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On detecting anthropogenic change points in sea level quantiles of mesotidal areas – Application to the German Bight

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In the recent past global and regional sea level development has been subject of many studies. Most of these studies deal with the identification of long term trends from instrumental records. The validity of trend estimations depends on the quality of the underlying data sets. The total sea level, which is observed at tide gauges, is a result of both natural (meteorological and oceanographic forcing, vertical land movements) and anthropogenic induced changes. Anthropogenic changes result from instrumental errors or coastal engineering measures. The challenge regarding the trend analysis is to separate large scale climatic influences from local effects as a result of anthropogenic interventions. Such local effects often express themselves through changes in the local tidal regime. While instrumental errors are visible in all tidal parameters, changes due to engineering measures or comparable interventions may only influence parts of the tidal range. It is a frequently observed phenomena that tidal low waters are considerably stronger influenced by changes in the tidal regime than tidal mean or high waters. Therefore, the separation of such changes is complicated due to an inhomogeneous distribution throughout the tidal range.

In this study a method for the reliable estimation of abrupt changes in mesotidal water levels will be presented. The method allows quantifying the distribution of anthropogenic changes throughout the tidal range and is based on the decomposition of sea level quantiles in empirical orthogonal functions (EOF). The EOF Analysis is often used in ocean sciences to describe the sea level variability of larger regional areas with one common time series. The innovation of this study is the use of the leading EOF for the detection of undocumented change points. The leading EOF of sea level observations in the German Bight accounts for approx. 95% of the total variability. Hence, the first EOF determines the common signal which is present at all considered tide gauges. In theory, more local effects such as changes due to instrumental errors or changes in the tidal regime are only present in the higher EOF's. Therefore, we use the product of the first EOF and the corresponding eigenvector for the prediction of a homogeneous reference series for every single tide gauge record, which can be used for the estimation of local anthropogenic change points. The statistically significance of detected change points is tested with the Standard Normal Homogeneity Test (SNHT) introduced by Alexanderson et al. (1986).

The sensitivity of this approach is tested on the basis of a quasi-homogeneous data set (a period of records, from which we know that they show plausible common signal) of sea levels observed from tide gauges located in the German Bight covering a period from 2000 to 2008: In a first step the method is applied for the quasi-homogeneous data set and no change point could be detected. In a second step artificial change points of different sizes are added to the data sets. The repetition of the above mentioned method shows that the eigenvectors of all tide gauges change under the presence of artificial change points. The eigenvectors of homogeneous observations tend to be smaller under the presence of a change point. For another observation of the same time period, the eigenvector of the observation with the artificial shift increases in proportion to the change point. Hence, in practice it is important to estimate the eigenvectors from homogeneous data sets (or periods), i.e. the 2000 to 2008 period. A more sophisticated way could be the estimation of homogenous eigenvectors using Hindcast data from two dimensional tide + surge models, which are not superimposed by local anthropogenic effects. This will be tested in the near future.