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Statistical modelling of precipitation time series including probability assessments of extreme events

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The analysis of climate variability as reflected in observational records is an important challenge in statistical climatology. Temperature time series can be interpreted as a superposition of trends, the annual cycle and its changes concerning amplitude and phase shifts, an episodic component and extreme events. After elimination of these structured components the residuals are undisdinguishable from the realization of a Gaussian distributed random variable with constant variance. In this case the least-squares estimator becomes a maximum likelihood estimator and can be used to estimate the structured components mentioned above in the mean value of the Gaussian distributed random variable. But the simple modell of a Gaussian distribution shifting with variation in time is insufficent to describe precipitation time series. We observe a skewed distribution, changes in variance and also changes in the shape of the distribution. Application of the least-squares estimator in precipitation analyses lead to eratic estimators.

Consequently, a generalized time series decomposition technique is presented allowing a free choice of the underlying probability density function (PDF). The signal (structured components like trends, annual cycle etc.) is detected in two instead of one parameter of a PDF, which can be chosen without any further restriction. So, the scale parameter of any PDF is no longer seen as a constant but rather affected by a deterministic process. In particular, the method introduced provides a consistent decomposition of precipitation time series in a statistical and a deterministic part. The full analytical description in terms of the estimated PDF for every time step of the observation period allows to quantify the probability of exceeding optional upper or lower thresholds, respectively, for any time step. Because each observed precipitation

total is interpreted as only one possible realization of the PDF at the given time the probability for exceeding any other thresholds can be estimated, too. And not only probability assessments of extreme events but also estimates of trends in the expected value based on the method introduced take changes in the location, the scale, and the shape of the distribution into account.

The analysis of a European station-based data set of recent monthly precipitation totals shows that the majority of the time series can be interpreted as a realization of a Gumbel distributed random variable with time-dependent scale and location parameter or a Weibull distributed random variable with time-dependent scale and shape parameter.

In the special case of 132 time series of monthly precipitation totals 1901-2000, from German stations, an increase in the probability of exceeding the 95th percentile and a decrease in the probability of falling under the 5th percentile can be detected most of the year at several stations in the southern part of Germany. In the western part, we observe the same phenomenon in the summer months but these changes go along with smaller magnitudes. However, climate is becoming more extreme in that region in winter: Probability for both exceeding the 95th percentile and for falling under the 5th percentile is increasing. Some stations show a shift of the maximum probability exceeding the 95th percentiles from summer to winter in the western part of Germany. This is closely related to an increasing scale parameter in winter and a decreasing one in summer. In the eastern part of Germany, increases in the probability of occurrence of relatively low precipitation in winter as well as decreases in both probabilities ($>$95th percentile, $<$5th percentile) in summer and autumn prevail.