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Cyclic behavior of ebb-tidal deltas from model simulations: the role of waves and tides

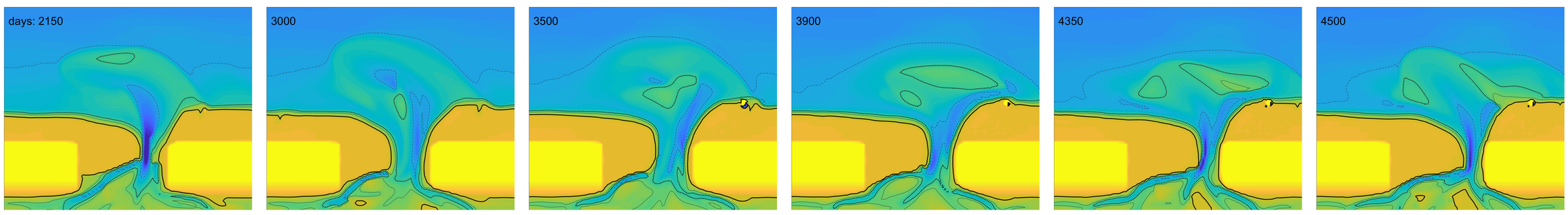
Introduction

- Ebb-tidal deltas are shallow sandy features located seaward of tidal inlets and are important for coastal safety in barrier systems.
- They act as a shield for incoming (storm) wave energy and they are a source of sediment for the barrier islands and the back-barrier basin.
- Often, cyclic behavior of shoal formation, migration and attachment to the downdrift island is observed.
- The Ameland Inlet changes from a one-channel-system to a two-channel-system and back during one cycle.

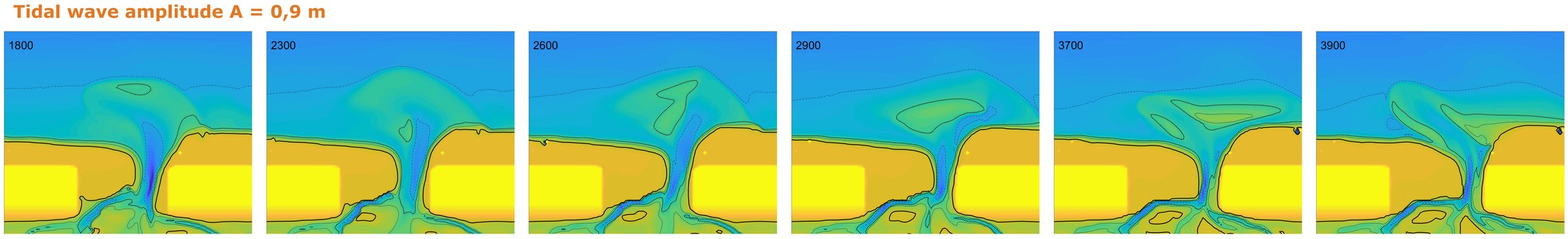
Main Question

What are the mechanisms of the observed cyclic behavior?

Tidal wave amplitude A = 1 m



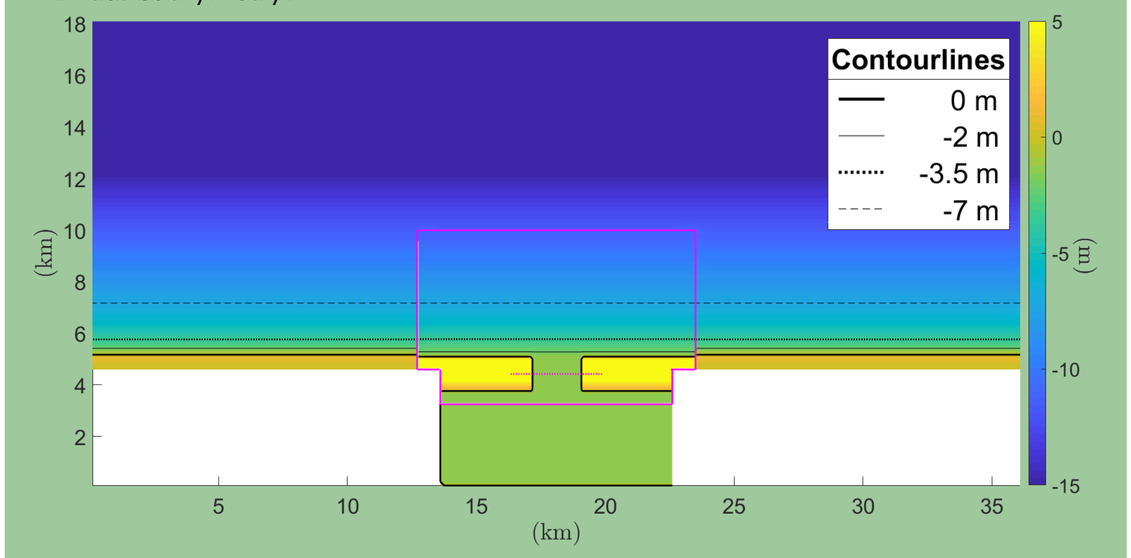
Tidal wave amplitude A = 0,9 m



Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 | Stage 6

Methodology

- Modeling with Delft3D/SWAN
- Initial bathymetry:



- High spatial (50 m) and temporal (12 s) resolution.
- Hydrodynamic forcing: combination of tides and waves.
- Tides: semi-diurnal tidal wave (amplitude A).
- Waves from NW: wave height H_s = 2 m and period T_{m02} = 7,5 s.
- Sediment transport formulation: Van Rijn et al. (2004), bed-load and suspended load (d_{50} = 0,25 mm). Morphological acceleration factor M_{fac} = 20.

Discussion

- During the modeled shoal migration, clockwise rotation of the main channel and subsequent channel breaching is found.
- The period between successive shoals decreases with decreasing tidal amplitude.
- Larger waves result in faster shoal dynamics and smaller time scales.
- In most model runs, the formation of shoals is triggered by a (temporary) decrease in tidal prism and export of sediment. However, in some other model runs, shoal formation is found with constant tidal prism and import/export.

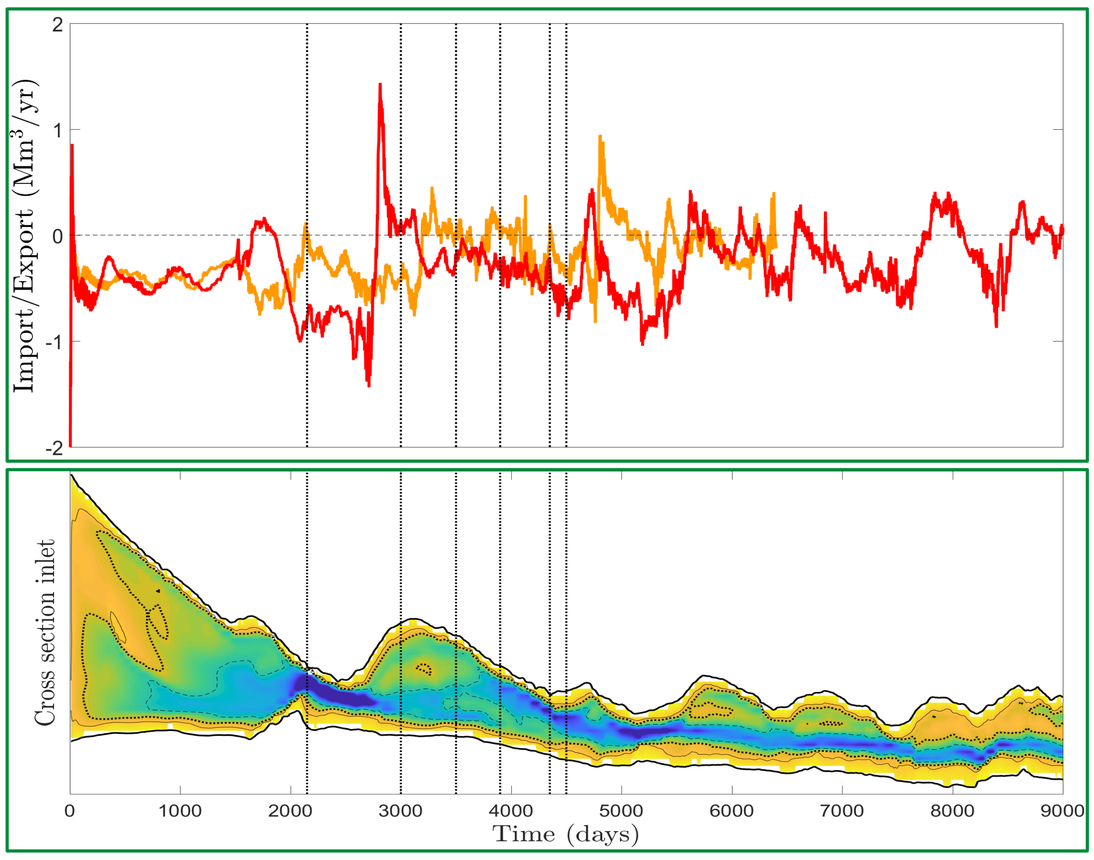
Watch full simulations

(H_s = 1,5 m)

Results

Stages in cyclic behavior:

1. Fully-developed ebb-tidal delta, one deep channel (t = 2150 & 1800 days)
2. Shoal formation, second channel forming (t = 3000 & 2300 days)
3. Shoal growth, clockwise rotation channel (t = 3500 & 2600 days)
4. Seaward growth of shoal (t = 3900 & 2900 days)
5. Shoal migration, channel breaching (t = 4350 & 3700 days)
6. Shoal attachment, one updrift oriented deep channel (t = 4500 & 3900 days)



Conclusions

Changes in the inlet - similar to the one-channel/two-channel transformation of the Ameland Inlet - are an inherent feature of some modeled periodic shoal dynamics.

Model results suggest that the observed cyclic behavior can be the result of a feedback effect:

Inlet narrows (one channel) → tidal prism decreases → sudden export of sediment forms shoal on ebb-tidal delta → shoal grows seaward → shoal migrates to downdrift island as a result of asymmetric wave related sediment transport → migrating shoal "bends" channel to downdrift orientation → channel breaches and old channel becomes abandoned → shoal attaches to downdrift island.