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Bar dynamics in scale-experimetns of estuaries: tidal bars determine a quasi-periodic estuary planform

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Introduction

Estuaries are often described with an ideal trumpet/converging shape (e.g. Langbein, 1963). However, alluvial estuaries filled with bars often show a planform that deviates from this ideal shape. Our <u>aim</u> is to study the feedback mechanism between the growth of forced bars and the large-scale narrowing and widening of the planform. We <u>hypothesize</u> that the quasi-periodic planform is caused by the forced bars and scales with these bars.

Fig. 1: Aerial photograph of the Thames (UK) with an ideal planform [top] and of the Western Scheldt (NL) with a more irregular planform [bottom].

Method

1. Extraction of outline on historic maps Western Scheldt
2. Experiments in a tilting flume: the Metronome, 15000 tidal cycles
   - Landward river inflow ($0.1\ L{\cdot}s^{-1}$)
   - Seaward waves ($H = 3$ mm, $f = 2$ Hz)
   - Initial converging channel
   - Tilting: $T = 40$ s
     max. gradient = $0.008\ m{\cdot}m^{-1}$

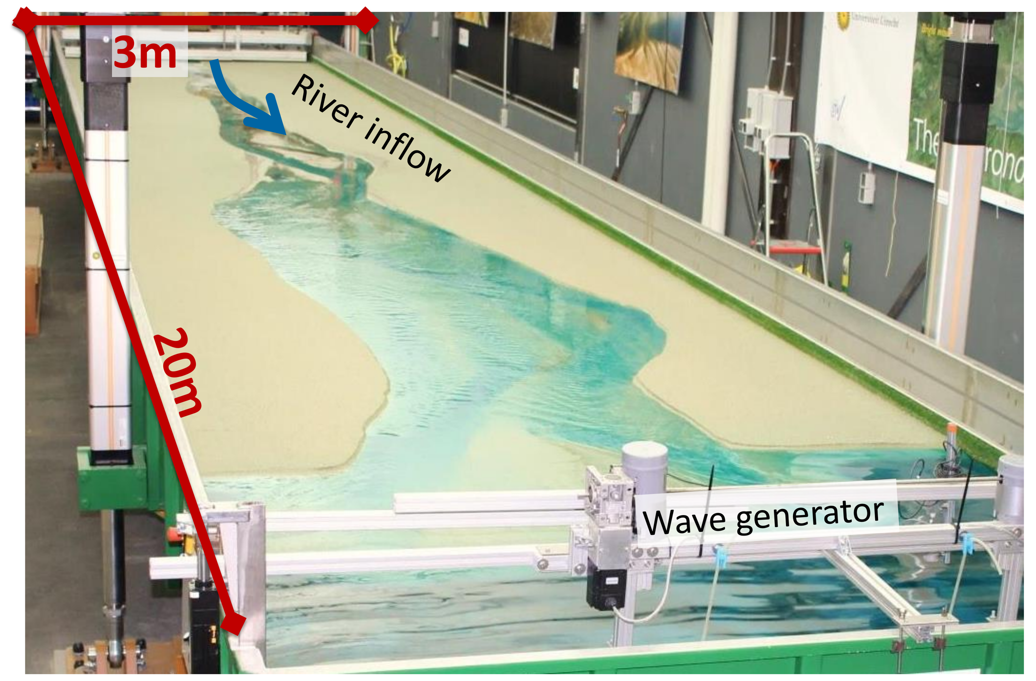


Fig. 2: Overview of the Metronome. See for more details Kleinhans et al. (2017).

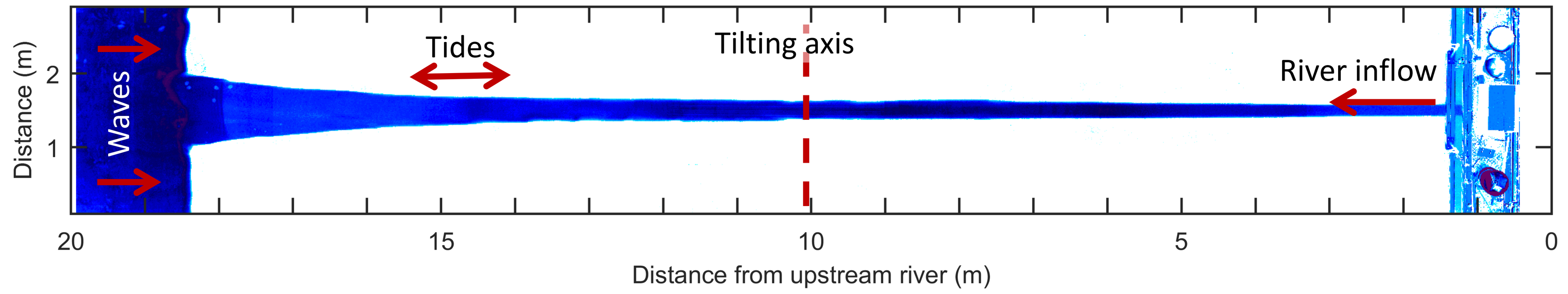


Fig. 3: Initial conditions of the experiment and boundary conditions.

Results experiment

Blueness was extracted from overhead images as an indicator for water depth.

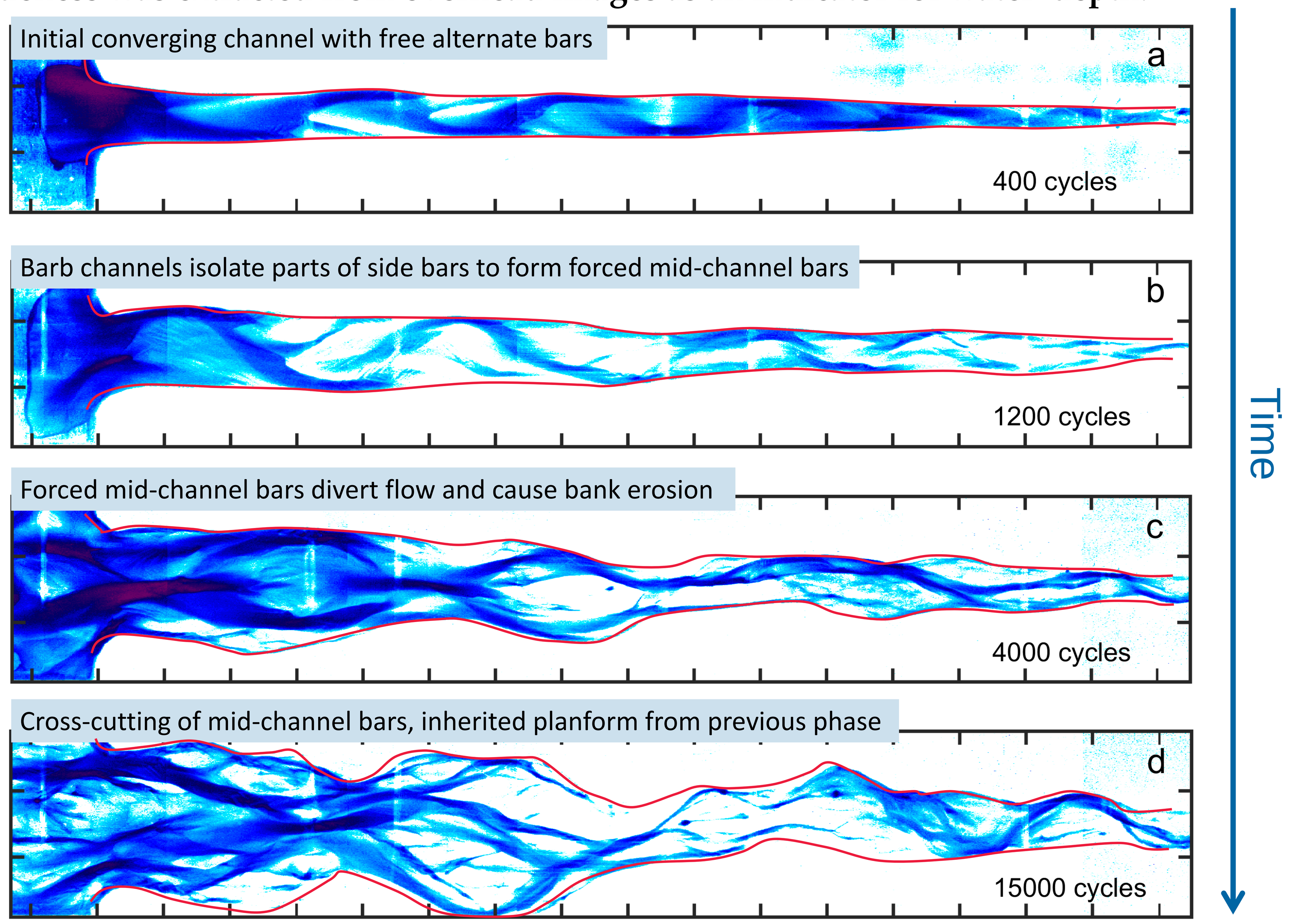


Fig. 4: Experimental evolution.

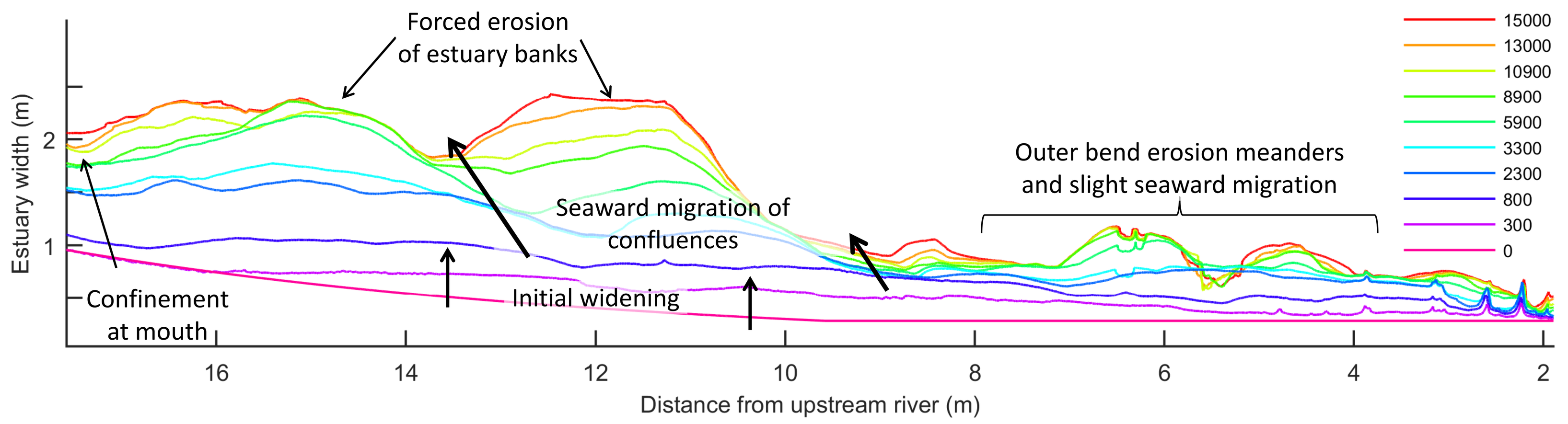


Fig. 5: Evolution of width profiles in the experiment.

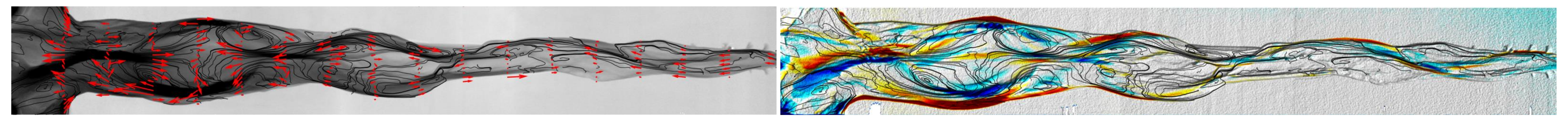
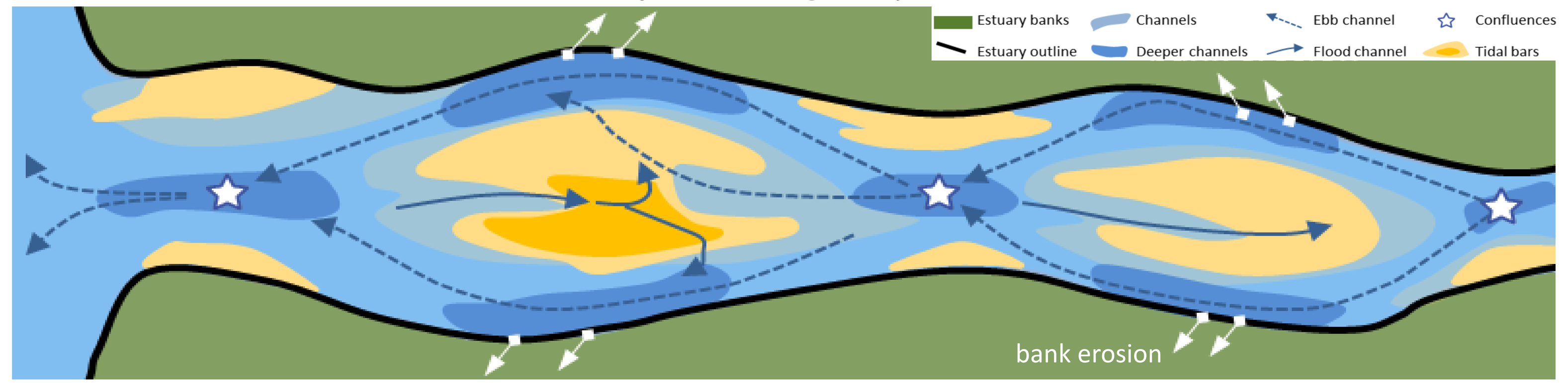


Fig. 6: Streamlines and residual currents [left] show that flow diverts around the bars and causes bank erosion [right]. Data based on surface PIV after 4400 and drawn on top of a Digital Elevation Model. Red colors indicate erosion, blue sedimentation for period between 4400 and 6900 cycles.

Forming mechanism

- Forced mid-channel bars divert flow and cause bank erosion
- Sidebars self-confine the estuary causing major confluence locations



Comparison with Western Scheldt

Digitised outlines resulted in width profiles over time.

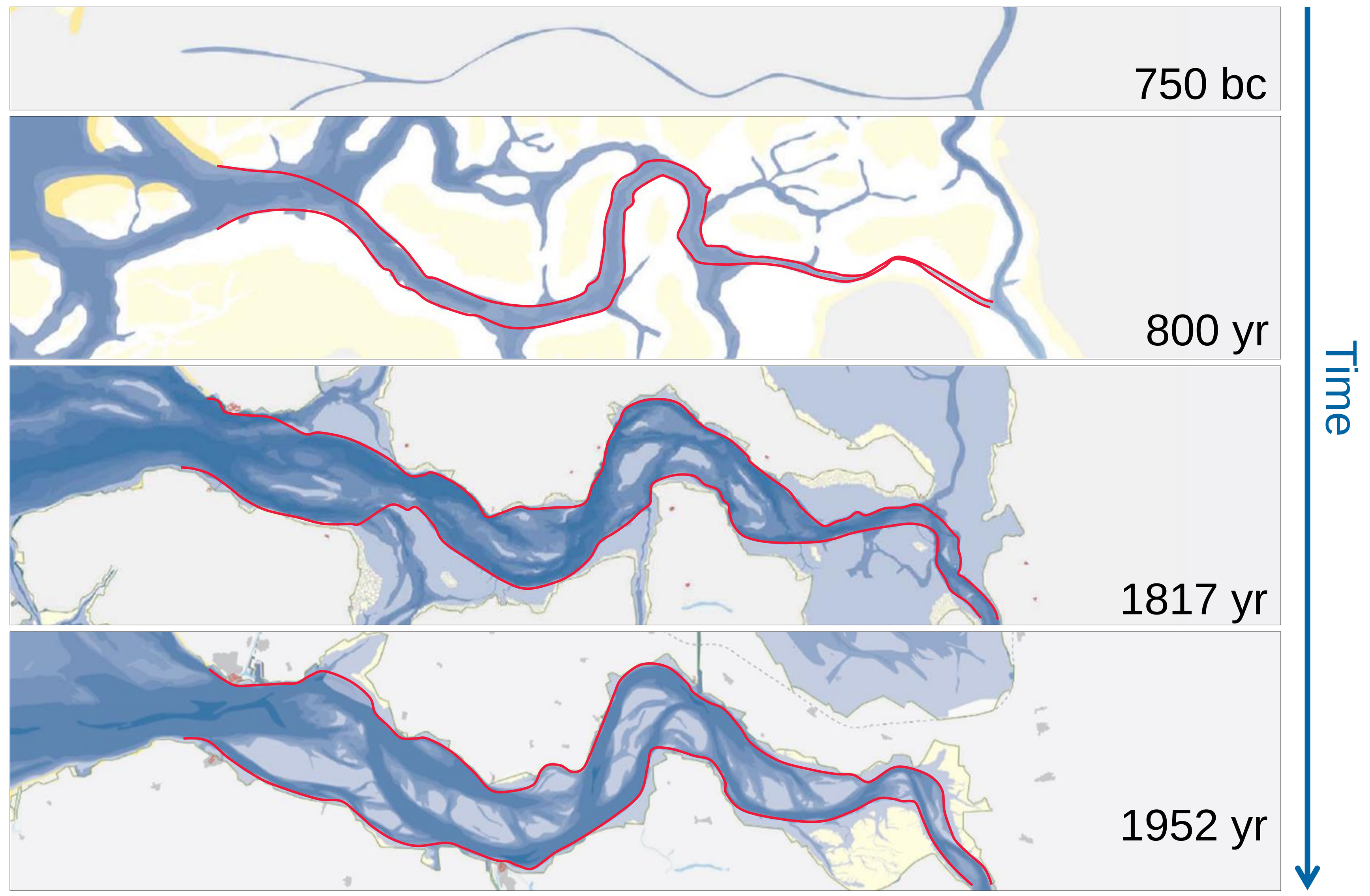


Fig. 7: Historic maps of the Western Scheldt (from Bosch & Sorée, 2016)

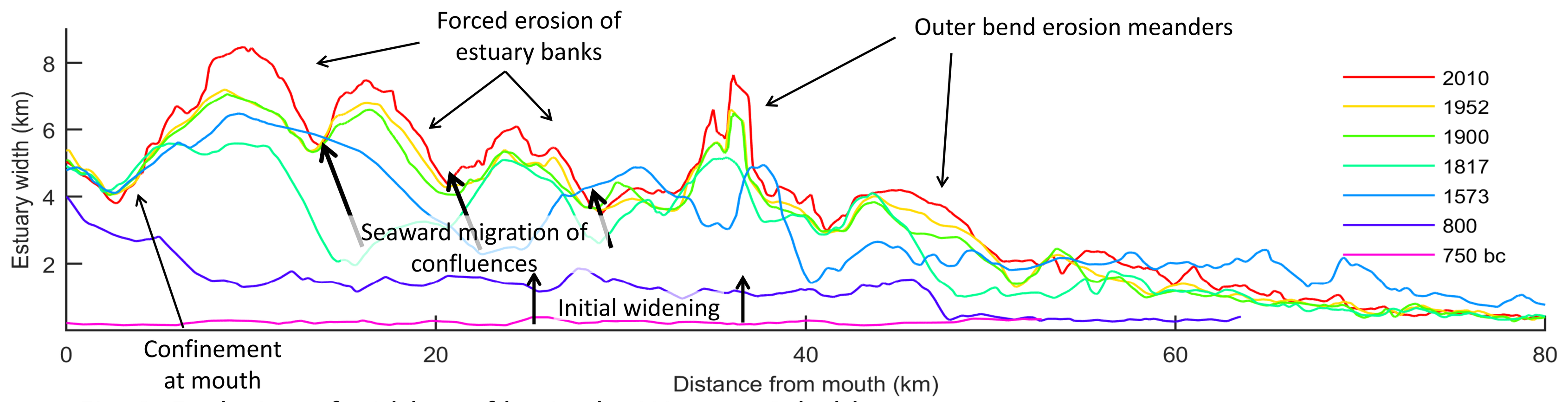


Fig. 8: Evolution of width profiles in the Western Scheldt.

Similarities experiment and Western Scheldt

Planform becomes progressively more irregular, rather than ideal

Confinements stabilize over time, while other locations keep expanding over time

Conclusions

- Quasi-periodic variation scales with bar dimensions
- Mid-channel bars hardly migrate, cause bank erosion such that channel curvature increases and bars become strongly forced which further enhances bank erosion
- This leads to quasi-periodic narrowing and widening, which may be an alternative equilibrium planform

References

- Bosch, J.W. & Sorée, C. (2016), Hydrobiografie Schelde-estuarium, *College van Rijksadviseurs*
- Kleinhans, M.G. et al. (2017). Turning the tide: comparison of tidal flow by periodic sea-level fluctuation and by periodic bed tilting in the metronome tidal facility. *Earth Surface Dynamics Discussions*, 1–35.
- Langbein, W. (1963). The hydraulic geometry of a shallow estuary. *Hydrological Sciences Journal* 8 (3), 84–94.

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Movie of the experiment

Metronome website

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