Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea*

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Abstract

The basic parameters of extra-tropical cyclones in the northern Baltic are examined in relation to extreme sea level events at Estonian coastal stations between 1948 and 2010. The hypothesis that extreme sea level events might be caused not by one intense extra-tropical cyclone, as suggested by earlier researchers, but by the temporal clustering of cyclones in a certain trajectory corridor, is tested. More detailed analysis of atmospheric conditions at the time of the two most extreme cases support this concept: the sequence of 5 cyclones building up the extreme sea level within about 10 days was very similar in structure and periodicity.

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1. Introduction

Sequences of certain weather patterns, rather than single events, cause different extreme environmental hazards in Europe like droughts in the case of anticyclones, or devastating wind-storms and floods in the case of extra-tropical cyclones. These hazards cause the largest economic losses and even loss of life. For the same reason, series or packages of extra-tropical cyclones force extreme storm surges in coastal seas. Mid-latitude storm tracks as regions where extra-tropical cyclones propagate with a higher density than in their surroundings have been a research topic for some time already (Hoskins & Hodges 2002). Most authors associate the spatial densities of cyclone tracks and their temporal changes with climate change. Mailier et al. (2006) show that extra-tropical cyclones do not cluster only in space, but that in certain regions they could also cluster in time. The Baltic Sea lies near the exit of one such region – the North Atlantic storm track – where cyclones are significantly clustered in the cold half year.

A number of factors influence the Baltic Sea level, the most prominent one being the seasonal cycle due to different meteorological and hydrographic factors, causing high sea levels at the end of the year and low levels from March to June as a long-term variability pattern. But sea level is also influenced by changes in the wind field, especially during storm events; by the water exchange between the Baltic and North Sea; by changes in precipitation and evaporation, and hence river discharge; by seasonal changes in water density; and by seiches (Wiśniewski & Wolski 2011). The part played by the different factors depends on the sea region, and especially on the morphometry of its coastline. Extreme sea level events in the Baltic Sea are predominantly meteorologically forced, and the role of tides lies well below 10 cm amplitude against the background of the dominant seasonal cycle (Raudsepp et al. 1999).

A storm surge is an extreme short-term (from minutes to a few days) variation in the sea level caused by high winds pushing against the surface of the sea. As the associated flooding threatens lives and property, this phenomenon has been widely described and studied in terms of its physical aspects, with the aim of simulating and forecasting sea-level behaviour in case of extreme storm surges (Suursaar et al. 2003, 2006, 2011, Wiśniewski & Wolski 2011). Historically, the highest storm surges have reached 5.7–5.8 m above the average water level, and such events can happen at either end of the elongated Baltic Sea: in Neva Bay off St. Petersburg, Russia, and in the coastal region near Schleswig, Germany. The extremely high sea levels in the central Baltic occur in the coastal waters of certain semi-closed sub-basins, open to the west, as the strongest winds in this region blow from this sector.