Assessment of tidal range changes in the North Sea from 1958 to 2014

Leon Jänicke*, **Andra Ebener, Sönke Dangendorf, Arne Arns, Michael Schindelegger, Sebastian Niehüser, Ivan D. Haigh, Philip Woodworth & Jürgen Jensen**

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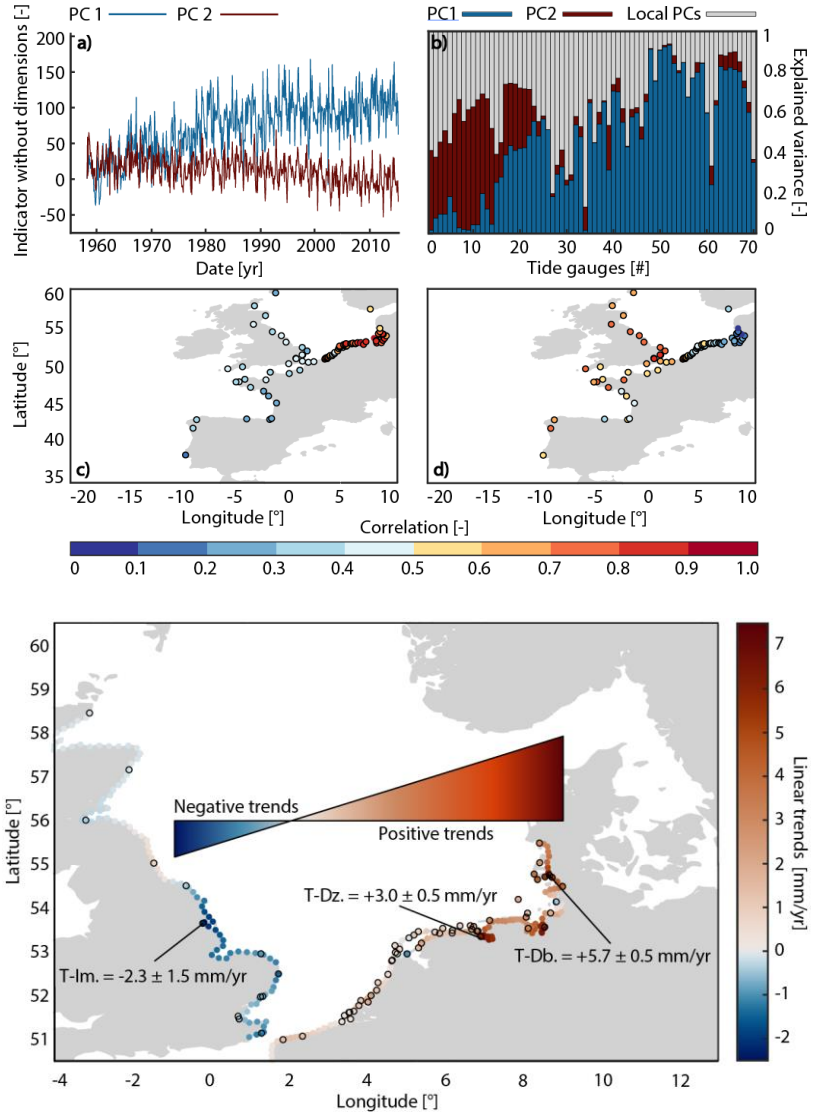
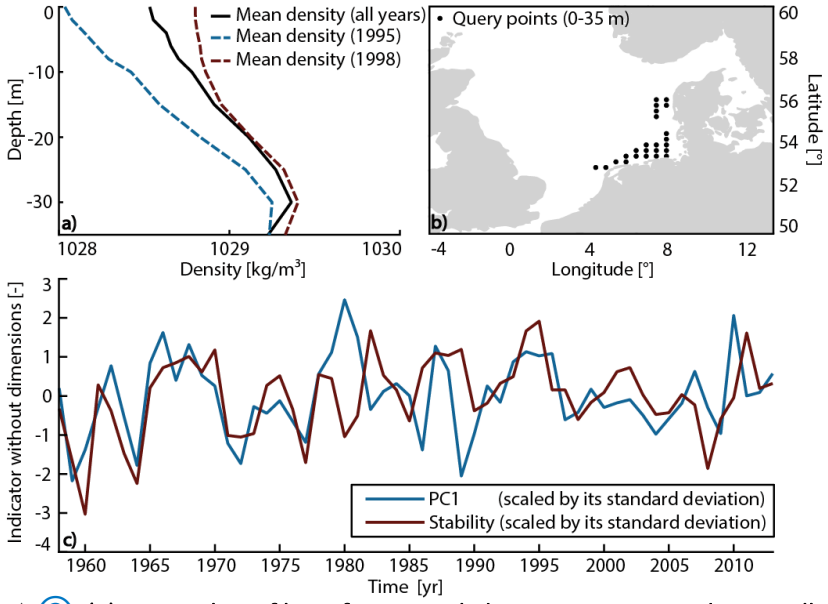
- 70 North Sea tide gauges evince contrasting trends in tidal range between the UK (-1.0 mm/yr) and the German Bight (3.3 mm/yr) on average between 1958 and 2014.
- We use principal component analysis (PCA) to separate local (e.g. building measures) from large-scale effects of oceanographic origin.
- By applying numerical and statistical analyses, we can assign a baroclinic (PC1) and a barotropic large-scale signal (PC2), explaining a large part of the overall variance.
- PC2 represents a large-scale barotropic signal and accounts for the negative trends in the UK area with a North Atlantic extent, while PC1 describes stratification changes, exerting a strong influence on the tidal range in shallow water at various time scales.



► ① Linear trends of tidal range between 1958 and 2014. Trends at measured sites are shown as dots with a black edge with exemplary linear trends at tide gauges Immingham (Im.), Delfzijl (Dz.) and Dagebüll (Db.) with their respective 95% confidence interval. Dots in between stations are based on Interpolation.

◄ ② (a) Time series of PC1 and PC2 and (b) their respective explained variance including local PCs, tide gauge numbering following roughly the coastline counter clockwise, starting at Lerwick on the Shetlands. In addition, the correlation of PC1 (c) and PC2 (d) to the tidal range is shown for both the North Sea tide gauges and the adjacent North Atlantic.



▲ ③ (a) Vertical profiles of potential density as averaged over all query points in (b) at depths from 0 to 35 m for the years 1958 to 2013 (black), the year 1995 (blue) and the years 1998 (red). (c) Comparison between PC1 changes and water column stability, where both time series were scaled by their standard deviation and adjusted for long-term trends.

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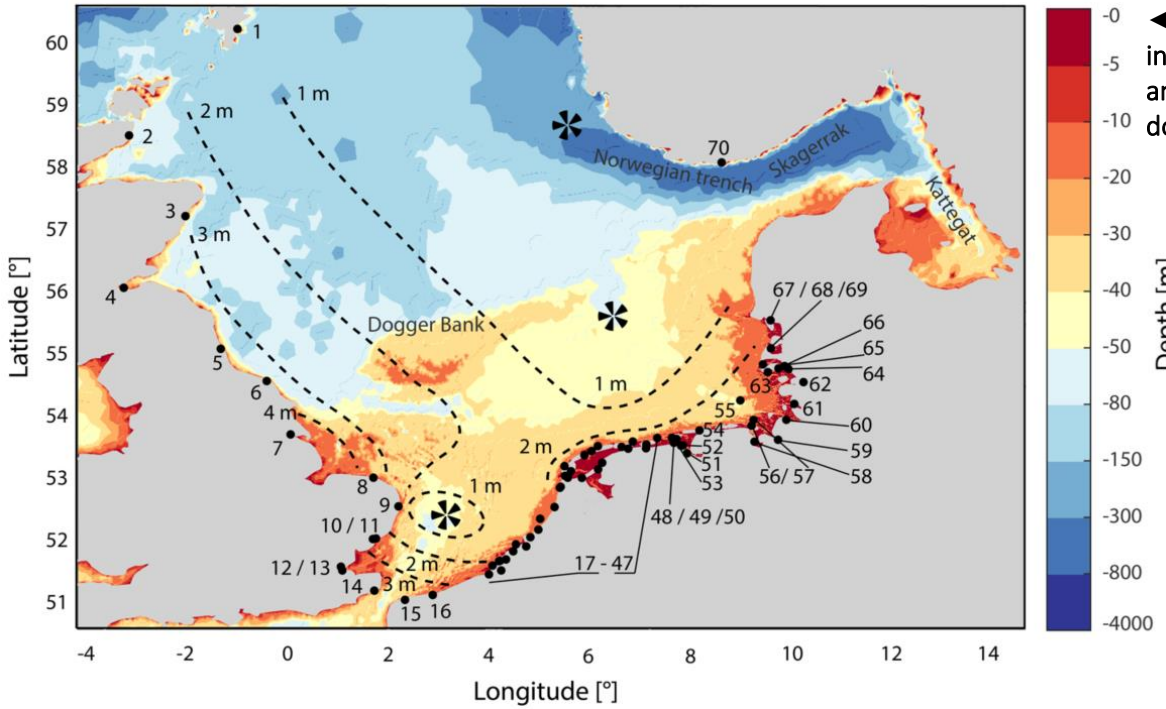
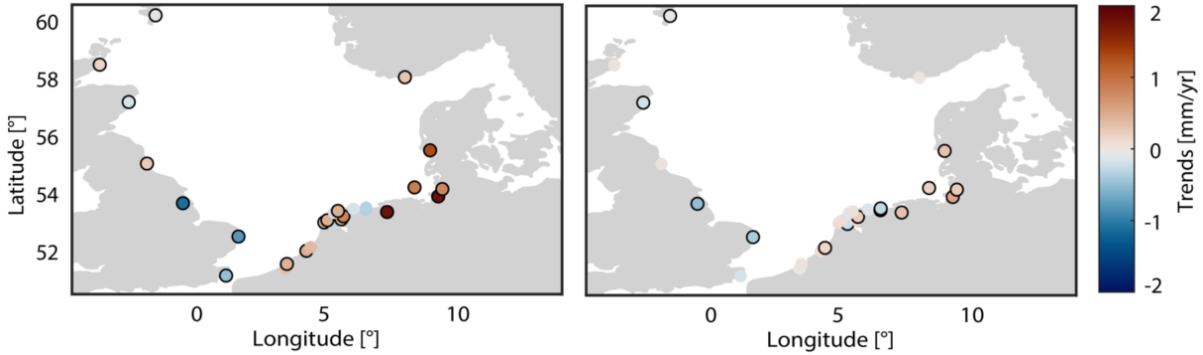


◄ Bathymetry of the North Sea. Also shown are the locations of tide gauges (black dots) used in this study including their respective numbering. The black propellers indicate the location of the three semidiurnal amphidromic areas (including the amphidromic points for the M2 and S2 constituent) and the black dotted lines indicate contours of equal mean tidal range.



▲ (left) Linear trends of the M2 and (right) S2 tidal constituents between 1958 and 2014 (significant trends outlined).

► Measured and reconstructed trends in tidal range and explained variance of the different regions.

Location		Mean Linear Trends [mm/yr]		Explained Variance [%]		
Region	Tide gauges	measured	Reconstructed PC1 and PC2	PC1	PC2	Remaining PCs (local)
Southwestern Coast of GB	Immingham to Dover	-1.0	-1.0	3	58	39
European West Coast	Calais to Huibertgat	0.8	1.0	45	10	45
North Coast of the Netherlands and German Bight	Oude Westereems to Esbjerg	3.3	3.5	77	3	20