Conference Paper, Published Version

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Statistics of Extreme Still Water Levels - Between Policy and Objectivity

STATISTICS OF EXTREME STILL WATER LEVELS - BETWEEN POLICY AND OBJECTIVITY

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For an efficient planning and design of coastal defense structures, an in-depth understanding of the stochastic behavior of extreme events is required. Consequently, several approaches for estimating probabilities of extreme still water levels have been developed over the last decades. Currently, different methods are applied on transnational, but also on national scales (e.g. in Germany), resulting in a heterogeneous level of protection. Applying different statistical methods can yield different estimates of still water levels. But even the use of the same model can produce huge discrepancies, caused by a subjective choice of the model setup. The comparison of design water levels of different federal states or countries is therefore hardly possible.

The most common methods for estimating probabilities of extreme still water levels are the block maxima method using GEV and the peak over threshold (POT) modelling using GPD. For both methods, a series of extreme values (sample) has to be selected. In the block maxima approach, the r-largest values within a block of usually one year are chosen. Despite its widely acceptance, extreme value analysis using block maxima with $r = 1$ is a wasteful method if further data of extremes are available. To overcome this issue, the use of the r-largest order statistics with $r > 1$, which incorporates more of the observed extreme data, can be applied. But even this method can be wasteful if one block contains more extremes than another (Coles 2001). An alternative is the use of the POT approach, which, however, is subjected to the choice of an appropriate threshold. Over the last decades, several threshold selection techniques have been introduced. Nevertheless, the determination of the threshold using most of these methods remains subjective and the threshold cannot be selected automatically. We use a double stage approach, which accounts for an automatic threshold selection technique. In the first stage, a hypothesis testing for GPD is applied followed by a plotting position based automatic threshold selection which leads to time invariant and stable return levels. In the German Bight, these results are similar to threshold values derived by the use of the 99.5th percentile, causing the least variability considering different sample sizes (Fig. 1).

The assessment of return levels should be stable and time invariant. Our analyses show, that not only the sample selection but also the sample pre-processing can impact return levels. While return levels derived by block maxima and POT methods in general strongly depend on the choice of r and the decluster time t_d, the estimation of extreme water levels along the German coastline exhibits another dependency. As shown in Woodworth and Blackman (2004), secular changes and the inter-annual variability of extremes are equal to those of the mean sea level (MSL). Due to the variability in higher percentiles, the trends of extreme sea levels get masked. The trend of the MSL is thus more reliable than the trend derived from the extreme sea level data.

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However, in the German Bight Mudersbach et al. (under review) showed that observed extreme high sea levels have risen faster than the MSL. The use of the MSL for trend correction purposes may thus underestimate the overall trend of extreme values, which can result in a nonstationary sample.

Our results highlight the strong sensitivity of both methods (block maxima and POT) against the parameters that have to be chosen. However, if one keeps the variable parameters fixed and gradually reduces the years to be included in the extreme value analysis, the POT performs much more stable than the block maxima methods using $1 \leq r \leq 6$. Using the Cuxhaven tide gauge data as an example, Figure 1 shows that using the POT method, around 35 years are required to obtain stable results whereas the block maxima approach with $r = 1$ requires at least 70 years. If peak values covering 70 years or more are available, the GEV performs very stable as well. As the GEV is a common and widely accepted method in flood frequency analysis, we use the GEV with more than 70 years as "reference truth" to compare the other methods with.

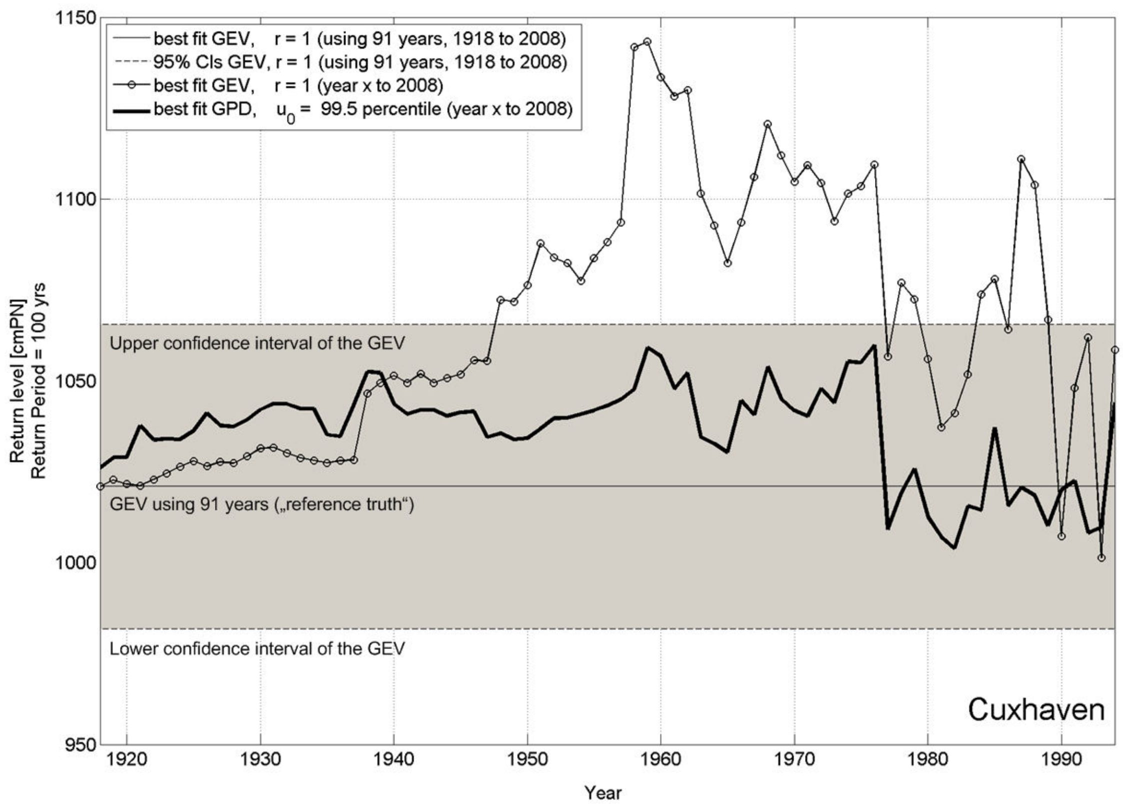

Figure 1 Stability of return water levels in Cuxhaven with a return period of 100 years using the GEV and the GPD, the starting year of the sample is steadily reduced, the last year included is 2008

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