Climate triggering of mass movements contributing to alpine sediment erosion

Conference Poster

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Climate triggering of mass movements contributing to alpine sediment erosion

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1 Introduction

Gravitational mass movements are key contributors to alpine sediment erosion. They are driven by complex physical processes and are challenging to predict.

→ Can we characterise mechanisms of sediment erosion by **triggering indices derived from climate variables**?

→ How well do these hydrometeorological indices correlate with records of mass movements?

2 Gravitational mass movements in the Alpine Rhine (1971-2022)

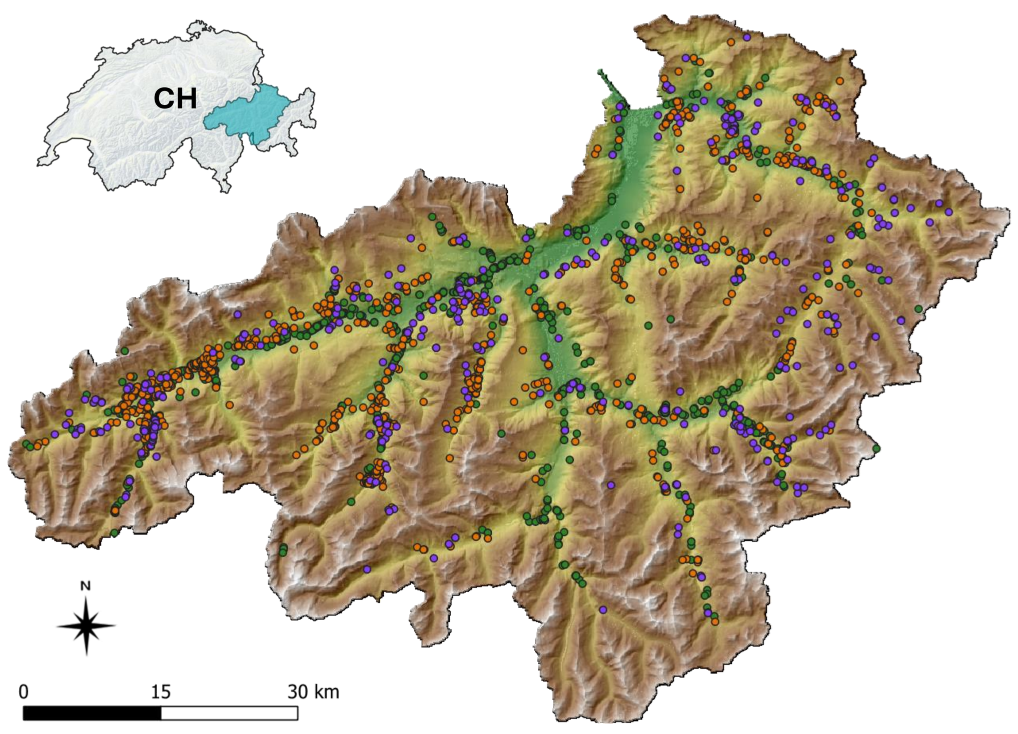


Fig. 1: Study basin of the Alpine Rhine with records of mass movements (1971-2022, FOEN StorMe).

Event-day cell counts for mass movement records

489	Shallow landslides
328	Debris flows
873	Rockfall

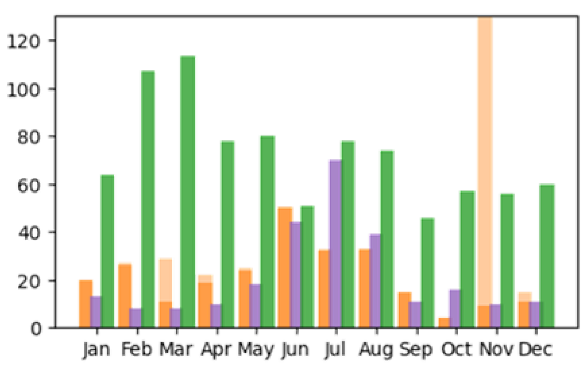
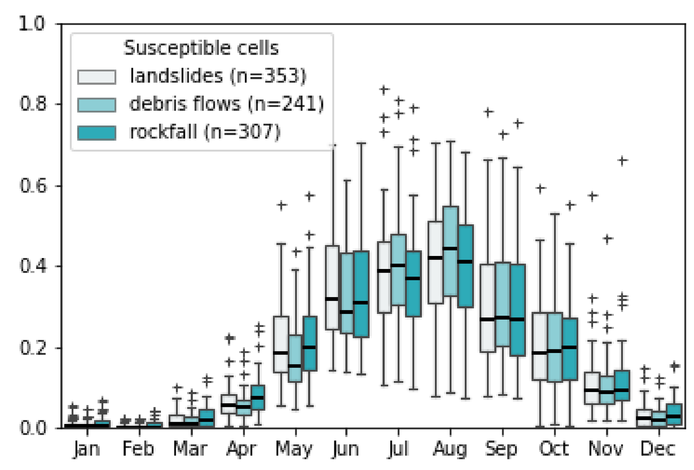


Fig. 2: Monthly counts of mass movement event-day cells (Leonarduzzi et al., 2017).

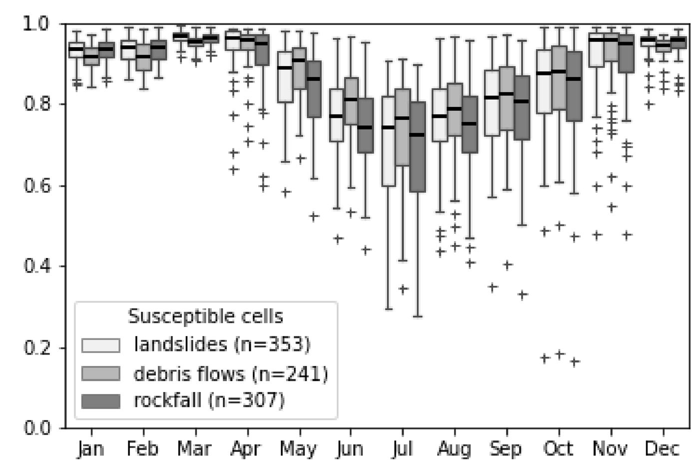
3 Modelling hydrometeorological indices on event days

A Modelling daily hydrometeorological conditions for 52 years (1971-2022) at a spatial resolution of 1 km^2, normalized by the maximum of the time series (Prenner et al. 2018):

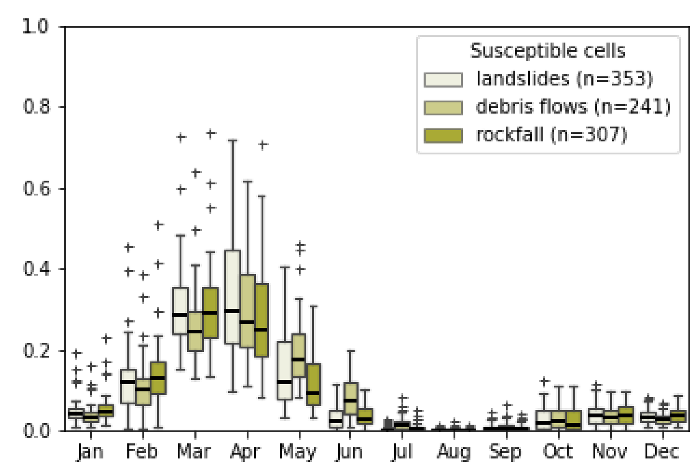
- **Rainfall index**
  Liquid precipitation



- **Soil moisture index**
  $\Delta SM = R + M - ET$



- **Snow melt index**
  Negative ΔSWE



- **Freeze-thaw index**
  Tmax for Tmin < -1 °C & Tmax > 0 °C if snowfree

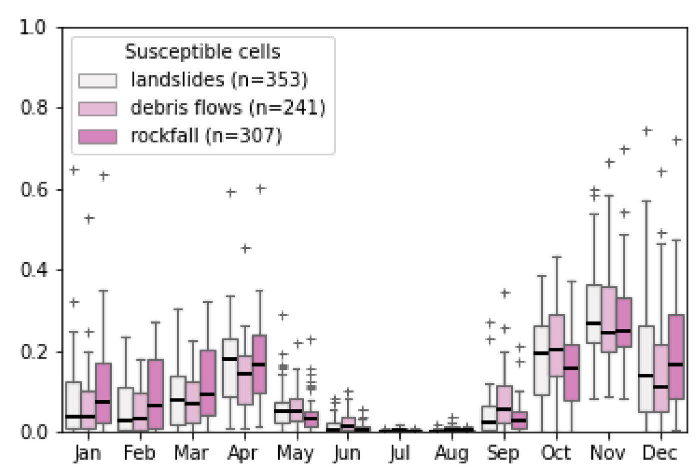


Fig. 3: Monthly variability of mean daily hydrometeorological indices in susceptible cells (1971-2022) for different mass movement event types.

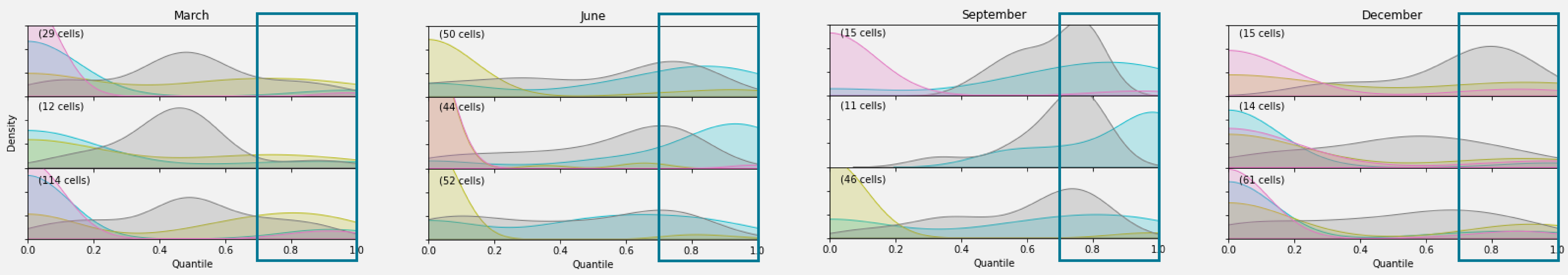
B Comparing hydrometeorological triggering indices on event days of mass movement records (FOEN StorMe) based on their monthly quantiles within the modelled time series of indices in susceptible cells:

Fig. 4: Quantiles of event day triggering indices for selected seasonal conditions (colors as in A, Fig. 3).

Landslides

Debris flows

Rockfall



Q3: 0.75 Q3: 0.75 Q3: 0.75 Q3: 0.75

Data sources

Federal Office for Meteorology and Climatology **MeteoSwiss**	Precipitation, temperature, rel. sunshine duration
WSL Institute for Snow and Avalanche Research **SLF**	Snow water equivalent (Mott et al. 2023)
Federal Office of Topography **Swisstopo**	Digital terrain model
Federal Office for the Environment **FOEN**	StorMe database of natural hazards

References

- Leonarduzzi E., Molnar P., McArdell B.W. (2017): Predictive performance of rainfall thresholds for shallow landslides in Switzerland from gridded daily data. Water Resour. Res., 53, 6612–6625.
- Mott R., Winstral A., Cluzet B., Helbig N., Magnusson J., Mazzotti G., Quéno L., Schirmer M., Webster C. and Jonas T. (2023) Operational snow-hydrological modeling for Switzerland. Front. Earth Sci. 11, 1228158 (20 pp.).
- Prenner D., Kaitna R., Mostbauer K. and Hrachowitz M. (2018): The Value of Using Multiple Hydrometeorological Variables to Predict Temporal Debris Flow Susceptibility in an Alpine Environment. Water Resources Research, 54(9), 6822–6843.

4 Conclusion

The results expand our understanding of **climate-induced erosion triggering mechanisms** in the Alps:

- **Soil moisture and rainfall** are dominant amongst the triggering indices for mass movement events in summer and autumn, with values ranging in the third quartile (> 0.75).
- **Soil moisture index** is the strongest driver for winter events, transitioning to **snow melt index** for events in spring.
- Especially rockfall events feature **freeze-thaw indices** in higher quantiles in winter and spring, yet with low frequencies.

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