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Spatial variation of statistical properties of extreme water levels along the eastern Baltic Sea

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Most of existing projections of future extreme water levels rely on the use of classic generalised extreme value distributions. The choice to use a particular distribution is often made based on the absolute value of the shape parameter of the Generalise Extreme Value distribution. If this parameter is small, the Gumbel distribution is most appropriate while in the opposite case the Weibull or Frechet distribution could be used.
We demonstrate that the alongshore variation in the statistical properties of numerically simulated high water levels along the eastern coast of the Baltic Sea is so large that the use of a single distribution for projections of extreme water levels is highly questionable. The analysis is based on two simulated data sets produced in the Swedish Meteorological and Hydrological Institute. The output of the Rossby Centre Ocean model is sampled with a resolution of 6 h and the output of the circulation model NEMO with a resolution of 1 h. As the maxima of water levels of subsequent years may be correlated in the Baltic Sea, we also employ maxima for stormy seasons.
We provide a detailed analysis of spatial variation of the parameters of the family of extreme value distributions along an approximately 600 km long coastal section from the north-western shore of Latvia in the Baltic Proper until the eastern Gulf of Finland. The parameters are evaluated using maximum likelihood method and method of moments. The analysis also covers the entire Gulf of Riga.
The core parameter of this family of distributions, the shape parameter of the Generalised Extreme Value distribution, exhibits extensive variation in the study area. Its values evaluated using the Hydrognomon software and maximum likelihood method, vary from about –0.1 near the north-western coast of Latvia in the Baltic Proper up to about 0.05 in the eastern Gulf of Finland. This parameter is very close to zero near Tallinn in the western Gulf of Finland. Thus, it is natural that the Gumbel distribution gives adequate projections of extreme water levels for the vicinity of Tallinn. More importantly, this feature indicates that the use of a single distribution for the projections of extreme water levels and their return periods for the entire Baltic Sea coast is inappropriate.
The physical reason is the interplay of the complex shape of large subbasins (such as the Gulf of Riga and Gulf of Finland) of the sea and highly anisotropic wind regime. The ‘impact’ of this anisotropy on the statistics of water level is amplified by the overall anisotropy of the distributions of the frequency of occurrence of high and low water levels. The most important conjecture is that long-term behaviour of water level extremes in different coastal sections of the Baltic Sea may be fundamentally different.