Modeling storm effects on sand wave dynamics

Geert Campmans
What are bed forms?
Why research their dynamics?

Large-scale rhythmic bedforms:
- Wavelength: 100-1000 meters
- Height: several meters
- Dynamic: migration and growth

Sand waves in the Euro channel to Rotterdam
(Rijkswaterstaat)
Nonlinear sand wave model development

• Before nonlinear models: **Linear stability analysis**
  • Small amplitude dynamics: GR, MR, FGM (Stage of Formation)
• Komarova & Newell (2000): **Weakly nonlinear analysis**
• Németh et al. (2006): **Nonlinear model** describing the evolution to **equilibrium height** of a single sand wave on a periodic domain
• Tonnon et al. (2007): **Delft3D** study on an artificial sand wave in the North Sea
• Van den Berg et al. (2012): Efficient nonlinear model for **larger domain** simulations
• Gerwen et al. (2018): Effect of **suspended load** and **tidal asymmetry** on finite amplitude sand wave dynamics using Delft3D
• Campmans et al. (2018): Effect of **storm effect** on finite amplitude sand wave dynamics
• Many aspects are still unknown!
Why investigate the effects of storms?

- Tidal flow
- Hydrodynamics
- Sediment transport
- Bed evolution
- Waves
- Wind-driven currents
Hydrodynamic model

Tidally averaged

Horizontal flow

Vertical flow

Vorticity
Evolution to equilibrium

Seabed evolution, $t = 0.00$ [yr]

- Depth, $z$ [m]
- Time, $t$ [yr]
- Horizontal coordinate, $x$ [m]

$\omega$ [1/s] $\times 10^{-3}$

$z_b$ [m]
Evolution to equilibrium
Evolution to equilibrium
Storm effects: Waves and Wind
Storm effects: Waves and Wind

(a) Tide only
(b) Tide + waves
(c) Tide + wind
(d) Tide + waves + wind

(e) Crest and trough evolution
(f) Profiles after 20 years
Intermittent storm effect

(g) Crest and trough evolution
Simulation with waves and wind

Seabed evolution, $t = 0.00$ [yr]

depth, $z [m]$ vs. horizontal coordinate, $x [m]$
Simulation with waves and wind

Seabed evolution, $t = 0.00$ [yr]

depth, $z$ [m]

horizontal coordinate, $x$ [m]

$\langle \omega \rangle$ [1/s]

0.01

0

-0.01

g.h.p.campmans@utwente.nl
Simulation with waves and wind

- Waves: Sand wave height decreases
- Wind: Causes sand wave migration

Seabed evolution, $t = 16.97$ [yr]

- Wind: Causes sand wave migration
- Waves: Sand wave height decreases

g.h.p.campmans@utwente.nl
Well-known processes have to be included as easy as possible to understand the system.

- **Waves:** Sand wave height decreases
- **Wind:** Causes sand wave migration

- g.h.p.campmans@utwente.nl