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Non-stationary Extreme Value Analysis of Annual Maximum Water Level Time Series and an Application to the North Sea Gauge Cuxhaven

Ch. Mudersbach and J. Jensen

Research Institute for Water and Environment, University of Siegen, 57076 Siegen, Germany
(christoph.mudersbach@uni-siegen.de)

The design of coastal protection measures is mostly based on water levels with a certain return period. Depending on the design criteria and the area to protect, the design return period varies in the range from 100 years to 10,000 years. The determination of the according water levels is done by a statistical extreme value analysis of the observed time series.

In many cases a non-stationary behaviour of the coastal water level time series is likely. Non-stationarities can exist both due to anthropogenic and natural effects. Common statistical methods postulate stationarity. A hydrologic time series can be assumed as stationary if it is free of trends, shifts, or periodicity. This implies that the statistical parameters of the series, such as the mean and variance, remain constant through time. Otherwise the time series is non-stationary (Salas 1993). If a non-stationary behaviour within the time series is likely, the use of a non-stationary extreme value analysis approach is recommended, where the constant parameters of the distribution function are replaced with time-dependent parameters. In this paper this method is realised by using a non-stationary approach of the Generalized Extreme Value distribution (GEV, Coles 2001) to calculate non-stationary return levels.

An application of the non-stationary GEV to the annual maximum water level time series of the North Sea gauge Cuxhaven was carried out. The 100- and 1,000-yr design water levels were extrapolated to the time horizon 2100 by using a non-stationary GEV approach. The extrapolation is based on the trends, given in the observed data up to the year 2007. The results were compared with the common method to determine future design water levels. It can be seen, that the non-stationary approach leads to a slight increase of the design water levels in 2100. The 100-yr design water level of the stationary approach in 2100 with an assumed sea level rise of 0.3 cm/yr amounts to NN+533 cm (NN: Normal Null, German reference datum) whereas the according non-stationary results vary from NN+540 cm to NN+554 cm.

The non-stationary GEV method offers also the prospects, not only to consider the observed trends, but also to incorporate climate scenarios for changing water level heights or frequencies. Assuming that the projected sea level rates in IPCC (2007) are also representative for the annual maximum water level –however, this assumption is not fully justified-, the analysis shows that the design water levels for the year 2100 based on an extrapolation of the given trends are equal to the values considering the projected mean sea level rise of the SRES-scenario A1FI (IPCC 2007).

Nevertheless, by using a non-stationary extreme value analysis approach the sources for uncertainties increase, because more information about the time-dependent behaviour of the time series is needed. Thus, at present time the non-stationary approach can be regarded as an amendment and not as a replacement for the common stationary methods used in practice.