Autocyclic channel migration in experimental self-formed tidal inlets


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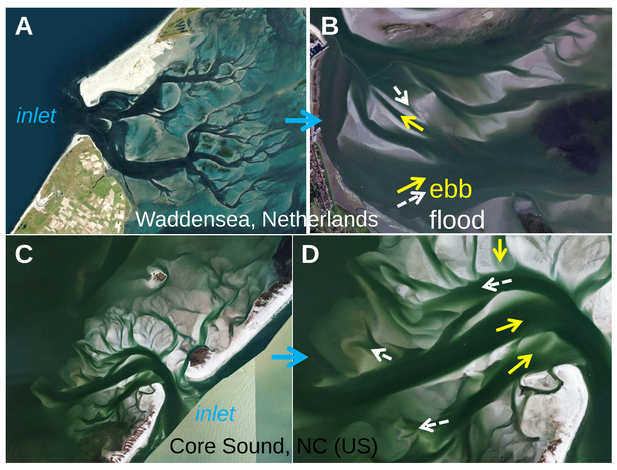
Research group River and delta morphodynamics

Background

Literature and coastal management institutes suggest autocyclic processes in tidal basins and estuaries (examples at bottom right), but field data lacks sufficient temporal resolution and models commonly produce static morphology.

Here we present experiments with self-formed tidal morphology showing cycles of ebb- and flood-dominated channels.



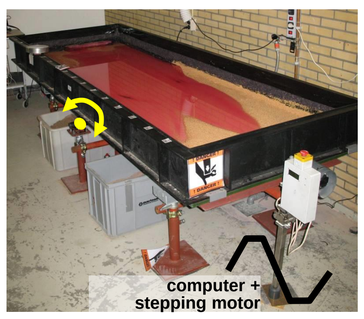
Objectives

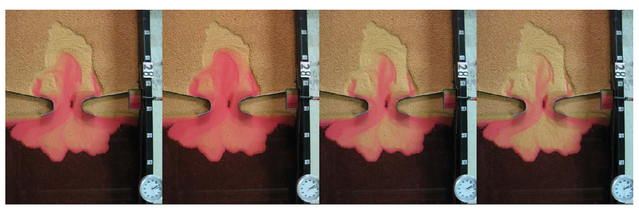
To experimentally investigate:

1. **to what extent geological setting determines dynamic morphologic equilibrium.**
2. **whether cyclic inlet channel behaviour is intrinsic without external forcing.**

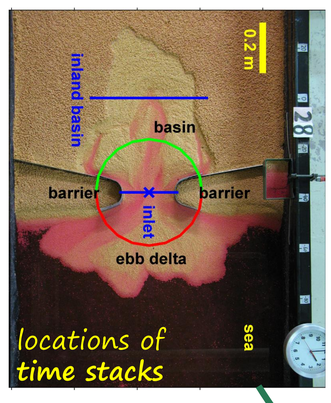
Experimental Setup

- Tilting flume for ebb- ***and*** flood-related sediment transport (Kleinhans et al. 2012, Kleinhans et al. RCEM Friday)
- Tilting period 79 s, slope = 0.005 m/m of max tilted position
- Flume : 3.8 x 1.2 m, inlet 20 cm wide, `land thickness' 4 cm
- Polystyrene sediment density 1042 kg/m^3, D10 = 1.03, D50 = 2.1, D90 = 2.8 mm
- Time stacks from profiles on L*A*B colour space-converted images



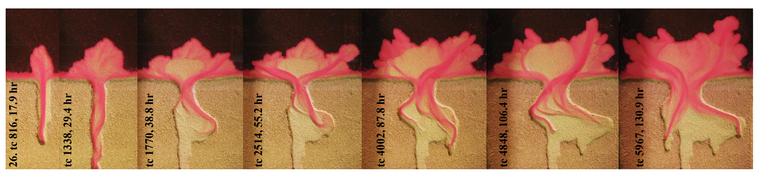

flood phase high tide ebb phase low tide

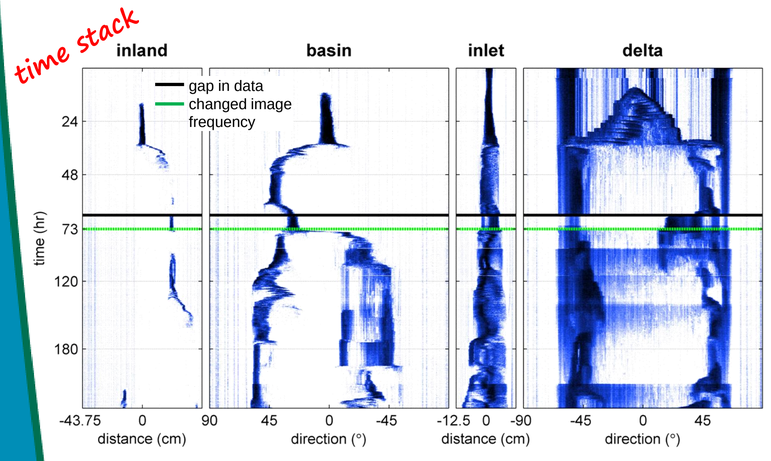
One tidal cycle by tilting the flume in 79 seconds



Erodible boundary

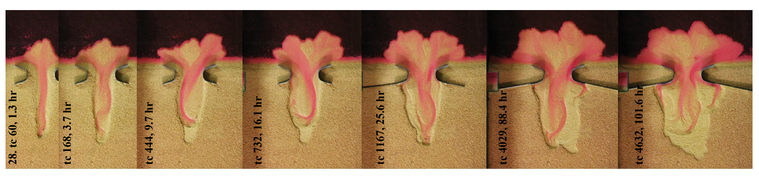
Constant sea level
Basin enlarges by boundary erosion

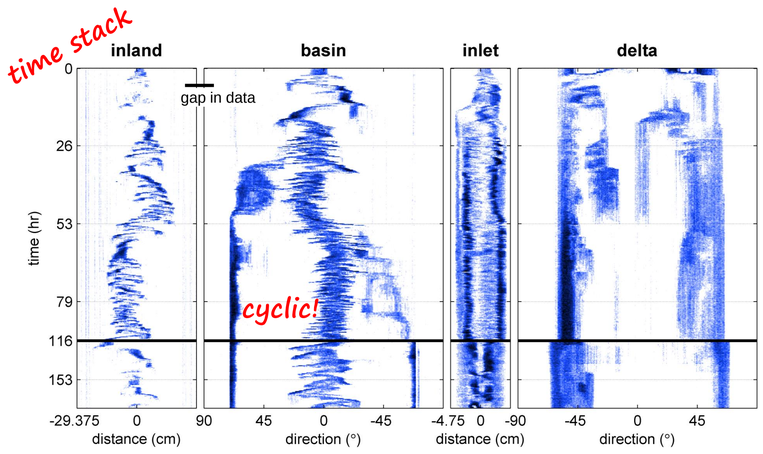




Fixed inlet

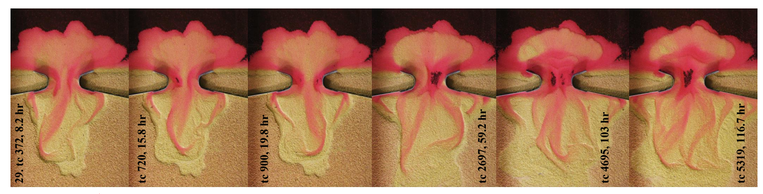
Constant sea level
Intertidal area nearly in equilibrium

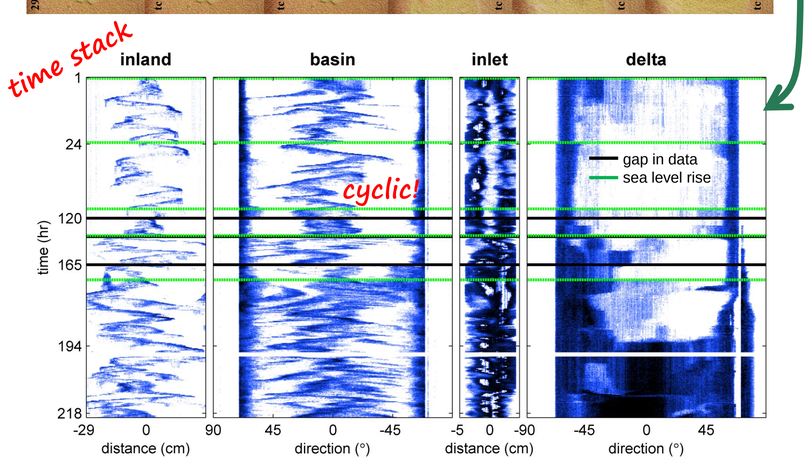




Sea level rise

Stepwise sea level rise, inlet fixed
Basin enlarges, delta drowns





Summary of results

Experimental tilting setup
- Tilting produces sediment transport in ebb and flood phases
- Mobility of sediment (Shields number) similar to field

Autocyclicity:
- Quasi-period alternation of inlet channel scours coupled to ebb / flood-channels
- Period is 1.5-2.5 hrs or 70-110 tides

Inlet and boundaries:
- Fixed inlet: the basin area reaches a near-equilibrium
- Erodible inlet the basin continues to enlarge until sediment is below motion

Delta
- Weak coupling between main channel directions on delta and in basin
- No inland transport from delta during sea level rise
- Instead higher sea level erodes basin area and creates new ebb shield

Conclusions

- Experimental reproduction of dynamic tidal basins possible in a rapidly tilting flume
- Erodible boundaries cause ongoing slow enlargement of basin and therefore of ebb delta
- Mutually exclusive ebb- and flood-dominated channels form
- Quasi-periodic behaviour of coupled inlet and basin channels and perhaps weak coupling to delta

youtube **movie** of Exp. 28

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Appendix: settings and scaling

variable	exp. basin	exp. inlet	Eierlandse Gat	Vlie	explanation
u [m/s]	0.1	0.2	1	1.5	velocity
h [m]	0.01	0.025	3	3	depth
T [s]	79	79	45360	45360	tidal period
H [m]	0.005	0.005	2	2	tidal amplitude
L [m]	0.7	0.7	20000	30000	basin length
A_t [m^2]	0.5	0.5	1.53E+08	6.68E+08	total basin surface
A_c [m^2]	0.05	0.05	4.70E+07	3.45E+08	channel area
P [m^3]	5.0E-03	1.3E-02	2.07E+08	1.08E+09	tidal prism
SLR [m]	0.008	0.008	0.13	0.5	sea level rise
tau [Pa]	0.23	0.50	1.43	3.21	shear stress
C [m^0.5/s]	21	28	83	83	friction
theta [-]	0.220	0.488	0.353	0.795	sediment mobility
Fr [-]	0.32	0.40	0.18	0.28	Froude
Re [-]	862	4310	2586207	3879310	Reynolds
Re* [-]	241	483	259	388	Reynolds particles