Seismic monitoring of Séchilienne rockslide

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www-lgit.obs.ujf-grenoble.fr/observations/omiv/SECHILIENNE

Different types of signals:

- rockfalls?
- debris flows
- micro-earthquakes?
- long-period earthquakes?

Rockslide dynamics and influence external forcings:

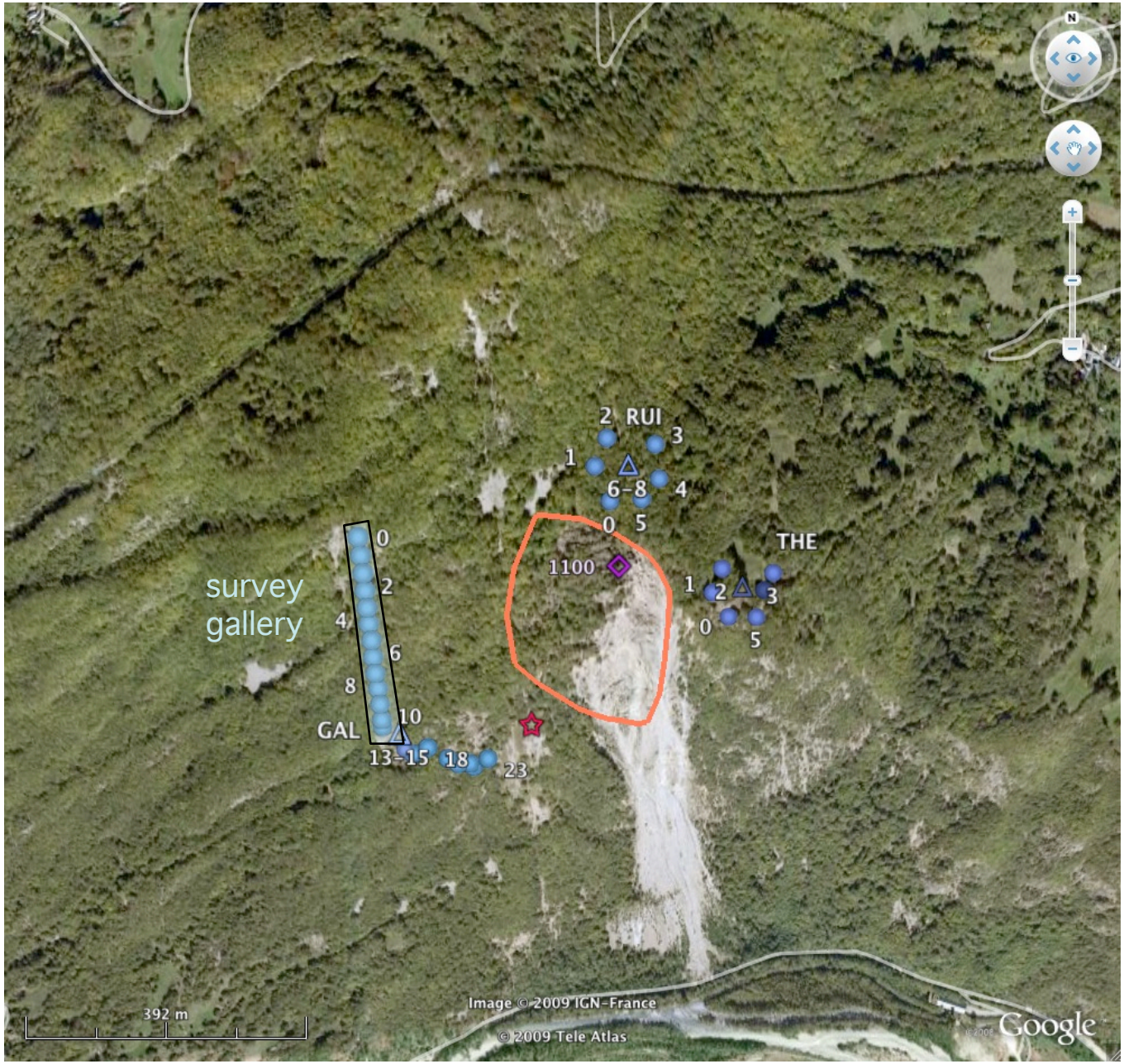
- triggering of rockfalls or microrearthquakes by rain?
- correlation between displacement and micro-seismicity?
- influence of external earthquakes on slope movement?

Séchilienne rockslide

Seismic network

- vertical seismometer
Δ 3 component Seismometer

Stations THE and RUI installed may 2007
GAL installed April 2008



Séchilienne

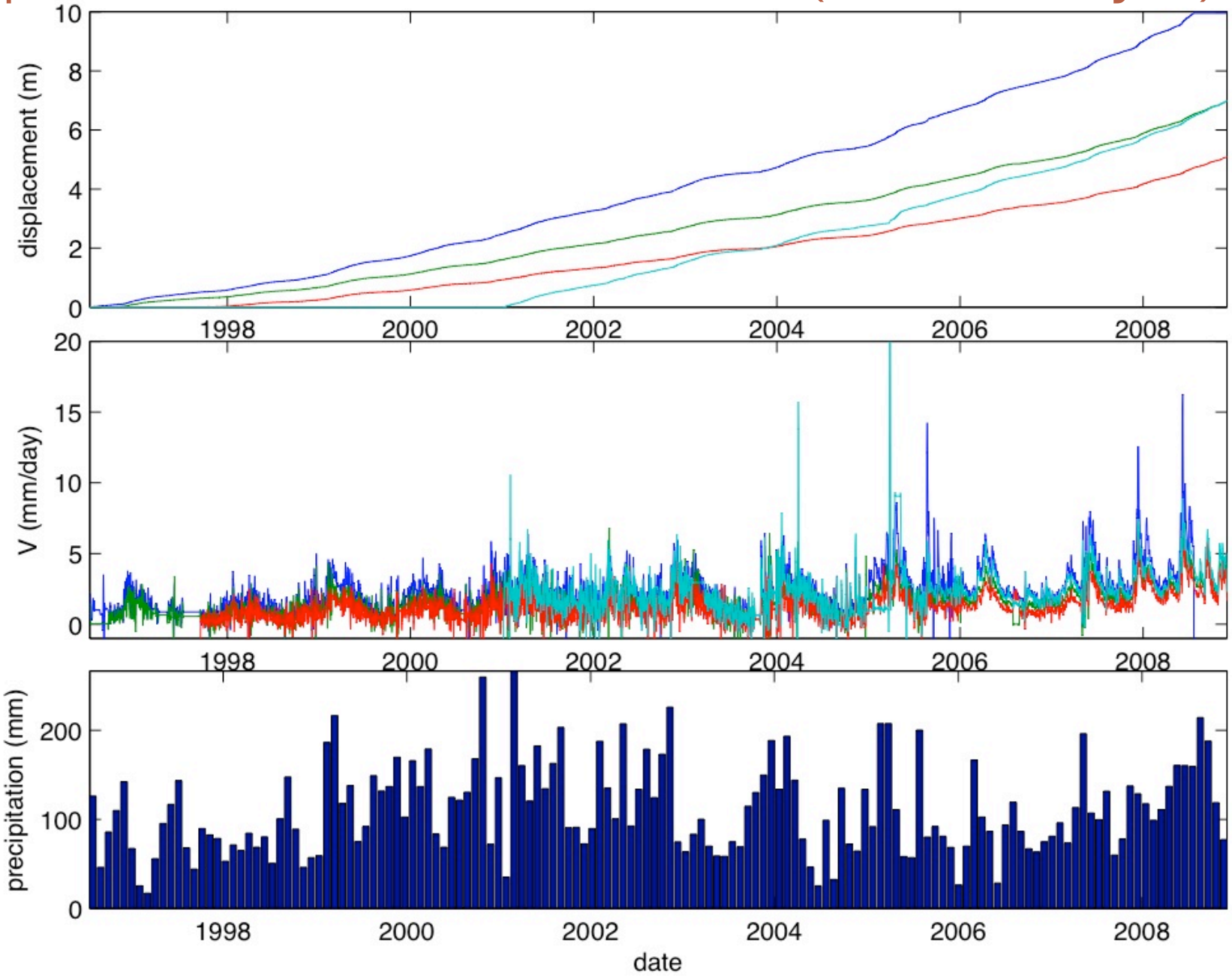
Photo taken from just above the most active zone :

Séchilienne

Limit of the most active zone (about 3 millions m^3)

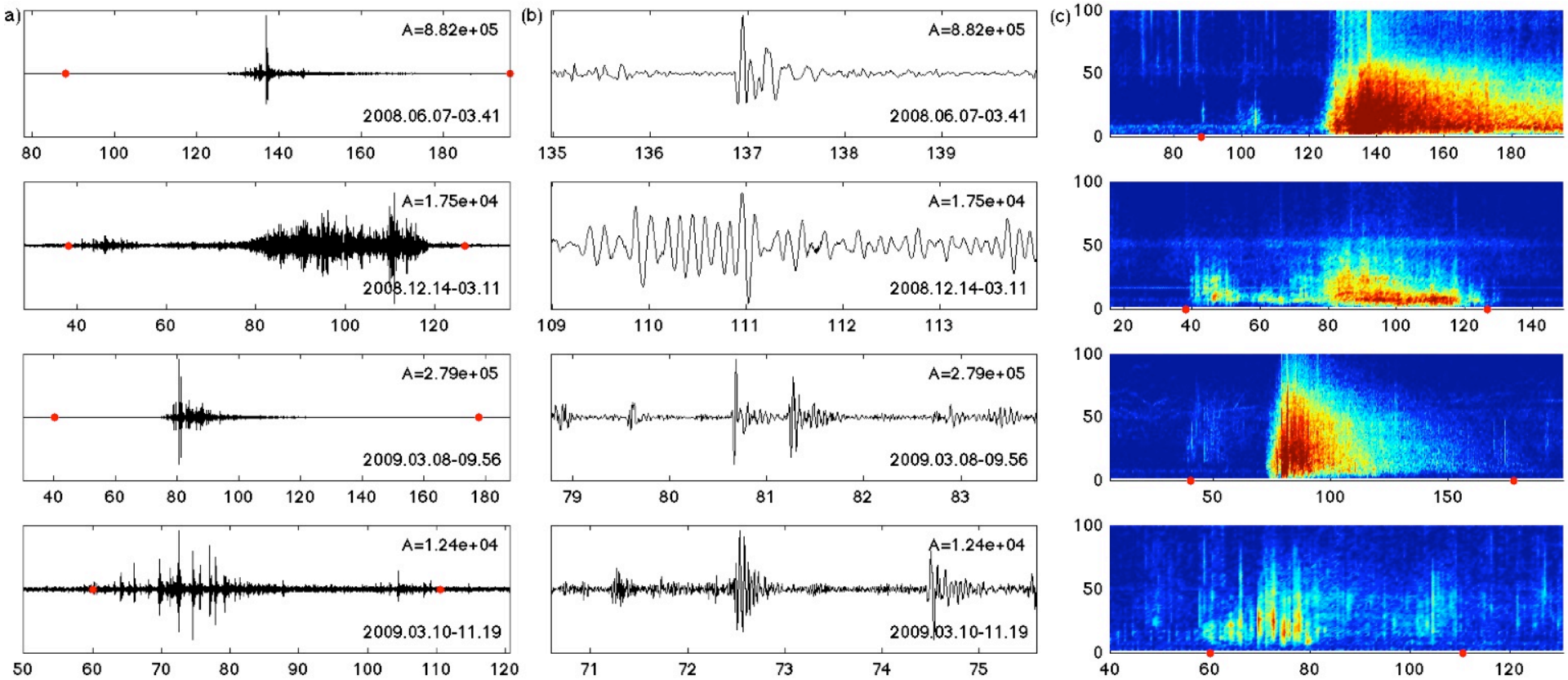
Photo by Y. Kaspersky

Displacement and rainfall since 1996 (Data CETE Lyon)



Rockfalls

Full signal zoom of 5 sec around peak spectrogramm

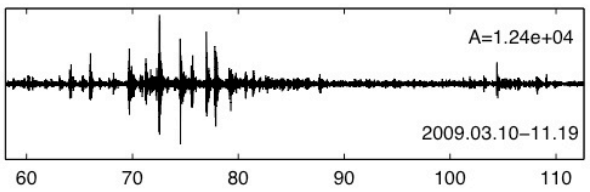


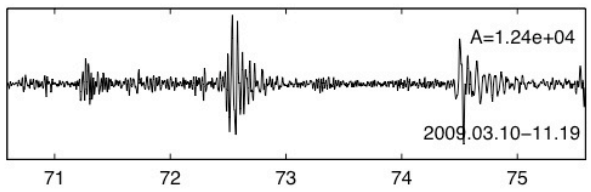
time (sec)

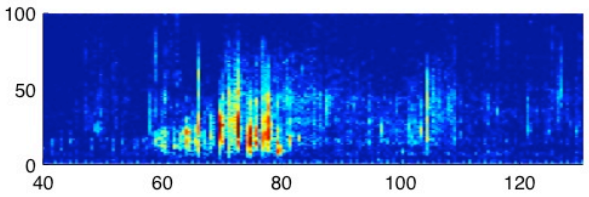
Last event: rock of about 0.05 m^3 droped from the top of the rock corridor

Rockfall experiments

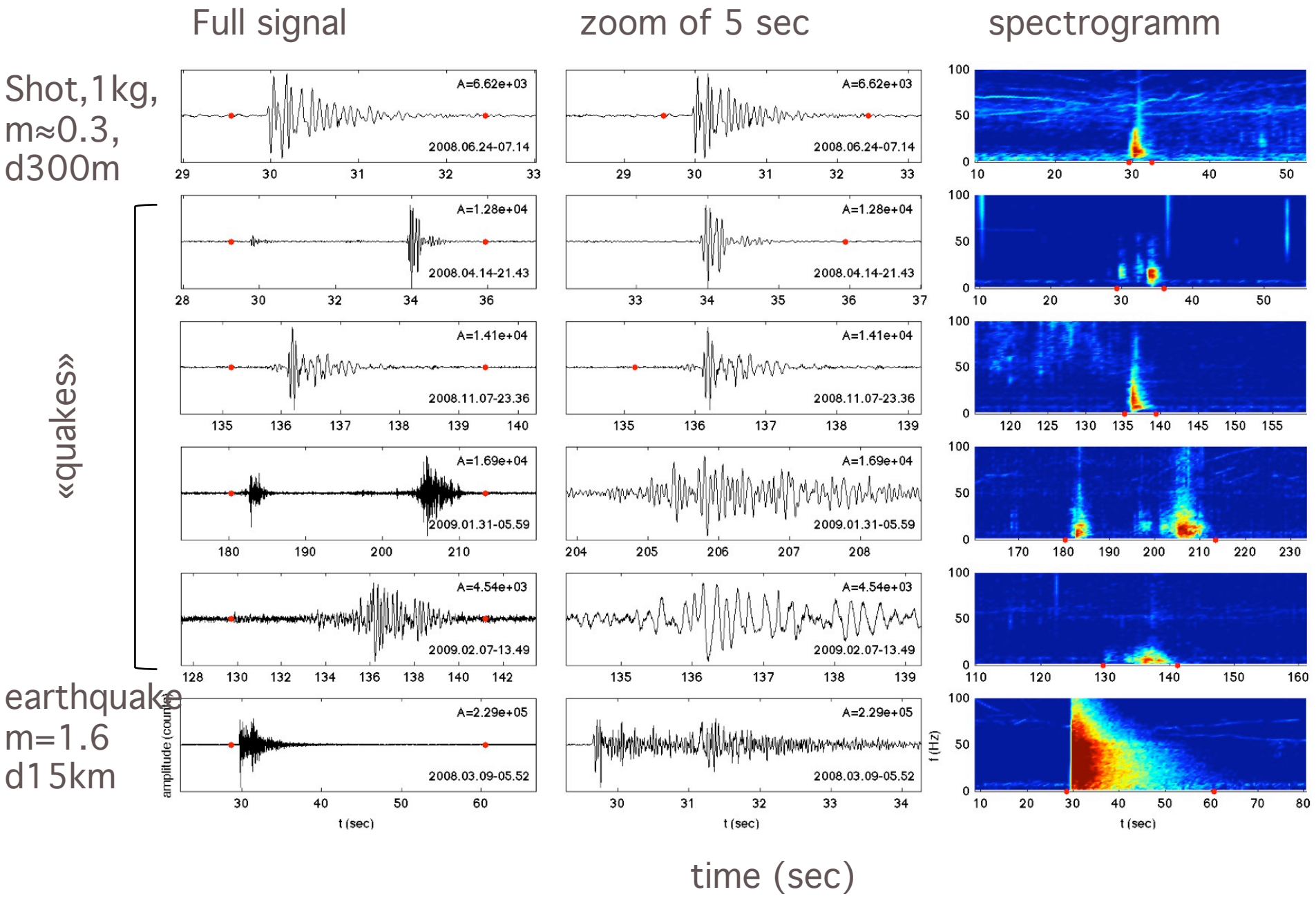
Rock boulder of ≈20x30x50cm pushed from the top of the ruins





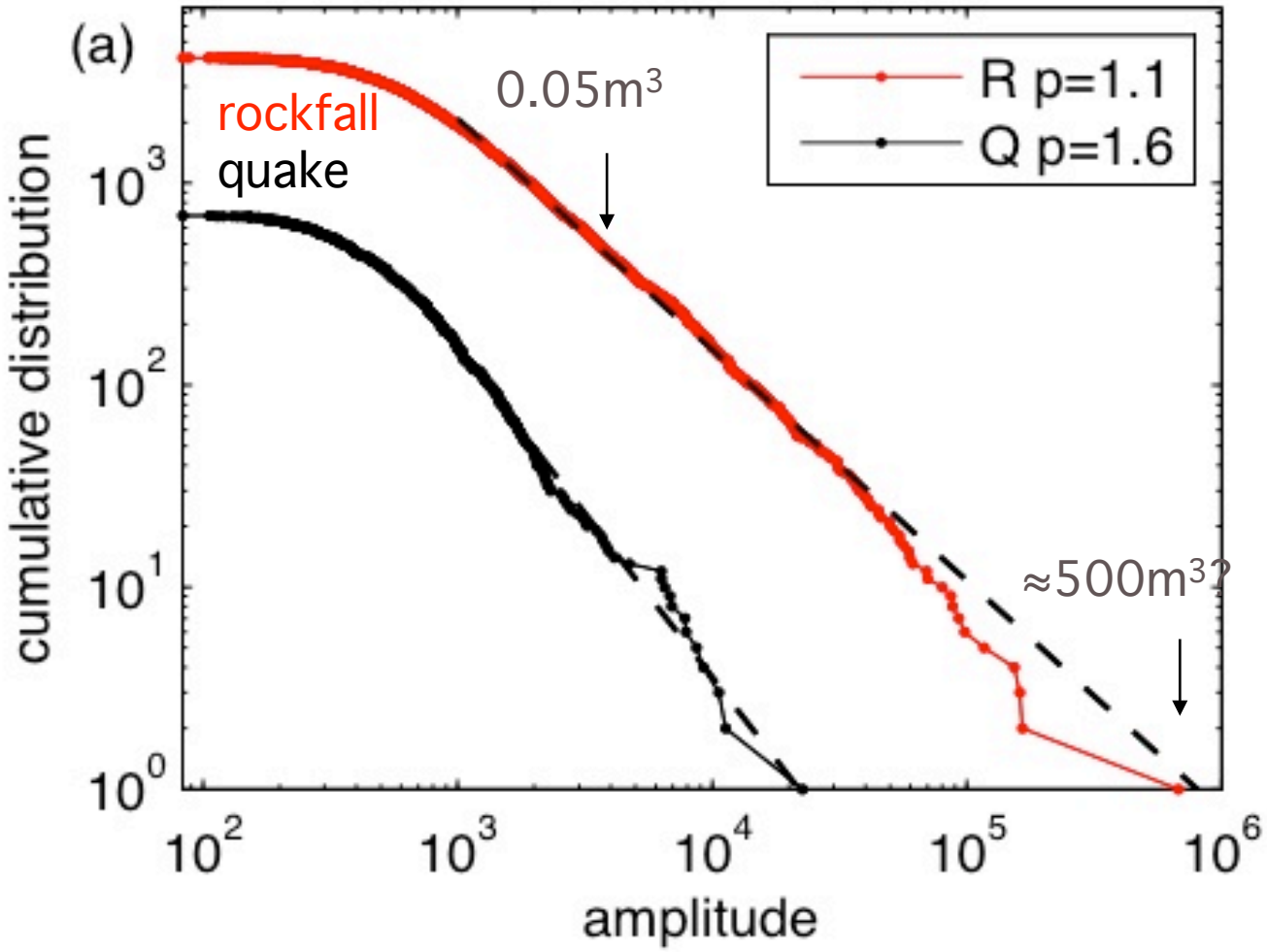


Other signals:

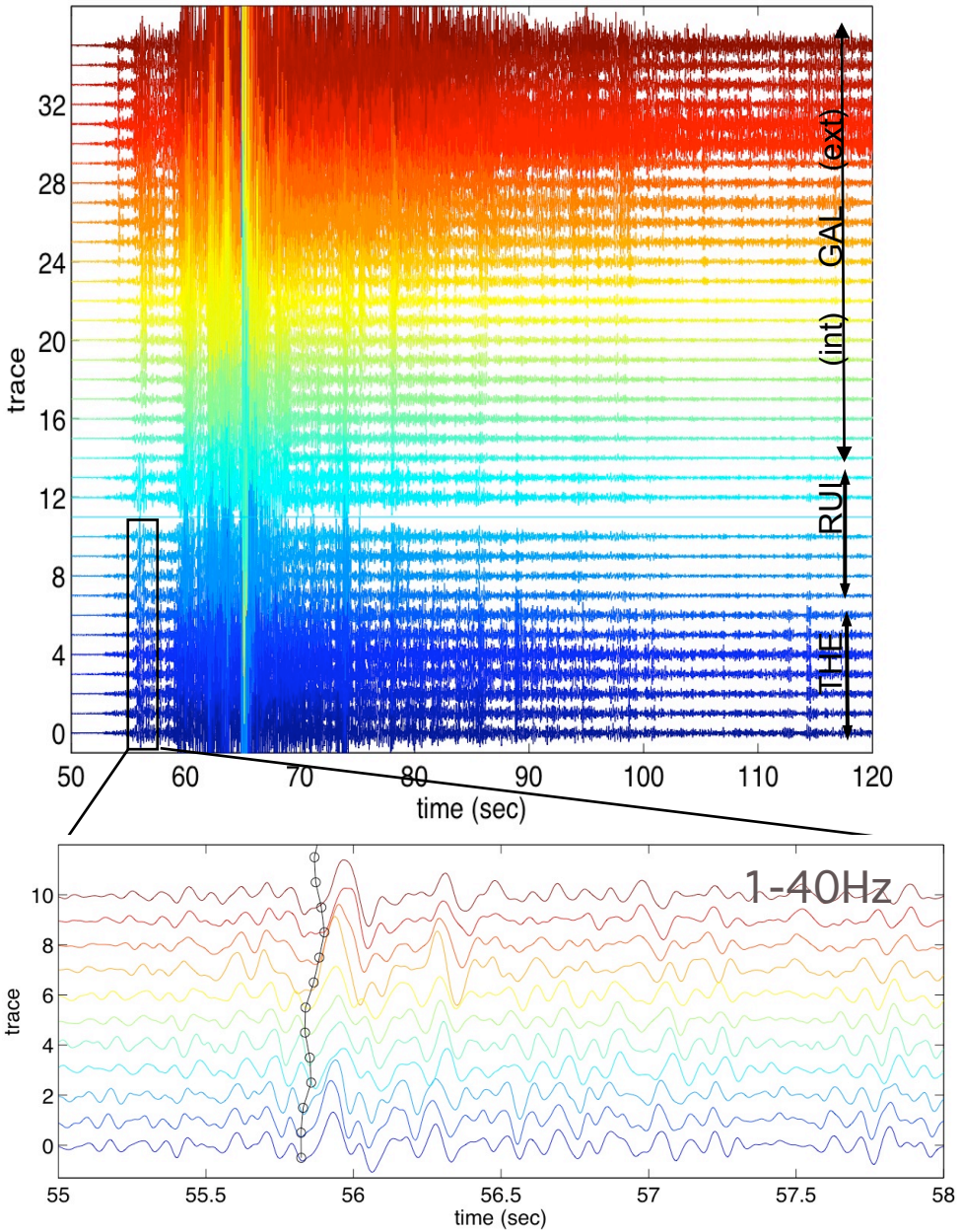


Distribution of events size

- Peak amplitude of seismometer for station THE ~ rockfall volume??

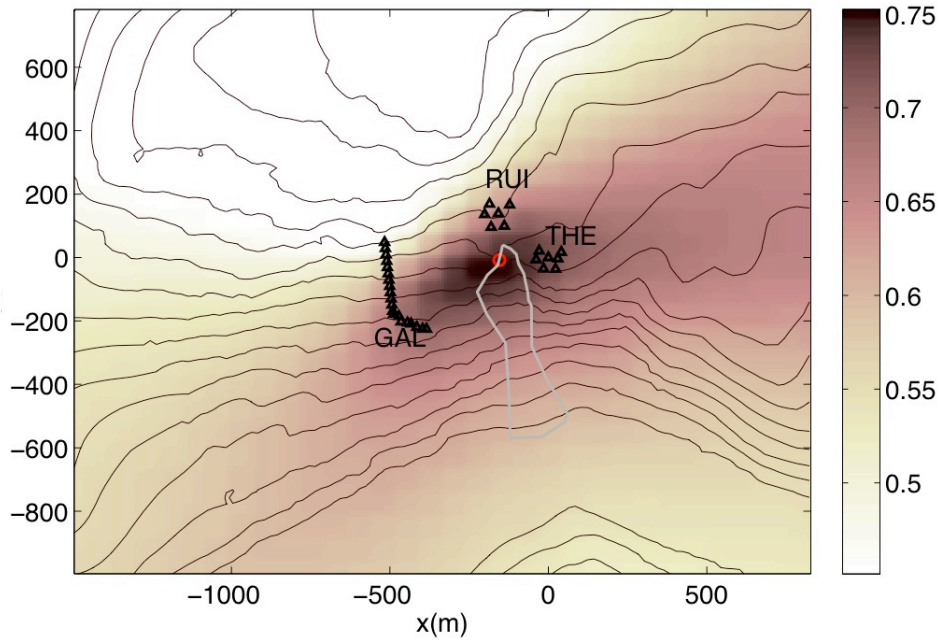


Location of seismic signals using beamforming methods

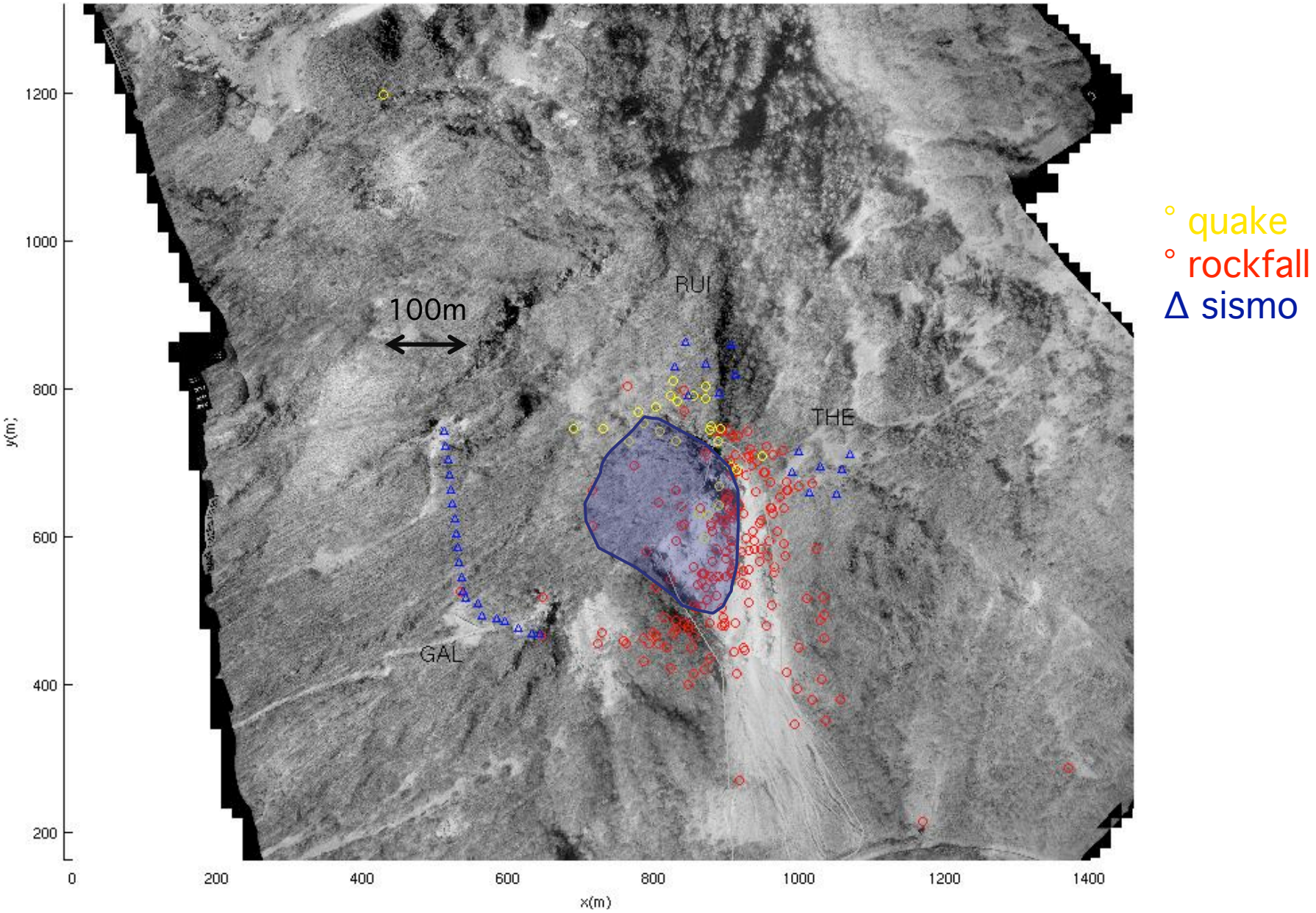


- find seismic wave velocity V and source location (x,y) by maximizing the average inter-traces correlation after shifting the traces in time by the travel time t=d/V

Map of average correlation

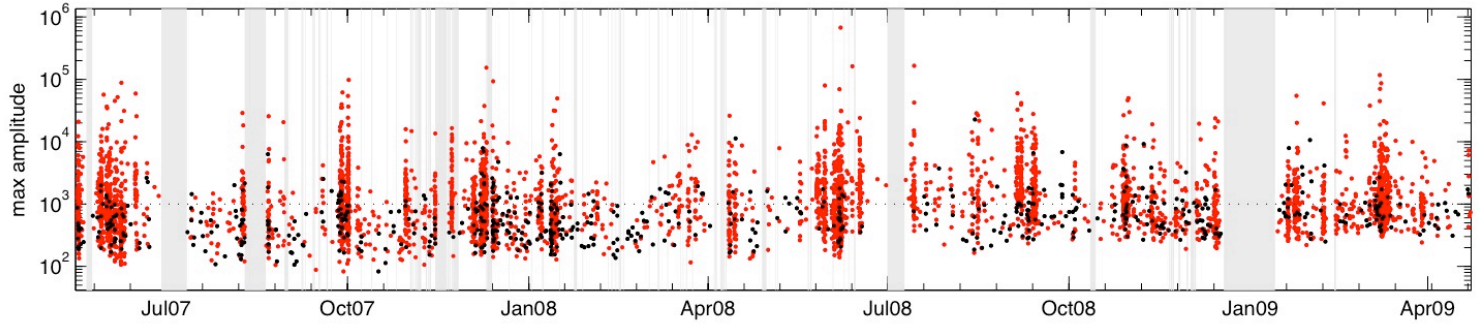


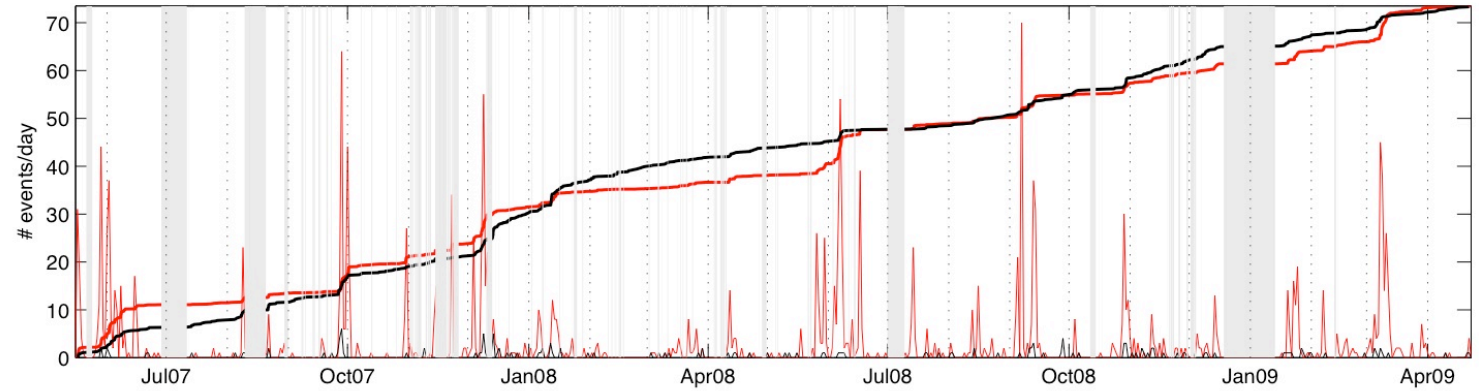
Location of seismic signals



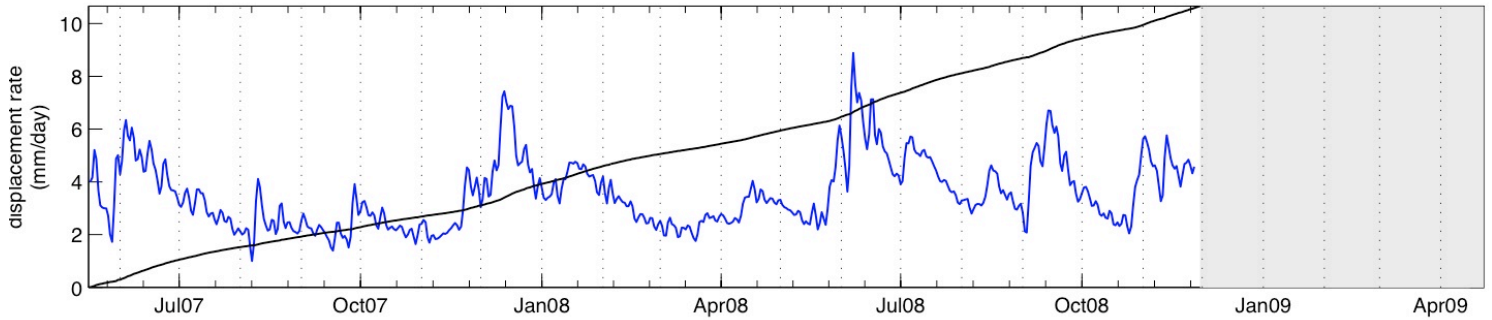
Natural local events recorded by station THE

quake
rockfall

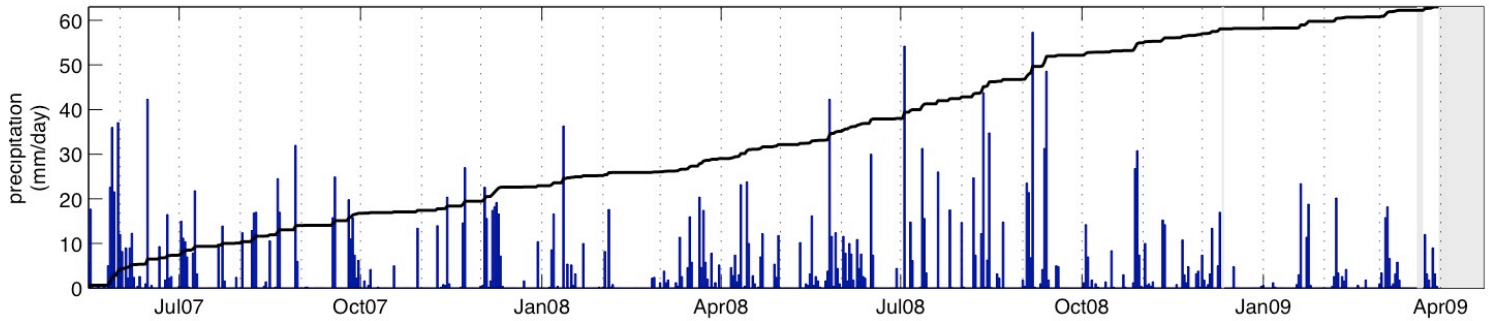




Displacement target 1101 (CETE Lyon)

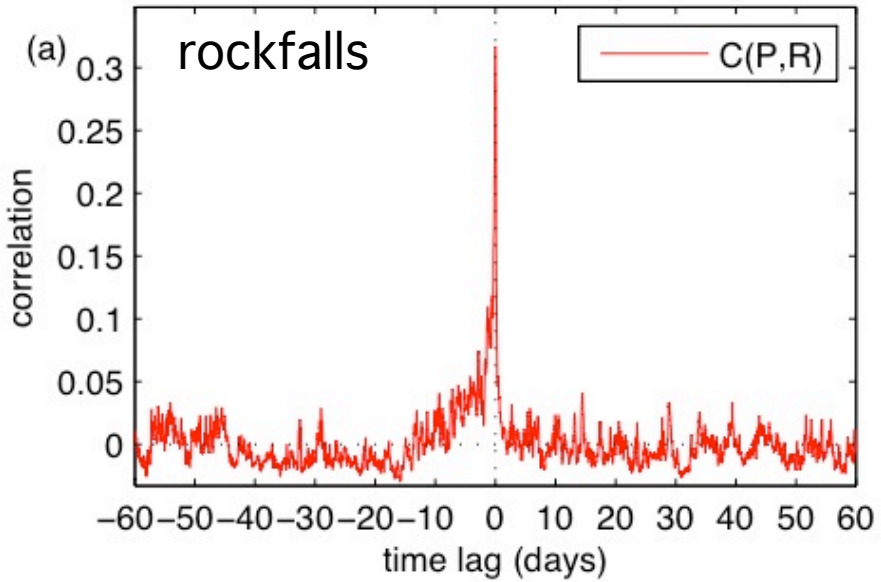


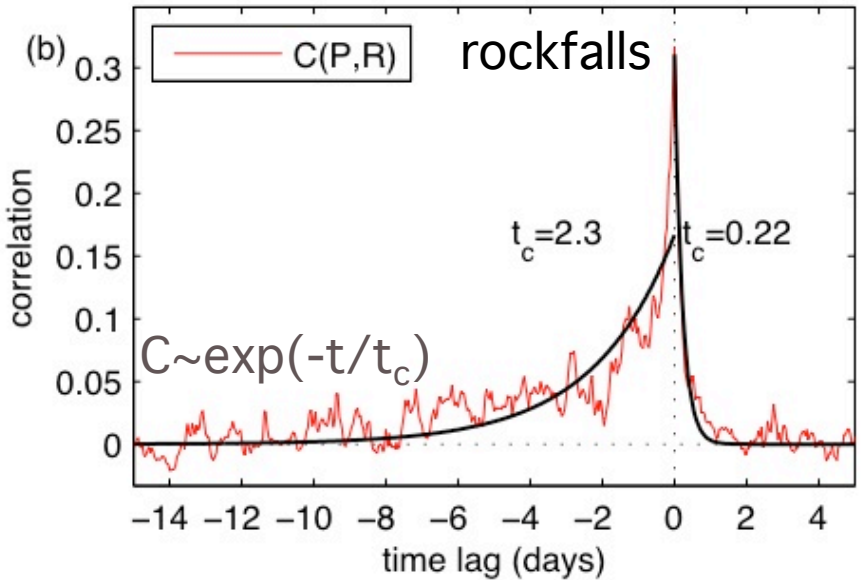
Rainfall Chamrousse Weather station (Meteo France)



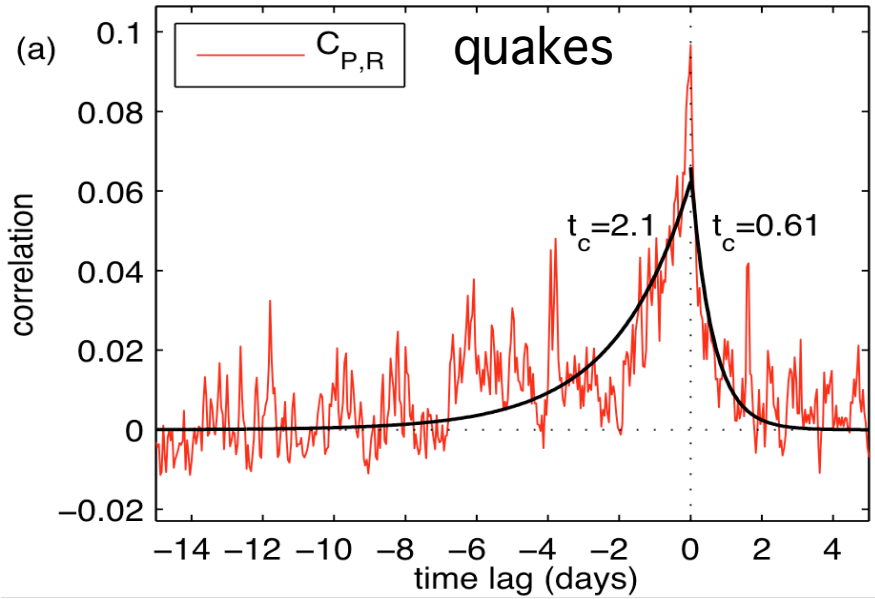
Influence of rainfall on rockfalls and micro-seismicity

Cross-correlation function of hourly rainfall and number of events per hour

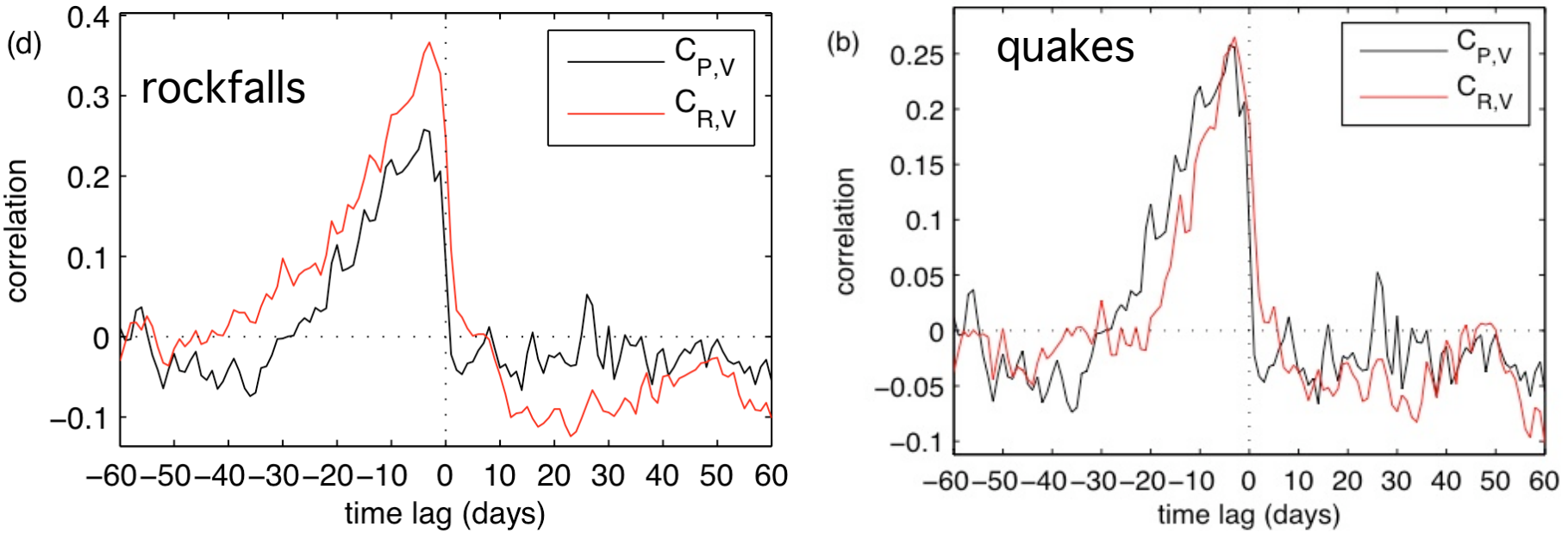




- $C_{X,Y}(t-t') = \langle X(t)Y(t+t') \rangle$
- rockfall starts immediatly during rain and last for ~ 10days
- correlation weaker for quakes than rockfalls



Correlation between rockfalls, and micro-seismicity, and displacement rate



- Peak correlation of C(V,P) and C(V,R) for t≈-2 days :
- Relaxation of rockslide movement much slower (50 days) than rockfalls (≈10days)
- Rockfalls and quakes start instantaneously following rainfall,

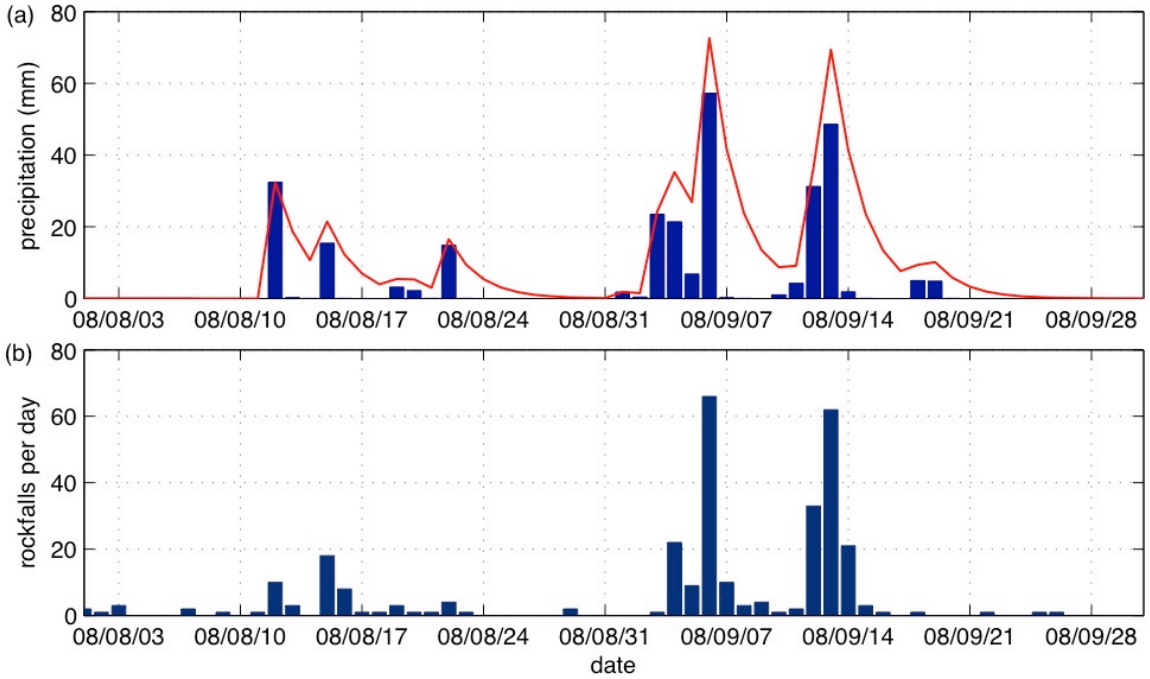
but accelerations are delayed by a few days

Triggering of rockfalls by rainfall

- Antecedent Rainfall model *[Crozier and Eyles, 1980; Glade et al., 2000]*

$$P_A(t_i) = \sum_{j=0:i} P(t_j) \exp(-(t_i - t_j)/t_c)$$

- delayed effect due to water infiltration, or snow melting
- We also assume rockfall occurrence ~ $P_A(t)$ ➔ t_c=1.8 days



Daily rainfall P (mm/day)

Antecedent rainfall P_A (mm)

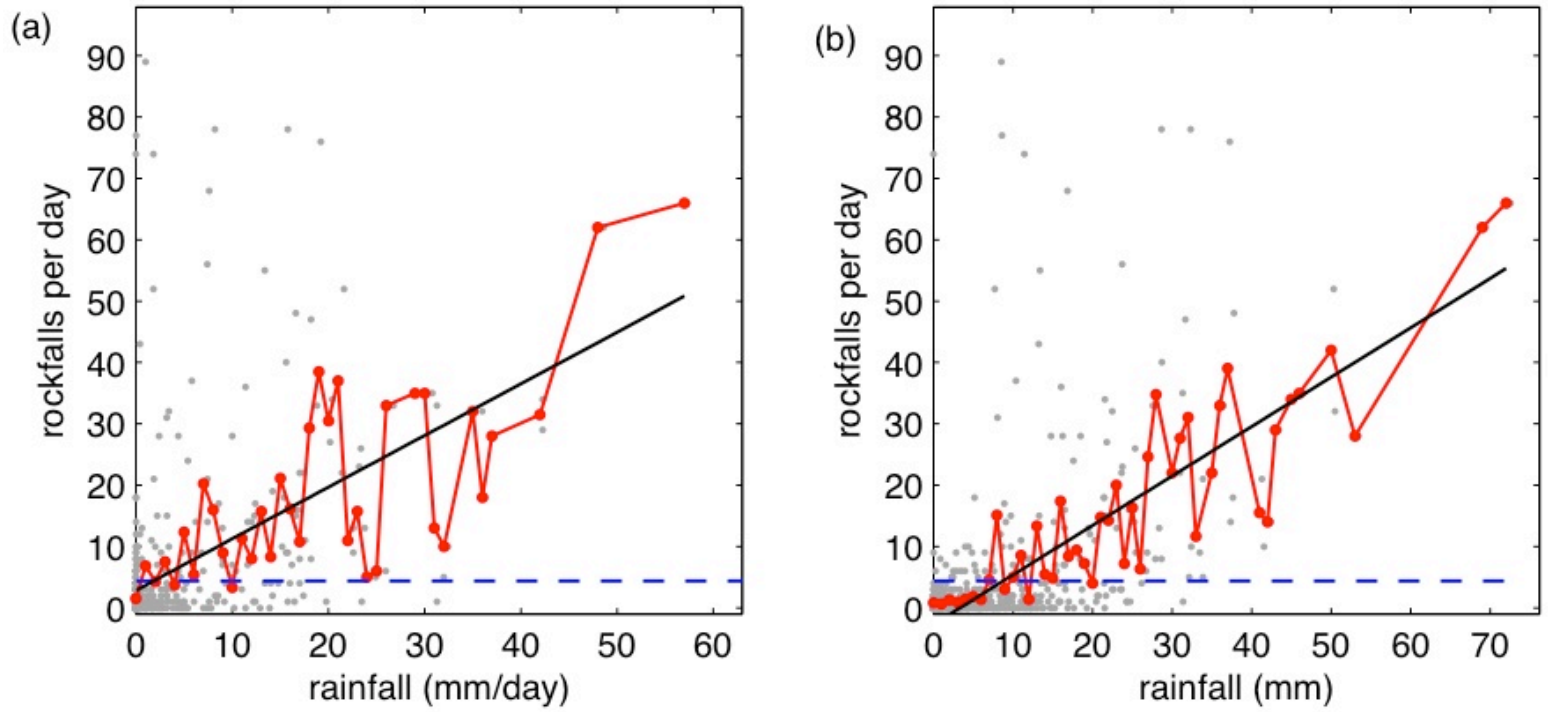
Number of rockfalls per day

- Accounting for antencedent rainfall slightly improves the corelation with rockfall occurrence : corr coeff increases from r=0.52 to r=0.59

Triggering of rockfalls by rainfall

- Average number of rockfalls as a function of rainfall or antecedent rainfall

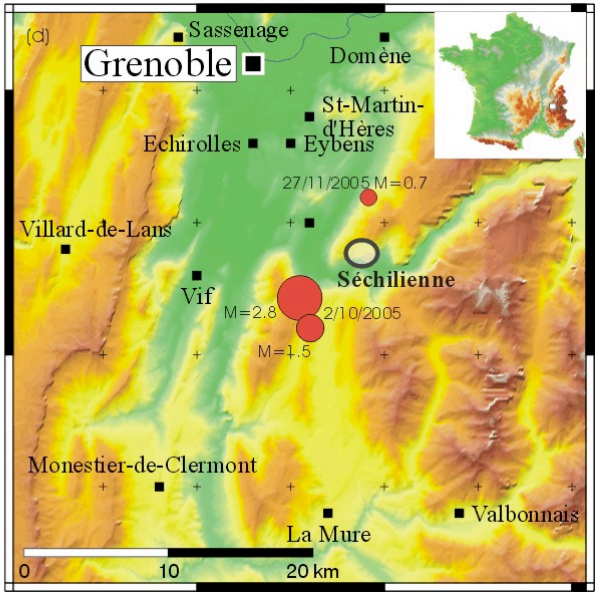
daily rainfall (mm/day) antecedent rainfall (mm)

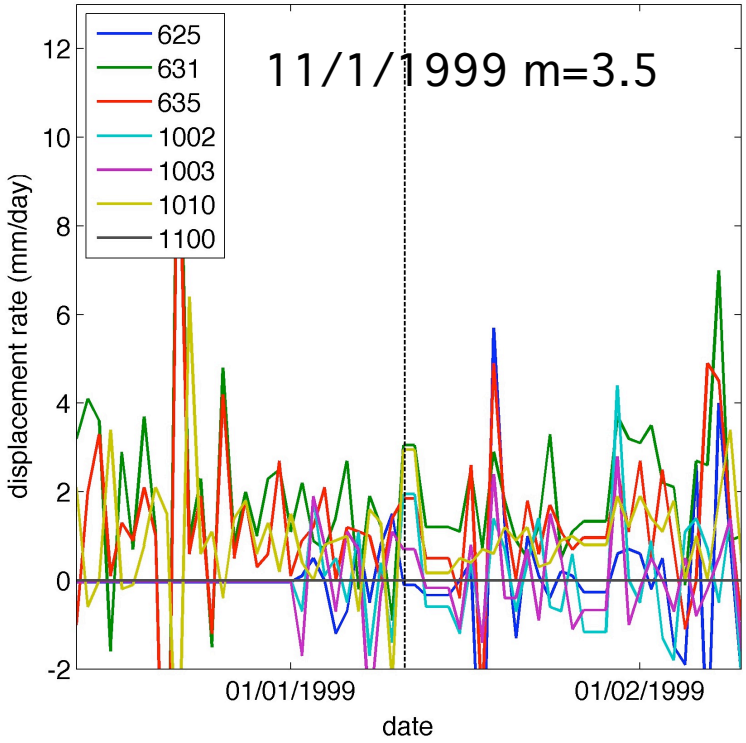


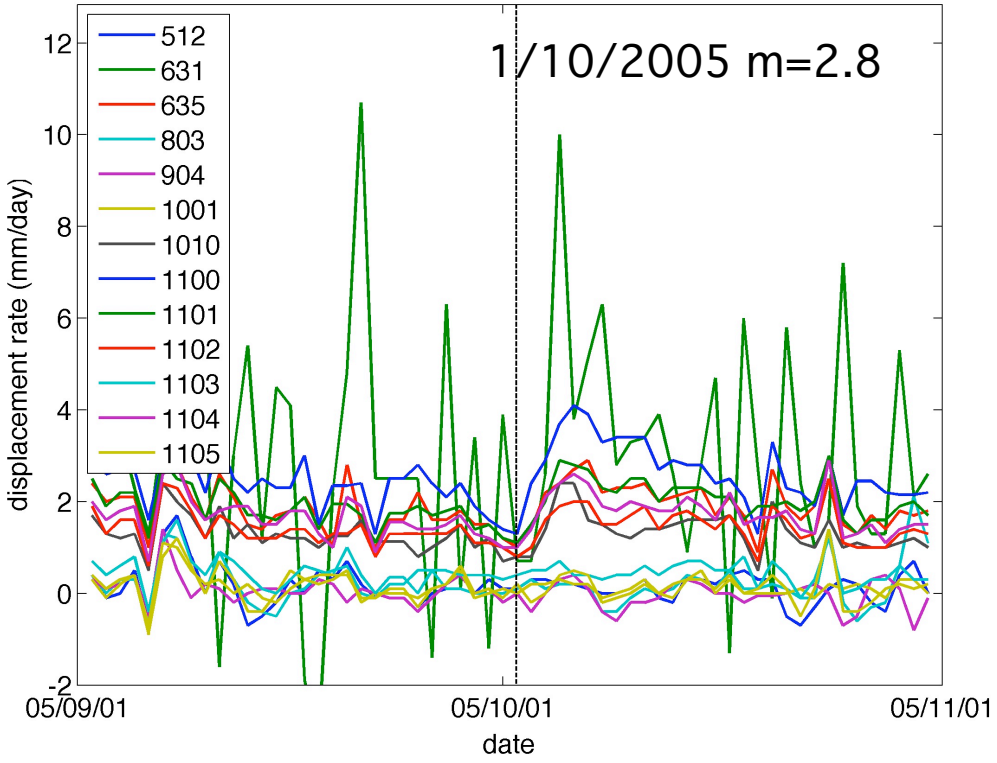
- no threshold: even 1mm rain enough for triggering
- rockfall occurrence more or less proportionnal to P(t) or $P_A(t)$

Influence of distant EQs on the landslide?

- 2 EQs occured about 7km from Séchilienne in 1999 and 2005, with m=3.5 and m=2.8
- Only the 2nd smaller EQ produced an acceleration of the movement !?

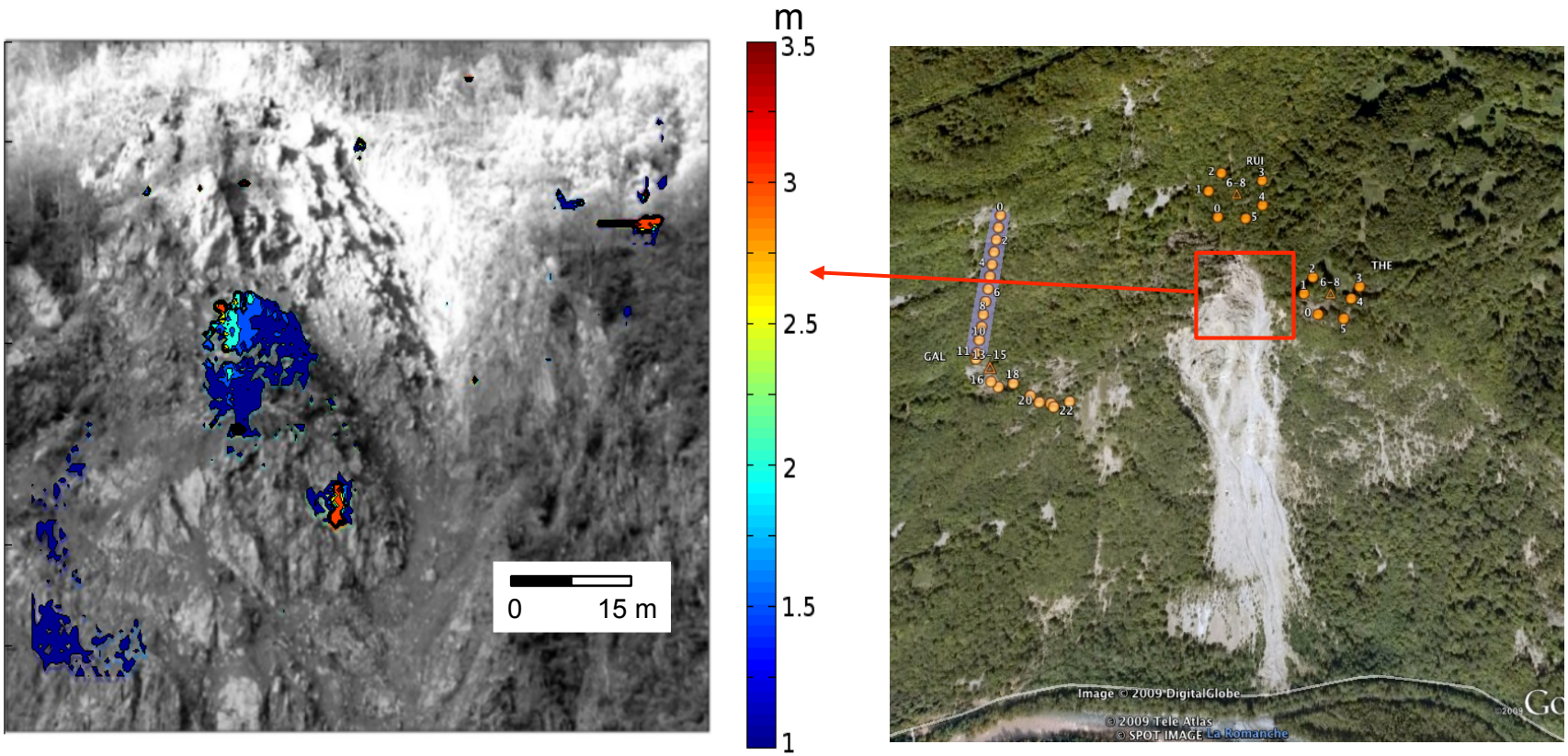






Displacement prior to the 2006 V>20000m^3 rockfall

Displacement amplitude measured by correlating pictures taken one day and a few hours before the rockfall, from the other side of the valley (photos by Y. Kaspersky)



Conclusion and perspectives

- A few thousands seismic events recorded of various types:

  Rockfalls, micro-EQs, and long-period EQs (fluid flow)?
- Intermittent activity, influenced by rainfall (and EQs?)
- Work in progress:
  - location of events (tomography + boreholes)
  - video camera → calibration of rockfall volume and speed
- Precursors of rupture? Landslides more predictable than EQs?
- Use of small events to forecast larger ones?

  extrapolation to much larger volumes and rainfall?