Seismic monitoring of the Séchilienne Rockslide (French Alps): analysis of seismic signals and their correlation with rainfalls

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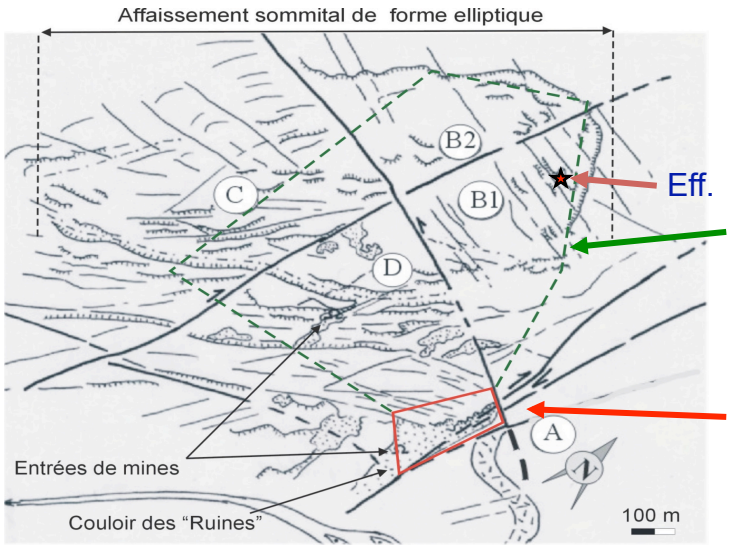
(1)

(2)

The Séchilienne landslide



« 70 ha active »

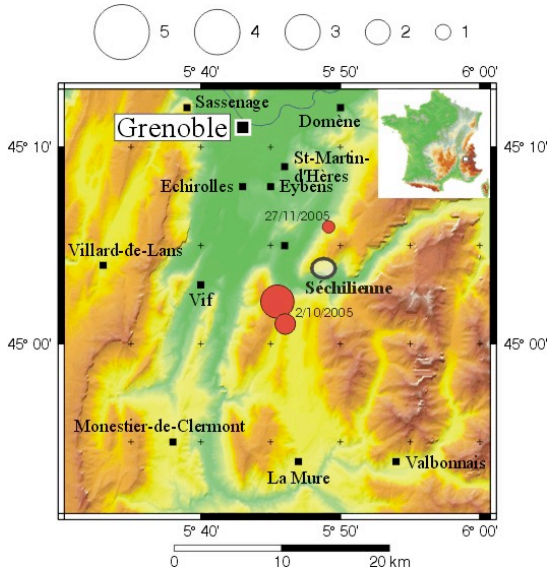
Eff.

Mean active zone

Very active zone

Key vulnerability problems

- *Rock Avalanche (roads, houses)*
- *Formation of a dam (flood?) chemical factories downstream*
- *Presence of an active faults*



Séchilienne rockslide

Surveillance & French National Observatory OMIV

- Déplacement

  A displacement network developed by CETE Lyon since 1986 including:

  - 66 laser mirrors
  - 30 radar reflecting points
  - 33 extensometers

  Camera in front of the landslide (summer 2009)

- Seismology

  LGIT: 3 stations (36 velocimeters) around active zone since may 2007

  +3 accelerometers in summer 2010

  INERIS: 2 stations, 8 receivers (4 1C, 4 3C) in boreholes, since november 2009

- Hydrogeology : boreholes piezometers (CETE Lyon), Spontaneous Potential network (SAGE & LGIT)

- Meteorological stations: Mont-Sec (CETE Lyon)

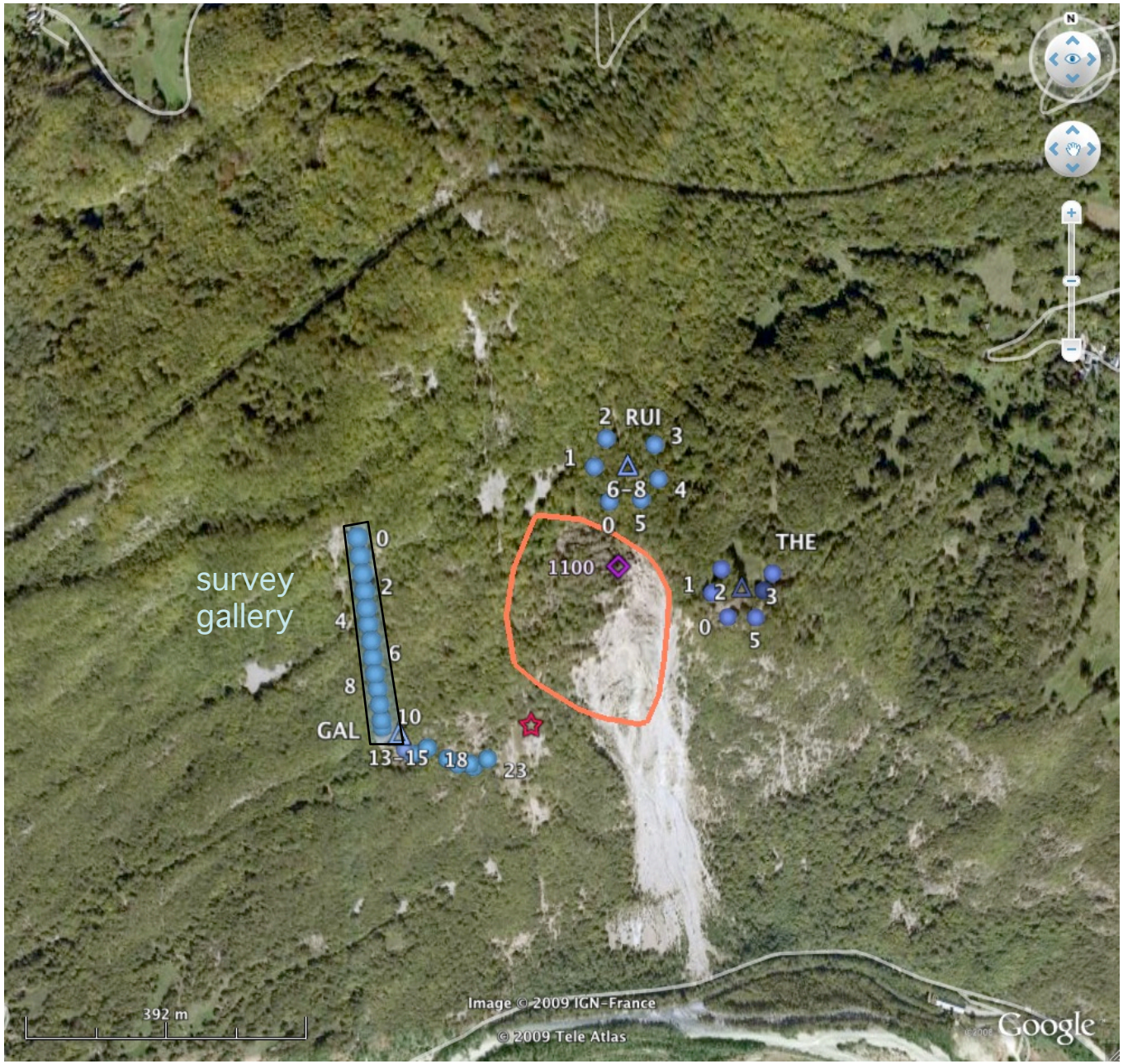
  + station LTHE on Luitel, METEO France in Chamrousse & Vizille

The seismological network

- Vertical seismo
Δ 3C Seismo

Stations THE et RUI installed in May 2007

GAL installed in April 2008



Séchilienne

Photo taken from just above the most active zone :

Séchilienne

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

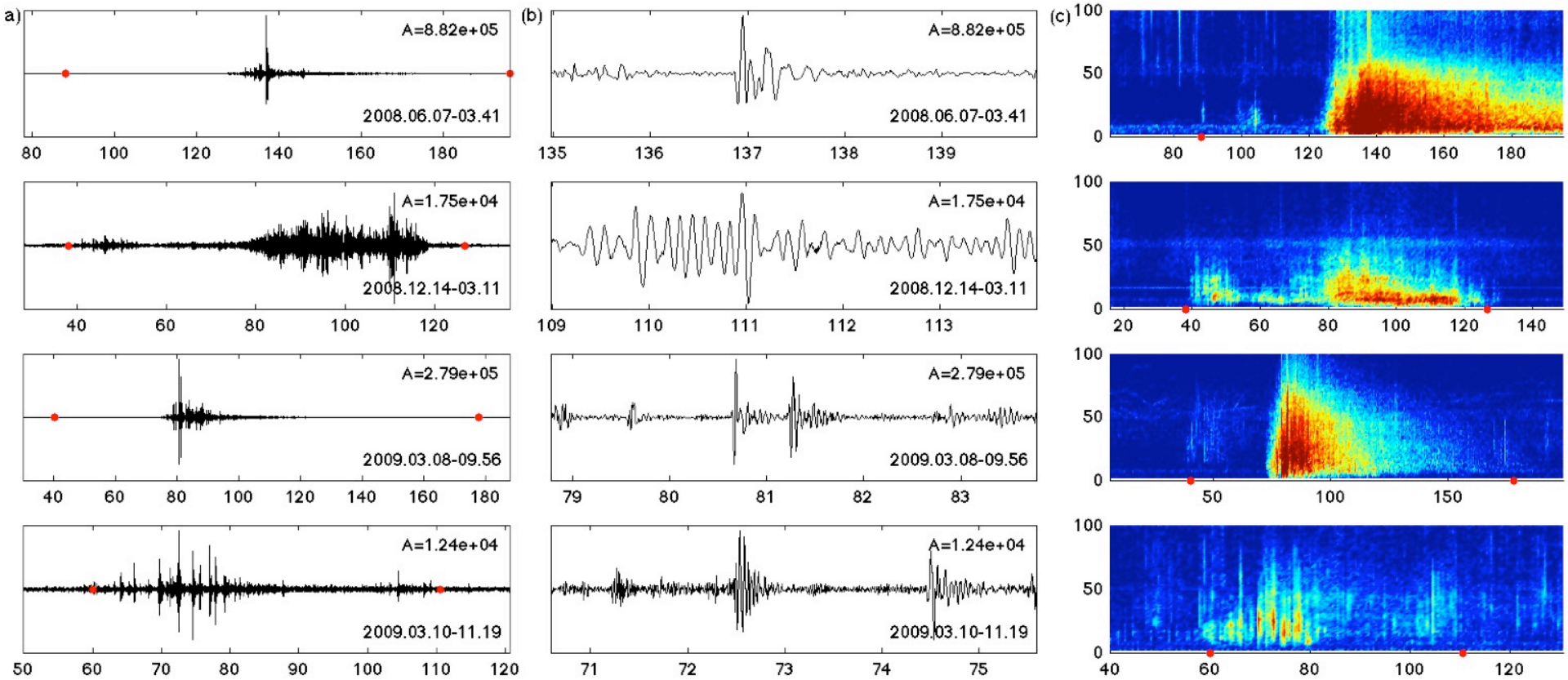
Photo by Y. Kaspersky

Main purposes of the seismological network

- Detection, classification & localization of seismogenic zones from microseisms and rockfalls. Evolution in time.
- Rockfall Characterization : (volume, propagation velocity & location): do precursory small events exist?
- Better understanding of local seismicity (Belledonne fault) and its impact to landslide dynamics.
- Seismic site effect assessment
- Correlations with rainfalls & landslide kinematic
- Passive tomography: seismic wave variability over time & space.

Rockfalls

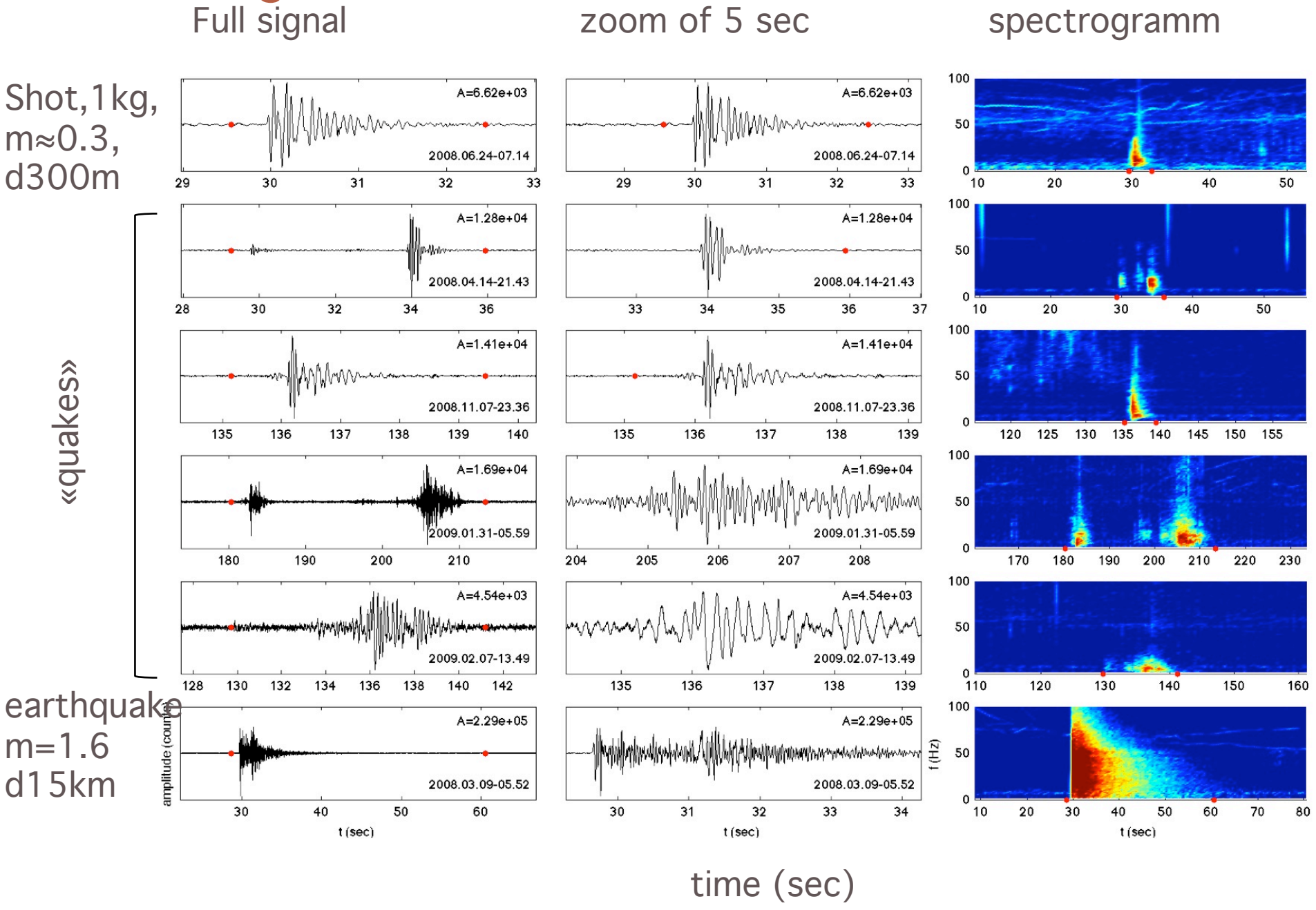
Full signal zoom of 5 sec around peak spectrogramm



time (sec)

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

Other signals:



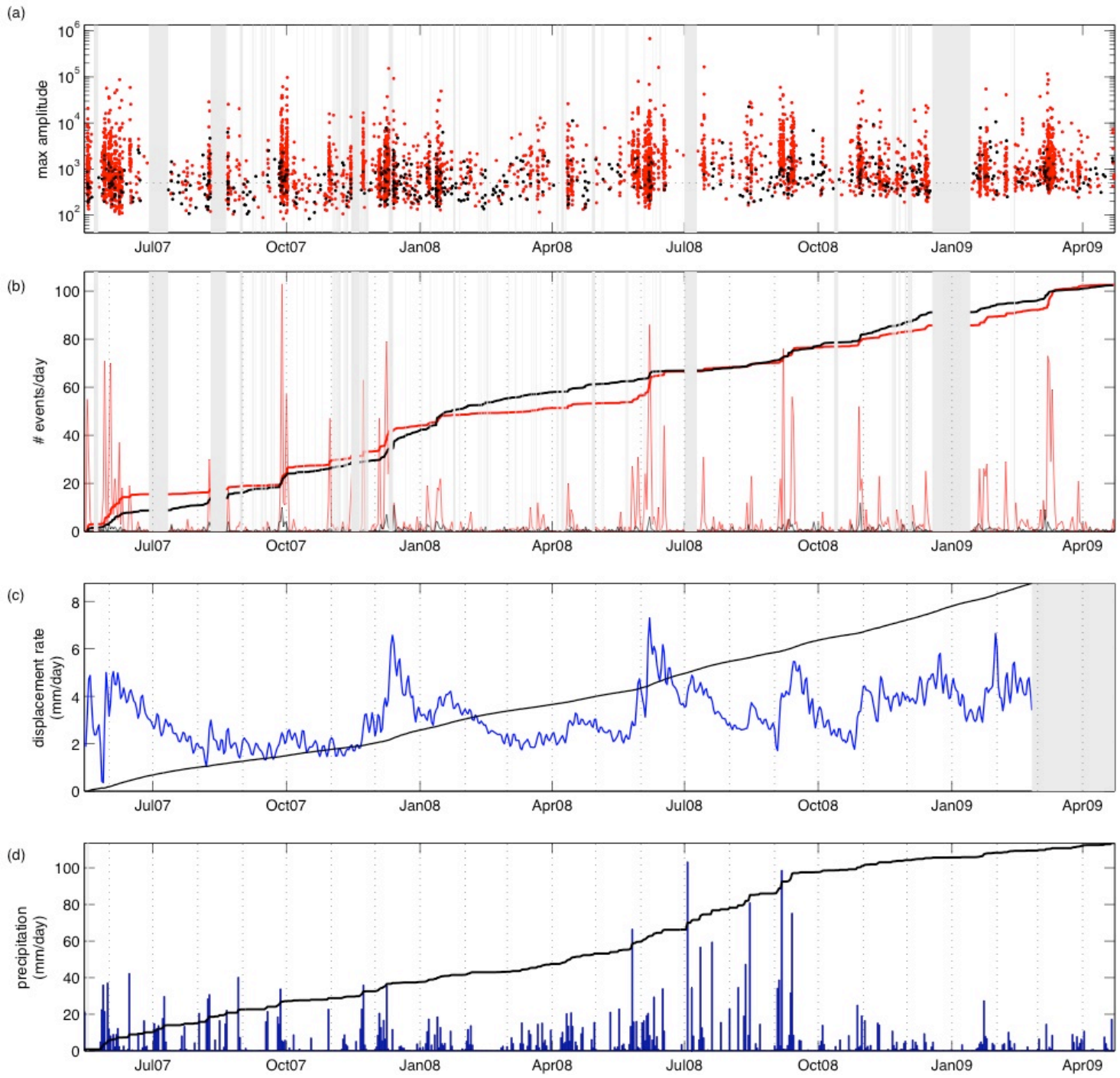
Amplitude
Microseisms
& rockfalls

Events/day
Microseisms
& rockfalls

Displacement
& Velocity
(mark 635)

Rainfall (Vizille)

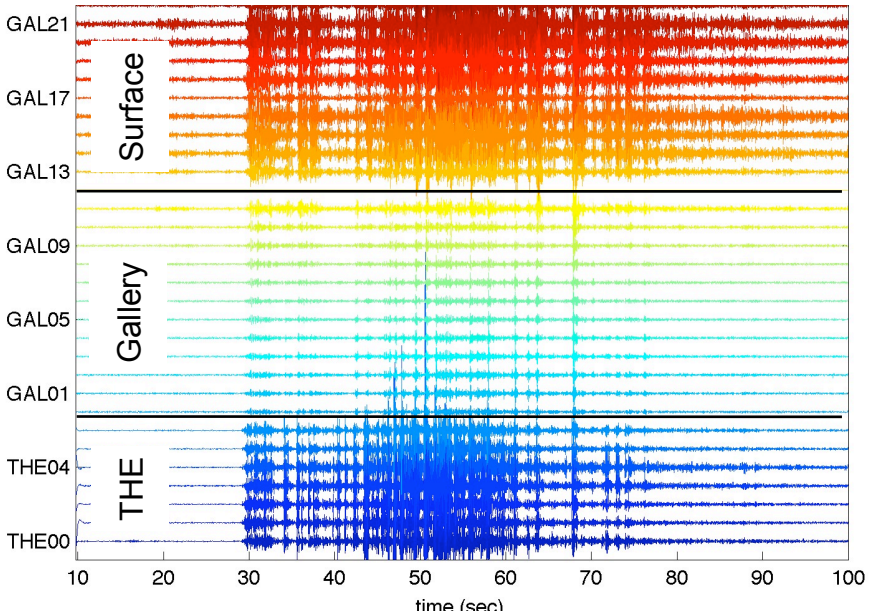
Temperature

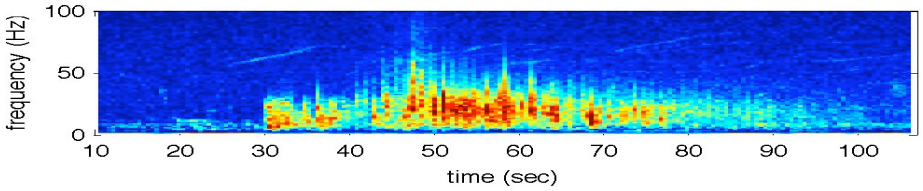


Seismograms of a visible rockfall

GAL

THE

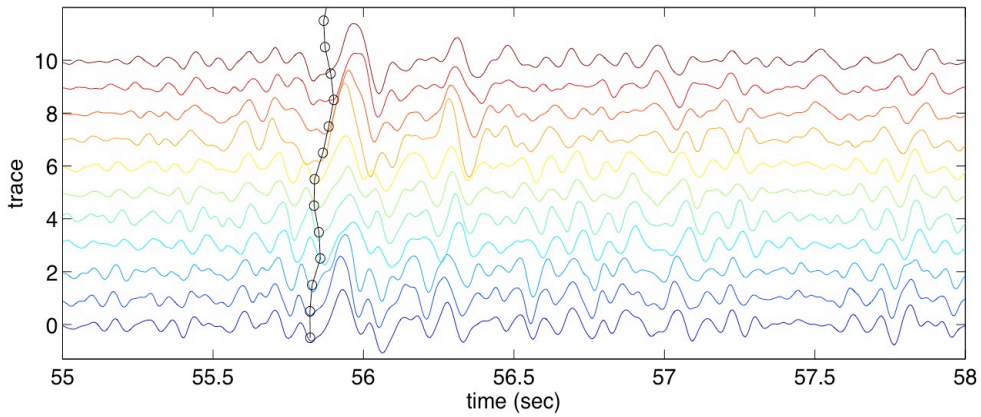




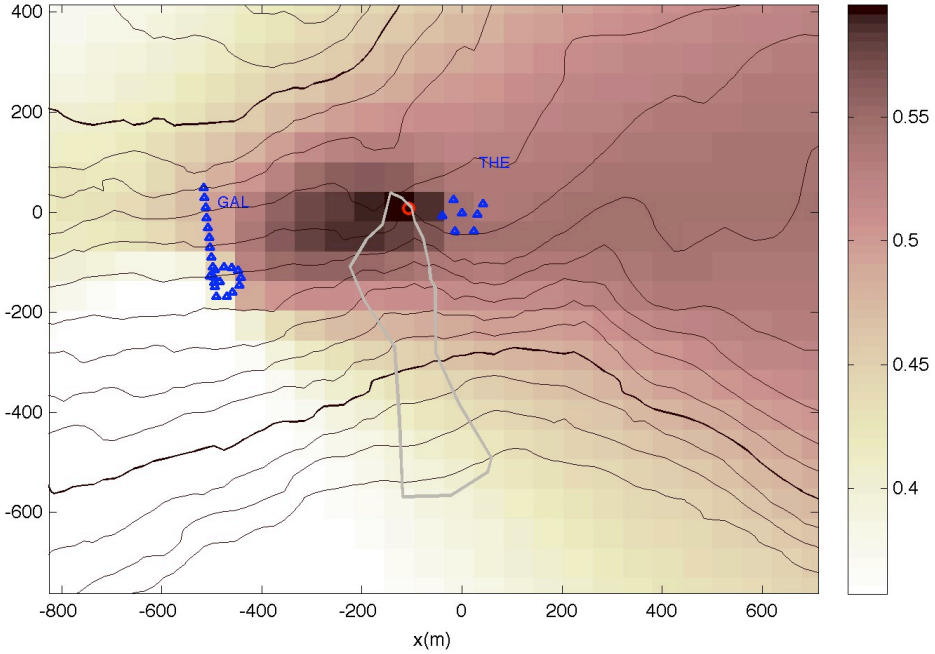
Localization of the start of the rockfall

- 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

Seismograms (zoom on start of rockfall) and modeled travel time



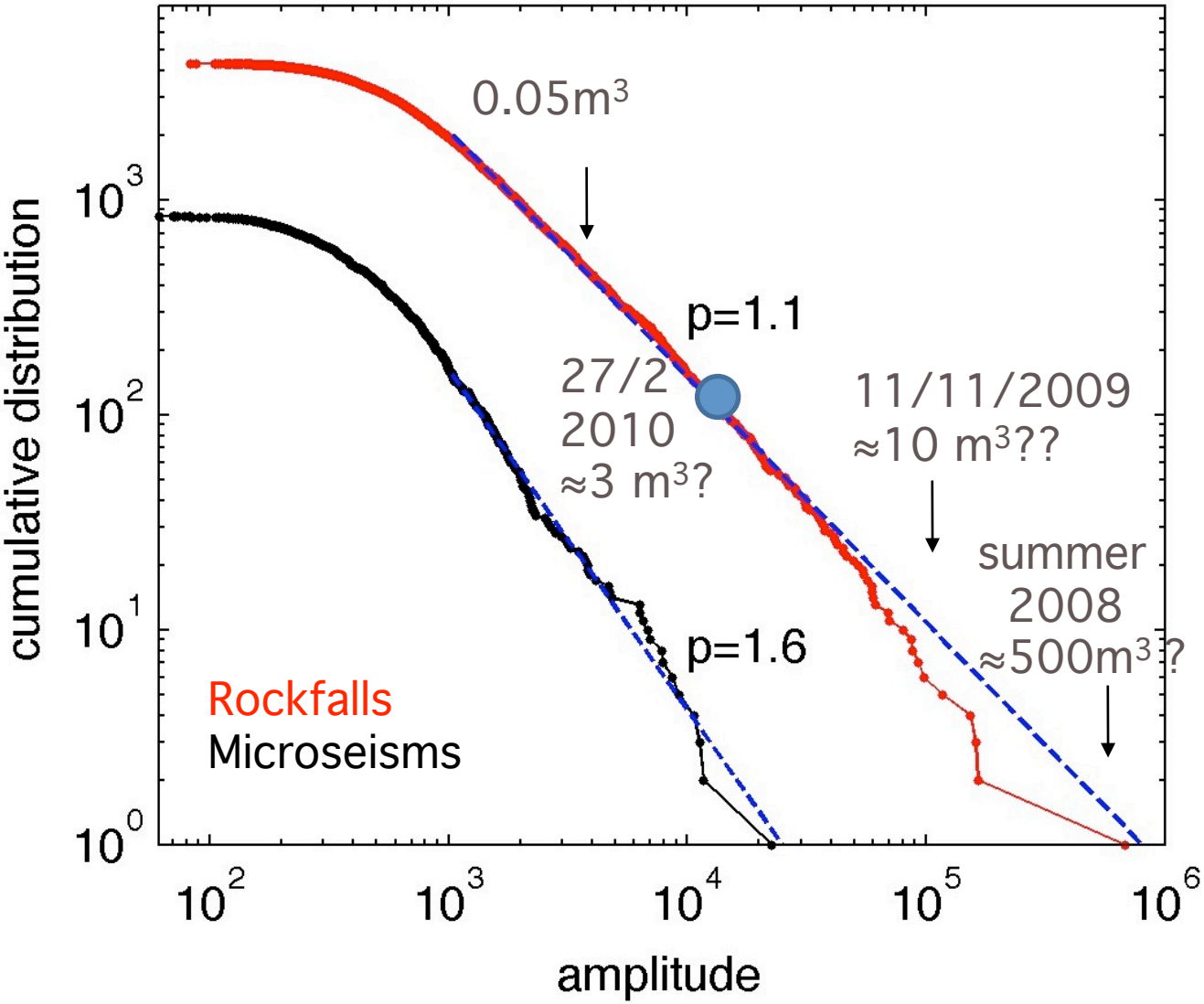
Map of average correlation and estimated location of rockfall



Amplitude distribution of recorded events

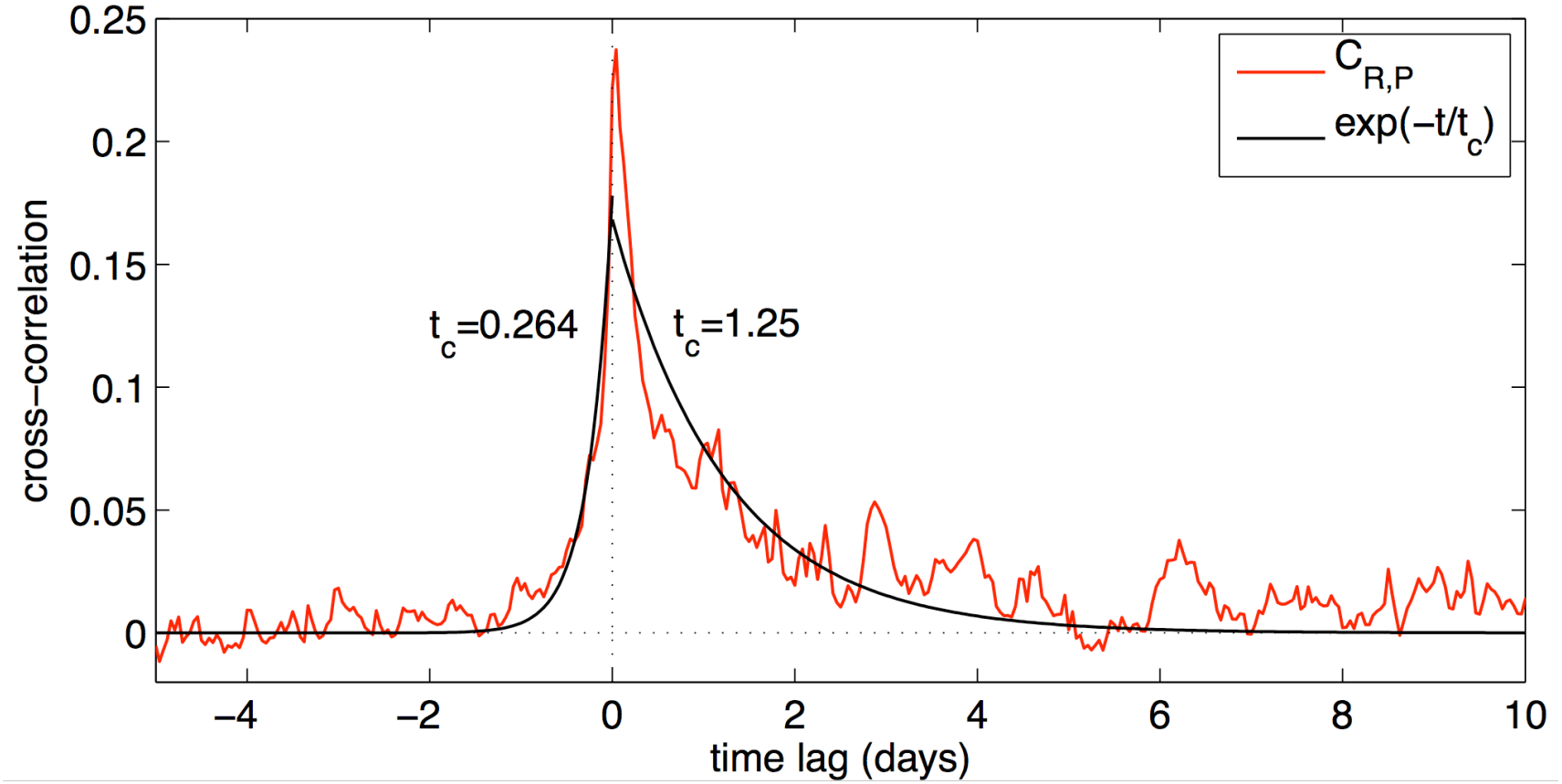
- amplitude max recorded at THE station ~ volume of rockfall ??

-> Need a calibration from surveillance camera.



Rockfall sensitivity to rainfall

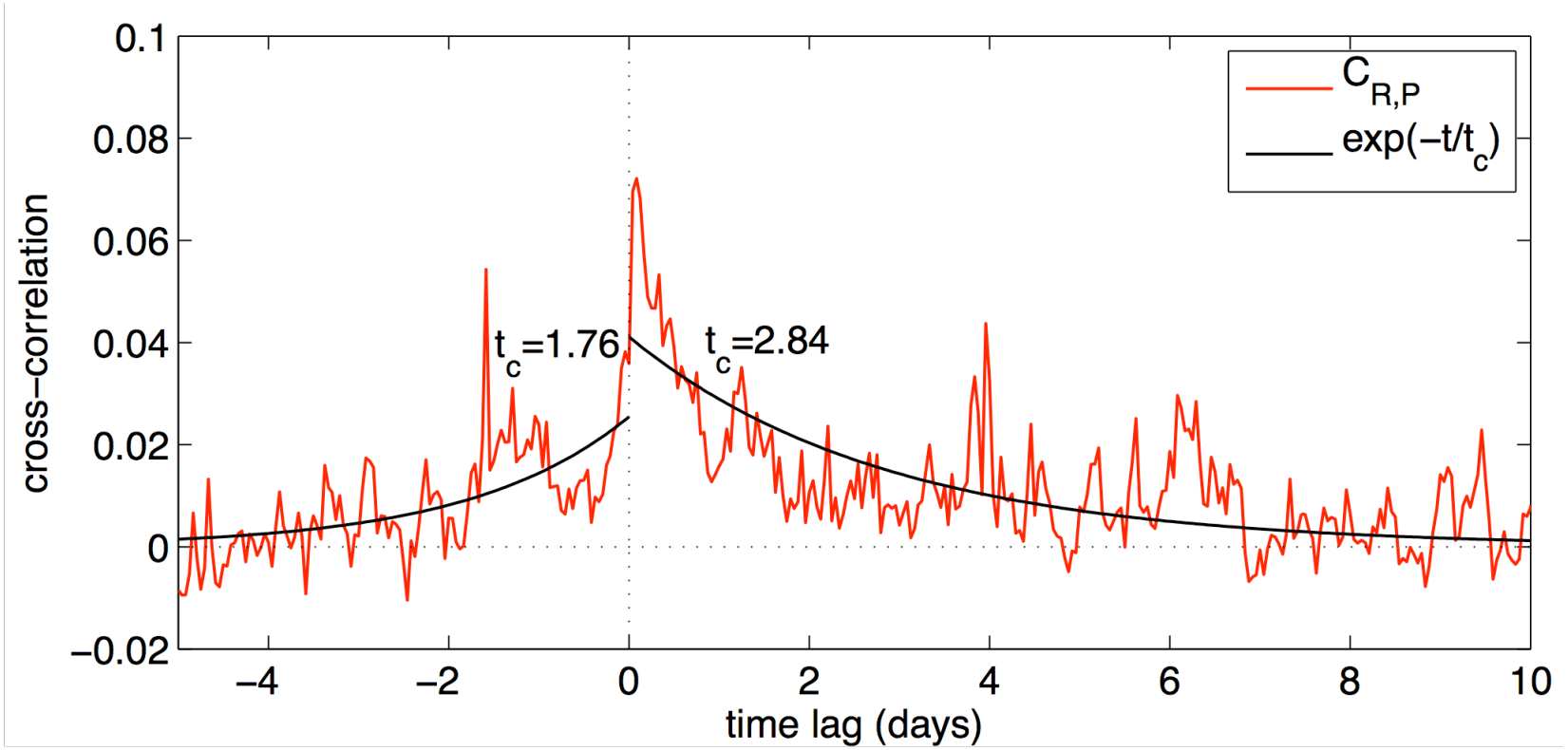
Cross-correlation between rockfall rate and rainfalls



- $C_{X,Y}(t-t')=\langle X(t)Y(t+t')\rangle$
- Rockfalls start almost instantaneously (<30mn) after a rainfall and last ≈5days
- Causes of the relaxation? Water infiltration? Snow melting? Nucleation?

Sensitivity of microseismicity to rainfall

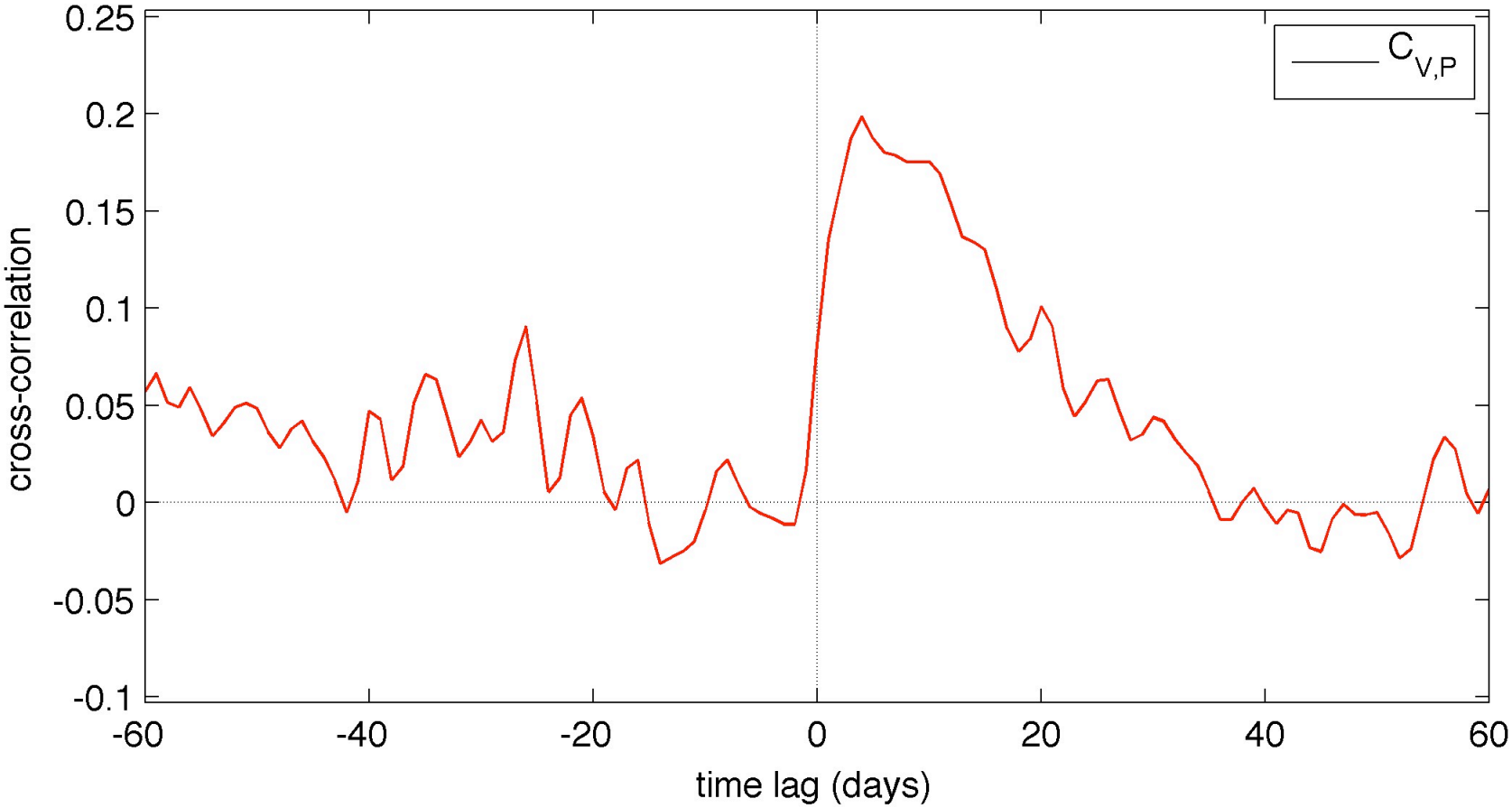
Cross-correlation of microseismicity rate with rainfalls



- Cross-correlation weaker than for rockfalls
- Characteristic relaxation time longer
- Time delay higher: 1.7 hr / 30 mn for rockfalls

Influence de la pluie sur le mouvement

Inter-corrélation de la vitesse de déplacement et des précipitations

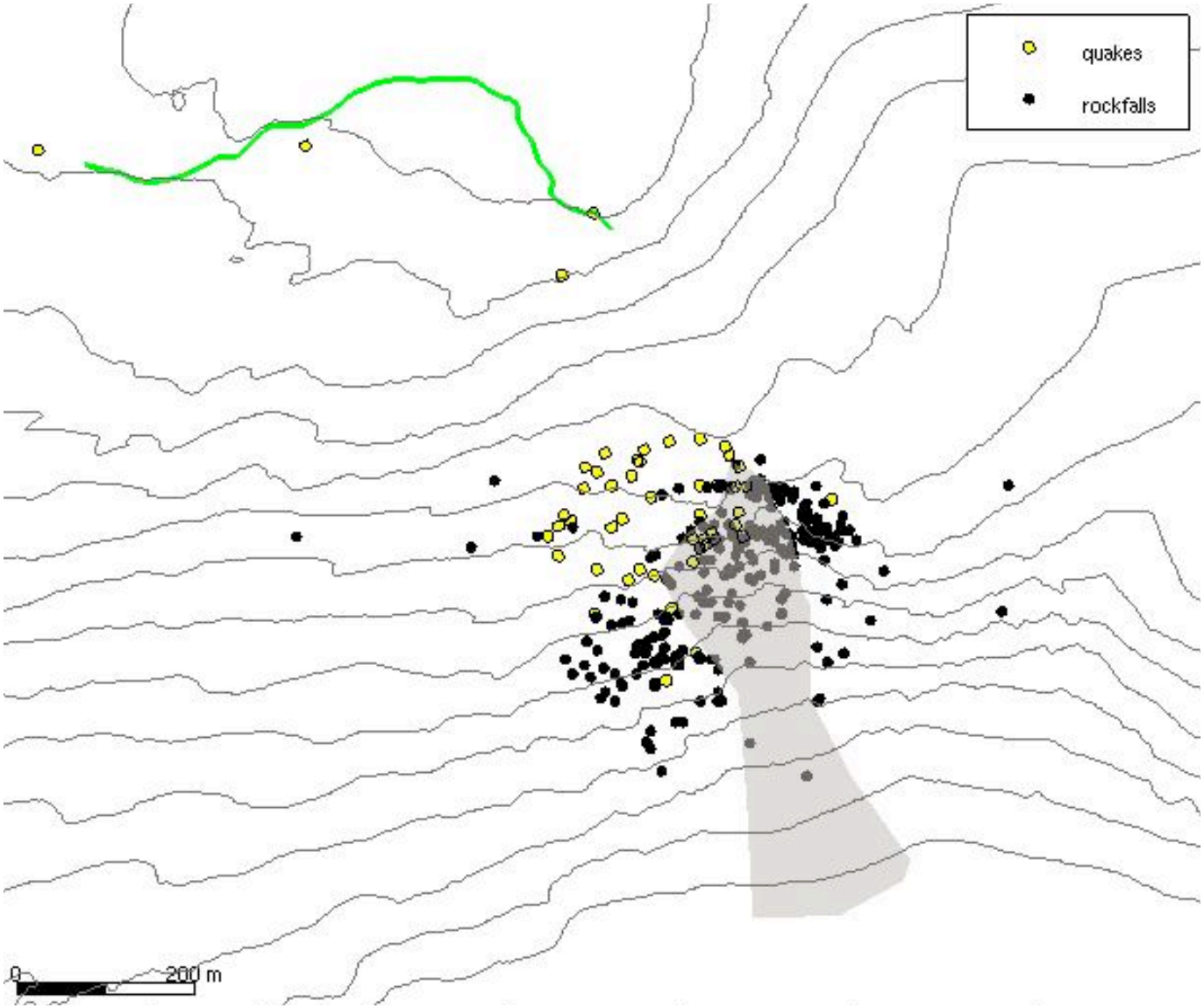


- corrélation maximum pour t≈4 jours
- relaxation de la vitesse beacoup plus lente (40 jours) que les éboulements ou la microsismicité (≈5 jours)

Conclusions – Future works

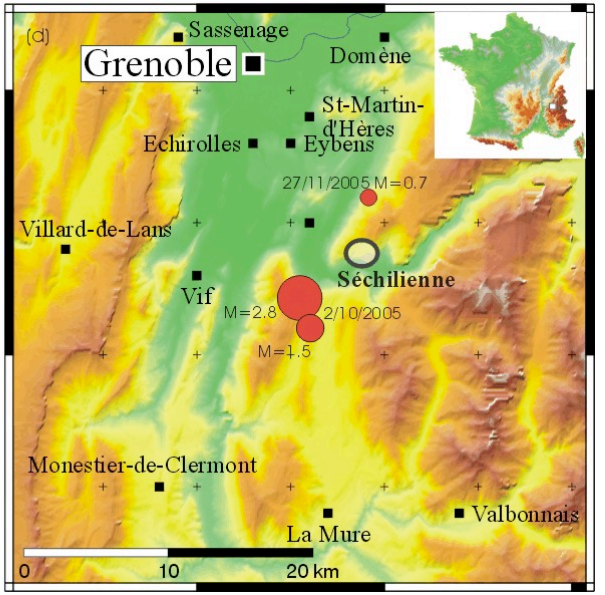
Ecoute sismique de Séchilienne :

localisation des signaux

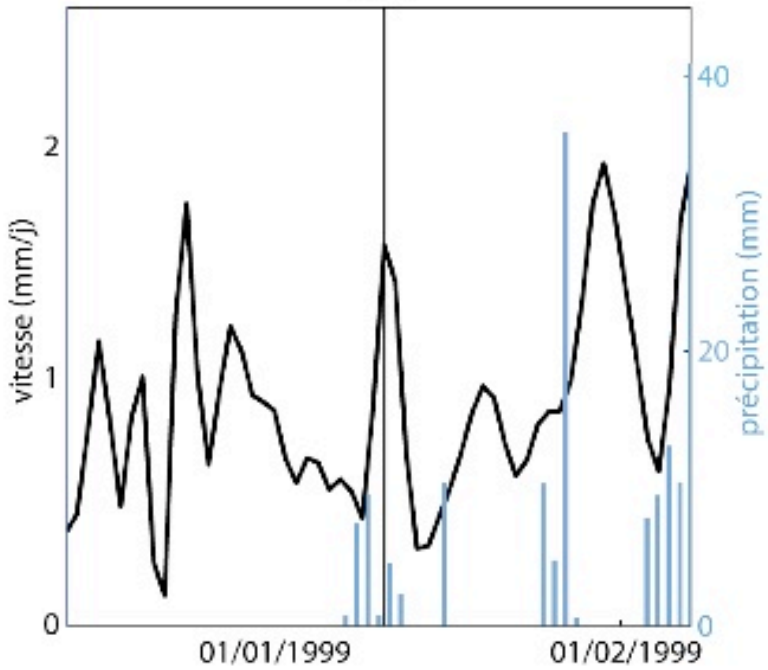


Influence des séismes sur le mouvement?

- 2 séismes ont eu lieu à ≈7km en 1999 et 2005, de magnitude m=3.5 et m=2.8
- légère accélération du mouvement, mais effet du séisme ou de la pluie?



11/1/1999 m=3.5



1/10/2005 m=2.8