Technical University of Denmark

Spatial variation in extreme water levels in the Baltic Sea – North Sea transition from tide gauge records

Sørensen, Carlo Sass; Andersen, Ole Baltazar; Knudsen, Per

Publication date:
2015

Document Version
Peer reviewed version

Citation (APA):
Sørensen, C. S., Andersen, O. B., & Knudsen, P. (2015). Spatial variation in extreme water levels in the Baltic Sea – North Sea transition from tide gauge records. Poster session presented at Workshop Global and Regional Sea Level Variability and Change, Mallorca, Spain.

Spatial variation in extreme water levels in the Baltic Sea – North Sea transition from tide gauge records

CARLO SØRENSEN*, OLE B. ANDERSEN & PER KNUDSEN
DTU Space, Lyngby, DK-2800, Denmark (*carlos@space.dtu.dk)

Introduction

Extreme water levels in the Danish waters, Figure 1, are governed by a variety of factors that provide a complex picture between locations, Figure 2 & Table 1, and where extremes may manifest themselves very differently between neighbouring locations and between water compartments during individual events.

Knowledge about extremes is essential for climate adaptation, design, and planning purposes. In an ongoing research project we seek to develop more robust and objective statistics for Denmark. This includes a revisit to all tide gauge stations' (TG) data and exploring methods for extreme value analysis (EVA).

Below we provide four cases from Danish TGs to address some issues and questions regarding our work. Any feedback is much appreciated!

Table 1 Range of extreme water levels, 50 y return wave heights and periods (from hindcast modelling), and tides for different Danish water compartments

Area	Extreme WL 100 y event [m]	Waves Hs [m] / T [s]	Tidal range [m]
Wadden Sea	4.0 - 5.0	7 / 14 (open coast)	1.3 – 2.0
Central North Sea	2.5 - 3.2	7 / 14	0.5 – 1.0
Kattegat	1.5 - 1.8	3 / 7	0.3 – 0.6
Limfjord	1.5 - 2.0	1 - 2.5 / 5	0.5
The Belts	1.5 - 2.0	2-2.5 / 6	0.4
North Sealand	1.6 - 1.7	4 / 9	0.4
Western Baltic	1.5 - 1.8	3.5 / 8	<0.3
Bornholm	1.3	6 / 10	<0.3

Figure 1 Denmark and surrounding waters

Case 1: An increasing number of extremes?

The Thyboron TG on the North Sea coast features natural variability in extremes and a marked increase in numbers since the 1980s (Figs 3 & 4). The latter is ascribed an increase in the cross-section together with changes in bottom configuration of the Thyboron Canal separating the Limfjord and the North Sea since 1958 from hydrodynamic modelling (Mike 21 HD). The effect is also modelled for the Limfjord TGs and included in current statistics showing that extremes are affected by other than climatic factors alone.

In general, this also means that caution is to be taken when using long series for EVA depending on changes observed in either position of the TG, harbour works, off-shore bathymetries, or other relevant measures.

Figure 3 The Thyboron Harbour tide gauge and it position by the Thyboron Canal (left)

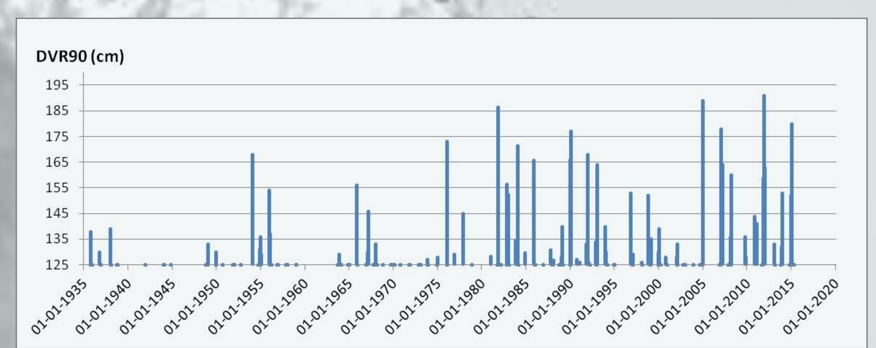
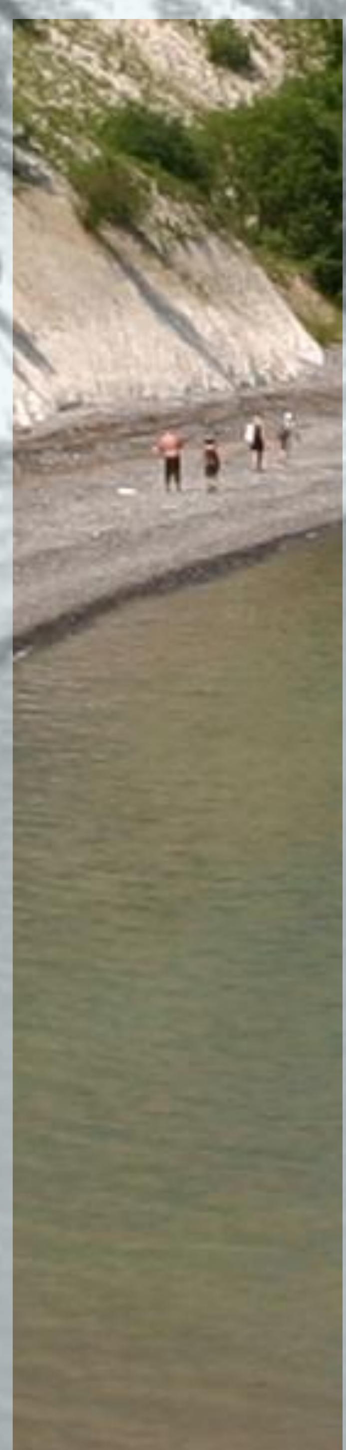


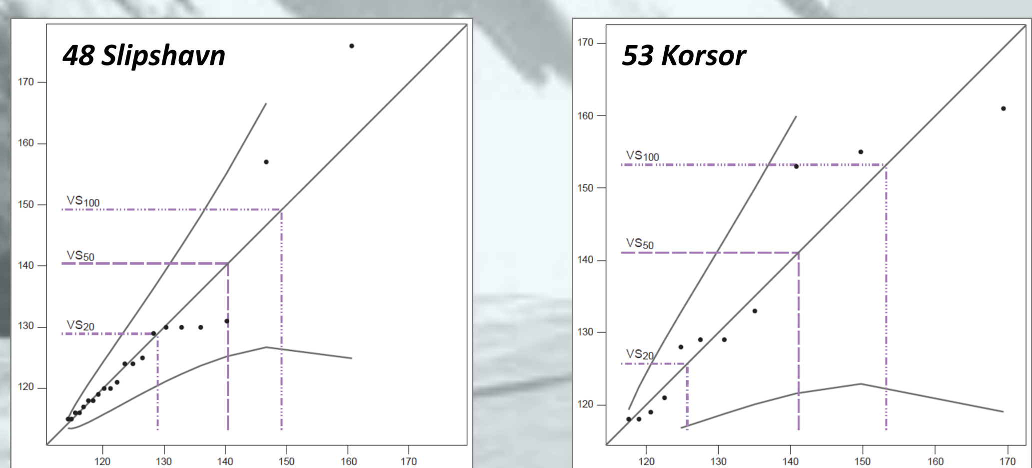
Figure 4 Measured extremes above 125 cm since 1935 at Thyboron Harbour (station 17 in Fig. 2)

Case 2: How often an extreme?

On many open coasts storm surges act fairly straight-forward with storms and onshore winds leading to high water levels. In the Great Belt external surges from either north or south on rare occasions lead to extremes somewhat higher than ordinary extremes and yield poor fits in the currents statistics (Figure 5 & Table 2). How can this be resolved? A first attempt in separating extremes into different distributions was not satisfactory and a certain number of extremes is needed to get robust statistics.

Furthermore, historical accounts of flooding with no exceptionally high water levels appear. Here, met forcing and waves may be included to reveal joint probabilities of flooding. But how?





48 Slipshavn:

Date	WL [cm]
1 November 2006	176
21 February 1993	157
31 December 1904	131
9 November 1945	130
20 November 1973	130
9 November 2007	130
22 December 1954	129
6 December 2003	125
4 January 1954	124
15 February 1989	124

53 Korsor:

Date	WL [cm]
1 November 2006	161
31 December 1904	155
21 February 1993	153
29 September 1914	133
16 December 1898	129
9 January 1914	129
28 November 1983	128
20 November 1973	121
24 October 1921	119
1 January 1922	118

Figure 5 & Table 2 QQ-plots (Weibull) and "top 10" water levels at Great Belt TGs (refer to Fig 2 for locations). Both data series cover the period 1890-2012. The Dec. 1904 was a storm event whereas Nov. 2006 (from north) and Feb. 1993 (from south) were mainly due to external forcing/basin effects in the Great Belt.

Figure 2 100 y return heights (in blue) in cm above datum (DVR90) for the 68 Danish tide gauge stations according to Sorensen et al (2013). POT from Weibull or Log-Normal distributions. No tides removed

Case 3: Too long ago an extreme?

Some of the Danish statistics are made from fairly short data series. This is in some sense unfortunate as they are not as reliable as long series for EVA but at least they reveal the importance of good quality data to decision makers etc. And people tend to forget former events!

The erosion and flooding impacts of the December 2013 storm on North Sealand saw the highest water level on record in 125 y (195 cm DVR90). Back in 1921-22 two very high water levels a month apart, included in the statistics, and comparable to 2013 also led to flooding (Figs 6-8). How do we best provide and communicate statistics, their validity and uncertainties for various uses?

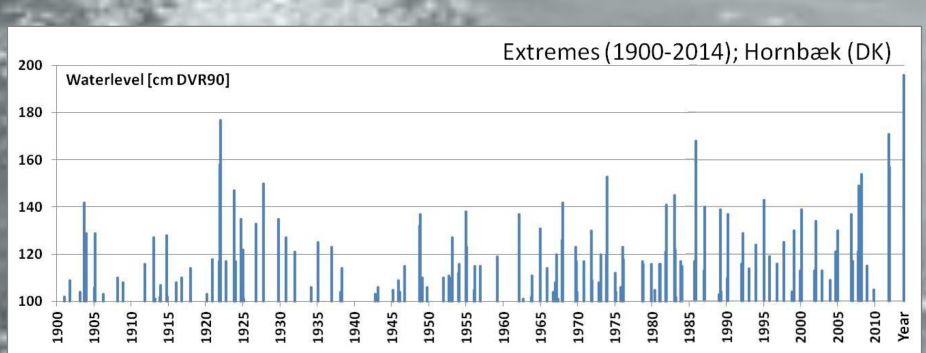


Figure 6 Extreme WLs at North Sealand TG (station 59 in Fig. 2)

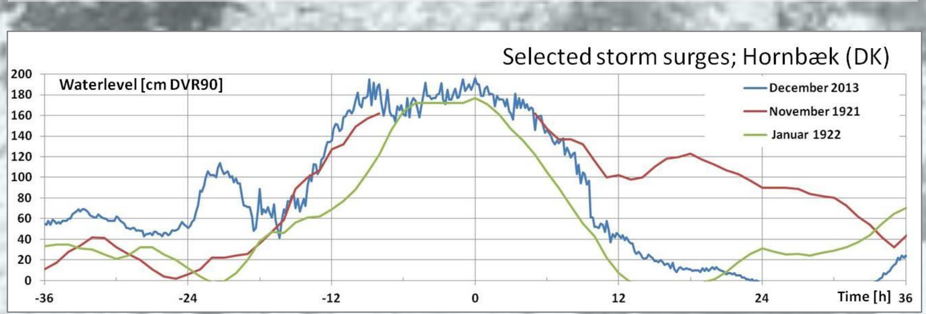


Figure 7 Comparison of peak WLs for three top-5 events at North Sealand (st. 59 in Fig. 2)

Figure 8 Flooded areas in identical locations in North Sealand, 1921 (bottom) and 2013.

Case 4: A fantastic history of storm surges?

Historic events predating tide gauge measurements need in some cases to be taken into account, but how do we deal with uncertainties, validation, and homogeneity if these are to be included? In general, accounts of these events tends to exaggerate WLs and they may manifest themselves differently today.

A classic example is the 1872 Baltic Sea storm surge with WLs in excess of 1.5 m from TG measurements. "Alternative" statistics have been attempted, Figure 9, based on assumptions about past weather patterns and transferred flooding accounts from other localities. Although sometimes used as "the truth", they are not, but it points to the issue on how to validate historic events and on how to make statistics more objective and extending accounts back in time.

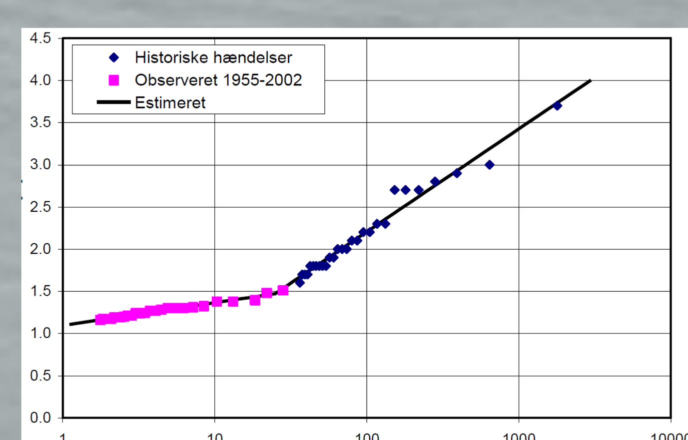


Figure 9 Alternative statistics (COWI, 1997; DHI 2008) from the Baltic Sea coast at Køge (st. 63 in Fig. 2), extending the TG record (pink) back to 1044 (!!!). Large extremes have occurred in the past at this location but many of the historic events included lack evidence of any water levels and have no reference to the area

WORKSHOP GLOBAL AND REGIONAL SEA LEVEL VARIABILITY AND CHANGE
Mallorca Spain, 10-12 June 2015

DTU Space
National Space Institute