


An Analysis of the 2017 Rock Avalanche and Debris Flows at Pizzo Cengalo, Switzerland (with a short update on the Illgraben force plate)

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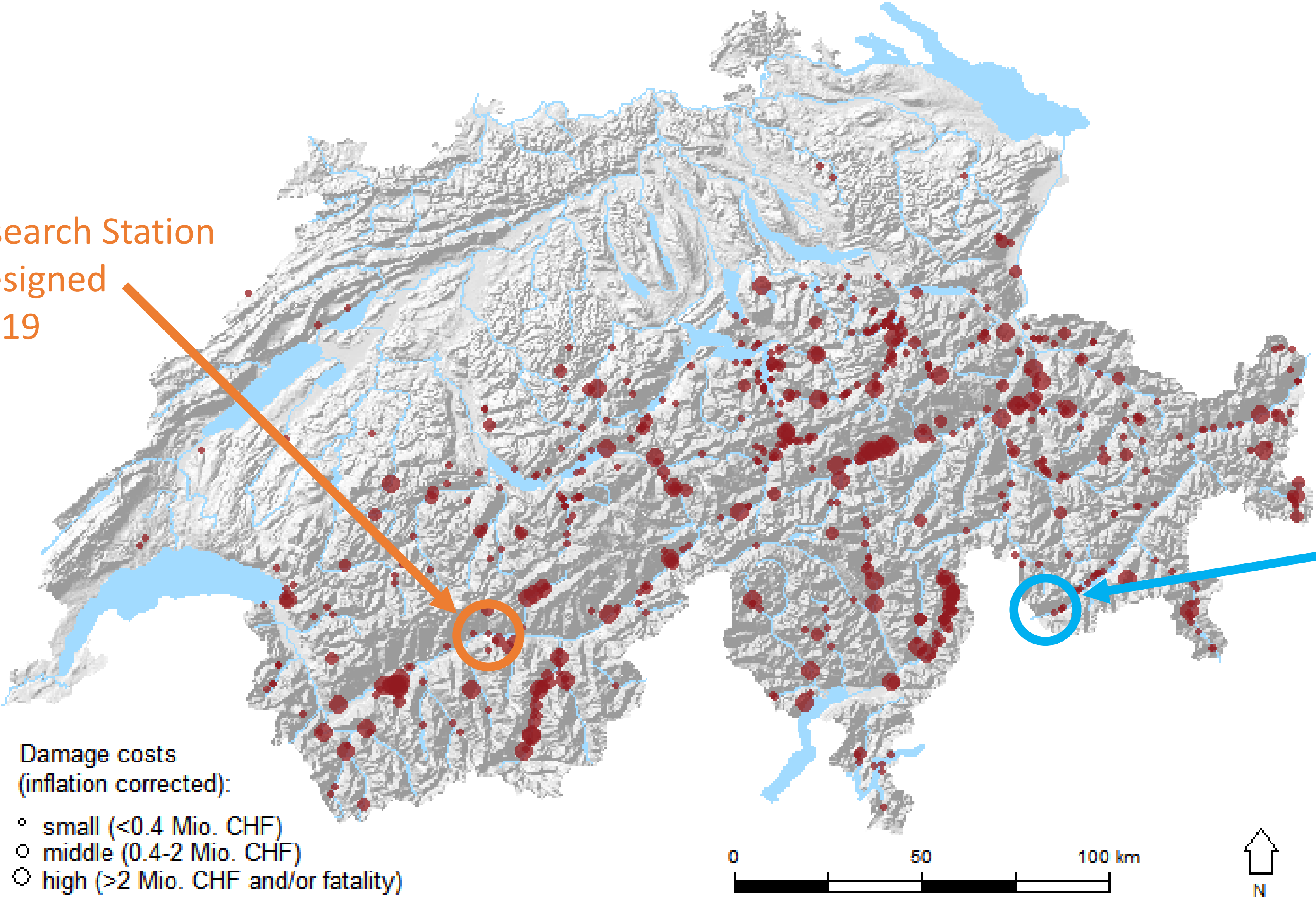
Early warning systems for debris flows: state of the art and challenges
Bozen-Bolzano, October 16-18, 2019

WSL

The debris-flow problem in Switzerland

An average of 15 events per year with damage since 1972



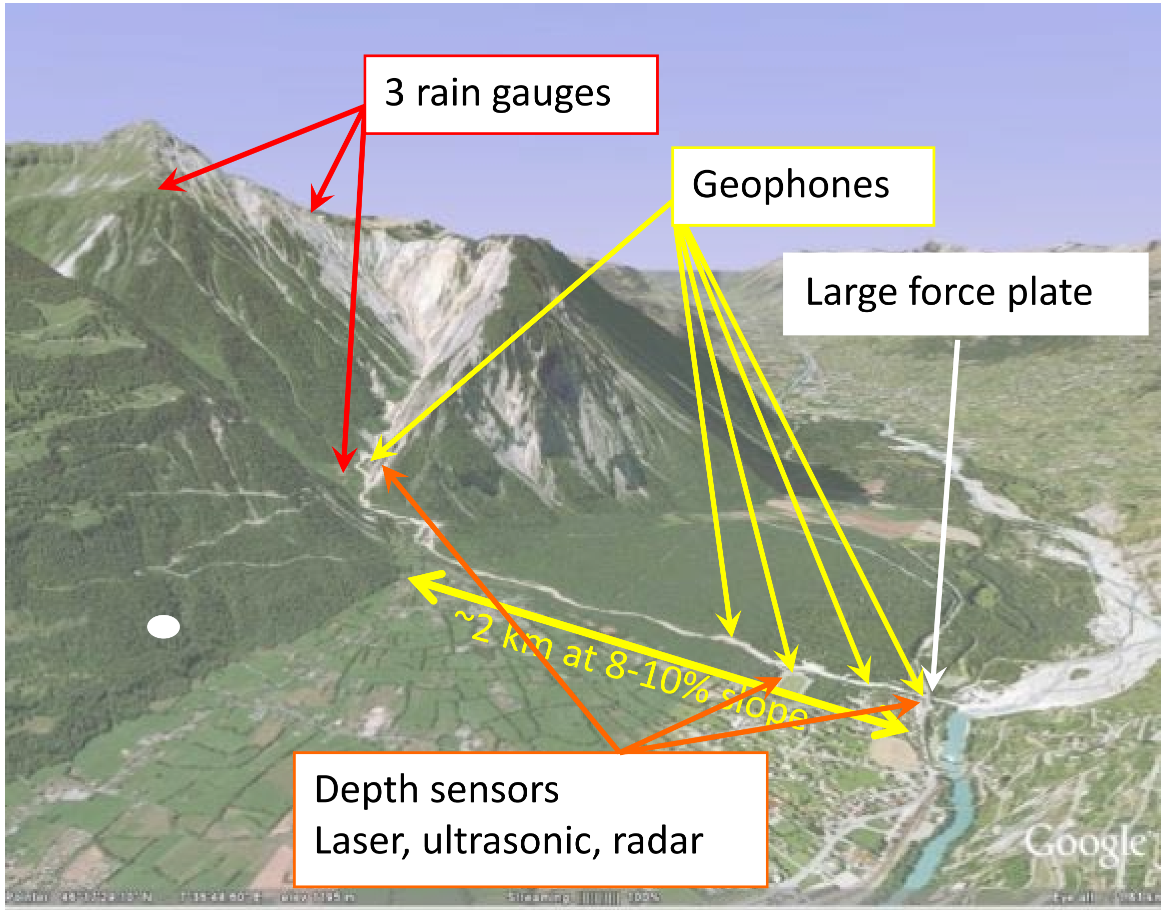
Source: WSL Damage Database

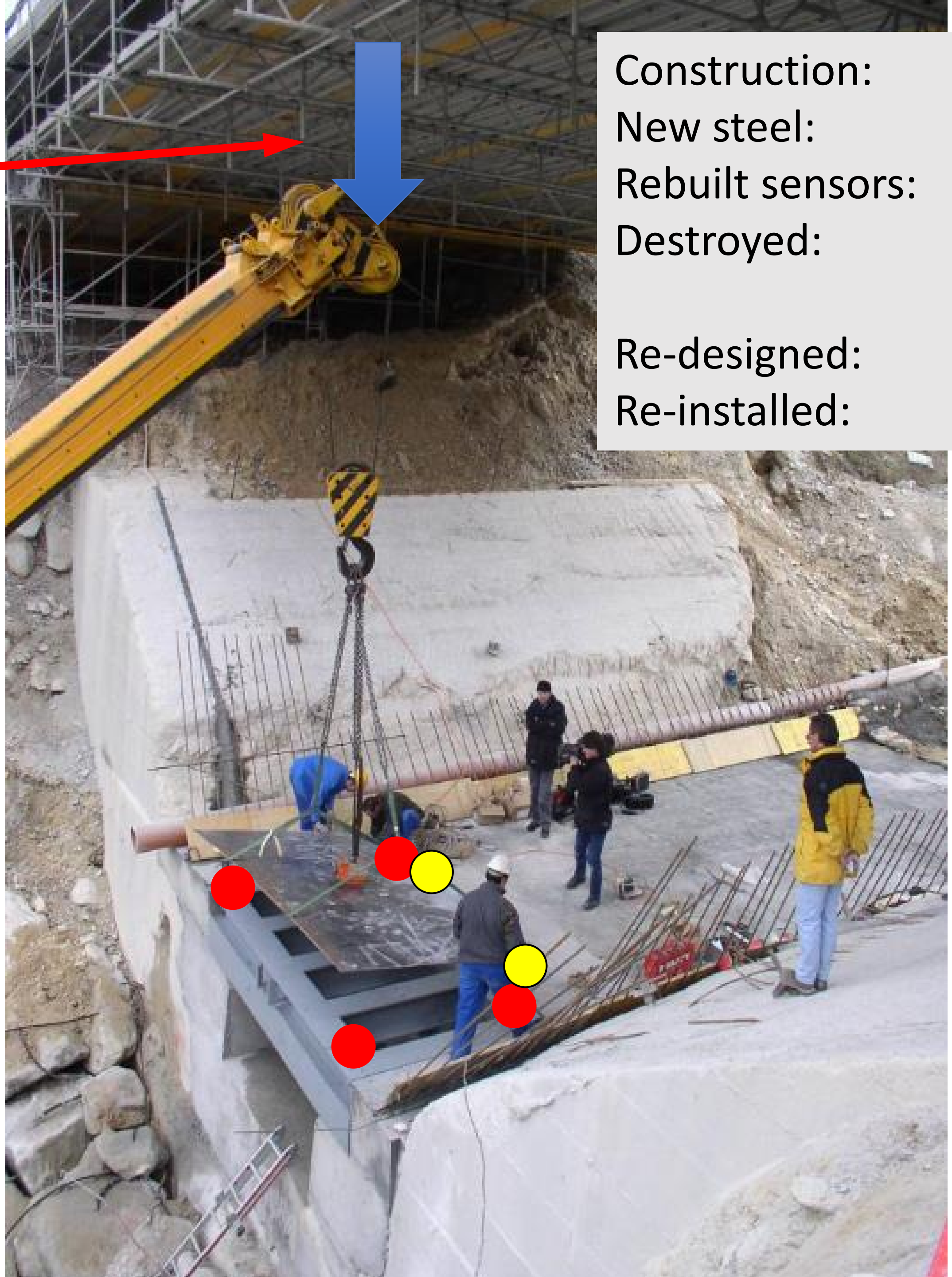
Illgraben Force Plate (2004—2016)

Laser & radar for flow depth

Normal force sensors (n=4)

Shear force sensors at the upstream end of the plate (n=2)





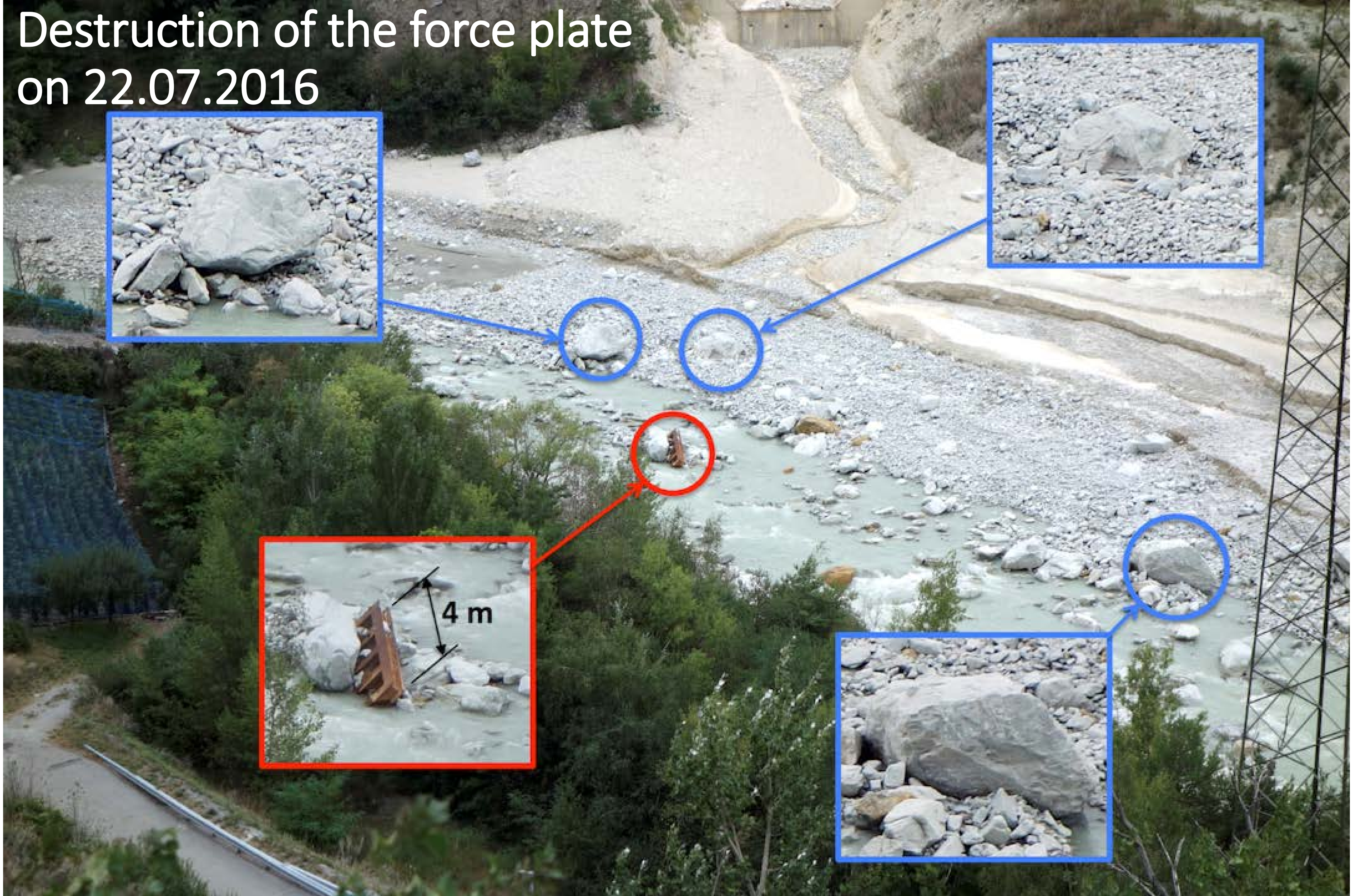
Construction:	2003
New steel:	2012
Rebuilt sensors:	2013
Destroyed:	2016
Re-designed:	2017-18
Re-installed:	2019

Destruction of the force plate on 22.07.2016

00:08,47

https://www.youtube.com/watch?v=Fsh5E9m3PrM

The force plate before and after the debris flow



Destruction of the force plate on 22.07.2016
4 m


Designed a new and Improved force plate
Installed February 2019


Calibration March 2019
For horizontal and normal forces

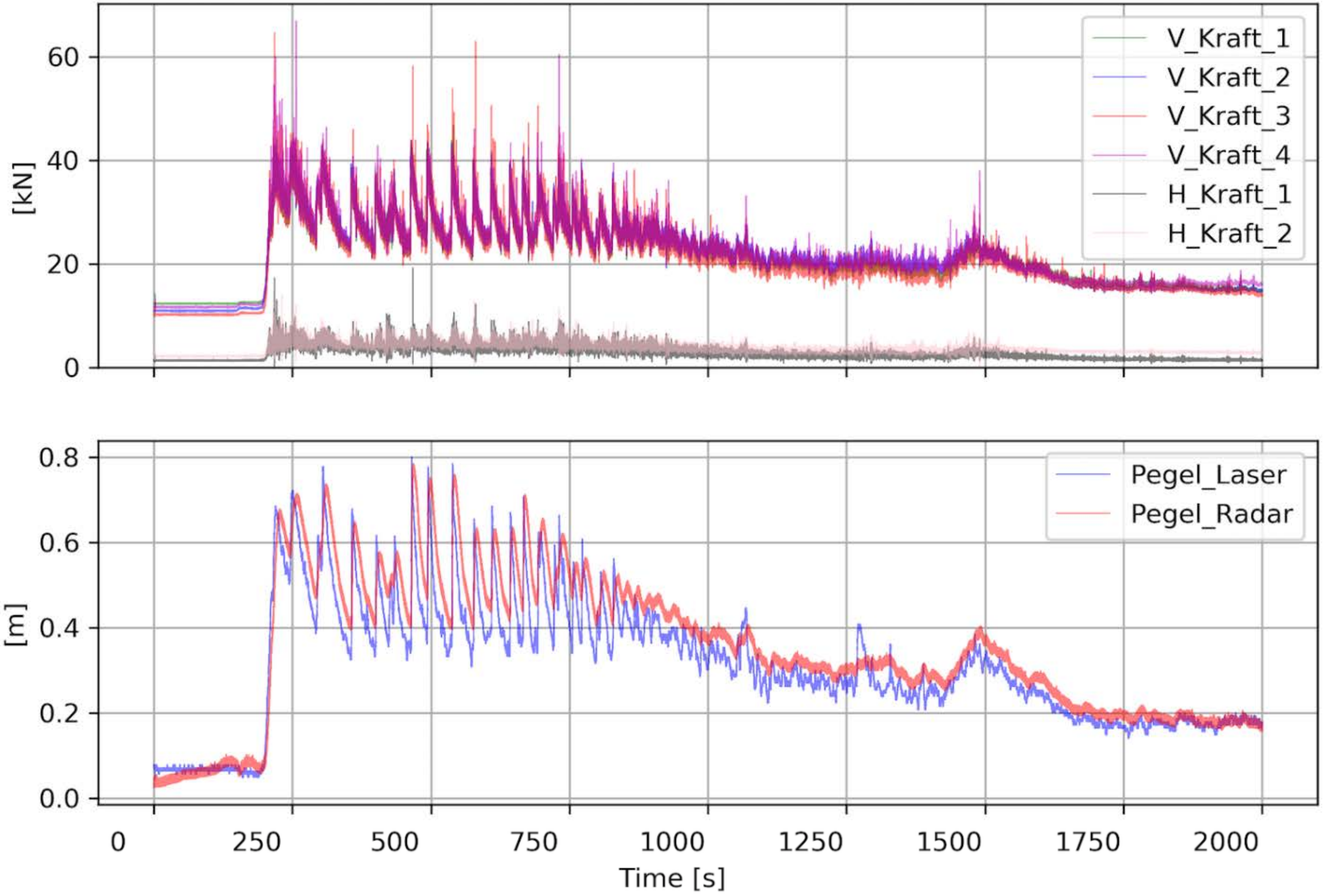
The new force plate:

- Identical dimensions to the old force plate (to characterize the bulk flow)
- New concept for construction: load sensors and steel installed as one unit
- Calibration planned (annually) for normal and shear forces
- Improved protection at the edge of the force plate
- Instrument channel for other sensors adjacent to the force plate
- New complimentary sensors planned for 2020

First results: Debris Flow on 10 June 2019

Raw force data

Flow depth

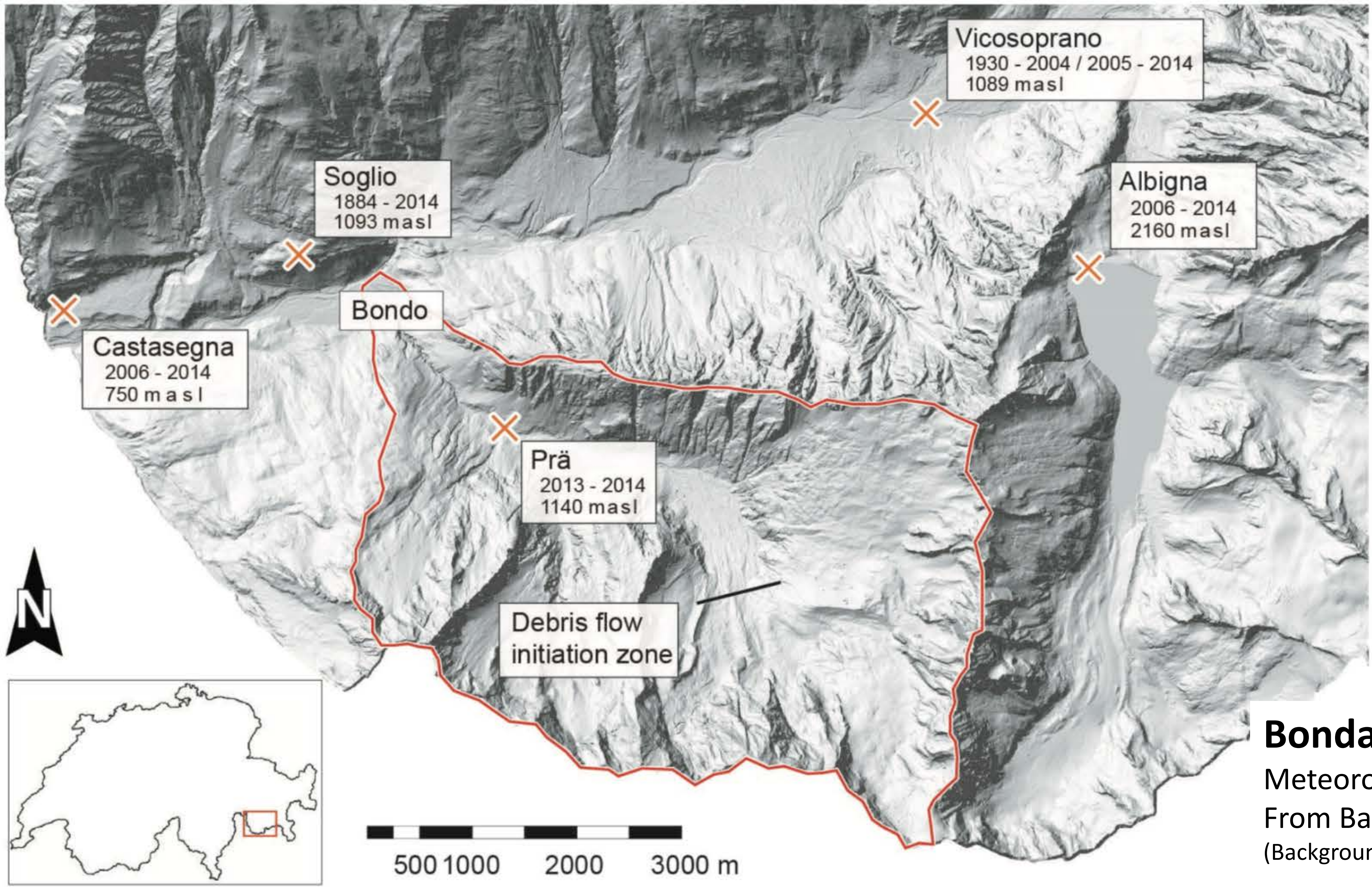


Sampling rate: 9600 Hz

Rock Avalanche + Debris Flows
Val Bondasca-Bondo

23 August 2017

Video: P. Wyss, https://www.youtube.com/watch?v=KITbIVl1R3w
Photo BWM 3 July 2019

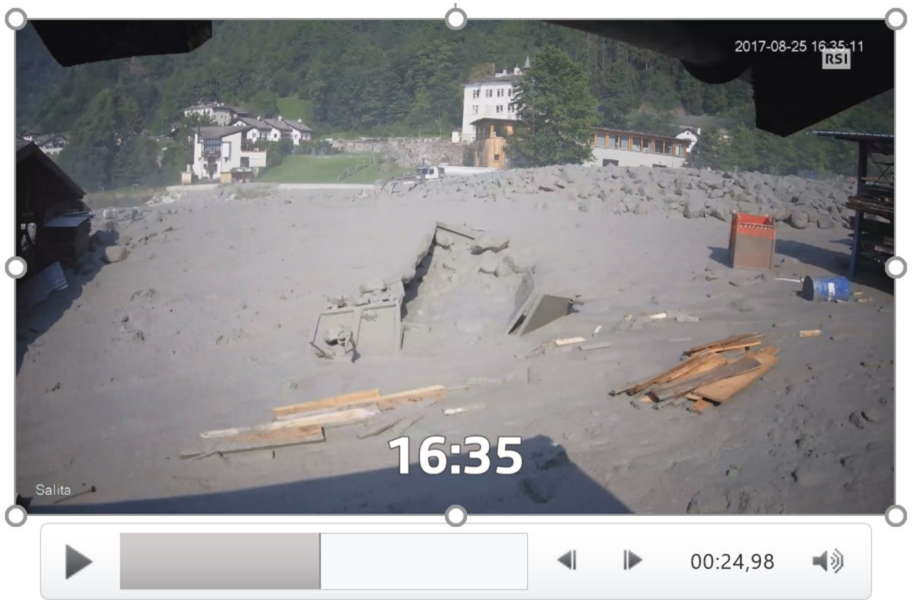


Bondasca Valley
Meteorological Stations
From Baer et al., 20127)
(Background hillshade Swisstopo DTM-AV)

Rock Avalanche + Debris Flows
Val Bondasca—Bondo

23 August 2017

9:31	Rock Avalanche 3.1×10^6 m^3 + ~500,000 m^3 glacier ice
9:48	First debris flow (slow, granular front) ~30,000 m^3 reaches Bondo
10:49–18:56	10–12 Debris flows, deposit 220,000 m^3 in Bondo
25 Aug.	2 Debris flows triggered, ~50,000 m^3
31 Aug.	Debris flow triggered by heavy rainfall, ~220,000 m^3



Event chronology: Amt für Wald und Naturgefahren, Kanton GR

Rock Avalanche + Debris Flows

23 August 2017

Remote sensing data: Copernicus Sentinel data 2017
For more information visit www.geo.ebp.ch and www.ebp.ch/en

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EBP

Interesting aspects of the 2017 ”process cascade”

1. Initial reports described it as being an exceptional and rare process cascade involving degraded permafrost, entrainment of glacier ice, and the generation of debris flows starting minutes after the rock avalanche

2. Why was the runout so short? Part of the flow path was on a glacier

3. Where did the water in the debris flows come from? The debris flows were triggered during good weather without rainfall

   Debris-flow volume 250,000 m^3 = 100,000 m^3 – 150,000 m^3 water

1. Initial reports of it being an exceptional or rare process cascade involving permafrost, entrainment and melting of glacier ice

- A similar sequence of events happened in 2011 & 2012 (Baer et al., 2017) but there were no debris flows triggered immediately afterwards
  - Rock avalanche in December 2011 → 4 debris flows in 2012
  - In 2011 the flow path was slightly different & less ice was entrained
  - The 2011 event was in December, less water present in the sediments and lower temperatures may have inhibited melting

- Literature >64 rock avalanches with travel on glaciers were found in the literature in the last 50 years. Many generated debris flows, but the timing is typically poorly constrained or unknown (Deline et al., 2015; Christen, 2018).

Conclusion: This process chain has been documented before, however the data from Cengalo are exceptional and should be investigated in more detail!

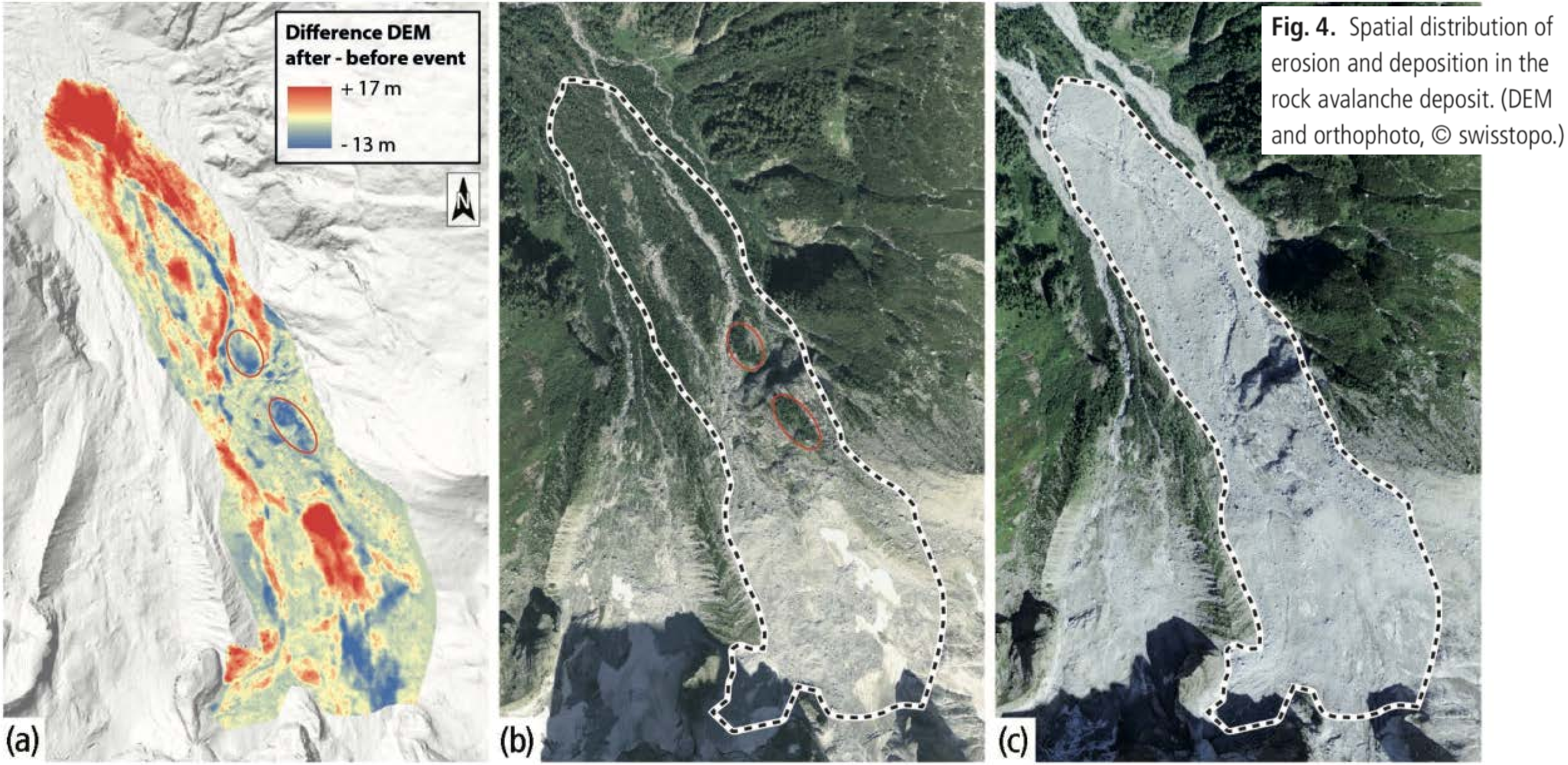
2011 Rock Avalanche, 1.5–1.7 million m^3

Fig. 2. Overview of the rock avalanche failure zone (red) and the main transit zone (blue). (Photo taken on 1 April 2012 by Lukas R. Vogel, Madulain.)

Baer et al., 2017, Geology Today

2011 Event: Erosion and deposition due to both rock avalanche and debris flows

DTM difference= (18 July 2012) – (2003 & 2009)

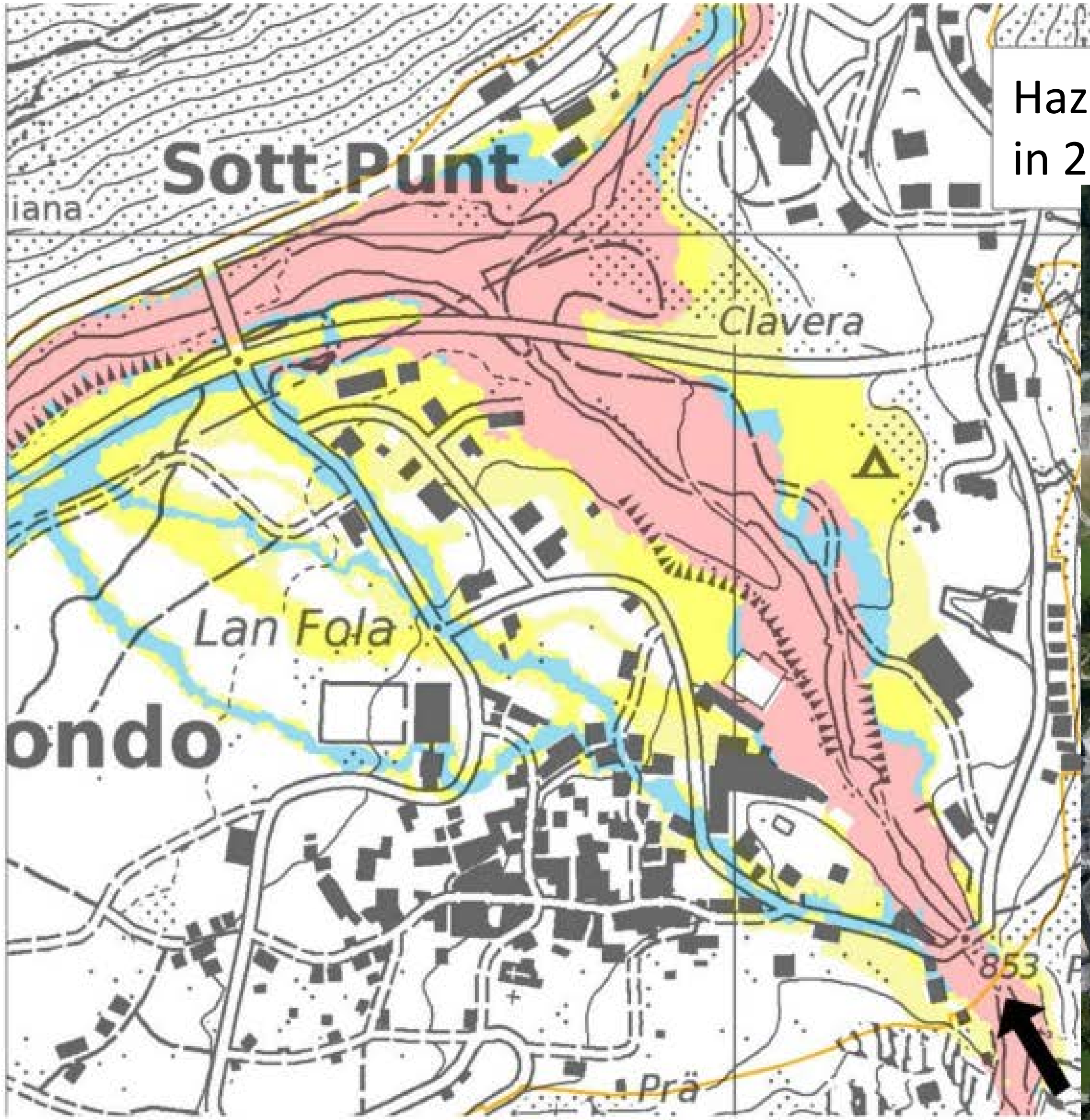


Baer et al., 2017, Geology Today

One encouraging aspect for engineering practice:

Hazard maps for land-use planning worked well even though the events in 2017 were complex

Hazard Map, revised following debris flows in 2012, & an air photo of the event



2. If a glacier was present on the flow path, why didn't the rock avalanche travel farther?

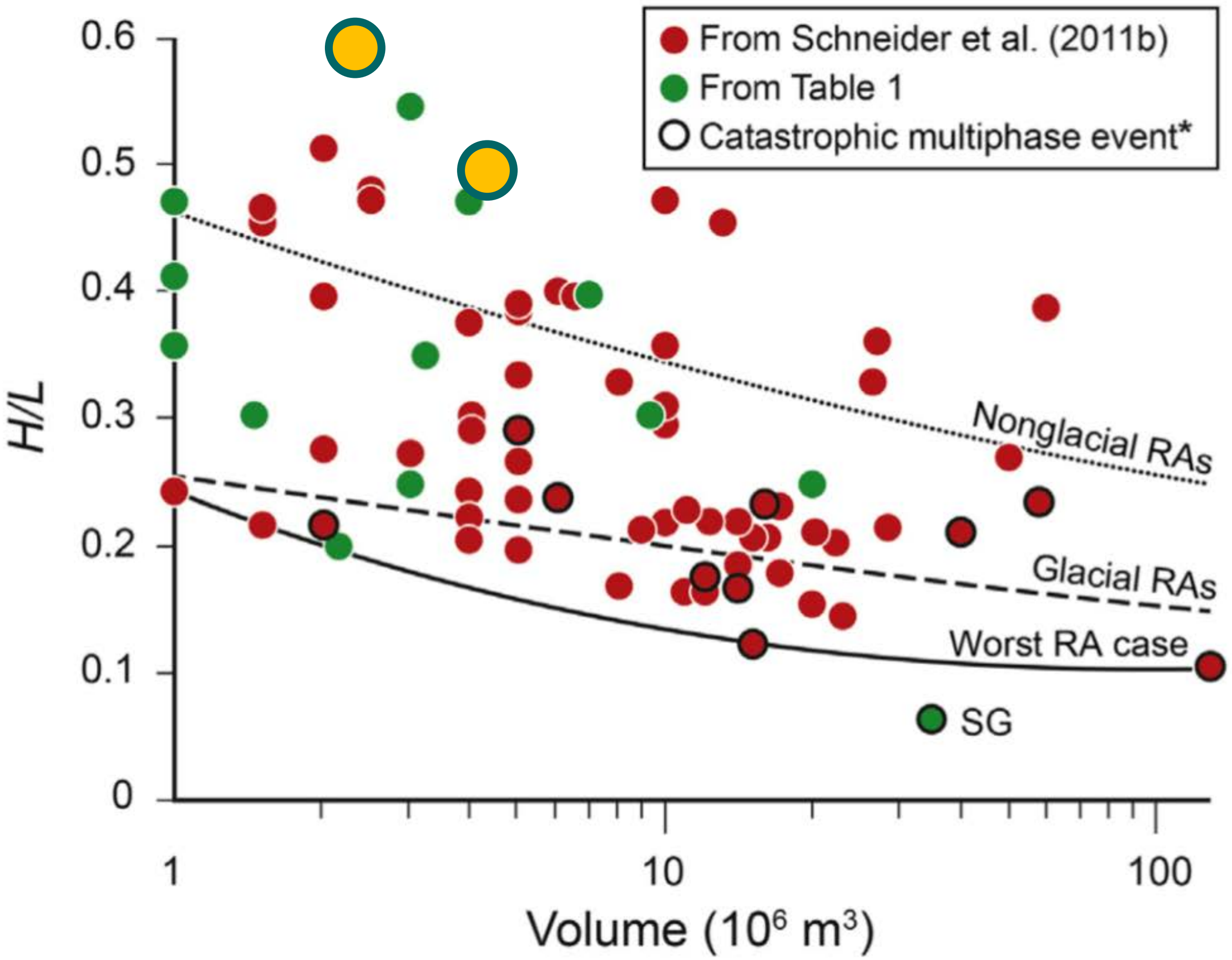


FIGURE 9.3 Mobility of rock avalanches (volume >1 Mm^3) on glaciers shown by the relationship between volume and ratio between vertical (*H*) and horizontal (*L*) travel distances; regression lines from Schneider et al. (2011b) and Evans and Clague (1988); SG, Steinsholtsjokull Glacier, Iceland; *, *sensu* Petrakov et al. (2008).

Pizzo Cengalo
2011 & 2017

Likely answers:

1. The travel path over ice was very short

2. If you include the first debris flow, H/L for the 2017 event would be smaller

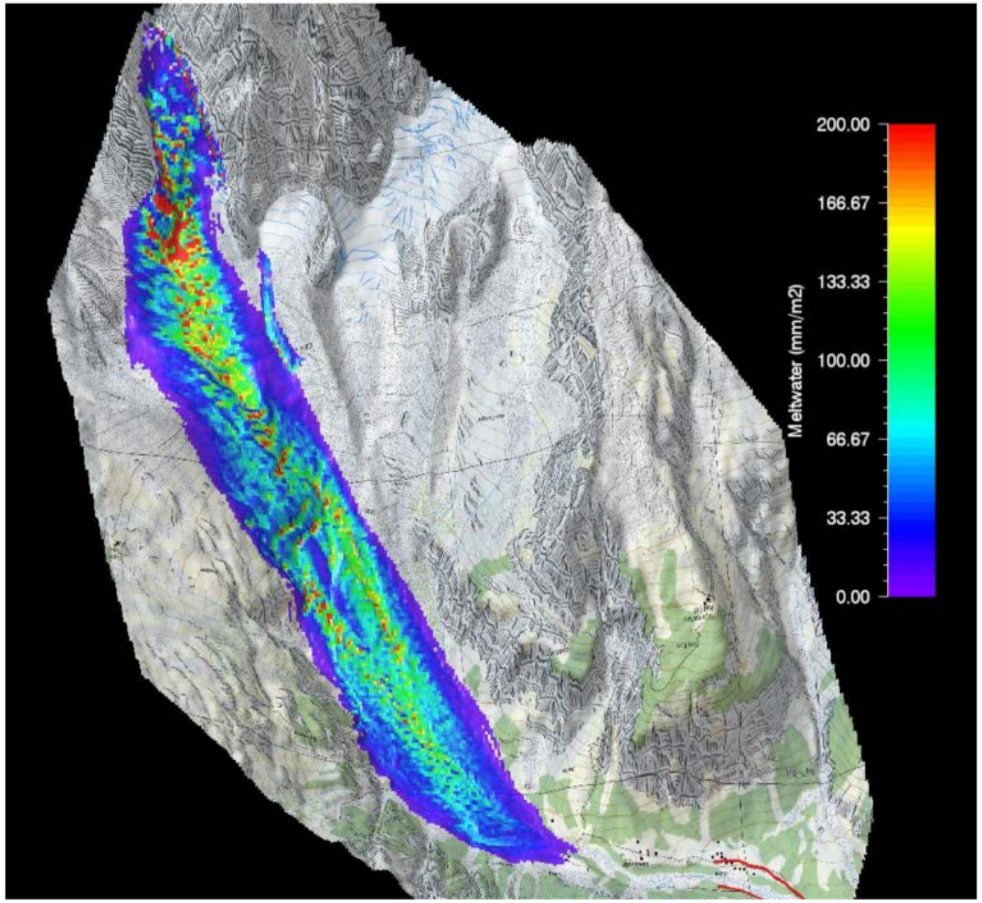
3. Abrupt change from near vertical rock face to relatively flat land surface may have resulted in extensive internal deformation and energy loss in the rock avalanche

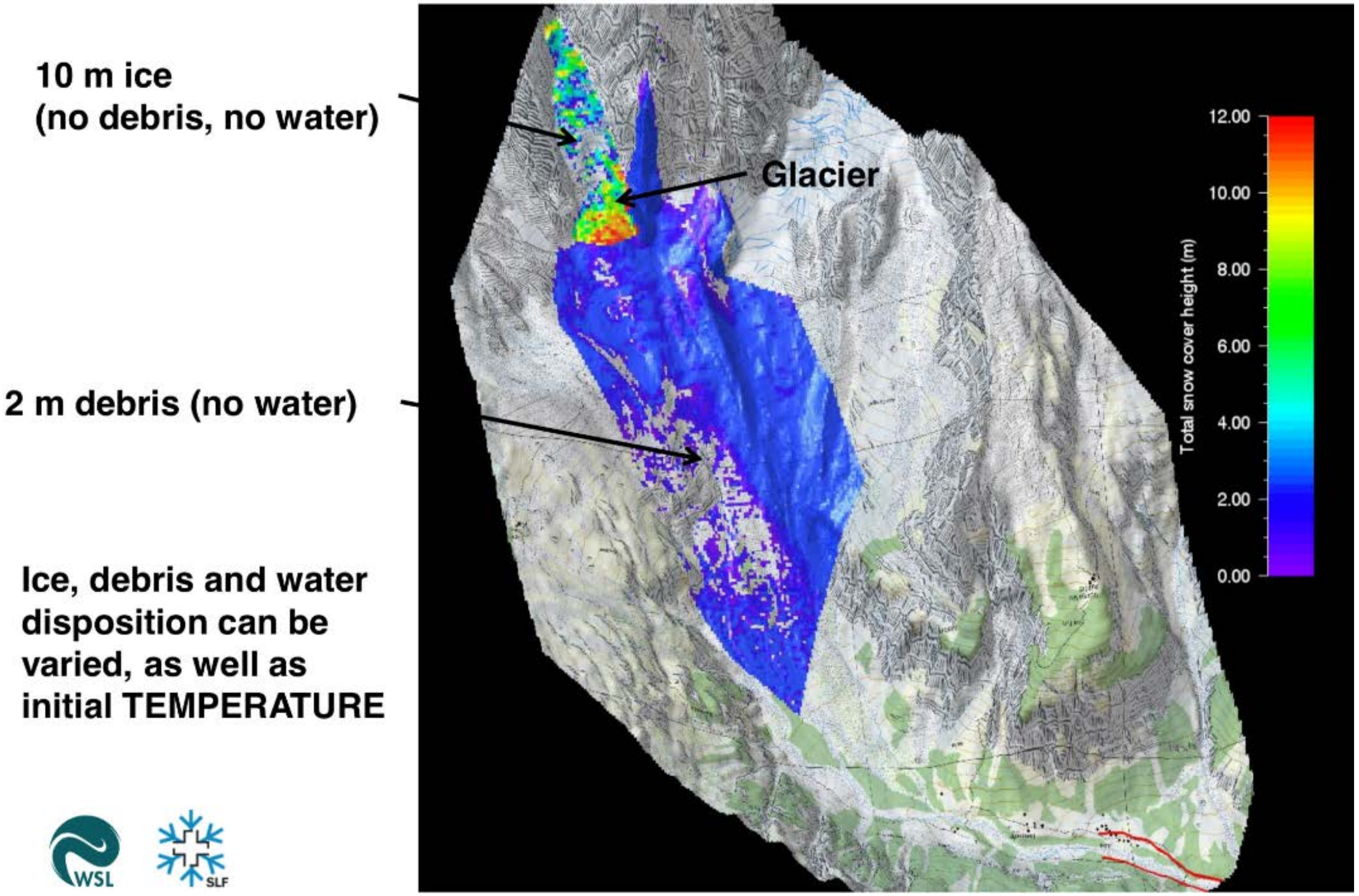
Deline et al., 2015

3. Where did the water come from? Possible sources:

Conclusion: Likely a combination of several sources.

Implications for modelling runout and hazard prediction

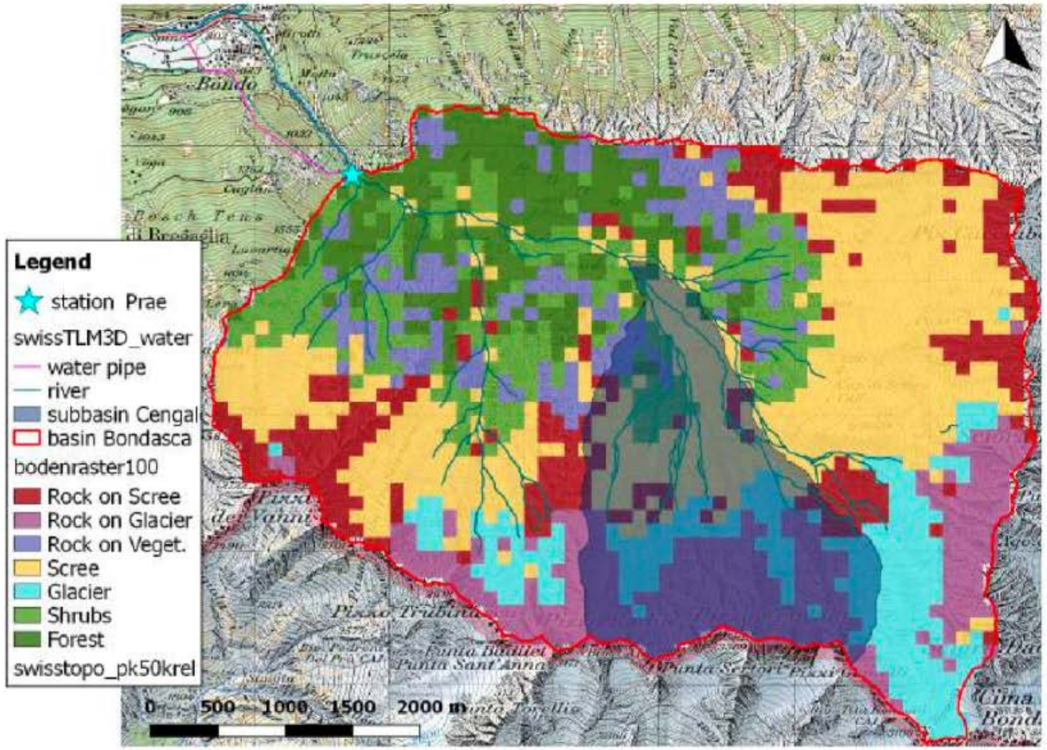




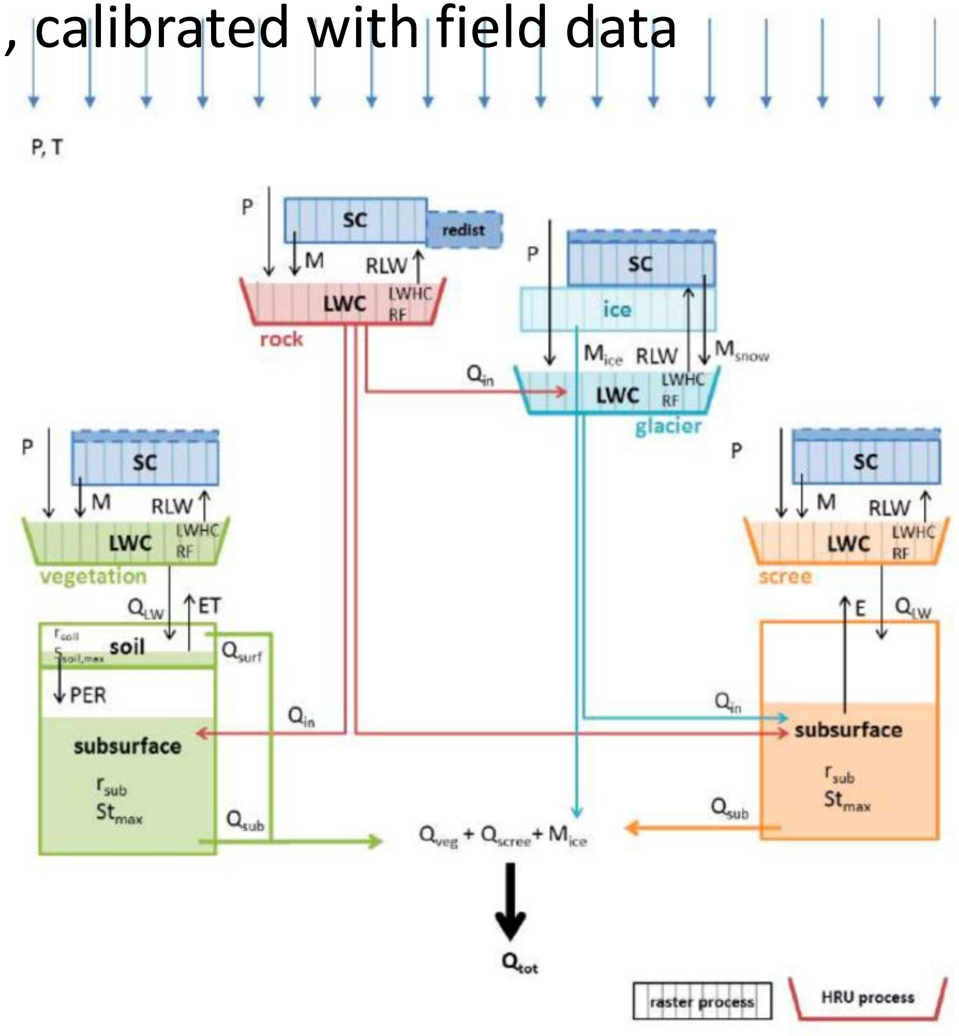
Runout modelling considering entrainment and melting of ice, images courtesy of Perry Bartelt, WSL-SLF (RAMMS model)

3. Where did the water come from?

Demmel, 2019, Masters thesis, ETH Zürich: Hydrogeological response units, linked, and lumped into a simple conceptual model, calibrated with field data



Hydrogeological response units on a 100 m raster and the location of a gaging station at Prä.



Sketch of the hydrogeological model developed for Val Bondasca.

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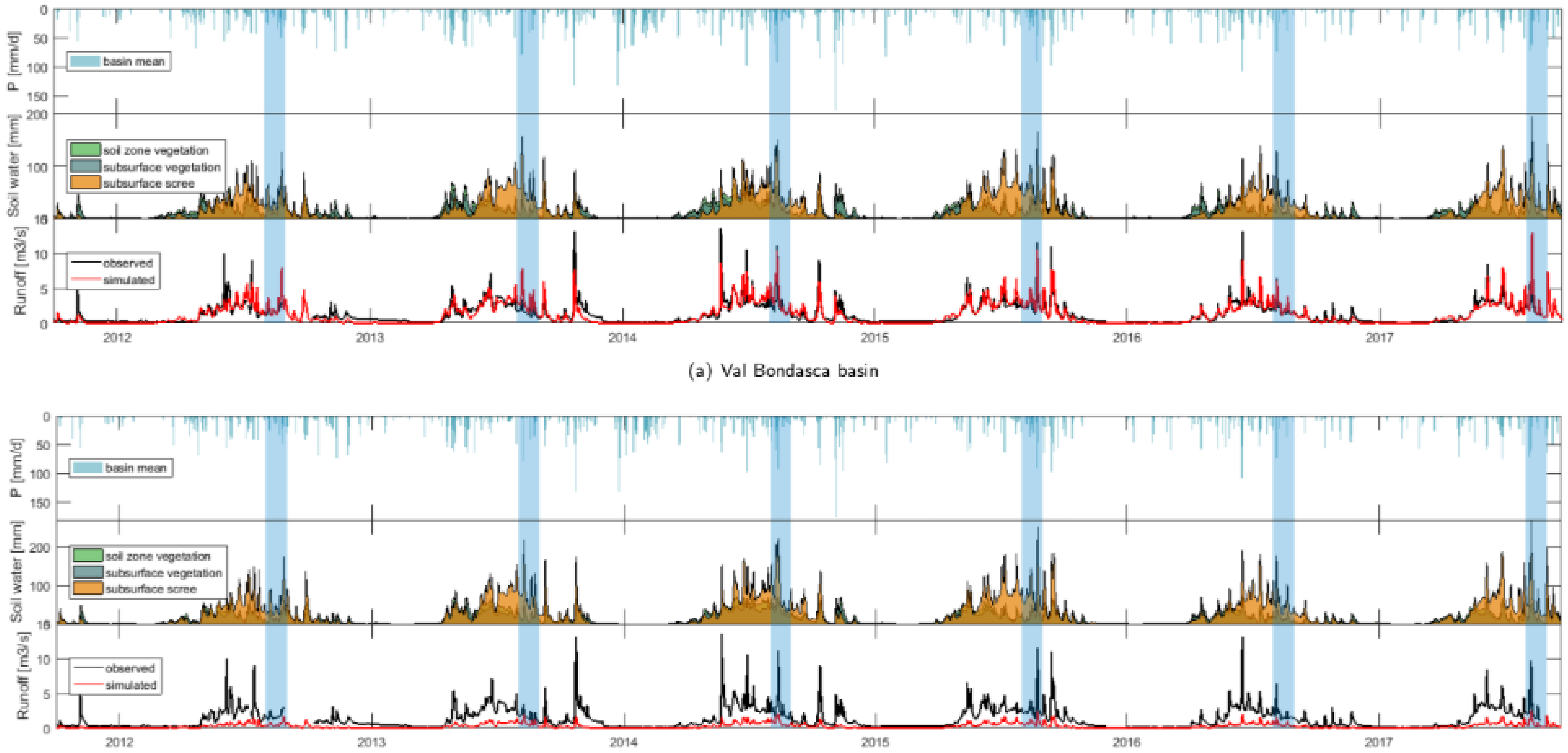

(a) Val Bondasca basin

(b) Cengalo subbasin

Figure 11: Observed daily precipitation, simulated soil water storage and observed vs. simulated runoff in Val Bondasca. Shown is the total simulation period (2012-2017) with the months of August marked in blue.

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4. **How will the magnitude and frequency of alpine hazard processes change under changing climate conditions? A new internal research program at the WSL started in 2018:** ***Climate Change Impacts on Alpine Mass Movements***

Climate Change Impacts on Alpine Mass Movements (CCAMM)

A WSL Strategic Initiative, ~12 PhD students

Rock-slope failures, debris flows and snow avalanches

► Changes in frequency, magnitude and spatial distribution?

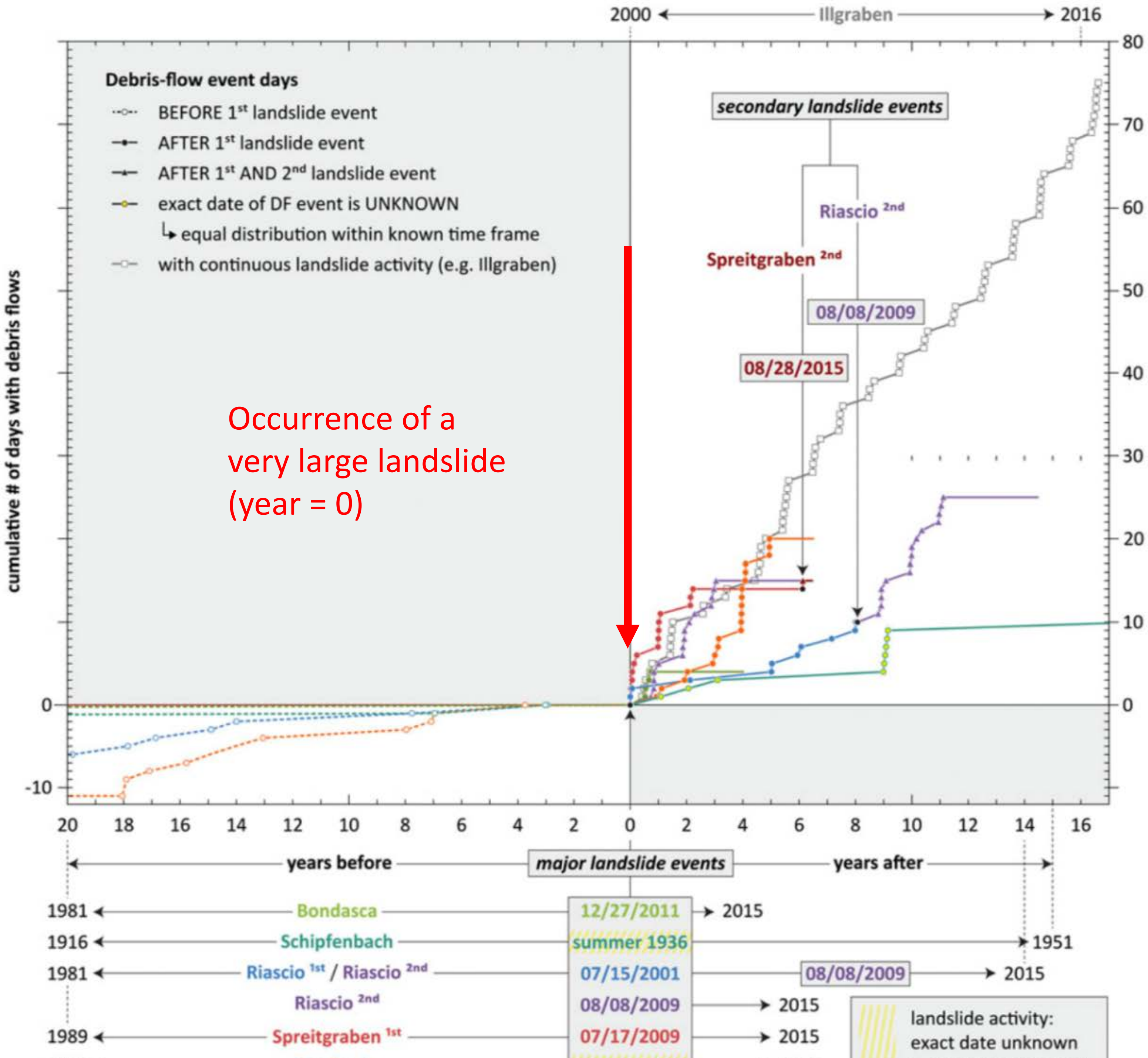
Initial conditions, flow dynamics and interactions with ecosystems

► Changes in impacts of mass movements?

climate and socio-economic induced changes in risk

► Adaptation strategies?

Outlook: How long will debris flows continue?



Cumulative number of days with debris flows

Frank et al., 2019
ESPL

Conclusions

1. The chain of processes at Cengalo provides an unusual opportunity to better understand the processes, their coupling, and improve hazard prediction
2. The source of water for the debris flows—without any rainfall—is likely from both entrained ice and water in the sediment along the flow path

3. The new Illgraben force plate is operating, 9 (10) events in 2019 so far

Thank you for your attention

Photo:
June 2014