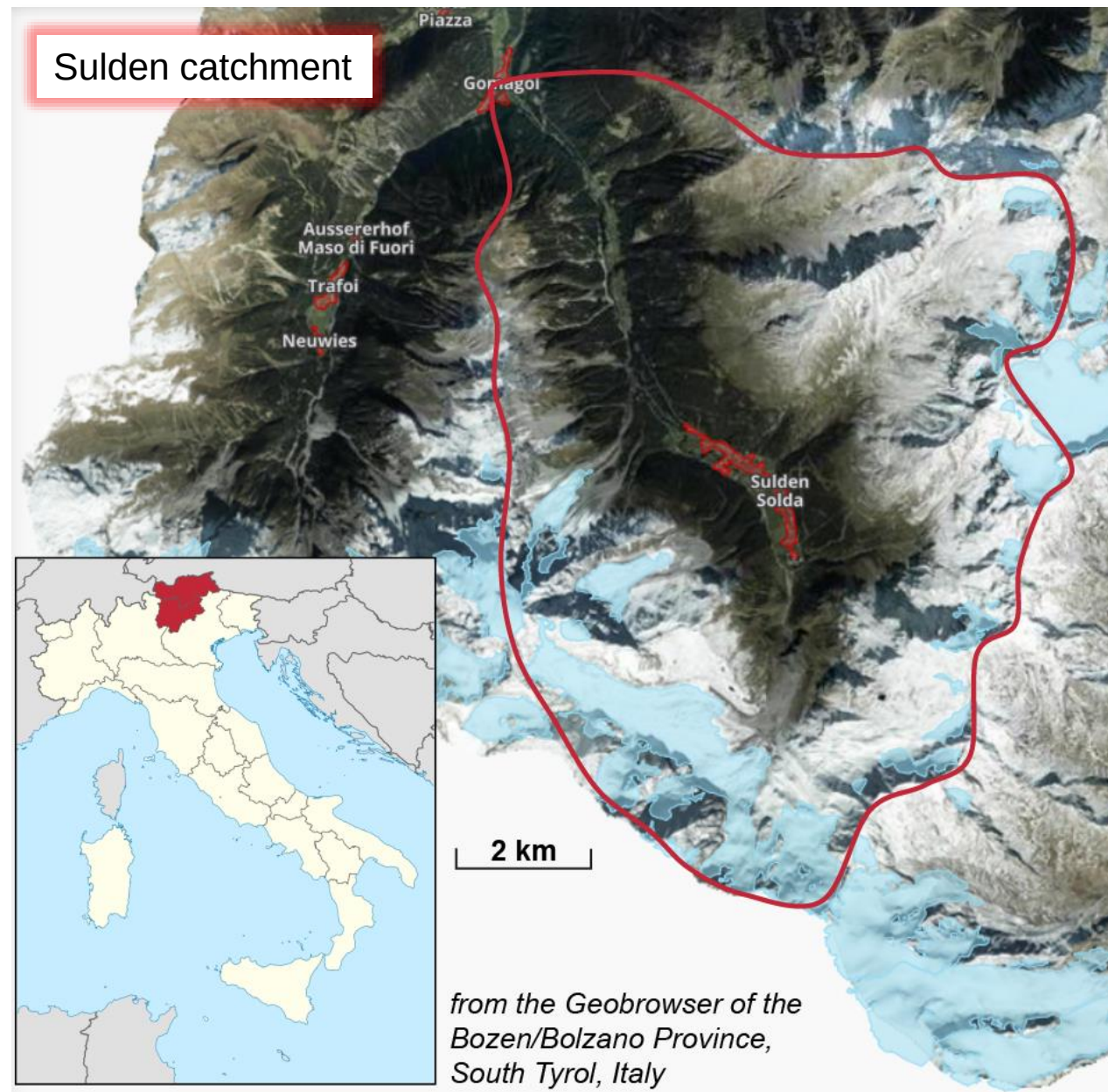


Pronounced increase in slope instability linked to global warming. Published in ESPL, 2021

Sara Savi (savi@geo.uni-potsdam.de), Francesco Comiti, and Manfred Strecker



Methods:

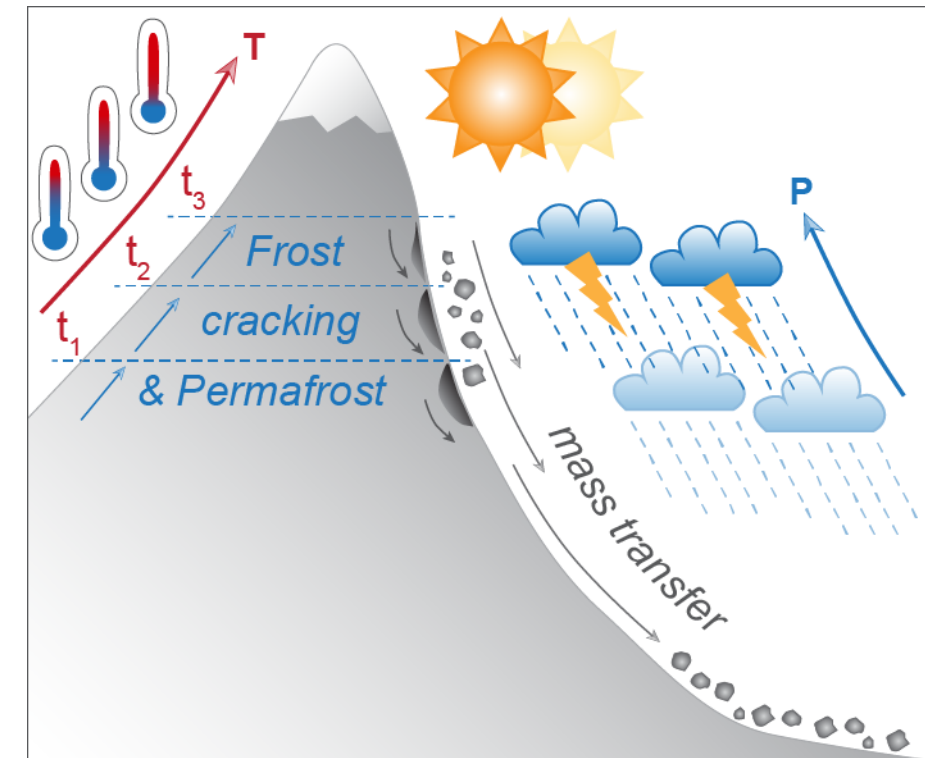
- Orthophotos from 1945 to 2019 → more than 1000 detachment points for rockfalls and debris flows
- Permafrost distribution map (Böeckli et al, 2011)
- Frost-cracking model (Hales and Roering, 2007, Scherler, 2015)
- Temperature and precipitation data

Results:

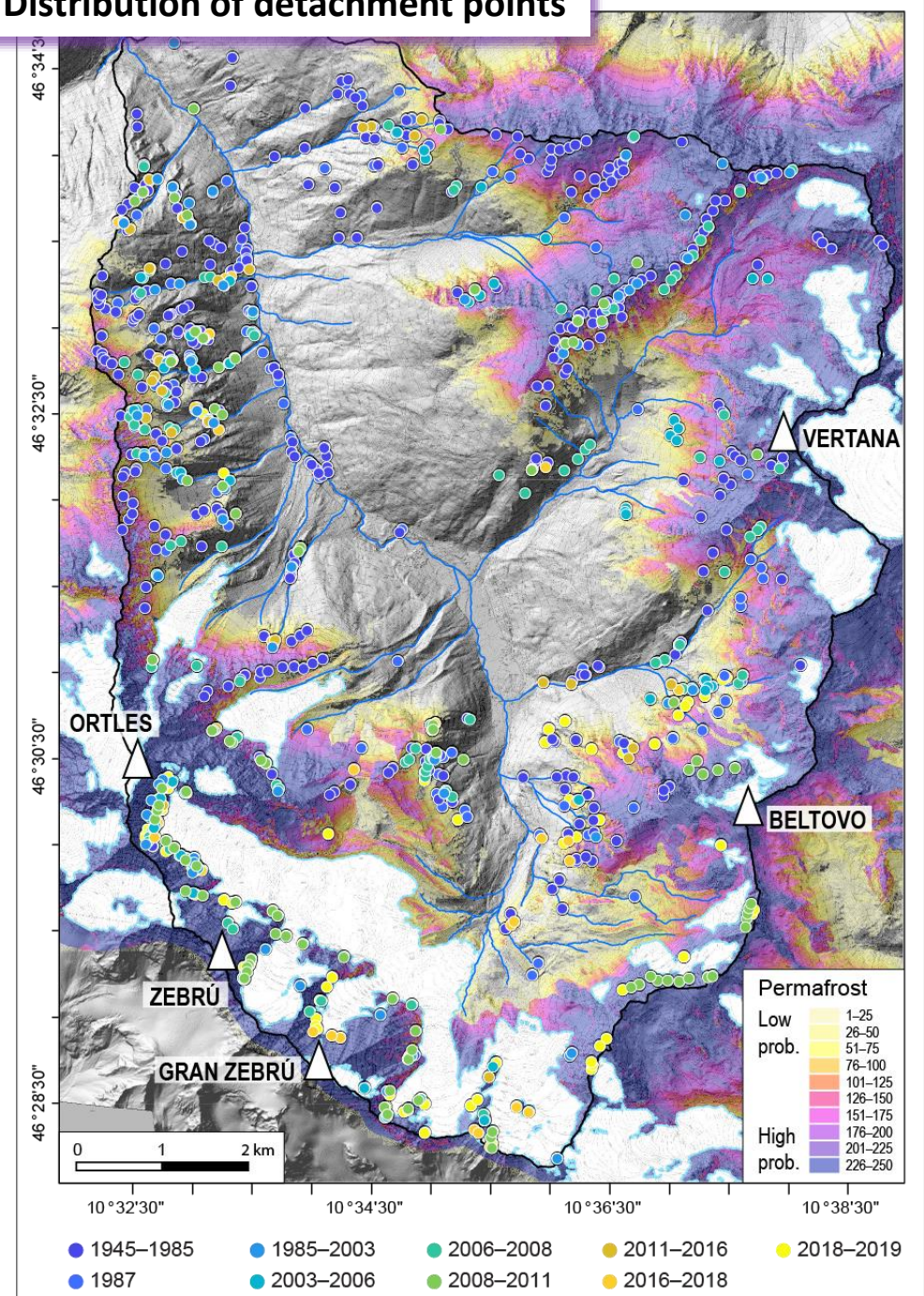
- Spatio-temporal evolution of shallow detachments

Findings:

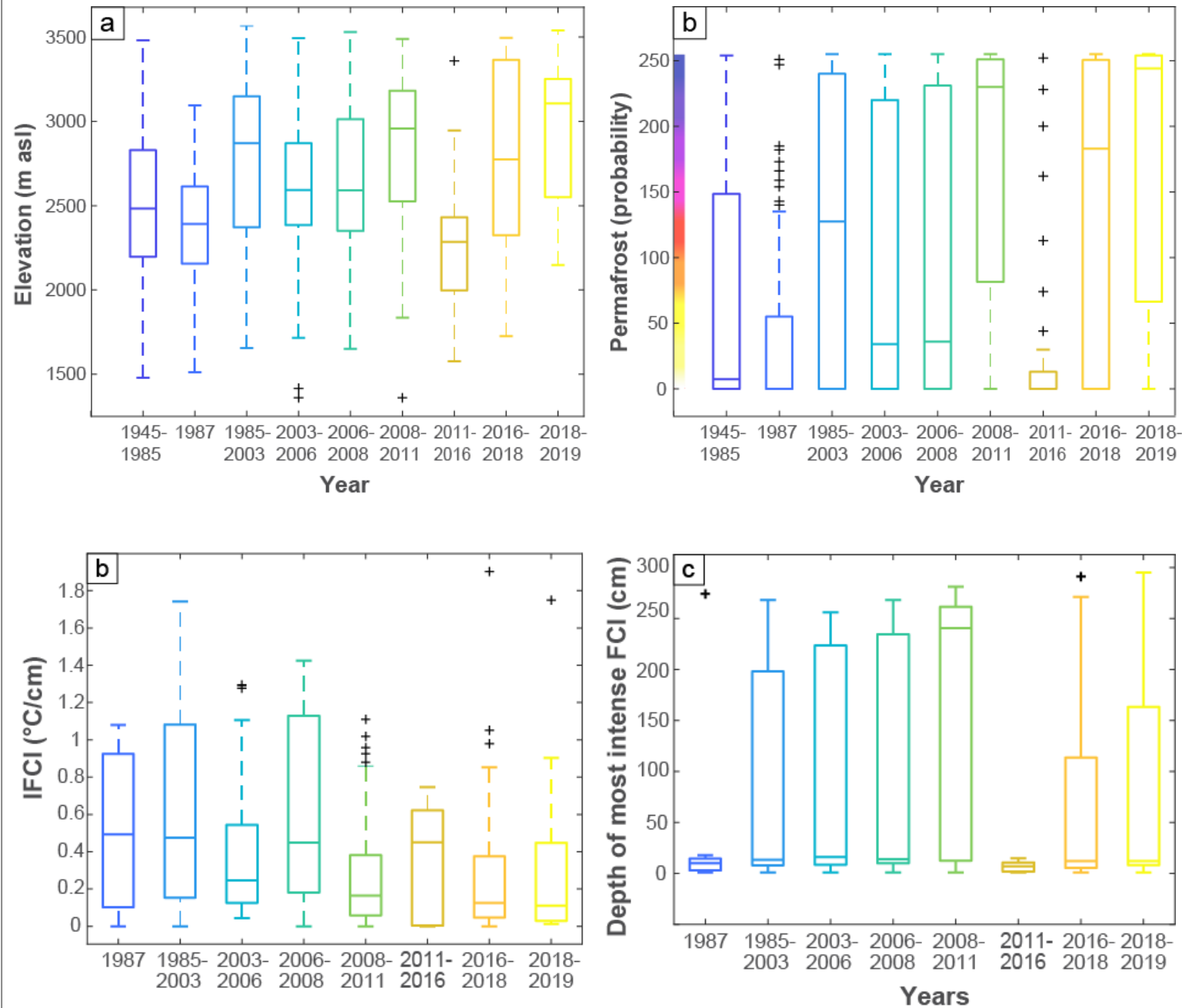
- Since 2000, increasing rockfalls (altitudinal shift of ca. 300 m)
- Since 2010, increasing debris flows



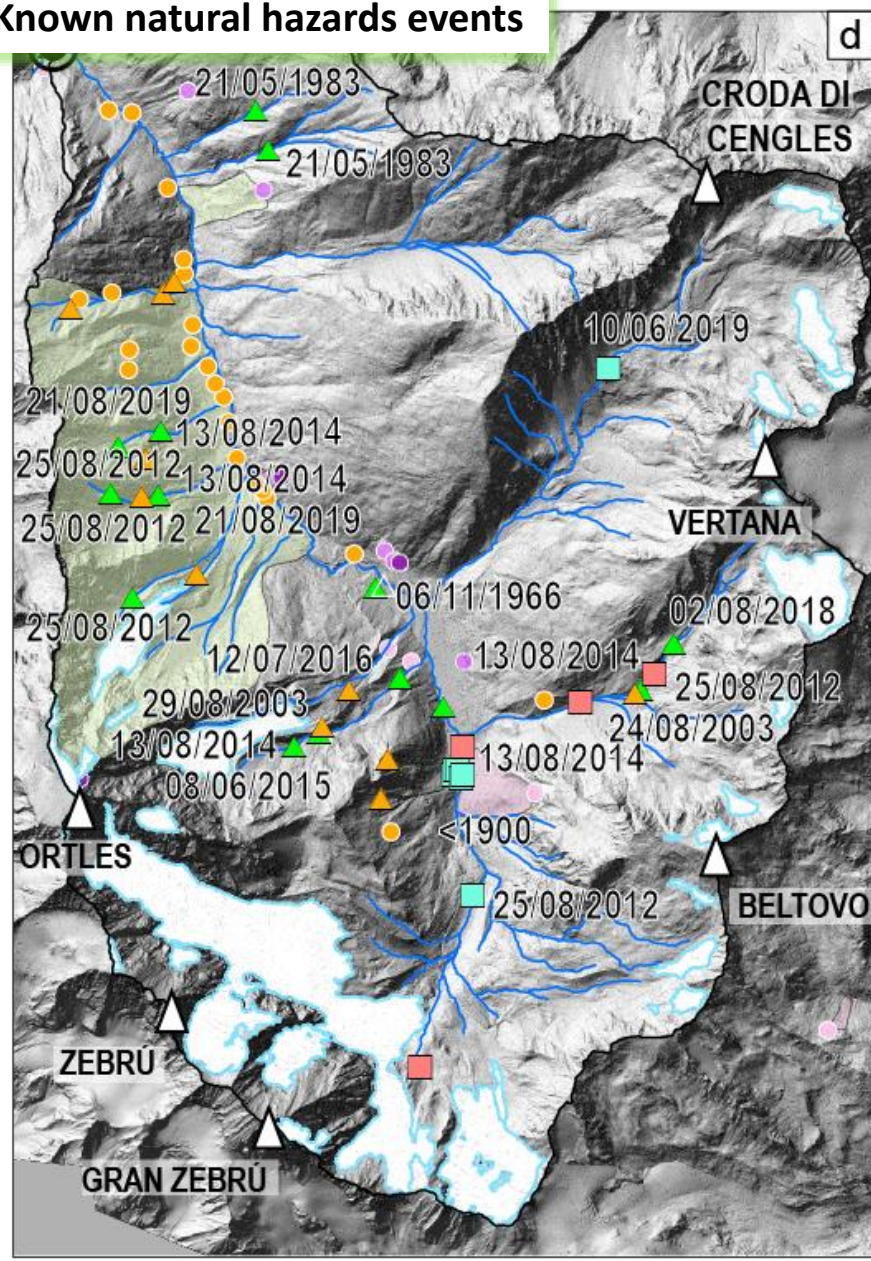
Distribution of detachment points



Landscape parameters

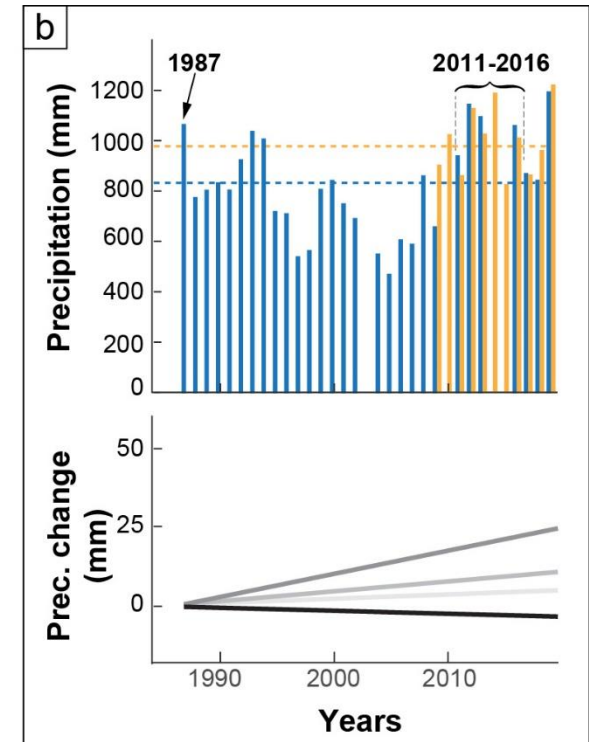
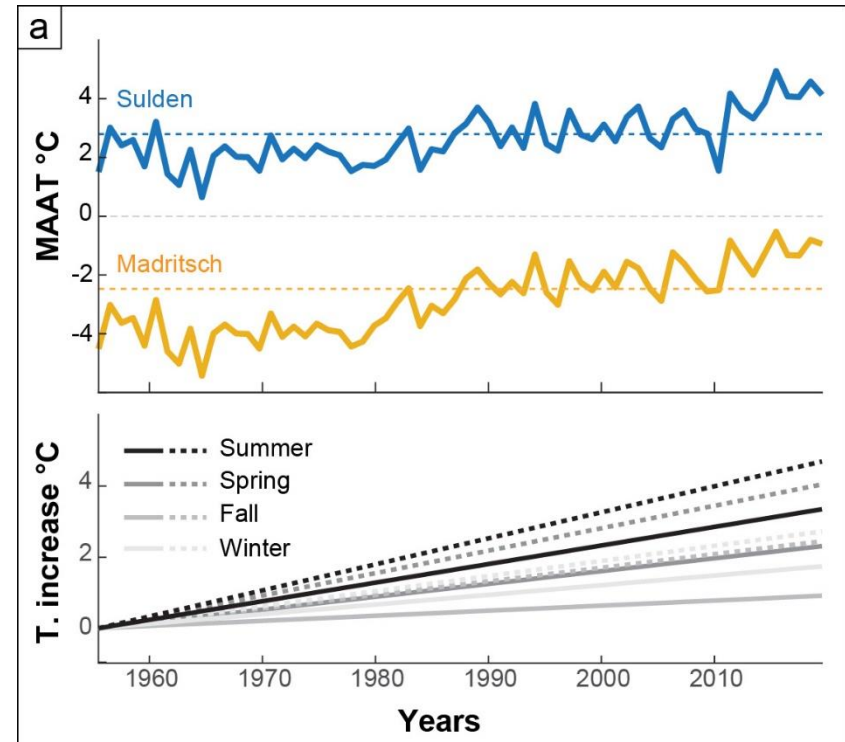
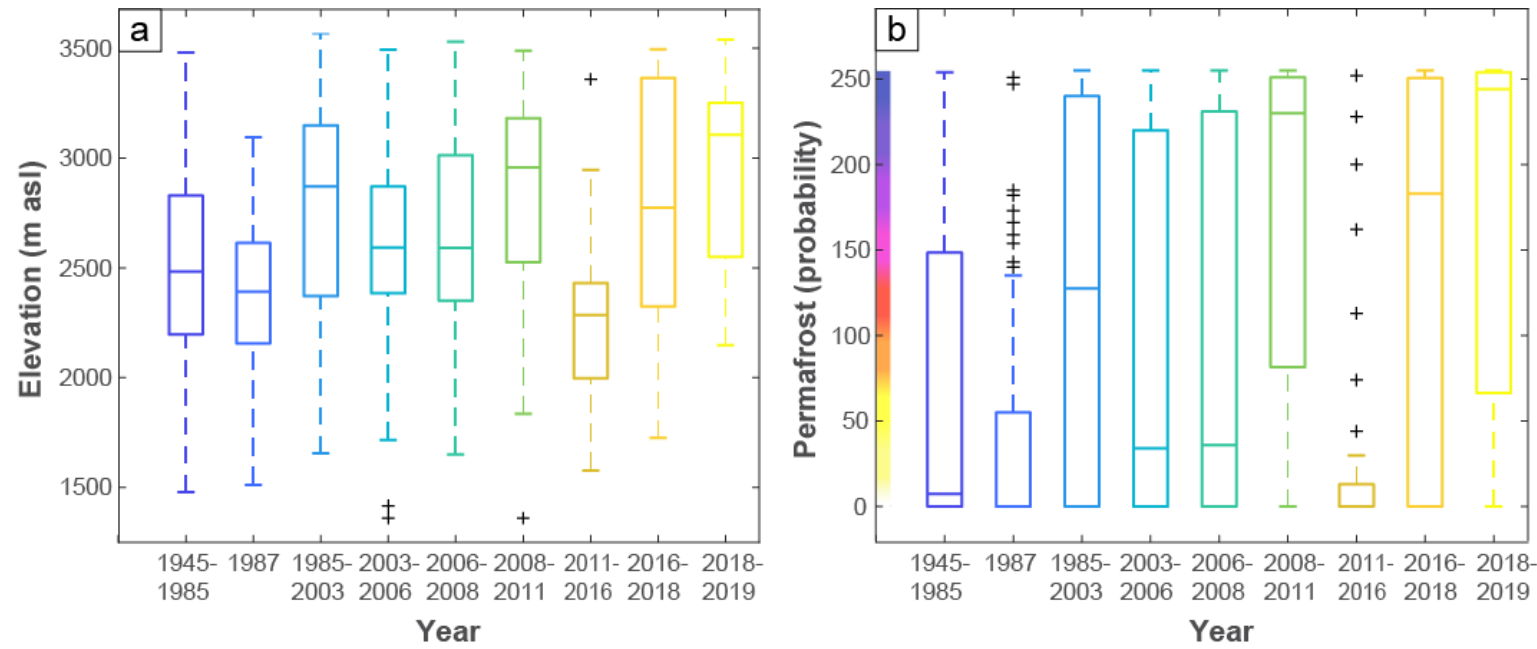


Known natural hazards events

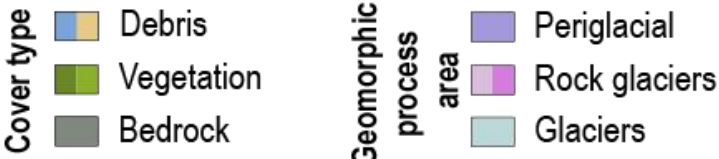
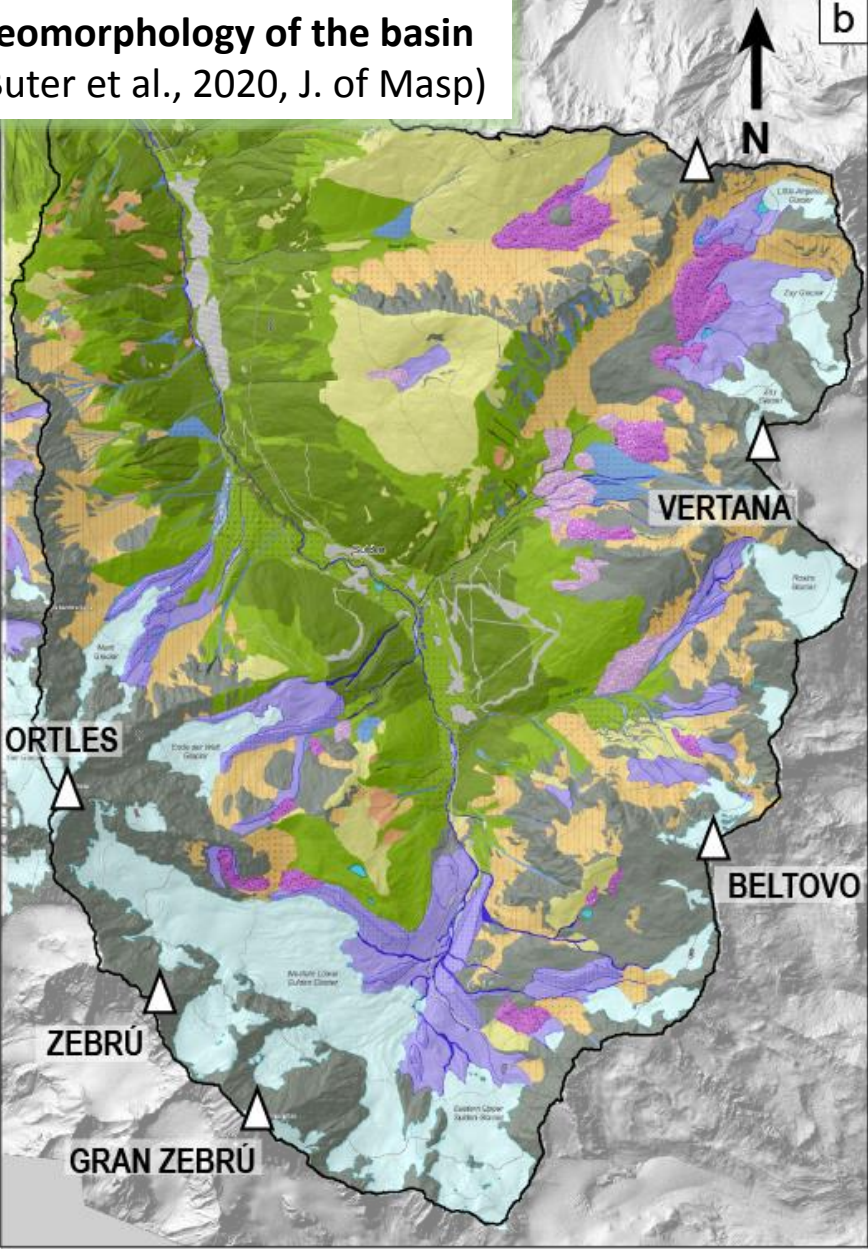


- Flood
- Debris flow
- Debris flood
- Debris flow 1987
- Rockfall
- Slide
- Complex
- 1987

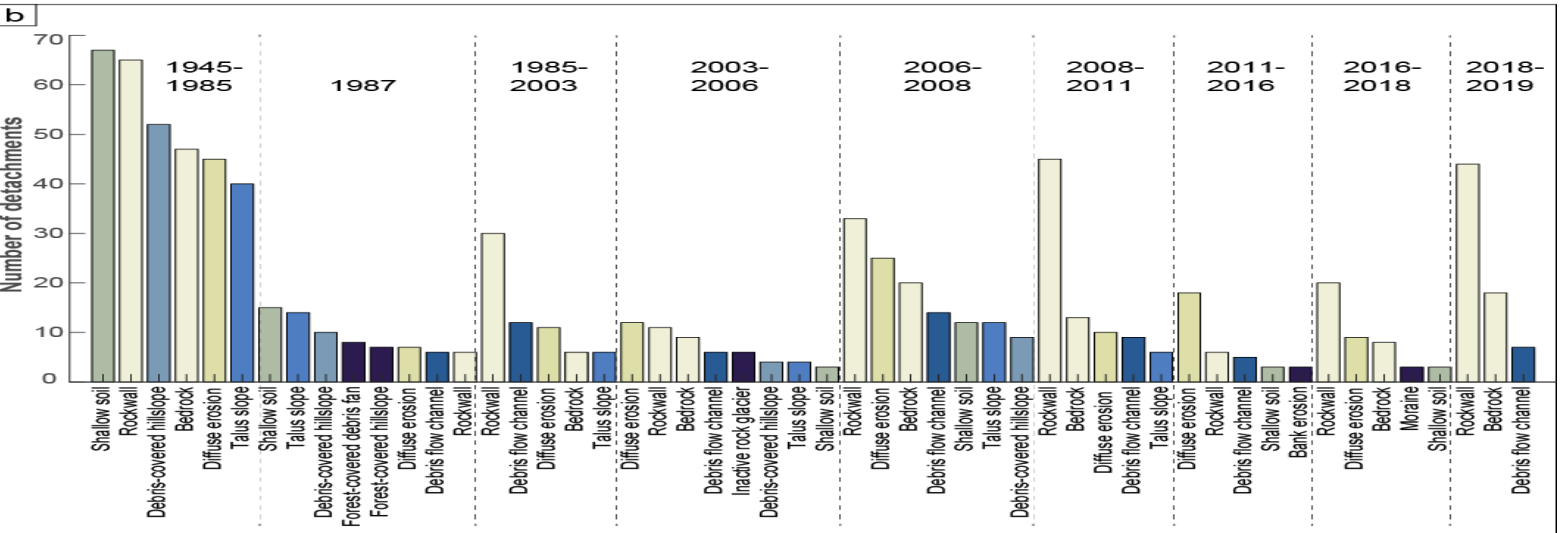
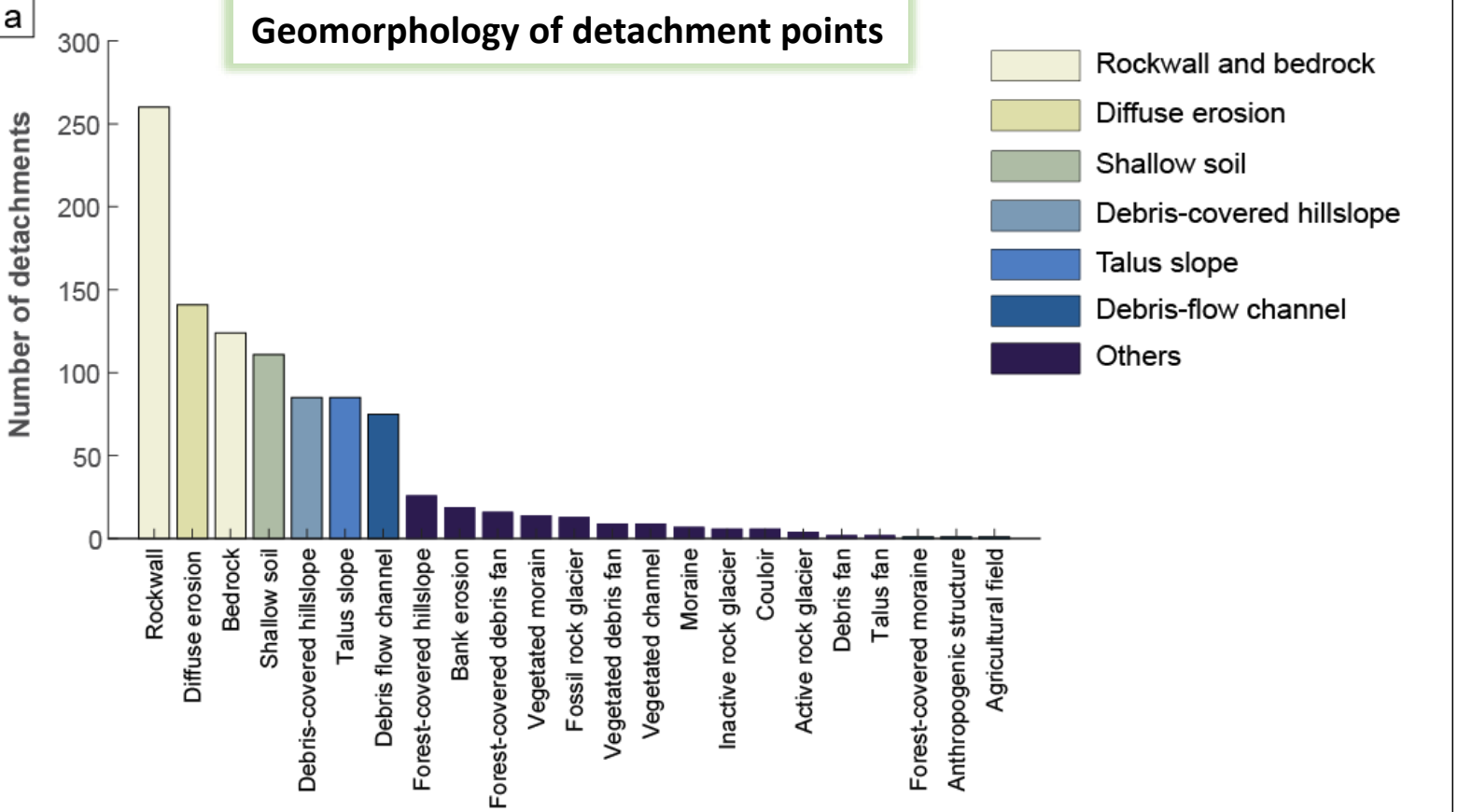
Climatic data



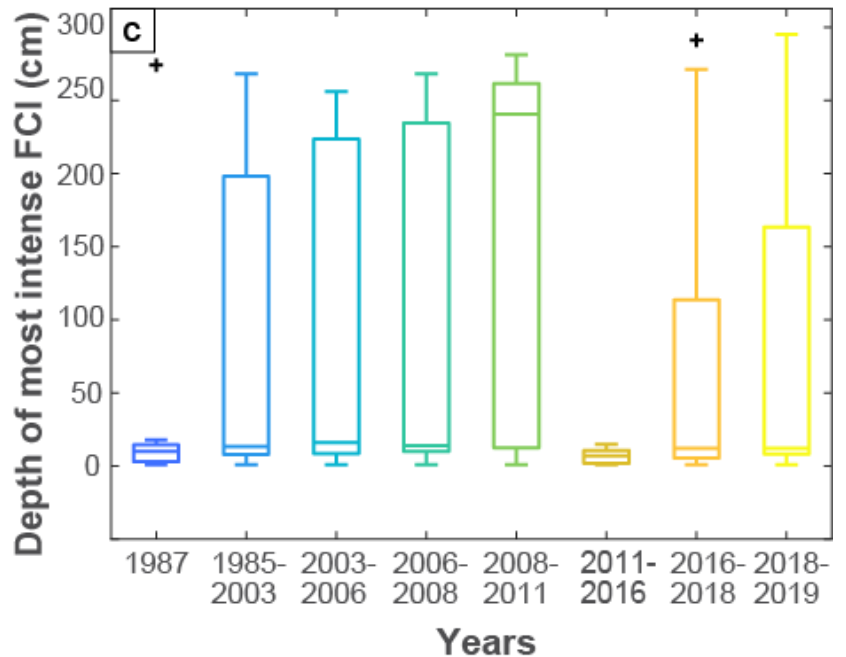
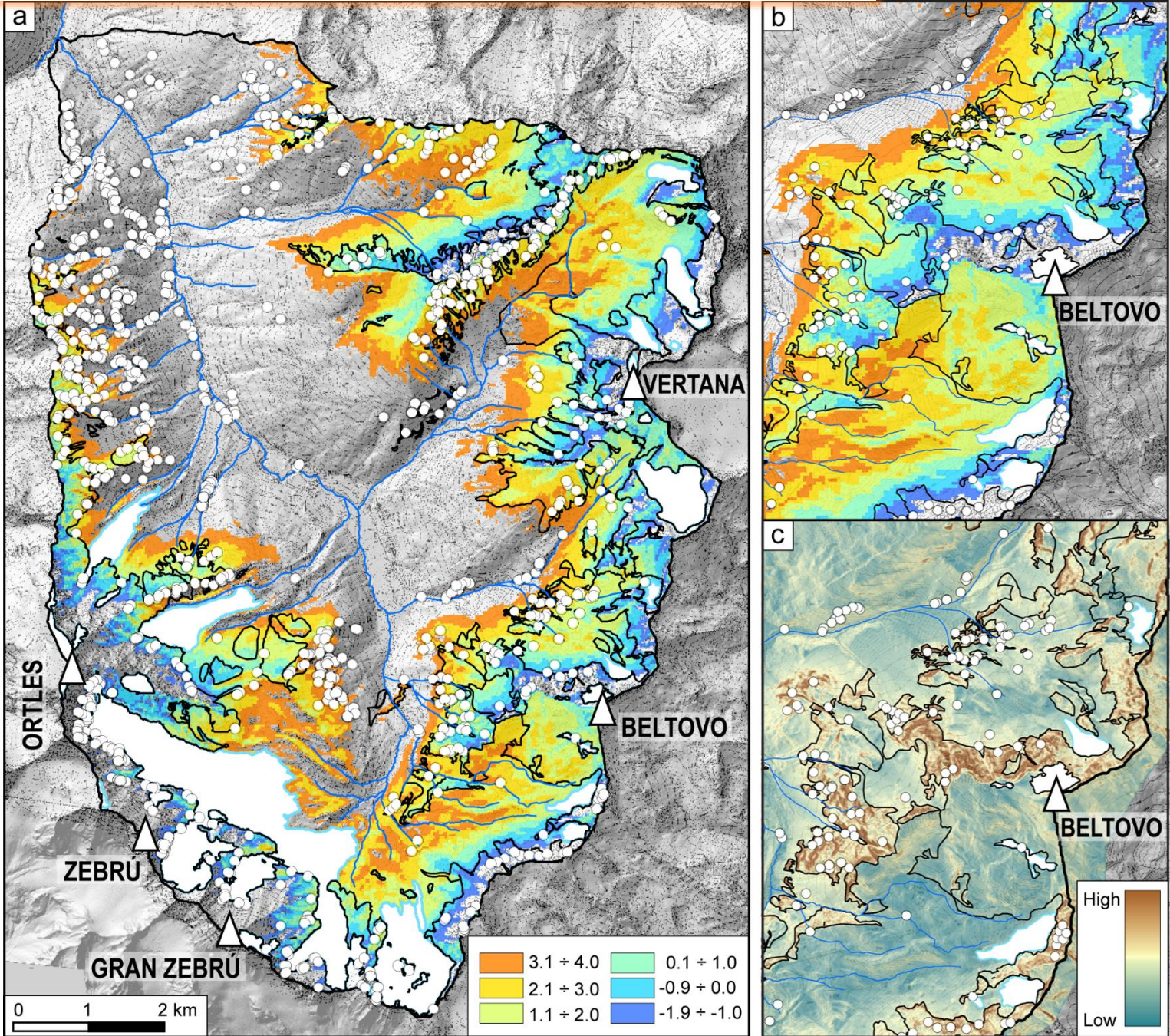
Geomorphology of the basin
(Buter et al., 2020, J. of Masp)



Geomorphology of detachment points

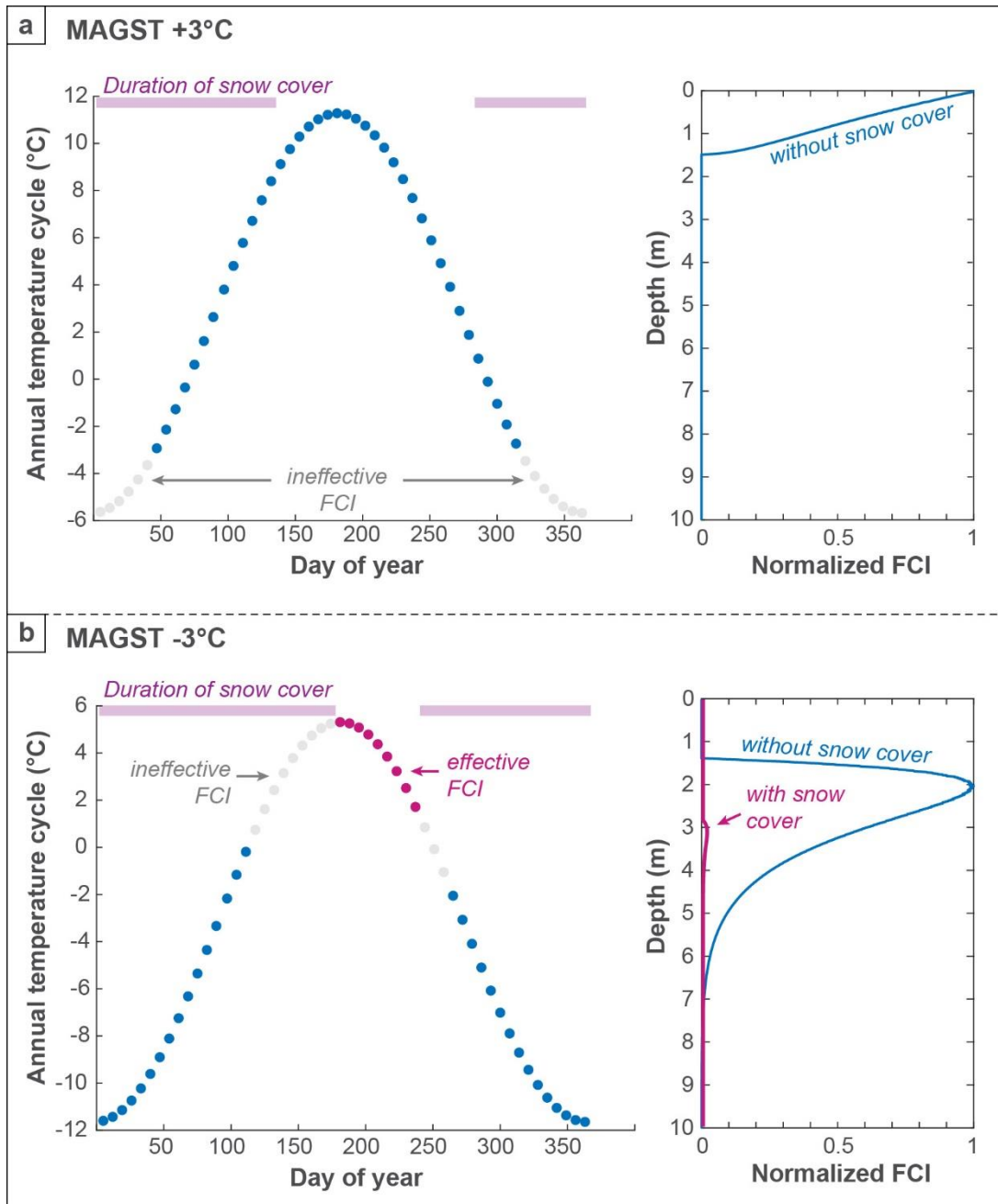


Temperature distribution and location of the detachment points



MAAT	Depth(cm) of most intense FCI	
6.0	0	too warm to freeze
4.0	1	
2.0	7	
0.0	17	
-1.5	15	
-2.0	264	
-4.0	258	
-6.0	240	
-8.0	0	too cold to melt

Snow cover effects on frost cracking and slope instability



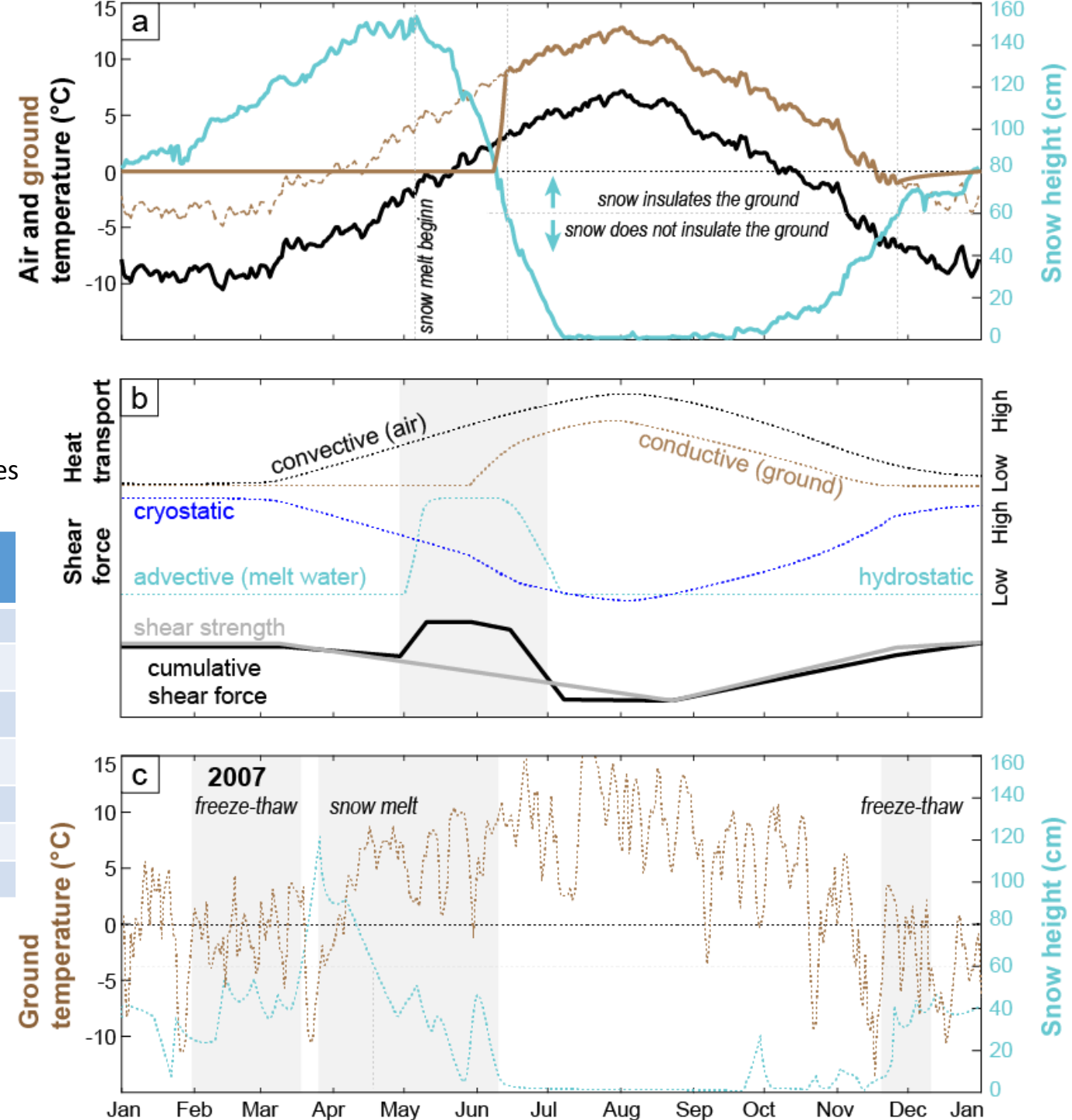
Location of the detachment points below the Ortles top (white circles). On the background is a connectivity map gently realized by Dr. Cavalli, CNR-IRPI, Italy (Cavalli et al., 2013)

Snow cover effects on slope instability

Slope instability window for the Silden catchment, following Draebing et al., 2014

Number of detachments, rainfall events that triggered a debris flow, and debris flows, together with the detachment (Det.) and debris-flow (D-F) rates calculated annually.

Time periods	Detachments	Rainfall	Debris flows	Det. rate (no/yr)	D-F rate (no/yr)
1985–2003	158	5	14	8.8	0.8
2003–2006	58			19.3	0.7
2006–2008	132			66.0	
2008–2011	92			30.7	
2011–2016	43	4	12	8.6	2.4
2016–2018	49	1	1	24.5	0.5
2018–2019	81	2	3	81.0	3.0

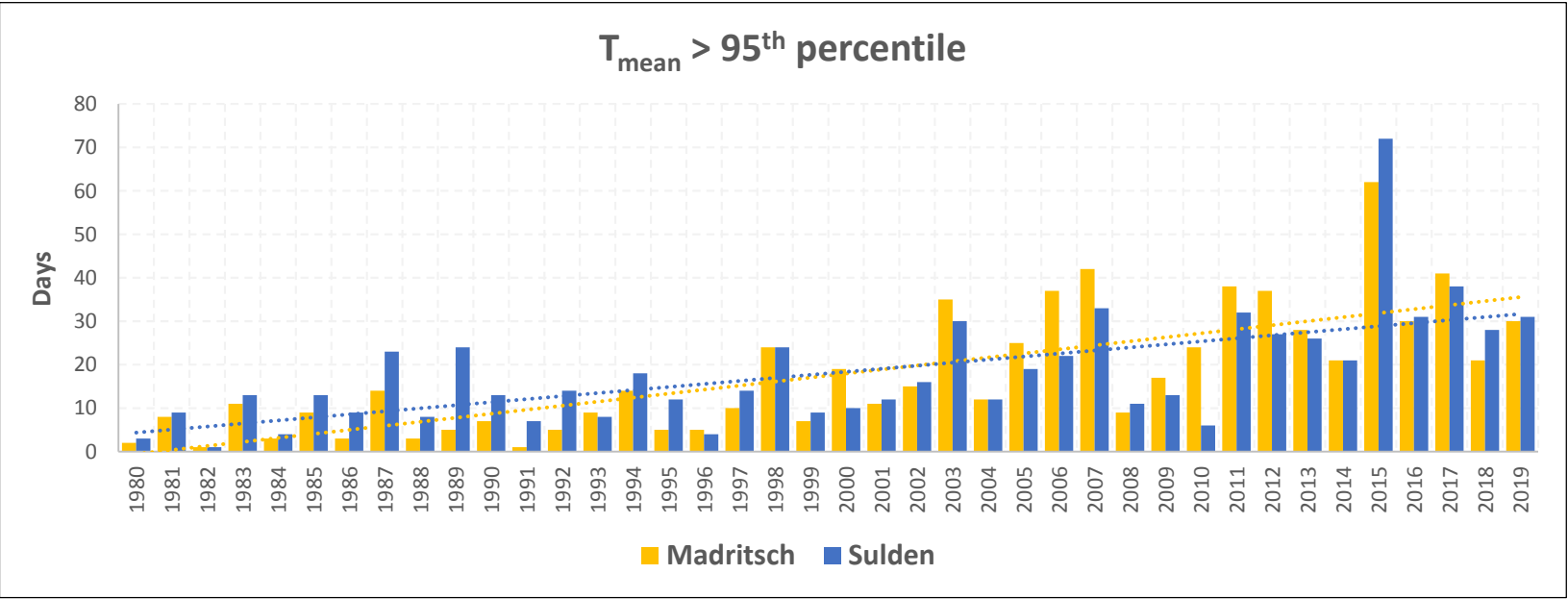


Climatic influence on slope instability

Decadal variations in temperature, precipitation, detachments (detach.), and debris-flow (D-Fs) events.

S = Sulden station at 1907 m asl,
M = Madritsch station at 2825 m asl.

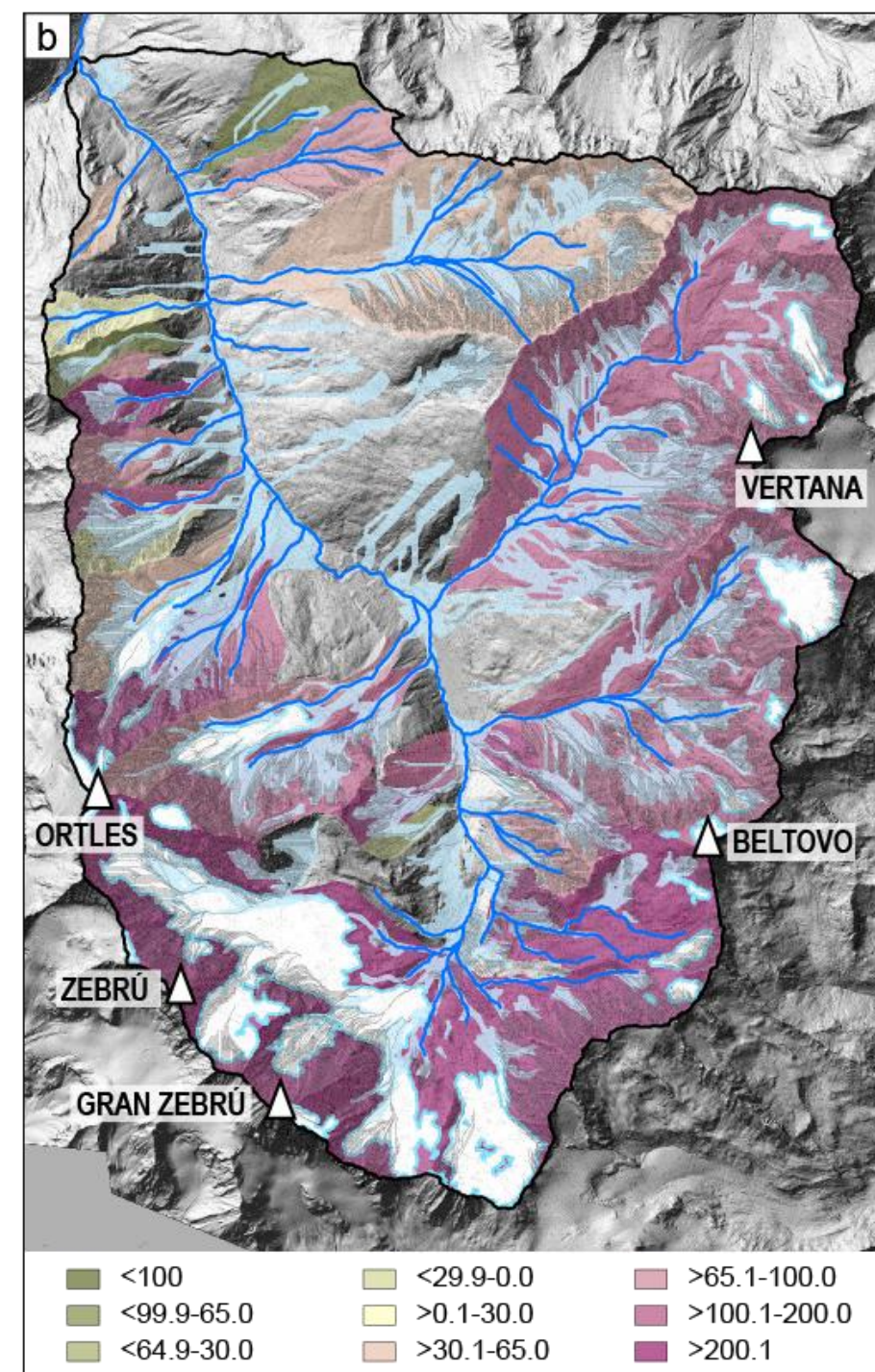
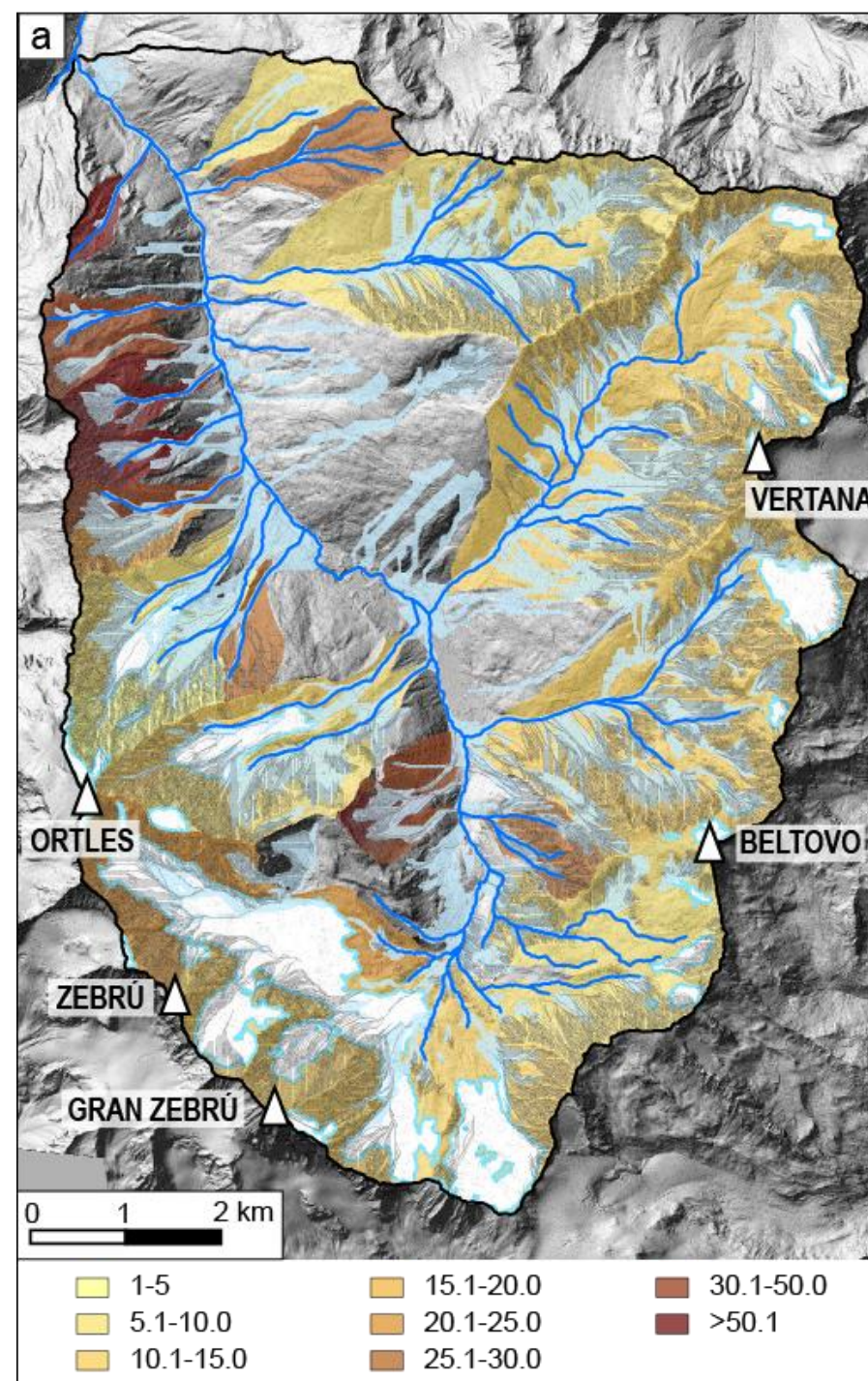
	Temperature				Precipitation				Events		
	MAAT* (°C)		Tmean > 95 th (days)		MAP* (mm)		Events > 75 th		No. of detach. points	No. of rainfall events triggering D-Fs	No. of D- Fs
	S	M	S	M	S	M	S	M			
1980–1989	2.4	-3	107	59					94	4	12
1990–1999	2.8	-2.3	123	87	800.5		103		88	0	0
2000–2009	3	-2.1	178	222	606.1		45		151	2	2
2010–2019	3.8	-1.3	312	332	891.8	1016.2	123	112	175	7	16

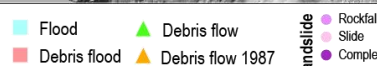
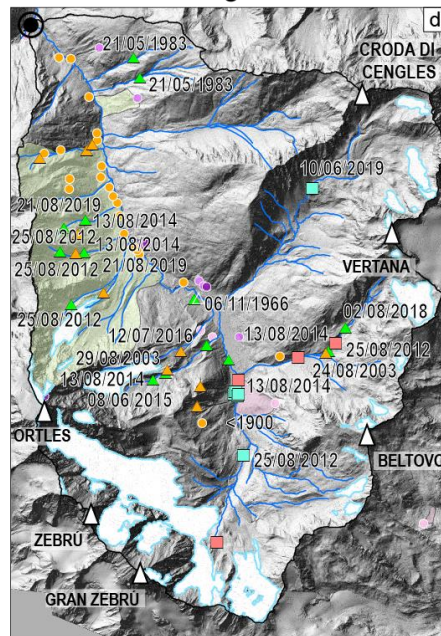
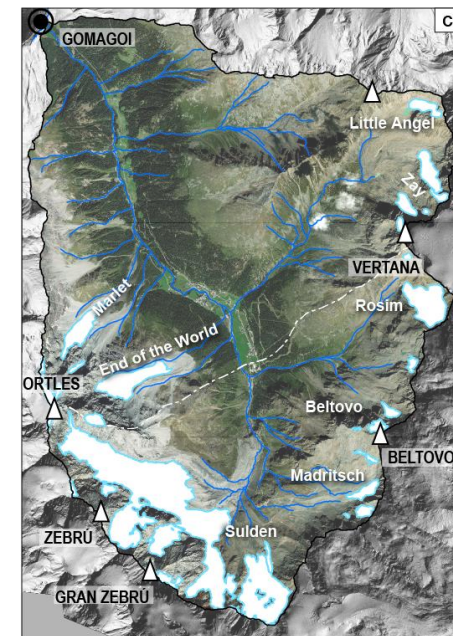
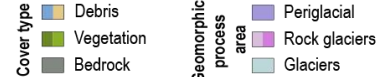
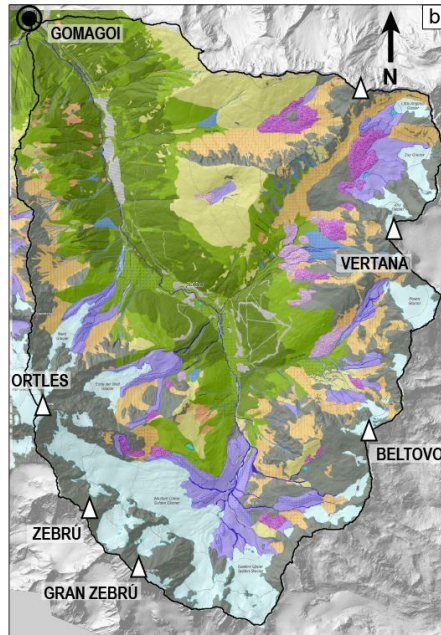
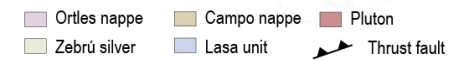
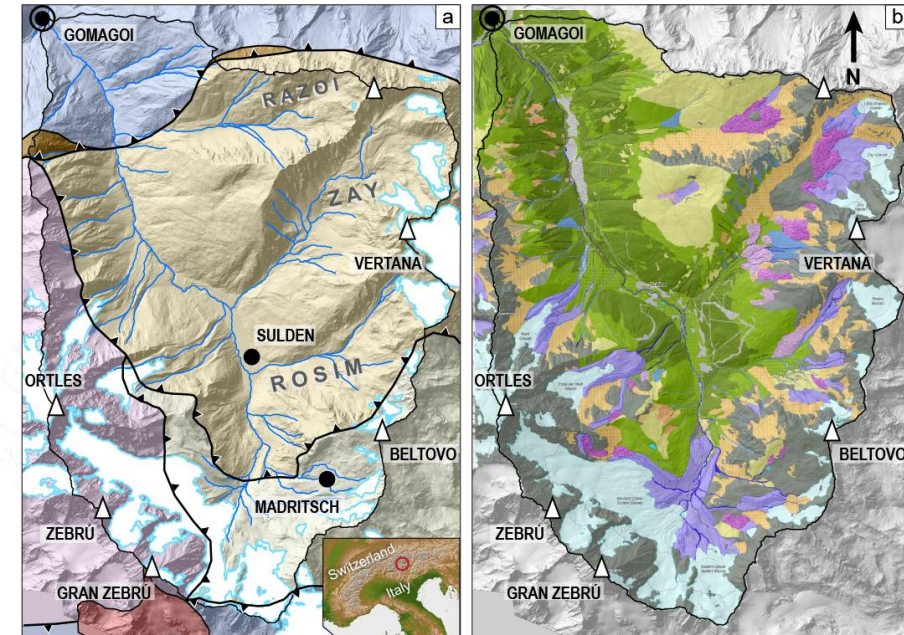


Change in slope instability and in possible related hazards

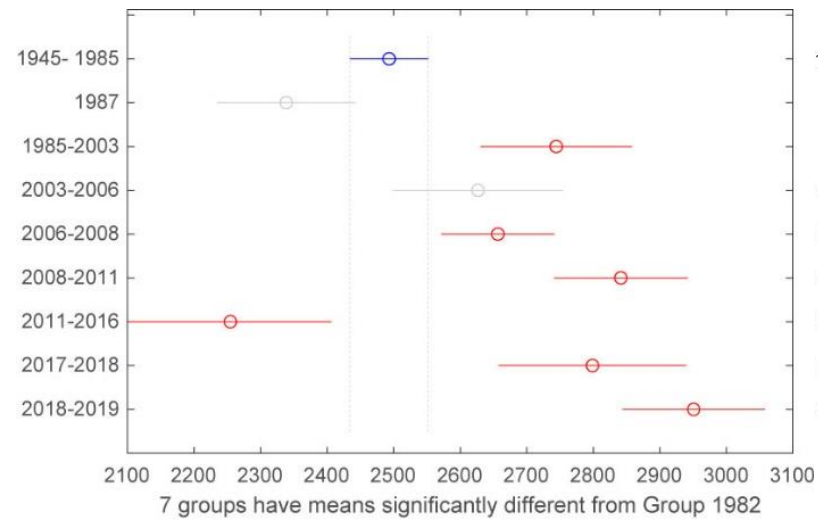
(a) Distribution of slope instability based on point density (e.g., number of detachments per km²) and showed for single tributaries (for the whole time period analyzed: 1945–2019).

(b) Percentage of change in point density between the time intervals 1985–2003 and 2003–2019

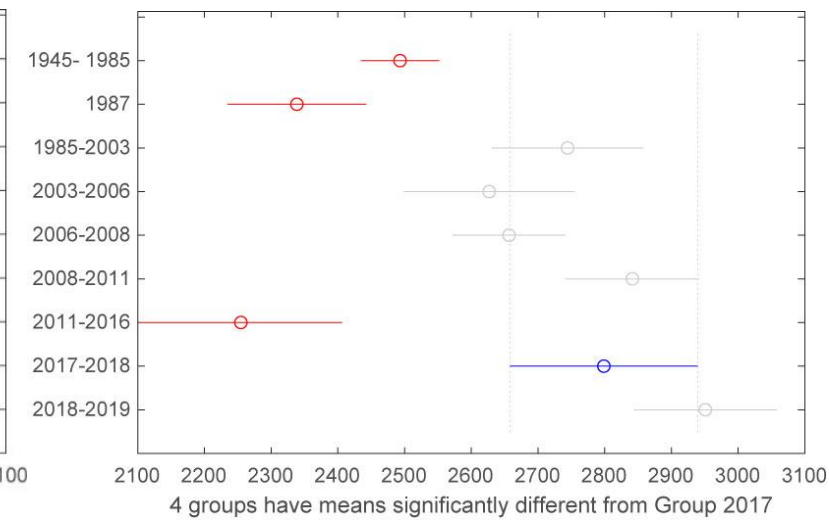




Comparison with the 1945-85 time period

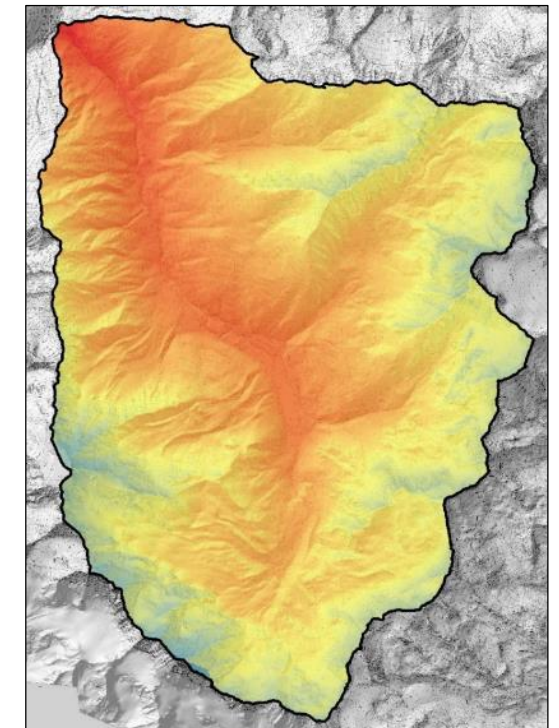
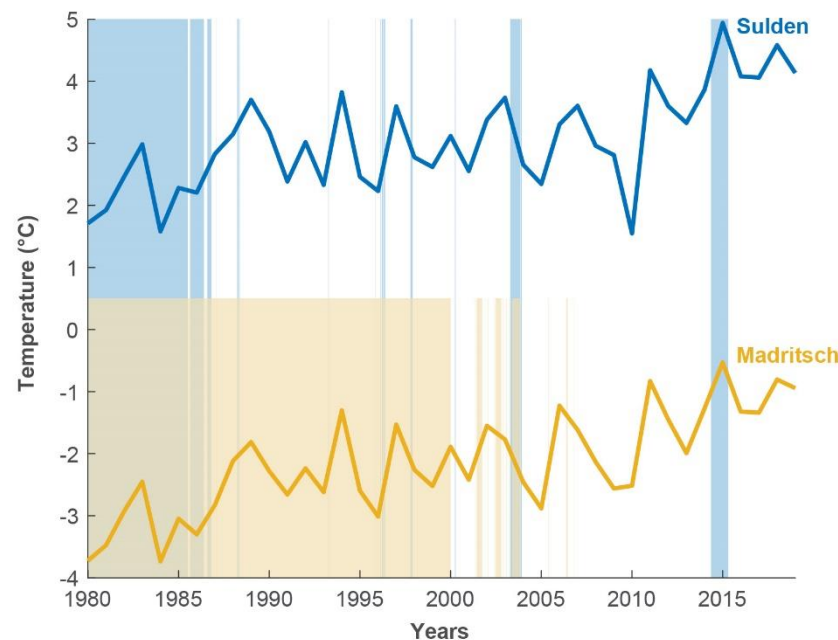


Comparison with the 2016-18 time period



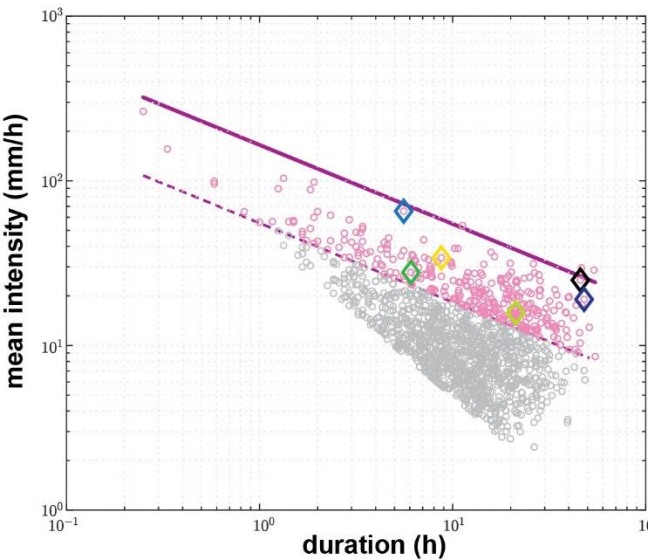
Temperature data and modeled MAGST

Mean Annual Air Temperature

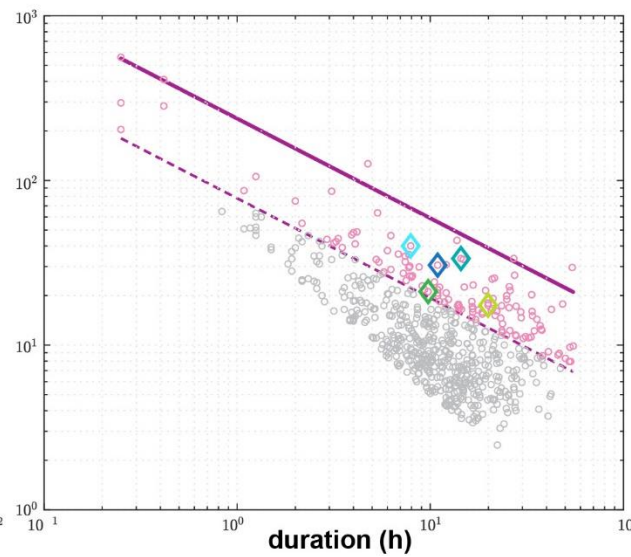


Rainfall: thresholds for debris flows

Sulden, threshold: 5mm, hiatus: 6h



Madritsch, threshold: 5mm, hiatus: 6h



I-D relationship

— This study
- - - 75th percentile

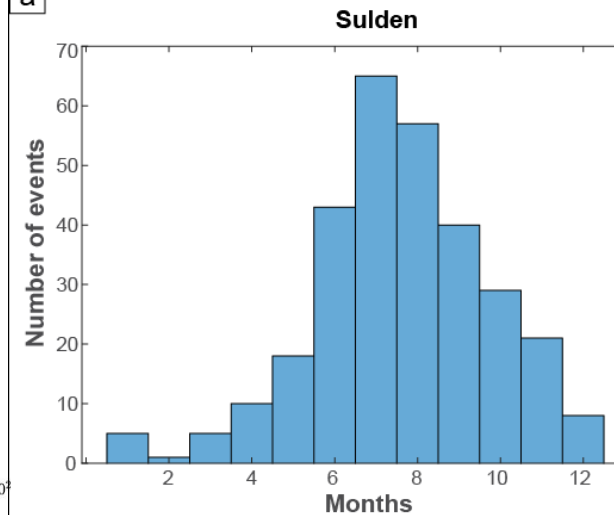
Debris -flows events

◊ 19-Jul-1987 ◊ 08-Jun-2015
◊ 24-Aug-1987 ◊ 12-Jul-2016
◊ 25-Aug-2012 ◊ 21-Aug-2019
◊ 12-Aug-2014

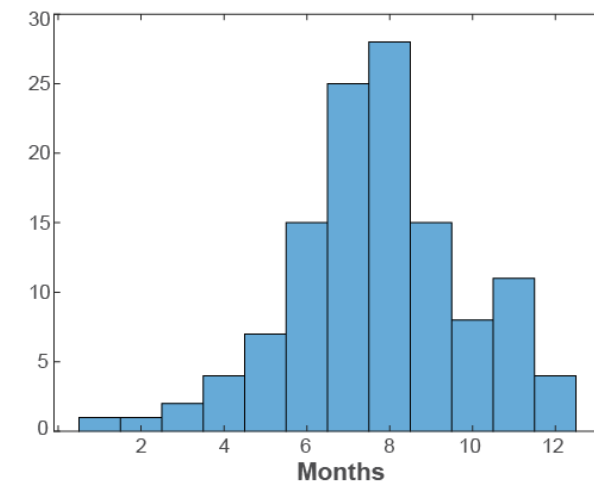
○ Rainfall events

Rainfall: variations through time

a



Madritsch



b

