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Assessing 20th century tidal range changes in the North Atlantic and the North Sea

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Tide gauges from the North Atlantic and especially from the North Sea show significant changes in the local tidal regime since the mid-20th century. For instance, high tides in the German Bight have been rising significantly faster than mean sea level, while low tides show smaller or even negative trends. The result is an increase in tidal range of up to 10 % since 1955 in this area. Simultaneously, a decrease of tidal range in the southwest of the North Sea can be detected. While there are several studies for regional changes of tidal range in different parts of the world, the large-scale causes remain unclear. Among others, Woodworth (2010, doi:10.1016/j.csr.2010.07.002) and Müller et al. (2011, doi:10.1029/2010JC006387) attempted to detect large-scale effects in their respective studies but were unable to identify large spatial patterns outside the North American coasts. The major challenge is related to the fact that local (e.g. building measures) and regional influences (e.g. changes in topography or morphology) superimpose large-scale changes (e.g. sea-level rise), making it very difficult to separate both.

Here we use empirical orthogonal functions (EOFs) calculated from a large set of tide gauge records and hypothesize that large-scale effects can be interpreted as a coherent signal appearing in the first EOFs and explaining the largest percentage of variability of the entire dataset. In contrast, small-scale (local) influences should be shifted into the upper EOFs due to their localized character, being only responsible for a small part of the variability. Indeed, we identify two leading EOFs, which explain together about 69 % of tidal range changes in the entire North Sea. The principal component of the first EOF describes an increasing tidal range with largest amplitudes in the southeastern North Sea, while the principal component of the second EOF describes a decreasing tidal range with the lowest amplitudes in the southwestern North Sea. The coefficients of the latter change with a “seesaw pattern” of positive values along the UK coastline and negative values in the German Bight, indicating a shift of major amphidromic points within the basin. In addition, we detect local effects at certain tide gauge locations from the upper EOFs and attribute them to possible causes (mostly local building measures). A comparison between the first two North Sea EOFs and tide gauge records along the European Atlantic coast, Iceland and Canada points towards significant correlations suggesting a large-scale forcing of the observed changes in the tidal range. To our knowledge, this analysis identifies for the first time a coherent large-scale and long-term signal in the tidal range of the North Atlantic.