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Ensemble-based evaluation of extreme water levels for the eastern Baltic Sea

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The risks and damages associated with coastal flooding that are naturally associated with an increase in the magnitude of extreme storm surges are one of the largest concerns of countries with extensive low-lying nearshore areas. The relevant risks are even more contrast for semi-enclosed water bodies such as the Baltic Sea where subtidal (weekly-scale) variations in the water volume of the sea substantially contribute to the water level and lead to large spreading of projections of future extreme water levels.
We explore the options for using large ensembles of projections to more reliably evaluate return periods of extreme water levels. Single projections of the ensemble are constructed by means of fitting several sets of block maxima with various extreme value distributions. The ensemble is based on two simulated data sets produced in the Swedish Meteorological and Hydrological Institute. A hindcast by the Rossby Centre Ocean model is sampled with a resolution of 6 h and a similar hindcast by the circulation model NEMO with a resolution of 1 h. As the annual maxima of water levels in the Baltic Sea are not always uncorrelated, we employ maxima for calendar years and for stormy seasons.
As the shape parameter of the Generalised Extreme Value distribution changes its sign and substantially varies in magnitude along the eastern coast of the Baltic Sea, the use of a single distribution for the entire coast is inappropriate. The ensemble involves projections based on the Generalised Extreme Value, Gumbel and Weibull distributions. The parameters of these distributions are evaluated using three different ways: maximum likelihood method and method of moments based on both biased and unbiased estimates. The total number of projections in the ensemble is 40. As some of the resulting estimates contain limited additional information, the members of pairs of projections that are highly correlated are assigned weights 0.6.
A comparison of the ensemble-based projection of extreme water levels and their return periods with similar estimates derived from local observations reveals an interesting pattern of match and mismatch. The match is almost perfect in measurement sites where local effects (e.g., wave-induced set-up or local surge in very shallow areas that are not resolved by circulation models) do not contribute to the observed values of water level. There is, however, substantial mismatch between projected and observed extreme values for most of the Estonian coast. The mismatch is largest for sections that are open to high waves and for several bays that are deeply cut into mainland but open for predominant strong wind directions. Detailed quantification of this mismatch eventually makes it possible to develop substantially improved estimates of extreme water levels in sections where local effects considerably contribute into the total water level.