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Estimating the consequences of a high impact event at the Ems estuary, Germany

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A Background & Introduction

- Storm induced extreme water levels are among the most severe natural hazards along the German North Sea coast.
- In the past, extreme water levels of several meters have been observed, but these events have not yet been the worst physically possible combinations of tide and surge in this region *(e.g. Dangendorf et al., 2016; Jensen & Müller-Navarra, 2008)*.
- Project EXTREMENESS examines the meteorological potential to find extremely large and unlikely but physically possible extreme storm surge scenarios.
- Sub-project EXTREMENESS-D (presented here) assesses the consequences of storm surges for a model region at the Ems estuary, with focus on following questions and tasks:

? How do the extreme storm surge scenarios amplify the consequences, in comparison to an observed extreme event (reference "REF" scenario)?

? Which are the most vulnerable sections in today's coastal protection with regard to protected assets?

! Provide information to increase public awareness and to improve disaster management preparedness.

C Scenario Storm Surges: Statistical Rating

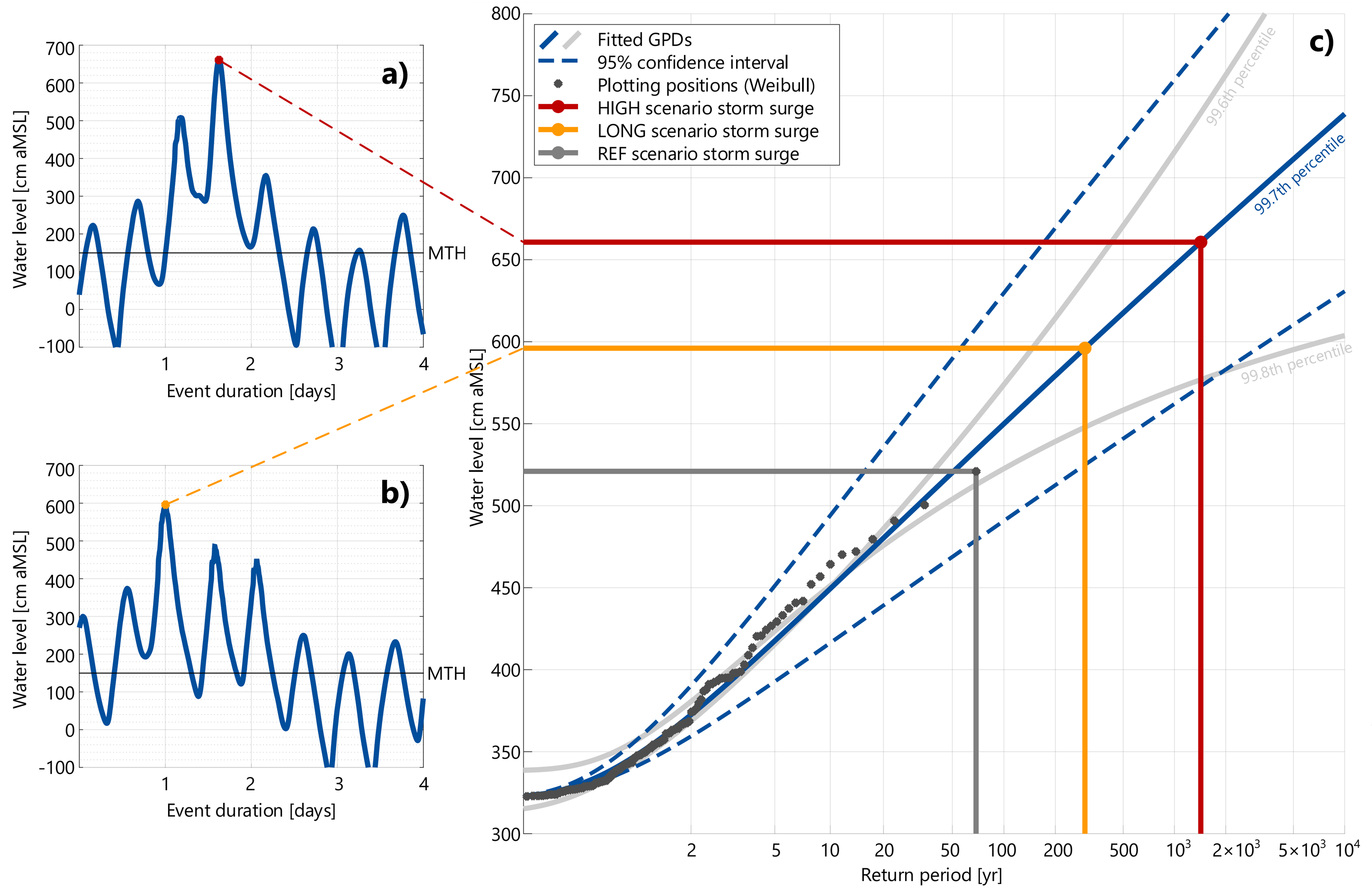

Fig. 3: *Extreme storm surge scenario water levels for Emden Harbor considering (a) the HIGH scenario and (b) the LONG scenario. The scenarios can be statistically rated by applying a peak-over-threshold approach to the local observations using the 99.7th percentile of threshold exceedances (cf. Arns et al., 2013). The fitted Generalized Pareto Distribution (GPD) allows a rating of the scenario peak water levels as 1,400 year and 300 year event for the high scenario and the long scenario, respectively. The GPD fits the observations well (R^2 = 0.991, RMSE = 5.2 cm) but, however, the return periods of the scenario events are only a rough estimate since uncertainties grow fast with far extrapolations, as shown by the 95% confidence bounds (dashed blue).*

D Flood Model Set-Up & Simulations

- 2D hydrodynamic-numerical inundation model (using DHI MIKE 21) was set up to estimate affected areas in case of a dike failure.
- Successively, 20 different dike failure locations (each representing a ~2 km dike section) were integrated in the model to estimate resulting inundation areas during different extreme storm surges (REF, HIGH, LONG; see Fig. 3 a/b).
- Results are compiled on a hexagonal grid for easier communication.

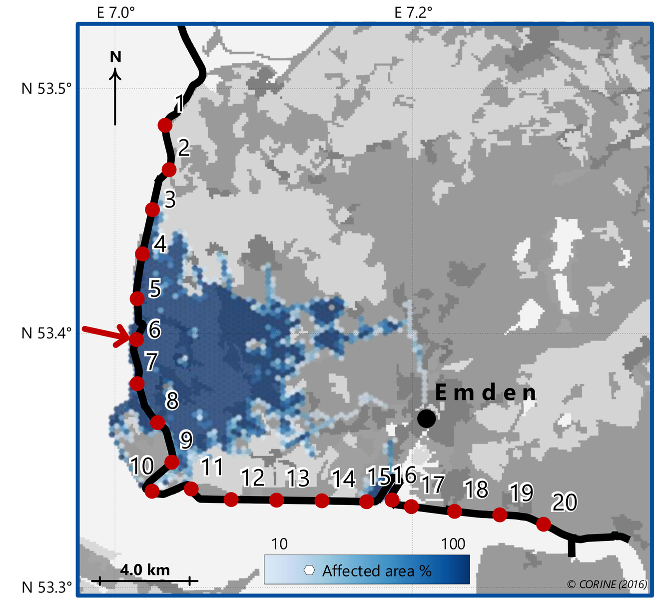

Fig. 4: *Dike line (black), locations of the dike failure scenarios (red dots), and an exemplary flood simulation result for failure location 6 under HIGH scenario conditions. The area affected by water [%] is colored as blue shading where dark blue denotes fully affected grid cells while light blue denotes only partially affected cells.*

F Comparison & Conclusions

- **Extreme storm surges amplify consequences compared to the REF scenario. The damage increase mainly depends on the dike failure location resulting in different damage distributions.**
- **Compared to rural areas, potential damages can be up to six times larger in urban areas (see Fig. 6).**
- **Critical infrastructure transfers consequences from flooded areas to non-flooded areas.**
- **Next step: Integrating infrastructures in the damage potential assessment to estimate the additional impact.**

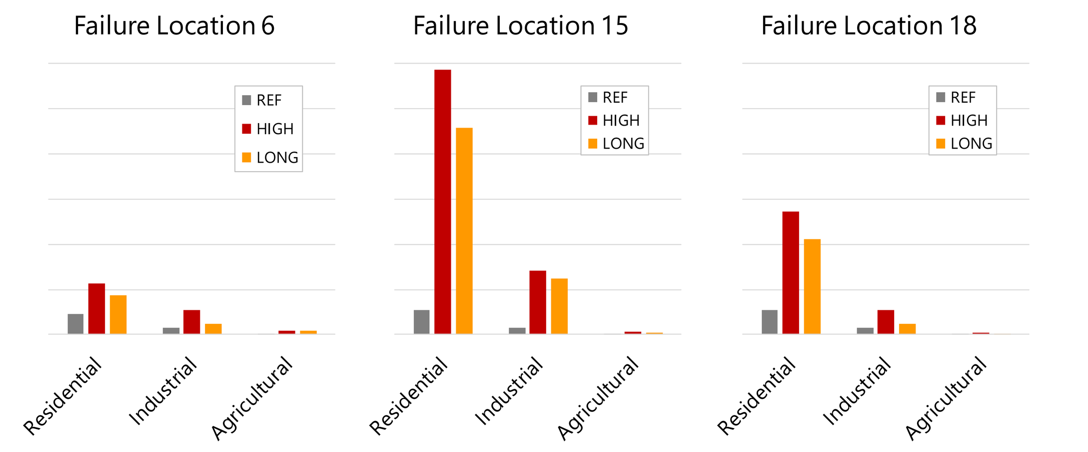

Fig. 6: *Comparison of total damage values for the three storm surge scenarios at different failure locations, summed up separately by land use classes. The comparison shows how the dike failure location controls the total damage and how the storm surge water levels significantly affects potential damages within each failure scenario.*

B Study Area: Emden & Krummhörn

Fig. 1: *Krummhörn region (red area) with the city of Emden (white dot) in Lower Saxony at the north-western German North Sea coast (for details see also Ulm et al., 2018).*

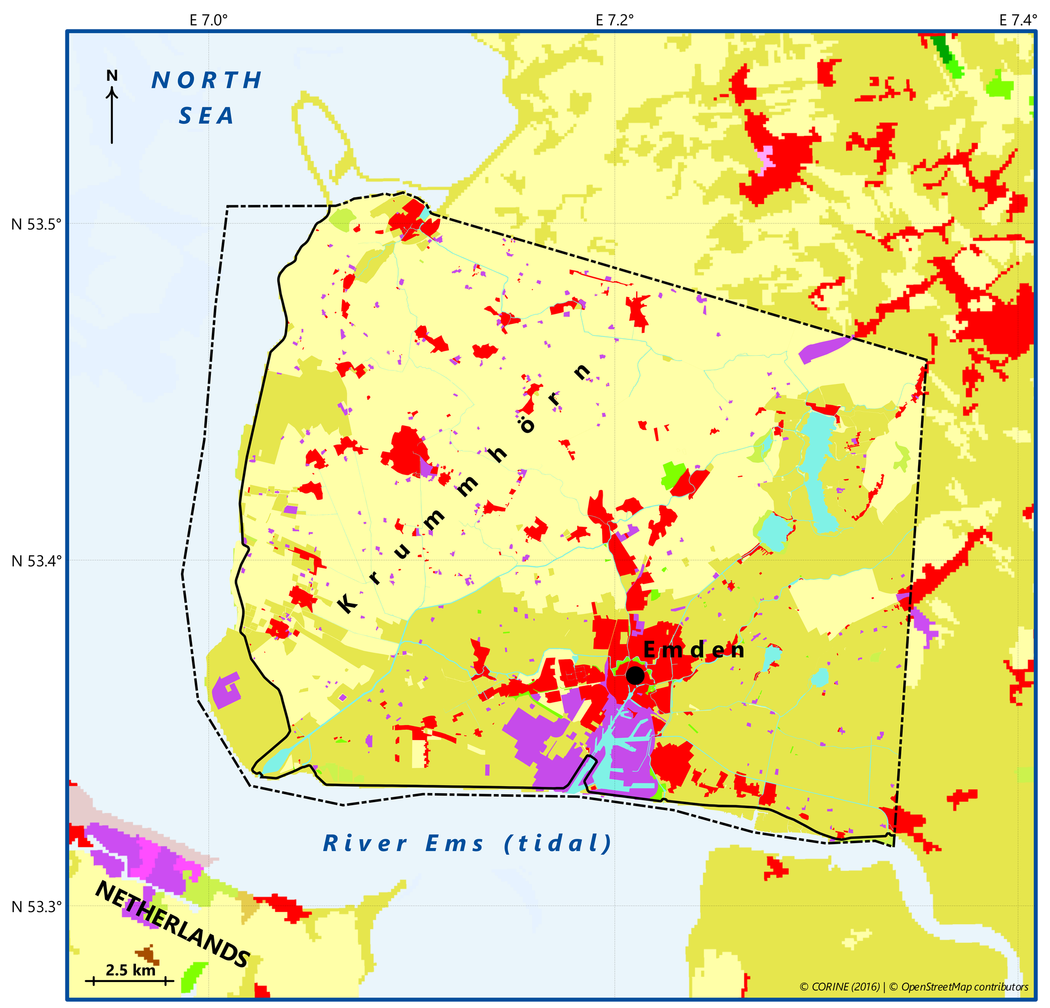

Fig. 2: *Study area (within black dash-dotted line) and neighboring regions color-coded by land use: residential (red), agricultural (yellowish), industrial (purple), water (bluish), dike line (black).*

E Scenario Storm Surges: Damage Potential Based Rating

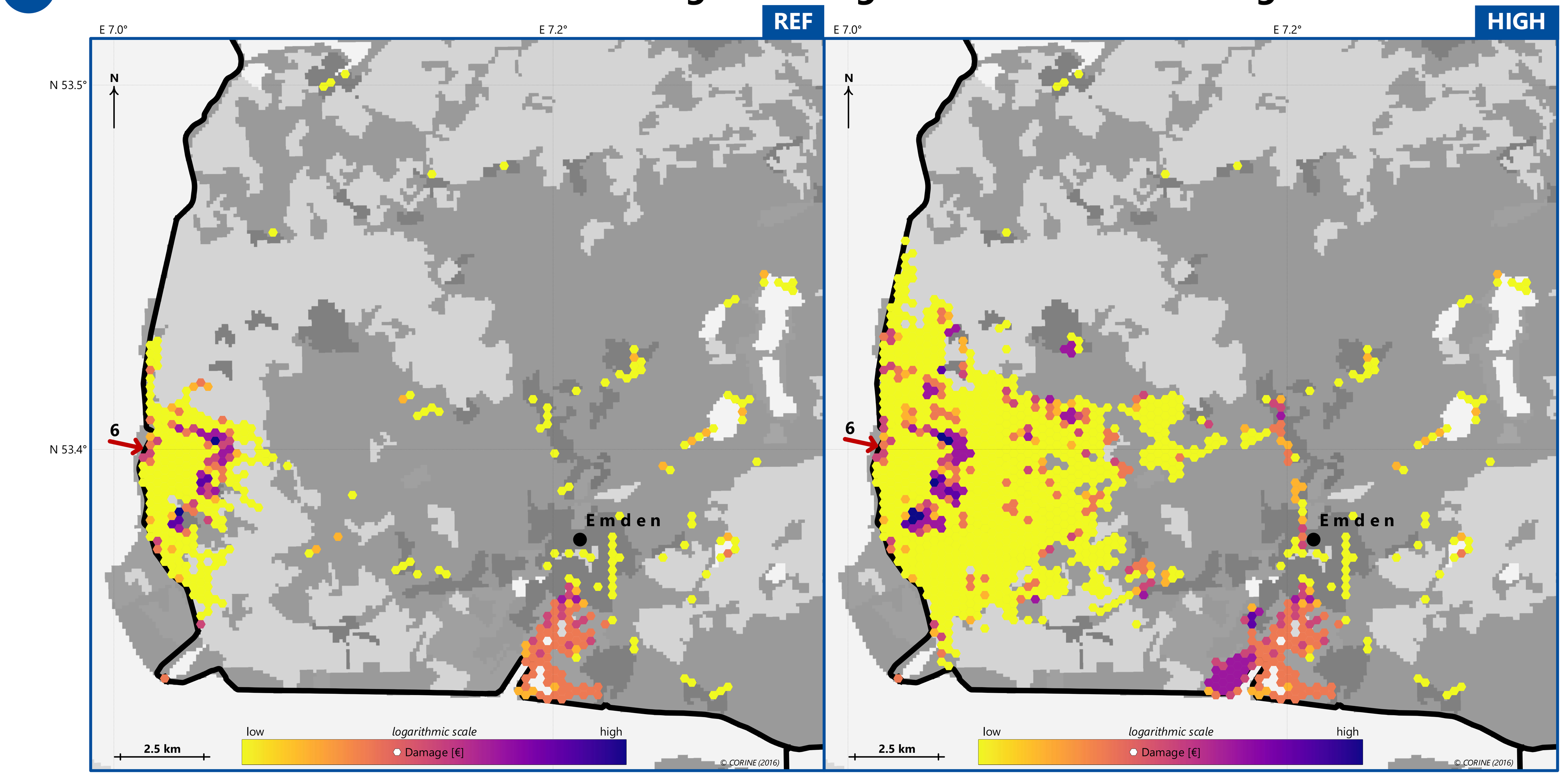

Fig. 5: *Potential damages due to an assumed failure of location 6 for the REF and the HIGH scenario. Damages were calculated for each simulation grid cell based on empirical damage data for the different land uses and compiled on the hexagonal grid. The damages are in the range of 10^5 to 10^8 € per hex cell. Since further analyses focus on a comparison (see Fig. 6), detailed values can be omitted.*

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