Historical Storm Surge Cases

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Abstract

This contribution presents details on a number storms surge cases: along the Southern Baltic sea coast, and the East China Sea coast at Qingdao. These case studies feature storm surge characteristics, specifically, losses of life and property, erosion extent, and relationship to extra-tropical and tropical storm intensity. The severity of the issue and the need of precautionary measures is demonstrated, not only for limiting the possible damages, but also for being able to manage for a possible failure of the coastal defense measures.

This article is a slightly revised and strongly shortened version of [1].

Keywords: Storm surges, Baltic Sea, Qingdao, Signal station data

1. Introduction

Storm surges are the major geophysical risk in coastal regions [2,3]; they are often associated with significant losses of life and property. Along the Bangladesh coast, tropical storms and their surges in 1876, 1891, 1970 and 1991 went along with a toll of a hundred thousand and more lives, and it was only in 2008 that the tropical storm Nargis killed more than 100,000 people in Myanmar [4]. In mid latitudes, the number of losses is usually several orders of magnitude smaller, namely up to a few hundred, which is, of course, bad enough.

We introduce case studies from the East China Sea coast at Qingdao, and the southern Baltic Sea coast. These examples are not representative but they illustrate some of the major issues and problems related to the global hazard of storm surges.

2. Cases of Qingdao 青島 (Yellow Sea)

Storm surges are the major marine disaster to China and are mainly caused by typhoons. The coast from Shanghai to Quanzhou and from the Zhujiang Estuary to northeast-Hainan areas are the two regions of China most affected by storm surge disasters [5]. From 1949-2009, storm surge heights exceeded 2.00 m 43 times, with most of them impacting the two aforementioned regions. The severity of these disasters, which are predominately in September, was found to be increased in last two decades [5].

China has 4000-year history with written documentation of storm surges. Records of storm surges were derived from Chinese historical literature [6]. The first storm surge ever recorded in China, and likely in the world, is in a Chinese history book titled the “Book of Han” that was completed in the first century. A storm surge in the Bohai Sea was described in this book: “*It rained for a long time. The northeast wind blew and the sea water was overflowed to southwest. The water intruded into the land for more than 100 kilometers and the land of Nine-River area was inundated.*“ [6] Unfortunately, the time of the surge was not mentioned.

Storm surges are a phenomenon that has always affected coastal inhabitants (e.g., [6,7]). When assessing the intensity of historical storm surges, the simplest method determine the maximum water level is to measure markings on buildings. The measures for protecting people and property against these extreme and dangerous events have a long history (cf. [8])

Qingdao is an important harbor city in China that faces the Yellow Sea and is located on the west coast of the Jiaozhou Bay. The major cause for storm surges in this area is typhoons, even though extra-tropical storms can cause surges and damages as well.

The tide gauge data in Qingdao from 1949 until 2003 revealed fourteen cases of high water levels related to typhoons [9]. Nine of these events were associated with sea levels exceeding +5.10 m.[1] The highest absolute water level was +5.48 m in 1997 - including tide and storm effect. The highest surge height related only to strong winds was 1.47 m in 1952.

Peak surge heights in the Qingdao depend on the typhoon paths. One type is typhoons that first make landfall on the Jiangsu coast before continuing north to Qingdao. Another one represents typhoons that make landfall in Fujian Province and then move north until turning east to Qingdao. The third moves north from the East China Sea to Qingdao. A fourth one stands for the typhoons that move northwest to Qingdao.


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Figure 1: The local newspaper reporting the damage of the Zhanqiao Pier in Qingdao in 2013 [1]

The following describes two severe storm surge disasters in Qingdao. The first storm was a (still nameless) typhoon that formed on 22 August 1939 in the Pacific Ocean. On the evening of 30 August the typhoon approached Qingdao and was accompanied by severe precipitation. At 6 AM on 31 August, the typhoon center was about 120 km south of Qingdao and the wind speed in Qingdao likely exceeded 150 km/hr. At 9 AM the typhoon made landfall on the west coast of Jiaozhou Bay, which is the location of the city of Qingdao. In Qingdao City, seventeen people were killed by storm surge. More than 1000 houses were destroyed and an additional 3000 houses were damaged. About 460 hectares of farmland near the coast was inundated. The loss of grain harvest was estimated at approximately 11 thousand tons. The total economic loss was equivalent to USD 4 million. The disaster is still remembered by the local people through oral transmission from the community elders [10].

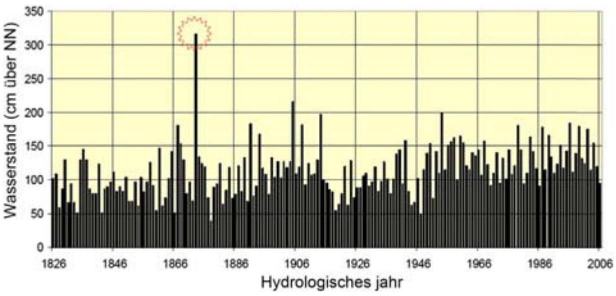
More recently, in August 1985, a storm surge disaster happened when Typhoon *Mamie* hit Qingdao. Twenty-nine people were killed in this disaster and 368 people were wounded. More than 8000 meters of sea dykes and other coastal defense measures were destroyed. The economic loss was equivalent to around 200 million US$.

Along this coast, extratropical meteorological storms can also cause storm surges. In May 2013 a storm surge hit Qingdao. The famous Zhanqiao Pier was damaged for the fourth time in 100 years (Figure 1).

3. The case of Dziwnów (Baltic Sea), 30. December 1913

The Baltic Sea is a semi-closed basin with limited connection to the North Sea via the Danish Straits. The tidal range in the Baltic Sea is practically negligible. Every couple of years, or so, the "filled basin" phenomena occurs, when a very strong wind blowing from W-NW moves water from the western to the eastern parts of the Southern Baltic Sea, pumping water from the North Sea to the Baltic Sea via Danish Straits at the same time. This causes more water to accumulate in the South Baltic and the level subsequently rises. When the strong wind changes direction to N-NE in a filled-basin situation, even more water accumulates at the western part of the South Baltic, and the water level increases significantly, reaching levels of +1.5m to 2.0m [11]. Such situation leads to catastrophic effects on the coast. Low dunes are eroded and water overflows thus creating coastal flooding. Cities located at the river mouths are usually affected by this event.

A filled-basin scenario has occurred many times in the history of southern and western part of the Baltic Sea. In historical reports we can find that in the past many strong storms at the Southern Baltic took place, which were associated with significant coastal and complete villages destroyed.



Figurer 2: Annual maximum surge heights in the years 1826-2006 in Travemünde, Germany Notice the peak for 1872. From [12]

The greatest documented storm event in this region took place on 13-14 November 1872. Many people lost their lives by the storm. The storm event on 13-14

[1] Here, and elsewhere in this article, sea level heights are given relative to some local reference

November 1872 was successfully reconstructed from pressure maps and surge heights, scattered air pressure data, and numerical modeling by [12]. The intensity of 1872 event is put into perspective when plotting annual maximum storm surges from 1926 to 2006 (Figure 2). The maximum surge height in 1872 was about +3.30 m, while in all other years the level of +2 m was almost never passed. It has been suggested that this event was due to the concurrent effect of a basin-filling, the wind-induced surge and a contribution of the major eigen-oscillation in the Baltic Sea.

At the end of the 19th century along the southern coast of the Baltic Sea, coastal dunes were perceived as a dam to protect against flooding [11]. People began to protect them by constructing fences to increase the deposition and accumulation of sand.

These dune restoration strategies took also place in the small town of Dziwnów located at Dziwna Strait. Since the middle of the 19th century, the originally small fishing village Dziwnów has gained importance as a holiday and spa resort, and began growing vigorously. Hotels and health centers, a beach hall, a promenade on the dune, beach baths (on piles over the beach), and a pier were constructed in 1890 and later. In a short period of time starting after 1890, Dziwnów became the most popular holiday destination on the Baltic coast.

Unfortunately, on 30 December 1913, a substantial storm devastated the "Pearl of the Baltic" [13] and the community has not since been rebuilt. The devastation started on 27 December with strong N-NW winds (Beaufort 8-9). On 30 December the winds shifted to N-NE and formed a strong storm surge. Elevated water levels in the region were observed, for example: Kołobrzeg (+1.59 m), Świnoujście (+1.98 m), Travemünde (+1.95 m) and Kiel (+1.82 m) [14] (Majewski et al., 1983). In the afternoon of 30 December water overflowed the low dunes and flooded the low-lying hinterland. Part of the town was affected and several buildings and tourist infrastructures were destroyed or damaged (Figure 3).

Figure 3: Postcards showing damages of the Beach Hall in Dziwnów caused by the storm surge on December 30, 1913. [1]

This 1913 event was reconstructed using a using a hydrodynamic model [15]. The modern day coastal profile was adopted and the dune morphology was approximated from old postcards: the dune top and width were estimated at +4m and +16m, respectively. A water level of +1.0m at the beginning of the storm was used with a maximum level of +1.14m (maximum water level in Dziwnów was noted +1.15m in 1874). Significant wave height was at 4.5 m

The simulation demonstrated an overflow effect after a couple of hours from storm initiation [16]. The model results corresponded well with descriptions provided by local witnesses shortly after the storm.

This same storm impacted other communities along the southern Baltic coast. In Gdańsk, located along the eastern shore of Gdańsk Bay, a water level of +1.56 was measured. There was a lot of damage to the port and tourist infrastructure. In Sopot, a famous resort in the Gdańsk Bay, water overflowed low dunes and caused flooding in the city.

The 30 December 1913 event was one of the greatest (biggest) storm surges in the southern part of the Baltic Sea coast. After the storm five tons of amber was found. Since then many protection measures have been implemented, including beach nourishment and dune restoration to make this area less vulnerable to future storm surge events.

Since the publication of [1] a new type of data has emerged – air pressure and wind observations taken at so-called "Signalstationen" (signal stations) all along the German and former German coastline, beginning in the late 19th century [17]. The data are presently digitized and their utility is examined. It turned out that the data are well suited for studying historical events. The wind-data for the storm surge on 31. December 1913 are depicted in Figurer 4, together with local water levels [17].

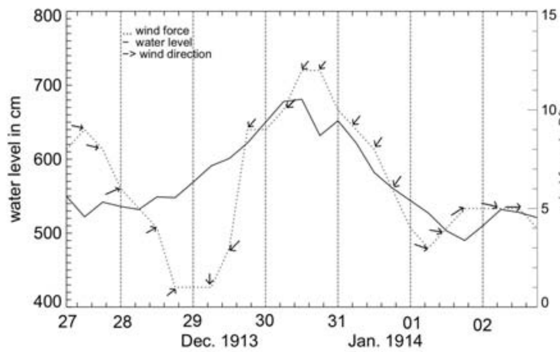


Figure 4: Chronological sequences of water level, wind force and direction at Greifswalder Oie in the period from 12 December 2013 to 1 January 1914. [17]

5. Concluding Remarks

The risk emanating from storm surges is a global, albeit regionalized phenomenon, affecting a large percentage of the world population, many urban conglomerates and centers of commerce and trade [18,19,20]. The scientific community, interested in the dynamics, prediction and management of the hazard of storm, surges, comprises oceanographers, meteorologists, hydrologists, coastal engineers, geographers, planners, historians and other earth and social scientists. Because of the breadth and the regionally limited impact of storm surges, this scientific community is highly fragmented, and is separated by regional languages, cultures and management concepts. More efforts are needed to bring this community together.

The specific case studies presented in this chapter demonstrate the multiple processes that result in storm surge and the various associated results. Changing coastal morphology, pumping ground water and compacting deltas are some examples of the results. While climate change, in particular via changing "the degree of filling" (sea level), is of great importance, storm surges deserve attention because of the challenge they represent today even without the predicted effects climate change.

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