nano-tera.ch
swiss scientific initiative in health / security / environment systems

X-Sense2 RTD 2013

FNSNF

A new strategy for natural hazard early warning: Codetection of acoustic emissions prior failure of heterogeneous media

Jérome Faillettaz
3G, University of Zürich

University of Zurich[UZH]

Early warning?


Capitalizing on heterogeneity

- ⇝ Break gradually → **Weakest parts break first**
- ⇝ Micro-cracks generate elastic **waves** that propagate through the medium
- ⇝ Capturing such waves enable to quantify the **micro-crack activity** (evolution of damage) prior to rupture

Motivation

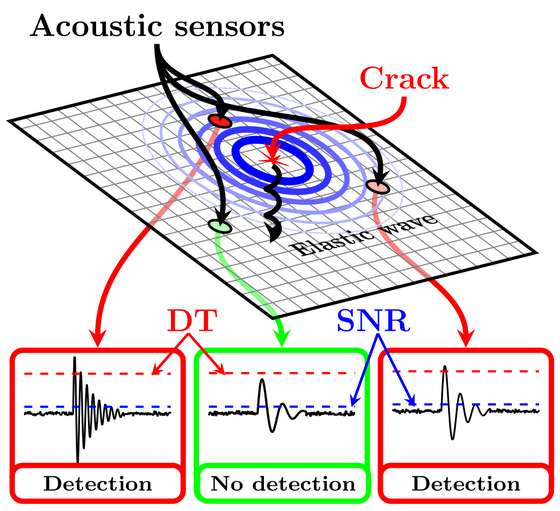
Predicting rupture in natural media remains a **challenge**:

- ⇝ Natural media are **heterogeneous**.
- ⇝ The heteregeneity is difficult to **quantify and measure**.
- ⇝ Rupture is a **nonlinear process** involving such heterogeneities.

Attenuation phenomenon

- ⇝ Wave *attenuates* during their *propagation*.
- ⇝ Attenuation ∼ distance to the source and frequency content.
- ⇝ Sensors detect an event if wave amplitude is large enough.

Signal detection

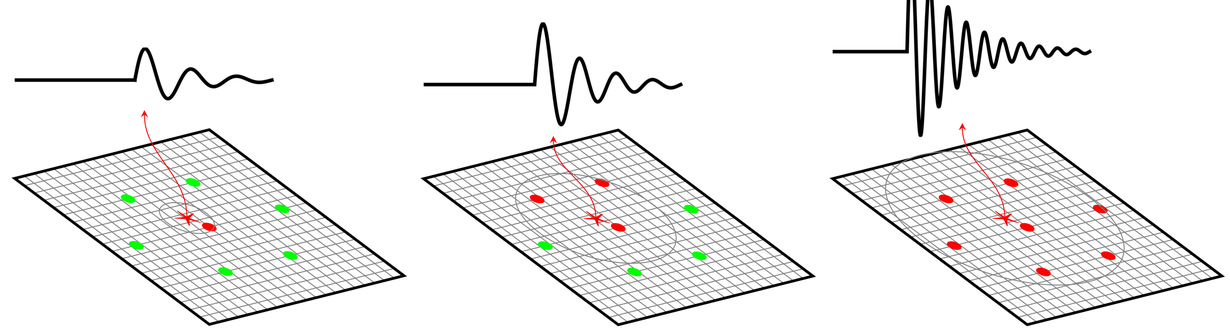


DT: Detection Threshold
SNR: Signal to Noise Ratio

Harnessing the attenuation phenomenon: Signal codetection

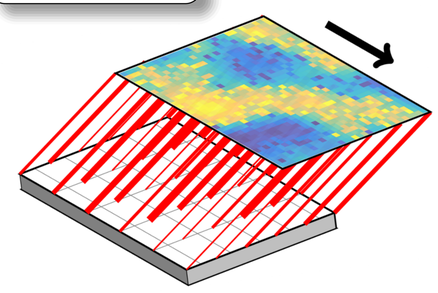
codetection: event simultaneously recorded on different sensors

- ⇝ Slope = low pass filter
- ⇝ Small event close to sensor = large recorded event!!!
- ⇝ **Ambiguity** in the interpretation of the magnitude/amplitude



Event co-detection by multiple sensors occurs **only** if its *initial* amplitude is sufficiently **large**

Model



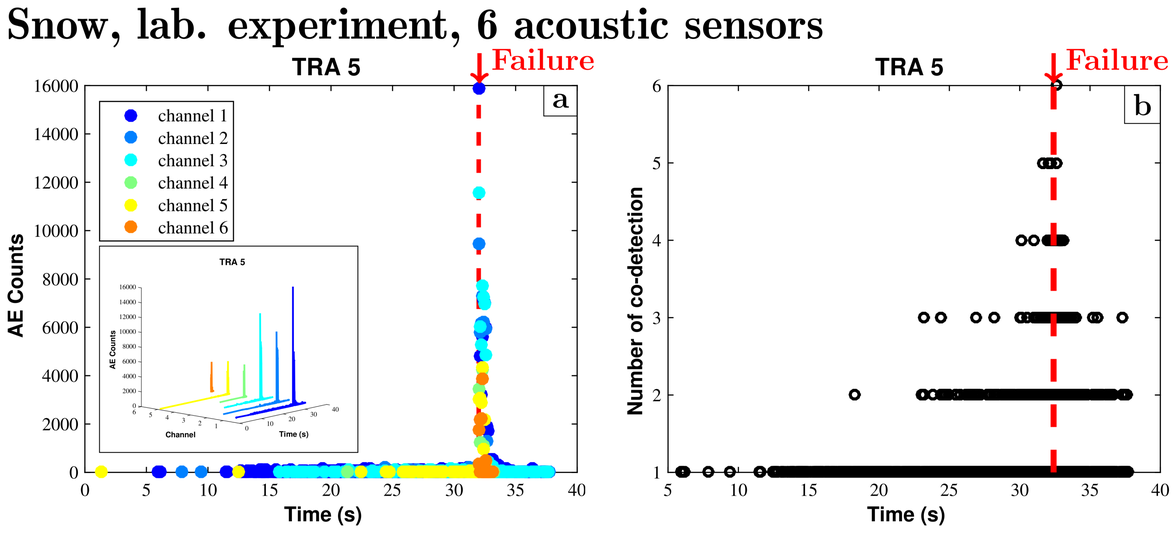
Fiber Bundle Model

- ⇝ simplest model of rupture
- ⇝ naturally includes heterogeneities
- ⇝ effect of stress redistribution
- ⇝ direct link to acoustic emissions

⇝ cascading failure events ("avalanches")∼ Acoustic emission

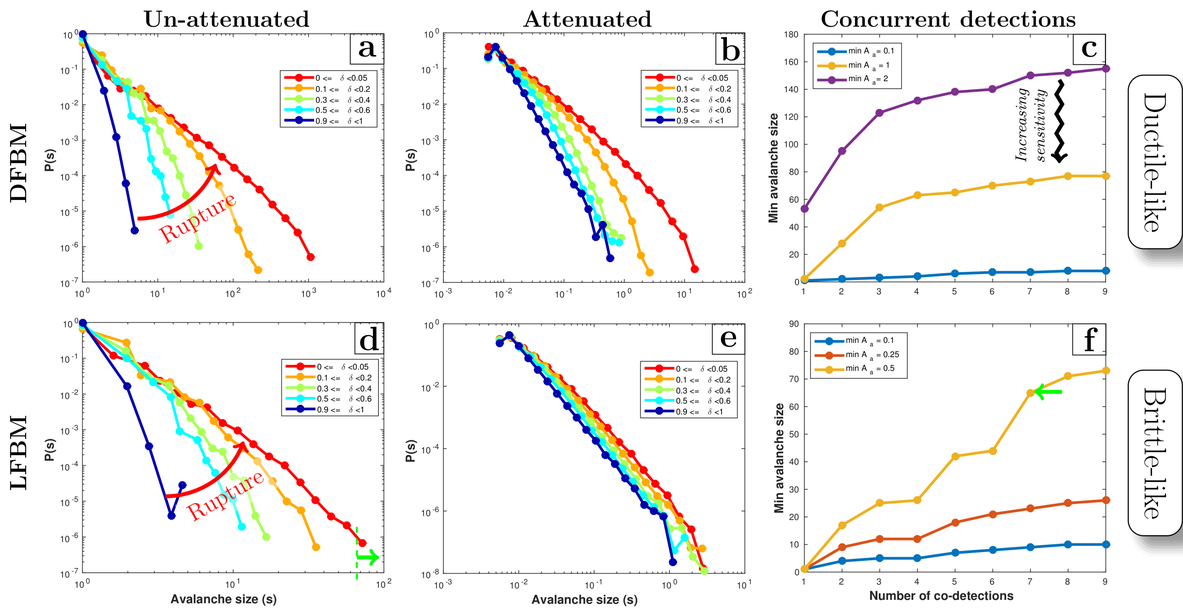
Applications to snow

Snow, lab. experiment, 6 acoustic sensors



- ⇝ sudden increase in signal maximal amplitude less than **1s** before failure.
- ⇝ **Early** increase in number of codetections more than **10 s** before failure

Results



- ⇝ Statistical properties of attenuated events lead to misleading results
- ⇝ Taking a sufficiently large threshold and number of co-detection events, the minimum size of the unattenuated events would fall in the range of $0 < \delta < 0.1$ i.e. just prior to rupture.

Conclusion

Codetection method

- ⇝ **simple**, low computational effort
- ⇝ works *independently* of rupture type (ductile/brittle)
- ⇝ Require dense sensor network.
- ⇝ Sensor must not be very sensitive
- ⇝ Network needs to be precisely **synchronized**

References

J. Faillettaz and D. Or (2015). Failure criterion for materials with spatially correlated mechanical properties. ***Physical Review E***, **91** (3), 032134, doi:10.1103/PhysRevE.91.032134.

J. Faillettaz, D. Or, and I. Reiweger (2016), Codetection of acoustic emissions during failure of heterogeneous media: New perspectives for natural hazard early warning, ***Geophysical Research Letters***, **43**, 1075-1083, doi:10.1002/2015GL067435.