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Projecting future wave climates and corresponding shoreline changes along the differently exposed coastal sections of the Baltic Sea

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The aim of the study is to analyze the recently observed and projected future coastal changes in differently exposed Estonian coastal sections as a result of changing wind and wave climates. Along the shoreline of the practically tideless Baltic Sea, the increase in storminess has already impacted the coastal environment over the last 50 years. However, the number of storms, as well as their pathways, has been fluctuating considerably over the last decades. Furthermore, forecasting future hydrodynamic conditions and corresponding coastal changes is a rather mixed, yet crucial task.

A number of Estonian study sites have been regularly examined by coastal scientists since the 1960s. Six coastal sections have been chosen for this study: Harilaid Peninsula (exposed to SW), Letipea–Sillamäe (N), Kõiguste–Nasva (SE), Kihnu–Pärnu (S), and two sides of the Osmussaar Island (W, N). Since the 2000s, use of GPS instruments and GIS software has enabled year-to-year changes in the shoreline to be tracked and the calculation of the corresponding areas or volumes due to accumulation and erosion. Recently digitized aerial photographs, as well as orthophotos and old topographic maps, enable the calculation of changes over longer sub-periods. Based on recorded and hindcasted changes in wind-driven hydrodynamic conditions, we found relationships between forcing conditions and the rates at which shorelines were changing.

For future changes, wave climates were projected for the selected coastal sections of special geomorphic interest, where also a series of hydrodynamic surveys (waves, currents, sea level) were carried out using ADCP-s in 2006-2014. Wave parameters were consecutively hindcasted using a site-dependently calibrated fetch-based wave model. As the full calculation period (1966-2013) might suffer from inhomogeneity of wind input data, a confidently homogeneous time cut (2004-2013; 10 full years with hourly resolution) was chosen as a baseline (or control) period. An ensemble of nine semi-realistic scenario calculations was obtained by modifying the original input data. The modifications were in line with greenhouse gas scenarios (RCP2.6, RCP4.5; previous SRES A1B and A2) and the corresponding narratives for future wind forcing ("increase in geostrophic wind by 5% above the Northern Atlantic; increase in mean wind speed by 1 m/s; increase in westerly wind component in winter", etc.)

The results showed that depending on exposition, the wave climates would change rather differently even within a single semi-enclosed sea. Although wave heights may even slightly decrease at some locations under specific scenarios, the ensemble means predicted increases in wave heights by 5-16%. The largest increases are expected at westerly exposed locations with the longest fetches. We have found that the current rates of coastal changes in the West Estonian study sites are already 2-3 times higher than in the 1950s and the rates are about to increase in the future. Using the previously established empirical relationships between wave parameters and shoreline changes, we predict that erosion will probably increase in transitional zones (annual shoreline recession may reach to 2m) while accumulation increases within bays. As a result, accumulation and siltation will increasingly affect ports and navigational channels; flattening of the coastal zone may lead to increasing risk of inundation during storms. Still, notable changes will take place on geomorphically active coasts, leaving roughly half of the Estonian coastline practically unchanged (at least until the sea level rise rate will not exceed 2-3 mm/yr). The results of the study may serve as an input for coastal management.

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