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# Mechanisms of long-term mean sea level variability in the North Sea

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We examine mean sea level (MSL) variations in the North Sea on timescales ranging from months to decades under the consideration of different forcing factors since the late 19th century. We use multiple linear regression models, which are validated for the second half of the 20th century against the output of a state-of-the-art tide+surge model (HAMSOM), to determine the barotropic response of the ocean to fluctuations in atmospheric forcing. We demonstrate that local atmospheric forcing mainly triggers MSL variability on timescales up to a few years, with the inverted barometric effect dominating the variability along the UK and Norwegian coastlines and wind (piling up the water along the coast) controlling the MSL variability in the south from Belgium up to Denmark. However, in addition to the large inter-annual sea level variability there is also a considerable fraction of decadal scale variability. We show that on decadal timescales MSL variability in the North Sea mainly reflects steric changes, which are mostly remotely forced. A spatial correlation analysis of altimetry observations and baroclinic ocean model outputs suggests evidence for a coherent signal extending from the Norwegian shelf down to the Canary Islands. This supports the theory of longshore wind forcing along the eastern boundary of the North Atlantic causing coastally trapped waves to propagate along the continental slope. With a combination of oceanographic and meteorological measurements we demonstrate that $\sim$80% of the decadal sea level variability in the North Sea can be explained as response of the ocean to longshore wind forcing, including boundary wave propagation in the Northeast Atlantic. These findings have important implications for (i) detecting significant accelerations in North Sea MSL, (ii) the conceptual set up of regional ocean models in terms of resolution and boundary conditions, and (iii) the development of adequate and realistic regional climate change projections.