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EFFECTS OF THE SEA LEVEL RISE ON ESTUARIES

An emperical approach to detect an accelerated sea-level rise

Among all consequences of climate change the expected global sea-level rise will have the greatest impact on the planning and design of coastal protection. Also for the operation and maintenance of tidal influenced water ways and seaports (which handle more than 95% of the intercontinental trade) the knowledge of the current and future sea-level rise is in the discussion about climate impacts essential. Background is the expected decreasing effect of the fresh water discharge with its flushing influence on sediments due to a reduced mean water level gradient between head water and estuary mouth [Fickert/ Strotmann, 2009].
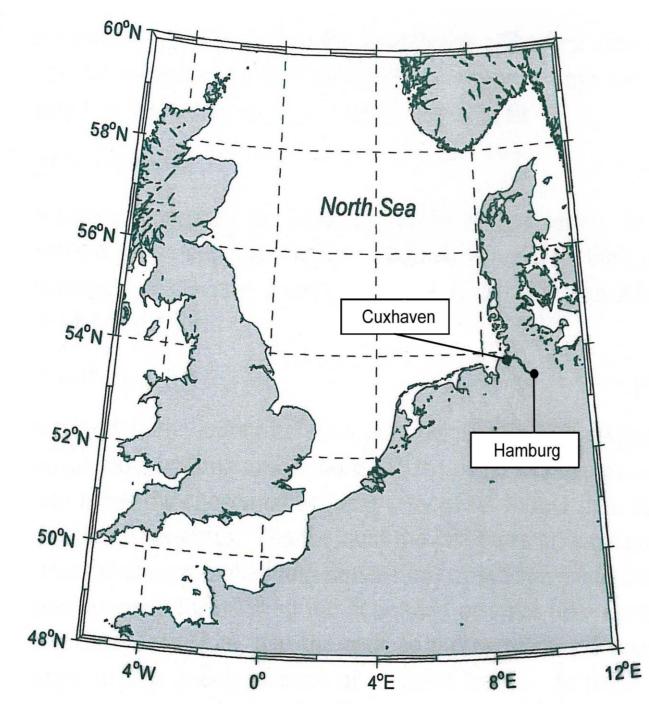

Figure 1: Map of the area

A hind cast of the influence of recent climate change effects on the development of the global sea-level rise with the help of linked atmospheric and hydronumerical models is hardly to validate because time series of extra terrestrial global observations of the sea-level are not yet long enough. In addition to that the land based gauge recordings include not only regional varying tectonically and techno-genic influences but also due to their geographical sight in relation to the dominating wind direction more or less strong meteorological signals (as wind set-up and sunk-in). As a result of the relatively shallow water depths in the North Sea this wind set-up in the German Bight leads to particularly great variations in the annual mean values of the tidal parameters which does forbid conclusions about trends.
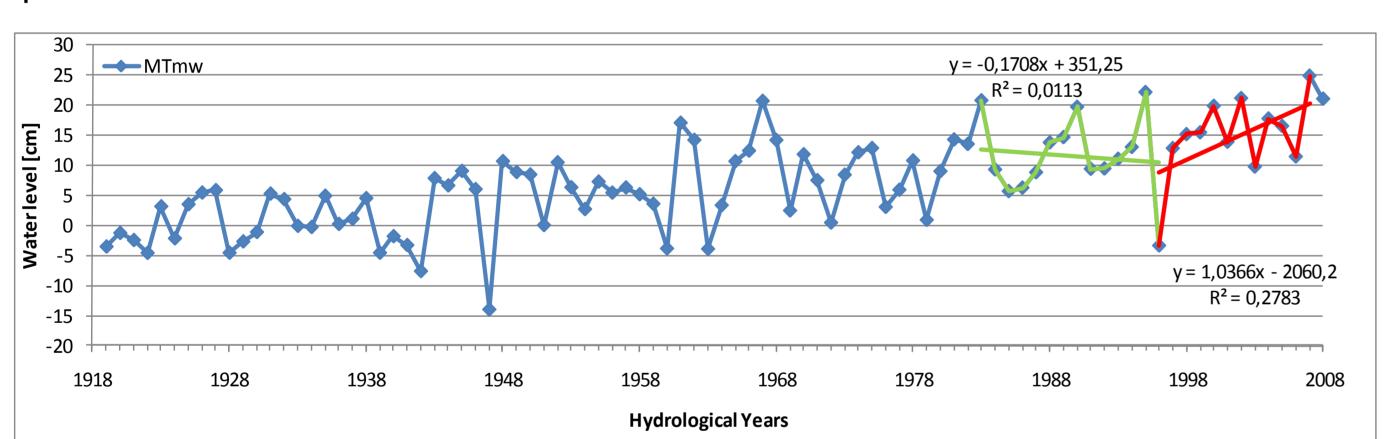

Figure 2: Tidal mean water level of Cuxhaven (blue), different trend calculations

For the gauge Cuxhaven the tidal mean water levels are shown in Fig. 2. Sensitivity analysis have shown that by implementing a simple linear regression over the annual mean values of the tidal mean water level the gradient of the function depends on the length, start and end of the used time period. Two examples can be seen in the figure above marked in green and red. For time periods of at least 10 years the results vary between -8.3 and +14.6 mm/y. Even by lengthening the time period to 30 years the bandwidth is still 0.7 to 4.3 mm/y (see Fig 3).
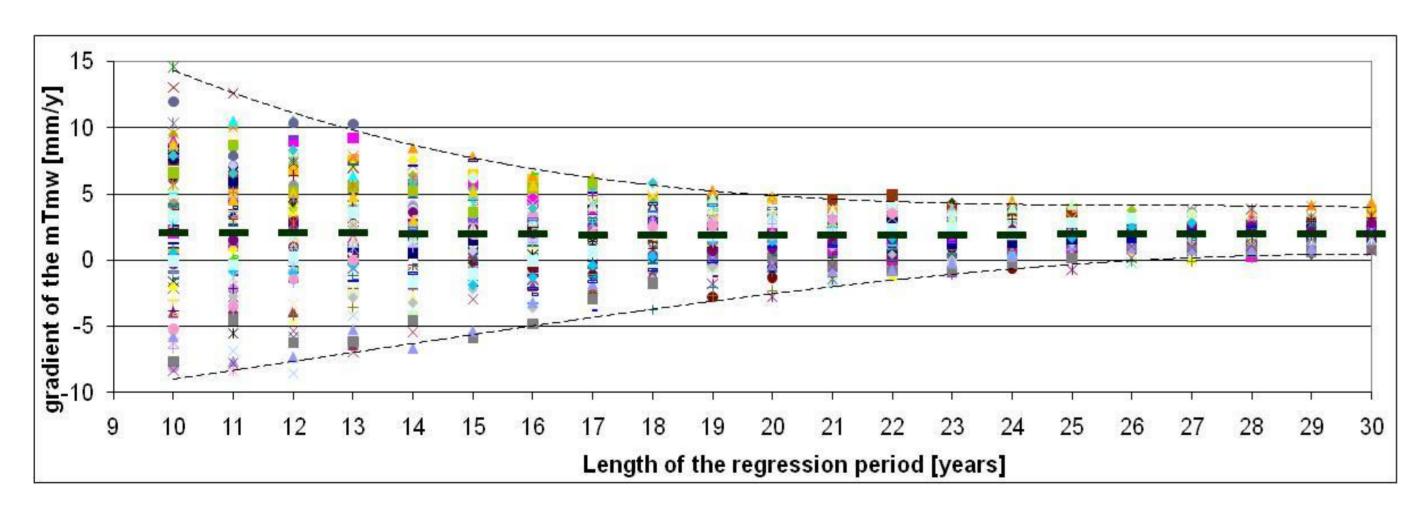

Figure 3: Bandwidth and convergence of linear trend calculations of the annual mean water level in Cuxhaven

To eliminate the influence of the wind, the mean water levels are revised by wind data. These are available from a near-by offshore station since 1969. The hourly mean values are squared because the shear stress is influenced by the squared wind velocity ($\tau_W=C_d{}^*\rho_a{}^*V_{10}{}^2$) and these data are divided in 16 wind direction categories. A multiple regression over these values was performed with an additional degree of freedom for the time scale

$$meanTmw=\Sigma(m_{cat}{}^*\Sigma V_{hour}{}^2(\Theta_{cat})) +m_0{}^*Year+Const..$$
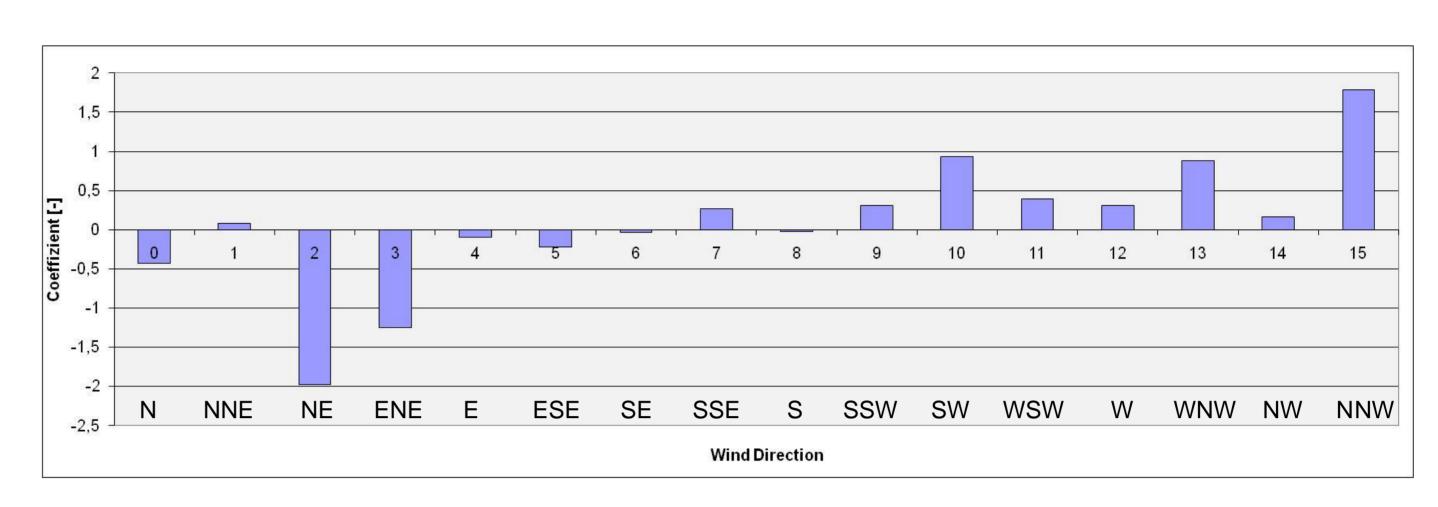

Figure 4: Regression coefficient for each wind direction

The results of the regression are shown in the above figure. Wind directions from North East and East North East produce the greatest wind sunk-in whereas the wind from the West add up in a wind set-up.

With the results of this regression the annual mean tidal water levels can be calculated and compared with the measured ones (below right diagram). The results have an excellent stability index and can be used for cutting down the water levels to their trend without further influence of the wind.
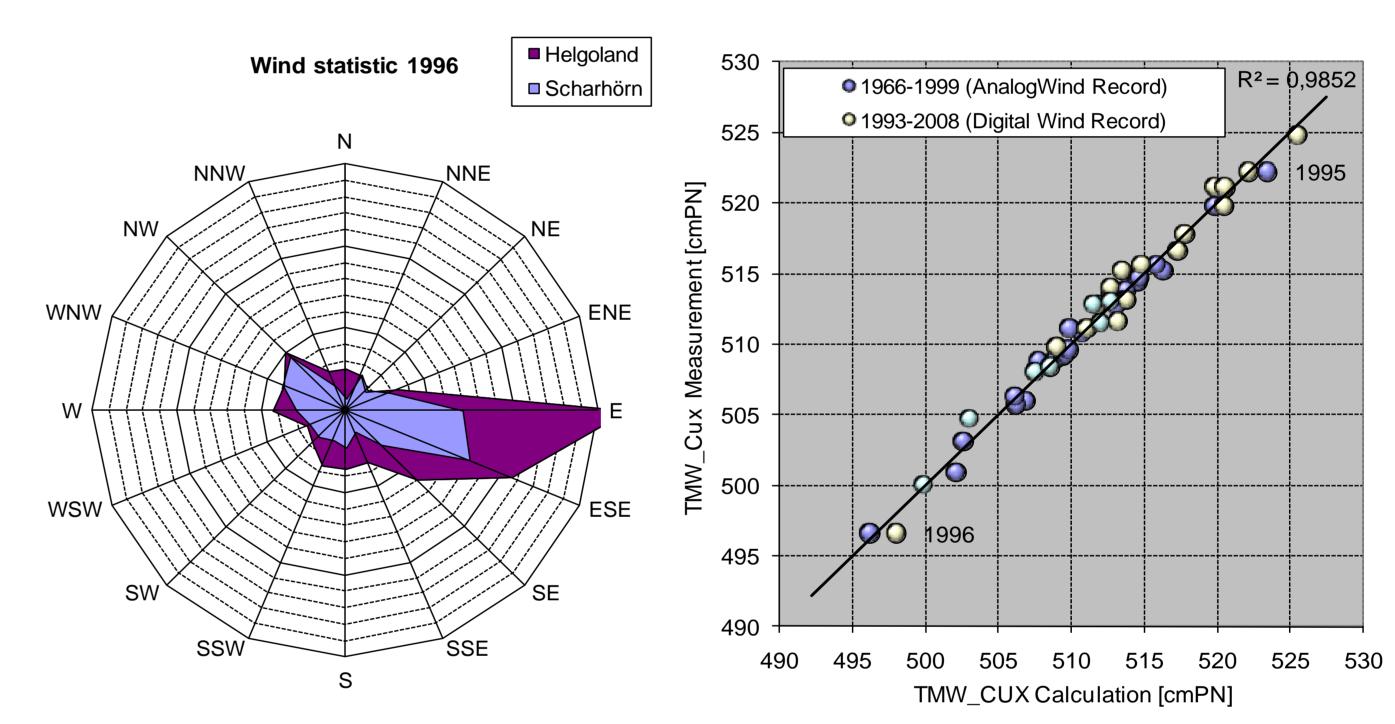

Figure 5: Windstatistic (1996) and result of the correction with the wind set-up

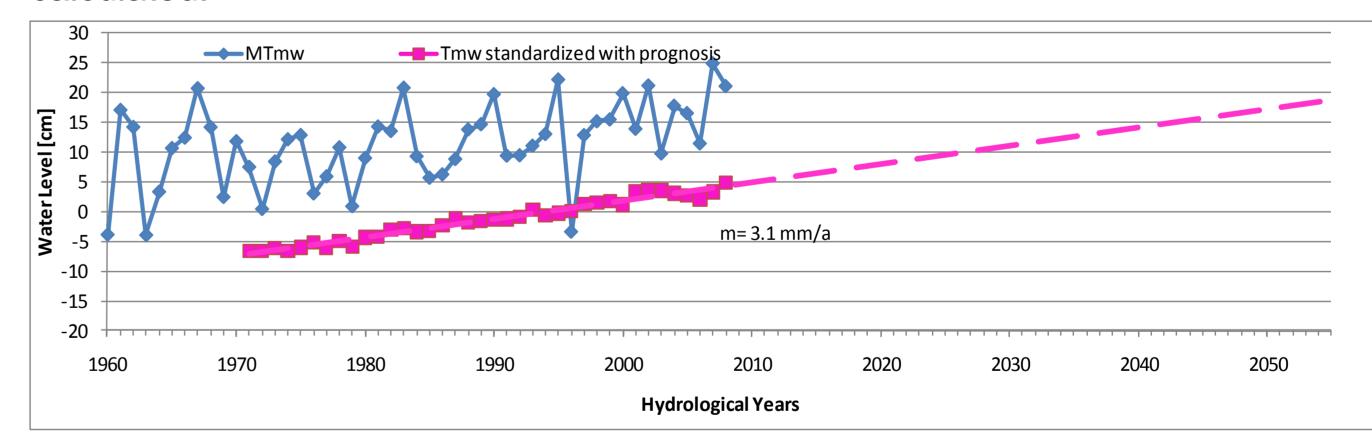For the gauge Cuxhaven a trend of the mean tidal water levels of 3.1 mm/y is calculated.

Figure 6: Tidal mean water level of Cuxhaven (blue), prognosis of sea level rise (pink)

With this simple method it is possible to work with even shorter time series to figure out the trend or the changes of trends (like acceleration) in the water levels. To check the quality of this method a sensitivity test can be performed. The increase of a 20 years mean value is comparatively stable and can be used for further interpretations and as input data in hydrodynamical models.

So this method allows analyzing the hydrodynamics of the Elbe estuary and its changes due to the sea-level rise. Particularly with regard to the questions of sediment transportation and maintenance of the fairway and the port basins this will be crucial in the future.

References
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