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Recent trends in heavy precipitation extremes over Germany: A thorough intercomparison between different statistical approaches

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The appropriate statistical evaluation of recent changes in the occurrence of hydro-meteorological extreme events is of key importance for identifying trends in the behavior of climate extremes and associated impacts on ecosystems or technological infrastructures, as well as for validating the capability of models used for future climate scenarios to correctly represent such trends in the past decades. In this context, most recent studies have utilized conceptual approaches from extreme value theory based on parametric descriptions of the probability distribution functions of extremes. However, the application of such methods is faced with a few fundamental challenges: (1) The application of the most widely used approaches of generalized extreme value (GEV) or generalized Pareto (GP) distributions is based on assumptions the validity of which can often be hardly proven. (2) Due to the differentiation between extreme and normal values (peaks-over-threshold, block maxima), much information on the distribution of the variable of interest is not used at all by such methods, implying that the sample size of values effectively used for estimating the parameters of the GEV or GP distributions is largely limited for typical lengths of observational series. (3) The problem of parameter estimation is further enhanced by the variety of possibly statistical models mapping different aspects of temporal changes of extremes like seasonality or possibly non-linear trends. Reliably identifying the most appropriate model is a challenging task for the lengths of typical observational series.

As an alternative to approaches based on extreme value theory, there have been a few attempts to transfer quantile regression approaches to statistically describing the time-dependence of climate extremes. In this context, a value exceeding a certain instantaneous percentile of the time-dependent probability distribution function of the data under study is considered to be an extreme event. In comparison with GEV and GP-based approaches, quantile regression approaches thus allow for more flexibility and make full use of all available observational values, no matter if extreme or not. Due to the latter fact, trends in extreme values can be more easily assessed based on shorter time series. However, the question under which conditions and to what extent regression and extreme value theory-based approaches provide consistent results has not yet been fully explored.

In this study, we provide a thorough inter-comparison between the recent trends in extreme precipitation events (assessed in terms of daily precipitation sums) from a large set of German weather stations as revealed by the classical (monthly) block maxima method with linearly time-dependent GEV parameters and linear quantile regression of the full time series. For the study period from 1951 to 2006, our main findings are as follows: (1) The spatial patterns of quantile trends for various high (>90%) percentiles and trends in the location parameter of the GEV distribution are qualitatively consistent and exhibit significant correlations, which, however, clearly deviate from an ideal correspondence. (2) In comparison with the trend parameters, the intercepts of the respective linear models for the GEV location parameter and different quantiles exhibit considerably larger mutual correlation values. (3) Quantile regression indicates more stations with strongly positive trends in extreme precipitation than the block maxima method. Moreover, the significance statements provided by the GEV statistics are more conservative than those resulting from quantile regression. Significant upward trends are generally restricted to Southern and Western Germany and are almost completely absent in the Northeastern part of the country. (4) More complex GEV models including linear trends in both location and dispersion parameter need to be considered only for a small subset of all stations (202 out of 2342). In most cases, linear trends in the location parameter are sufficient (which are significant for 803 stations).

In summary, quantile regression provides a prospective alternative tool for statistically identifying and quantifying robust trends in hydro-meteorological extremes, which has certain conceptual benefits that allow its application to shorter time series than commonly required in the context of studies on time-dependent extremes. However,

further systematic inter-comparisons with classical approaches based on extreme value theory are necessary in order to identify the fundamental causes of deviations between the trends revealed by both concepts.