Istituto di Ricerca per la Protezione Idrogeologica

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Sistemi di allerta per le colate detritiche: metodologie e sensoristica

Webinar Ordine dei Geologi Regione Umbria - 15 giugno 2021

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SUMMARY

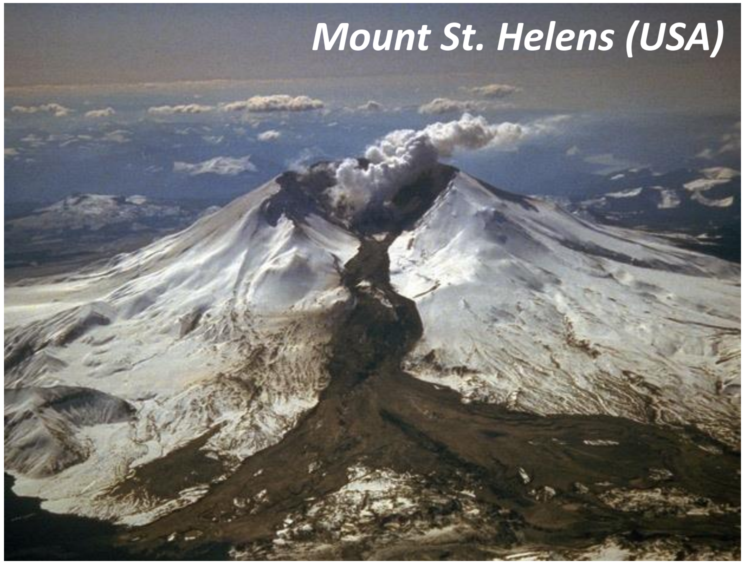
Introduction on non-structural mitigation measures for debris flows

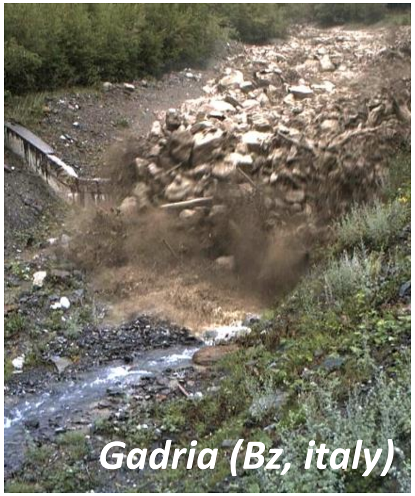
Early warning systems (examples from different sites)

The Gadria early warning system (BZ)

An exotic case study

*"Similar **landslides** in similar **materials** are caused by similar **processes** under similar **conditions**"*



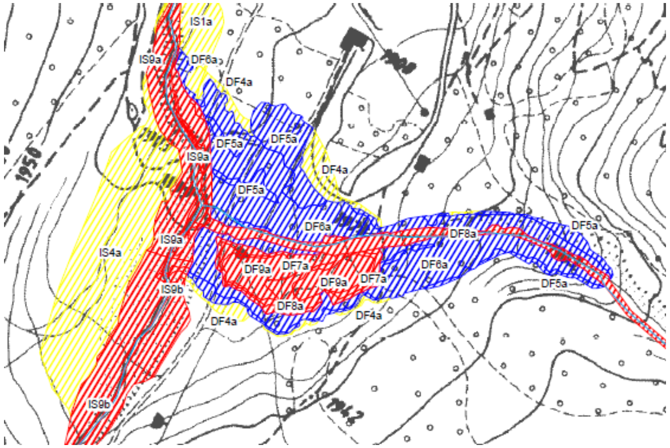


Varnes, D. J. (1984). IAEG Commission on Landslides & other Mass Movements. Landslide hazard zonation: a review of principles and practice, 63.

Debris flow mitigation measures

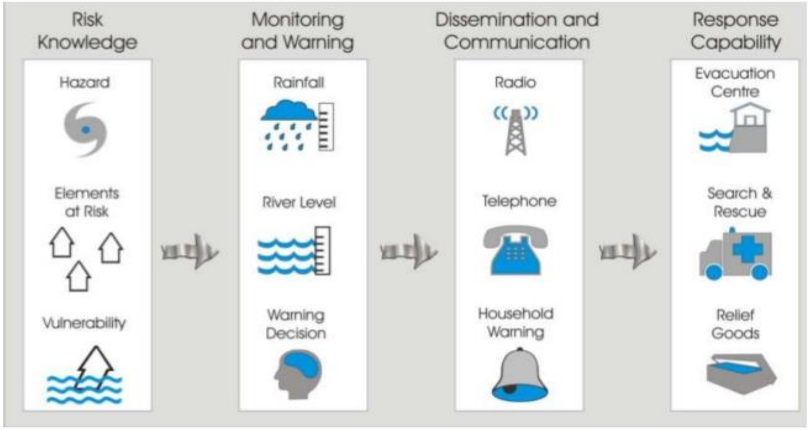
Structural measures → hazard

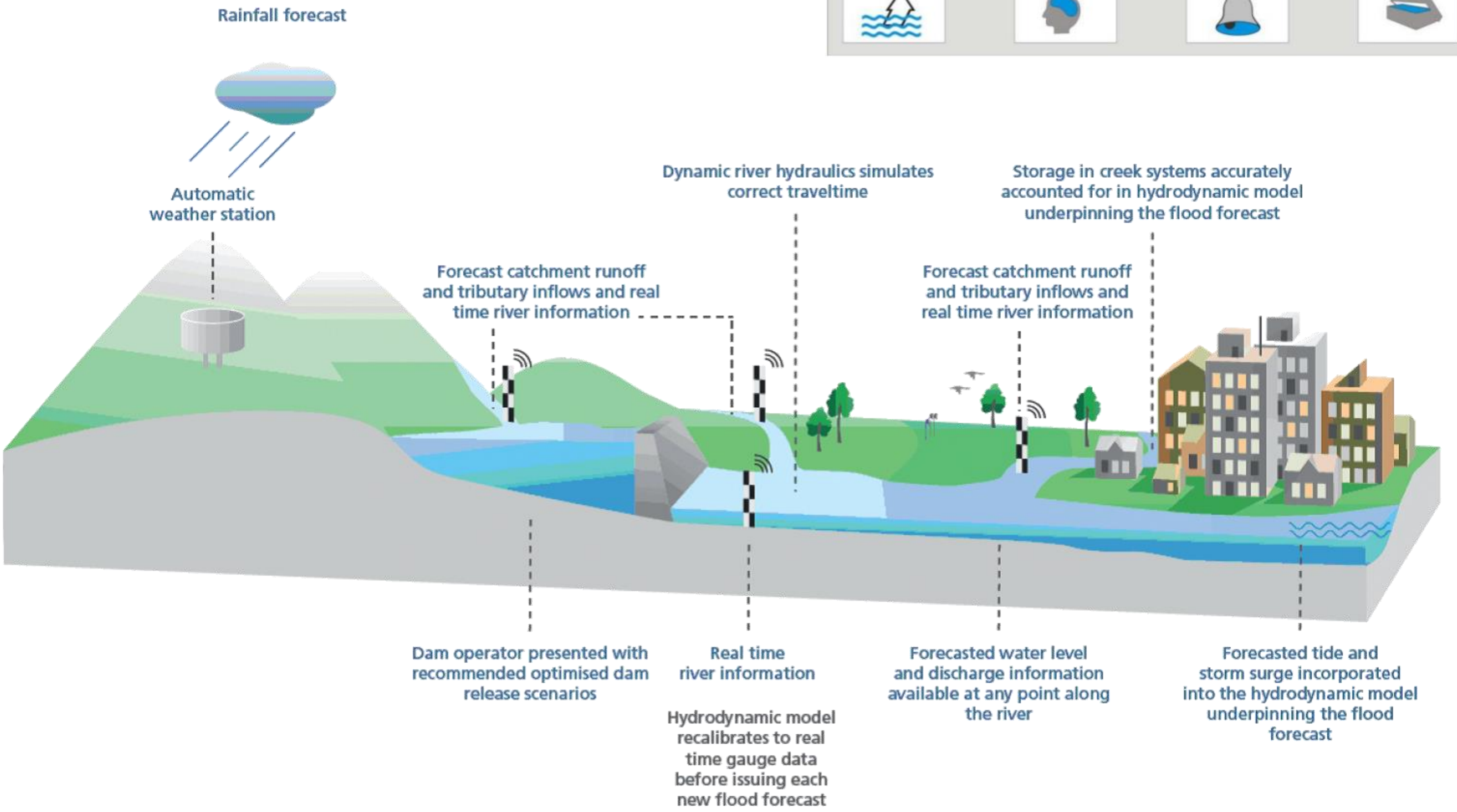
Non-structural measures → vulnerability/exposure



EWS for floods

More knowledge on flood processes, larger alert time, civil protection agencies involved





Landslide monitoring for warning purposes

1) Temporal/spatial resolution, precision and accuracy of the measure, etc.

2) Parameters to monitor: surface deformations as a proxy of landslide movement, ground vibrations as precursory events, rainfall as triggering factors

3) Practical issues: where do we install the sensors? Inside/outside the landslide body / the channel bed? At which distance? Which kind of instruments do we use? Active/passive, maintenance costs, etc. What about data transmission?

Gallivaggio, Central Italian Alps

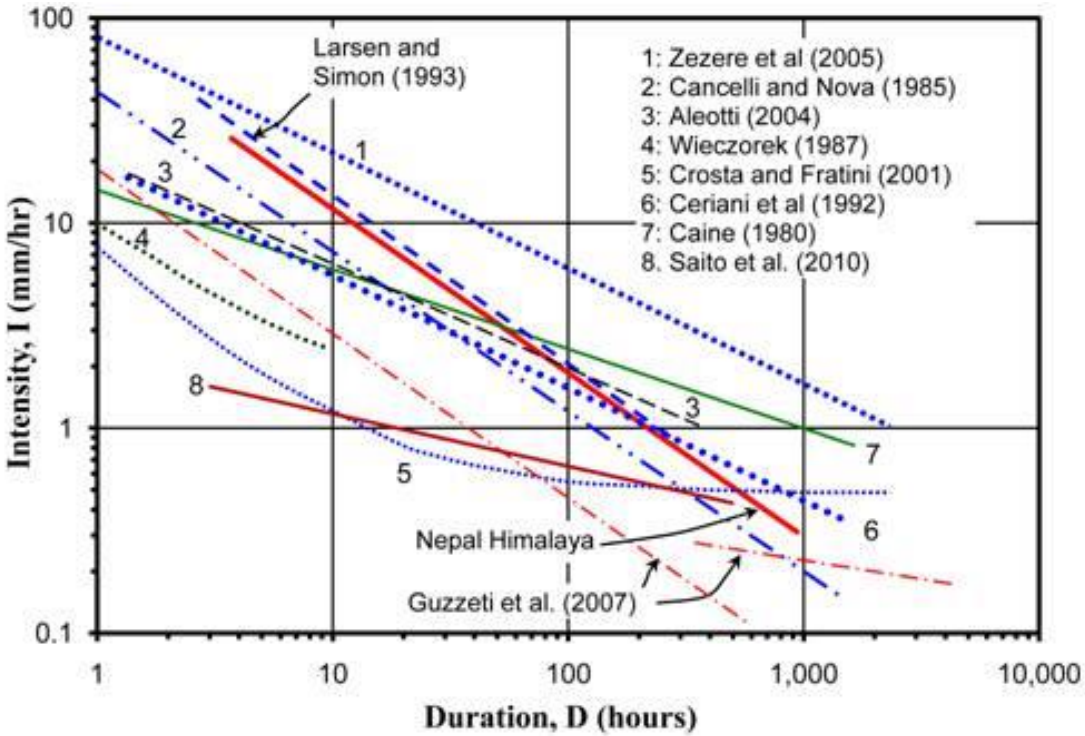
Landslide monitoring for warning purposes

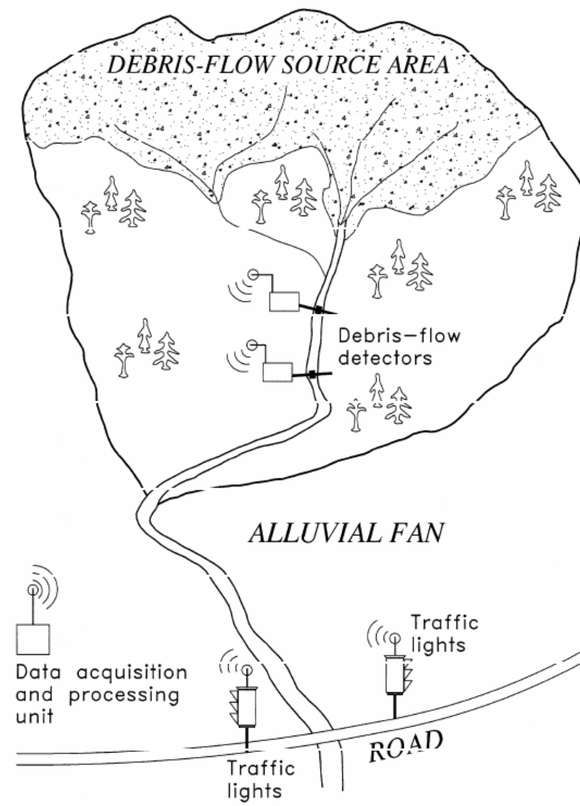
Parameter	Technique/sensor	Process
Deformations and displacements	Total station, GB In-SAR, photogrammetry, videocameras, extensometer	Rock slides, rock falls, soil slides
Ground vibrations	Seismometers, geophones	Rock slides, rock falls, **debris flows**
Rainfall	Rain gauges	Rock solides, rock falls, soil slides, **debris flows**
Flow height	Stage sensors	**Debris flows**

Early Warning Systems (EWS) for debris flows

Warning systems for debris flows can be classified into two main types: advance warning and event warning (Arattano and Marchi, 2008). **Advance warning systems** predict the possible occurrence of a debris flow by monitoring hydro-meteorological processes that may lead to initiation conditions, typically rainfall. **Event warning systems** are based on the detection of debris flows when the processes are in progress.

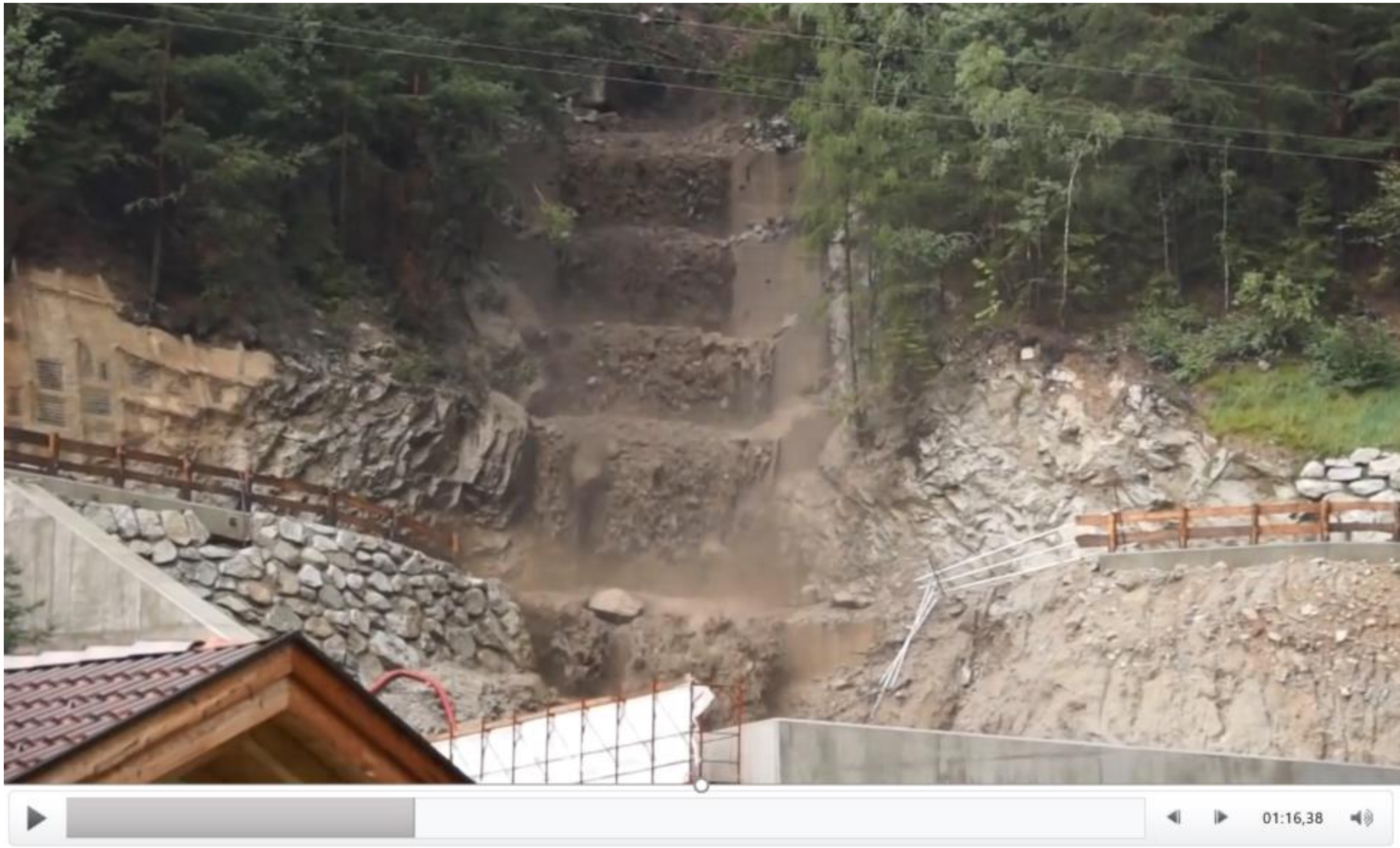
Dahal R.K., 2010





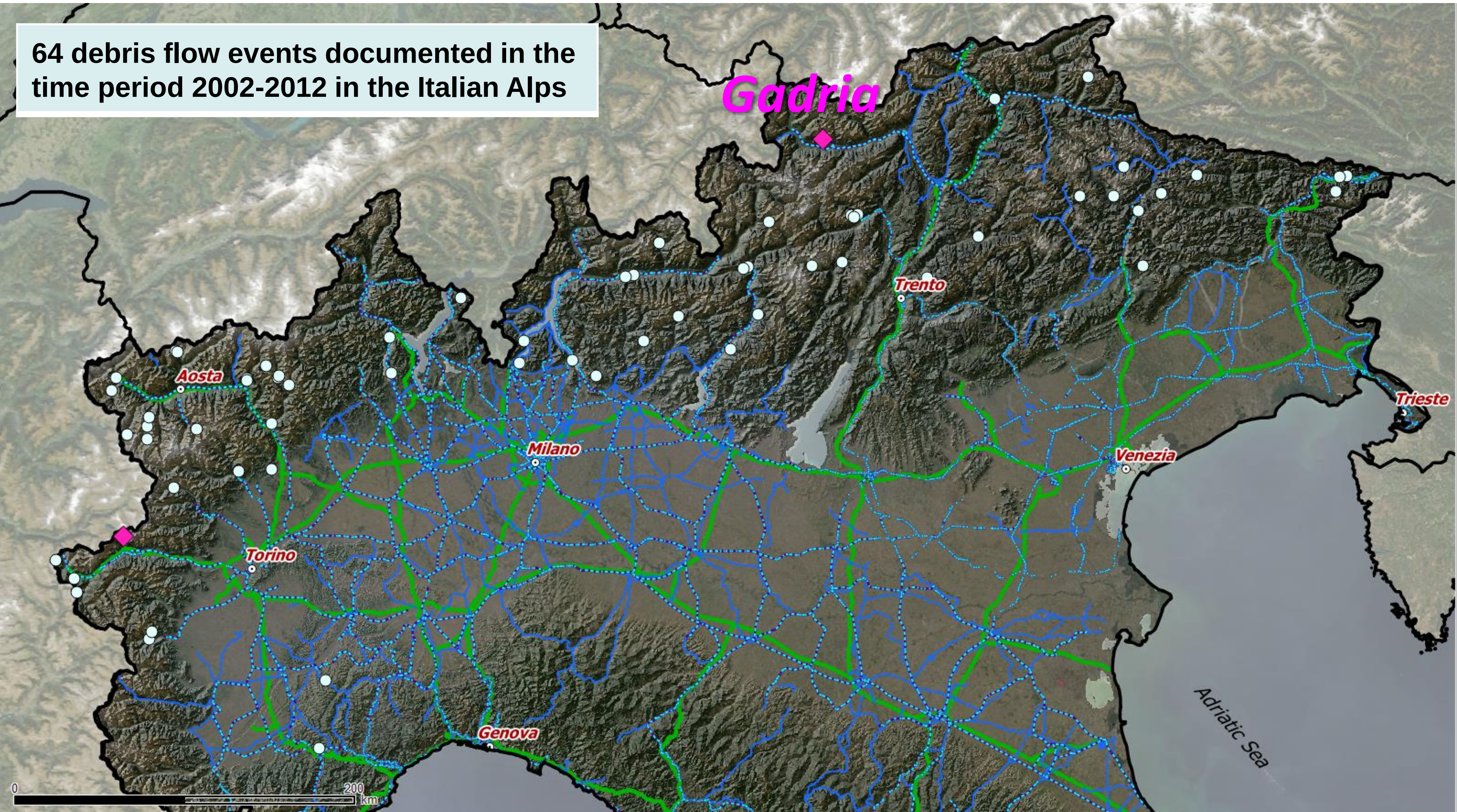
Arattano and Marchi, Sensors 2008
https://www.mdpi.com/1424-8220/8/4/2436

https://www.youtube.com/watch?v=buLdrwBZZE4



Debris flow impact on communication routes in Northern Italy

Palladino et al., landslide database CNR IRPI

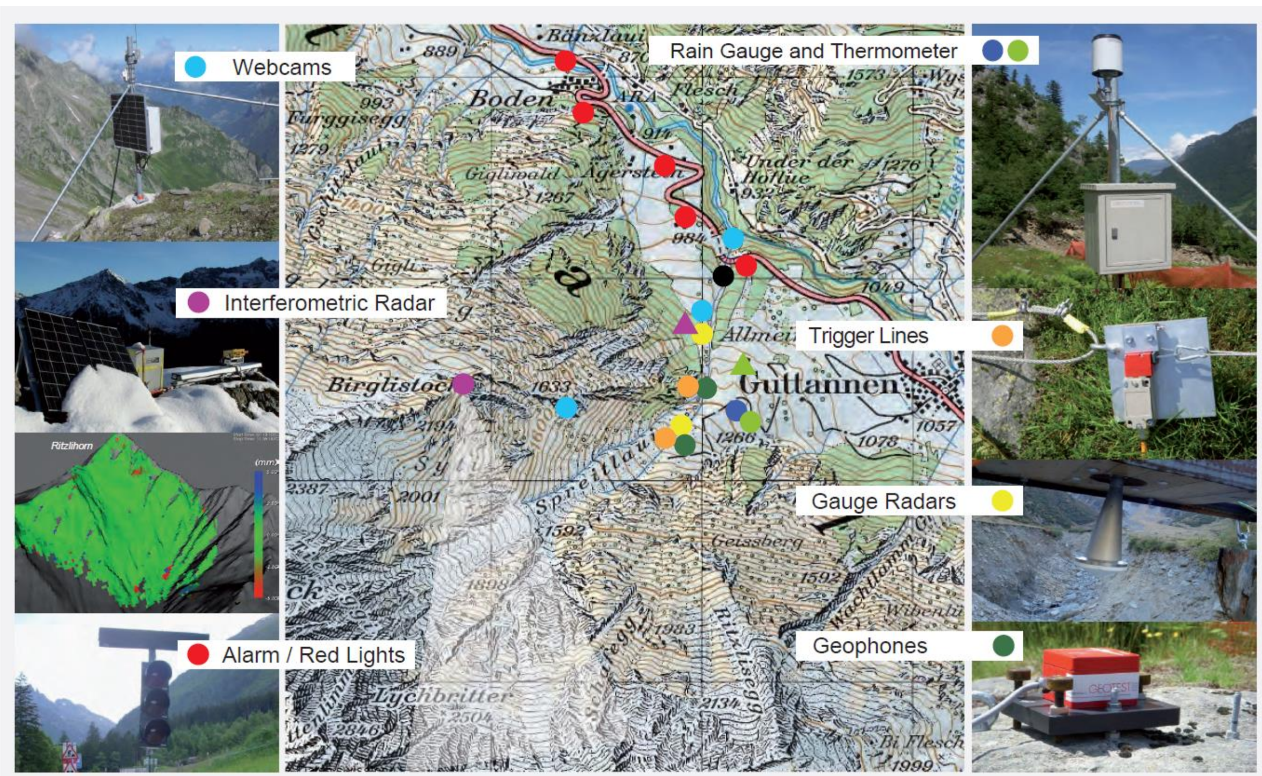


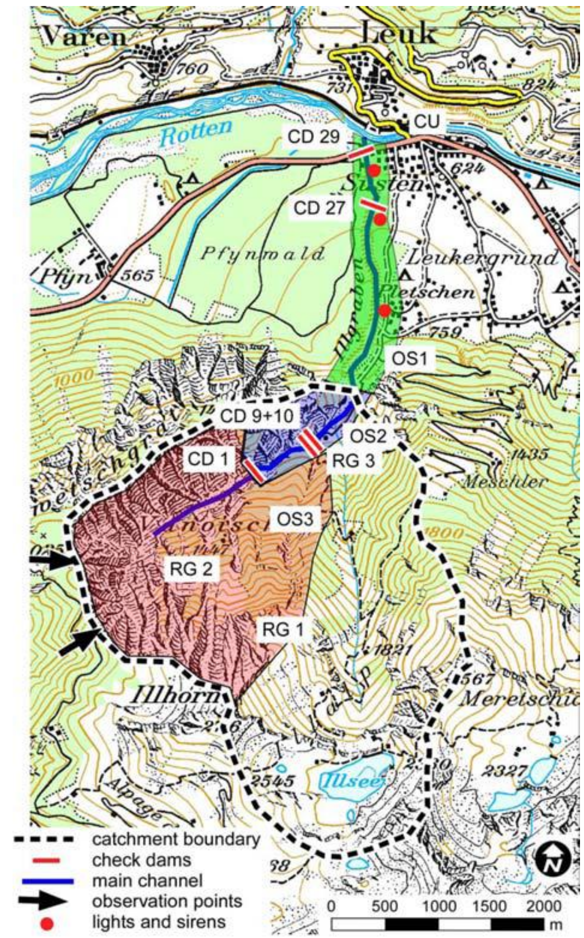
Early Warning Systems for debris flows

Few examples of **event warning systems** have been deployed so far (e.g. Badoux et al., 2008; Coviello et al., 2021; Gianora et al., 2013; Jacquemart et al., 2015) because the designing is complex (hardware + software + sensors algorithm) and needs a complete knowledge of the event dynamics and previously acquired monitoring data.

Badoux et al., 2008

Jacquemart et al., 2015





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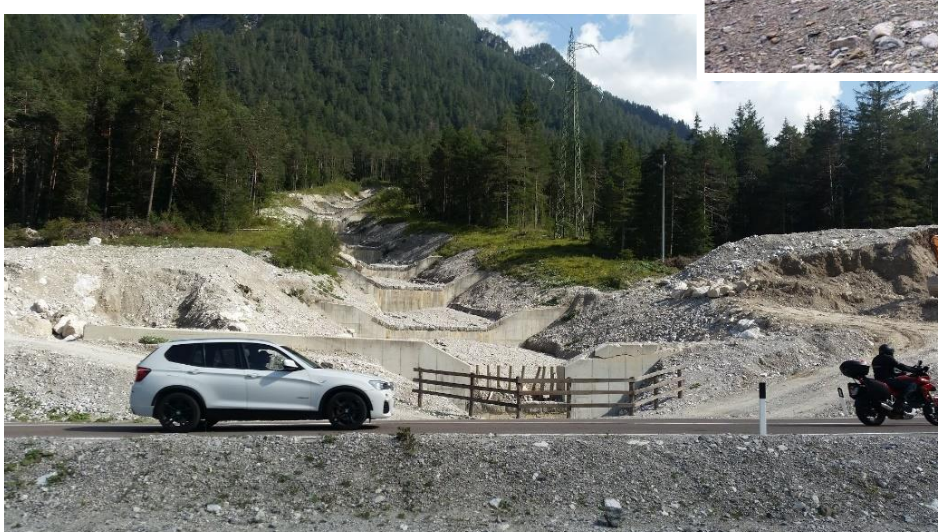
Coviello et al., INTERPRAEVENT 2021
https://gyroconference.no/workspace/interpraevent/documents/IP_2021_EA.pdf



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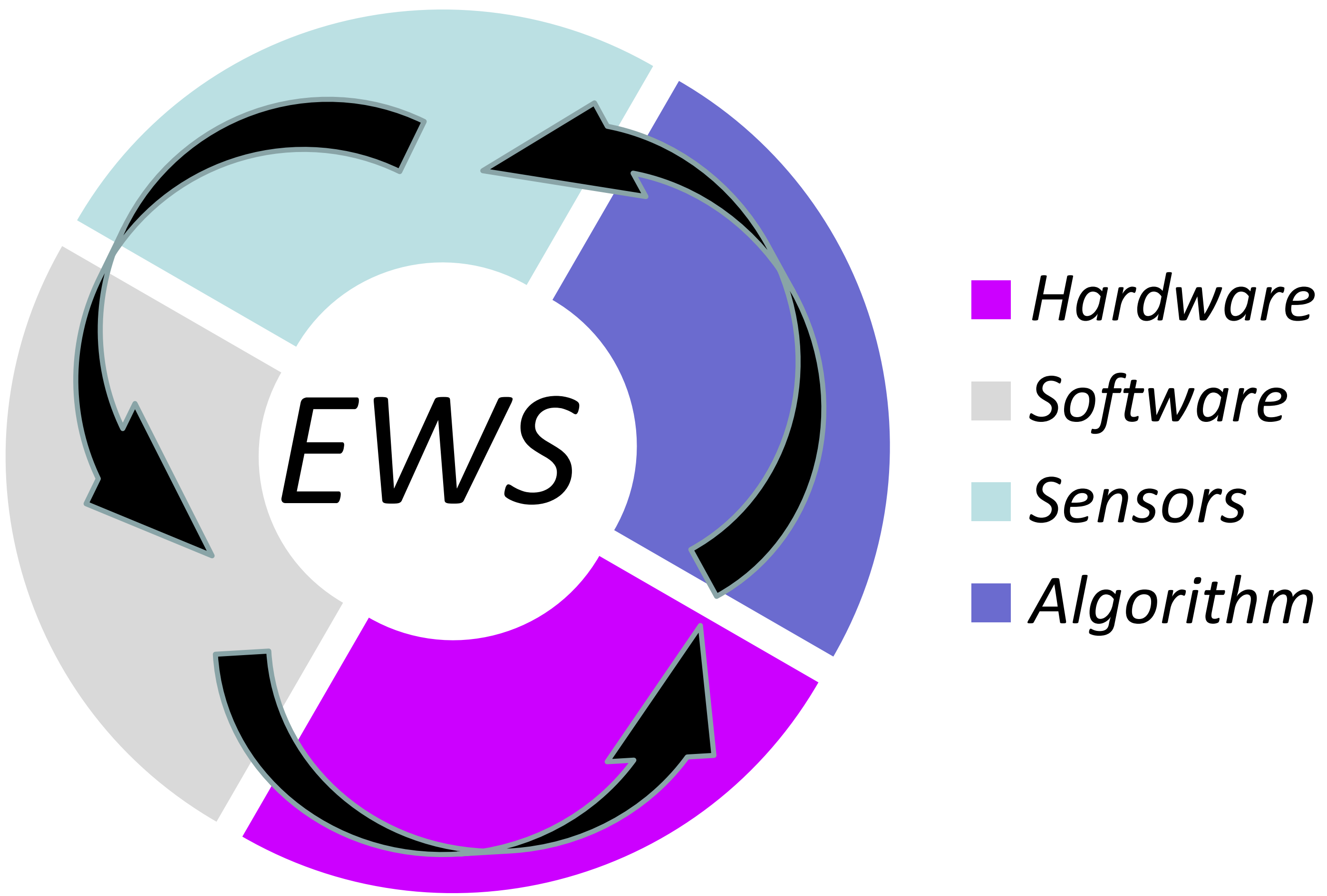
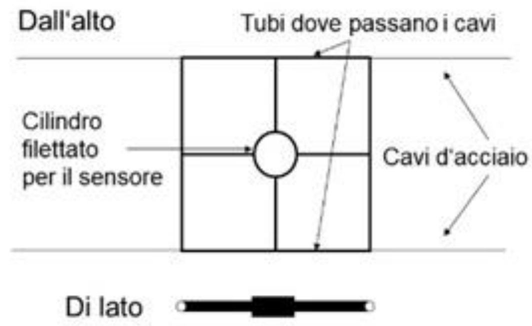
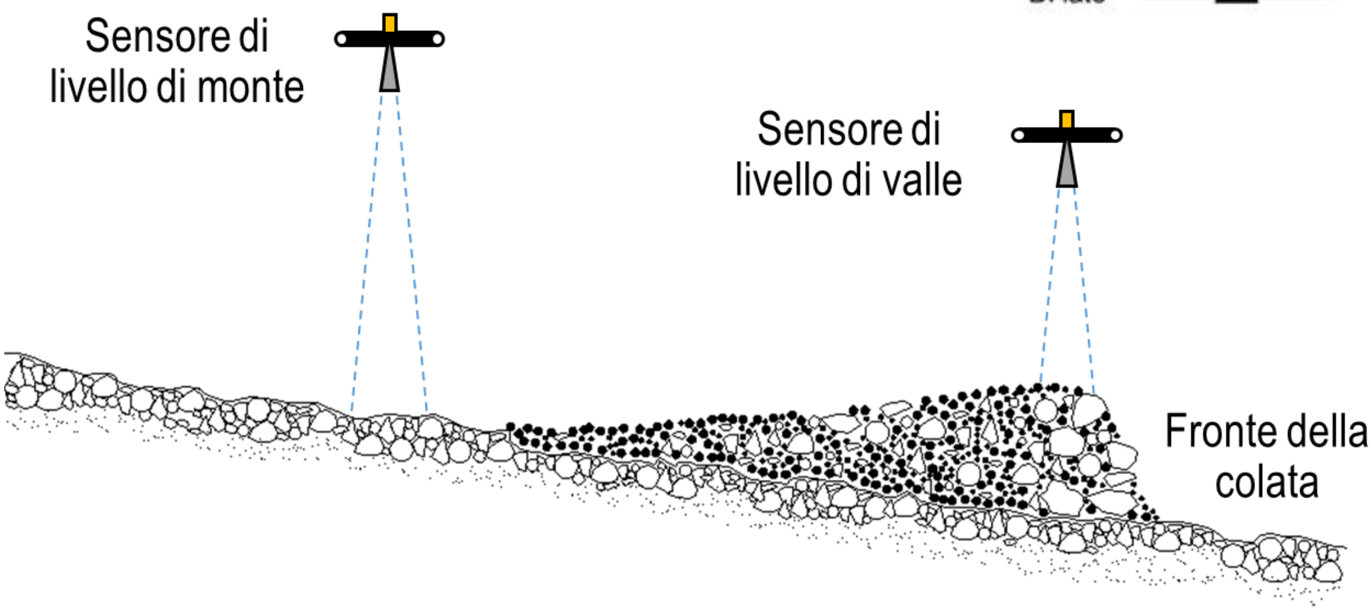


Sensors for debris-flow warning (i): flow stage sensors

Pros: record a valuable information (hydrograph)

Cons: installation costs, need maintainance, erosion/deposition may impede detection of subsequent surges





Marchi, Coviello, Crema, and Macconi (2021) - Strumentazione per colate rapide, in: Dei Cas L., Trigila A., Iadanza C. (eds) Linee Guida per il monitoraggio delle frane. Linee Guida SNPA https://www.snpambiente.it/2021/05/18/linee-guida-per-il-monitoraggio-delle-frane/

Sensors for debris-flow warning (ii): contact sensors

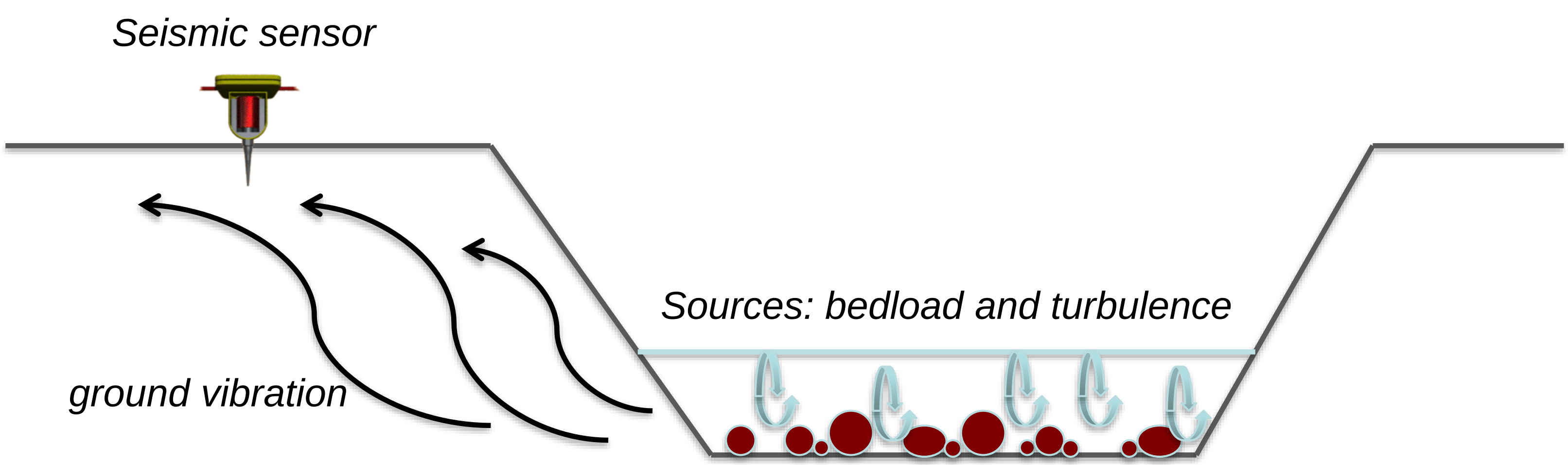
Pros: simple methods

Cons: installation costs, need maintainance, detection of subsequent surges not possible with trip wires

Coviello et al., INTERPRAEVENT 2021

https://gyroconference.no/workspace/interpraevent/documents/IP_2021_FA.pdf

Sensors for debris-flow warning (iii): seismic sensors



Seismic detection of fluvial processes

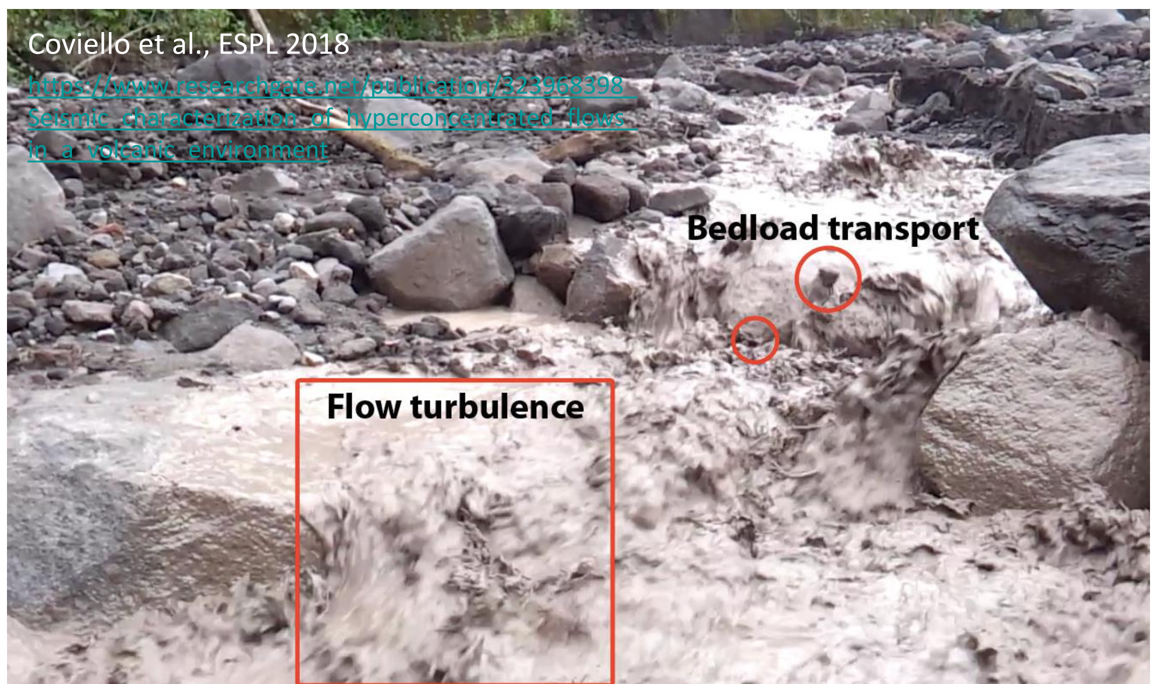
Govi et al., HS 1993

Arattano and Moia, HS 1999

…

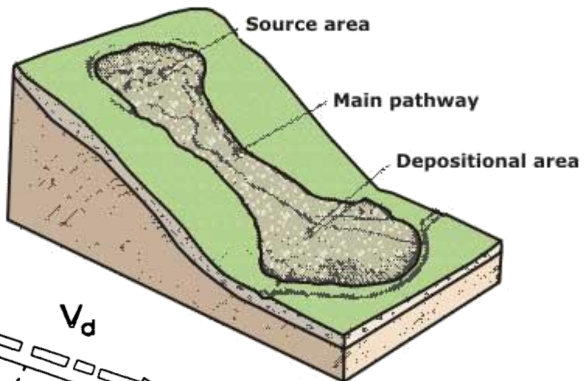
Gimbert et al., JGR 2014

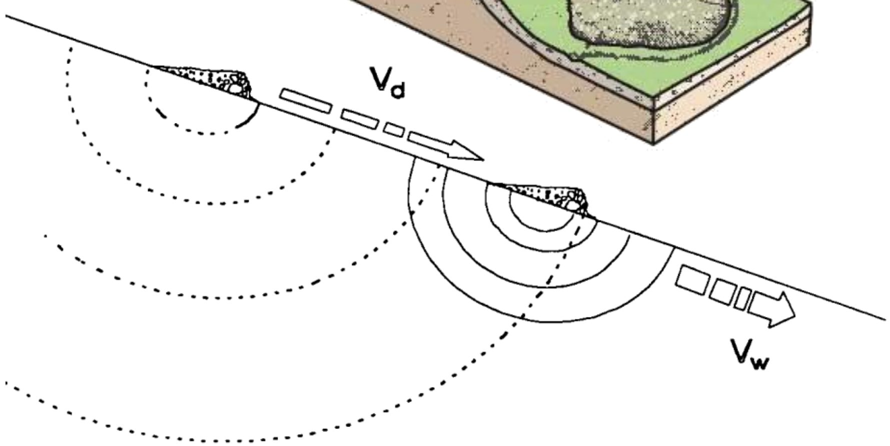
Coviello et al., ESPL 2018



Advantages of Ground Vibration Detectors (GVDs)

- *Most monitoring devices (stage detectors, video cameras, contact sensors) need to be placed inside, above or very close to the channel with a consequent high probability of damage*
- *GVDs are passive sensors, highly adaptable to the site conditions*
- *GVDs can detect the debris flow front arrival tens of seconds earlier than other type of devices*
- *Among the GVDs, geophones are among the most easy to install and low cost monitoring devices*



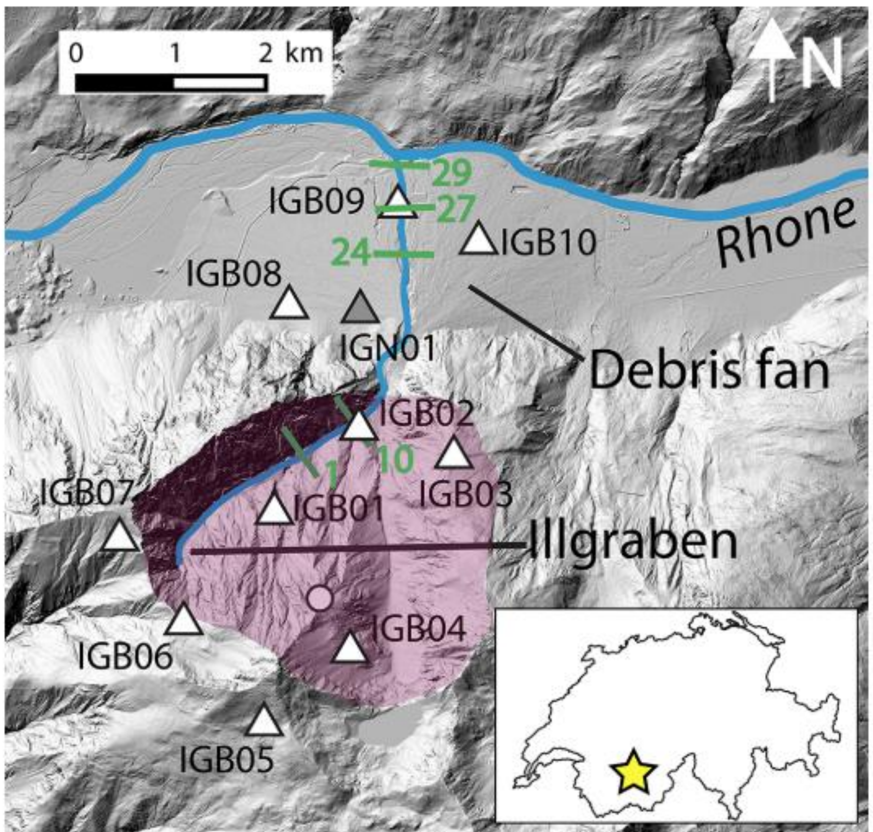


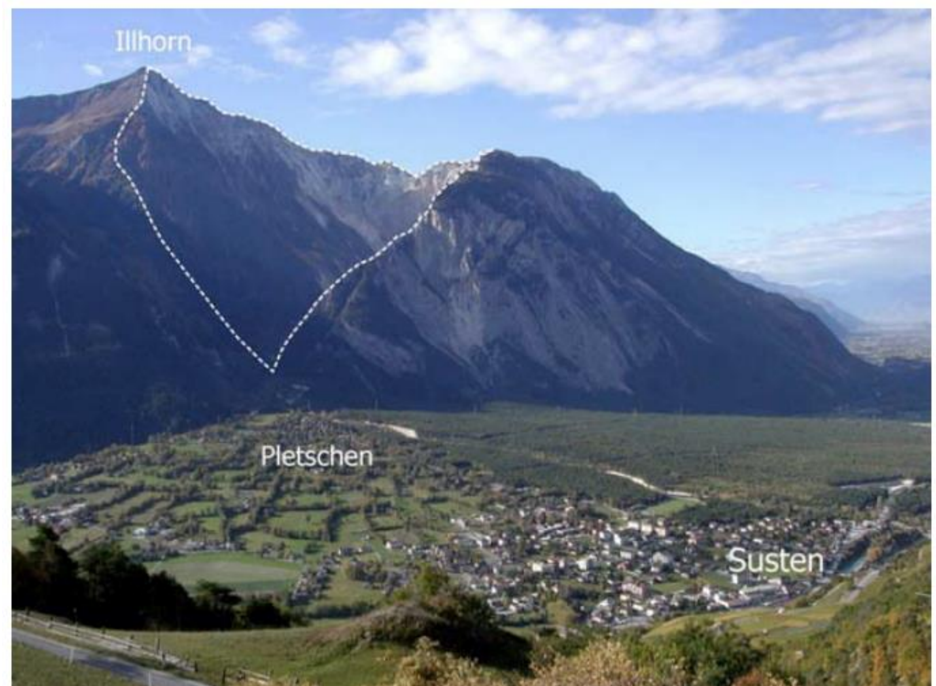
The velocity of the debris V_d , and the propagation velocity of the vibrations induced in the ground V_w (Arattano, 2000)

Geophone installation methods: (a) embedded in concrete, (b) fixed on rock surface; (c) dug in the ground (Coviello, 2015)

Seismic detection of debris flows: sites and methods

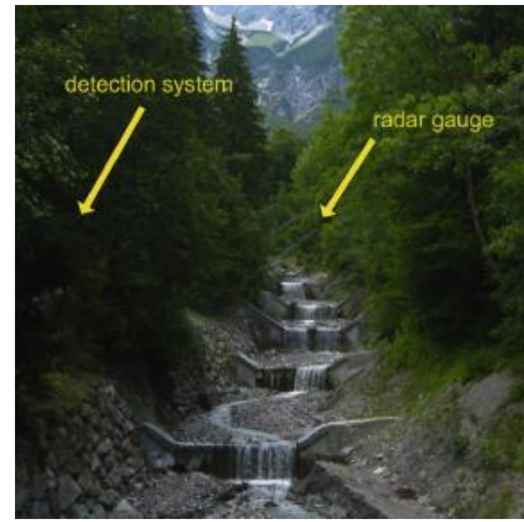
1) Illgraben (CH): amplitude/duration threshold, seismic amplitude source location, infrasound array, machine learning applied to seismic data
Baboux et al., NHZ 2008; Walter et al., NHESS 2017; Marchetti et al., JGR 2019; Chmiel et al., JGR 2020

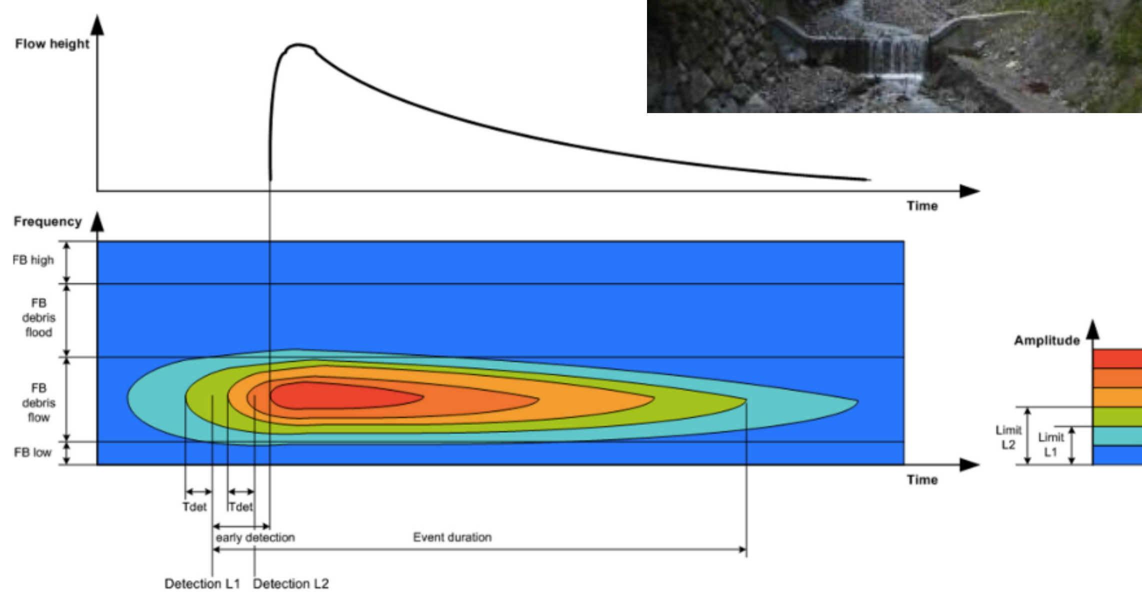




Seismic detection of debris flows: sites and methods

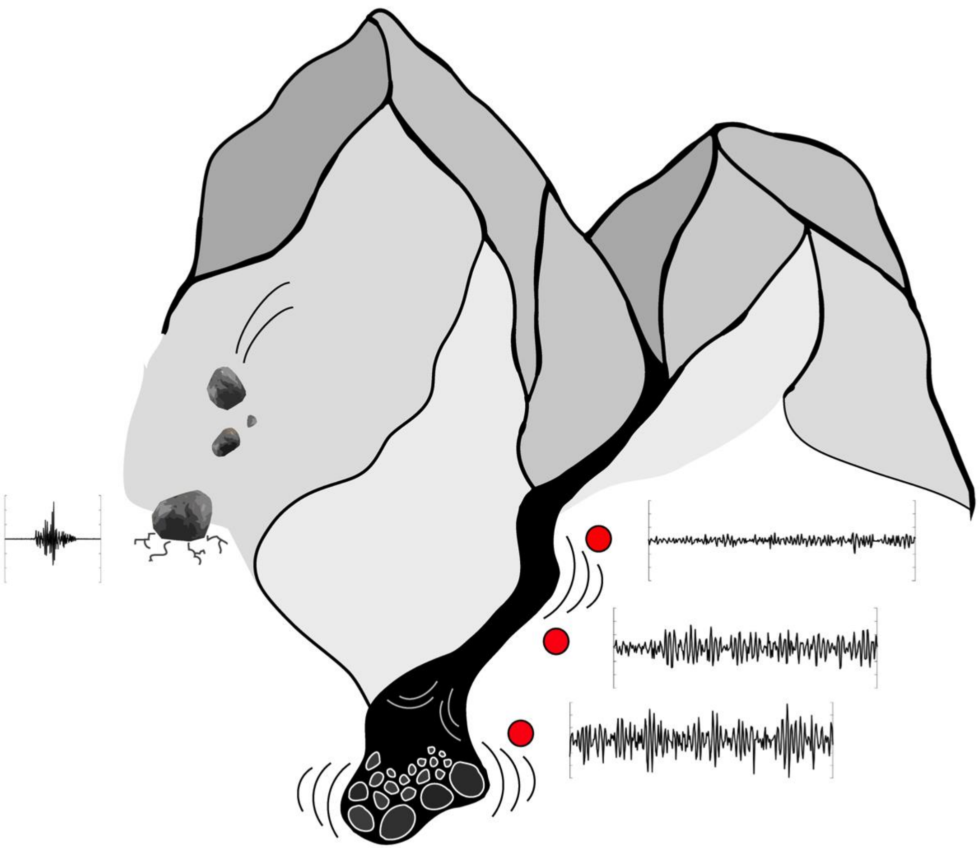
2) Lattenbach (AT): detection algorithm based on an amplitude/frequency threshold on a geophone+infrasound array
Schimmel and Hubl NHZ 2015; Schimmel et al., Sensors 2018





Seismic detection of debris flows: sites and methods

3) Gadria (ITA): detection algorithm based a STA/LTA threshold, linear array of geophones
Arattano et al., NHESS 2015; Coviello et al., JGR 2019; Coviello et al., INTERPRAEVENT 2021

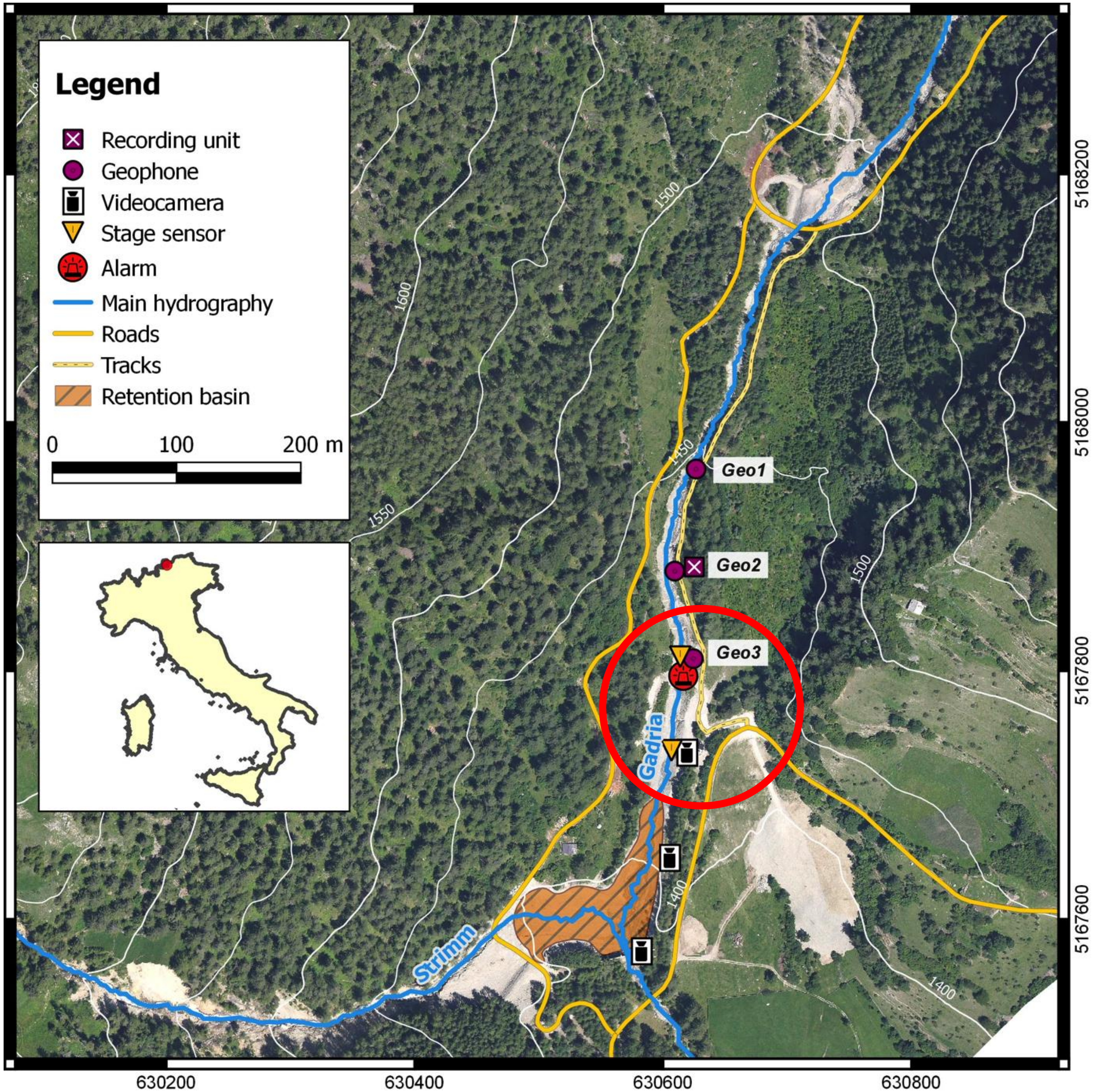


Coviello V., Arattano M., Marchi L., Comiti F., Macconi P. (2019). [Seismic characterization of debris flows: insights into energy radiation and implications for warning](), Journal of Geophysical Research – Earth Surface.

Gadria monitoring station (ITA)

Testing field for debris-flow seismic detection methods and early warning algorithms

NO INFRASCTRUCTURES OR SETTLEMENTS EXPOSED TO RISK

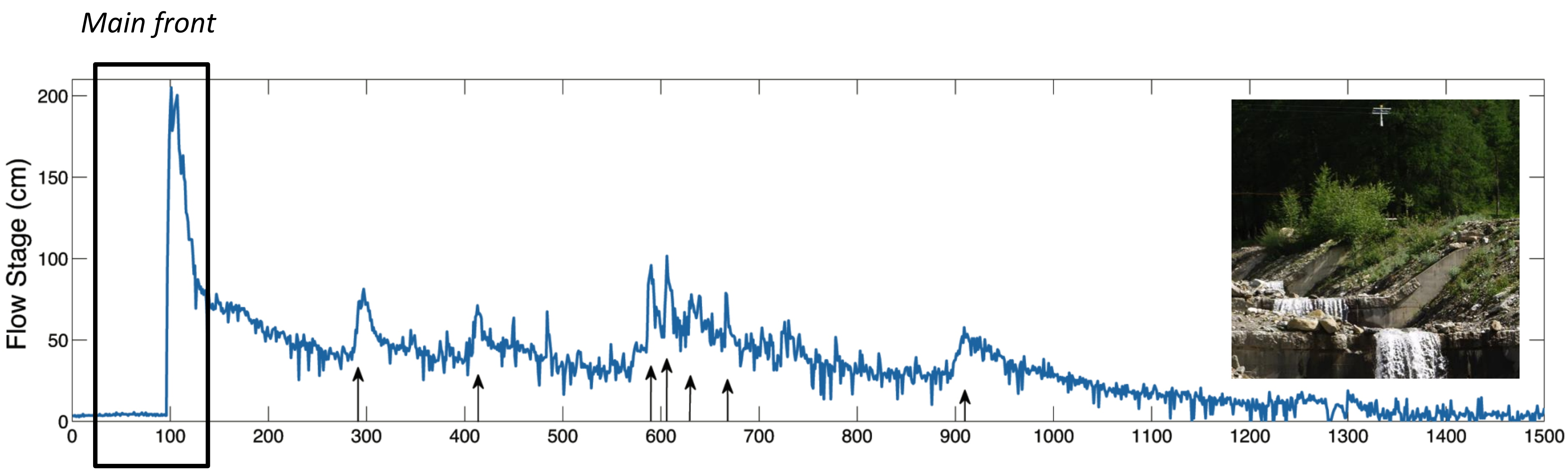


Coviello V., Arattano M., Marchi L., Comiti F., Macconi P. (2019). [Seismic characterization of debris flows: insights into energy radiation and implications for warning](), Journal of Geophysical Research – Earth Surface.

Debris flow monitoring at Gadria

https://www.youtube.com/watch?v=DXA7D82S4Ow

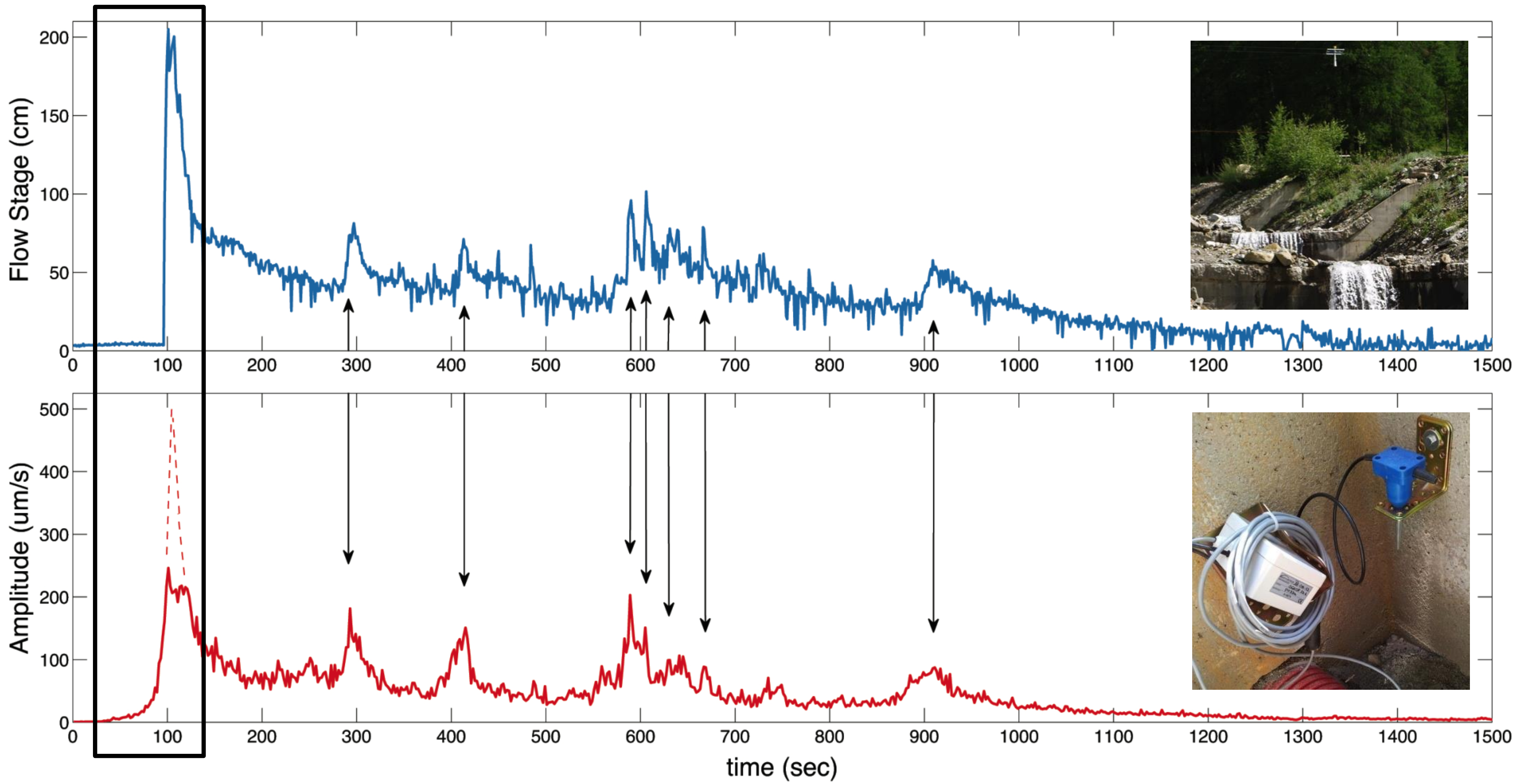
Gadria, monitoring data of 18 July 2013



Coviello V., Arattano M., Marchi L., Comiti F., Macconi P. (2019). [Seismic characterization of debris flows: insights into energy radiation and implications for warning](), Journal of Geophysical Research – Earth Surface.

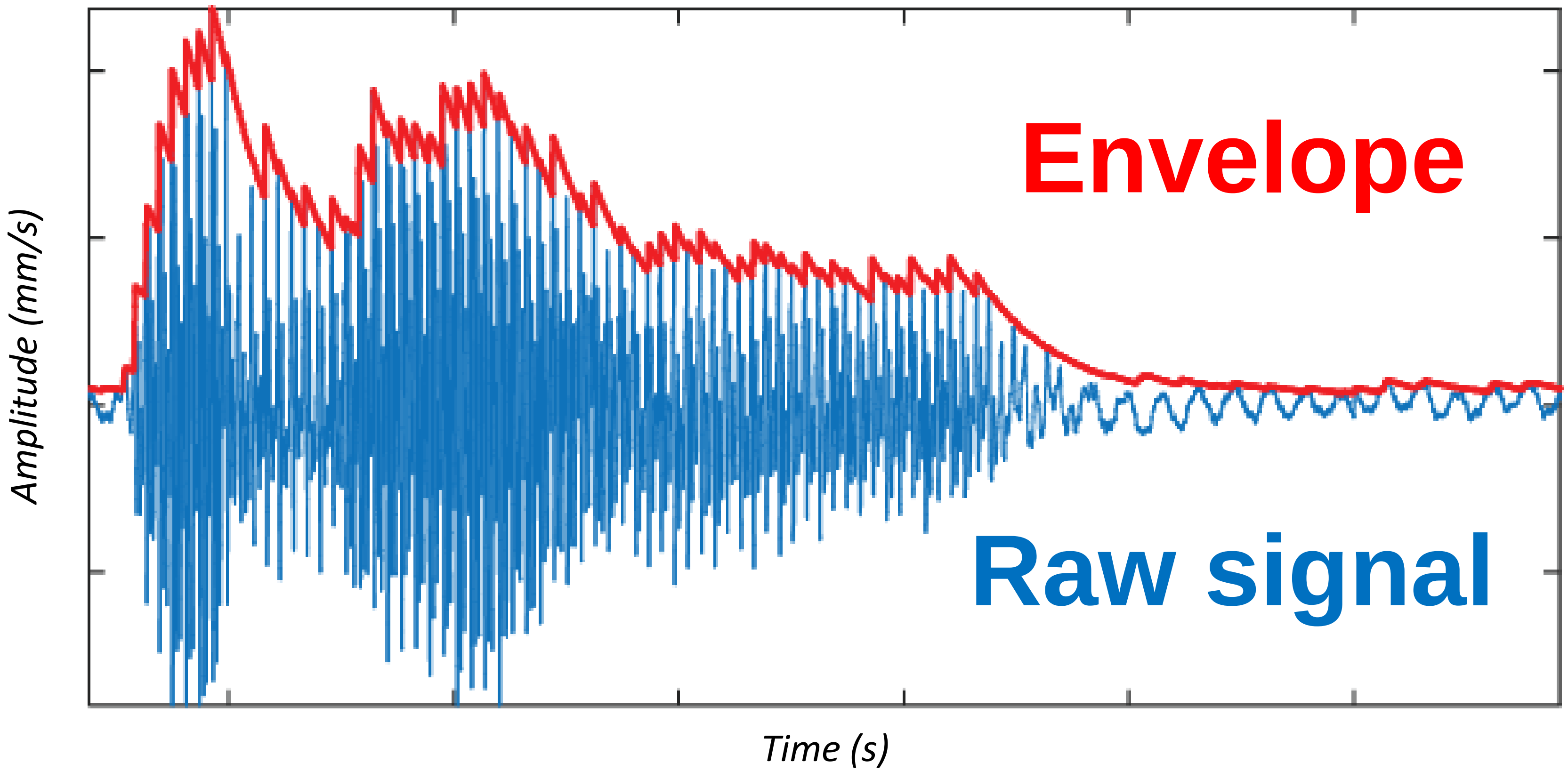
Gadria, monitoring data of 18 July 2013

The geophone detects the main front one minute before it reaches the monitored cross-section



Coviello V., Arattano M., Marchi L., Comiti F., Macconi P. (2019). [Seismic characterization of debris flows: insights into energy radiation and implications for warning](), Journal of Geophysical Research – Earth Surface.

Trasformazione (e semplificazione) del segnale sismico

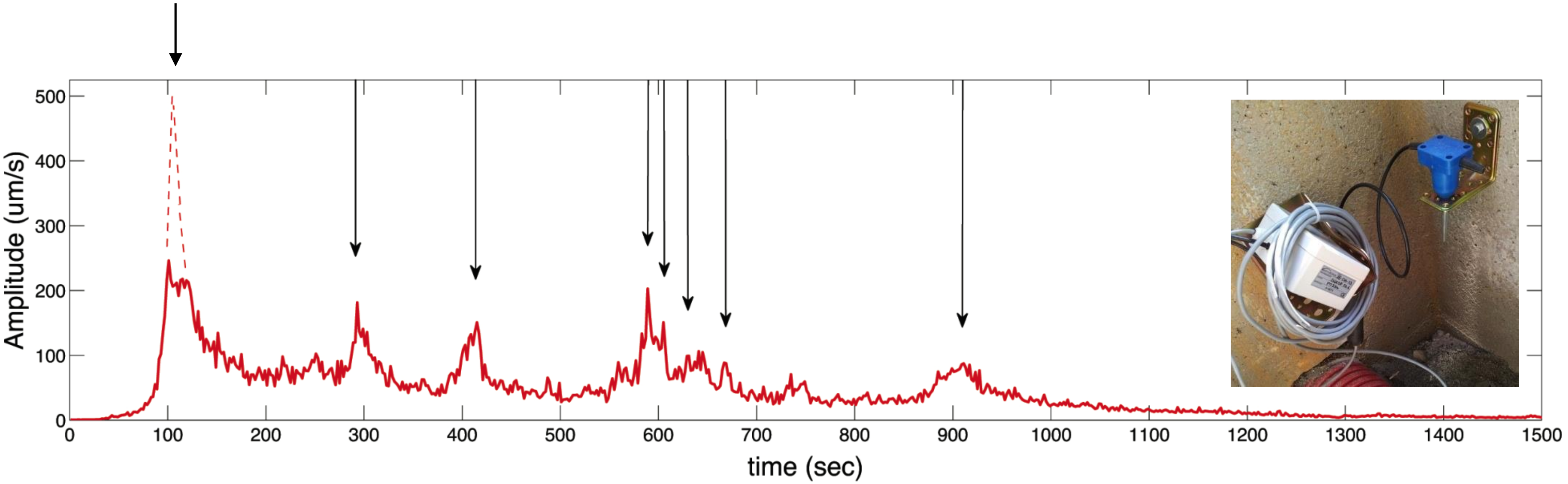


$$A = \frac{\sum_{i=1}^{F} |v_i|}{F}$$

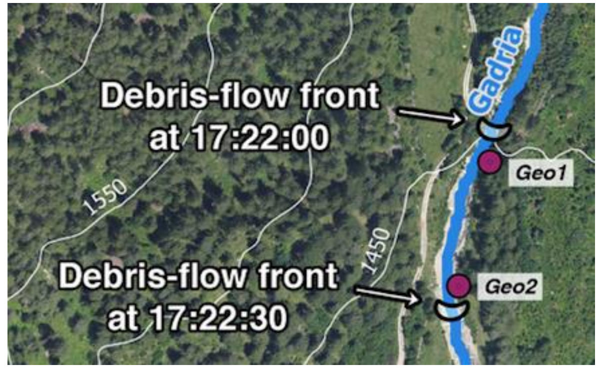
A is the amplitude and v_i is the ground oscillation velocity, obtained multiplying the voltage values, sampled at the frequency F, by an instrumental transduction constant. A value of A can then be stored each second by the data recorder device (datalogger or PC), providing a recording of the signal at a frequency of 1 Hz

Gadria, monitoring data of 18 July 2013

Why the fronts produce such an intense ground vibration?



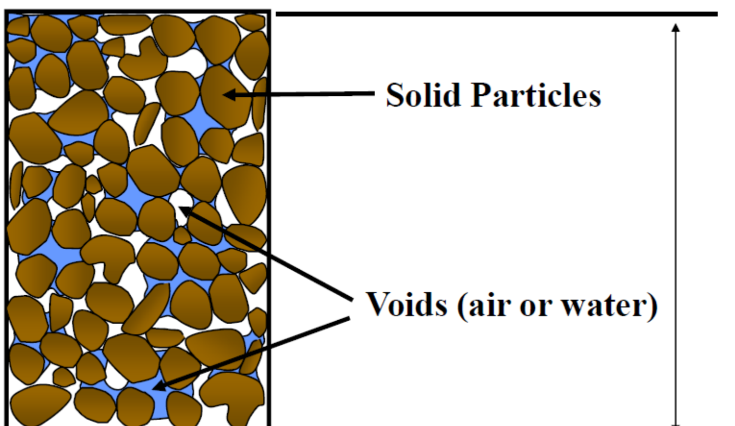
Energy transfer model



$$E_k = \frac{1}{2} \cdot m \cdot v^2$$

$$m = \boxed{[\rho_s \cdot C_v + \rho_w \cdot (1 - C_v)]} \cdot h$$

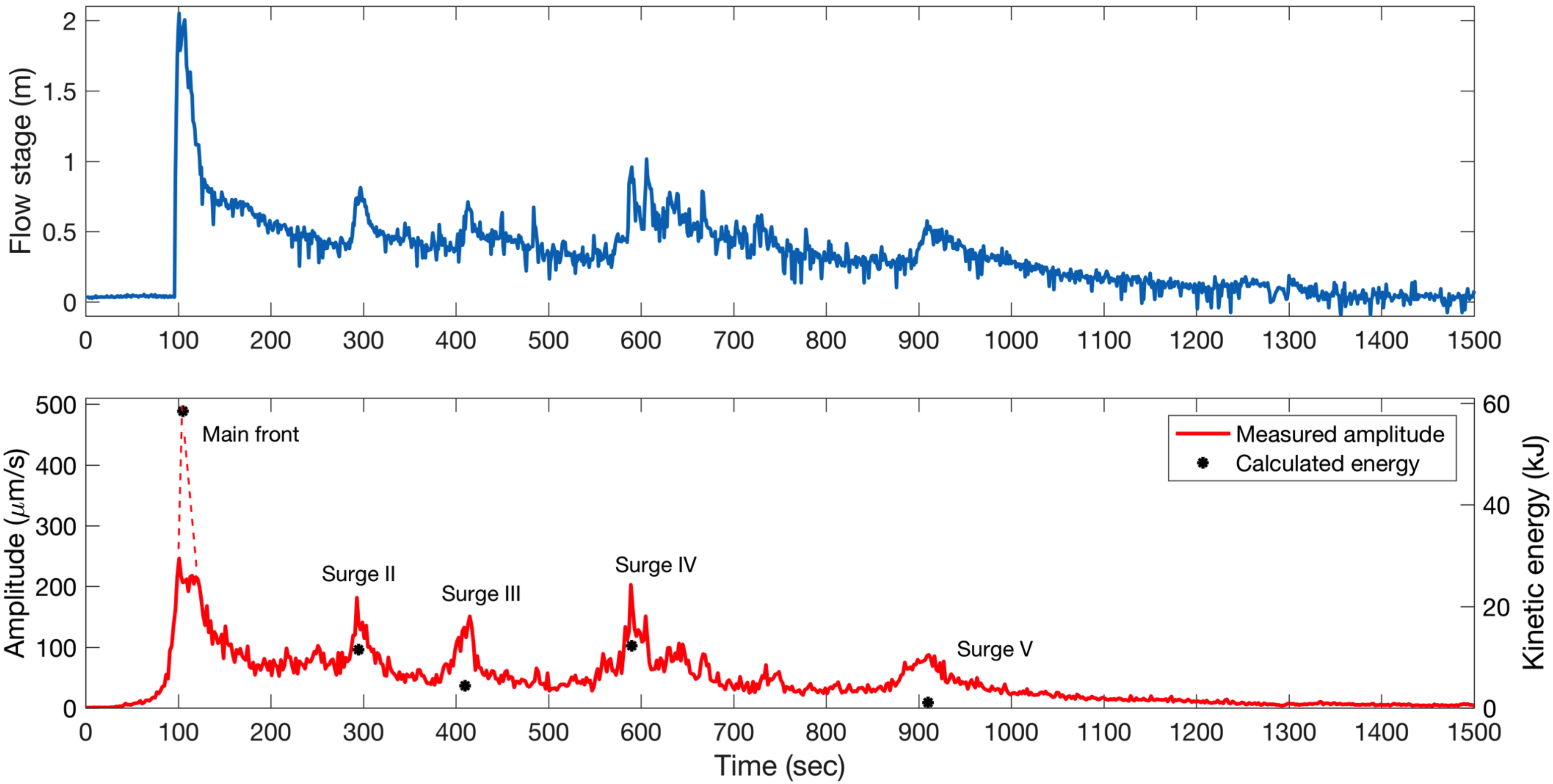
C_v *inferred from video images (semi-quantitative)*



Coviello V., Arattano M., Marchi L., Comiti F., Macconi P. (2019). Seismic characterization of debris flows: insights into energy radiation and implications for warning, Journal of Geophysical Research – Earth Surface.

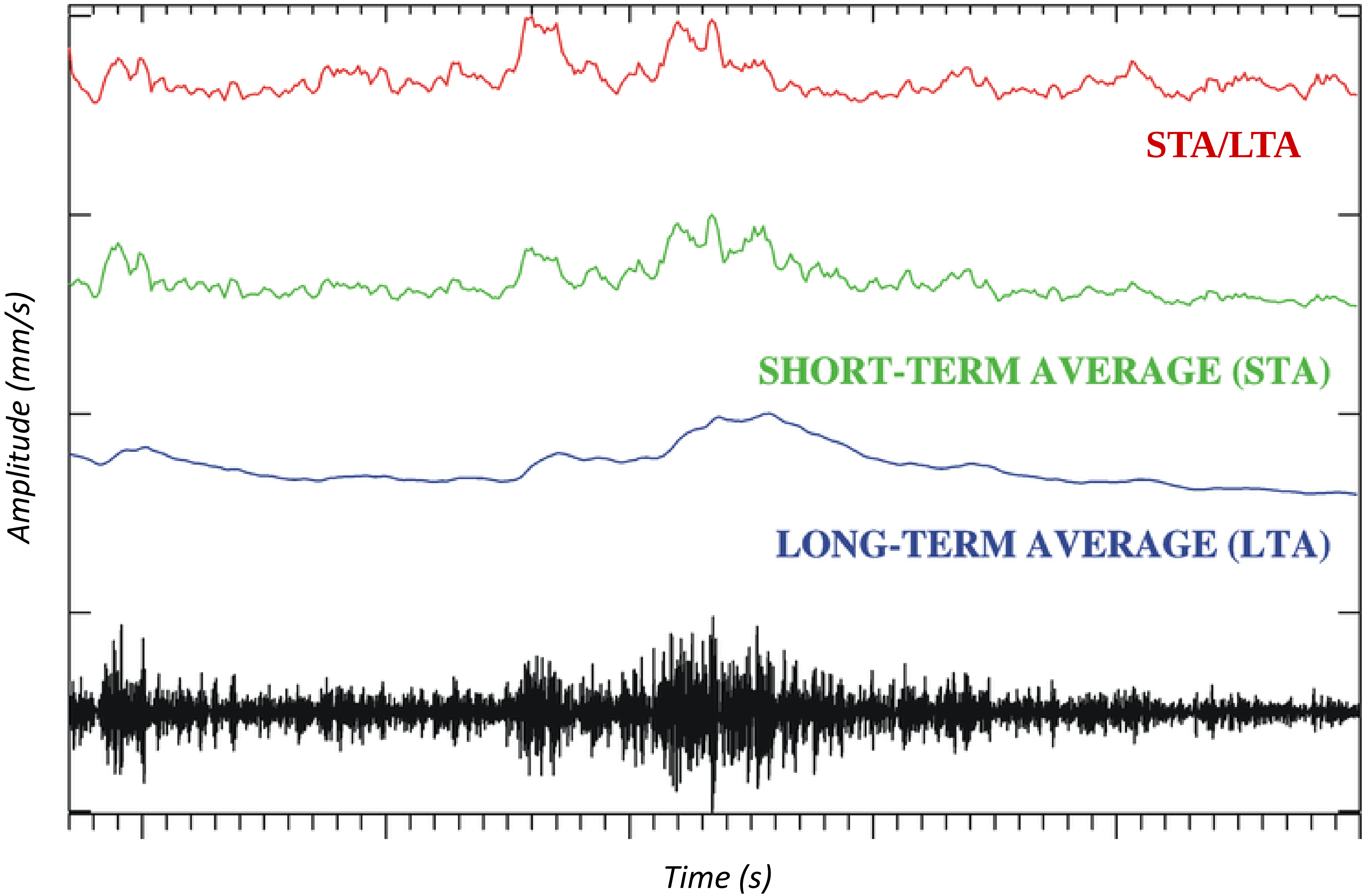
Application of the energy transfer model

Debris flow of 18 July 2013



Coviello V., Arattano M., Marchi L., Comiti F., Macconi P. (2019). [Seismic characterization of debris flows: insights into energy radiation and implications for warning](), Journal of Geophysical Research – Earth Surface.

Debris flow early warning system at Gadria



See Trnkoczy, A. (2012). Understanding and parameter setting of STA/LTA trigger algorithm. In P. Bormann (Ed.), New manual of seismological observatory practice 2 (NMSOP-2), (pp. 1–20). Potsdam: Deutsches GeoForschungsZentrum GFZ

Debris flow early warning system at Gadria

https://agupubs.onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1029%2F2018JF004683&file=jgrf21037-sup-0002-2018JF004683-ms01.mp4

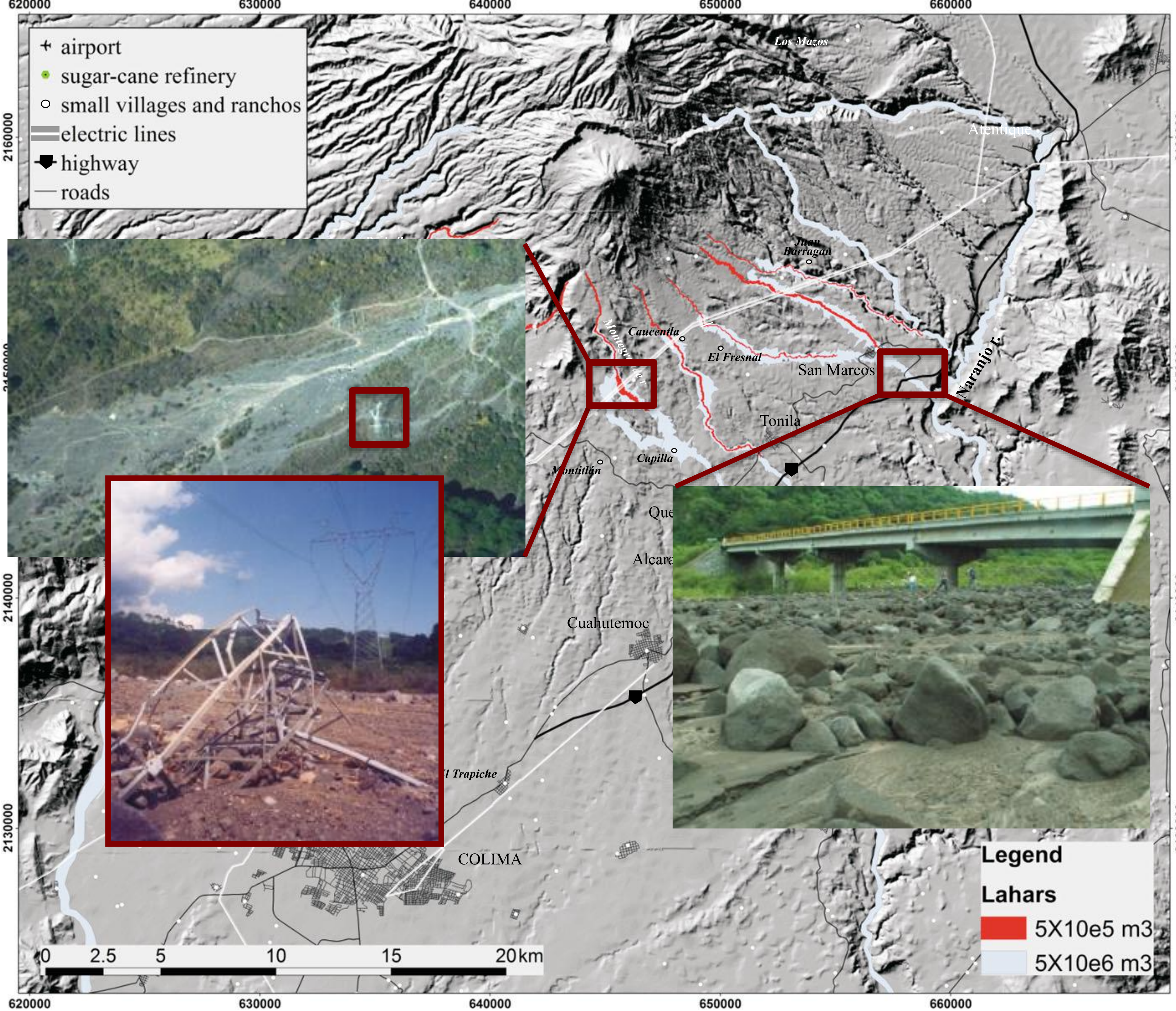
Volcàn de Colima, Mexico

- Seismic detection of hyper-concetrated flows and lahars
- Automatic classification algorithm
- Implication for early warning

Let‘s go elsewhere…

… an exotic case study!

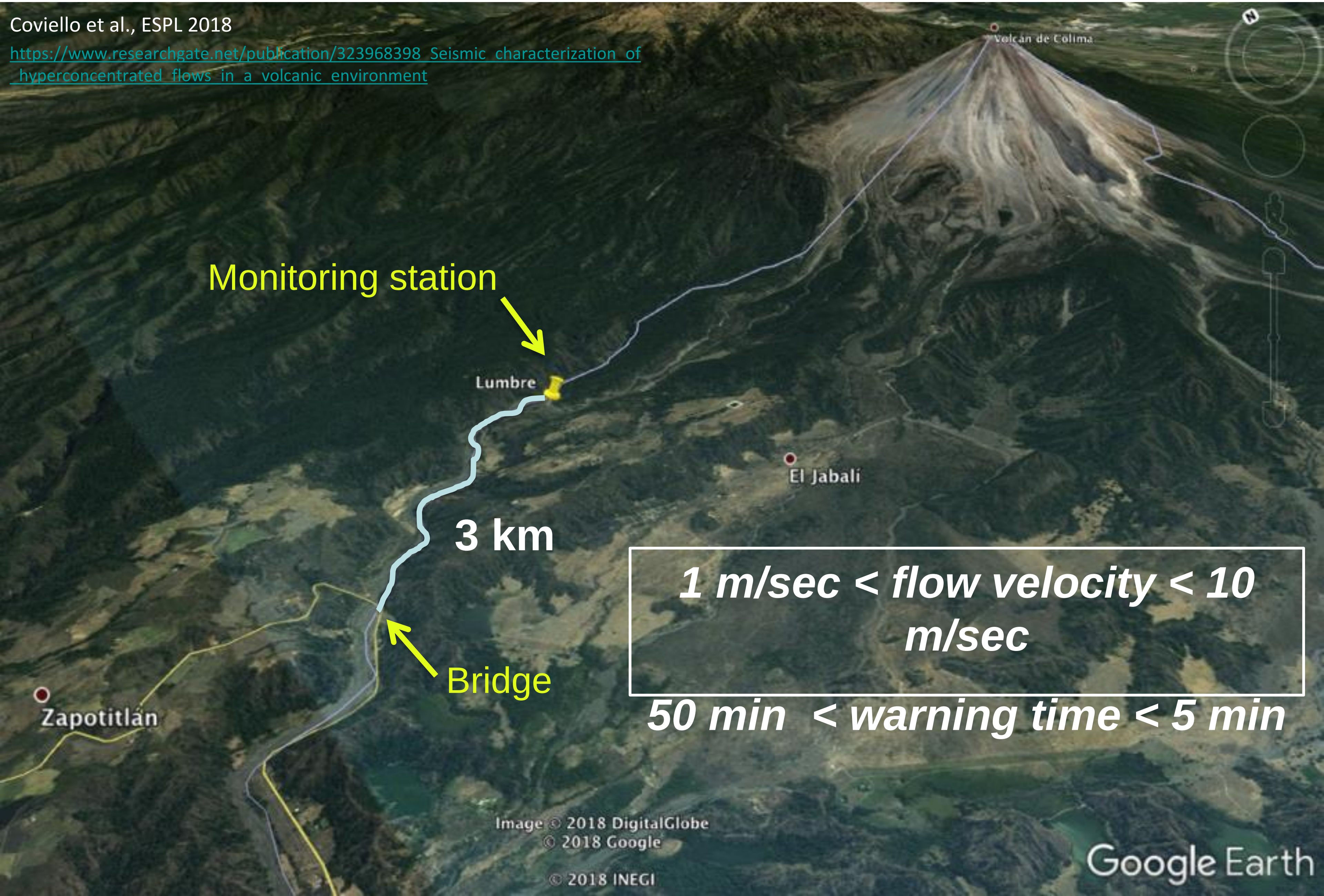
Colima volcanic complex



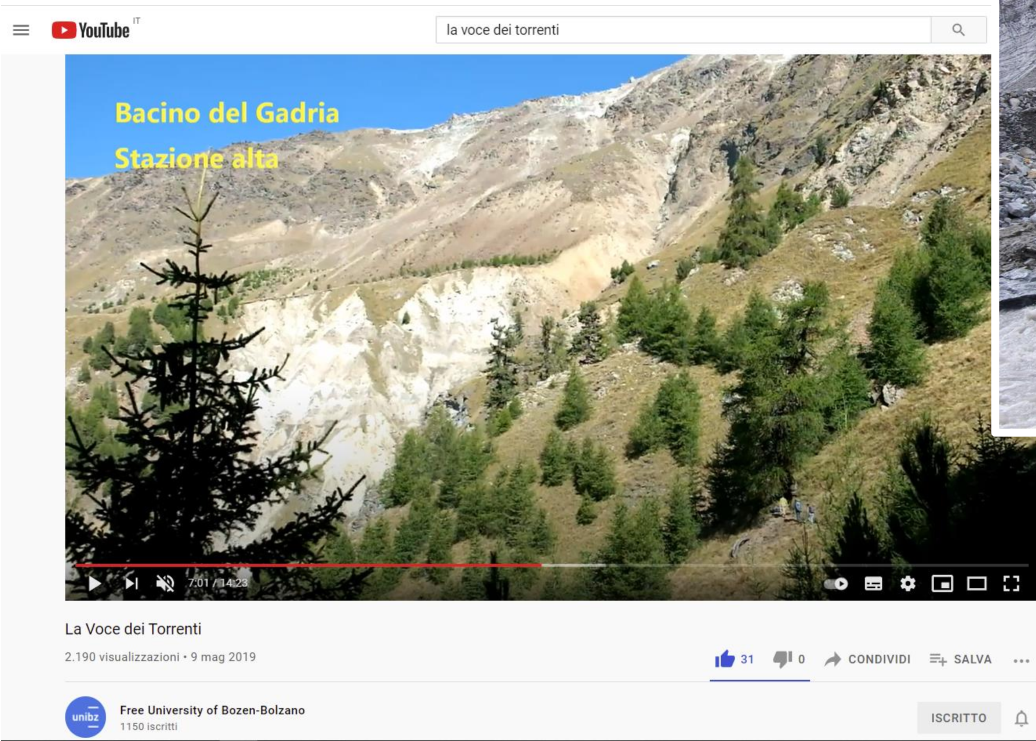
Capra et al., 2014

https://link.springer.com/article/10.1007/s11069-014-1480-1 https://www.youtube.com/watch?v=PHs9rHez0Jc

Volcán de Colima, Mexico



Dissemination



La voce dei Torrenti (short documentary, Jacopo Pasotti)
https://www.youtube.com/watch?v=VZzMiyGBYKo

La ricerca che ascolta la voce dei torrenti (Giulia Negri, OggiScienza)
https://oggiscienza.it/2019/06/27/algoritmi-studiare-torrenti/

Lungo le discese (story map, Gianluca Liva - Radar Magazine)
https://uploads.knightlab.com/storymapjs/be2393f5b821b88edfcd53c6f0561323/lahar-o-colate-detritiche/index.html