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Mean Sea Level and Tidal Analysis along the German North Sea Coastline

The aim of the research project "AMSeL - Mean Sea Level and Tidal Analysis at the German North Sea Coastline" was the detailed analysis of the huge amount of available German North Sea tide gauge data. Mean sea level (MSL) and its variability over the last centuries in the German North Sea area is analysed as well as the tidal regime in terms of residence or dwell times of water levels on different height levels and sequences of extreme tidal high and low waters. Thirteen tide gauges along the German North Sea coastline providing high quality sea level measurements over a time period of at least 50 years up to 166 years are considered. This data shows various acceleration periods of sea level rise (SLR) at the end of the 19th century and for the last decades. Analysis of dwell times, mean tide curve progression and sequences of extreme tides show increasing trends [1].

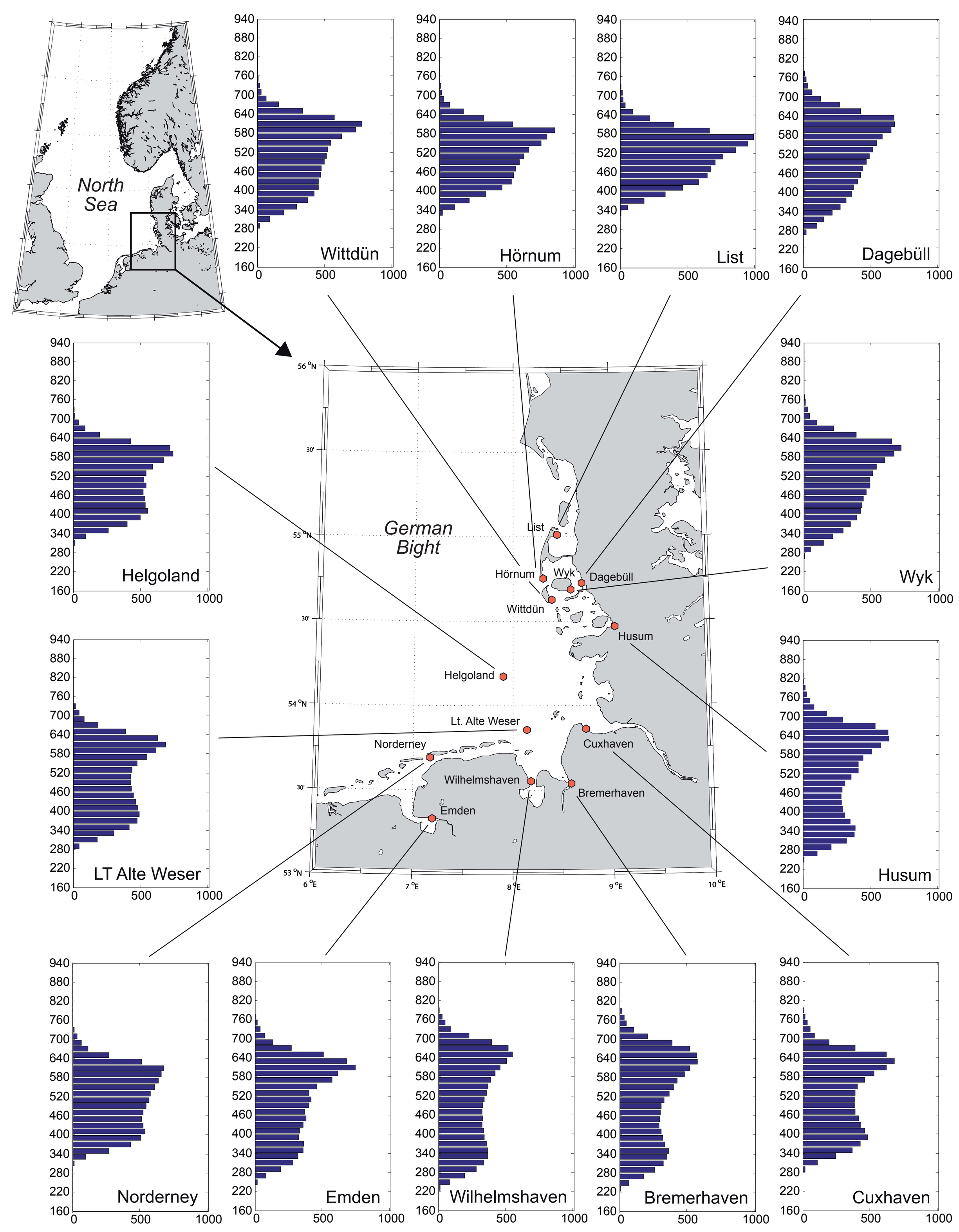

Figure 1 - Investigation area

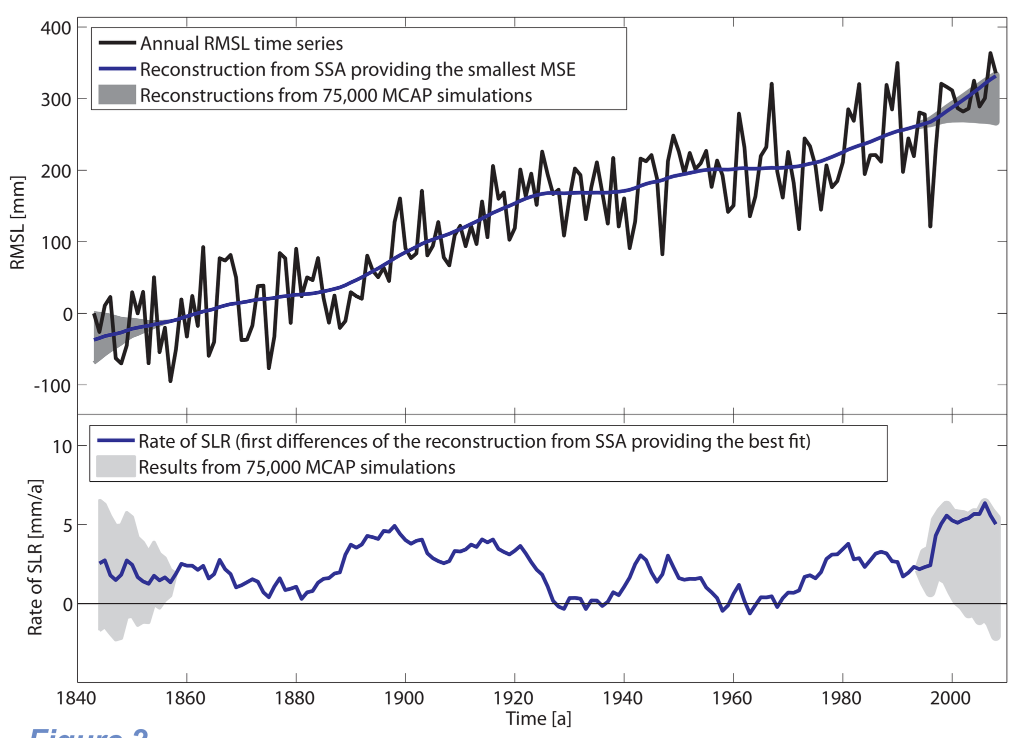

Figure 2

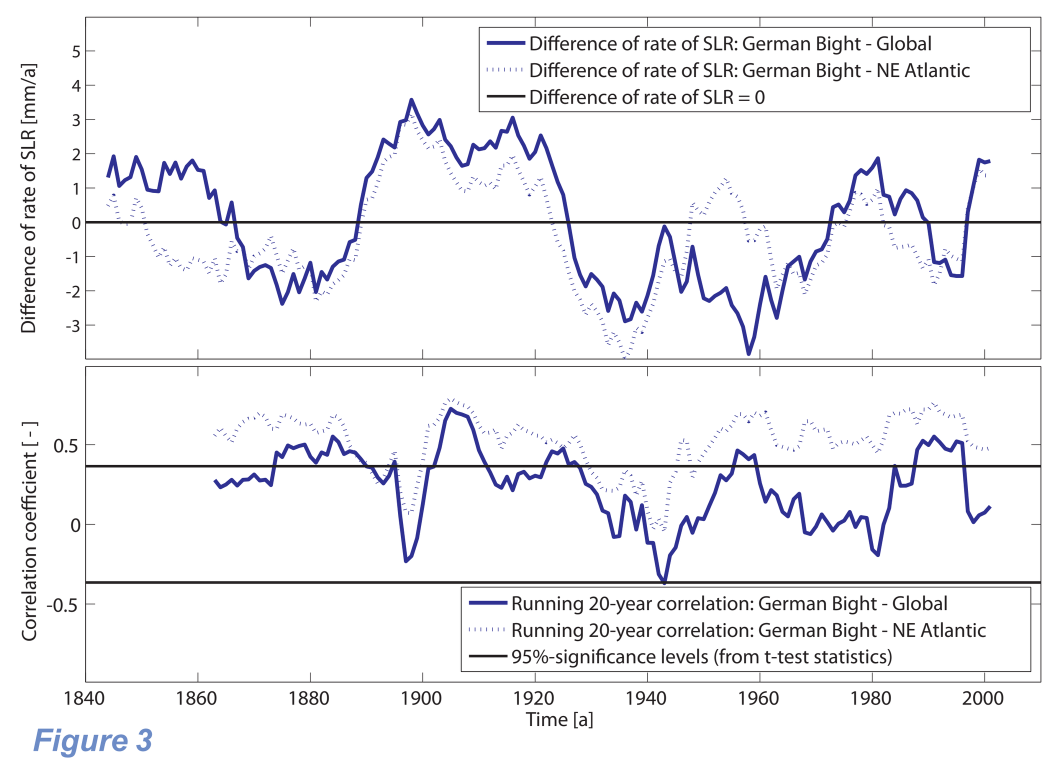

Figure 3

Fig. 2 (top) shows the estimated virtual station time series of the German Bight. This relative mean sea level time series has a linear trend of 2.0 ± 0.08 mm/a for the entire period since 1843 (quoted errors are 1-σ standard errors). In addition the results from analysing the virtual station time series using SSA (singular system analysis) with an embedding dimension of 15 years and 75,000 MCAP (Monte-Carlo autoregressive padding [2]) simulations for the reconstruction near the boundaries are shown. Fig. 2 (bottom) shows the first deviation of the reconstruction providing the best fit for the observed data. The results show various periods of acceleration and similar rates of SLR in the past as well as in recent years (order of 4 - 5mm/a). The German Bight reconstruction shows different decadal variability compared to a global reconstruction [3] but is in good agreement with a northeast Atlantic reconstruction [4] (Fig. 3). This highlights the importance of regional vs. global scenarios when considering regional coastal protection planning.

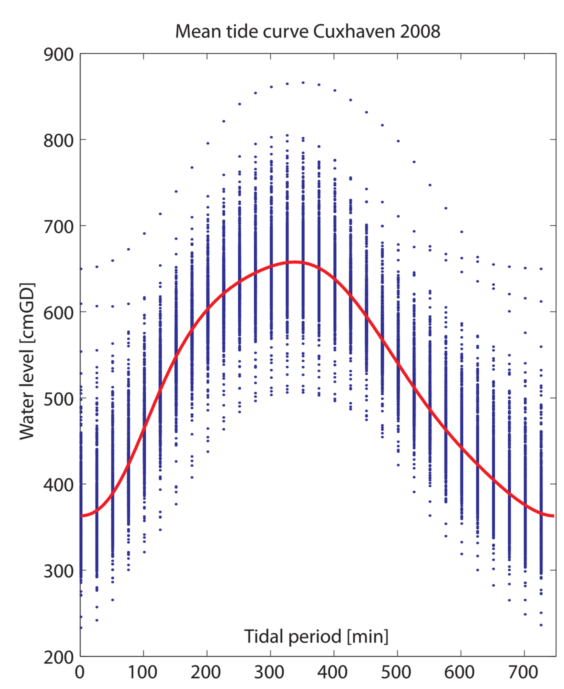

Figure 4

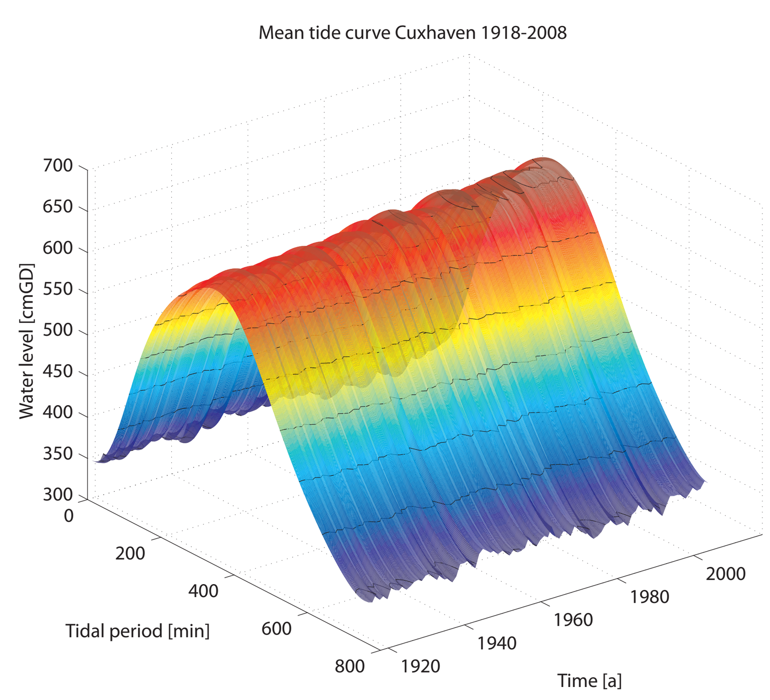

Figure 5

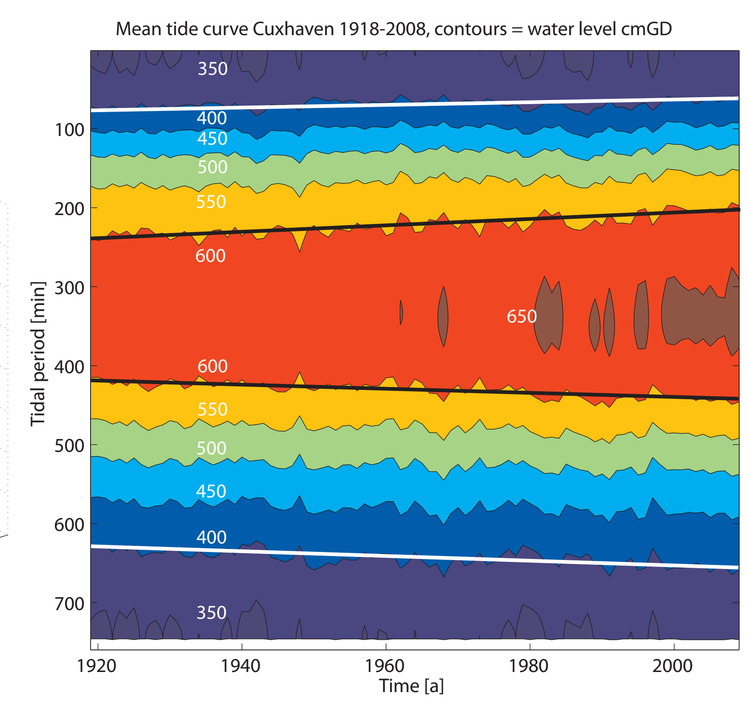

Figure 6

Fig. 4 to 6 show the transition and analysis of high frequency sea level data. Fig. 4: thinned out plot of all water level values of one year according to tidal period (blue dots) used to derive residence times at various elevation intervals (see residence time plots around investigation area, Fig. 1) and the mean tide curve of the respective year (red continuous line). For the Cuxhaven gauge, available time series length allowed generation of mean tide curves from 1918 to 2008 shown as 3D envelope (Fig. 5). Fig. 6 shows this envelope of the mean tide curve viewed from top. Shaded areas and contour lines show water level elevation. Thick black lines show 36 % increase of mean dwell time over 600 cmGD (cm above Gauge Datum) from 1918 to 2008 (180 min to 244 min; 0,7 min/a). Thick white lines show 7 % increase of mean dwell time over 400 cmGD from 1918 to 2008 (559 min to 598 min; 0,43 min/a).

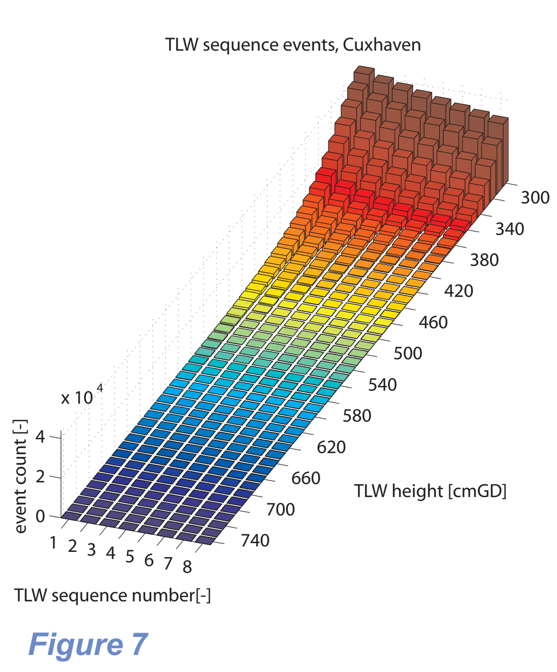

Figure 7

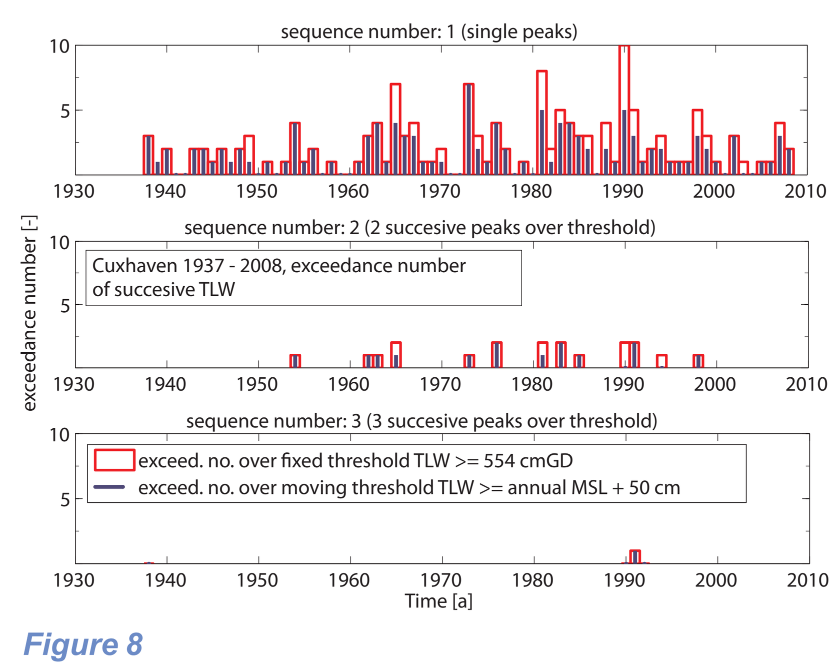

Figure 8

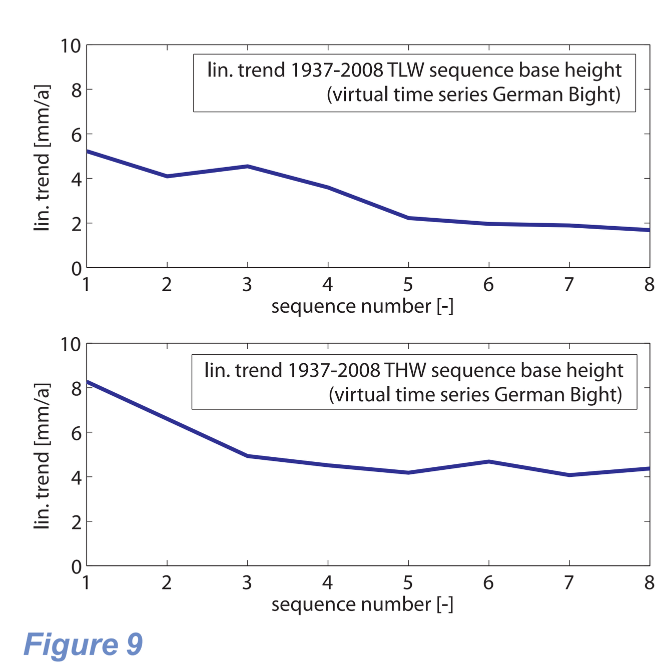

Figure 9

Fig. 7 shows the analysis of the TLW (Tidal Low Water) time series for the Cuxhaven gauge. It is defined that n consecutive TLW exceeding a given water level are forming a TLW sequence for this level. The time series is examined for such occurrences (n = 1 - 8) and a 3D histogram is build. From this result, further analysis is performed. Regarding exceedance number and distribution of sequences of various length over various threshold levels this is shown in Fig. 8. From top to bottom, first single TLW then events of 2 and finally 3 succesive TLW are shown for fixed and moving thresholds. Fixed levels are of importance in regard to load assessment of various coastal features like cliff bases etc. while moving thresholds show occurrences of sequence events relative to the annual MSL. Between the mid-1970s and mid to late-1990s an elevated count of successive tidal high and low water events is observed. Fig. 9 shows trends of sustained reached and exceeded peak water levels of the various sequence lengths which predominantly are higher than respective trends of mean tidal low and mean tidal high water as well as mostly higher than the trend of the Mean Sea Level at the respective gauge.

References:

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[3] Church, J. A. and White, N. J. (2006): A 20th century acceleration in global sea-level rise, Geophys. Res. Lett., 33, L01602.
[4] Jevrejeva, S.; Moore, J. C.; Grinsted, A. and Woodworth, P. L. (2008): Recent global sea level acceleration started over 200 years ago?, Geophys. Res. Lett., 35, L08715.

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