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Determining Storm Surge Return Periods: The Use of Evidence of Historic Events

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Storm Surge January 4, 2017

After a long period of westerly winds, the mean sea level of the Baltic Sea was about 0.5 meters above normal, with a lift towards north and east. A heavy low pressure system caused winds from north east over the entire area, releasing and enforcing a seiche of the tilled water and at the same time blocking outflow to the North Sea.

This caused a “quiet storm surge” – a surge without a storm – on the southern Baltic shores, with sea levels of 1.57 meters just south of Copenhagen in Køge and 1.77 meters further towards west in Aabenraa.

With present day statistics, this was considered a 100 year event. The surge was well forecasted, minimizing damages and avoiding casualties.

In many places, including Copenhagen, serious flooding would have occurred if the water had been a few tens of centimeters higher.

Materials

The present study focuses on the bay of Køge, just south of Copenhagen, where the mean level of historic events, corrected to present day conditions have been estimated, taking into account land rise and mean sea level change.

The storms in 1872 and 1913 were of this type.

The storms causing the surges can be split in 2 types. Type 1 is most common and has a low pressure system from the Atlantic towards east. Type 2 has a high pressure over northern Scandinavia and a low pressure moving from south to north over central Europe. The storms in 1872 and 1913 were of this type.

The probability of a major storm surge from the Baltic Sea hitting the Copenhagen metropolitan area is officially determined by the Danish Coastal Authority based on tide gauge records. We have a long history for tide gauge measurements, with 120 years of data available for the calculations. However, the oldest of these tide gauge stations was set up after a major storm surge in 1872, and no events of similar severity have occurred since.

Including the evidence of the historic events from the 18th century changes the return period statistics, with a best estimate of a 100 year event changing from 1.5 meters rise (Sørensen et al. 2013) to 2.6 [2.2 – 2.8] meters (present study) in Køge just south of Copenhagen. Thus, with the tide gauge-based statistics, the storm surge on January 4 2017, a 100 year event but with the revised statistics using historic evidence, much larger events can be expected.

Further, we assess the very large impact of sea level rise on the storm surge statistics. As an example, according to the official statistics of southern Copenhagen, the flooding of a present day 100 year event will statistically occur every 10 years with just 27 cm of mean sea level rise.

Future Storm Surges

There are two key parameters for the effect of climate change on storm surges: mean sea level changes (relative to land) and changes in the wind.

Mean sea level changes are expected to have the highest impact, massively changing return periods for a given level of flooding. The figure illustrates the change in return period of a present day 10 year event as a function of mean sea level rise for Aabenraa (based on Sørensen et al. 2013). For instance, a present day 10 year event will occur every 10 years with 0.26 meters mean sea level rise. Figures are very similar for Danish stations within the southwestern Baltic region, including Copenhagen.

The effect of changing wind patterns is less certain. Ensemble studies of regional climate models show a decrease in the mean wind speed over the North East Atlantic, but a small increase in the highest wind speeds over the south western Baltic Sea.

Since the Arctic region is heated more than the global average, we speculate that Type 2 storm systems will become less likely in the future, and the largest storm surges will be from Type 1 storms. However this needs further investigation.

Literature

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