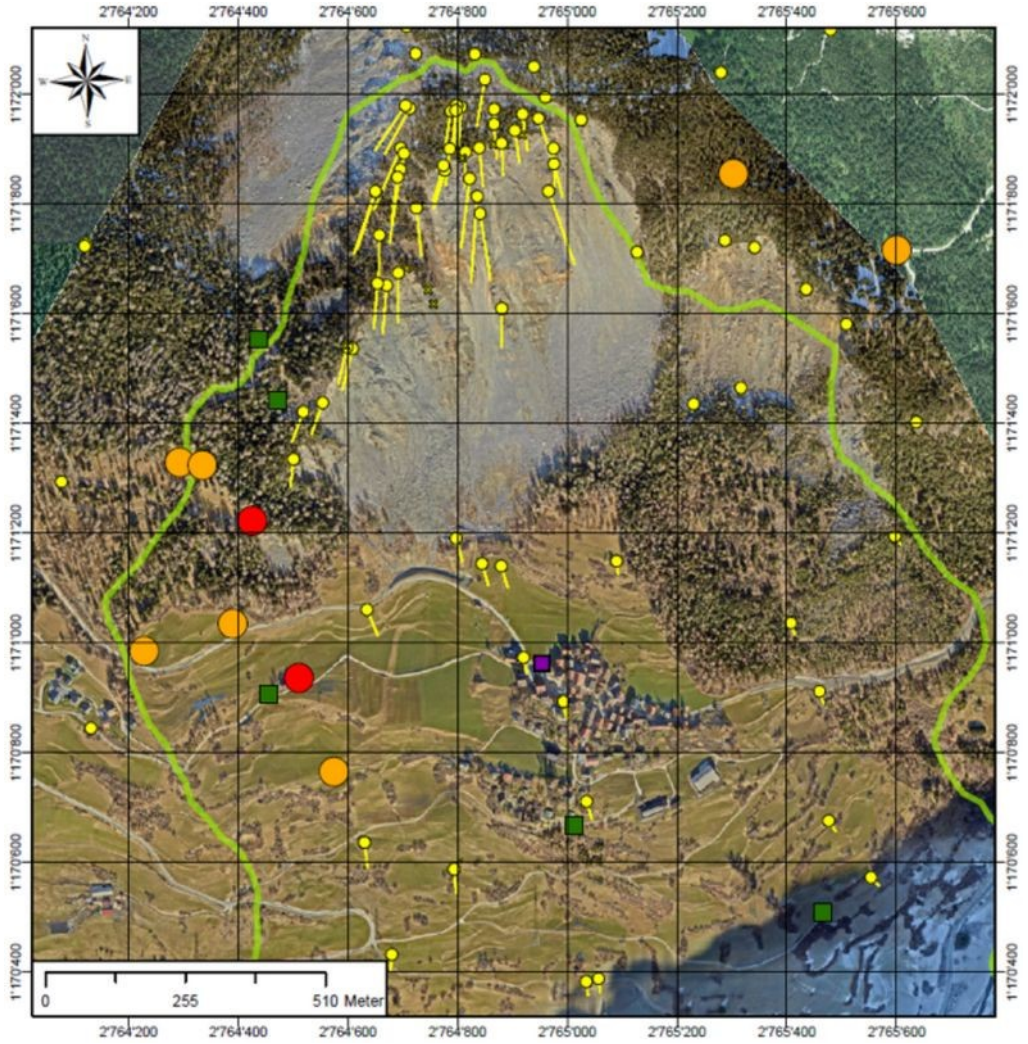


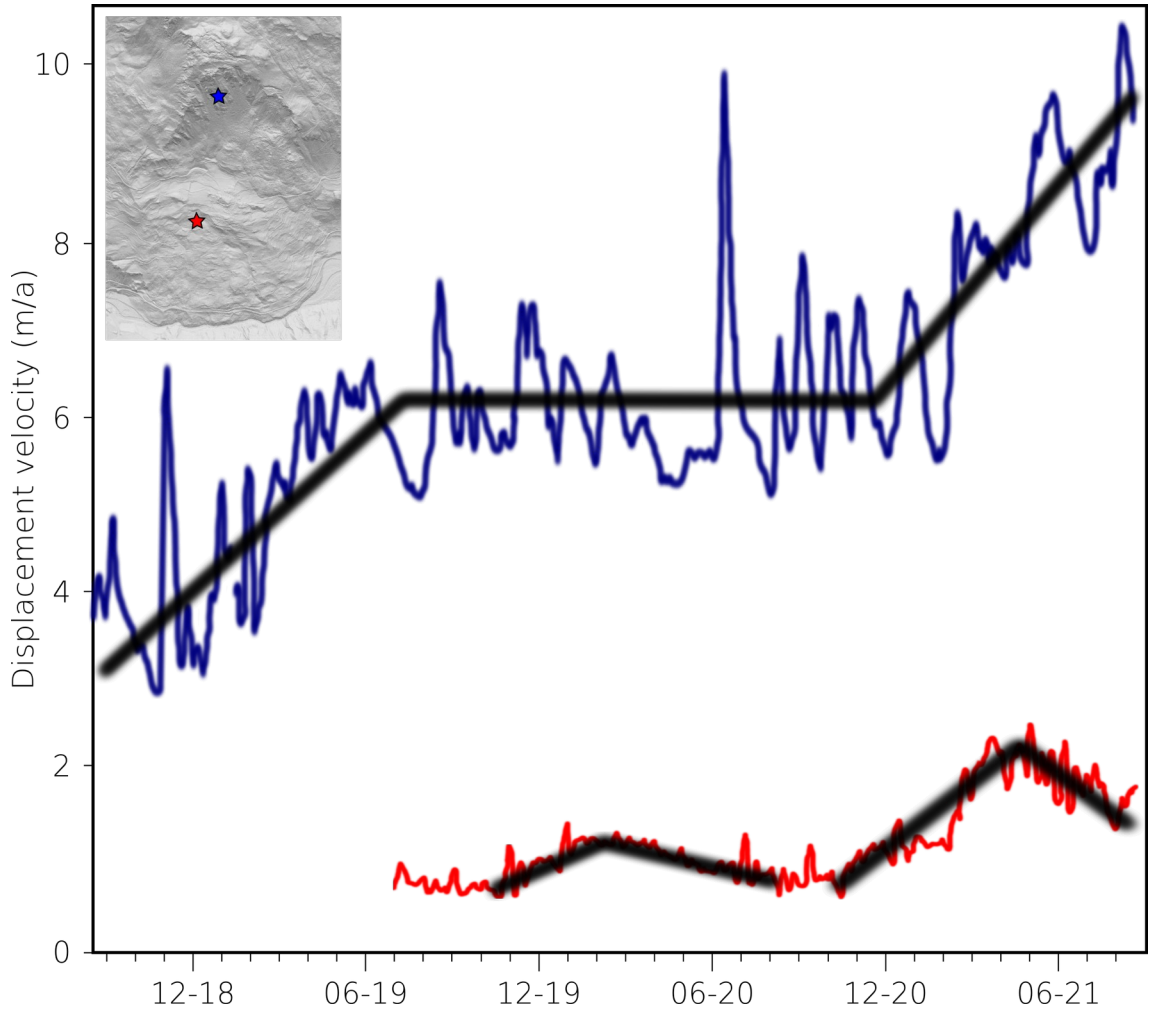
Data from www.albula-alvra.ch: 500,000 m³

22,000,000 m³ (~ Chamoli-Event)

Existing, sophisticated monitoring and warning network

FOCUS ON ESTBALISHED, STATE-OF-THE-ART TECHNIQUES, INCL. FULL WORKFLOW FOR EVACUATION





Data from www.albula-alvra.ch:

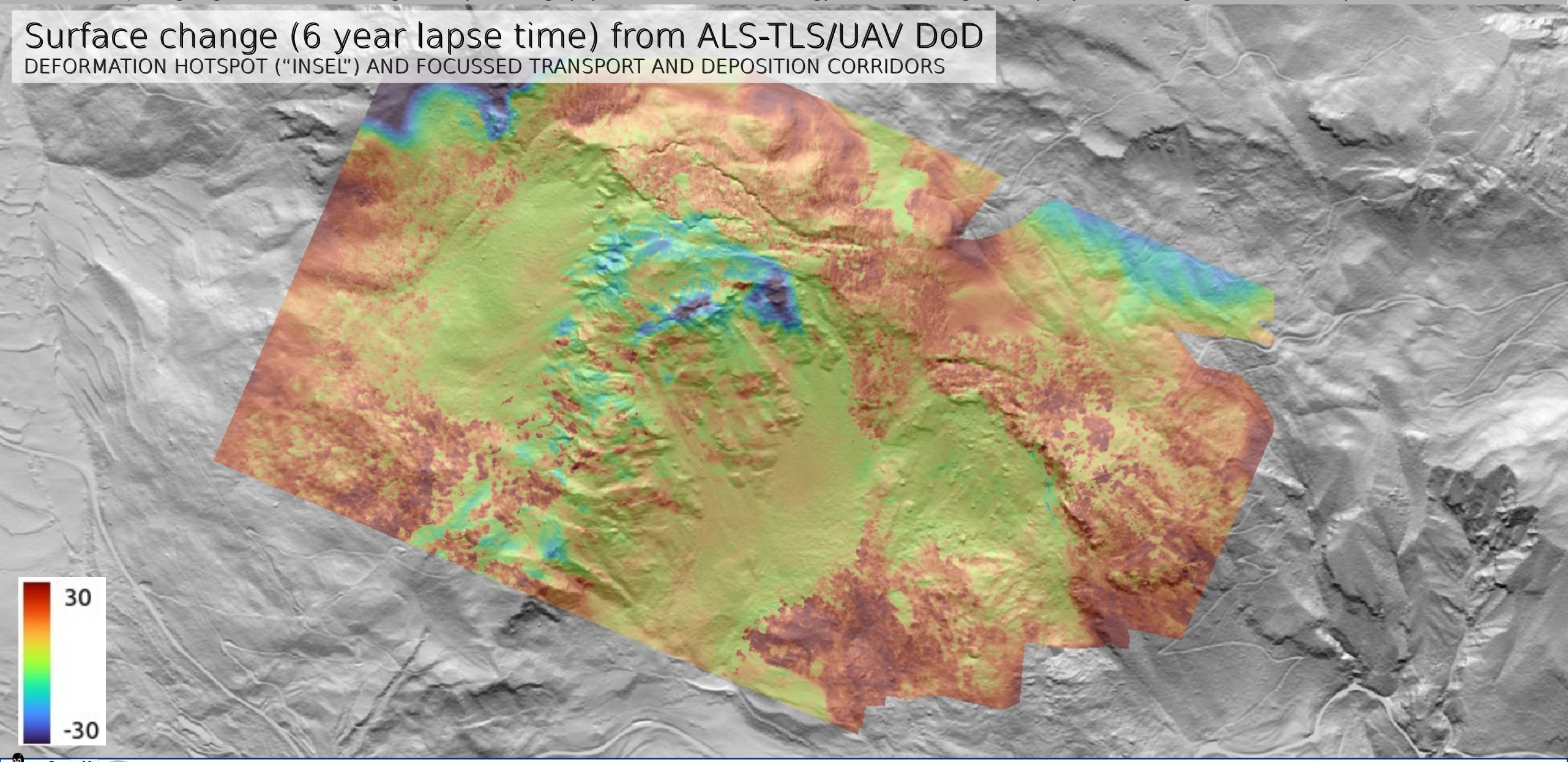
Space-time-resolved event surveying

COMBINED TLS/UAV AND SEISMIC SURVEYING OF SURFACE CHANGE

800 m

Surface change (6 year lapse time) from ALS-TLS/UAV DoD

DEFORMATION HOTSPOT ("INSEL") AND FOCUSSED TRANSPORT AND DEPOSITION CORRIDORS



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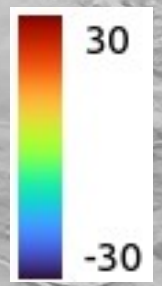
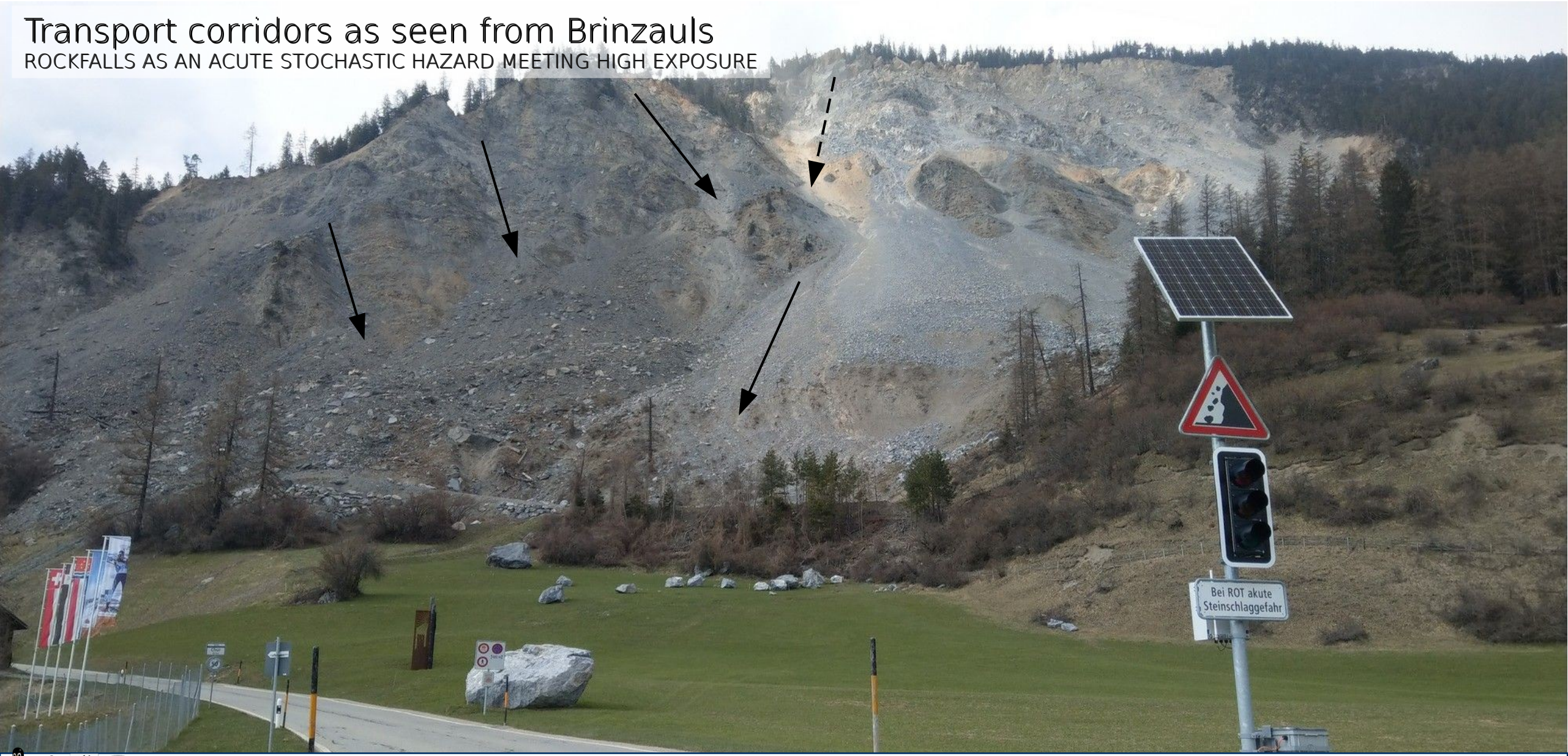


Transport corridors as seen from Brinzauls

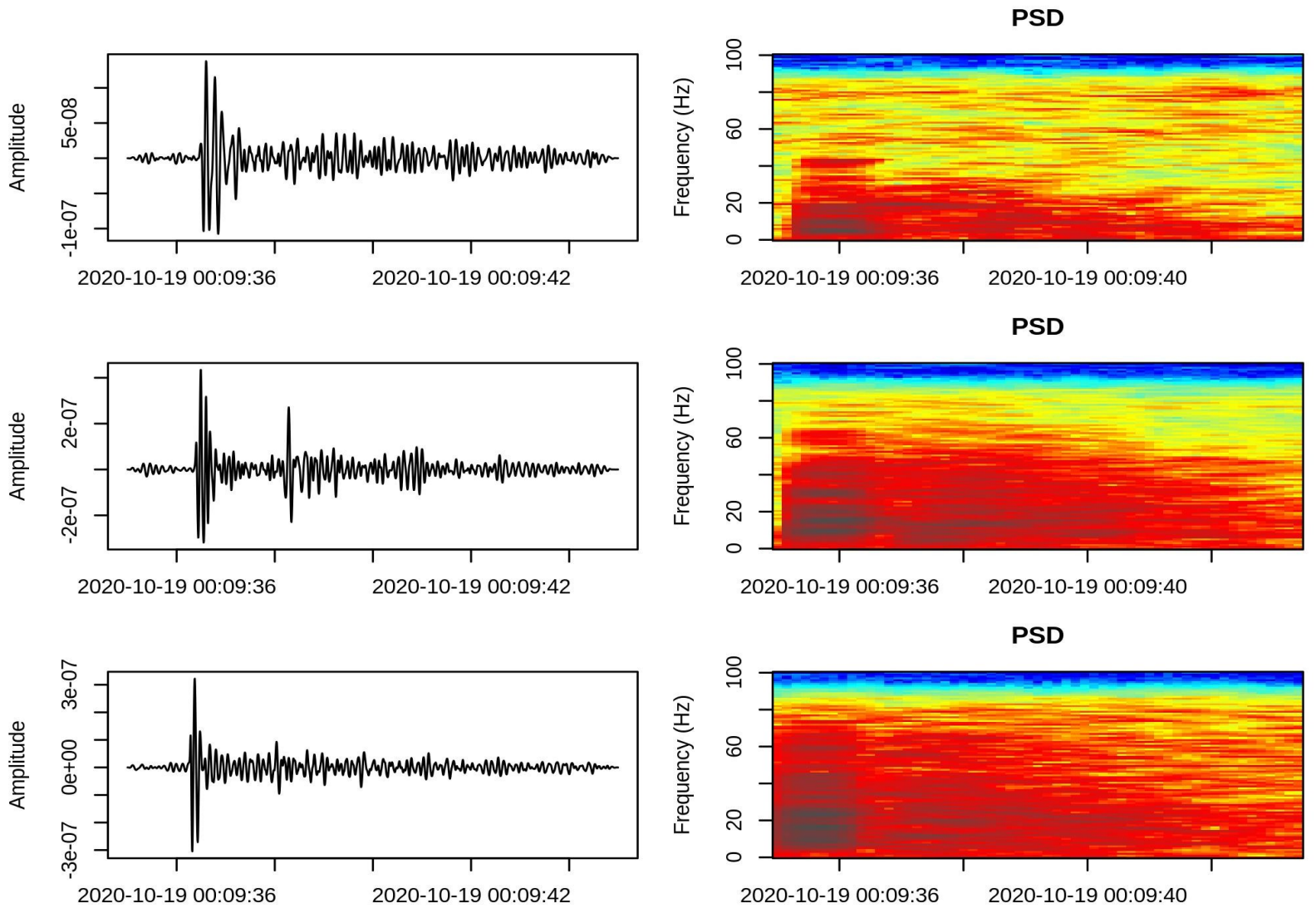
ROCKFALLS AS AN ACUTE STOCHASTIC HAZARD MEETING HIGH EXPOSURE



Main road to Brinzauls (closed now), old school building in the back

Seismic event detection

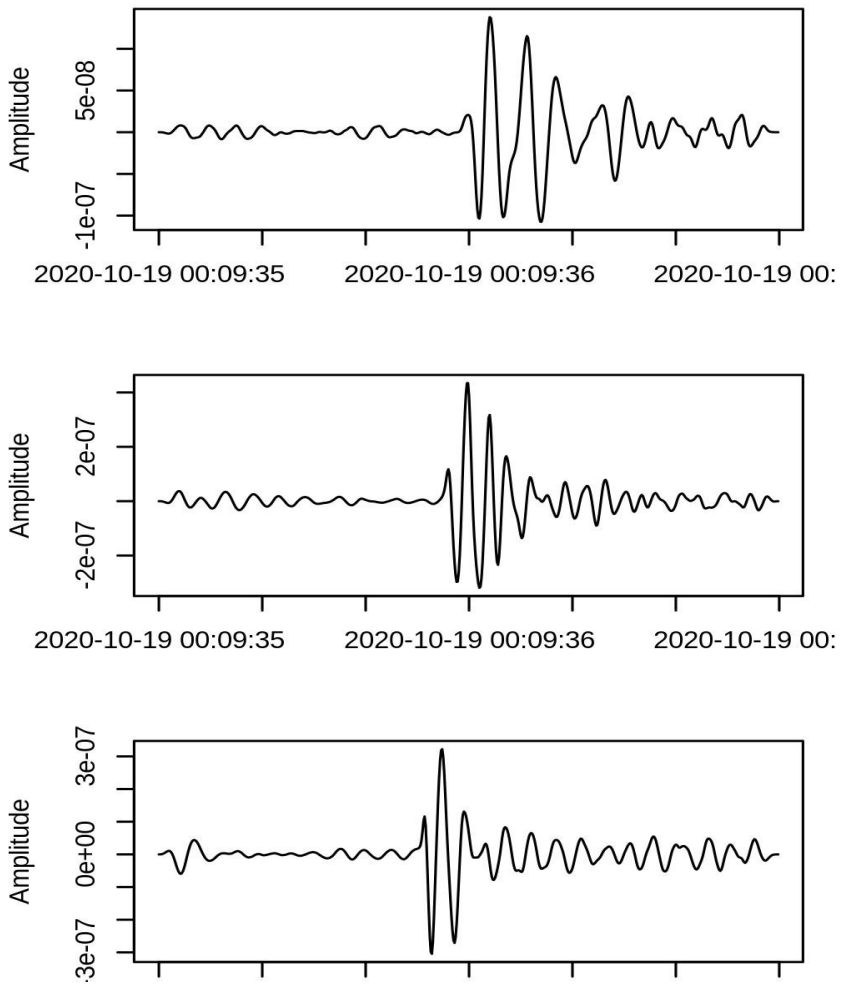
"SIMPLE" SIGNALS, EASY TO AUTOMATICALLY IDENTIFY



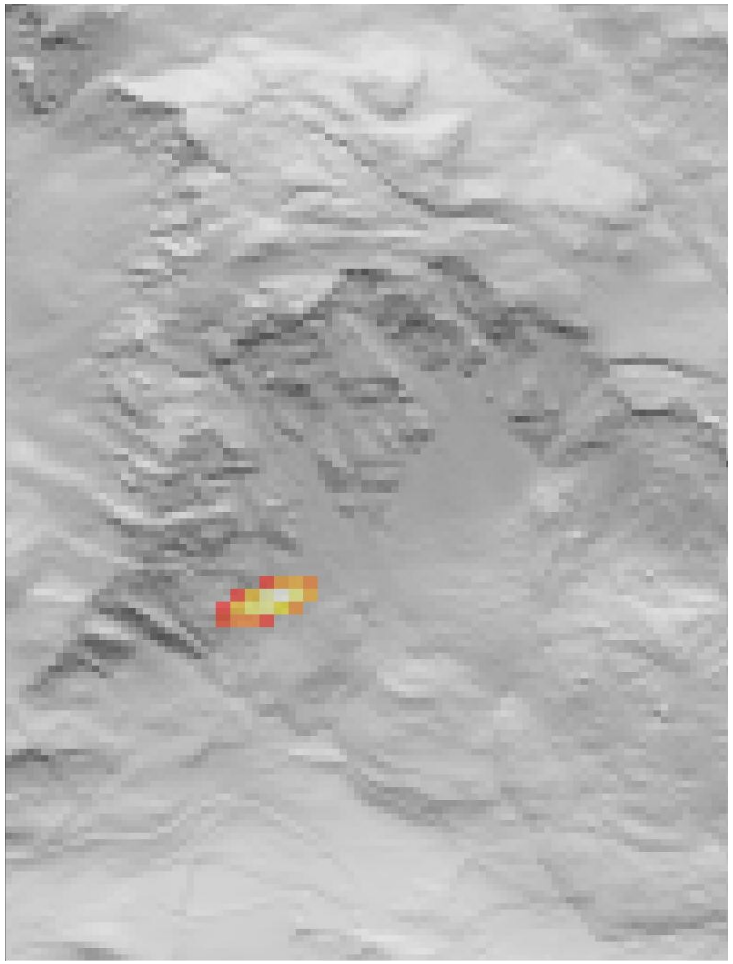
Seismic event location

COMBINING TWO INDEPENDENT FAST ALOGIRTHMS TO RAPIDLY DELIVER ROBUST SOURCE LOCATIONS

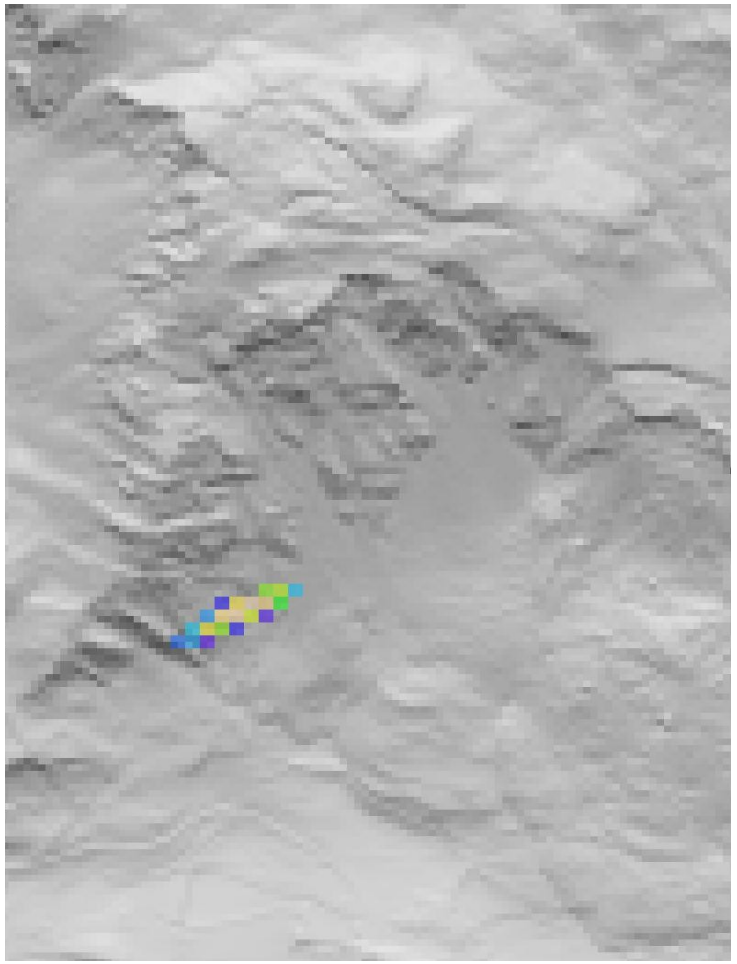
Seismograms (5-10 Hz)



Location (signal migration)

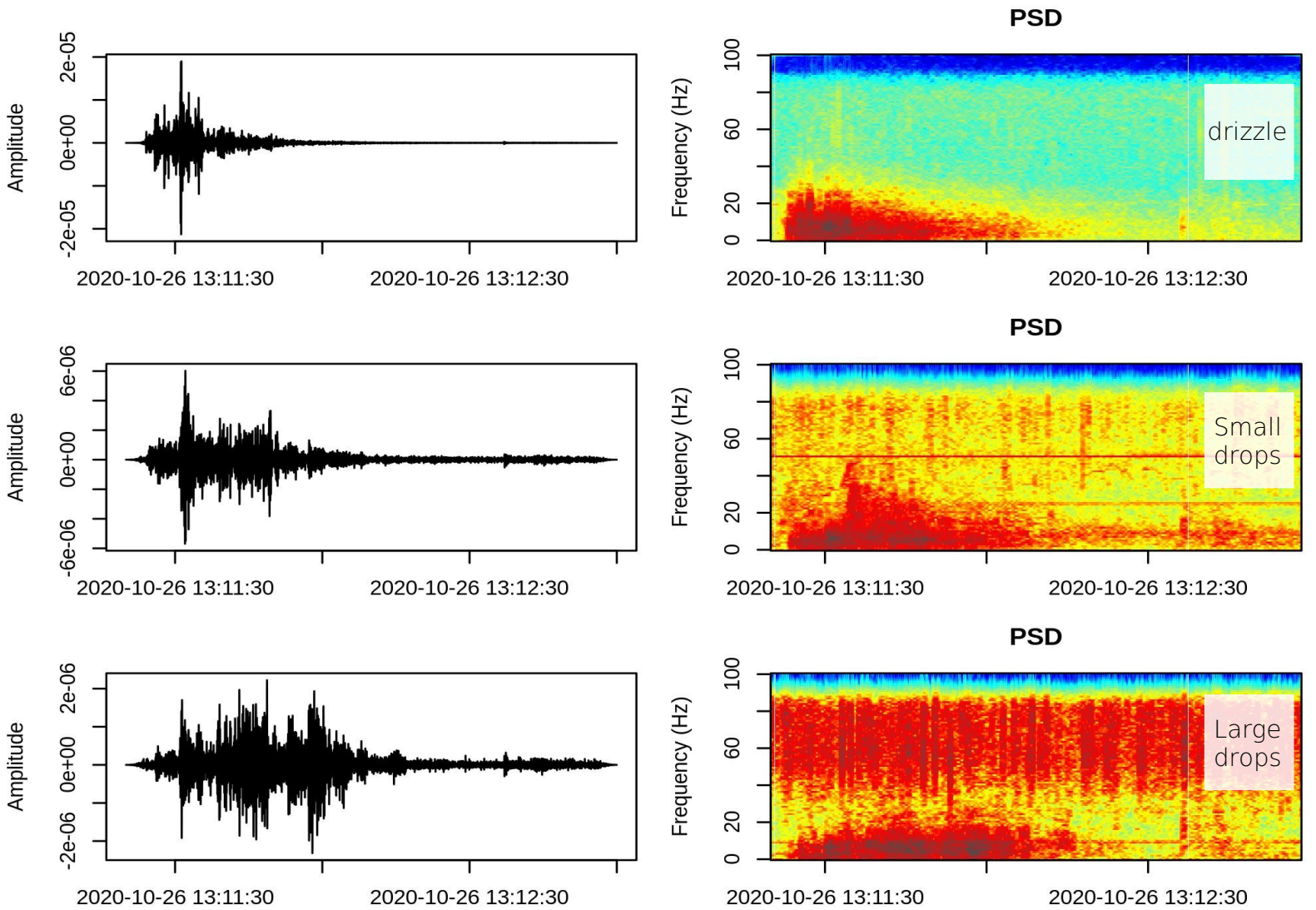


Location (amplitude modelling)



Seismic events propagating through the slope instability

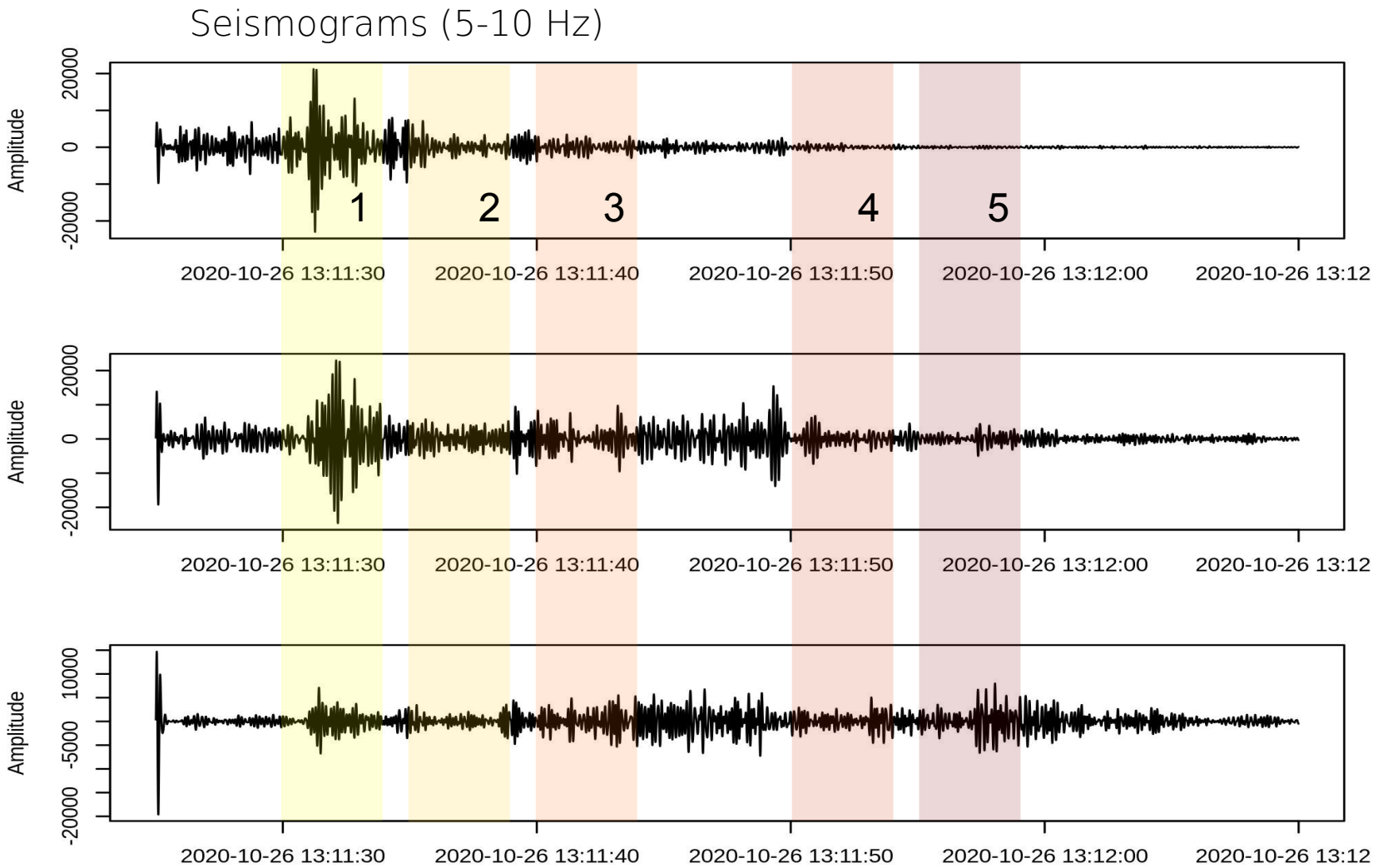
LESS CONSISTENT WAVEFORMS ACROSS STATIONS & INTERFERENCE WITH METEOROLOGICAL ACTIVITY



Seismograms look different depending on the (time variant) distance of source and seismometer

Adoption of the amplitude modelling technique for mobile sources

TIME WINDOWED AND TRAVEL TIME CORRECTED SOURCE LOCATION → TRACKING MASS WASTING TRAJECTORIES



Event tracking in 5 s intervals, methods see Cook, Rekapalli, Dietze et al. (2021, Science)

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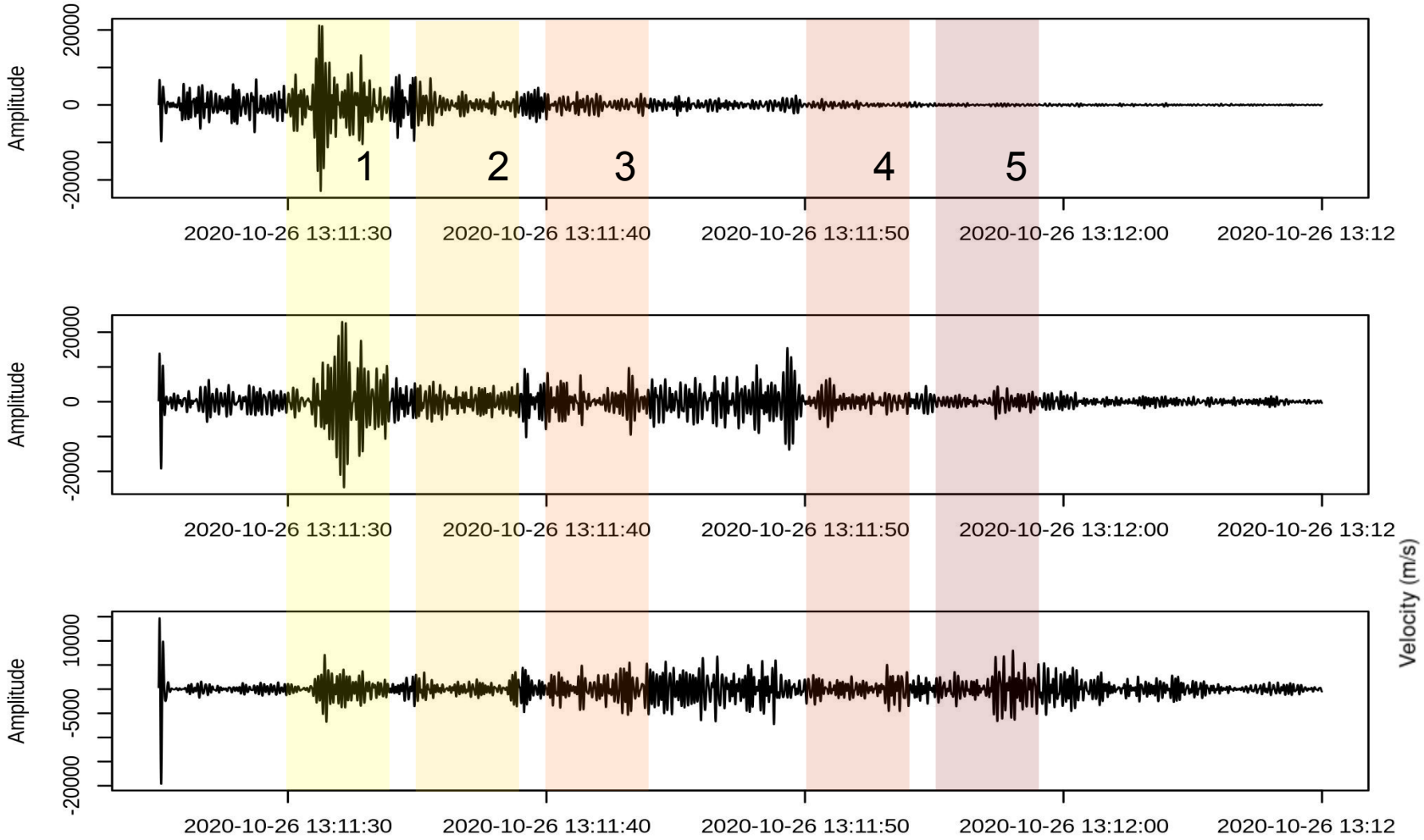

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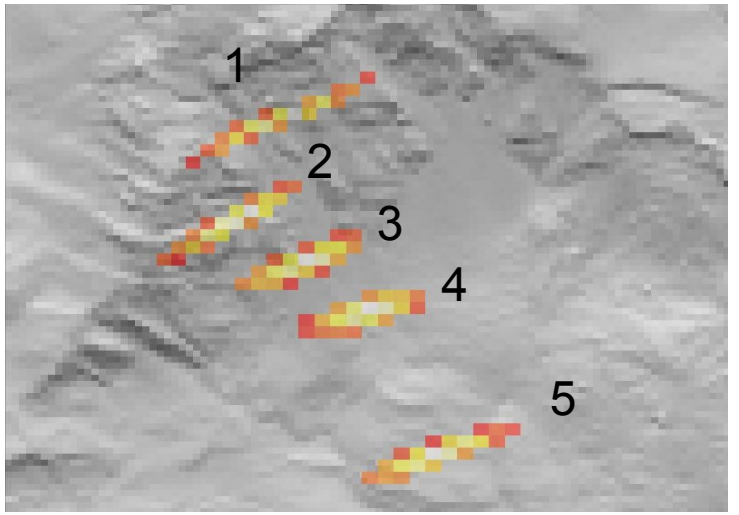

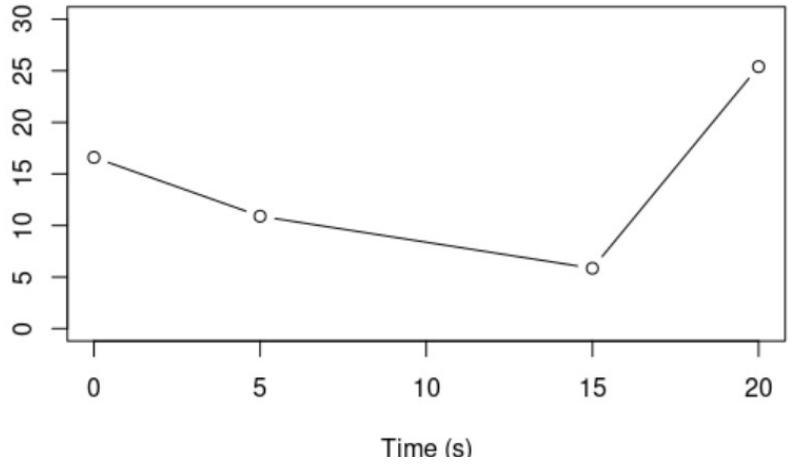

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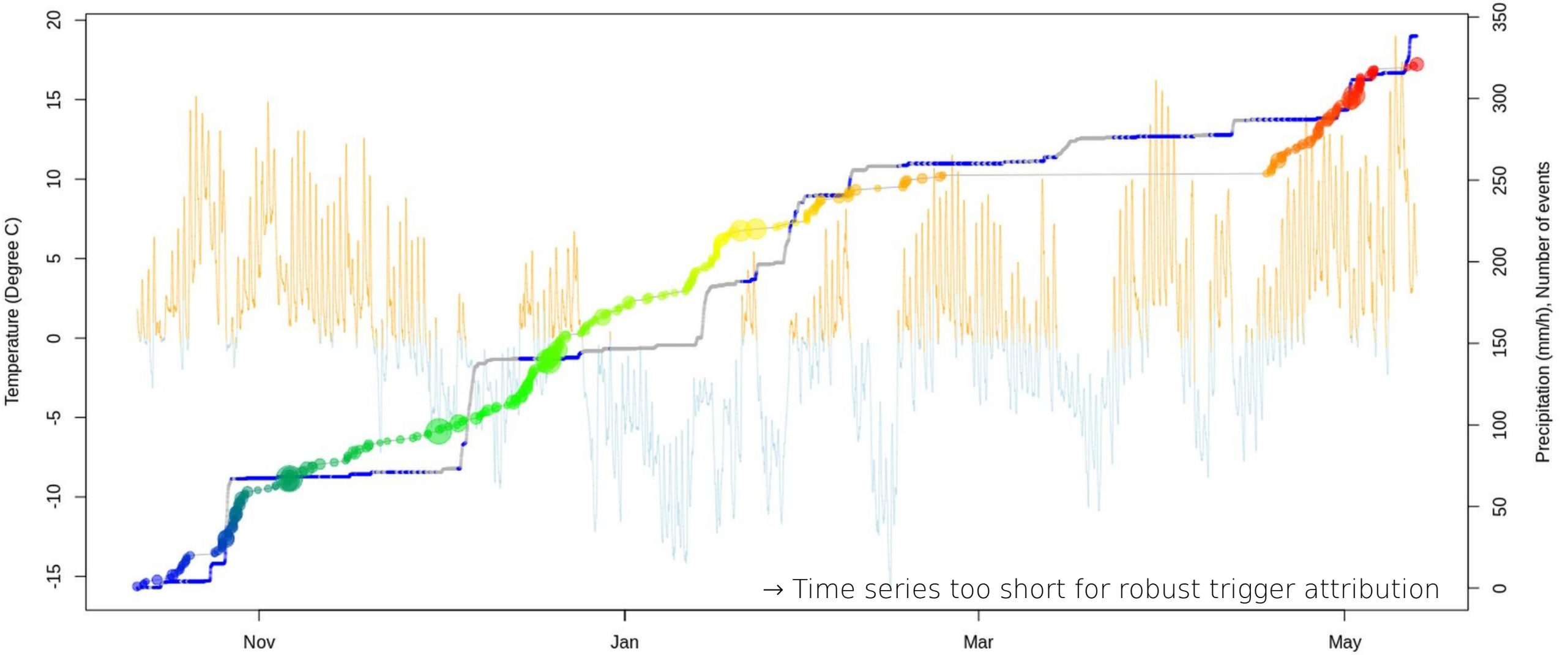
From single event anatomy to seasonal patterns and trigger attribution

COMPLEX SUPERPOSITION OF SEVERAL POTENTIAL DRIVERS & TRIGGERS REQUIRES HIGH RESOLUTION EVENT CHARACTERISATION



What remains to be said?

A BRIEF SUMMARY OF IMPORTANT POINTS

Seismic networks can be used to probe subtle material state changes and stochastic emission signals beyond the point scale, and to detect/locate/track rapid mass wasting

Seismic networks deliver continuous but indirect data on event reparation and evolution
→ We have develop models that turn ground motion data into rock mechanic metrics

Seismic networks can work out alone, but when complementing other, direct sensing methods, we see a tremendous gain in robustness and depth of information

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