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Extreme North Sea storm surges and the changing climate: An ensemble study

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The low-lying Netherlands are vulnerable to storm surges from the North Sea. Climate change might alter storm characteristics and lead to higher surges, posing an extra risk to the country. To investigate this possibility a surge model of the Northwest European shelf region is driven by output from a 17-member ensemble of climate change simulations under the SRES A1b scenario. The large number of runs provides a good statistical basis to assess changes of the 10 000-year return water level, which describes the Dutch safety level.

1. Introduction

According to Dutch law the coastal defense systems have to withstand a water level that is exceeded only once in 10 000 years. This level is determined by extrapolating the ≈120 years of observations, using extreme value statistics. Extrapolating over two orders of magnitude naturally results in large uncertainties, hiding possible changes.

2. Method

To reduce the statistical uncertainty when estimating (future) surge heights we use the output of the large ESSENCE ensemble [1] to force WAQUA/DCSM98, a surge mode of the Northwest European shelf. In ESSENCE the ECHAM5/MPI-OM climate model has been run 17 times from 1950 to 2100 (SRES A1b scenario). Thus for both ``present'' (1950-2000) and ``future'' (2050-2100) periods 867 years of data are available. The annual mixima are fitted to a GEV distribution and extrapolated to return times of 10 000 years.

3. Results

3.1 Winds

Surges result from wind. The model projects a slight increase of strong winds (Figure A, left), but at most grid points the increase is insignificant due to the large variability (right). This is confirmed in Figure B: theconfidence intervals overlap. Furthermore, Figure A shows that the increase is solely due to south-westerly winds, which are not important for surges along the Dutch coast.

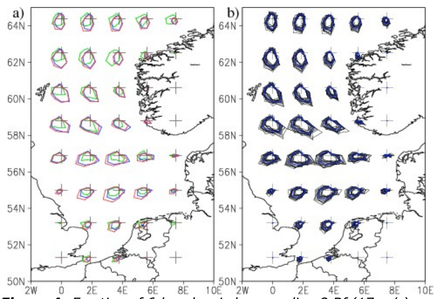

Figure A: *Fraction of 6-hourly winds exceeding 8 Bf (17 m/s) per 30-degree sector for all grid points in the North Sea. (a) Means over all ESSENCE members for the present (1950-2000, blue) and future (2050-2100, red) climates. For comparison, ERA-40 is added in green. (b) All 17 members for the present climate and their mean (blue).*

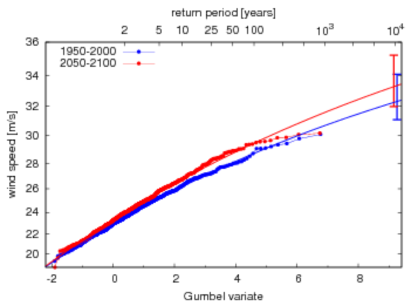

Figure B: *Wind speed at (5ºE, 55ºN) for present and future periods in the ESSENCE ensemble. The wind speed is given as function of the Gumbel variate, which is directly related to the return period (upper axis). The dots represent model values, and the thin lines are GEV fits. The bars denote the 95% confidence intervals of the 1-in-10 000 years wind speed.*

3.2 Water levels

Figure C shows a comparison between observed and modeled water levels, together with the impact on the uncertainty of having 867 years of data instead of 120 years. The model does a good job in reproducing the observations, and the confidence interval is substantially reduced.

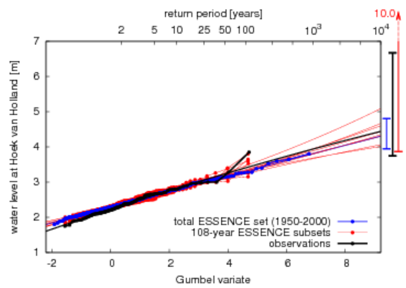

Figure C: *Gumbel plot for water levels at Hoek van Holland. Black: 118 years of observations (1888-2005, thick) and GEV fit (thin). Red: data from eight 108-year chunks of ESSENCE-WAQUA/DCSM98 thick) and corresponding fits (thin) for the present climate (1950-2000). 108 was chosen because 8 × 108 = 864 is as close as possible to 17 × 51 = 867, the total number of years available. Blue: All 867 years of ESSENCE-WAQUA/DCSM98 together. The bars at the right margin indicate the 95% confidence ntervals for the 10 000-year return value. The red bar corresponds to the curve with the highest best estimate of 5.1 m.*

Figure D shows a comparison between modelled water levels for the present and future periods, respectively. Within the uncertainty limits they are identical. According to our model climate change will not impact on surge levels at the Dutch coast.

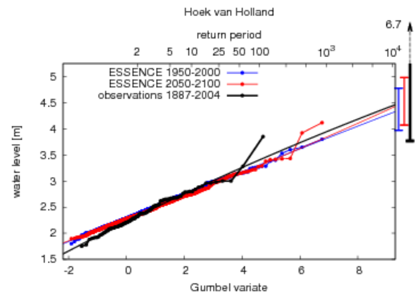

Figure D: *Gumbel plot for water levels at Hoek van Holland from the ESSENCE-WAQUA/DCSM98 ensemble. Black: observations, blue: present-day climate (1950-2000), red: future climate (2050-2100). The observed data and present-day simulations are the same as in Figure C. The thin lines are the fits to a GEV, and the bars in the right margin indicate the 95% confidence interval of the 10 000-year return value.*

4. Conclusions

This poster:

- **wind speeds will slightly increase**
- **increase is for SW winds**
- **surges will not change**
- **large ensemble greatly reduces statistical uncertainty**

Further results [2]:

- **sea level increase does not affect surges**
- **tides and surges strongly interact**

Acknowledgement

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References

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[2] A. Sterl et al. (2009), An ensemble study of extreme surge related water levels in the North Sea in a changing climate, Ocean Sci., 5 (2009), 369-378, http://www.ocean-sci.net/5/369/2009

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