

## O07.2

### Tidal amplification in reflection influenced estuaries – partial tide differentiated examinations

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#### Abstract

Estuaries are subject to natural variations and anthropogenic measures, often leading to significant changes in estuarine tidal oscillation. Various river engineering measures have established tidal wave reflection at cross-sectional constrictions in the Elbe estuary in the Port of Hamburg and at the weir, and have increased the tidal range in the Elbe estuary over the past century. Between 1990 and 2010, the tidal range rose about 0.75 cm/a. From 2011 to 2017, the gradient was with 2.8 cm/a almost four times greater, although the last major river engineering measures occurred 2000 (deepening) and 2004 (tidal space reduction) (Figure 1).

Although many studies were conducted investigating the tidal wave transformation in estuaries, studies based on spatially well-distributed empirical data covering periods over more than a year are rare. To develop a better understanding of estuarine tidal oscillation with reflection induced formation of partially standing waves in anthropogenically modified estuaries, we analysed the partial tides specific oscillatory behaviours. For this purpose, a harmonic analysis method of least squares was applied to 22-year hydrographs of 25 gauges distributed across the estuary.

The tidal constituents' oscillatory behaviour including the formation of reflection induced partially standing waves were determined (Figure 2). The tidal constituents exhibit common frequency group-specific partial clapotis. As reflection can cause resonance in tidal influenced rivers, tests were developed to analyse whether criteria for resonance are met and the system specific resonance frequency was determined. Furthermore, dependencies of the tidal oscillation on influencing factors such as river discharge and morphological changes were investigated.

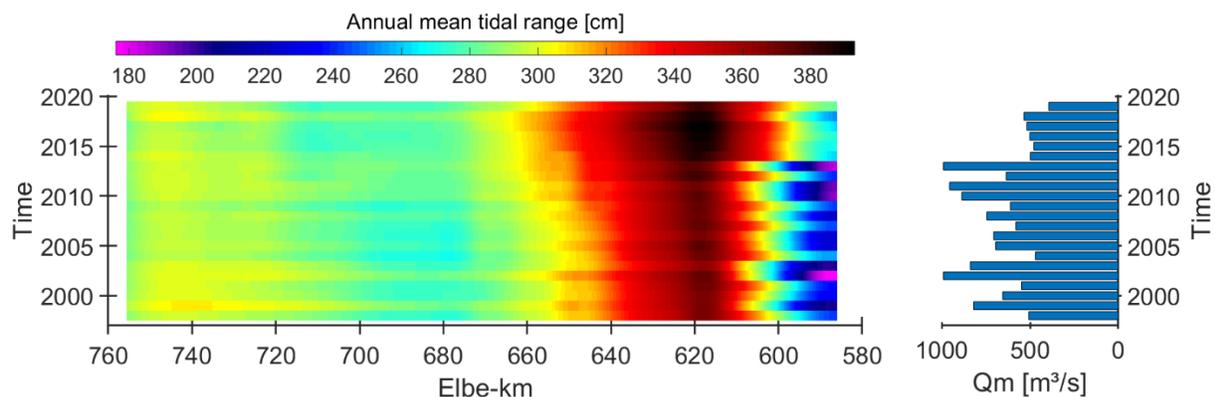


Figure 1: a) Overview of tidal ranges inside the Elbe estuary. b) Yearly mean river runoff (Qm).

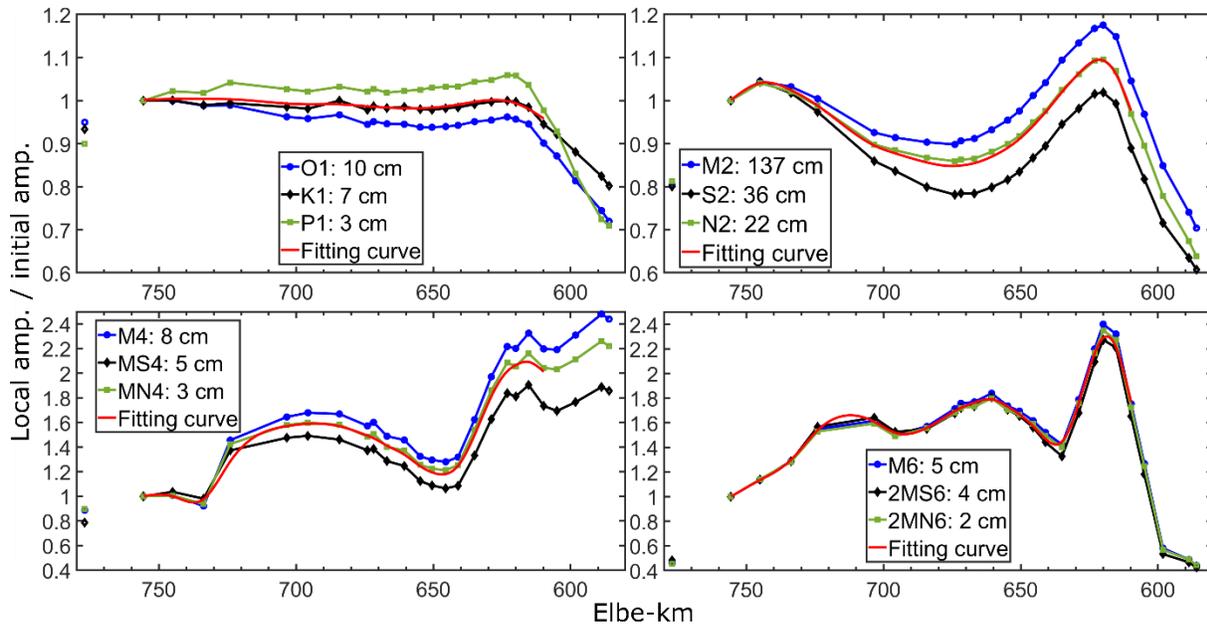


Figure 2: Wave forms of a) diurnal, b) semidiurnal, c) quarter-diurnal and d) sixth-diurnal tides. Amplitudes normalized to incoming amplitudes (legends). Hein et al. (2021)

## Keywords

estuarine tidal amplification, tidal constituents, tidal reflection, tidal resonance