

Meteorological and hydrological conditions triggering rockfall events in Germany

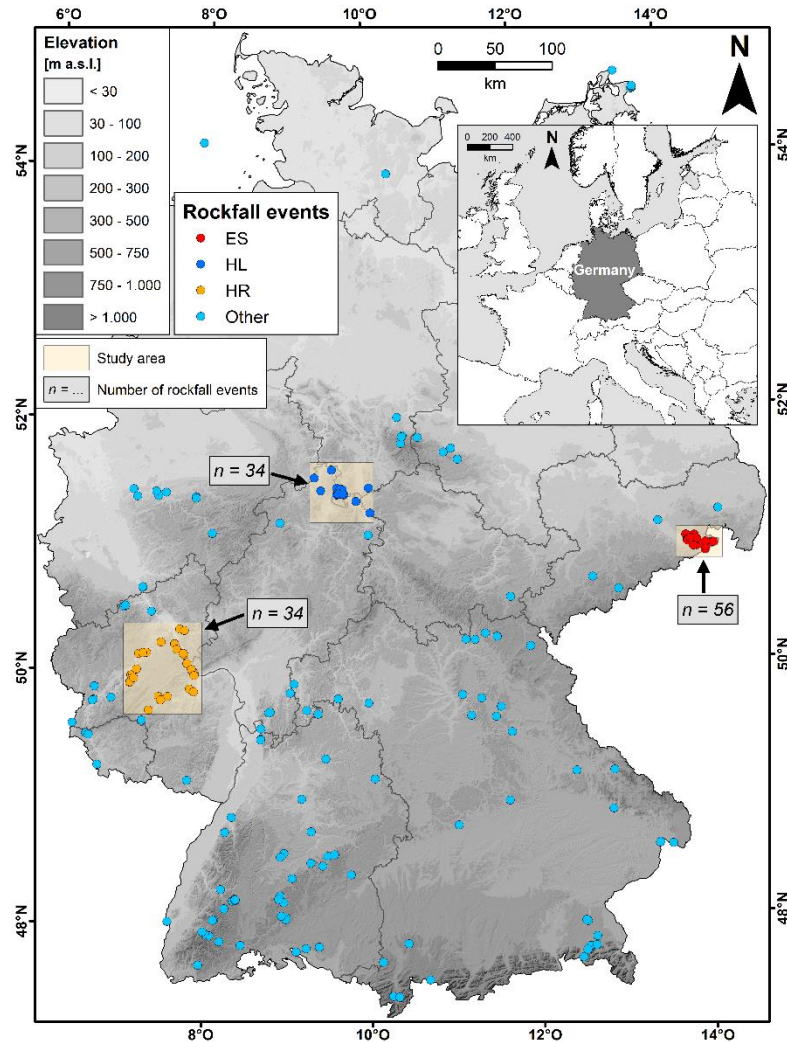
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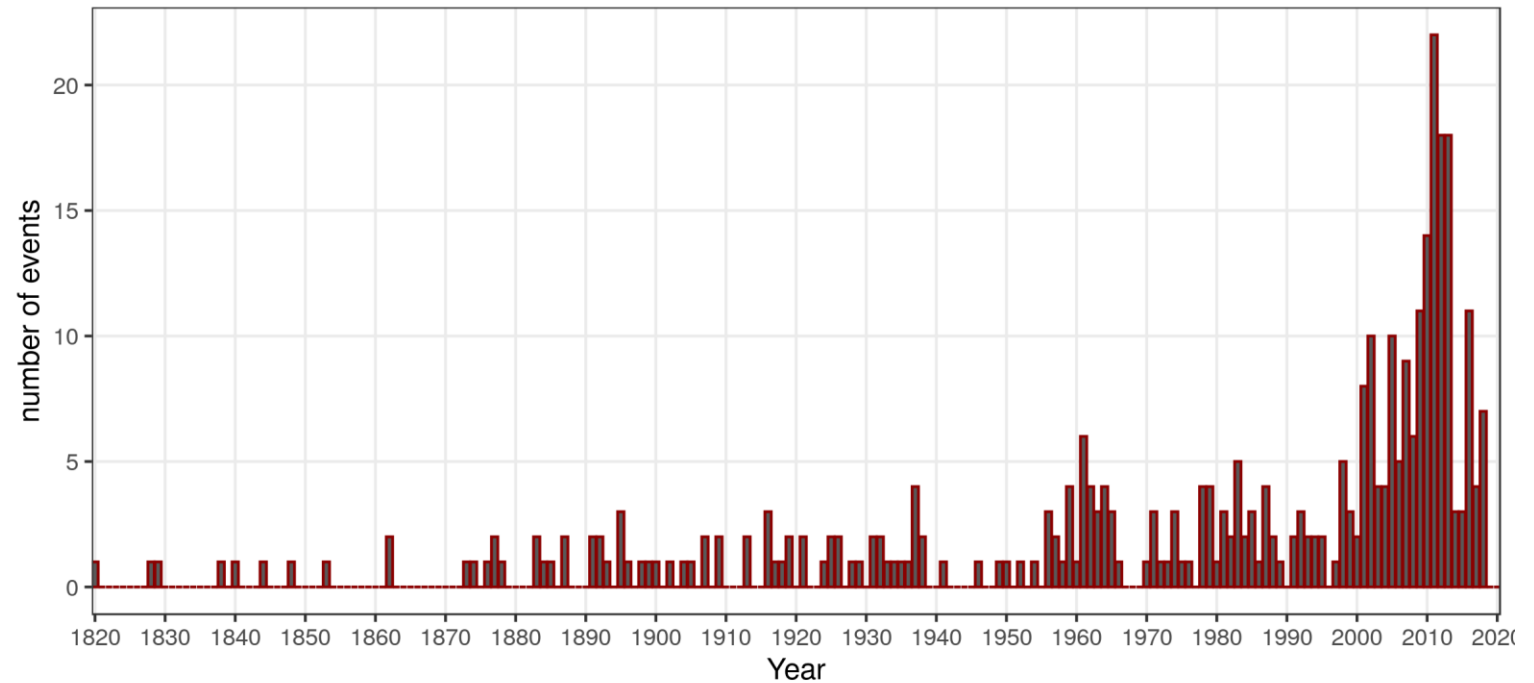
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Rockfall Data



The rockfall events are a subset taken from the landslide database for Germany (Damm and Klose, 2015, Rupp and Damm, 2020)

Rockfall events in data base



Relevant meteorological and hydrological parameters (literature)

- Precipitation (e.g. Sandersen et al. 1996, Dietze et al. 2017)
- Soil moisture for porous rocks (e.g. West 1994, Vásárhelyi 2005)
- Freeze-thawing cycles (e.g. Porter and Orombelli 1981, D'Amato et al. 2016)

Meteorological and hydrological data used in this study

Variable	Name of data set	Description	Temporal coverage	Horizontal resolution
Precipitation (amount)	REGNIE	Observations interpolated to a regular grid (Rauthe et al. 2013).	Starts 1931 (West Germany) or 1951	1 km ²
Precipitation (intensity)	RadKlim	Radar adjusted to rain gauge at hourly resolution (Winterrath et al. 2018)	Starts 2001	1x1 km
Soil moisture		Soil moisture simulations with mHM (Samaniego et al. 2010). Calibrated using gauge measurements.	1951-2013	5x5 km
Temperature	E-Obs	Cornes et al. 2018 Ensemble mean of daily maximum and minimum used to find freeze-thawing episodes	Starts 1950	0.1°x0.1°

Relationship between meteorological and hydrological factors and rockfall probability can be confirmed

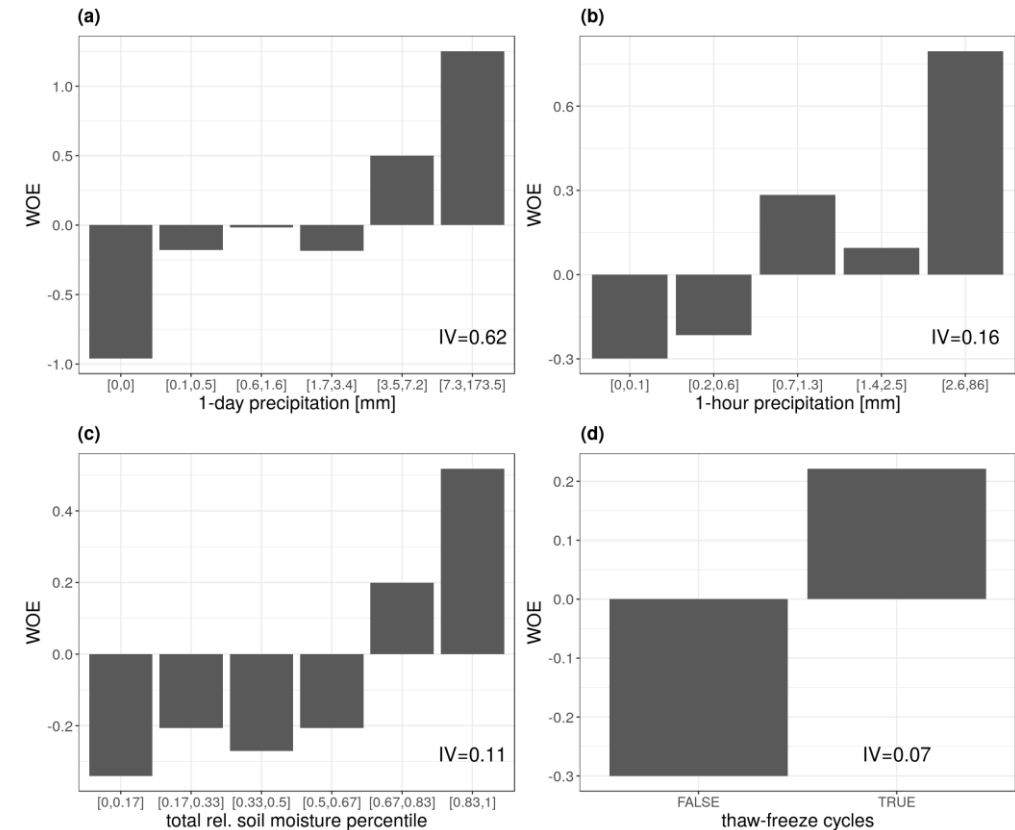
Method: Weights of Evidence (WOE)

Probability of Y for a given condition X_j

$$\log \frac{P(Y = 1|X_j)}{P(Y = 0|X_j)} = \underbrace{\log \frac{P(Y = 1)}{P(Y = 0)}}_{\text{sample log-odds}} + \underbrace{\log \frac{f(X_j|Y = 1)}{f(X_j|Y = 0)}}_{\text{WOE}}$$

Information Value (IV)

$$IV_j = \int \log \frac{f(X_j|Y = 1)}{f(X_j|Y = 0)} (f(X_j|Y = 1) - f(X_j|Y = 0)) dx$$



The figures show how the probability for rockfall events changes for different states of meteorol./hydrol. conditions.

A statistical model to quantify changes in rockfall probability that considers interactions between triggering factors was build

Method: The best logistic regression model was selected based on the logarithmic skill score using cross validation

Best logistic regression model:

$$p_k = \frac{1}{1 + \exp(-\beta_0 - \beta_1 precip_1d_k - \beta_2 sm_k - \beta_3 fe_k - \beta_4 precip_1d_k sm_k)}$$

p_k : Probability for rockfall event at day k

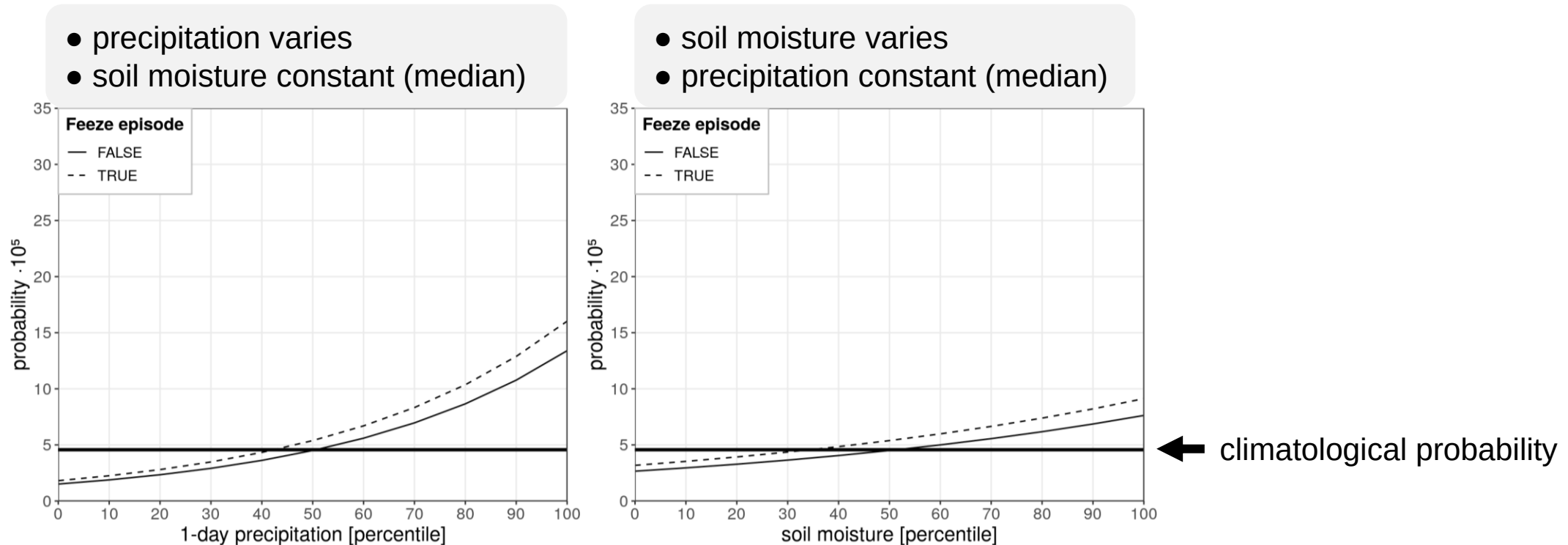
$precip_1d$: Local percentile of daily precipitation

sm : Across-site percentile of relative soil moisture (0-1.8m depth)

fe : Freezing episode occurred in previous 3 weeks

β : Regression coefficients

Results of statistical model



The figures show how the probability for rockfall events changes according to the logistic regression model. A dashed/solid curve denotes the result for situations with/without the occurrence of a freezing episode in the previous three weeks. Left: For different local percentiles of daily precipitation under constant (median) soil moisture conditions; Right: For different percentiles of soil moisture under constant (median) precipitation conditions.

Conclusions

- A statistical model was build that quantifies changes in rockfall probability under different meteorological and hydrological conditions.
- The most important factor is precipitation amount (intensity did not improve the model).
- Precipitation is more effective if the soil moisture content is high.
- A rockfall event is more likely if a freezing episode occurred in the previous weeks.

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