Tidal bars determine a quasi-periodic estuary planform

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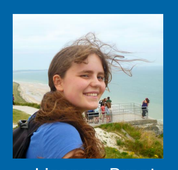
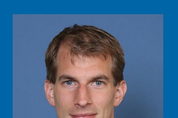


Lisanne Braat



Wout van Dijk

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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.

Fig. 1: Aerial photograph of the Thames (UK) with an ideal planform.

Our **aim** is to study the feedback mechanism between the growth of forced bars and the large-scale narrowing and widening of the planform. We **hypothesise** that the quasi-periodic planform is caused by the forced bars and scales with these bars.

Fig. 2: Aerial photograph of the Western Scheldt (NL) with a more irregular planform.

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 $m \cdot m^{-1}$

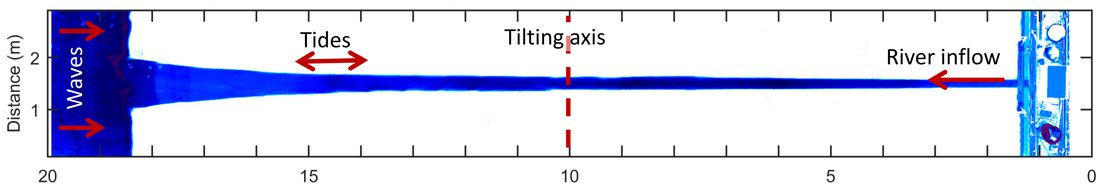


Fig. 3: Initial conditions of the experiment and boundary conditions.

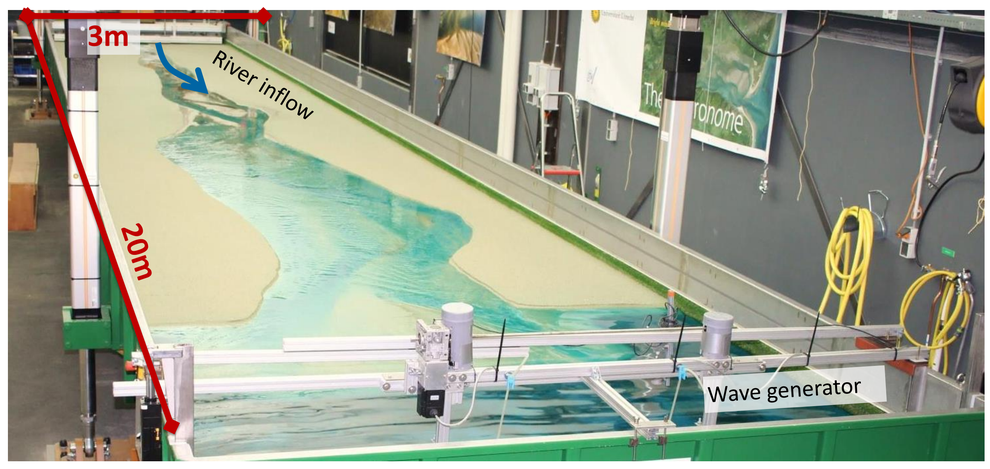


Fig. 4: Overview of the Metronome. See for more details Kleinhans et al. (2017) submitted to E-Surf.

Results experiment

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

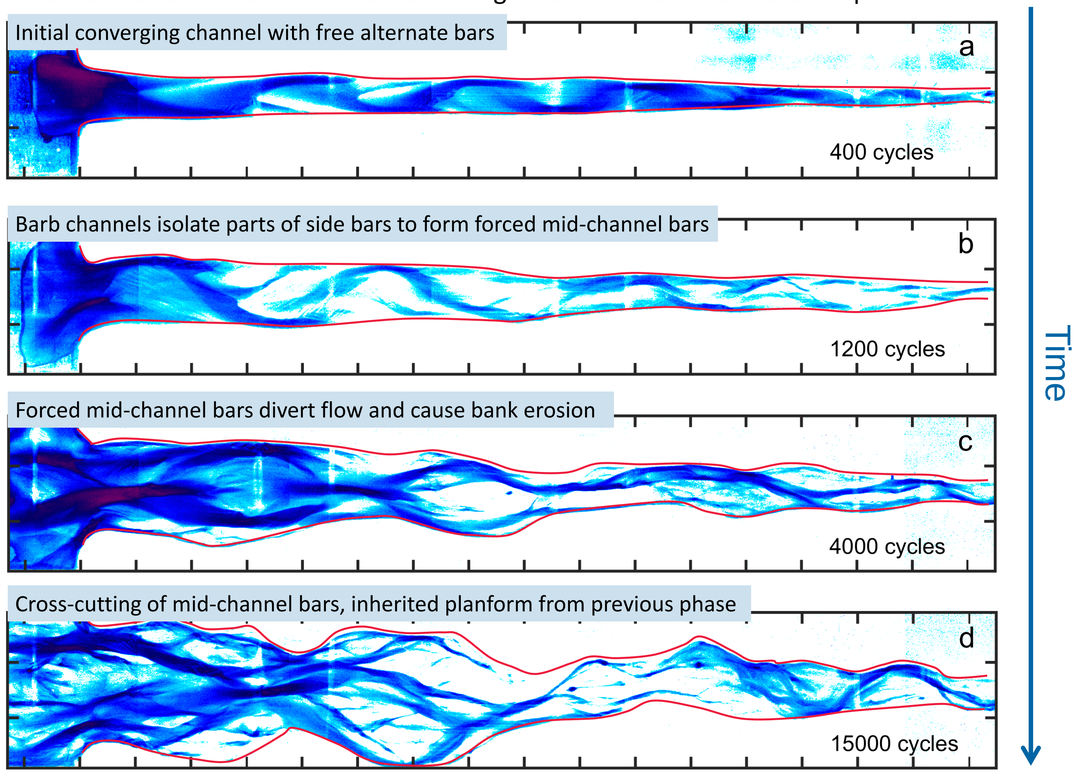


Fig. 5: Experimental evolution.

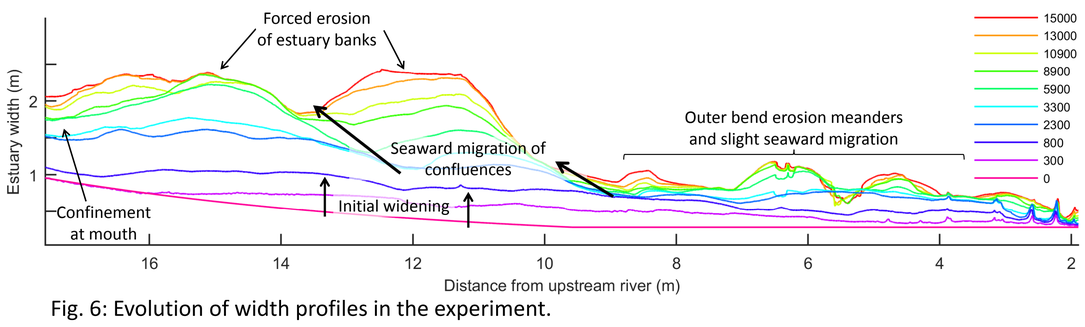


Fig. 6: Evolution of width profiles in the experiment.

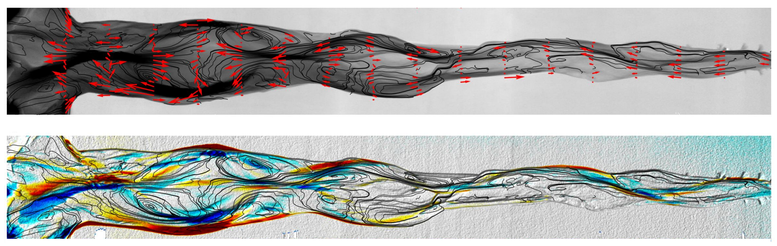
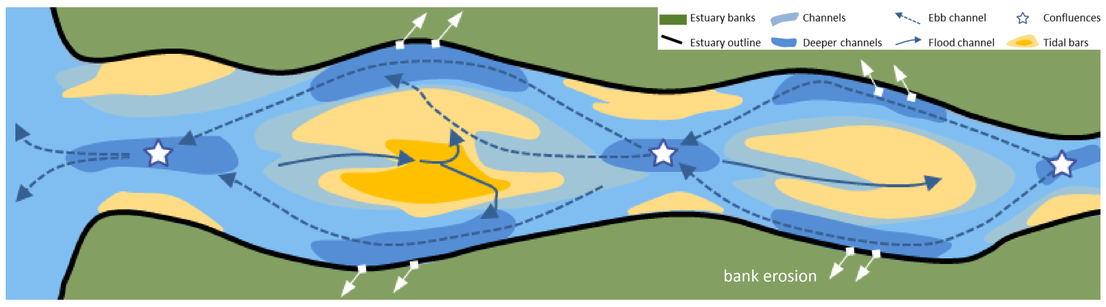


Fig. 10: (top) Streamlines and residual currents after 4400 cycles based on surface PIV, on top of a Digital Elevation Model. (bottom) Digital Elevation Model of Difference (DoD) for period between 4400 and 6900 cycles with streamlines.

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

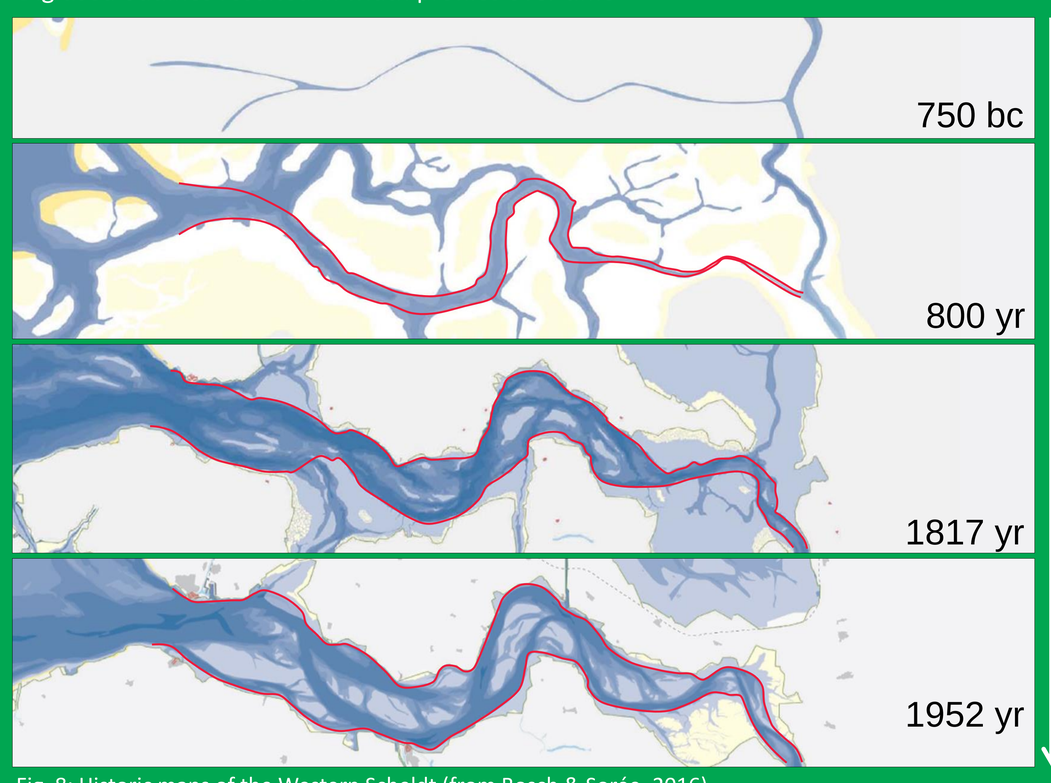


Fig. 8: Historic maps of the Western Scheldt (from Bosch & Sorée, 2016)

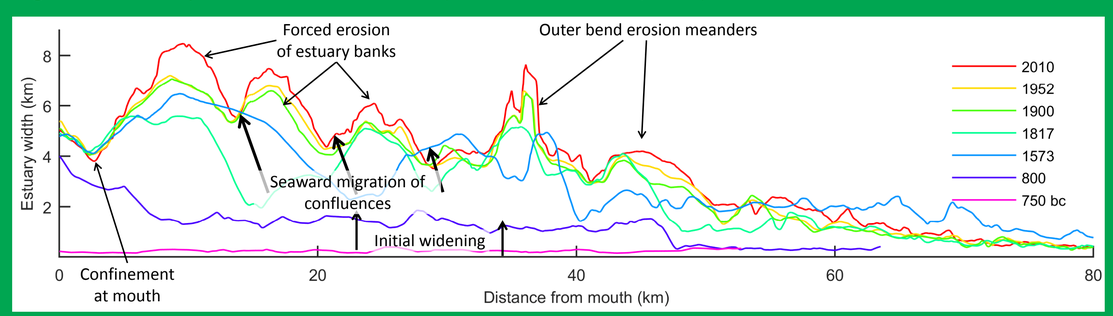


Fig. 9: Evolution of width profiles in the Western Scheldt.

Fig. 11: Streamlines on top of a Digital Elevation Model of Difference (DoD) for Western Scheldt. DoD is based on the difference in bathymetry between 2009 and 2015, streamlines are given for the SCAL-WEST model (RWS) on bathymetry of 2009.

Similarities Experiment ↔ Western Scheldt

- Planform evolves from initially ideal into quasi-periodic
- Planform becomes progressively more irregular
- Locations where estuary width expands remain fixed in place
- Confinements stabilise 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

Movie of the experiment

Metronome website

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 sealevel 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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