Wave modelling and field measurements in a complex estuary

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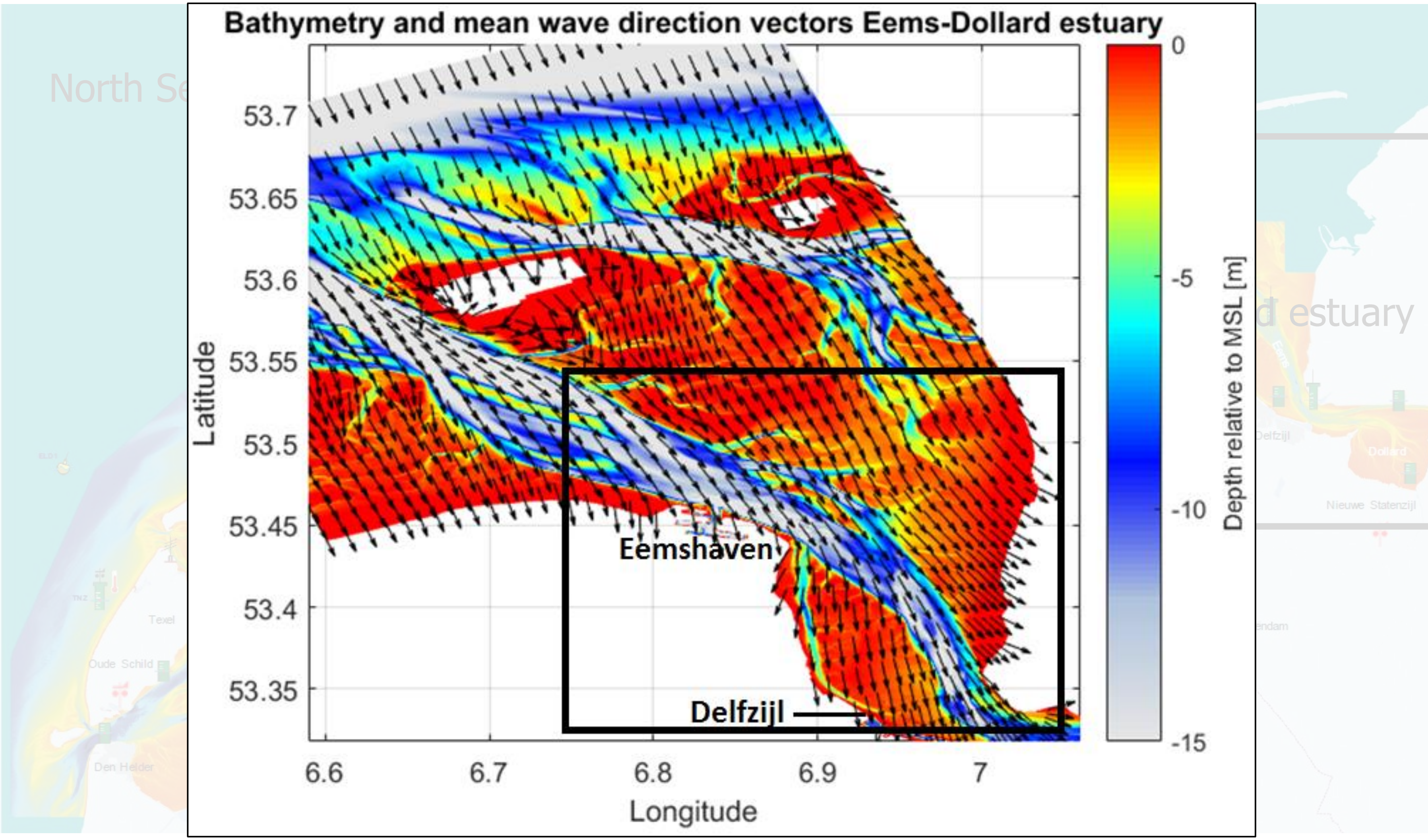
Area of interest: Eems-Dollard estuary



Field measurements Eems-Dollard

12-year long project

- Combining extensive field measurements and numerical modelling
- Reducing uncertainties in design conditions and improving safety assessment modelling systems




Field measurements Eems-Dollard

Onshore wave measurements

- Measuring wave run-up and overtopping
  - Innovative wave overtopping tanks
  - Innovative laser scanner system

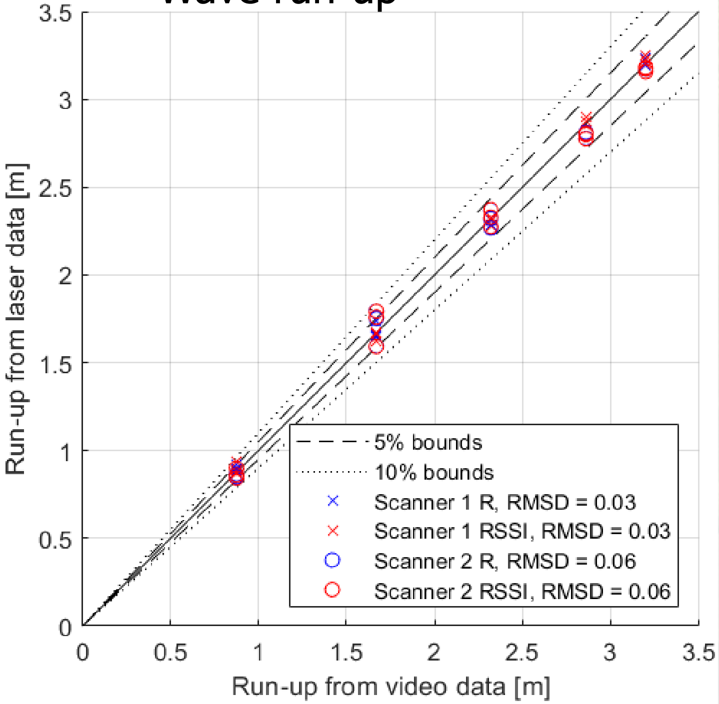
Storm 8-1-2019

Field measurements Eems-Dollard

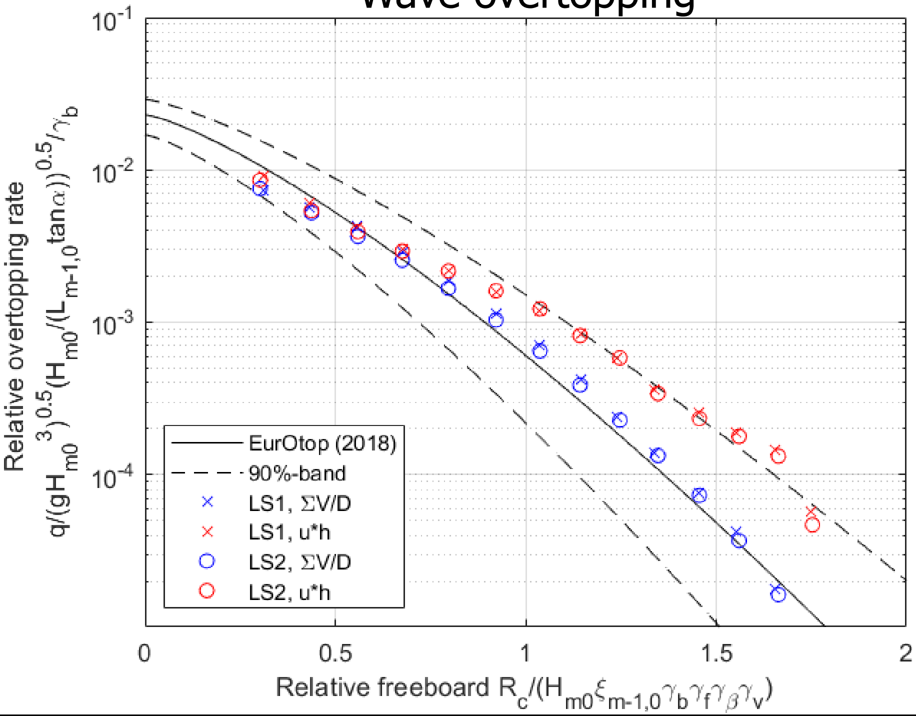
Onshore wave measurements

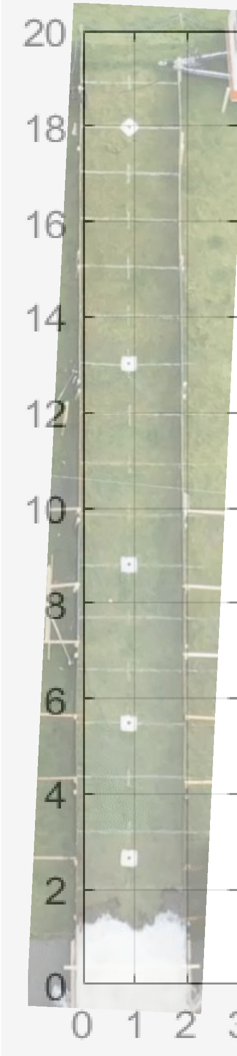
- Innovative laser scanner system
  - First validation tests with wave run-up simulator

Wave run-up



Wave overtopping





Focus & Approach

- Focus on evolution of waves as they propagate into the estuary

- Previous research:
  - Possible fundamental limitations in linear refraction approach in phase-averaged models in areas with steep slopes
  - Diffraction, wave tunnelling, nonlinear effects may play a role

- Approach:
  - From simple to complex, gradual build-up in model complexity
  - Gain insight into which processes play a role
  - Comparison phase-averaged (SWAN) vs. phase-resolving model (SWASH)
  - When available, comparison and validation with measurements

SWAN versus SWASH

	SWAN	SWASH
Model type	Phase-averaged	Phase-resolving
Equations	Wave action balance	NLSW equations
Propagation	x	x
Diffraction	**(x)**	**x**
Reflection	x	x
Transmission	x	x
Wave growth by wind	**x**	
Dissipation	x	x
Nonlinear interactions	**x**	**x**

SWAN & SWASH models

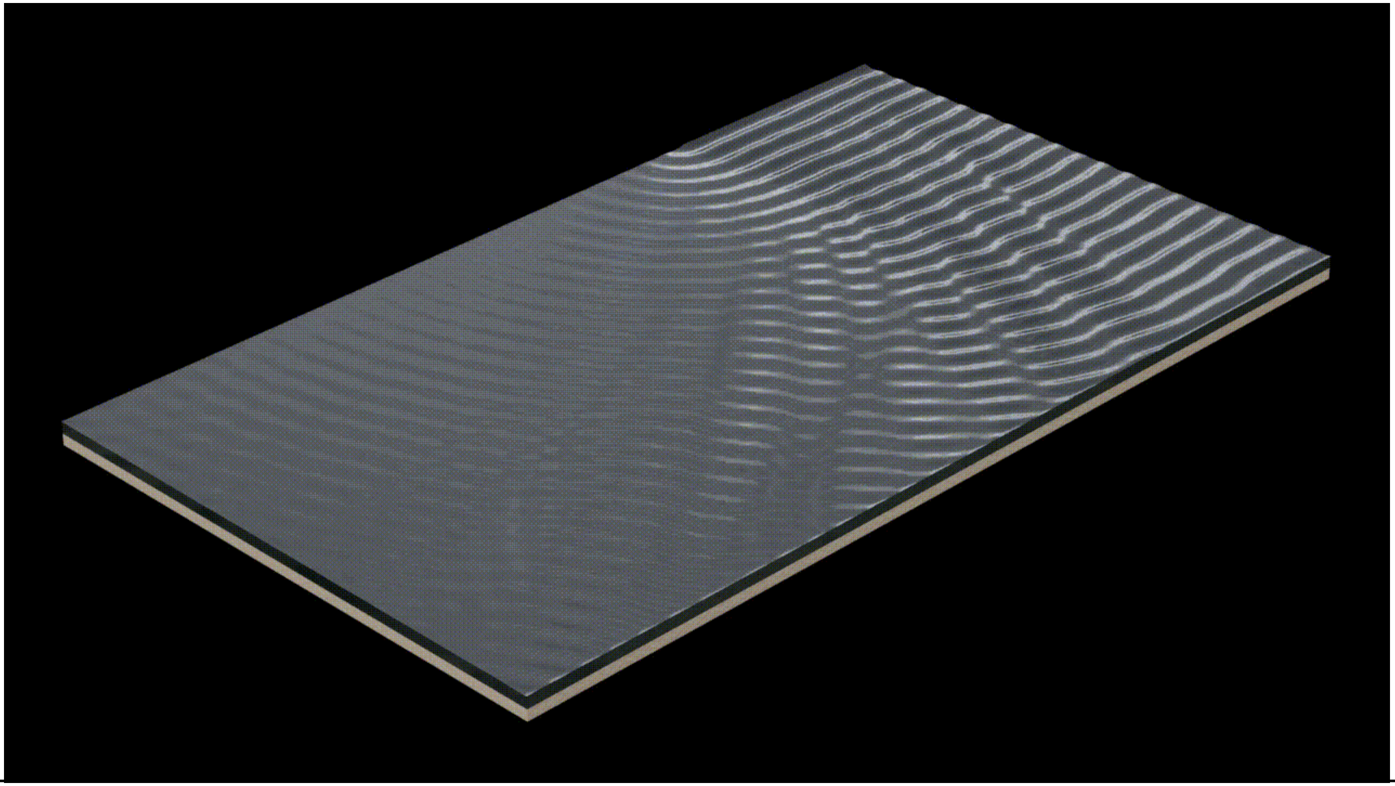
- SWAN:
  - Stationary mode
  - (Initially) 20 m grid cell size
  - **3 versions of the 3rd-generation physics:**
    - **Van der Westhuijsen et al. (2007)**
    - **Komen et al. (1984)**
    - **Rogers et al. (2012) (ST6)**
  - **Variations in:**
    - **Grid cell size**
    - **No. directional bins**
    - **Diffraction approximation**
    - **Stop criterion**

- SWASH:
  - Non-hydrostatic mode
  - **2 vertical layers**
  - Weakly reflecting b.c.'s & sponge layers
  - **Dike schematised with exception values**
  - Increase in applied H_s necessary
  - Calculations on Dutch national supercomputer Cartesius
  - Several issues encountered → Fixed in newest SWASH version (6.01)
  - Choice of spectral estimation method important

1. Semi-infinite breakwater case

Monochromatic, unidirectional waves

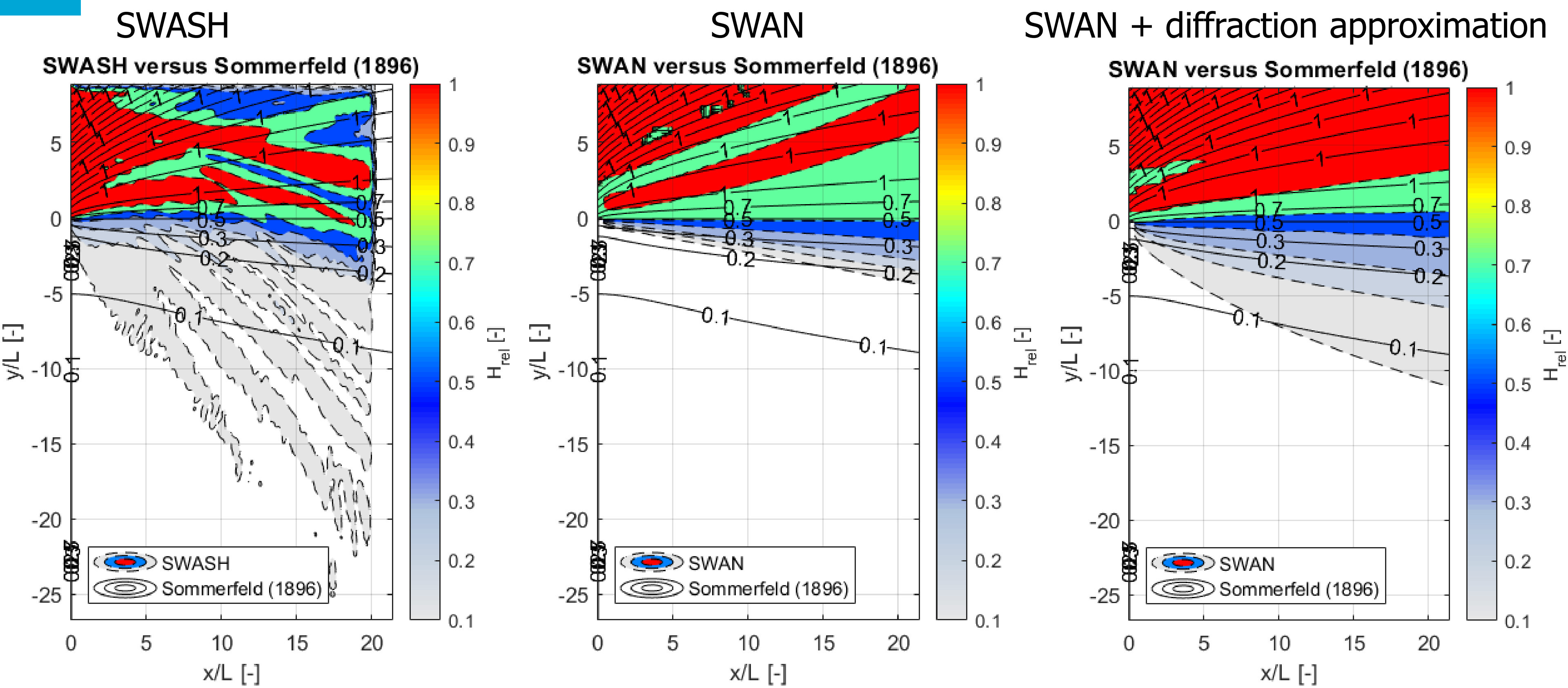
- Focus on wave propagation, excluding other physical processes
- d = 18.5 m, H = 3 m, T = 6 s, θ = 270°



1. Semi-infinite breakwater case

Monochromatic, unidirectional waves

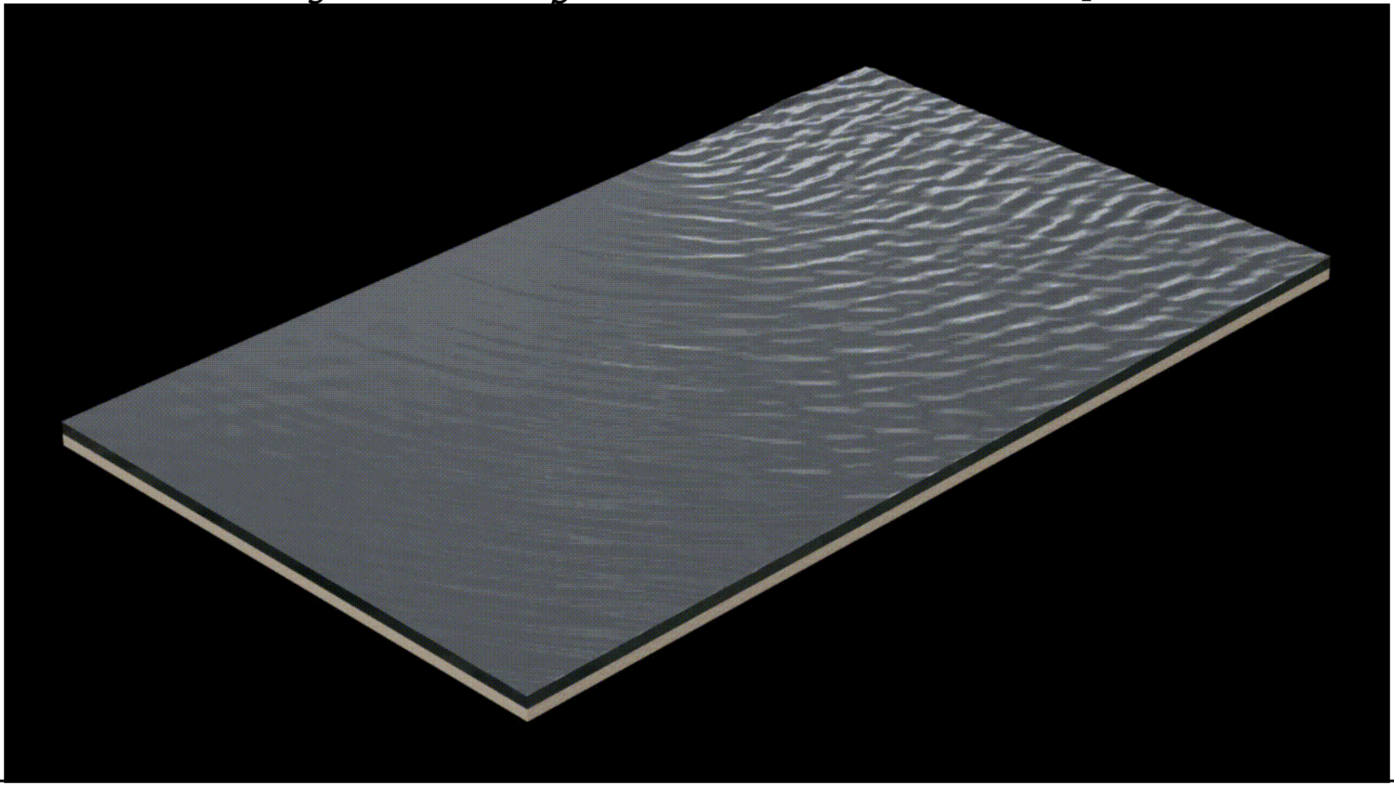
- Relative wave height compared to Sommerfeld (1896) solution



2. Semi-infinite breakwater case

Irregular, directional waves

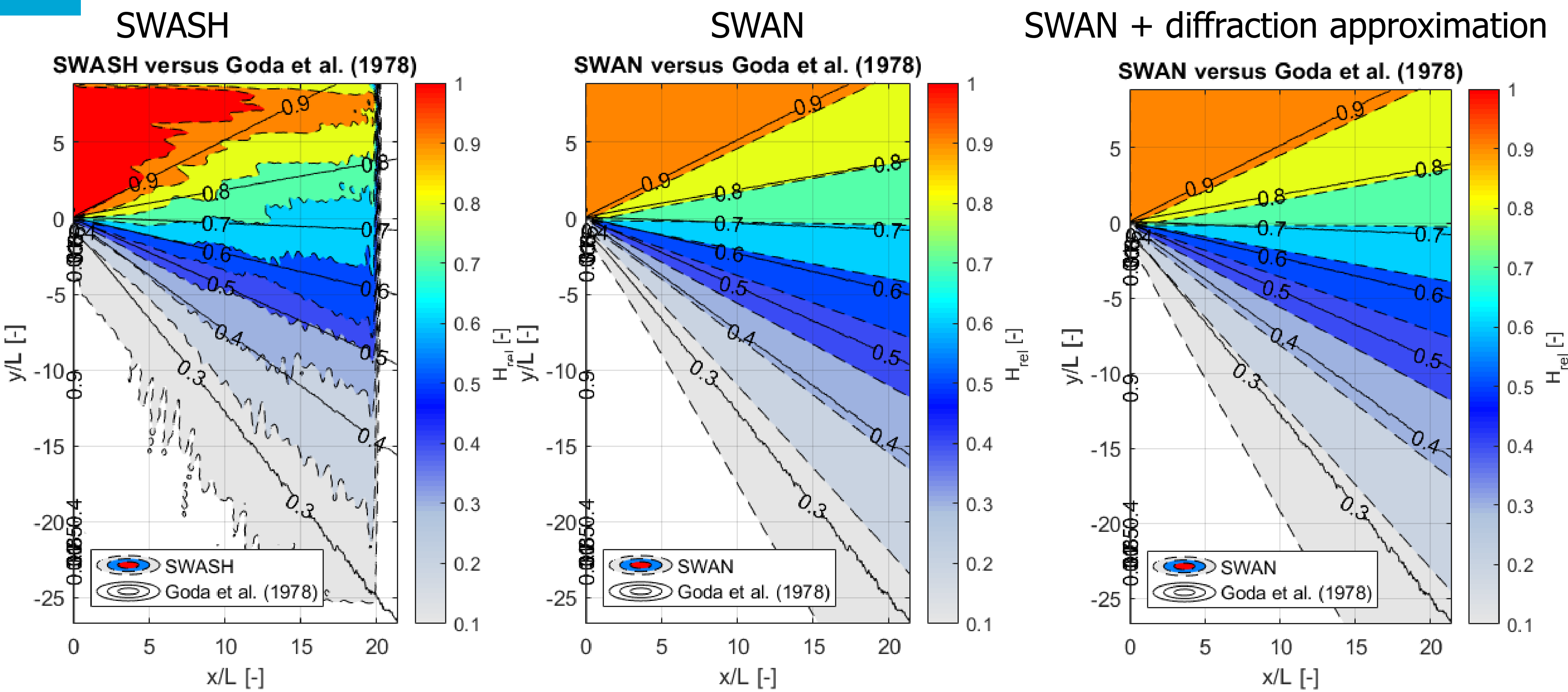
- Focus on wave propagation, excluding other physical processes
- d = 18.5 m, H_s = 3 m, T_p = 6 s, θ = 270° , **dspr = 25**°



2. Semi-infinite breakwater case

Irregular, directional waves

- Relative wave height compared to Goda et al. (1978) solution



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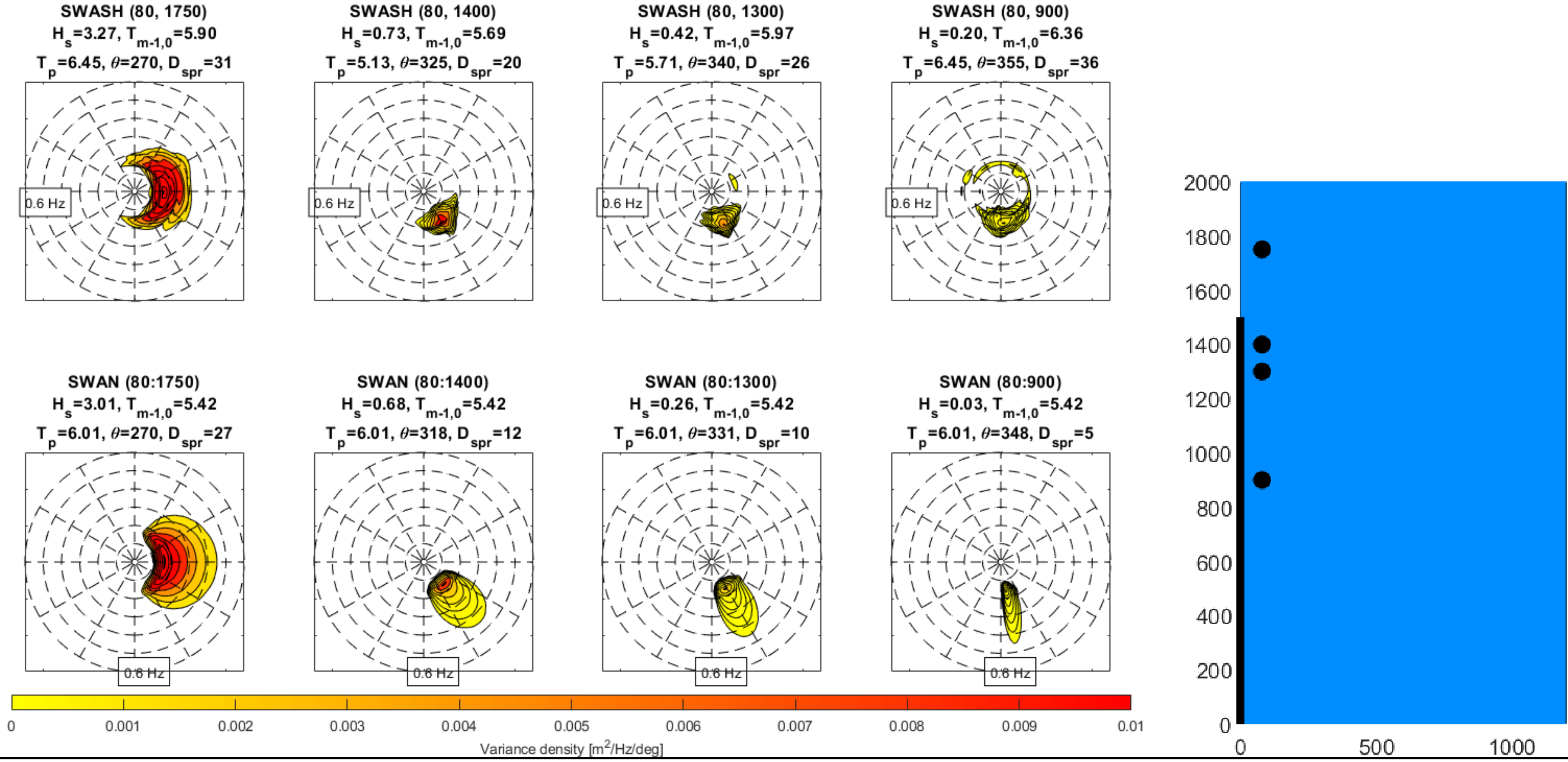
2. Semi-infinite breakwater case

Irregular, directional waves

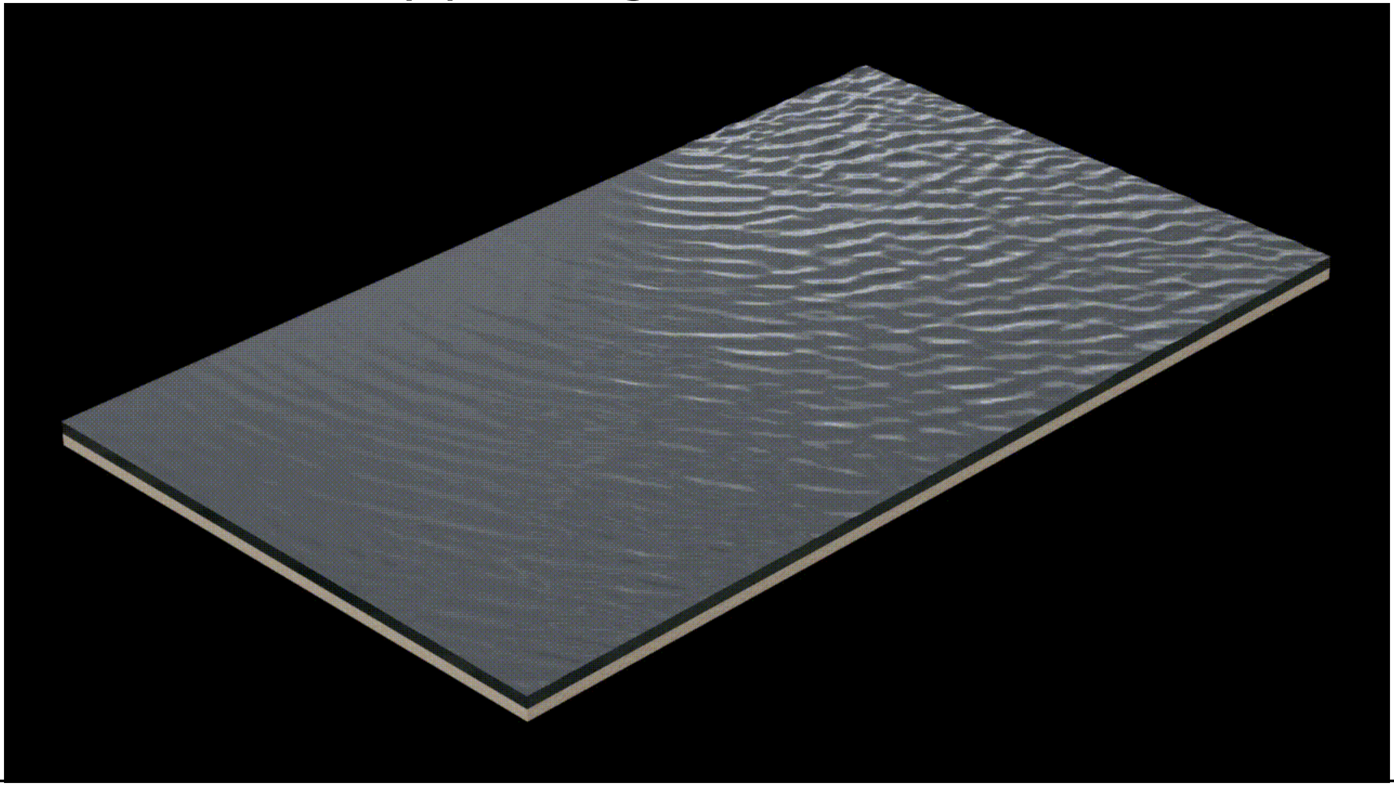
- Comparison 2D wave spectra SWASH & SWAN



3. Storm conditions case

Focus on wave propagation effects only

- d = 18.5 m, $\boldsymbol{H_s}$ **= 3.4 m**, T_p = 6 s, $\boldsymbol{\theta}$ **= 279°** , **dspr = 30°**
- Partial reflection by porous grid cells



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3. Storm conditions case

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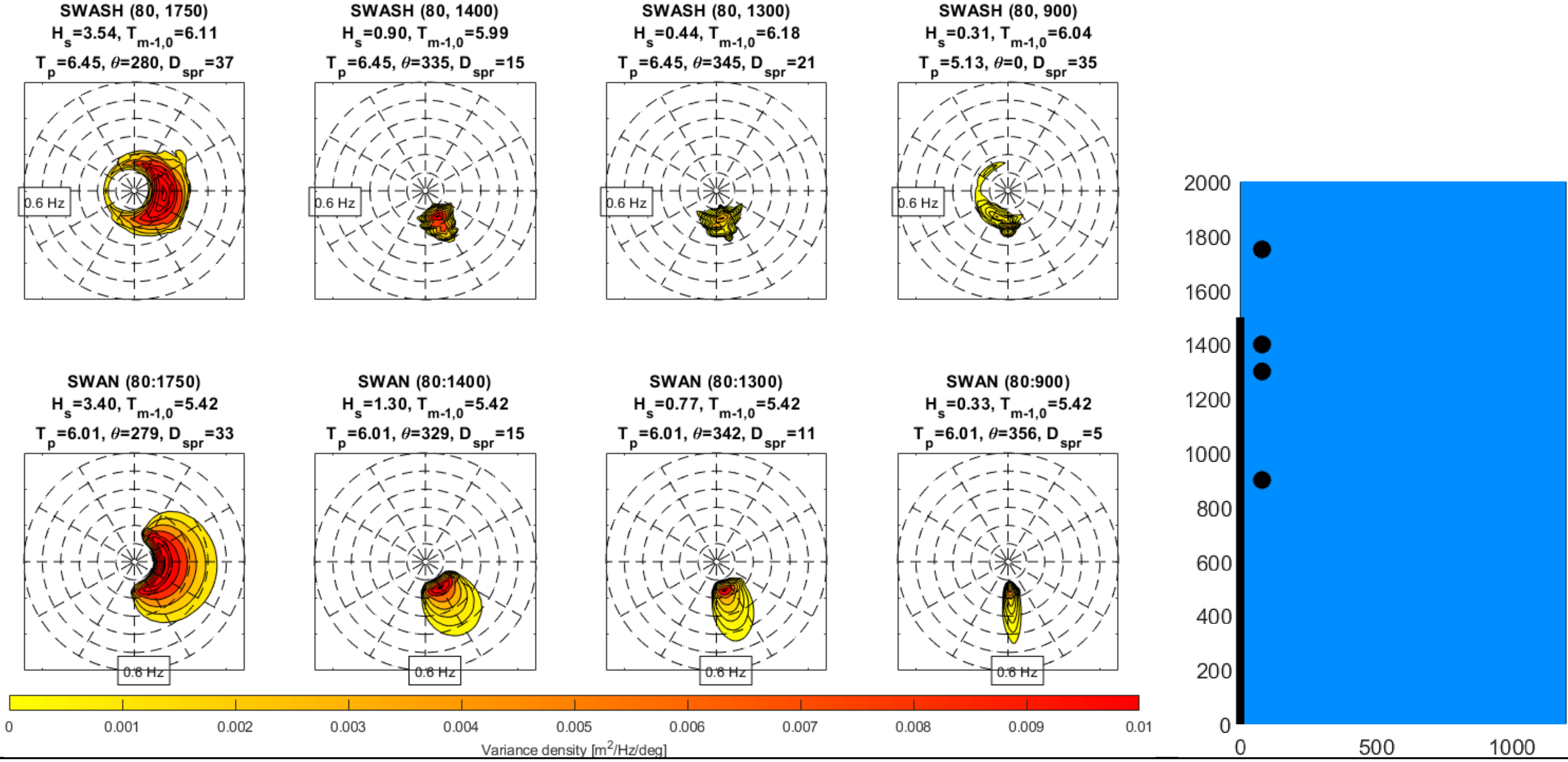
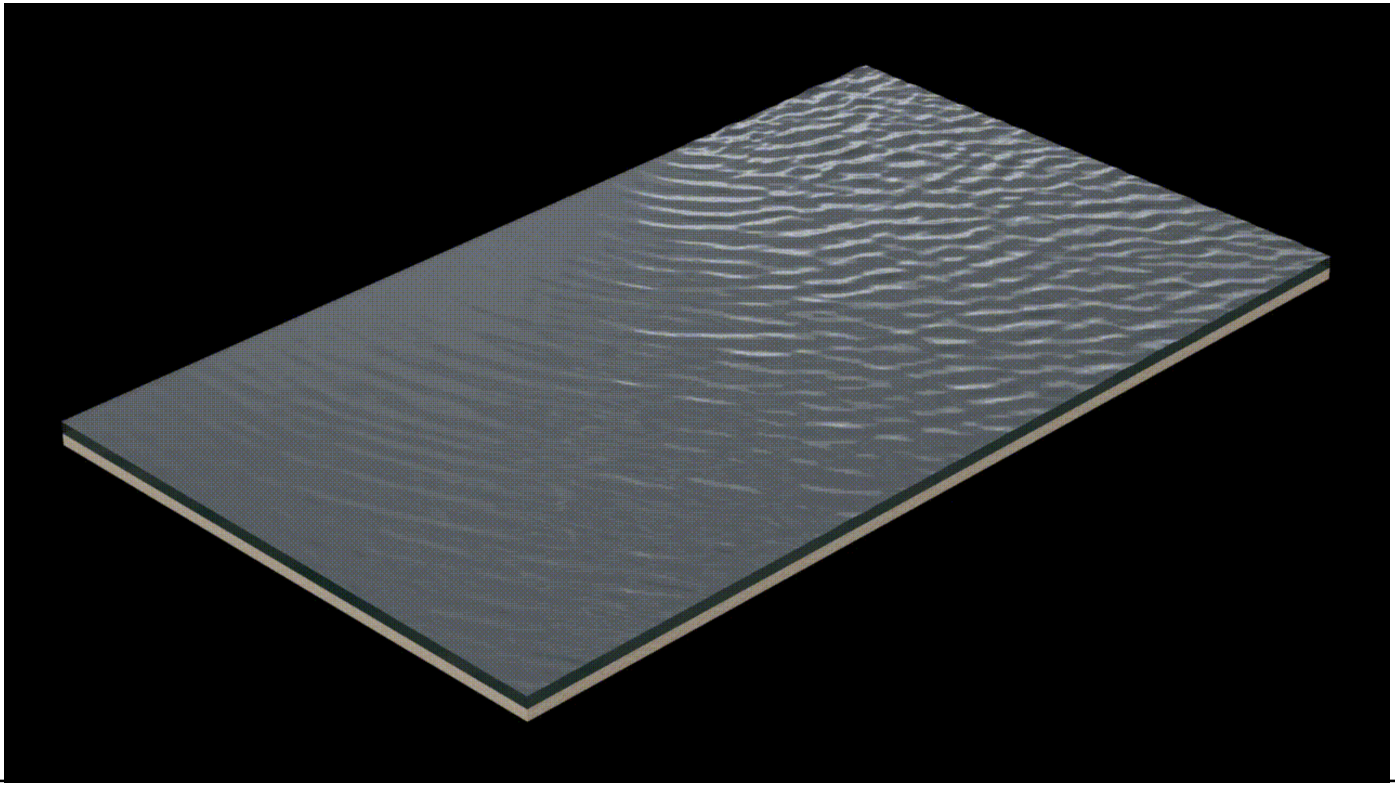
- Comparison 2D wave spectra SWASH & SWAN



4. Storm conditions case

Focus on all physics, except wind

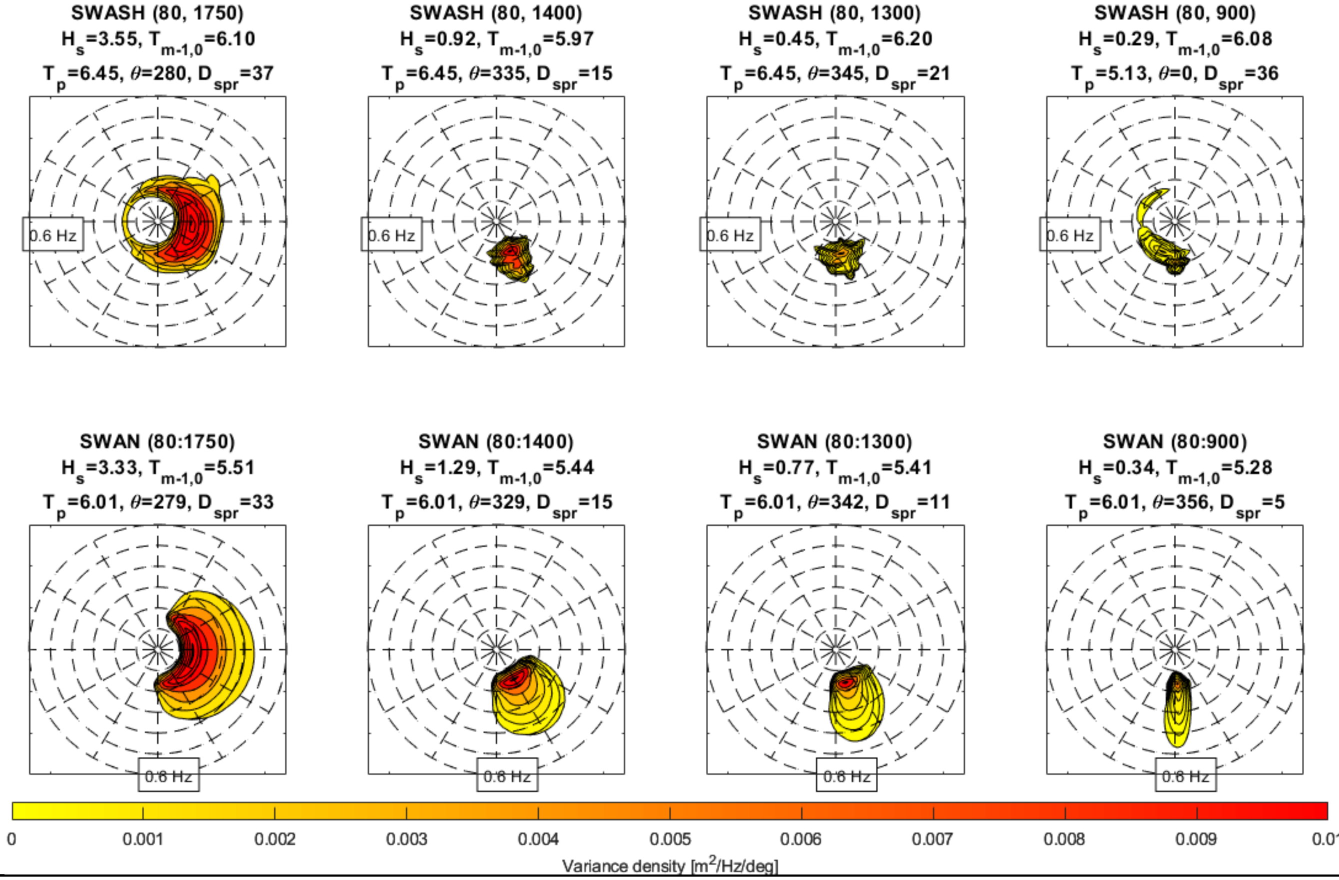
- All physical processes except wind growth turned on

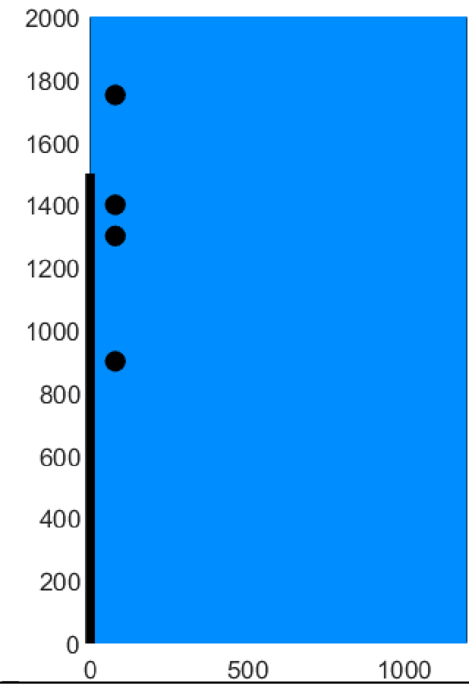


4. Storm conditions case

Focus on all physics, except wind

- Comparison 2D wave spectra SWASH & SWAN



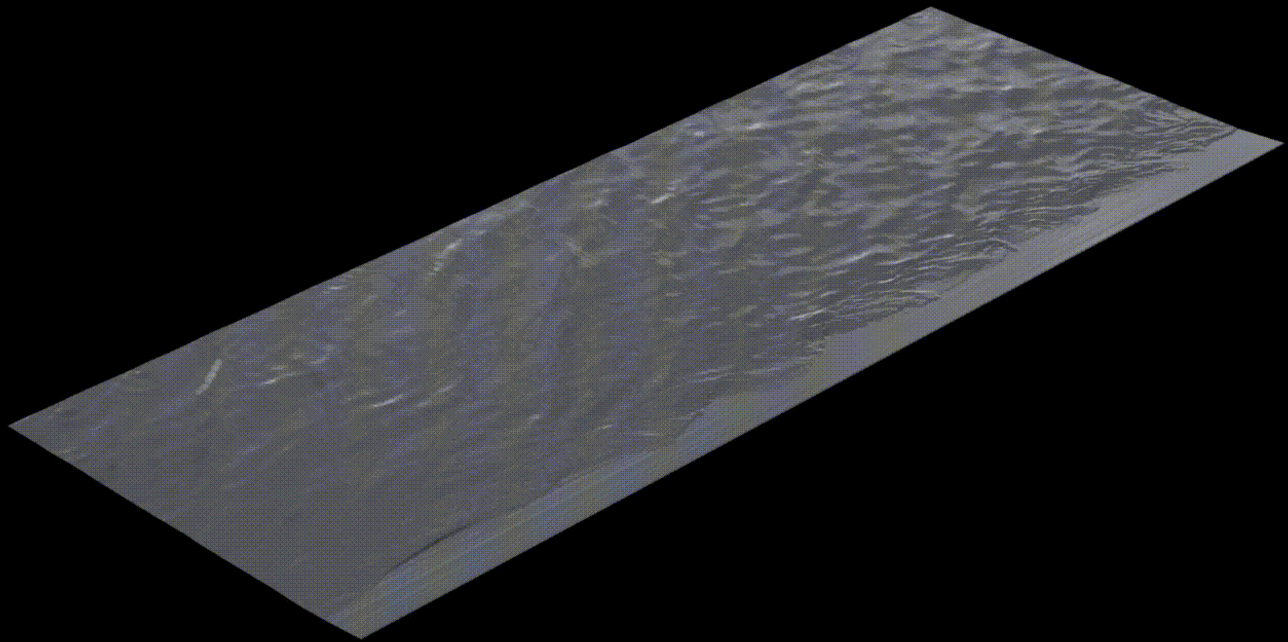


Conclusions

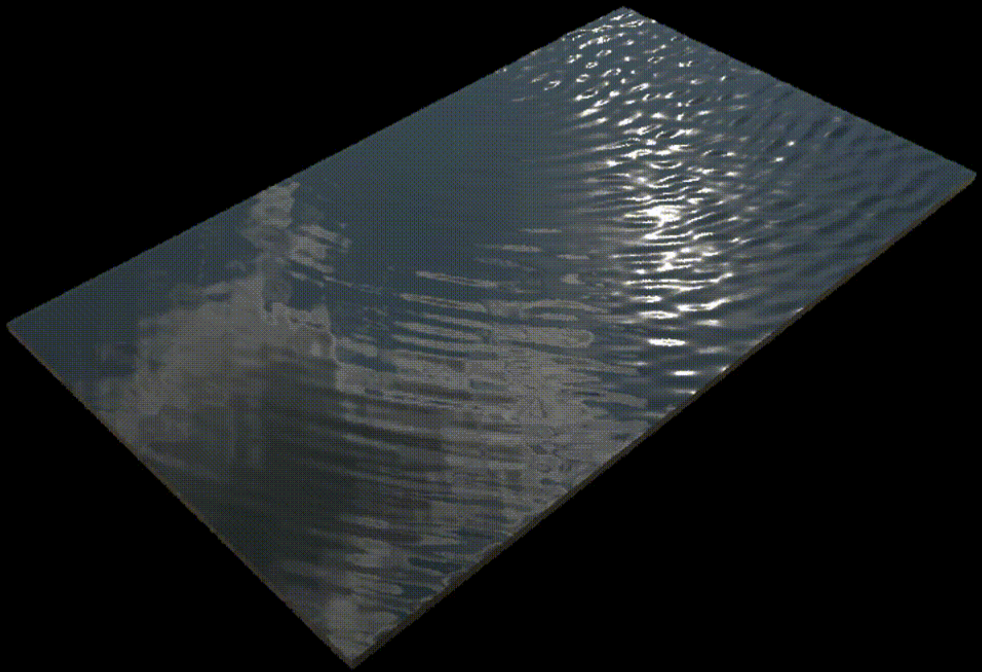
- 12-year long **extensive field measurements** in, and **numerical modelling** of the estuary
- Phase-averaged models cannot cope with **diffraction** and **unidirectional** waves
- Performance for **directionally spread waves** is much better
- All physics, no wind: **HF peak** missing in SWAN, SWAN gives larger H_s, smaller ***Dspr***
- Current case: only **quadruplets** and **whitecapping** of influence

Ongoing and future work

- Field measurements and further studies ongoing for at least 10 more years
- Continuation of measurements and analyses of oblique wave run-up and overtopping
- Next steps in wave modelling of the area:
  - Tests with XNL quadruplets (see also H2, Van Vledder)
  - Influence of wind
  - Adding shallow area and slope to model
  - Adding channel to model
  - Modelling with actual bathymetry
  - Comparison and validation with measurements whenever available



Thank you



Animations by Ricardo Alanis & Patrick Oosterlo
https://www.artstation.com/patomico