Seismic detection and characterization of rockfalls in Austria

universität wien | ZAMG

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Abstract

Rapid gravitational mass movements, such as landslides, rockfalls, or avalanches are repeatedly recognized during routine seismic monitoring at national earthquake observatories. Yet, utilizing the tools of seismology for fast detection and characterization of mass movements is still uncommon.

Seismology recently gained attention for the assessment of gravitational mass movements because it can potentially provide continuous realtime detection and approximate localization of events. However, the applicability on country scale needs to be tested and the seismological determination of precise location and of event parameters is challenging.

Here we present a set of past rockfall events in Austria and neighboring countries, which were well-recorded by several permanent and temporary seismic stations. We aim at identifying seismically observable parameters of rockfalls in comparison with additional geological and geographical data.

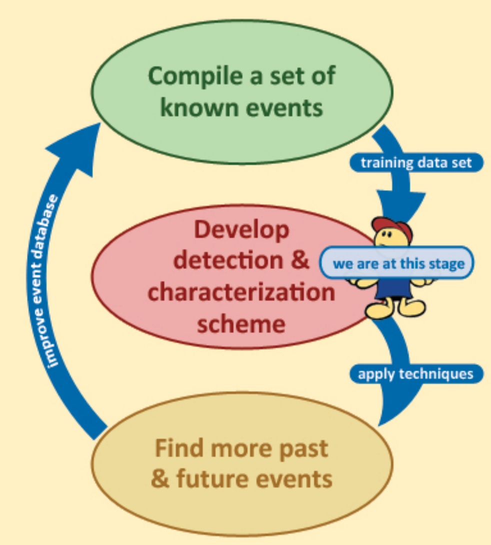
Quick facts

dataset of 19 rockfalls in/near Austria recorded between 2007 - 2016

➤ confirmed by **ZAMG** using **regional seismic network**

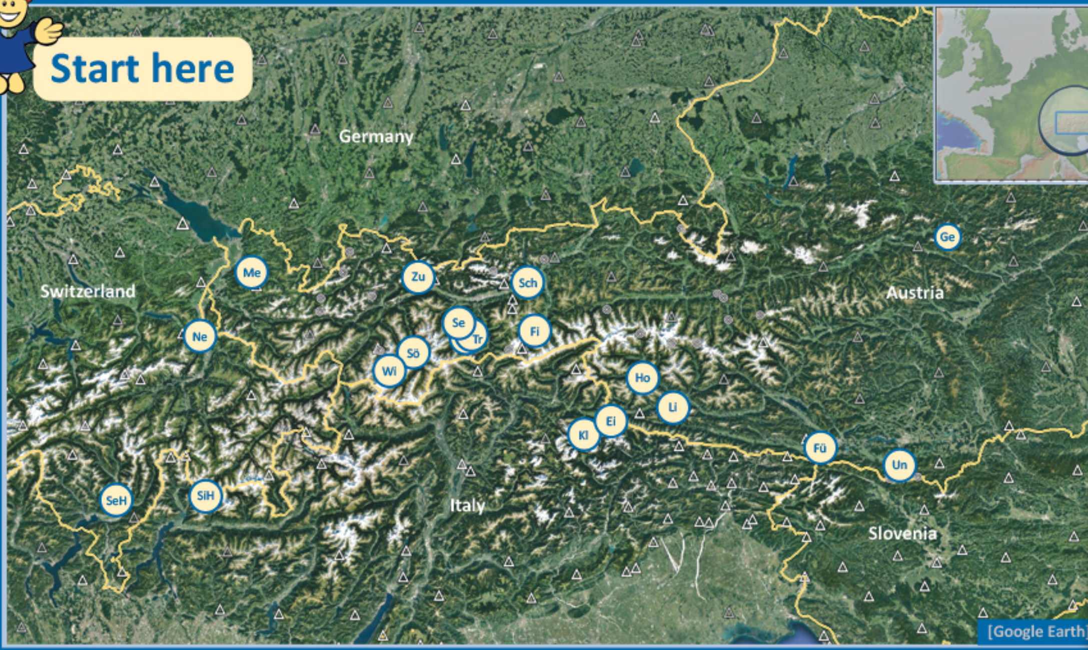
(Zentralanstalt für Meteorologie und Geodynamik)

Workflow



Map of confirmed seismically detected rockfalls

Start here



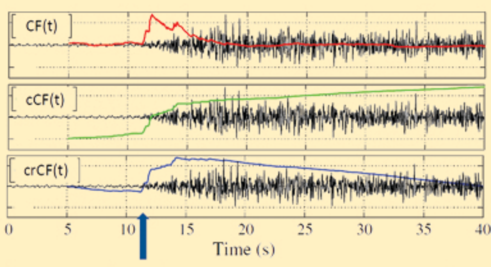
● Rockfall location ● (event in geological database seismic confirmation pending) Seismic station: △ permanent △ AlpArray

Detection with STA/LTA trigger

How to pick correct onset?

Onset determination

For such emergent signals we determine signal onset from **Kurtosis change**
(5 s sliding window for Kurtosis calculation around STA/LTA trigger time)



$CF(t) = \beta(t, \Delta T)$ — Kurtosis of sliding window from $t-\Delta T$ to t

$cCF(t) = \sum \text{slope}(t)$ — Cumulative sum of slopes up to time t if slope > 0

$crCF = \text{lin. corr.}(cCF)$ — Linear correction such that min(cCF) and max(cCF) are moved to 0

this we can detect !

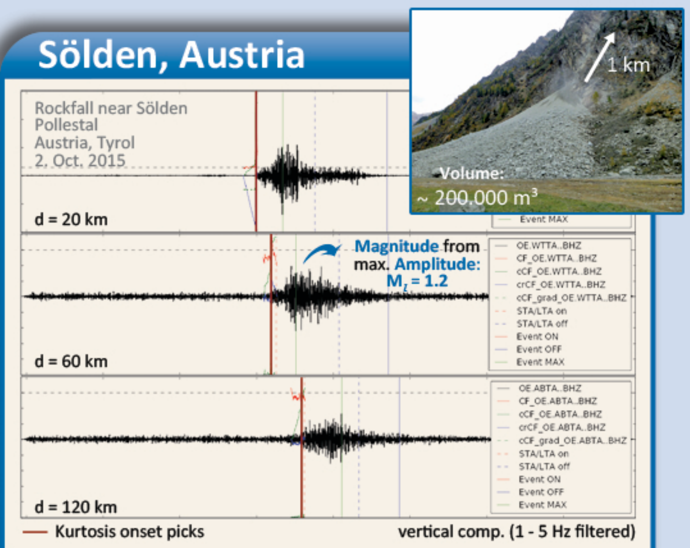
Alternatively: Onset = Maximum Slope(cCF)

This method can only detect amplitude changes. Potential improvement: **Autoregressive Prediction** picker?

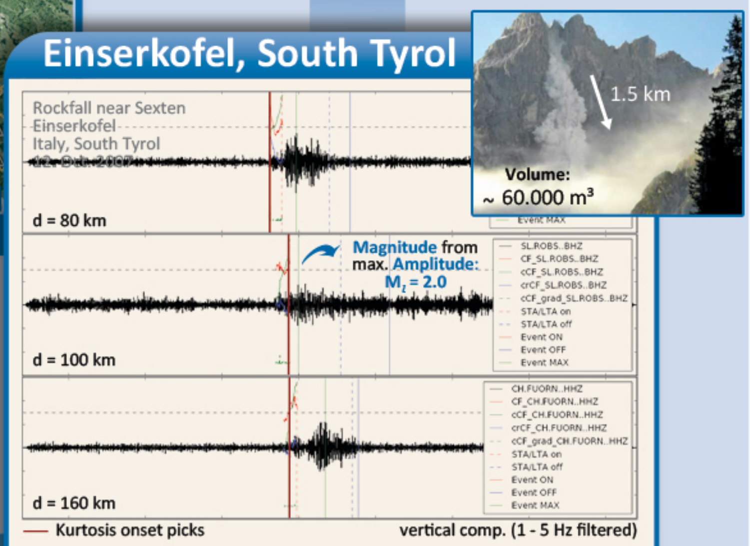
(method adopted & graphs modified from Hibert et al., 2014)

How well does it work?

Sölden, Austria



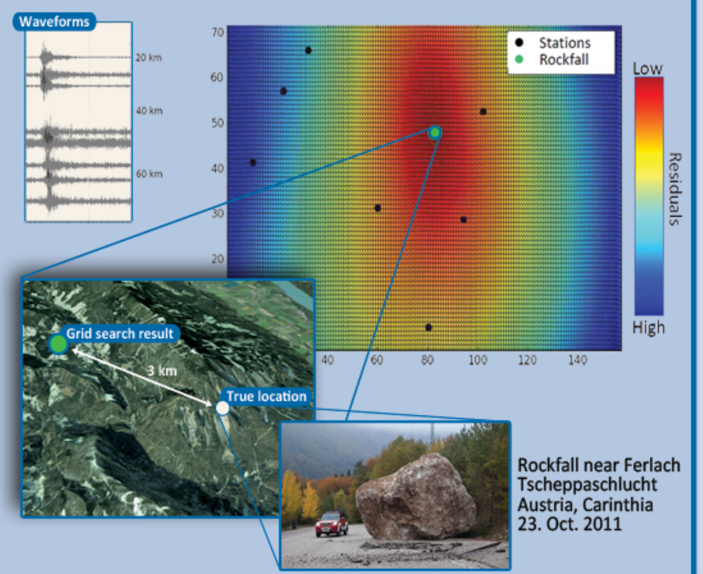
Einserkofel, South Tyrol



Is it precise enough for accurate location?

Location

For **close stations** (< 100 km) preliminary location with a **grid search**
(minimize travel time residuals, homogeneous velocity, no topography)



Rockfall near Ferlach
Tscheppaschlucht
Austria, Carinthia
23. Oct. 2011

Kurtosis picks forwarded as Pg to HYPO-CENTER code

Comparison with true locations

The Kurtosis **onset picks** are treated as **Pg phases** and forwarded to a modified **HYPOCENTER** code (Lienert & Havskov) for proper location. Travel times are calculated using a **simple 1D velocity model**. No systematic outlier handling is applied at the current stage. **Deviation from true location**:

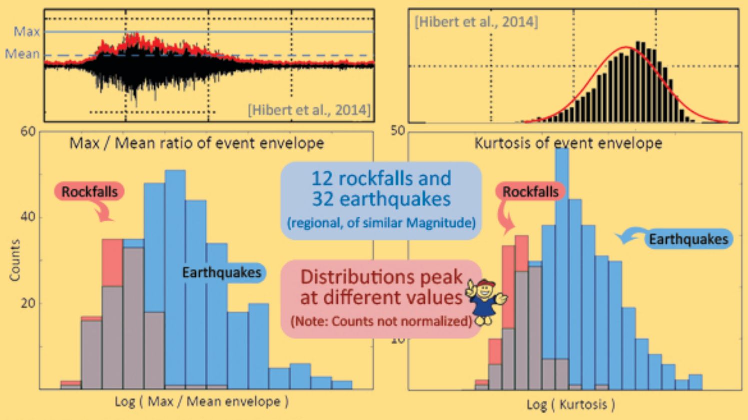
Event	Deviation	Potential reason for deviation
Seehorn:	0.7 km	
Sölden:	4.3 km	
Kleine Gaisl:	4.3 km	
Finkenberg:	4.8 km	
Mellental:	5.0 km	
Unterbergen:	5.6 km	
Nenzinger:	5.8 km	
Zugspitze:	8.3 km	(low SnR, STA/LTA activated on S wave)
Einserkofel:	8.8 km	(low SnR, STA/LTA activated on S wave)
Silvretta:	9.0 km	(travel time too long for coincidence trigger)
Sellrain:	11 km	(low SnR, only 3 stations not well distributed)
Gesäuse:	16 km	(bad SnR, picks wrong)
Fürnitz:	16 km	(low SnR, station not well distributed)
Trins:	26 km	(low SnSr, STA/LTA activated on S wave)

Promising!

Possible improvements: introduce error checks, use local velocity model

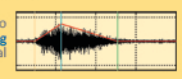
Discrimination from regional seismicity

To automatically **discriminate rockfalls from earthquakes** a **combination of several waveform criteria** is required. We explored several criteria for a small test dataset of 12 rockfalls and 32 earthquakes of similar amplitude and from the same region..



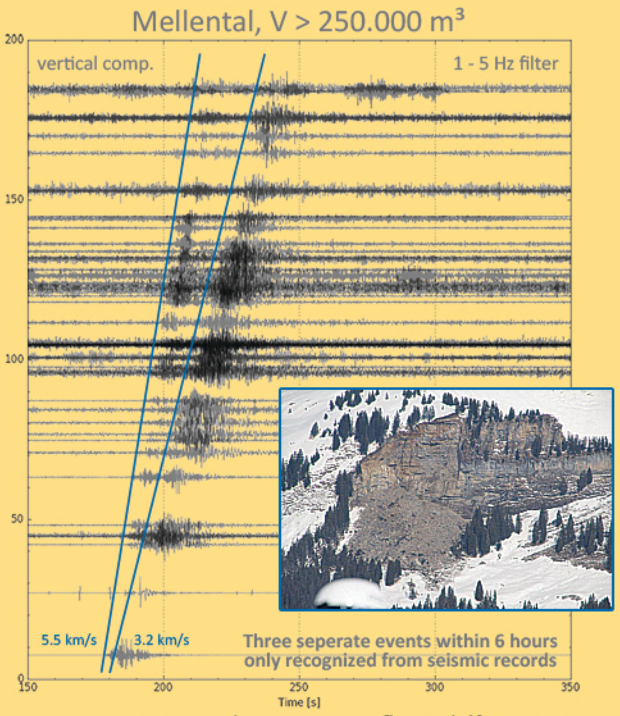
Combination of Max/Mean ratio *AND* Inc/Dec ratio *AND* Kurtosis criteria ➤ **100% classification**

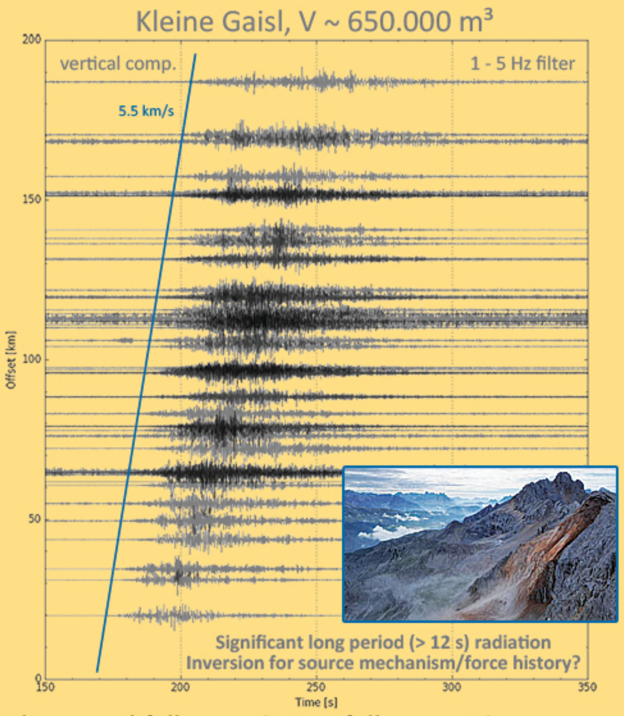
Other criteria: e.g. time ratio of the **Increasing/Decreasing** amplitude parts within signal



(criteria adopted from Hibert et al., 2014)

Waveforms of two large events





Do P and S waves reflect different stages within a rockfall event? Free fall, runout?

Conclusions (at this stage)

➤ **Location** of larger **rockfalls** on **regional scale** is **possible**
Detection even works with comparably unsensitive STA/LTA triggers

➤ **Kurtosis** based **picking** works even for low SnR
(some error checking required to further improve accuracy)

➤ Rockfall/earthquake **distinction** by **criteria combination**
Simple AND combination of 3 criteria sufficient for small test data set

➤ Seismic **Magnitude** (M_l) does **not relate** to **rock volume**
Which effect/mechanism is responsible for the maximum amplitude?

➤ **Distant stations** (> 100 km) can help to **separate phases**
Open question: Which information is carried by the P- and S-waves?

References

Hibert, C., Mangeney, A., Grandjean, G., Baillard, C., Rivet, D., Shapiro, N. M., Satriano, C., Maggi, A., Boissier, P., Ferrazzini, V. and Crawford, W. (2014), Automated identification, location, and volume estimation of rockfalls at Piton de la Fournaise volcano, JGR: Earth Surface, 119, 2014

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