National Research
Council of Italy

Research Institute for Geo-
Hydrological Protection

Le colate detritiche nei bacini alpini: fenomenologia e pericolosità

Debris flows in alpine basins: phenomenology and hazards

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Conference “Early warning systems for
debris flows: state of the art and challenges”

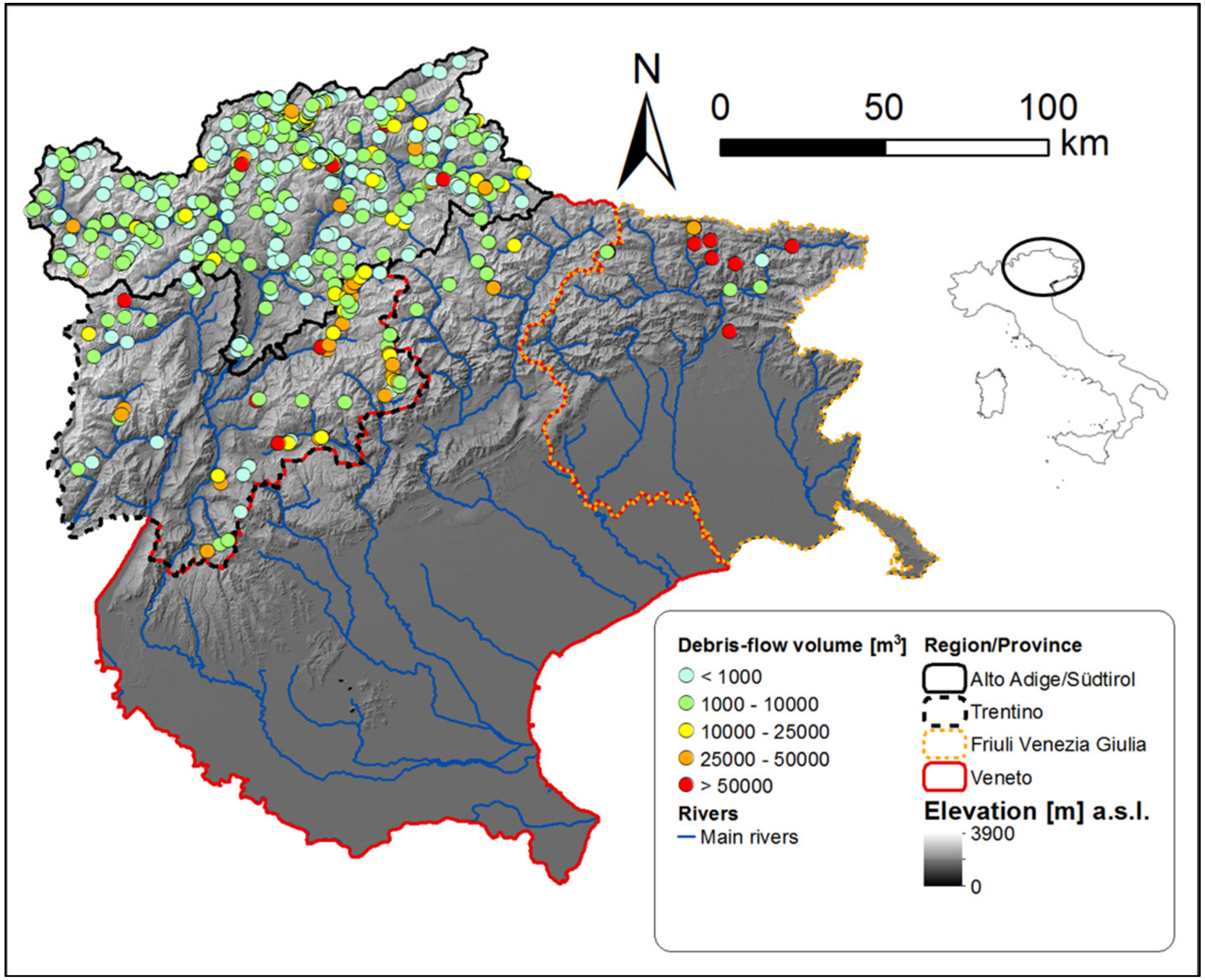
Bolzano - Bozen, 16.10.2019

Introduction

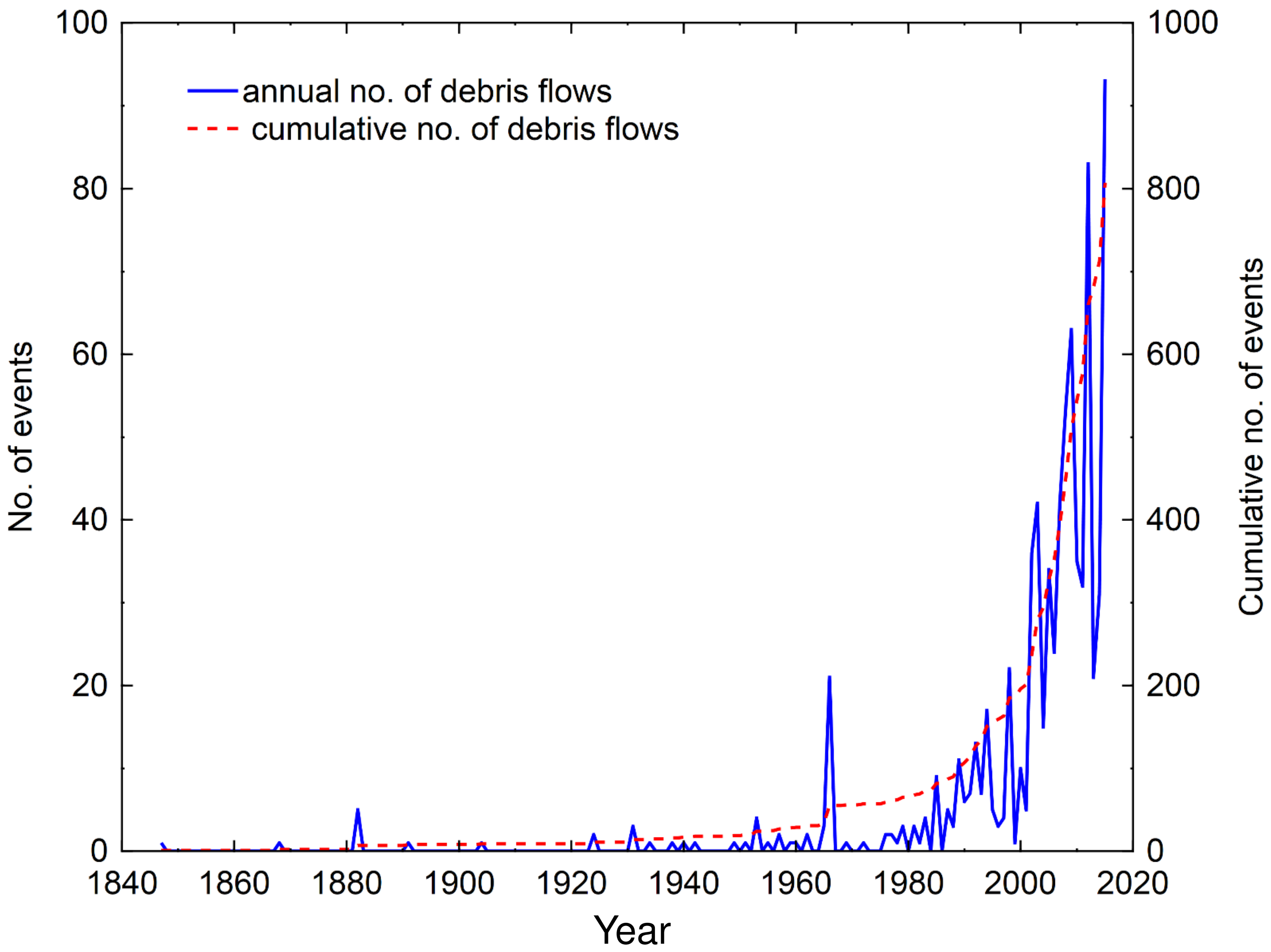
Selected issues in debris-flow phenomenology and hazards

- Data collection and variations with time
- Debris-flow volumes: measurement errors and scaling with catchment area
- Flow type variability (intra-event and between events)
- Debris-flow hydrographs
- Relationships between debris-flow volume and peak discharge

Collection of basic data



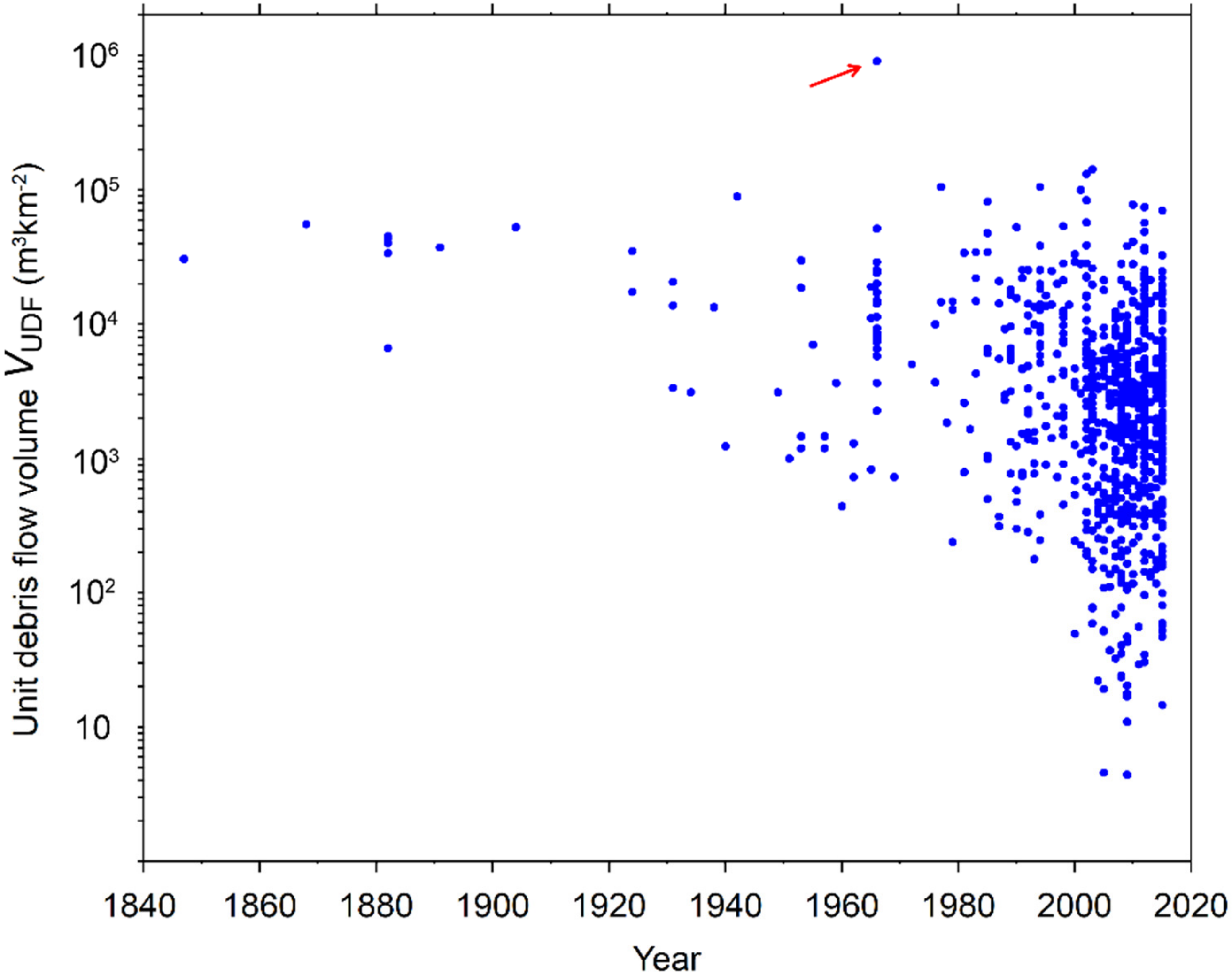
Data collection – no. of debris flows vs. time



- Large number of debris flows observed in the last two decades
- Spike in the mid-1960s (November 1966 event)

More systematic data collection?

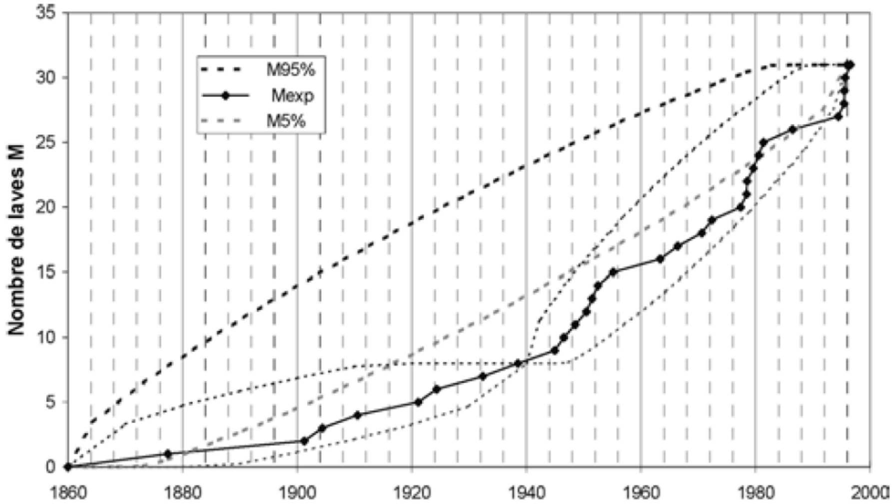
Variation of debris flows volumes with time



- The increased number in recent years is mostly caused by the sampling of small debris flows.
- Occurrence, in the last 40 years, of five debris flows with the largest unit volume: an effect of current climate changes?

Variation of debris flows volumes with time

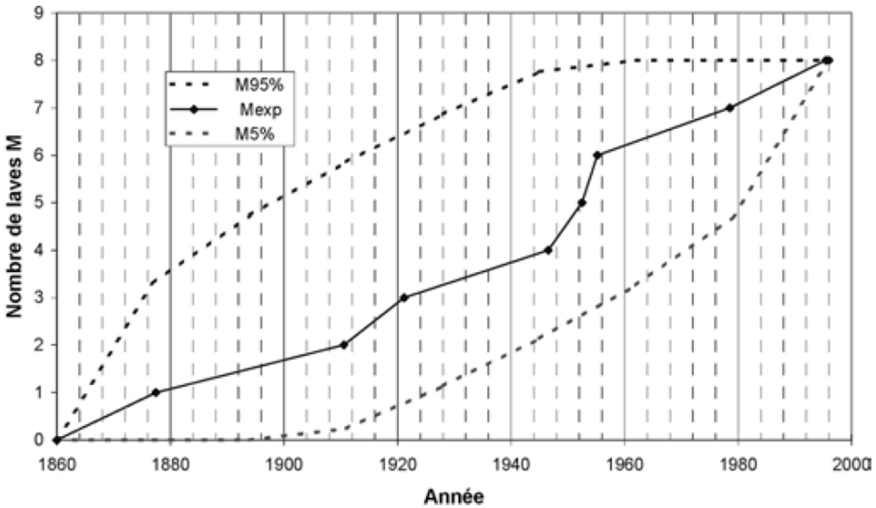
- Poucet Torrent (French Alps) – stationarity test for the date of occurrence of debris flows



All debris flows

1860-1996

1860-1940 and 1941-1996



Large debris flows only

1860-1996.

Brochot et al., 2002

- Apparent increase of debris-flow frequency after 1940, ascribed to small debris flows.

Debris-flow volume - measurement errors

Debris-flow volume: probably the variable most commonly assessed in post-event surveys

Direct application in the design of sediment traps
Correlation with other variables (peak discharge, runout distance…)

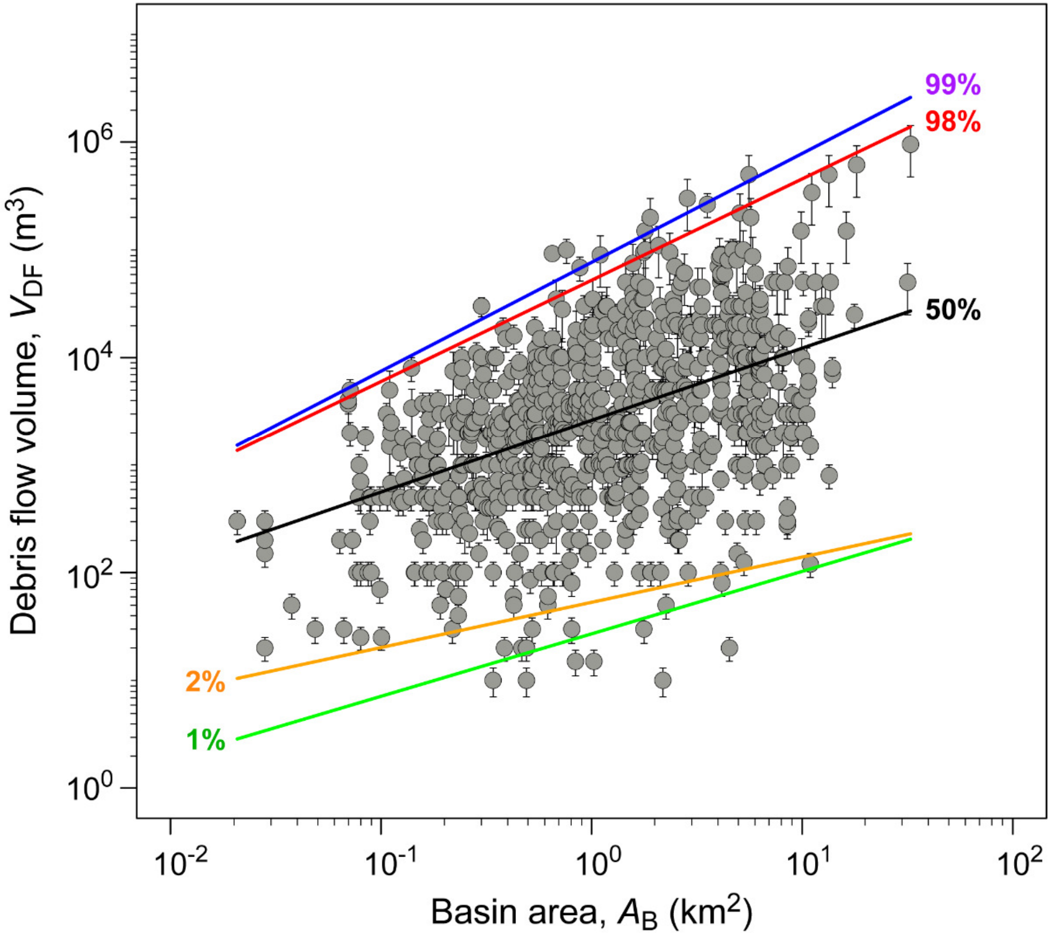
Measurement errors: implications for hazard assessment…

Table 22.1 Preliminary results of volume estimations with different methods

Method	Volume (m^3)	Error ($\pm m^3$)	Survey time
2 stage sensors along the channel, using the velocity of the main front	15,000	3,000	During the event
2 stage sensors along the channel, using the velocities of all the surges	10,000	2,000	During the event
TLS/TLS DoD	8,130	910	After the event
TLS/Photogrammetry DoD	7,870	740	After the event
Channel sediment budget*	4,600	1,400	After the event

*missing 1/3 of the main channel length due to inaccessibility

Arattano et al. (2015)

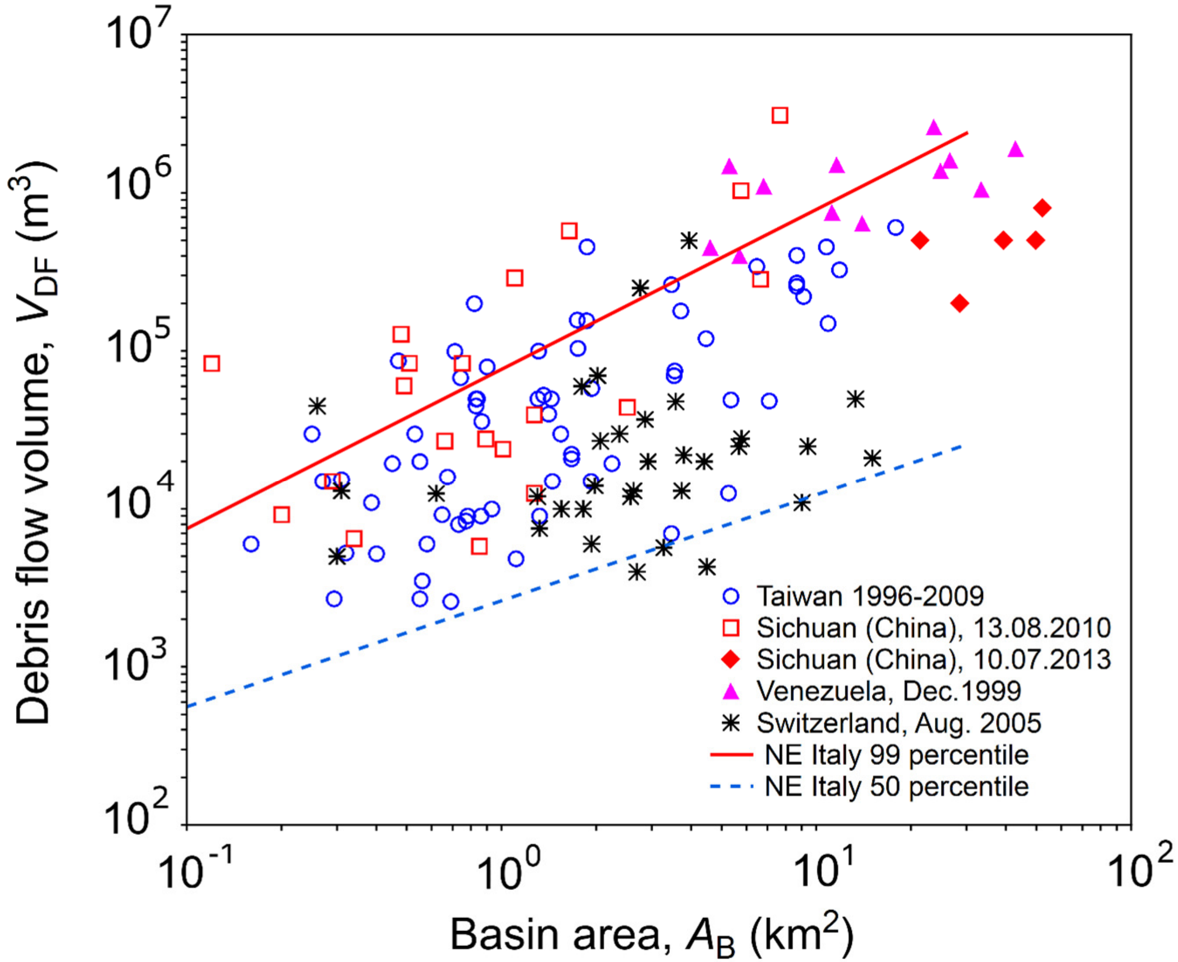


Percentile (%)	Equation
1	$V_{DF} = (27 \pm 2) \cdot A_B^{(0.58 \pm 0.07)}$
2	$V_{DF} = (53 \pm 4) \cdot A_B^{(0.42 \pm 0.05)}$
50	$V_{DF} = (2620 \pm 60) \cdot A_B^{(0.67 \pm 0.02)}$
98	$V_{DF} = (52000 \pm 4000) \cdot A_B^{(0.94 \pm 0.04)}$
99	$V_{DF} = (77000 \pm 7000) \cdot A_B^{(1.01 \pm 0.06)}$

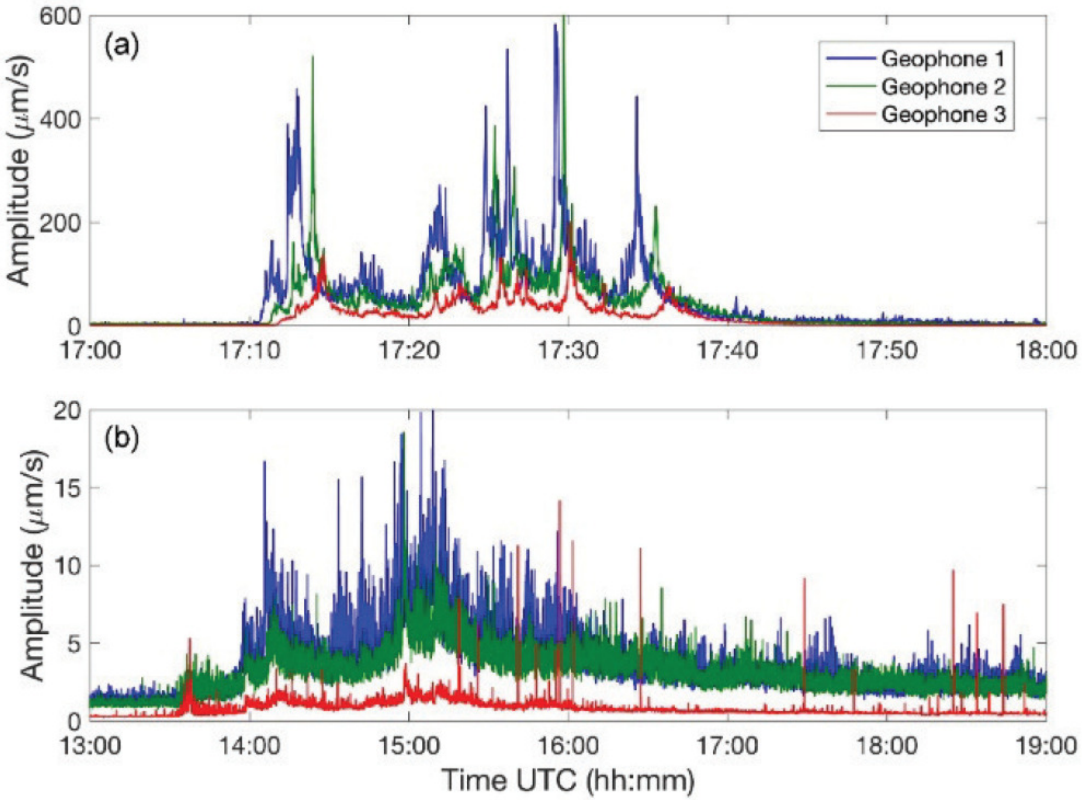
Marchi et al. (2019)

- The empirical relationship linking V_{DF} to A_B is obtained assuming a power-law equation of the form $V_{DF} = k\, A_b^{\gamma}$
- The power law is fitted to the dataset using the quantile regression method.

Debris-flow volume: scaling with basin area



Comparison with datasets in other geographical regions



Debris flow

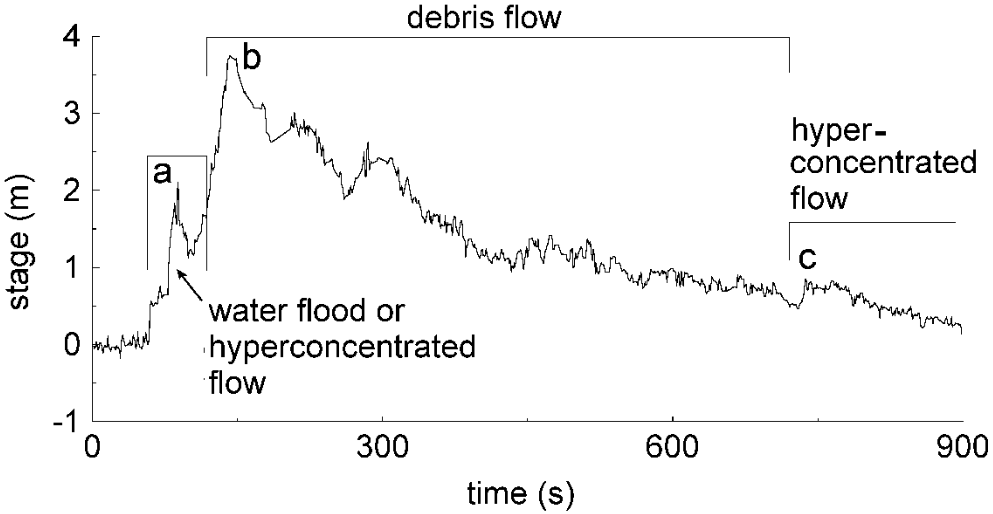
Flood with Bedload / Debris flood

Gadria Creek 2014-2015

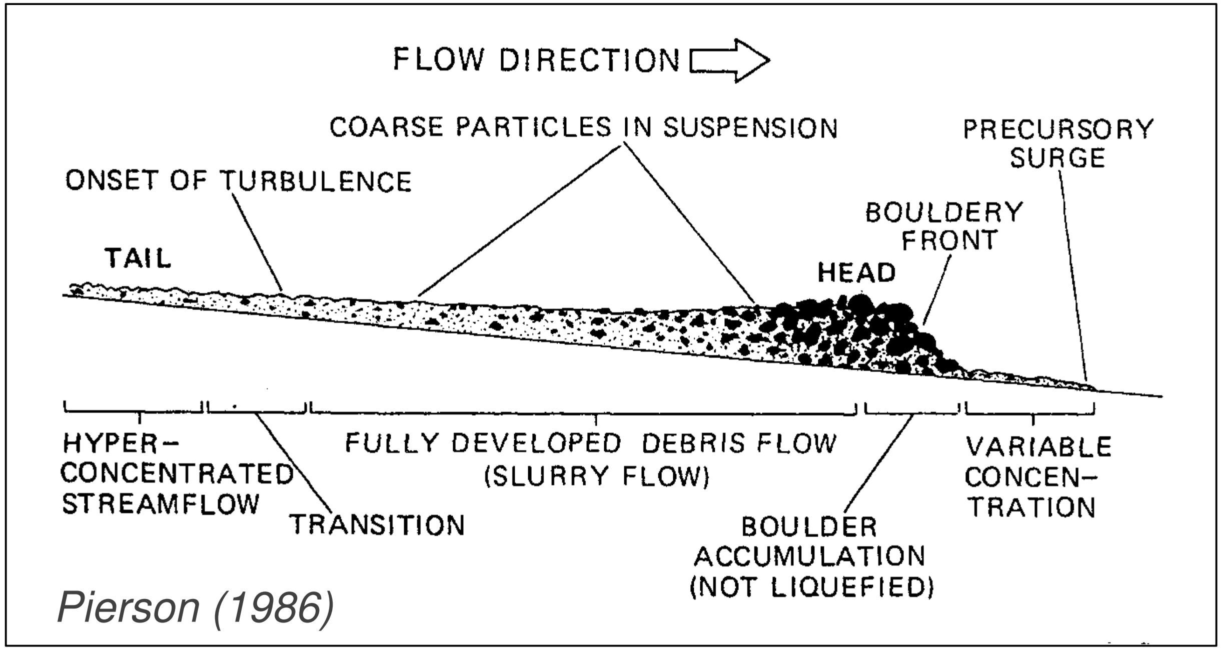
- 2 debris flows (duration: 26 and 50 minutes);
- 15 bedload floods (duration from 120 to 600 minutes)

Coviello et al., 2019

Moscardo Torrent



Intra-event flow type variability



Pierson (1986)

Precursory surge: not always present

Recession phase – onset of turbulence

Moscardo Torrent

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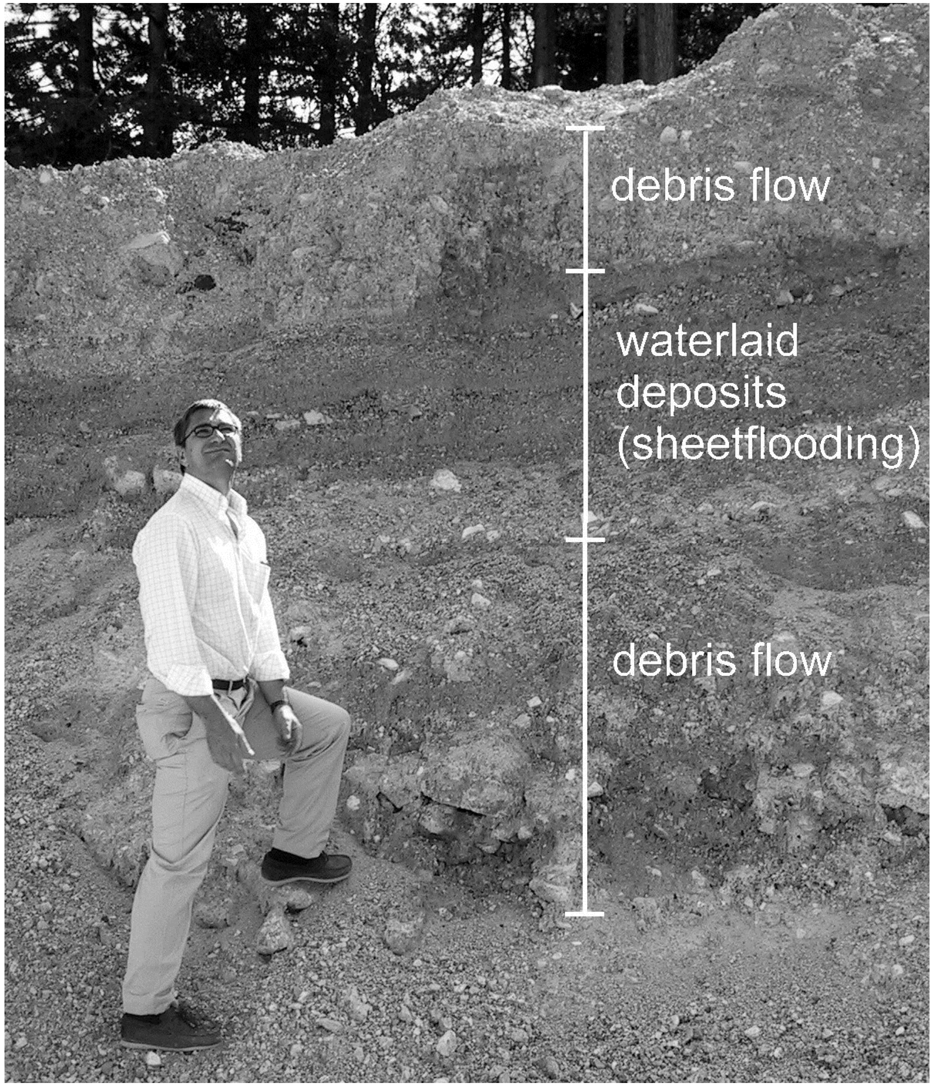
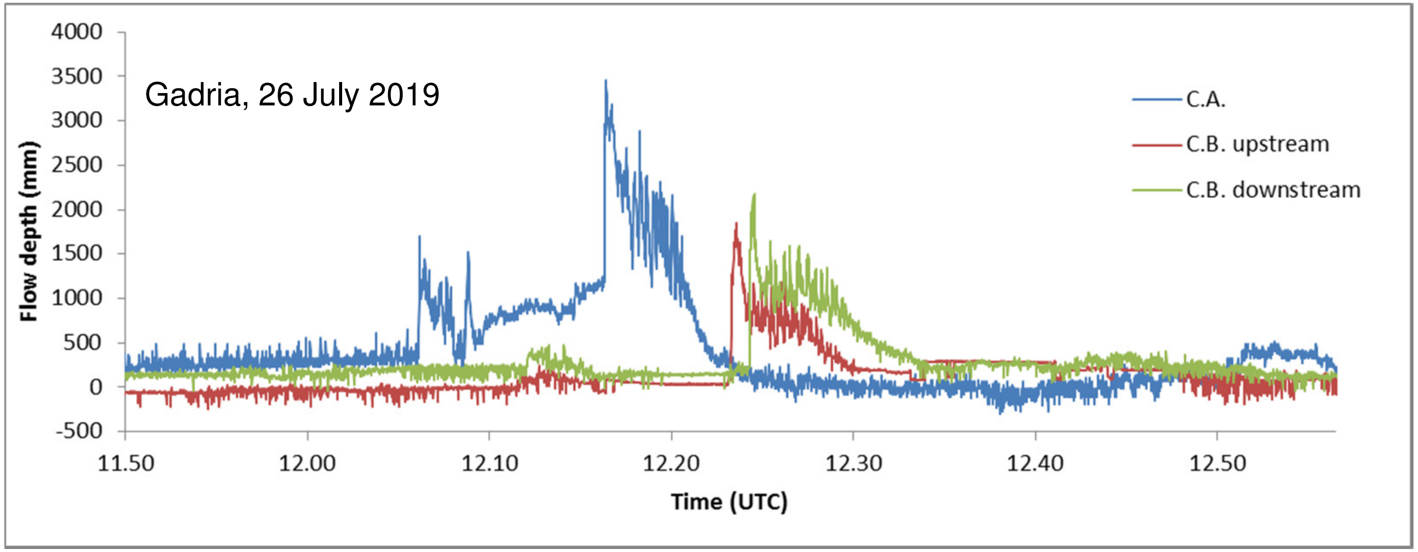
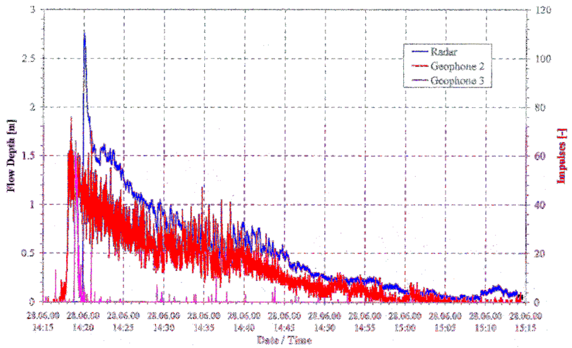


Marchi et al. (2009)

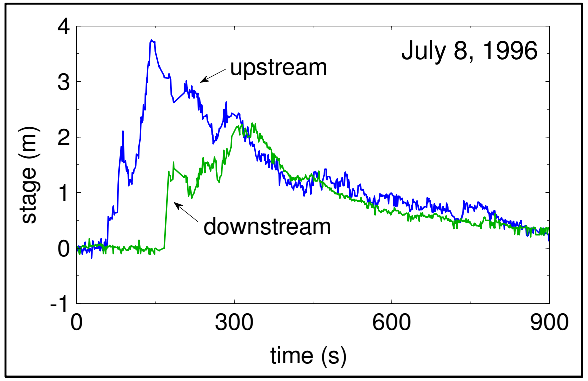
Val Canale, August 2003
(photo Civil protection Friuli Venezia Giulia)

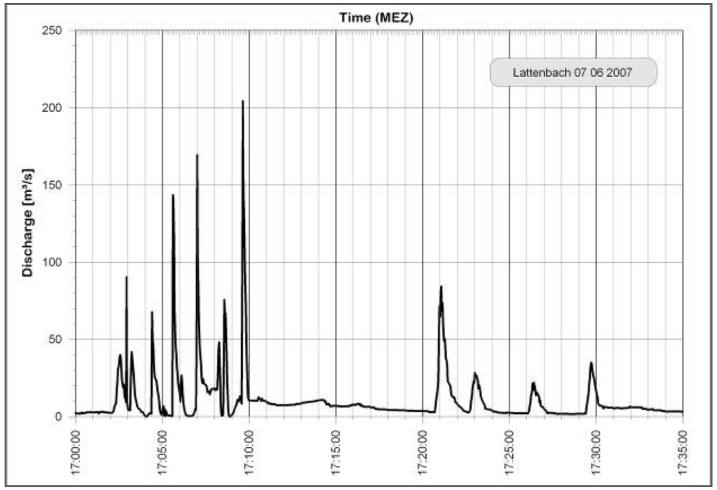
Debris-flow hydrographs

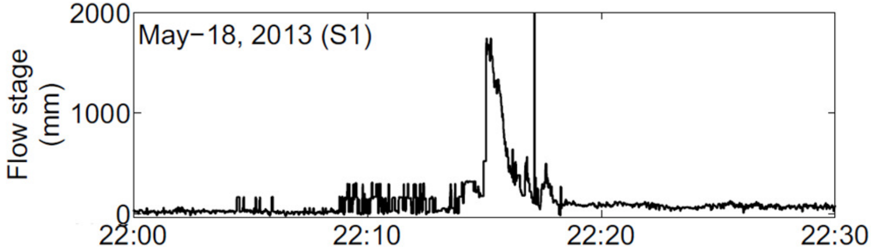




Recorded Signals of the June 28th 2000 debris flow

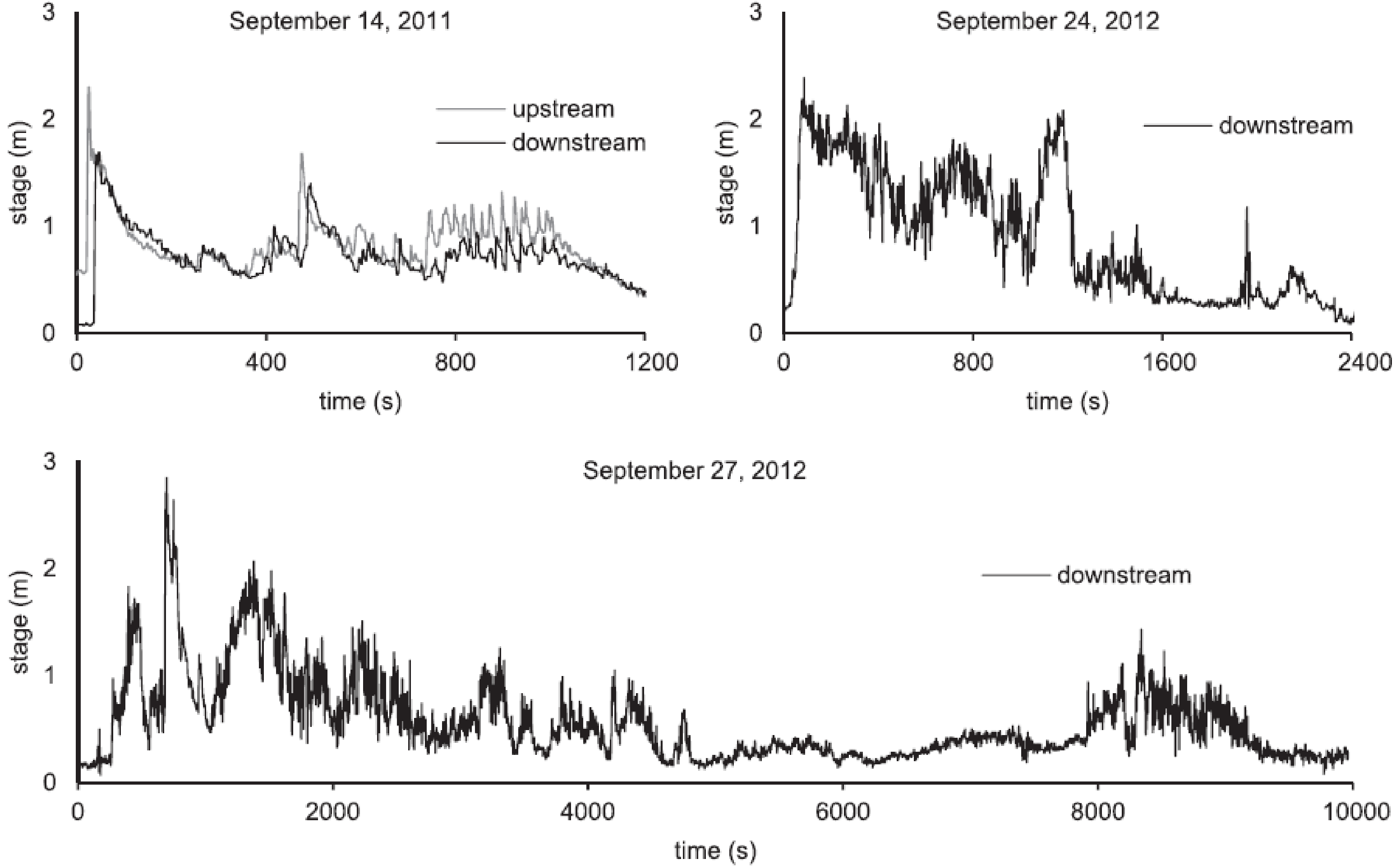






Hürlimann et al. (2003)
Huebl and Kaitna (2010)
Navratil et al. (2013)
Bel (2017)

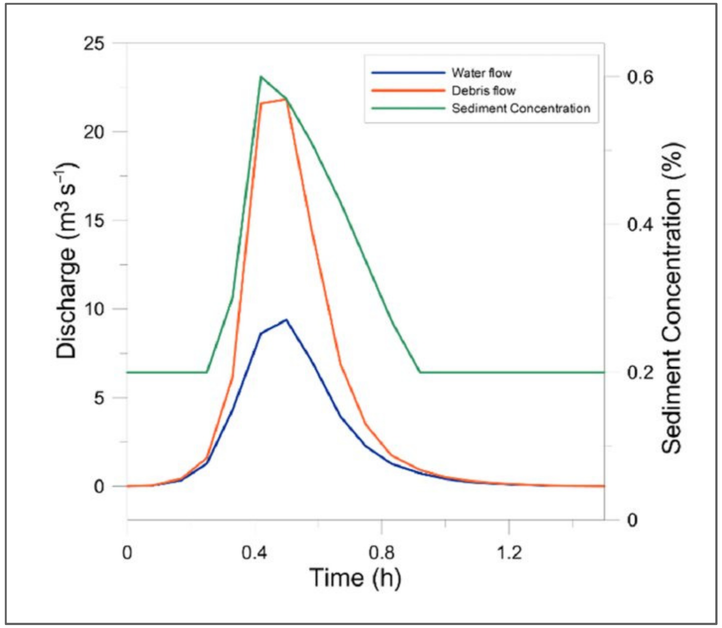
Debris-flow hydrographs



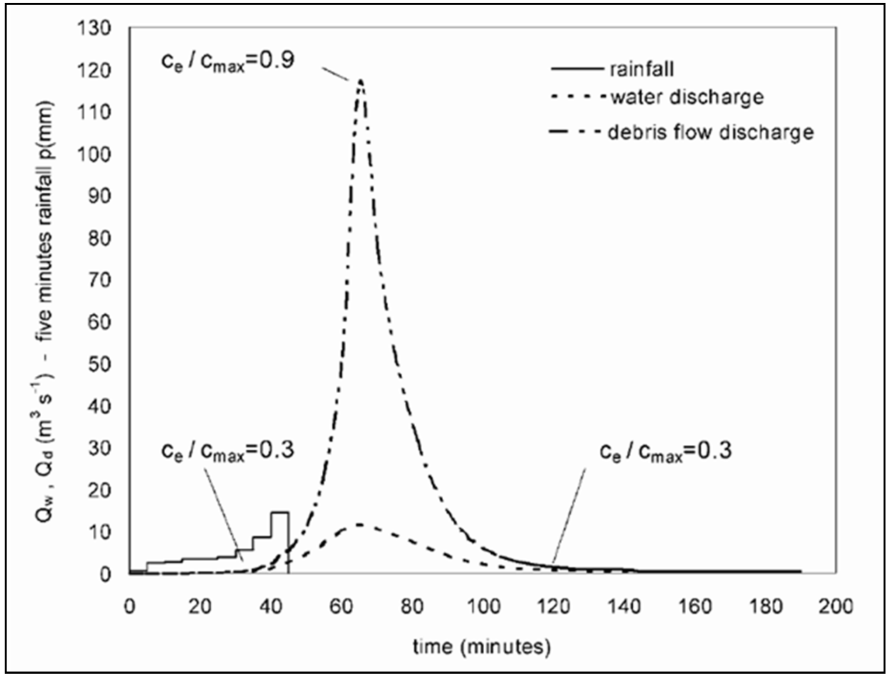
Blasone et al. (2014)

Debris-flow hydrographs

Design hydrographs based on rainfall-runoff modelling and sediment bulking: do they actually represent debris-flow hydrograph?



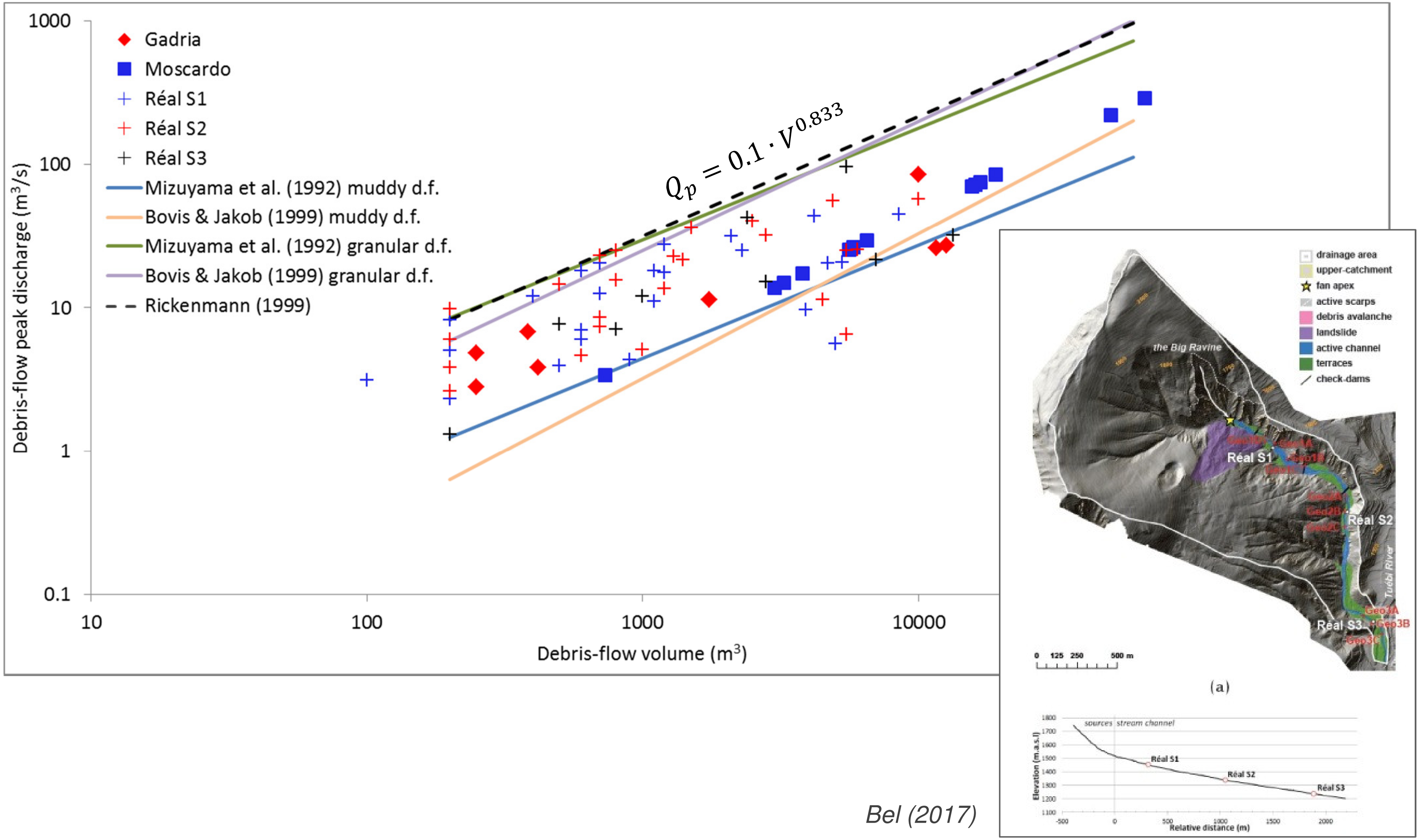
Flo-2D applications



D'Agostino and Marchi (2003)

A promising prospective: rainfall-runoff simulation for headwater channels at the initiation areas of debris flows

(Gregoretti et al., 2016)



Gadria
Moscardo
Réal S1
Réal S2
Réal S3
Mizuyama et al. (1992) muddy d.f.
Bovis & Jakob (1999) muddy d.f.
Mizuyama et al. (1992) granular d.f.
Bovis & Jakob (1999) granular d.f.
Rickenmann (1999)
$Q_p = 0.1 \cdot V^{0.833}$
Debris-flow peak discharge (m³/s)
Debris-flow volume (m³)
1000
100
10
1
0.1
10
100
1000
10000
drainage area
upper-catchment
fan apex
active scarps
debris avalanche
landslide
active channel
terraces
check-dams
the Big Ravine
Réal S1
Réal S2
Réal S3
Tuébi River
0 125 250 500 m
(a)
sources stream channel
Réal S1
Réal S2
Réal S3
Elevation (m a.s.l)
Relative distance (m)

Bel (2017)

Concluding remarks

- Progress in event documentation at regional scale has enabled better assessment of basic debris-flow features (time of occurrence, scaling of volumes with catchment area, etc.).
- Measurement errors should be taken into account when using debris-flow volumes to assess other variables by means of empirical or physically-based models.
- The variability of flow characteristics (sediment concentration, velocity, depth) makes the assessment of design debris-flow hydrographs especially challenging.
- Instrumented catchments have a fundamental role in collecting data for better understanding of debris flows.


Thank you for your attention

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