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# Evolution of sandy beaches in Estonia as indicator of increased storminess in the Baltic Sea region

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## Abstract

Warmer winters, increased cyclonic activity and frequent occurrence of extremely strong storms in northern Europe seem to be closely related phenomena caused by climate change. Climatic changes in moderate and high latitudes have led to critical changes in the dynamics and development of coastal areas. In Estonia, the greatest destruction occurs on sandy beaches that are well exposed to waves and is associated with stormy periods when storm surge elevates sea level. Ice-free sea and unfrozen sediments enhance the activity of shore processes.

Keywords: Climate change; Shore processes; Sandy beaches; Baltic Sea.

## Climate change and increased storminess

The Baltic Sea region has seen a statistically significant increase in mean air temperature from 0.5 to 0.9°C over the past century. Global climate warming is very well expressed also in Estonia. Statistically significant increase in monthly mean temperature is present only during the period from January to May with the maximum in March. The decrease in duration of snow cover in Estonia and ice cover in the Baltic Sea is also a clear consequence of the higher mean air temperature. Changes in atmospheric circulation over Estonia have taken place during the last decades. Warmer winters, increased cyclonic activity and frequent occurrence of extremely strong storms in northern Europe seem to be closely related phenomena caused by climate change.
Time series of annual frequency of storm days in the coastal stations indicate high temporal variations and a general increase in storminess. Results of the Mann-Kendall test show that the increasing trend in storminess is statistically significant on $P<0.05$ level. Change in annual frequency of storm days is significant in coastal stations of Estonia but changes in monthly values are of different magnitude. In general, increase in January and February is the most substantial.

### *Local sea level fluctuations caused by changes in the wind regime*

SW winds prevail above the Baltic Sea with the increase in westerlies due to the climate change over the last half-century. In strongly indented and semi-enclosed coastal areas the conditions vary considerably between straight coasts and long tapering bays, leeward and windward sides of the sub-basins, etc. The local sea level differences may be up to 1m or even more at a distance of only about 100km. An increase in wind speed from specific directions, for instance 220° for the Pärnu Bay, elevates the sea level in that bay. The effect is very small in case of low wind speed values but very strong during storm events. The effect is more pronounced in semi-enclosed small sub-basins of the Baltic Sea, like the Gulf of Livonia and some others (Suursaar *et al.*, 2004).

### *Influence of increased storminess on shore processes*

Warmer winters in moderate latitudes have led to critical changes in the dynamics and development of coastal areas. Extensive erosion and alteration of depositional coasts, *e.g.* sandy beaches, has been observed during the last decades in Estonia (Orviku *et al.*, 2003 *etc.*). The lack of evidence for sea level rise during this period suggests that beach erosion is largely due to the recent increased storminess in the eastern Baltic Sea. The greatest destruction potential in the coastal zone in Estonia occurs on depositional coasts that are well exposed to waves and is associated with stormy periods when storm surge elevates sea level. The results of comparison of maps from different times and the field measurement results in study sites clearly reveal an increased activity of both erosion and accumulation processes.

### *Dynamics of sandy beaches on Harilaid Peninsula*

Changes in shoreline displacement and the shore processes characteristics have been studied throughout the 20$^{th}$ century on Harilaid Peninsula, NW Saaremaa Island. The north-westernmost point of the peninsula consisting of sandy beaches has migrated remarkably to the north-east during the last century. The main reason for the migration of the cape is intense erosion on the western coast and transport of sand along the western coast to the south, where it is re-deposited. Part of the eroded sediment is also deposited on the north-eastern and eastern coasts of Harilaid. Extrapolation from aerial photographs from 1957, 1981, 1995 and 1998 suggests the western coast has receded by over 30m or nearly 2m per year. The last three intense erosion events on NW coast of Harilaid have been recorded in winter 1999/2000, 2001/2002 and 2004/2005.

### *Measurements and calculations at Järve beach*

A comparison of topographic surveys at Järve study site on the southern coast of Saaremaa made before and just after the stormy period in winter 1990 (eight days with storm, maximum wind speed 25m.s$^{-1}$, S, sea level +171cm) shows that the 4km-long scarp in sands had receded by 4-5m. Over 6,500m$^3$ of sand was eroded from the scarp. This coastal destruction resulted from the cumulative effect of strong storms with high sea level and the absence of ice cover. During the next relatively passive period (without

severe storms) from 1990-1999, beaches in the west Estonian archipelago were more stable. A new vitalisation of shore processes has started since 1999.

### *Changes on the eastern shore of Ruhnu Island*

Ruhnu Island in the middle of the Gulf of Livonia has experienced cyclic beach development. Sediment is typically transported along the eastern shore from north to south, which is deposited as an excellent sandy beach with foredunes and dunes. Strong southerly storms at the end of February 1990 (six days with storm with maximum wind speed 19m $s^{-1}$, S and SW, sea level +143cm) caused a reversal in sediment erosion, transport and accumulation processes. An extensive fresh scarp was eroded into the foredunes in the SE and the sand was transported along the shore to the north. A 1.5km long and 15-20m wide sandy beach was formed in the long-term area of erosion. During the next five years, the newly-formed beach was completely eroded away by northerly storms. The sand was transported southwards, and accumulated on a 10-15m wide active beach to form a series of young foredunes.

## Adaptation and restoration options of sandy beaches in Estonia

A number of sandy beaches high in recreation value have strongly suffered from strong storms over the last half-century. Pirita beach in Tallinn, the capital city of Estonia, Pärnu and Valgeranna in the south-western part of the mainland, Järve beach on Saaremaa are just a few examples. In many cases natural processes without interruption of man can restore the destroyed beaches. In most cases preserving the beaches in good condition needs certain protection measures. Beach nourishment, an expensive technique used for instance in restoration of Narva-Jõesuu sandy beach in the end of the 1980s, has shown good results so far in Estonia.

## Conclusions

The frequency and magnitude of storms has increased during the last decades. The most exceptional changes in shoreline position and contour of sandy beaches are attributable to a combination of strong storms, high sea level and ice-free sea. As a result, the balance between erosion and deposition is fragile and an initial shape of beaches may not be restored in natural way between the storms.

## References

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