

# Lessons from a large model ensemble: Extreme temperatures and surge heights

Andreas Sterl\*

Society and ecosystems are usually adapted to the mean climate, but are vulnerable to weather extremes like storms or heat waves. By definition, extremes are rare events, and physically possible extremes might have not occurred in known history. Estimating their magnitude requires extrapolation from short time series and over several orders of magnitude, resulting in large confidence intervals. The problem becomes worse when the climate changes. To reduce the statistical uncertainty of such estimates, we use results from the ESSENCE project, in which the ECHAM5/MPI-OM climate model has been run 17 times under the SRES A1b scenario. This large ensemble comprises enough data for both present and future climate to estimate extremes with long return times and their changes with error estimates that are of practical use. We here show results for  $T_{100}$ , the once-in-one-hundred years temperature, and water levels along the Dutch North Sea coast, where Dutch law requires a safety level of the coastal defense systems of once in 10 000 years.

## 1. Data and method

### ESSENCE

- ECHAM5-MPI/OM
- 17 runs 1950-2100
- SRES A1b (720 ppm of CO<sub>2</sub> in 2100)

### Data

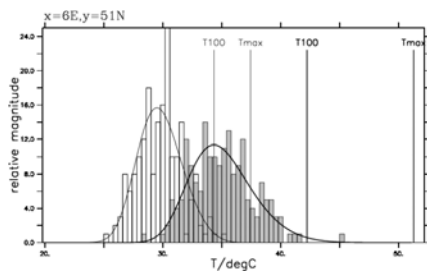
- Raw daily  $T_{max}$
- Max. water levels from WAQUA (surge model), driven by winds and pressure from ESSENCE

### Method

Block maxima: GEV fit to annual max.:

$$G(x) = \exp\left\{-\left[1 + \zeta\left(\frac{x - \mu}{\sigma}\right)\right]^{-1/\zeta}\right\}$$

### Example



**Figure A:** Empirical PDF of annual  $T_{max}$  at grid point "Netherlands" for present (1991-2000, grey) and future climate (2091-2100, black), together with GEV fits and  $T_{max}$  and  $T_{100}$ . The histograms are derived from  $17 \times 10 = 170$  years of data and a bin width of 0.4 K. Clearly, the PDF becomes wider, and the extremes change faster than the means.

### Acknowledgement

ESSENCE was carried out with financial support from DEISA, HLRS, SARA, and NCF. HLRS and SARA staff provided technical support. The MPI for Meteorology in Hamburg made available their climate model ECHAM5/MPI-OM and provided valuable advice. The Dutch Delta Committee initiated the research into surges.

### References

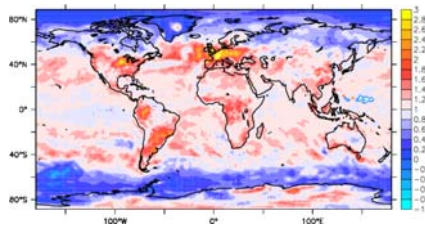
- [1] A. Sterl et al. (2009), When can we expect extremely high surface temperatures? Geophys. Res. Lett., 35, L14703, doi: 10.1029/2008GL034071
- [2] A. Sterl et al. (2009), An ensemble study of extreme surge related water levels in the North Sea in a changing climate, Ocean Sci., 5, 369-378, <http://www.ocean-sci.net/5/369/2009>

### Contributors

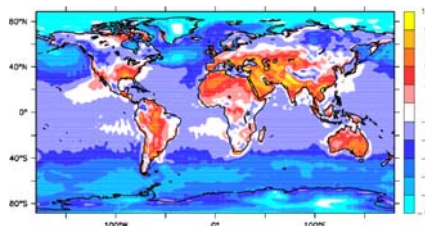
H. v/d Brink, R. Haarsma, E. van Meijgaard, C. Severijns, H. de Vries, H. Dijkstra, W. Hazeleger, G.J. van Oldenborgh, M. v/d Broeke, G. Burgers, B. v/d Hurk, P.J. van Leeuwen, P. van Velthoven

## 2. $T_{100}$

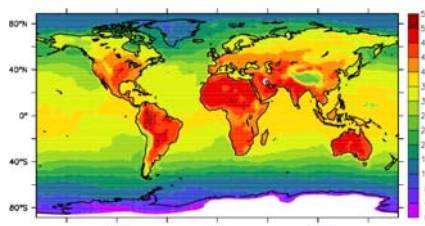
- Change in  $T_{100}$  much larger than change in  $T_{mean}$  (Figs. A + B)
- Large bias wrt to ERA-40 (Fig. C)
- Bias-corrected  $T_{100}$  reaches dangerous levels ( $> 50^\circ\text{C}$ ) in certain areas at the end of this century (Fig. D)



**Figure B:** Difference between 2090-2099 and 1990-1999 of  $T_{100}$ , expressed as a multiple of the ensemble mean temperature change during the same period. Red (blue) colors mean that  $T_{100}$  grows faster (slower) than the mean temperature.



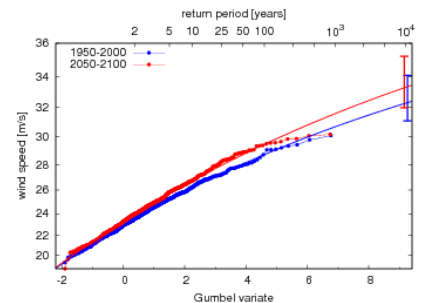
**Figure C:**  $T_{100}$  from Essense (whole ensemble) minus  $T_{100}$  from ERA-40 for the entire ERA-40 period (1958 - 2001).



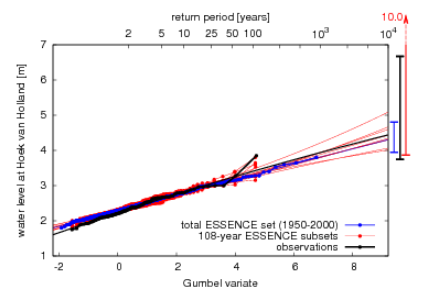
**Figure D:**  $T_{100}$  from Essense for the period 2090-2100, corrected for the bias with respect to ERA-40 (Figure B).

## 3. Water levels

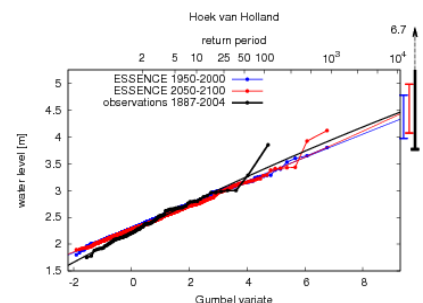
- Slight increase of (extreme) winds (Fig. E), but from south-west
- Large reduction of uncertainty due to large ensemble (Fig. F)
- No significant future changes of surges (Fig. G)
- Sea level rise has no impact on surge height (not shown)



**Figure E:** Wind speed at (5°E, 55°N) for present (blue) and future (red) 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.



**Figure F:** 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, and corresponding fits (thin) for the present climate (1950-2000). 108 was chosen because  $8 \times 108 = 864$  is as close as possible to  $17 \times 51 = 867$ , the total number of years available. Blue: All 867 years of ESSENCE/WAQUA together. The bars at the right margin indicate the 95% confidence intervals for the 10 000-year return value. The red bar corresponds to the curve with the highest best estimate of 5.1 m.



**Figure G:** Gumbel plot for water levels at Hoek van Holland from the ESSENCE/WAQUA 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 F. 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.