A decrease in rockfall probability associated with changing meteorological conditions in Germany

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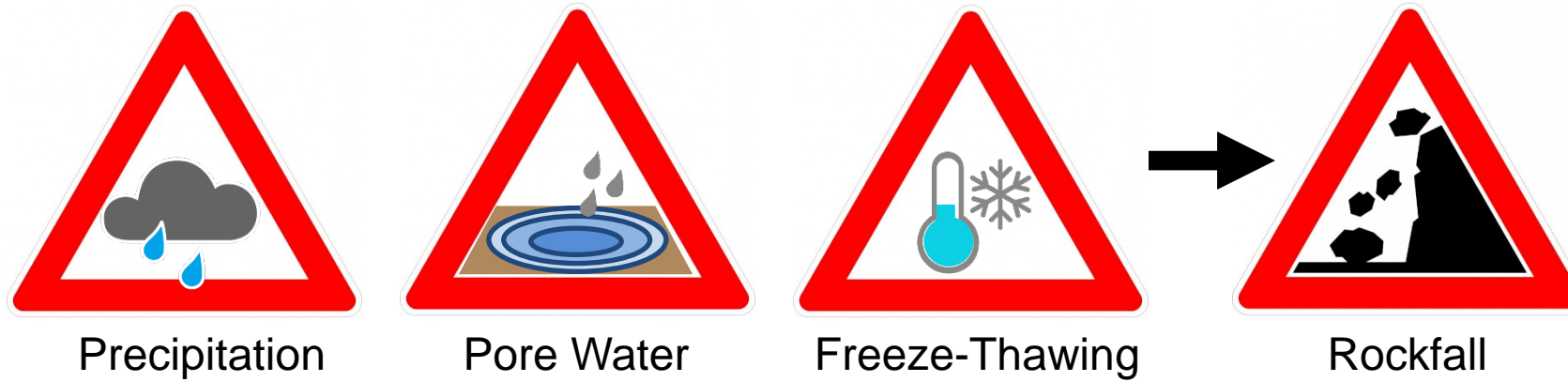
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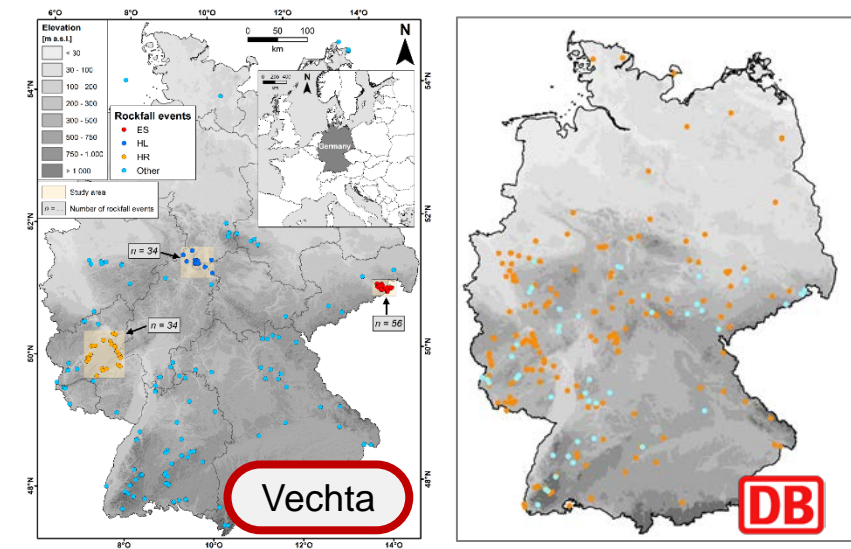
Background

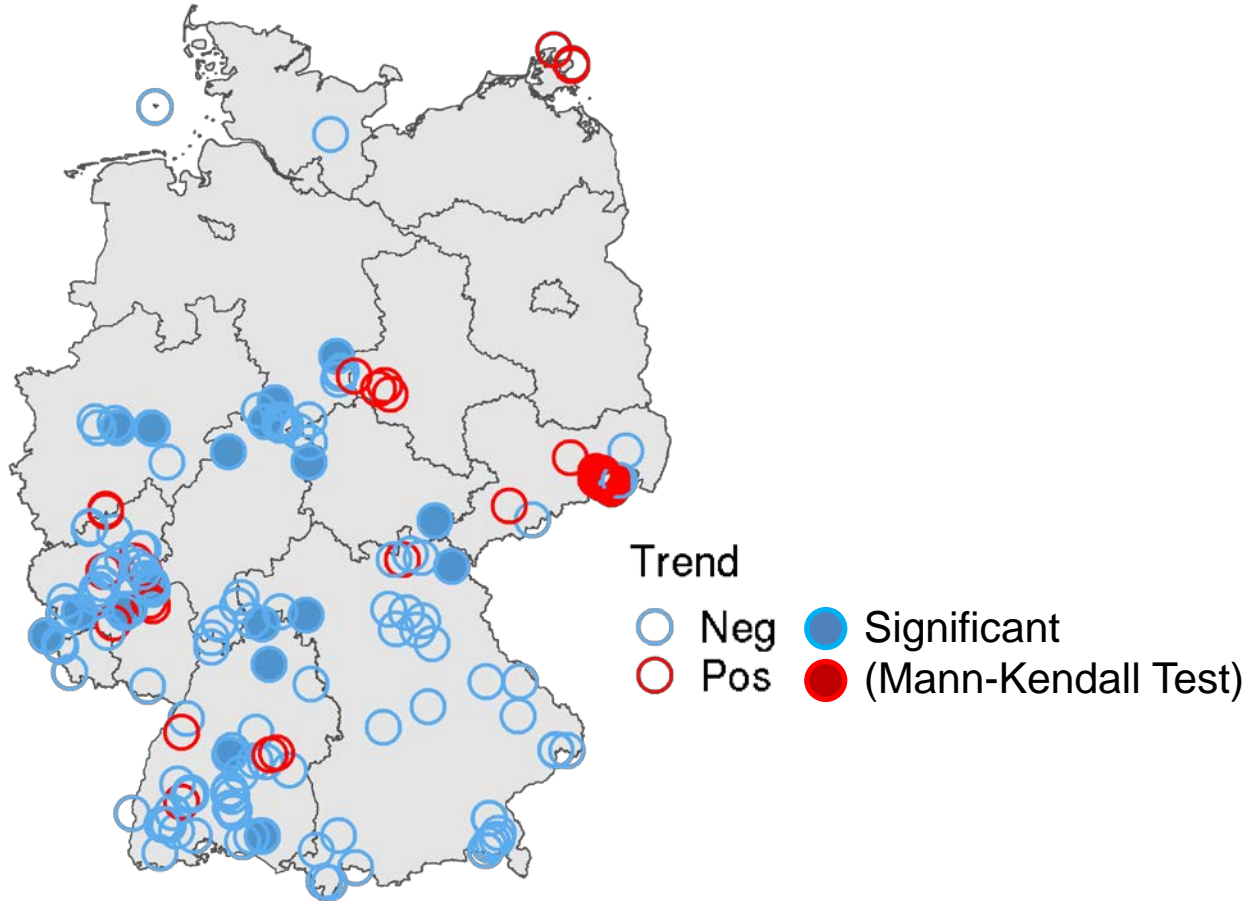
Precipitation   Pore Water   Freeze-Thawing   Rockfall

Logistic regression model:

$$p = \frac{1}{1 + \exp(-\beta_0 - \beta_1 precip - \beta_2 pw - \beta_3 ft - \beta_4 precip\ pw)}$$

Nissen et al.: https://doi.org/10.5194/nhess-2021-243 (under review)

Rockfall data

Trends (1950-2020) from logistic regression model

Trend
- Neg (open blue circle)   ● Significant
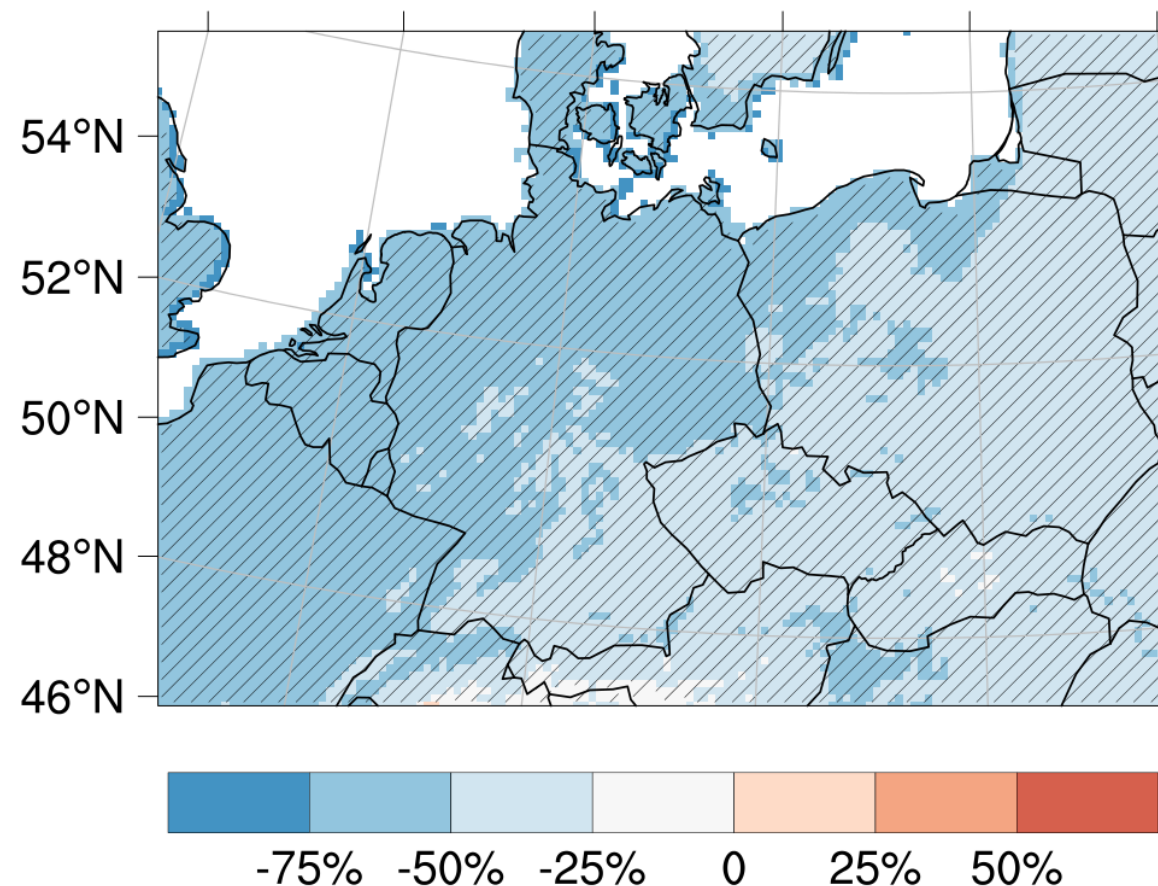- Pos (open red circle)   ● (Mann-Kendall Test)

Input: Gridded meteorological station data

- E-OBS (Tmin,Tmax) *Cornes et al. 2018*
- REGNIE (Precip) *Rauthe et al. 2013*

Trend in annual number of days with prob>prob$_{clim}$ mostly negative. Stat. significant only at few stations.
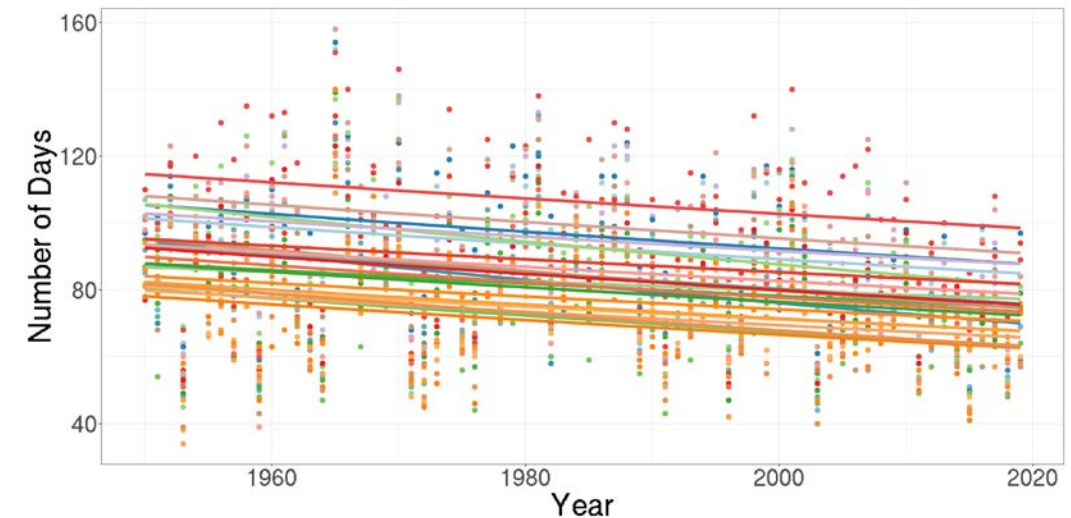
Decrease at stations with statistical significance is between -2 and -4% per decade

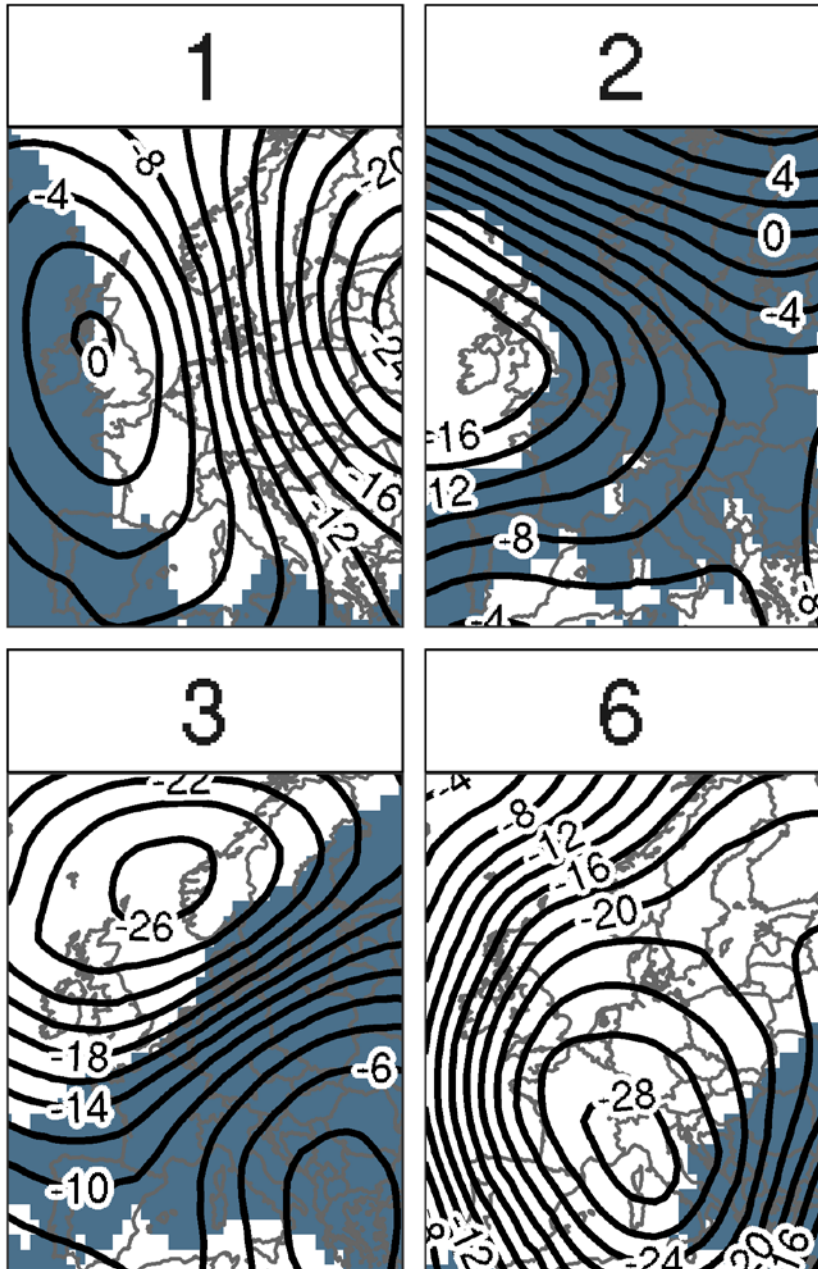# Analysis of climate change simulations using the logistic regression model

1971-2000 vs. 2071-2100
RCP8.5 EURO-CORDEX-11

Driving Model	Regional Model
CNRM-CERFACS-CNRM-CM5	SMHI-RCA4-v1
ICHEC-EC-EARTH	SMHI-RCA4-v1
IPSL-IPSL-CM5A-MR	SMHI-RCA4-v1
MOHC-HADGEM2-ES	SMHI-RCA4-v1
MPI-M-MPI-ESM-LR	SMHI-RCA4-v1
ICHEC-EC-EARTH	DMI-HIRHAM5-v1
NCC-NORESM1-M	DMI-HIRHAM5-v1
IPSL-CM5A-MR	IPSL-INERIS-WRF331F-v1
CNRM-CERFACS-CNRM-CM5	CLMcom-CCLM4-8-17-v1
ICHEC-EC-EARTH	CLMcom-CCLM4-8-17-v1
MOHC-HADGEM2-ES	CLMcom-CCLM4-8-17-v1
MPI-M-MPI-ESM-LR	CLMcom-CCLM4-8-17-v1
MPI-M-MPI-ESM-LR	MPI-CSC-REMO2009-v1
CNRM-CERFACS-CNRM-CM5	KNMI-RACMO22E-v2
MOHC-HADGEM2-ES	KNMI-RACMO22E-v2
ICHEC-EC-EARTH	KNMI-RACMO22E-v1
IPSL-IPSL-CM5A-MR	KNMI-RACMO22E-v1
MPI-M-MPI-ESM-LR	KNMI-RACMO22E-v1
NCC-NORESM1-M	KNMI-RACMO22E-v1
MPI-M-MPI-ESM-LR	GERICS-REMO2015-v1
NCC-NORESM1-M	GERICS-REMO2015-v1

Colour: Number of days per year with prob > $prob_{clim}$ decreases
Hatched: Monte Carlo Test indicates at least 90% statistical significance in 90% of the models

Alternative approach

Idea: Large-scale weather patterns are more robust than small scale meteorological variables
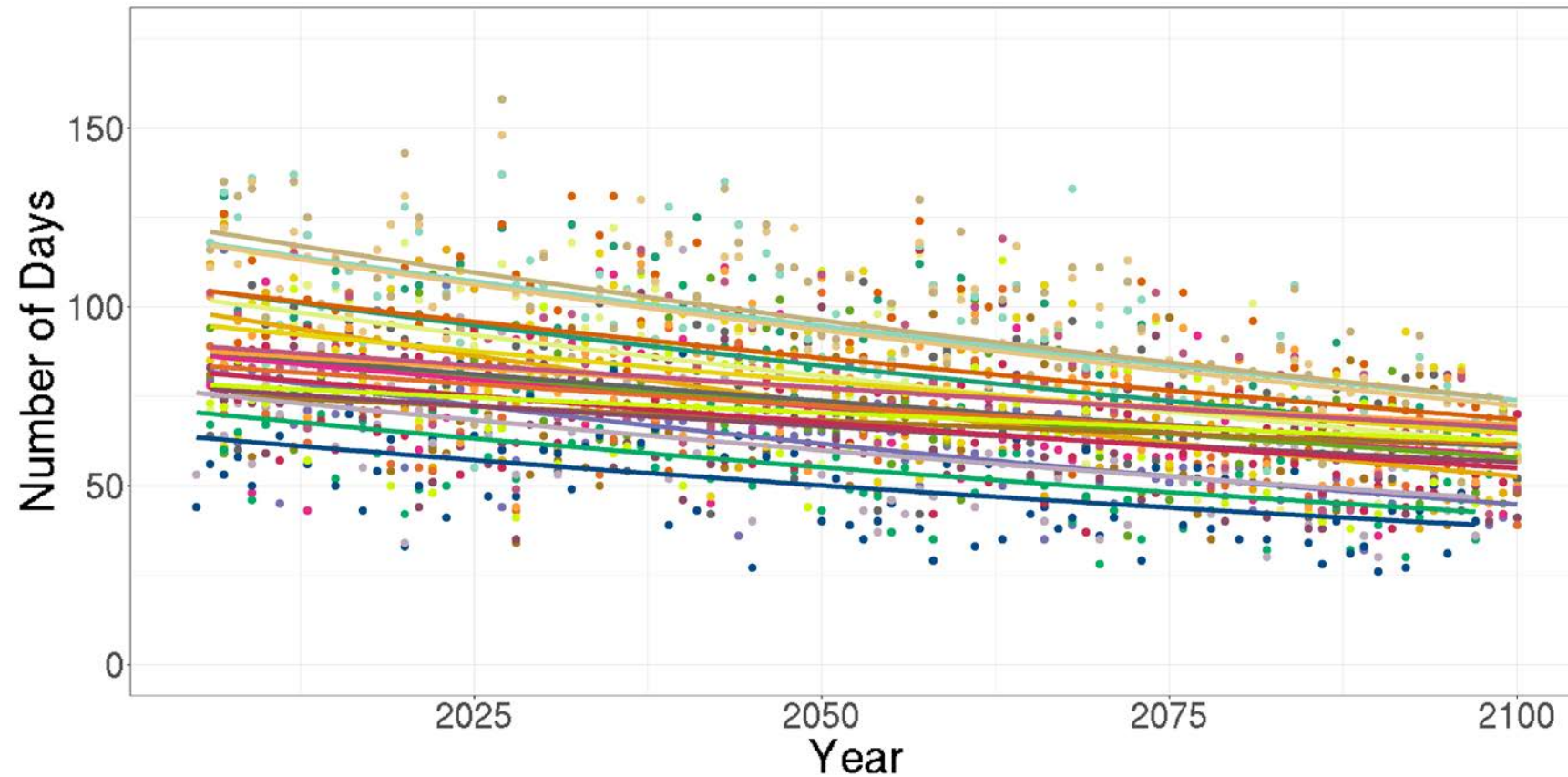
Identification of relevant weather patterns:
1. SANDRA clustering algorithm applied to weather situations at rockfall days (ERA5 data)
2. All other days are assigned to clusters and relevance of classes for rockfall is determined (X^2-test).
3. Comparison of 220 classifications based on 500hPa geopotential height (GPH500) or mean sea-level pressure.

Result: 4 relevant large-scale patterns. They include 34% of the events and 16% of all days. Combined probability increase 106%

Figure: Composite of GPH500 (dam) and water vapour anomalies for the relevant large-scale weather patterns

Analysis of climate change simulations based on weather patterns

RCP8.5 EURO-CORDEX-11

Trends in the number of days associated with the relevant weather patterns are negative and statistically significant (95%) in all scenario simulations.
Decrease between -0.5 and -1.5% per decade.
The colours represent the different simulations.

Summary

Analysis trends in rockfall probability due to meteorological conditions
- 2 methods (logistic regression and large-scale weather patterns)
- 2 periods (observational period, climate scenario simulations)

Robust signal: Decrease in the probability for rockfall in Germany