Storm surges – the case of Hamburg, Germany

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Along the coast of the North Sea, storm surges present the major geophysical risk (Gönnert et al., 2001). A long history of disaster has deeply engraved the severity of this danger into the cultural texture of the local population (Petersen and Rhode, 1977). The stories about the loss of a major island, Nordstrand to the North Sea and the “great man-drowning” (grote Mandränke) on 16 January 1362 is part of an ubiquitous folklore, which reminds people that the North Sea is a dangerously stormy “subject”, actually named “Blanke Hans” in the region.

While the situation has not much changed in rural regions, the situation has changed significantly in Hamburg. Hamburg lies about 140 km upstream of the North Sea and is connected by the Elbe estuary. Hamburg has often been subject to storm surges with significant damages. However, the risk, and the vulnerability of the population has changed quite a bit. The objective of this short note is to describe these changing risks and vulnerabilities.

Past development[1]

In the 18th century, storm surges and breaking dikes were relative frequent in Hamburg. The dike failures took place at water levels of about NN + 5,20m, or so. Interestingly, these storm surges came along in clusters. After the severe storm surge in 1825 dike heights were raised to NN+5,70m; since then, until 1962, only one severe storm surge happened, namely in 1855. After this storm flood, for more than 100 years until 1962 the improved dike levels were not really challenged. All gauge readings were well below NN+5.00 m.

During this time, the conditions of the dikes deteriorated, as some of them were increased but without taking into account an appropriate improved base. Thus, the dikes became to steep, so that waves and overflow had a stronger impact, with an increased chance for failure in case of a storm surge.

When the big flood came, in 1962, severe damage occurred all along the German North Sea coast. Many dikes in Hamburg broke and more than 300 lives were lost in Hamburg. Nobody expected such a disaster, and many are told to have perished because inhabitants were refugees from the east and simply were unprepared for the danger. The calm period of more than 100 years certainly lead to a false perception of safety, which increased the vulnerability.

After 1962 massive investments into the coastal defense were made; dikes were raised to NN+7.20 m. A very strong flood happened in 1976, well above the 1962-

level, namely NN+6.45 m, however the newly enforced costal defense held and damages were insignificant in Hamburg. Nevertheless, dikes were raised again to a level between NN+8.00m and NN+9.30m. Since 1962 several very high storm surges took place with heights between NN+5.50 m and NN+6.00 m, but only minor damages were reported.

Thus the history of storm surges in Hamburg, as documented since 1750, had three phases – the frequent damage-period prior to 1850, the calm period, 1855 – 1962, and a period of elevated but well-managed storm surge-levels since 1962.

It has been speculated that the increase in Hamburg St. Pauli since 1962 would contain a significant component reflecting global man-made climate change. This is very likely false – the main part of the increase is due to the improvement of coastal defense; another cause is the dredging of the shipping channel. The intensification of the North-Atlantic Oscillation during the period between 1960 and 1995 may have contributed a minor increase in level (Weisse and Plüss, 2007). A measure of the effect of the former two is the difference of storm surge heights in Cuxhaven, at the mouth of the Elbe estuary and in Hamburg. Before 1962 storm surges in Hamburg were on average about 30 cm higher than in Cuxhaven. After 1962 this difference rose to about 1 m (Grossmann et al., 2007). Experts estimate that about ¾ of this increase is related to coastal defense measures, and ¼ to the deepening of the shipping channel from less than 11 m to 14.50 m.

Thus, modifications of the river Elbe has significantly increased the storm surge height in Hamburg, while climatic effects were rather minor (cf. Weisse and Plüss, 2005; WASA, 1998; Alexandersson, et al., 2000)

Scenarios describing global climate change

The ongoing rising concentrations of carbon dioxide and other radioactively active trace gases in the atmosphere lead to global climate change, the effect of which is now already detectable mostly in terms of thermal variables (in particular global mean air temperature; IDAG, 2005). A cascade of models, global and regional atmospheric models, followed by a hydrodynamic model (describing water levels and currents) may be used to estimate future storm surge levels along the North Sea coast – under the assumption of different emissions of greenhouse gases in the coming decades (Woth et al., 2006). Interestingly, these scenarios differ little among a series of different model set-ups, and among two rather different emission scenarios (Woth, 2005).

Based on these North Sea storm surge scenarios, Grossmann et al. (2007) have used an empirical link between coastal and estuarine water level variations to derive a consistent estimate for Hamburg. Their results, shown in Figure 1, take into account both an estimate of mean sea level rise (due to thermal expansion as reaction on global warming) and the elevated wind-driven surges.

Thus, according to these projections, water level extremes, in terms of the mean maximum water level in a storm season, would rise by 15 cm ± 5 cm in Cuxhaven at the mouth of the river and 20 cm ± 5 cm in Hamburg until around 2030, relative to 1980-90 levels. Such an increase does not cause significant concern among coastal engineers. However, at a later time in the 21st century, say 2085 representing the last three decades of the century, the increase may amount of about 50 cm ± 15 cm in Cuxhaven and 60 cm ± 20 cm. Such an increase would need adaptations in both places, Cuxhaven and Hamburg.

These projections have been calculated under the assumption that the river topography will remain unchanged in the future. In fact, in seems unlikely that this assumption will be fulfilled. Because of disadvantageous patterns of sediment transport, plans are now made to slow the hydrodynamic regime in the Elbe estuary, as outlined in the German-written „Concept for a sustainable development of Tidal Elbe River as an artery of the metropolitan region Hamburg and beyond" (http://www.tideelbe.de/pdf/Strategiepapier_Tideelbe_deu.pdf) of Hamburg Port Authority.

When the tidal regime in the Elbe is slowed down, then not only ecology and sediment transport is affected but also the movement of water, including tides and storm surges. Therefore part of the earlier increase in storm surge heights in Hamburg may possibly be taken back, so that the perspectives for future storm surges may be smaller than what was envisaged under unchanged topographic conditions in Figure 1.

Conclusion

In this short note, we have discussed changing storm surge conditions in Hamburg in Northern Germany during the past 200 years, and perspectives for the future. The major conclusions to be drawn are:

1. Human interventions into the topography of the river Elbe had a significant impact on storm surge heights and their statistics – the surges rose by something like 70 cm.
2. The timing of storm surge events can not be described as a Poisson-process with random waiting times between any two events. Instead, the series of events show clustering and extended active and passive stretches of time.
3. So far, a change in the storm statistics related to elevated levels of greenhouse gases in the atmosphere can not be detected .
4. For the future, a speeding up of the increase of storm surge heights, due to rising mean sea level and changing storm patterns, are plausible. The perspectives depend only little on the assumed future emissions of greenhouses gases. Until 2030 the changes are not serious for coastal defense; later in the century the changes likely will need dedicated adaptation measures.
5. While this increase of surge height along the North Sea appears unavoidable, the earlier modifications of the geometry of the estuary indicate possibilities to counteract the expected raise in surge heights in Hamburg to some extent.

When speaking about future risks, one has to take into account also changing patterns of vulnerability of coastal populations. It seems that the vulnerability of the population has increased in the recent past. The effective coastal defense has created a perception of absolute security, even if scientists have demonstrated that a slight modification of past storms (in terms of path and speed) could cause significantly exaggerated high storm surges. The vulnerability increases also because of the influx of people not originating from the coastal zone, who simply are not aware of the severity of the risk.

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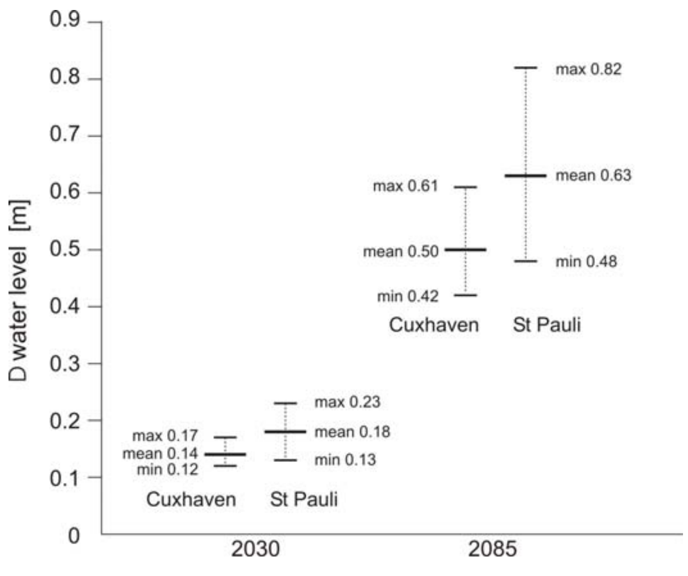

Figure 1: Scenarios of changes in storm surge heights as the mean maximum water level occurring on average in a storm season relative to 1980 – 1990 levels (related to mean sea level rise and changing wind statistics) in Cuxhaven (at the mouth of the

river Elbe) and Hamburg (some 140 km upstream of Cuxhaven). From Grossmann et al. (2007)