Black Swans and Risk – Assessing Consequences of Extreme Events for the German Bight

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Background and Introduction

- Wastewater and north-western storms regularly hit the German North Sea coast causing surges of several meters at the dikes.
- In the past, severe storms did not lead to physically possible maximum water levels.
- Total water level components (i.e. mean sea level, surge, and tide) were not at their observed maximum during past extreme events (Dongenborg et al., 2016).
- Earlier research suggests: Water levels may likely exceed historical by at least 1.40 m (Jensen & Dijkstra, 2006).
- Project EXTREmeness was initiated to examine the meteorological potential to find extremely large and unlikely but physically possible storm surge events, which we refer to as “black swans”. Furthermore, the new level (SLR) impact will be investigated.
- Sub-project EXTREmeness-A/B identifies possible extreme meteorological events. Sub-project EXTREmeness-C simulates the resulting storm surges in the German Bight.
- Sub-project EXTREmeness-D (presented here) assesses the consequences of the storm surges for a model region at the German Bight, with regard to following questions and tasks:
  - How large is the damage potential and which are the most important and most vulnerable sections to current state coastal protection?
  - Are there possibilities to make the region more resilient?
- Provide information to increase public awareness and to improve disaster management preparations.

Study Area: Emden & Krummhörn

- Model region for the German Bight (see Fig. 2).
- Different challenges: The region is located at an estuary (River Elbe), low lying with large parts below mean sea level requiring drainage with tide gates and pumping stations, and various objects/infrastructures at risk:
  - Large agricultural areas (~200 km²), mixed-use pastures/crops (see yellowish areas in Fig. 2).
  - Residential development ~50,000 people in Emden, ~20,000 people in the surrounding Krummhörn region (see red areas in Fig. 2).
  - Industrial areas: i.a. harbor of Emden, large car factory (see purple areas in Fig. 2).
  - Important infrastructures (i.e. gas terminals, offshore wind energy).
- Dike heights between 6.50 m and 8.40 m ASL.
- 44.6 km primary dike line in the study area (see black line in Fig. 2).

First Results

- Peak water level of the Reference Flood (as occurred 2006) is at ~5.00 ASL. Emden (bottom).
- First simulations of this Reference Flood and variations with an assumed sea level rise (SLR) show significantly larger inundation areas where SLR is considered. Fig. 3 shows an example for a dike failure at section 6 (red dot).
- Fig. 4 shows the affected area for the Reference Flood, Fig 3b considers 100 cm SLR.
- Areas affected by the dike failure are mapped on a hexagonal grid.
- Due to dike failure, initially dry land is completely flooded after the dike failure to Polar blue color; only some of the area is affected by flooding.
- For a dike failure at section 6: The overall affected area is 1.68 times larger when 100 cm SLR scenario is considered.
- At some dike sections, simulations show a doubling of the affected area.

Conclusions and Outlook

- The Reference Flood would have caused large inundation areas if a dike failure had occurred. Combining this storm with SLR shows that inundation areas would significantly increase up to a doubling of the affected area.
- Extreme storm surges (“black swans”) that are currently derived from climatic data by our project partners are expected to be even higher and/or with larger high water durations. Affected areas will likely be higher compared to the Reference Flood.
- Damages have not been considered yet. The irregular land use distribution may lead to significantly larger damages even if the total affected area does not increase much and vice versa. The dike failure location mostly controls the extent of damages.
- Further steps in the project will include:
  - Statistical classification of the black swans (i.e. return periods based on today’s observations).
  - Consideration of the affected land use and infrastructure including the damage potential due to inundations.
- Discussion of the results with local authorities and disaster management to draft measures to improve preparedness for even extremely unlikely events.

Methods and Data

- Simulation of hitherland flooding due to dike failures during extreme storm surges with a two-dimensional hydrodynamic/numerical model (using DUNE 21 FM).
- Water-side forcing: Storm surge water levels along the coast of the total river Elbe (output from EXTREmeness-C simulations).
- Bed roughness: Spatially varying based on eight land use categories. Land use is derived from CORINE (2006) and Operational data 2016 (Emden harbor)
- Bathymetry/topography: DEM and bathymetry with 5 resolution, used on an unstructured computational grid with cell edge lengths between 10 m and 75 m.
- Assumed dike failure: Simulation of each storm surge scenario with a breach in the center of one of 20 dike sections. Each section is approx. 2 km long.
- Breaches are simplified as trapezoidal openings in the dike line with a top width of 650 m, based on observations after the storm surge 2006 (Kramer et al., 2006).
- Reference Flood: Water levels from Nov. 1st 2006 storm surge, which did not cause flooding in reality but is remembered as a “close call” by locals and authorities.
- Mapping of flooded areas for each dike failure scenario.
- Identification of flood prone areas and affected critical infrastructure.
- How would flooding slowly develop or obstruct disaster relief?
- Estimation of damage potential based on affected land use and buildings.
- Which type of extreme storm surge would lead to the most severe damages?

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References