Geophysical Research Abstracts
Vol. 14, EGU2012-5472, 2012
EGU General Assembly 2012

Numerical modeling of storm-induced morphodynamic changes at a micro-tidal sandy coast

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Due to a recent climate change, the coasts of the southern Baltic Sea have been experiencing increased levels of erosion due to increasing sea level and more frequent and severe storms. This tendency is very likely to continue into the future, making a better understanding of morphodynamic processes in the coastal zone in those new conditions an ecological and economic necessity. Because interactions between wind, waves, currents and sediment transport in the coastal zone are very complex, reliable modeling of them remains a challenge and is often limited to empirical and semi-empirical formulae, applicable to a certain range of conditions. Most numerical and observational studies of the sediment transport and beach and dune erosion in extreme wind and wave conditions are valid for tidal coasts (e.g., the North Sea) and their results are not directly transferable to micro-tidal conditions of the Baltic Sea.

The area of the present study is situated in the central part of the Gulf of Gdansk (southern Baltic Sea). It is a narrow sand spit separating a shallow lagoon from the sea, with sand dunes covered with sparse vegetation. Narrow, flat "passages" crossing the spit and ending with fan-shaped "deltas" on the lagoon side attest to past storm events. The cross-shore profile, with relatively narrow and steep beach and surf zone, leads during storm conditions to high waves propagating without much dissipation very close to the shore.

In this work, a two-dimensional state-of-the-art model XBeach is used to assess the susceptibility of the study area to coastal erosion during storm conditions. The model is set-up and validated based on: (i) measured time series of wind speed and direction, water level and wind-wave data; (ii) high-resolution topographic and bathymetric measurements of surface elevations; and (iii) the results of granulometric analyses of sand probes from a set of locations inside the study area. An ensemble of model simulations is performed for various wind speeds and directions, water levels, and observed as well as artificially changed surf-zone and beach profiles. A dataset generated in this way allows to identify synoptic situations that are particularly dangerous from the point of view of beach and dune erosion. The analysis of the modeling results concentrates on poorly-understood mechanisms of transport and sorting of coastal sediments in the coastal zone in extreme conditions.