An idealized meteorological-hydrodynamic model for exploring extreme storm surge statistics in the North Sea in an alternative way

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Storm surges are a threat for low lying areas near coasts. Insight in and quantification of extreme storm surge events are essential for the design of coastal protection systems. Time series of surge levels, used for statistical extrapolation to define extreme surge levels with a 10,000 year return period, is only 150 years. This results in large uncertainty in the extreme values. In addition, the currently used approach results in lack of insight into the coupling between the storm and the storm surge. Little is known about the duration and course of extreme surges.

This study focuses on the properties of storms causing extreme surges at Hoek van Holland, The Netherlands. This alternative method is based on a joint probability model of the storm characteristics at the North Sea, in which surges are modeled with an idealized coupled meteorological-hydrodynamical model. Six storm characteristics are used to define each storm. Using historical data, probability density distributions have been derived for these parameters. The model output is the water level at Hoek van Holland, as a function of time. The model has been applied to define extreme surge levels using Monte Carlo Analysis, see Figure 1. The computed surge level (including tide) with a statistical return period of 10,000 years is 5.4 m, 5.6 m and 6.1m (based on three different datasets), compared to 5.10 m according to the hydraulic boundary conditions determined by the Dutch government. The output also indicates that the average duration of computed surges with a return period of 10,000 year is roughly two hours longer than the storm duration currently adopted.

In conclusion, a strongly idealized meteorological-hydrodynamic model reasonably matches the observed wind speeds and surge levels for individual storms at the North Sea. Using Monte Carlo Analysis, the estimates of extreme surge levels are similar to the statistically extrapolated values. It is recommended to further explore this alternative method by using more realistic numerical models for hydrodynamic behavior (e.g. 2DH or 3D modeling).

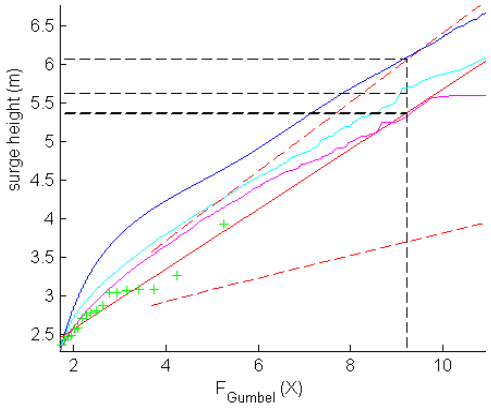

Figure 1: Gumbel plot of $1 \cdot 10^{-4}$ year^{-1} surges (at vertical dashed line). Surge levels based on model output are denoted in blue. Results of improved datasets are shown in cyan and magenta. Results based on extrapolation of measurements (green plusses). The solid red line shows the currently adopted probability of exceedance curve, the 95% probability interval is shown by red dashed lines.