Turning the tide: experimental estuaries

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Background

Laboratory experiments of tidal systems have been rather unsuccessful the past century. Recently, Kleinhans et al. (2012) discovered that a periodically tilting flume generates dynamic tidal morphology, which opens up experimental investigation to complement numerical modelling.

Objective

The main question is: what is the effect of upstream river discharge on the small-scale dynamics and large-scale equilibrium dimensions of estuaries?

We hypothesise that fluvial inflow (1) enhances dynamic shifting of ebb and flood tidal channels, and (2) increases the width, length and tidal prism of estuaries depending on the fluvial discharge relative to the tidal amplitude.

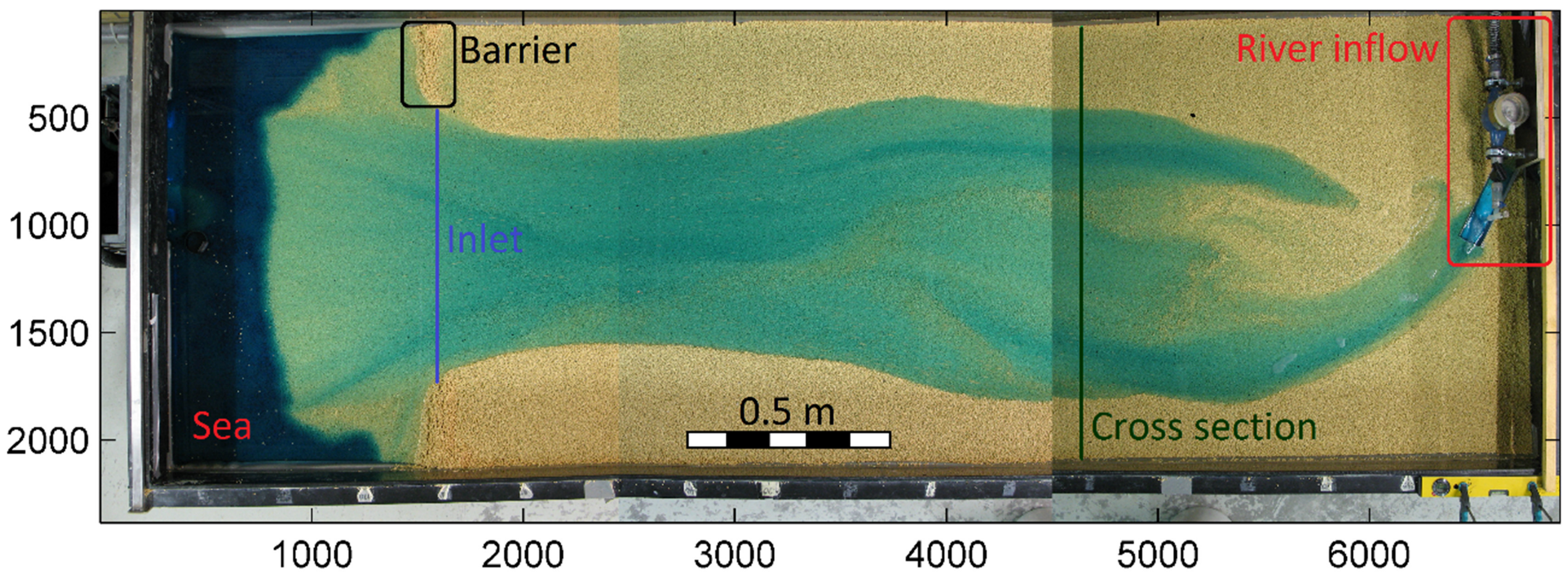


Fig. 1: Top view of experiment. Locations of cross-sectional profiles used in this study are indicated. Image is taken from experiment 26 after 150 tidal cycles.

Experimental setup

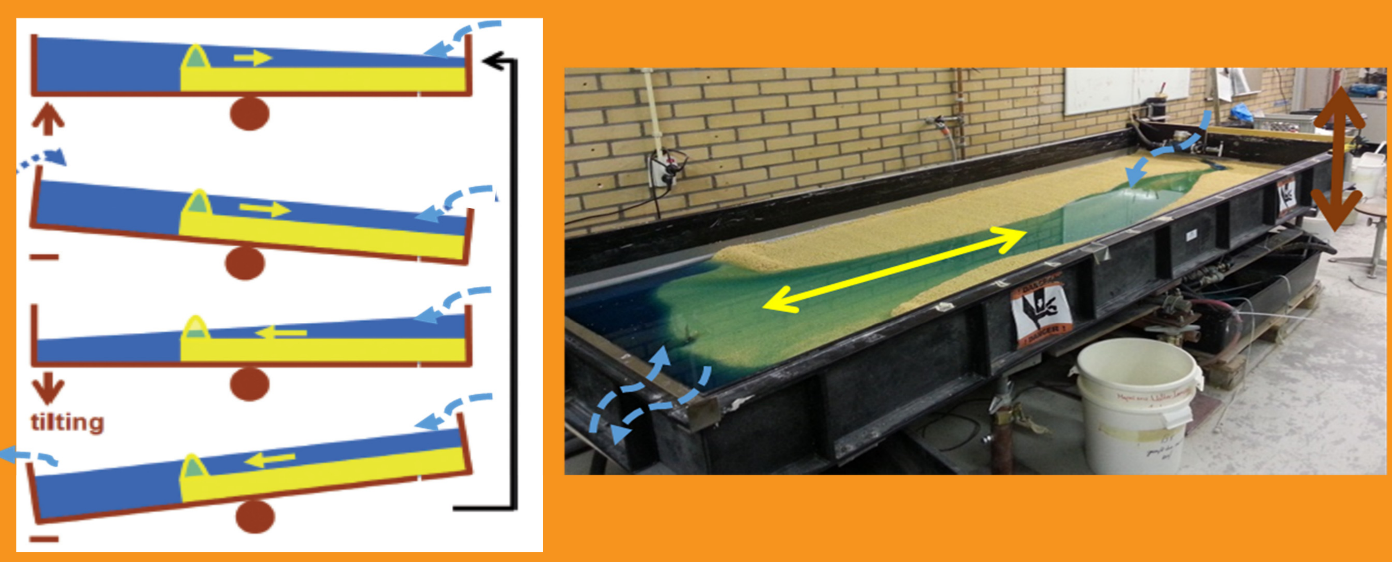


Fig. 2: (left) Schematic drawing showing the principle (Kleinhans et al., 2012). Yellow arrows indicate sediment transport, blue arrows pumping direction and brown arrows tilting direction. (right) Photograph showing the experimental setup.

Experiments

Tilting amplitude was set to 3.0 mm, resulting in maximum slopes of 0.0015. A stepping motor controlled constant tilting velocity (40 mm/minute) of flume. At maximum flume slope, the stepping motor paused 2 seconds before tilting direction changed. The resulting tidal period (T) is 22 seconds. Sea level and sediment bed level were set to a constant value of respectively 0.054 m and 0.055 m above flume floor. Dunes were represented with an erodible sediment barrier (Fig. 1) of 0.02 m high.

YouTube Movie of Exp. 26

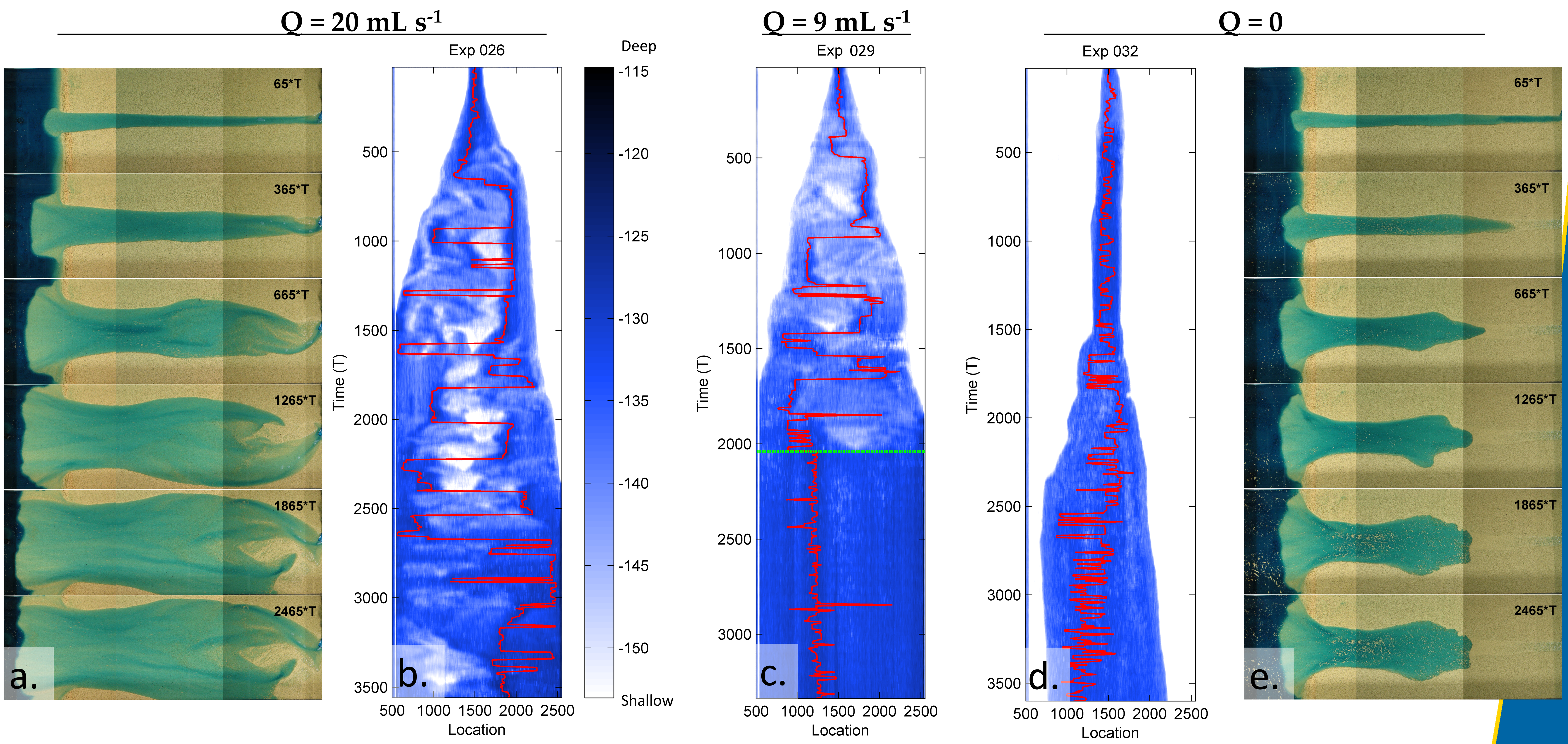


Fig. 3: (a,e) Time series of images taken from 2 m above the flume. (b,c,d) Time stack of upstream cross-section (see Fig. 1). From the images, the B-band (yellowness – 0-256) of LAB colour space is used as a proxy for relative channel depth. The colour value of the sediment bed is higher than 153 and thus not shown. Maximum channel depth is used as upper range of the colour scale. Location given in amount of pixels (width of one pixel is 0.51 mm). T corresponds to the duration of one tidal cycle. The ***red line*** *indicates the location of the maximum channel depth. The* ***green line*** *indicates when the river closed off by infill of sediment at the upstream boundary.*

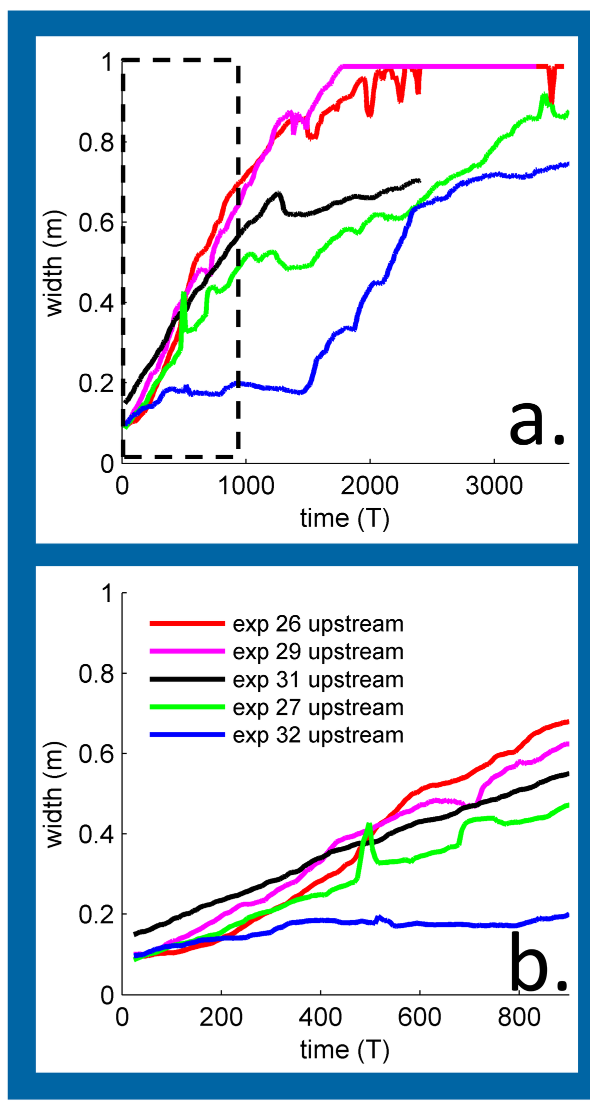
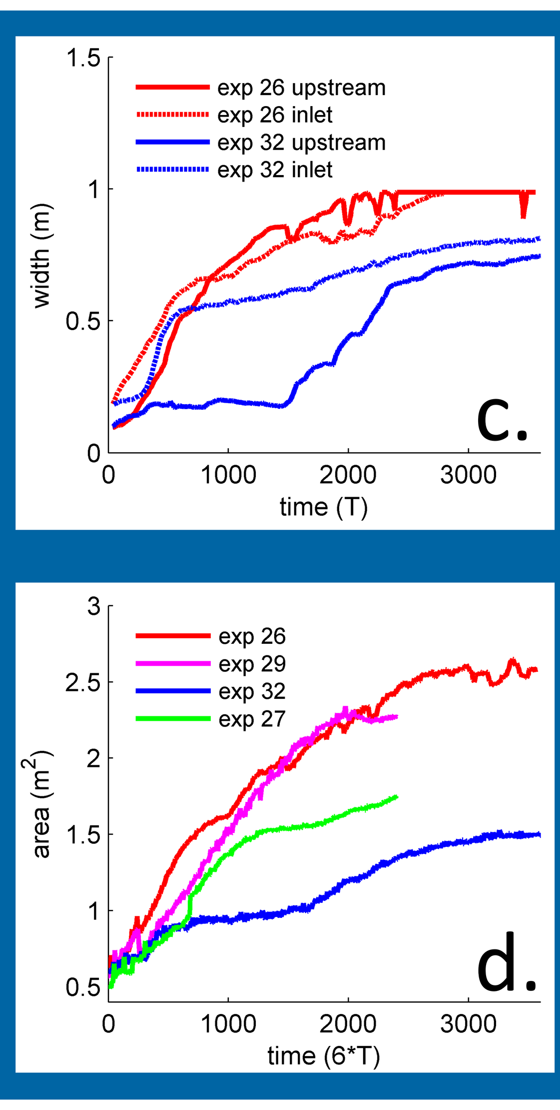


Fig. 4: (a) Time series of channel width at upstream cross-section; (b) Enlargement of the box shown in panel (a), showing the initial evolution of channel width; (c) Comparison of the evolution of inlet width and upstream channel width in experiments 26 and 32; (d) Time evolution of total estuary surface area in the experiments. In all panels T corresponds to the duration of one tidal cycle.

Exp.	Q (mL s^{-1})
26	20
29	9.3
31	9.0
27	6.1
32	0



Conclusions

- River inflow increases the dimensions of the upper estuary (Fig. 4abc) and probably causes wider and longer estuaries (Fig. 4d).
- River inflow enhances small-scale dynamics, particularly migration and shifting of channels and reversals in ebb and flood dominance of channels (Fig. 3bcd).
- Without river inflow a tidal system evolves into a short tidal basin (Fig. 3ae).

References

Kleinhans, M.G., van der Vegt, M., Terwisscha van Scheltinga, R., Baar, A.W. and Markies, H., 2012. Turning the tide: experimental creation of tidal channel networks and ebb deltas. *Netherlands Journal of Geosciences*, 91(3), pp. 311-323.

Acknowledgements

Chris Roosendaal, **Henk Markies** and **Marcel van Maarseveen** – technical support