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Effects of Seasonal MSL Variability on Extreme Sea Levels in the German Bight

EFFECTS OF SEASONAL MSL VARIABILITY ON EXTREME SEA LEVELS IN THE GERMAN BIGHT

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The German Bight is located in the southeastern part of the North Sea. As a part of a shallow shelf sea it is characterized by a large variability, which is a result of a strong interaction of both oceanic and continental influences. The tidal regime is semidiurnal and the mean tidal range varies between
2 and 4.5 m. Storm surges are the most serious hazard in the German Bight with considerable influences on the shape of coastal regions.

Changes in the seasonal cycle of mean sea level (MSL) may affect the heights of storm surges and thereby the flood risk in coastal areas. In the German Bight the seasonal MSL cycle has mean amplitudes of about 20 to 29 cm, which is overlapped by a large inter-annual and inter-decadal variability. As outlined in Dangendorf et al. (2012) observed winter MSL (January-March, i.e. spring (April-June), summer (July-September), autumn (October-December)) trends in the German Bight are up to 4 mm/yr larger compared to those observed in the remaining months, resulting in a changing character of the seasonal cycle. A major part of these differences can be explained with changes in meteorological forcing, which is represented by the North Atlantic Oscillation (NAO). For coastal engineering aspects in the German Bight this development is of major interest, as it may have influences on the heights of coastal defense structures. In the German Bight, the highest water levels in the last decades mostly occurred during January and February. Higher MSL trends in these winter months may additionally affect the level upon which surges built up. Therefore, it is of considerable interest, whether or not the development of extreme sea levels has been followed the MSL.

In this study we will examine the seasonal development of sea level quantiles at the tide gauge of Cuxhaven on the basis of hourly sea level data in order to investigate the effects of intra- and inter- annual MSL variability on extreme sea levels. Mudersbach et al. (submitted) analyzed extreme annual sea level quantiles for five tide gauges located in the German Bight and found that the observed trends are significantly larger than those found in the MSL. However, here we investigate in which manner seasonal differences are responsible for the heterogeneous development. Figure 1 displays the linear seasonal trend estimates (dark grey squares) for different quantiles through the whole tidal range. The related 1 and 2σ standard errors are represented by the black and grey bars. The annual MSL trend is shown by the dark line (1 and 2σ standard errors = dotted lines). Generally, the findings from Mudersbach et al. (submitted) can be confirmed, i.e. the quantile trends differ significantly from the annual MSL development, but it should be noted that the larger trends in the upper quantiles are mainly present during the winter season (Figure 1). While from the 95 % winter quantile on the linear trends vary between

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~4 and 7 mm/yr, all remaining quantiles vary in a significantly smaller window between ~-0.5 and 3 mm/yr. The figure further illustrates that the trends show large variations from season to season. The trends during winter are considerably larger than those observed in the remaining seasons. This gradient is present in all quantiles, even if the trend characteristic changes from values near zero for the lower quantiles to large trends in the upper quantiles. However, the similar behavior is noticeable and suggests an interaction between MSL and sea level extremes. This is important, as extreme sea levels are the main measure for coastal structures. Hence, the differences between mean and extreme sea levels have direct implications for coastal planning in Cuxhaven. Summarizing, the findings of our investigation show that there are seasonal effects in MSL driving the heights of extreme sea levels.

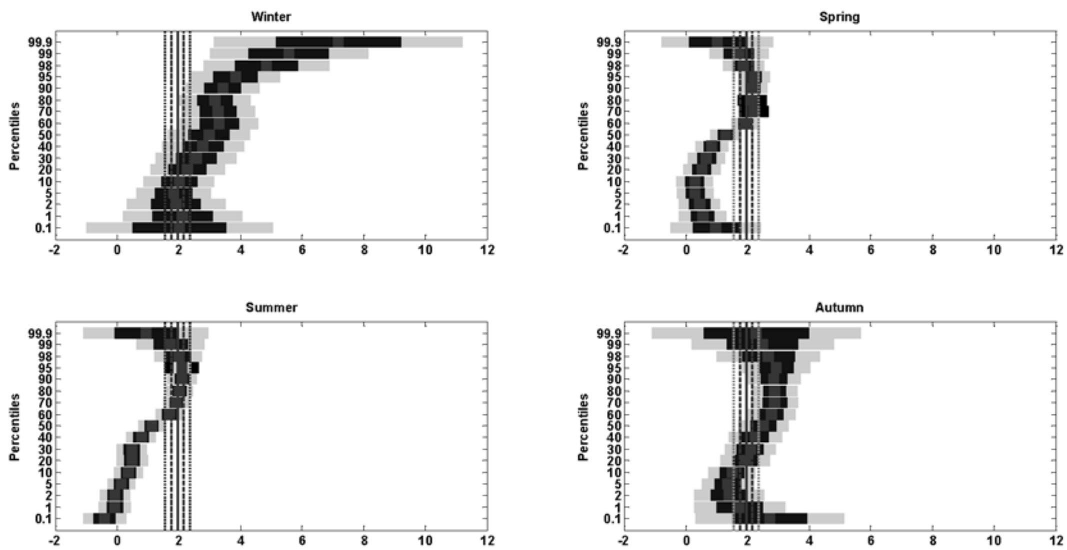

Figure 1: Seasonal quantile trends at the tide gauge of Cuxhaven over a period from 1951 to 2008. Seasonal trend estimates are displayed as dark grey squares, while the black and grey bars represent the related 1 and 2σ standard errors. The annual MSL trend is shown through the dark line. The 1 and 2σ standard errors are presented by the dotted lines.

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