Finite-amplitude bed form dynamics in tidal basins

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1. Motivation

- field observations in tidal basins reveal (see Fig 1):
  - meandering of main tidal channels
  - migrating connection channels that link main channels
- aim of present work: model & understand these features
- new aspect: focus on nonlinear finite-amplitude behaviour

Approach

1. formulate model and basic state (morphodynamic equilibrium)
2. linear stability analysis of equilibrium
   - eigenmodes, physical mechanisms only initial pattern formation!
3. nonlinear analysis: expand variables in eigenmodes
   - finite-amplitude behaviour

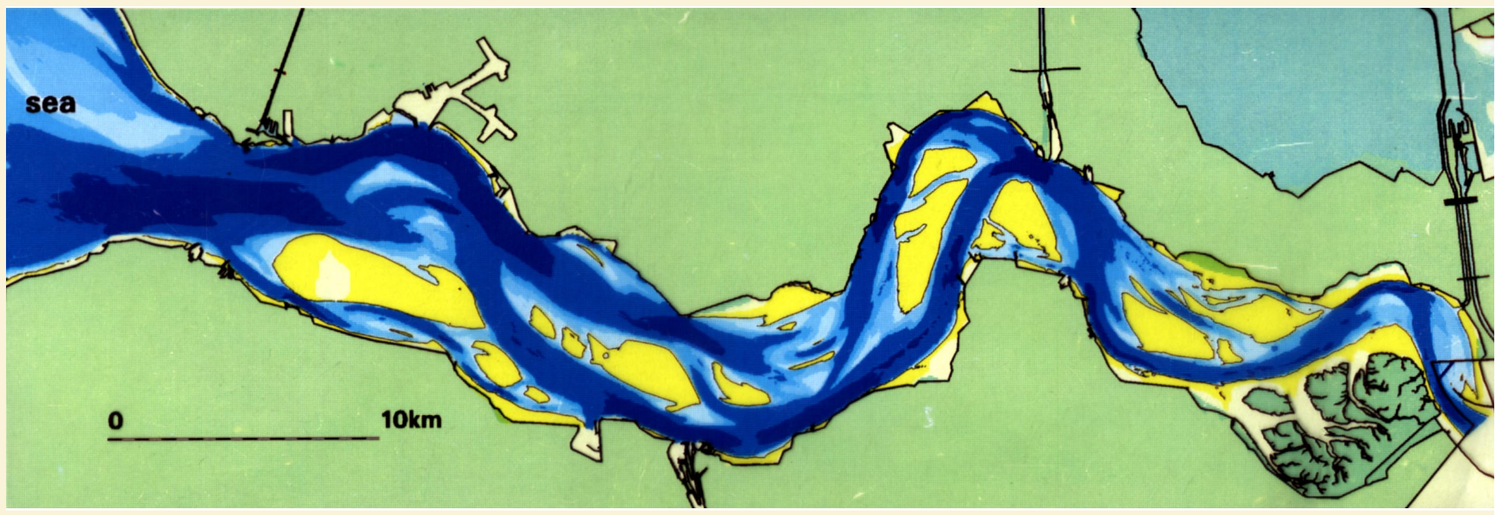

Figure 1: Marine part of the Dutch Western Scheldt estuary.

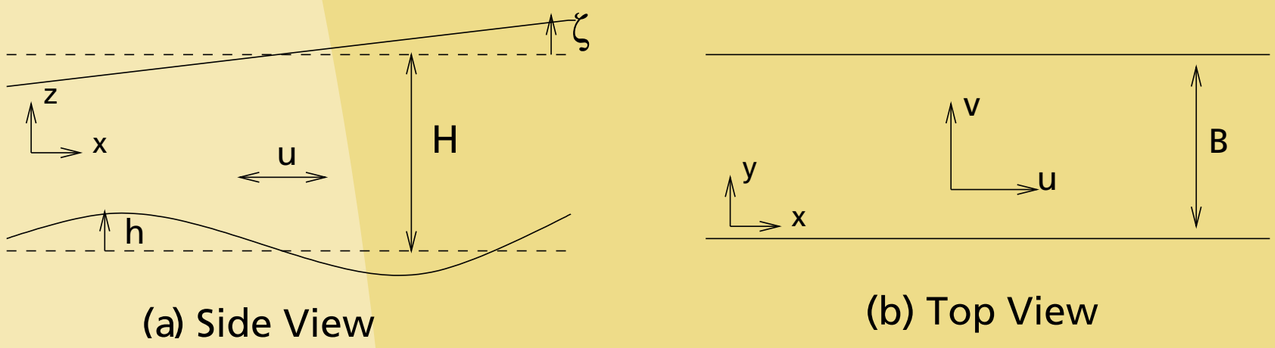

Figure 2: Geometry of the model. Typically, B = 3.5 km. and H = 10 m.

2. Model setup

- domain: open channel width straight side-walls (see Fig. 2)
- 2DH shallow water equations with suspended load
- only M_2 tidal forcing (frequency $\sigma = 1.4 \times 10^{-4} s^{-1}$)

Basic state: M_2 tide moving over a horizontal bottom

Review of linear stability analysis

- crucial parameters: bottom friction r and channel width B
- bottom perturbations can only grow if $r > r_{cr}$ (B)

3. Results of nonlinear analysis

- tendency to form new 2D morphodynamic equilibria
  Examples: see Fig. 3, top panels
- systematic picture: amplitude of bottom perturbation vs r
  bifurcation plots (see lower panels of Fig. 3)
- stable static morphodynamic equilibria exist
- static equilibria possible even if $r < r_{cr}$ (Fig. 3, bottom right)
- multiple equilibria may exist as well (Fig. 3, $r < r_{cr}$)
- besides steady states also finite-amplitude periodic solutions (see movie)
- type of equilibrium depends upon parameter settings (Fig. 4)

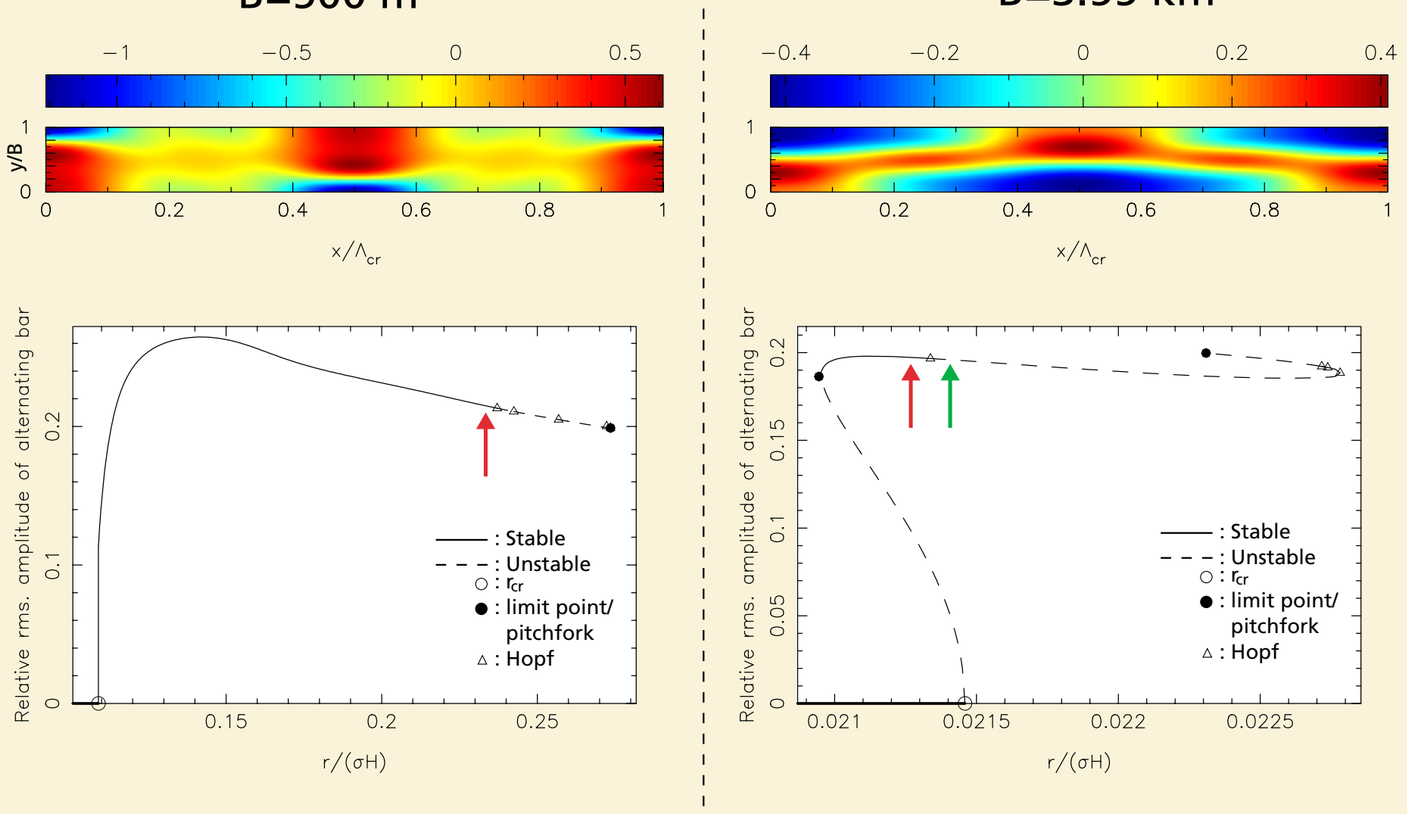

Figure 3: Top panels: 2D equilibrium bed profiles for B = 500 m and B = 3.55 km. Positive (negative) values correspond to shoals (troughs). The horizontal extend is approximately 40 km. Bottom panels: bifurcation diagrams for B = 500 m. and B = 3.55 km. The basic state (zero amplitude) is always stable for $r < r_{cr}$. Red arrows indicate the values used for the top panels' images. The green arrow refers to a periodic state (see movie).

Figure 4: Who's afraid of red, yellow and blue? Parameter space divided in regions of different types of morpho-dynamic equilibria. The upper right part is a blow-up of the rectangular region at the bottom right and shows more clearly the region of multiple steady states (green).