

# ASSESSMENT OF EXTREME STORM SURGE HYDROGRAPHS

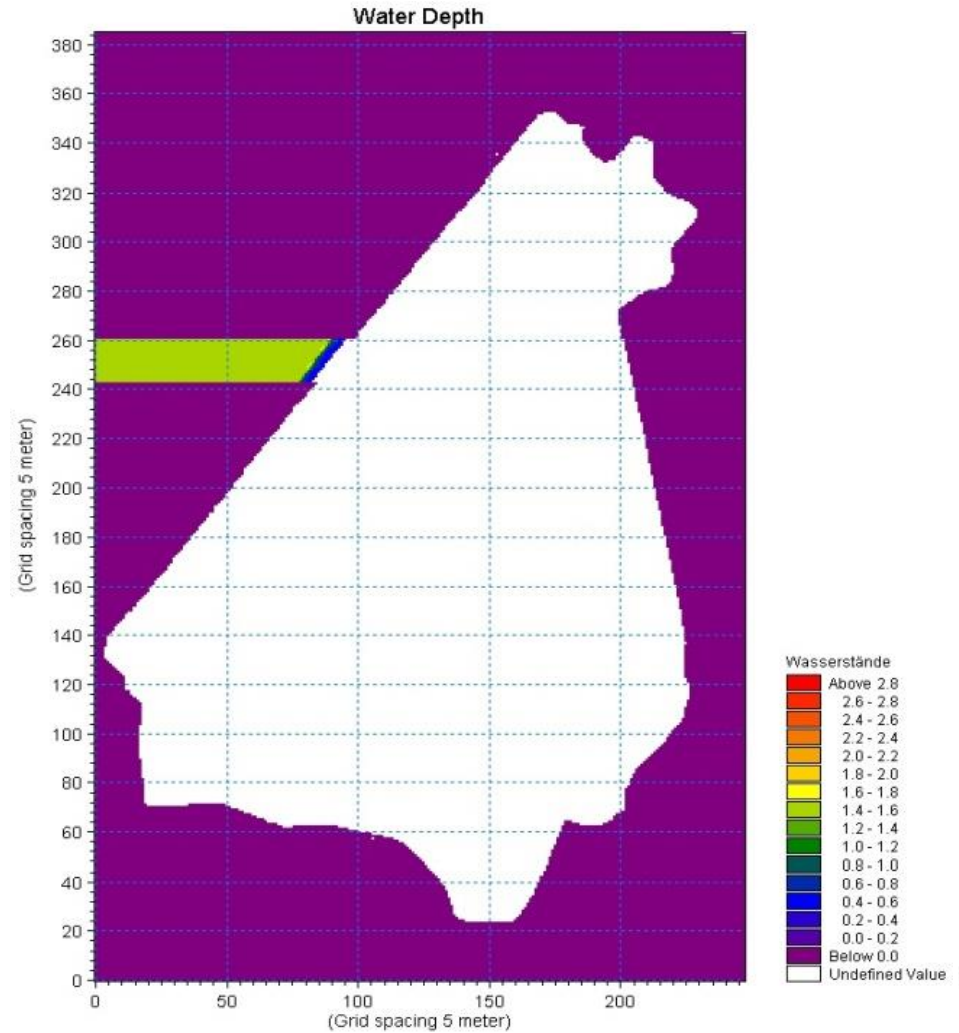
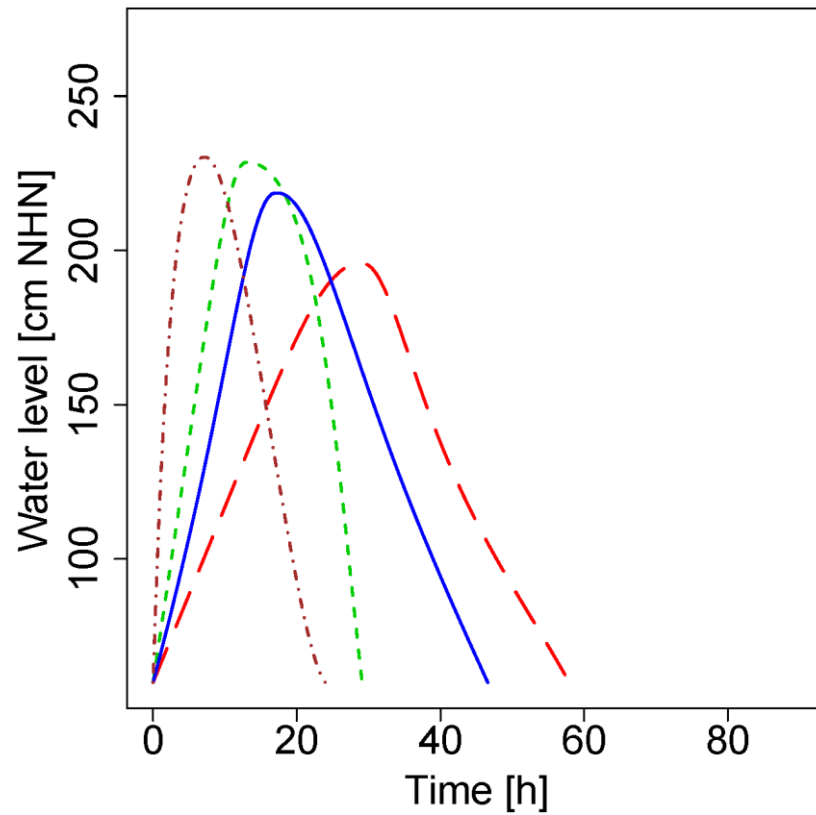
FOR THE SOUTH-WESTERN BALTIC COAST USING UNIVARIATE AND BIVARIATE  
STATISTICAL MODELS

*Dörte Salecker, Peter Fröhle (doerte.salecker@tuhh.de, peter.froehle@tuhh.de)*

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### Introduction

When designing flood protection structures it is common practice to define storm surge water levels with a certain return period that the structure must withstand to ensure the protection of lives and property. In German Coastal Engineering practice, typical probabilities of occurrence are in the range between  $10^{-2}$  and  $10^{-5}$  (return periods 50 to 500 years respectively). For certain protection structures, such as dikes and/or the maximum water level during a storm surge is crucial. In the duration of the high water event, with the erosion of the dike or the failure of a long pipeline reaches the dike.

Therefore storm surge hydrographs being the progression of water levels over the time, are needed to design these protection structures or to assess their reliability.

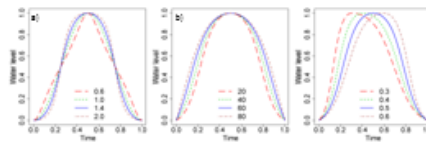


Fig. 2: General shape of the storm surge hydrographs (a) based on the peak water level (b) on the peak water level (c) on the peak water level

### Data and Methods

Inputs: Hourly measurement of water level at selected gauging sites (Fig. 1). Peak water level of the highest storm surge recorded.

Univariate Statistical Analysis: Probabilities of occurrence are assigned to water level and times (area under the storm surge hydrograph) samples using the Gumbel distribution for water level samples and the Generalized Extreme Value Distribution as well as the Log-Normal Distribution for times samples.

Bivariate Statistical Analysis: The relation between high water level and corresponding times of storm surge hydrographs modeled using the Gumbel copula (Fig. 3)

Dimensionless Storm Surge Hydrographs: To generate random hydrograph shapes (Fig. 2) both peak water level and time of the peak water level are generated randomly. The time of the peak water level is then the initial actually measured time for each location.

$$F(x, y) = \frac{a}{(\ln(x) \pm a)(\ln(y) \pm a)^2} \quad \text{Eq. 1}$$

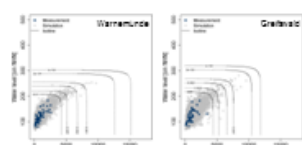


Fig. 3: Comparison of measured and simulated data sets of water levels and times at the locations Wismar and Gellinick

### Application

Similarly for the locations Wismar and Gellinick four dimensionless storm surge hydrograph shapes are simulated (Fig. 5). These shapes are being used in a first and with a bivariate copula to model water level and times with a required probability (see Eq. 4). In a first step the height of the storm surge hydrograph being scaled by multiplying the desired peak water level.

In a second step the storm surge hydrograph is scaled in width by multiplying the ratio of the desired to the actual times. In Fig. 5 the dimensionless hydrograph shapes are scaled to real values. With regard to their peak water level and their times and under the assumption that all generated storm surge hydrograph shapes have the same probability of occurrence all scaled hydrographs shown have a probability of occurrence of  $10^{-2}$ . This equals a return period of 200 years.

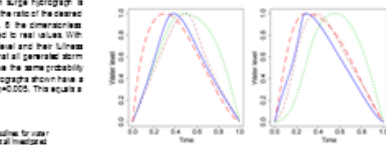


Fig. 4: Random dimensionless shape of storm surge hydrographs for the locations Wismar and Gellinick

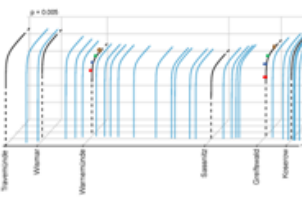


Fig. 5: Scaled storm surge hydrographs with a return period of 200 years for the locations Wismar and Gellinick

Conclusion: Storm surge hydrographs (all in their peak water level and their duration as well as their shape) can be generated. The plausibility of the results is proved by comparison of generated storm surge hydrographs and actually measured storm surge hydrographs. At present the presented method is not applicable to simulate more complex shapes like storm surge hydrographs with two or more peak water levels. It is assumed that hydrograph shapes appear as equiprobable. This assumption has not been proved yet.