On the effects of uniform and non-uniform sea-level rise on European Shelf tides

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In theory, sea-level rise has not only a direct linear effect on the total instantaneous water level, but also an indirect effect on tide, surge, waves and induced sediment transport. Focusing on the SLR effect on the water level, the total water level ξ can be written:

$$\xi = \xi_{T,0} + \xi_{S,0} + SLR + I(\xi_{T,0};\xi_{S,0};SLR)$$

With $\xi_{T,0}$ and $\xi_{S,0}$ being respectively the tide and the surge water level contributions for SLR=0. SLR is the sea-level rise contribution and $I(\xi_{T,0};\xi_{S,0};SLR)$ the term of interaction between the three components (tide, surge and SLR). Several studies have investigated the effects of SLR on the tides ξ_T of the western European continental shelf (mainly the M2 component). We further investigate this issue using a modelling-based approach, considering uniform SLR scenarios from -0.25 m to +10 m above present-day sea level.

Assuming that coastal defenses are constructed along present-day shorelines, the patterns of change in high tide levels (annual maximum water level) are spatially similar, regardless of the magnitude of sea-level rise (i.e., the sign of the change remains the same, regardless of the SLR scenario) over most of the area (70%). Notable increases in high tide levels occur especially in the northern Irish Sea, the southern part of the North Sea and the German Bight, and decreases occur mainly in the western English Channel. These changes are generally proportional to SLR, as long as SLR remains smaller than 2 m. Depending on the location, they can account for +/-15% of regional SLR. High tide levels and the M2 component exhibit slightly different patterns. Analysis of the 12 largest tidal components

highlights the need to take into account at least the M2, S2, N2, M4, MS4 and MN4 components when investigating the effects of SLR on tides. Changes in high tide levels are much less proportional to SLR when flooding is allowed, in particular in the German Bight. However, some areas (e.g., the English Channel) are not very sensitive to this option, meaning that the effects of SLR would be predictable in these areas, even if future coastal defense strategies are ignored. Additional numerical computations show that SLR-induced tidal changes result from the competition between reductions in bed friction damping, changes in resonance properties and increased reflection at the coast, i.e., local and non-local processes.

The above results are based on the assumption that sea level will rise uniformly. However, future sea-level rise will display regional variability. We therefore analyze to what extent tidal changes induced by a uniform or a non-uniform SLR would be significantly different by considering a synthetic idealized non-uniform SLR field, based on Slangen et al. (2014). This SLR scenario corresponds to the current state of knowledge of the regional variability of future sea-level rise on the European continental shelf, given a global mean sea-level rise of 0.5 m by 2100 and the RCP4.5 climate change scenario. The preliminary estimate of tidal changes by 2100 under a plausible non-uniform SLR scenario shows that even if changes display similar patterns, high water levels appear to be sensitive to the non-uniformity of SLR.