A multi-scale and model approach to estimate future tidal high water statistics in the southern German Bight

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High Water Statistics & Climate Change

Interactions of tides, external surges, storm surges and waves with an additional role of the coastal bathymetry define probabilities of extreme water levels at the coast. Probabilistic analysis and also process based numerical models allow to estimate future states.

High water statistics can be represented by 1 year ($mTHW_1$) and 10 year ***mean tidal high water*** ($mTHW_{10}$). In Germany, $mTHW_{10}$ is a typical mean period which is in use for coastal protection. Predictability of future tidal high water statistics depends on the ***functional understanding of the historic variability*** (Hein et al., 2011b). A common method is to transform time series into the frequency space.

A ***model chain*** reproduces historic statistics of tidal high water levels as well as predicts future statistics of high water levels. Wavelet based multi-scale methods applied to results of the model are biased in the frequency space.

Data & Model

Tide gauge data are the original and quality assisted observations originating from the ***German Federal Waterways and Shipping Administration (WSV)***. Five representative tide gauges of more than 100 operated tide gauges are used.

The North Sea is modelled by the HAMburg Shelf Ocean Model (***HAMSOM***, Backhaus, 1985). This model is a established numerical model for long-term simulations (Schrum, 1994; Pohlmann,2006). Two different hindcast simulations (1950 – 2000) are compared with respect to the observations to validate model results. One climate run with a simulated period of 150 years (1950 – 2100) is analysed. This allows a gain insight into future states. Details about the model chain are pictured in **Figure 1**.

Multi-scale adaptation of model results

To adapt long-term processes, which are present in both observed and modeled data, the time series of the water levels are transformed into a time varying frequency space by means of a ***wavelet transform***. Beginning from the longer periods, each frequency is fitted to the observations in order to adjust phase and amplitude of the model chain. Backward integration generates the new time series.

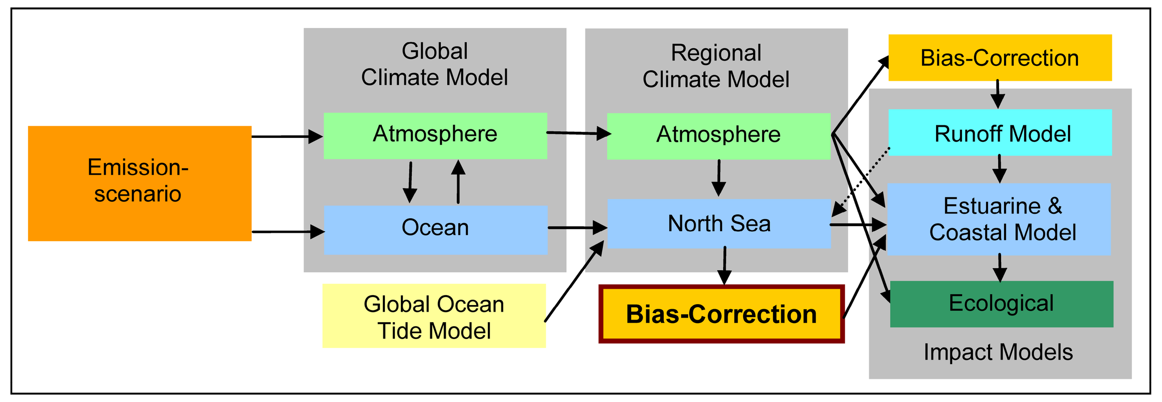

Figure 1: *Model-chain to simulate future states of tides and impact, this study: Bias correction in the red Box.*

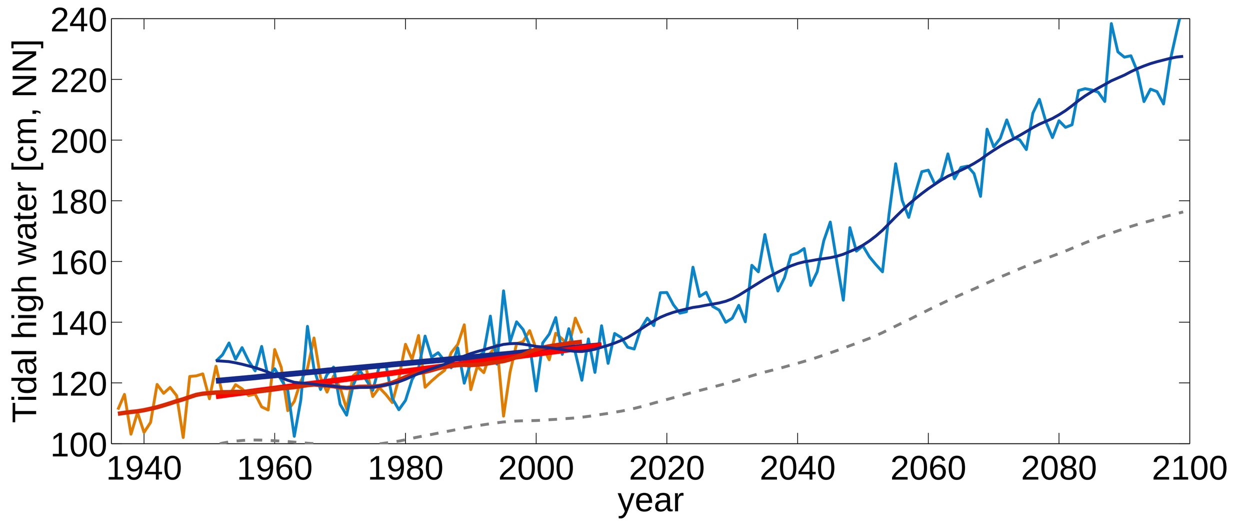

Figure 2: *Possible rise of the* $mTHW_1$ *(simulated light blue, measured orange),* $mHTW_{10}$ *(simulated dark blue, measured red), and trend (simulated blue, measured red), mean sea level (MSL, NN + 100cm, dashed grey).*

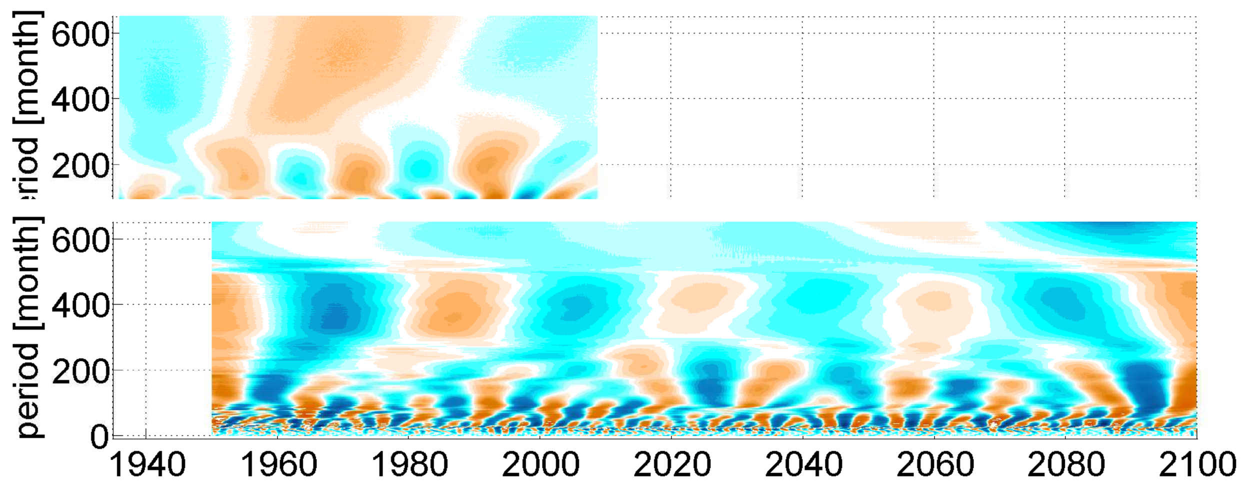

Figure 3: *Wavelet spectrum from observed water levels. Spectrum of the bias correction.*

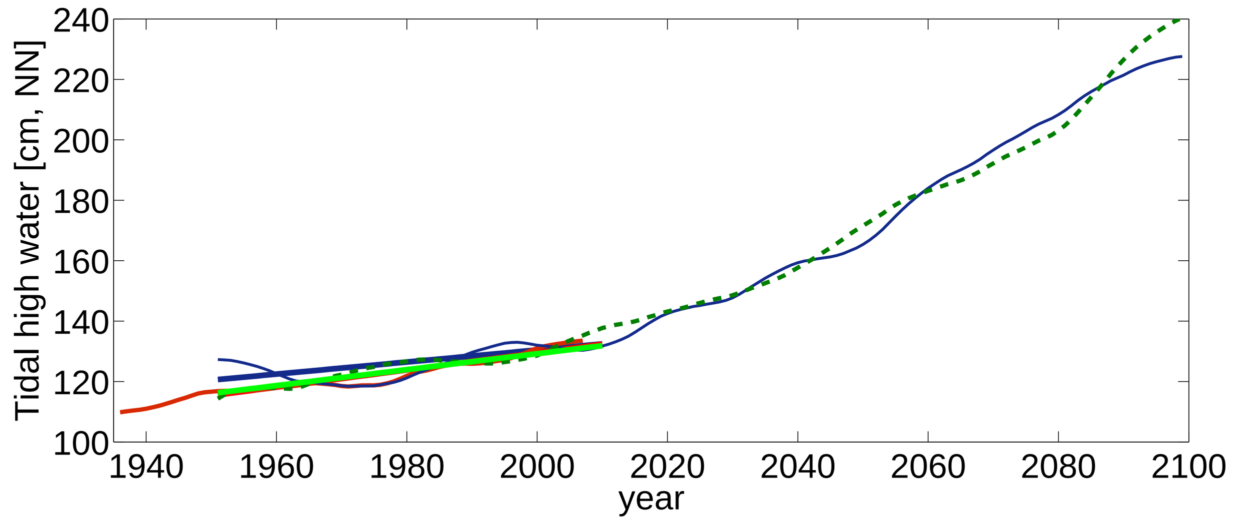

Figure 4: *Possible rise of the* $Mhtw_{10}$ *(green dashed) and trend (light green) after bias correction (other colours Fig 2.).*

Results

From **figure 2** following can be recognized: Because of the increasing tidal range (e.g., Müller et al., 2010) future changes of $mTHW_{10}$ are stronger than these of the MSL. Historical trends estimated from the model appear to be weaker than trends estimated from measurements; caused by the multi-annual and decadal variability.

Figure 3 visualises the $mTHW_1$ in the frequency space. The lower panel shows the differences between the bias corrected and original modelled data in the frequency space.

Figure 4 shows the bias corrected reconstructed time series. Trends fit to better those of the measurements. The predicted future states show a different behaviour, i.e. a more linear trend in the next years and accelerated rise of the $mTHW_{10}$ between 2030 and 2060.

Conclusion

One method for multi-scale model output statistics is presented. A small step in the direction of the ***optimization of model outcomes*** for purposes of the estimation of future climate states has been provided. The strong relation of the water levels in the German Bight with the overall atmospheric variability (e.g. Dangendorf et al. 2012) is confirmed. Phases of the variability are not represented by climate model chains. The optimized ***bias-corrected time series*** allows to force long-term climate impact models of coastal and estuarine regions. These are recently available (Hein et al., 2011a, 2012). Further improvements must be done in sense of detailed uncertainty analysis of the resultant time series.

Literature

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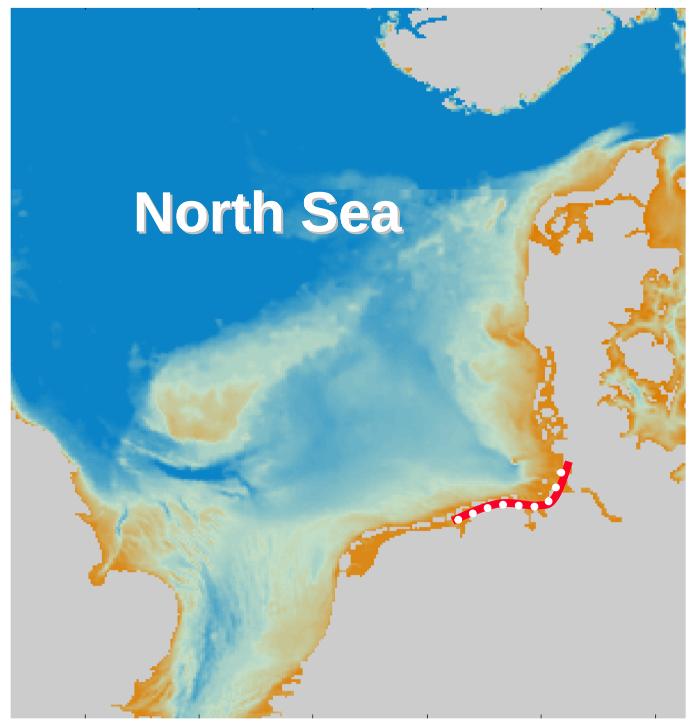

Hartmut Hein[1]
S. Mai[1]
B. Mayer[2]
T. Pohlmann[2]
U. Barjenbruch[1]

[1] Federal Institute of Hydrology
Department M1
Coastal Hydrology

Am Mainzer Tor 1
56068 Koblenz

[2] Institute of Oceanography
University of Hamburg
Germany

www.kliwas.de
hein@bafg.de

EGU2012, Wien

bfg
Bundesanstalt für Gewässerkunde

Federal Ministry of Transport, Building and Urban Development