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Meteorological forcing of the annual MSL cycle and its impacts on flood risk in the German Bight

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Dangendorf et al. (under review) recently analyzed the annual mean sea level (MSL) cycle for 13 tide gauges located in the German Bight. Using an empirical method they did not find any significant long-term changes in the amplitude of the annual cycle, but a large inter-annual variability. Furthermore, it has been recognized that in the last two decades the occurrence time of the annual peak has been shifted from the late autumn into the months from January and February. This is important, since changes in the annual MSL cycle may affect the heights of storm surges and thereby the flood risk in coastal areas. The shift has been triggered by large trends during the winter (January to March) months, which have been considerably higher compared to the remaining months. The authors explained this shift with changing pressure conditions over the North Atlantic, which lead to anomalous large trends in the North Atlantic Oscillation index (NAO) in the period from 1951 to 2008.

However, as mentioned by Suursaar and Soosäär (2007), the NAO is not a single forcing factor affecting sea level. The NAO rather influences sea level over Northern Europe through different related meteorological parameters, such as wind, sea level pressure (SLP), or precipitation. In this study we use time series of local wind (u and v-components), SLP and precipitation from the 20^{th} century reanalysis data sets (Compo et al. 2011) to assess the contribution of the different parameters on the annual MSL cycle in the German Bight. A multiple regression analysis is used to describe the influences on seasonal MSL variability and trends for the period from 1951 to 2008. The influence of the different parameters varies throughout the different seasons. The u-wind is the dominating factor in every season ($r > 0.7$). SLP is used as a second predictor in winter, spring and autumn, while precipitation has considerably additional influences during spring and summer. The v-wind is only important during the summer season. Overall, the regressions account for 93% of the variance in winter, 51% in spring, 52% in summer and 81% during autumn. Furthermore, the multiple regressions explain the large gradient between the winter and the remaining seasonal trend components. The removal of the meteorological influences implicates a more homogeneous long term development during the different seasons with considerably smaller standard errors. Sensitivity analysis shows that the u-wind - as a NAO related process - is mainly responsible for the gradient between monthly MSL trends and thereby for changes in the annual cycle.