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Trends in the components of extreme water levels signal a rotation of winds in strong storms in the eastern Baltic Sea

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The water level time series and particularly temporal variations in water level extremes usually do not follow any simple rule. Still, the analysis of linear trends in extreme values of surge levels is a convenient tool to obtain a first approximation of the future projections of the risks associated with coastal floodings. We demonstrate how this tool can be used to extract essential information about concealed changes in the forcing factors of seas and oceans. A specific feature of the Baltic Sea is that sequences of even moderate storms may raise the average sea level by almost 1 m for a few weeks. Such events occur once in a few years. They substantially contribute to the extreme water levels in the eastern Baltic Sea: the most devastating coastal floodings occur when a strong storm from unfortunate direction arrives during such an event.

We focus on the separation of subtidal (weekly-scale) processes from those which are caused by a single storm and on establishing how much these two kinds of events have contributed to the increase in the extreme water levels in the eastern Baltic Sea. The analysis relies on numerically reconstructed sea levels produced by the RCO (Rossby Center, Swedish Meteorological and Hydrological Institute) ocean model for 1961–2005.

The reaction of sea surface to single storm events is isolated from the local water level time series using a running average over a fixed interval. The distribution of average water levels has an almost Gaussian shape for averaging lengths from a few days to a few months. The residual (total water level minus the average) can be interpreted as a proxy of the local storm surges. Interestingly, for the 8-day average this residual almost exactly follows the exponential distribution. Therefore, for this averaging length the heights of local storm surges reflect an underlying Poisson process. This feature is universal for the entire eastern Baltic Sea coast. The slopes of the exponential distribution for low and high water levels are different, vary markedly along the coast and provide a useful quantification of the vulnerability of single coastal segments with respect to coastal flooding.

The formal linear trends in the extreme values of these water level components exhibit radically different spatial variations. The slopes of the trends in the weekly average are almost constant ($\sim$4 cm/decade for 8-day running average) along the entire eastern Baltic Sea coast. This first of all indicates that the duration of storm sequences has increased. The trends for maxima of local storm surge heights represent almost the entire spatial variability in the water level extremes. Their slopes are almost zero at the open Baltic Proper coasts of the Western Estonian archipelago. Therefore, an increase in wind speed in strong storms is unlikely in this area. In contrast, the slopes in question reach 5–7 cm/decade in the eastern Gulf of Finland and Gulf of Riga. This feature suggests that wind direction in strongest storms may have rotated in the northern Baltic Sea.