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Modelling probabilities of heavy precipitation by regional approaches

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Extreme precipitation events are associated with large negative consequences for human society, mainly as they may trigger floods and landslides. The recent series of flash floods in central Europe (affecting several isolated areas) on June 24-28, 2009, the worst one over several decades in the Czech Republic as to the number of persons killed and the extent of damage to buildings and infrastructure, is an example. Estimates of growth curves and design values (corresponding e.g. to 50-yr and 100-yr return periods) of precipitation amounts, together with their uncertainty, are important in hydrological modelling and other applications. The interest in high quantiles of precipitation distributions is also related to possible climate change effects, as climate model simulations tend to project increased severity of precipitation extremes in a warmer climate.
The present study compares – in terms of Monte Carlo simulation experiments – several methods to modelling probabilities of precipitation extremes that make use of 'regional approaches': the estimation of distributions of extremes takes into account data in a 'region' ('pooling group'), in which one may assume that the distributions at individual sites are identical apart from a site-specific scaling factor (the condition is referred to as 'regional homogeneity'). In other words, all data in a region – often weighted in some way – are taken into account when estimating the probability distribution of extremes at a given site. The advantage is that sampling variations in the estimates of model parameters and high quantiles are to a large extent reduced compared to the single-site analysis.
We focus on the 'region-of-influence' (ROI) method which is based on the identification of unique pooling groups (forming the database for the estimation) for each site under study. The similarity of sites is evaluated in terms of a set of site attributes related to the distributions of extremes. The issue of the size of the region is linked with a built-in test on regional homogeneity of data. Once a pooling group is delineated, weights based on a dissimilarity measure are assigned to individual sites involved in a pooling group, and all (weighted) data are employed in the estimation of model parameters and high quantiles at a given location. The ROI method is compared with the Hosking-Wallis (HW) regional frequency analysis, which is based on delineating fixed regions (instead of flexible pooling groups) and assigning unit weights to all sites in a region.
The comparison of the performance of the individual regional models makes use of data on annual maxima of 1-day precipitation amounts at 209 stations covering the Czech Republic, with altitudes ranging from 150 to 1490 m a.s.l. We conclude that the ROI methodology is superior to the HW analysis, particularly for very high quantiles (100-yr return values). Another advantage of the ROI approach is that subjective decisions – unavoidable when fixed regions in the HW analysis are formed – may efficiently be suppressed, and almost all settings of the ROI method may be justified by results of the simulation experiments. The differences between (any) regional method and single-site analysis are very pronounced and suggest that the at-site estimation is highly unreliable.
The ROI method is then applied to estimate high quantiles of precipitation amounts at individual sites. The estimates and their uncertainty are compared with those from a single-site analysis. We focus on the eastern part of the Czech Republic, i.e. an area with complex orography and a particularly pronounced role of Mediterranean cyclones in producing precipitation extremes. The design values are compared with precipitation amounts recorded during the recent heavy precipitation events, including the one associated with the flash flood on June 24, 2009.
We also show that the ROI methodology may easily be transferred to the analysis of precipitation extremes in climate model outputs. It efficiently reduces (random) variations in the estimates of parameters of the extreme value distributions in individual gridboxes that result from large spatial variability of heavy precipitation, and represents a straightforward tool for 'weighting' data from neighbouring gridboxes within the estimation procedure.
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