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Coastal Engineering

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Scour and erosion processes around offshore structures in combined wave-current conditions

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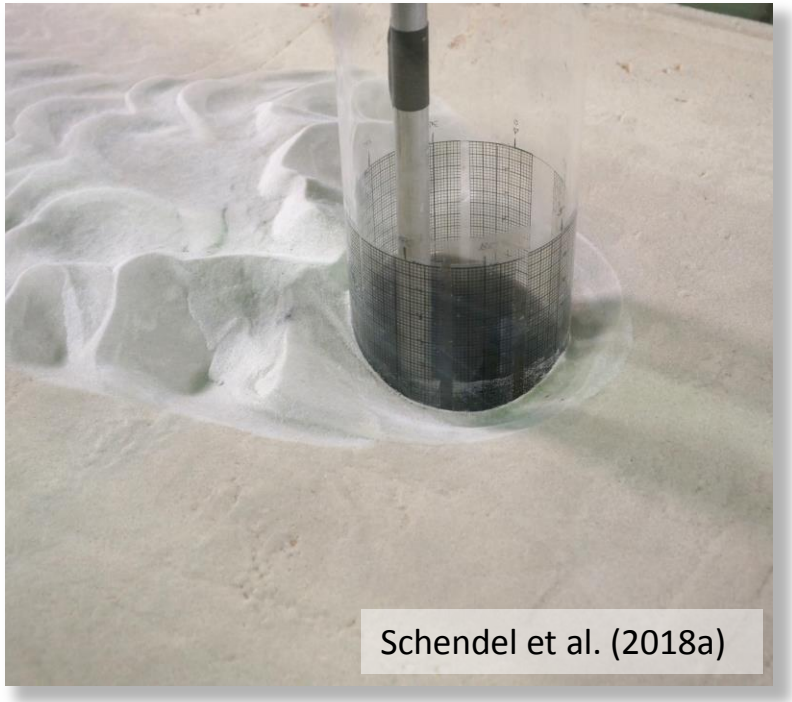
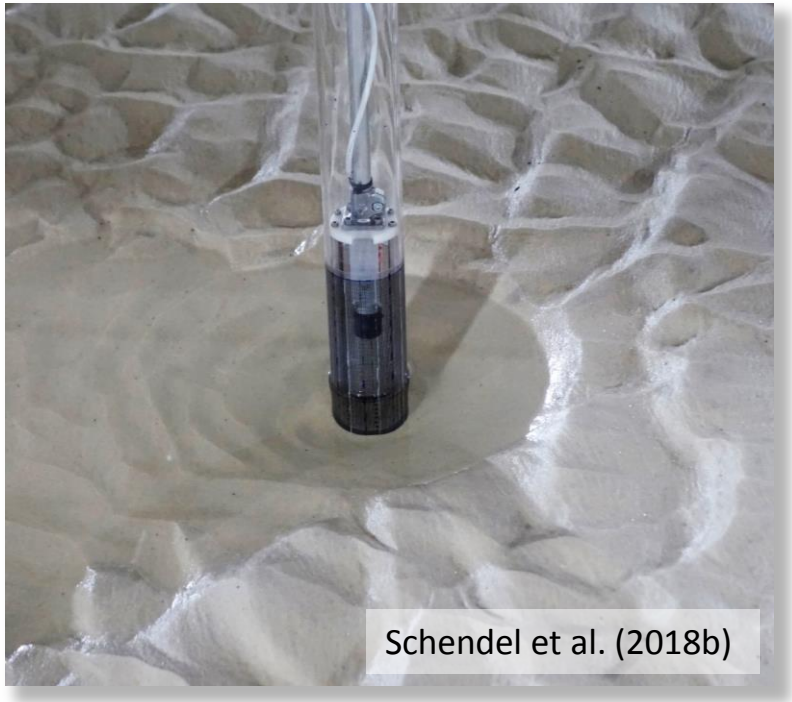
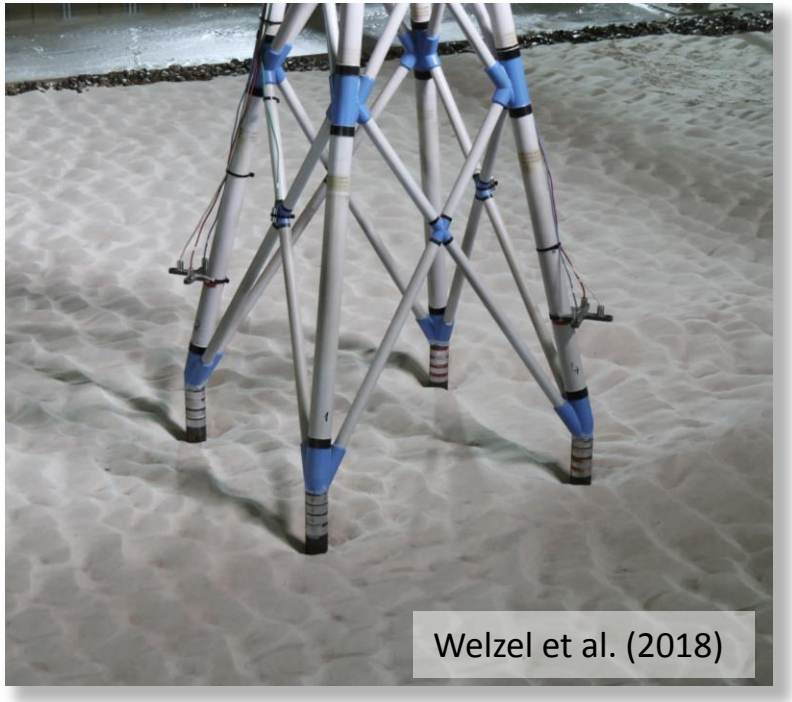

Schendel et al. (2018a)


Schendel et al. (2018b)


Welzel et al. (2018)

Motivation

- Consideration of the degrading effects of scour on the stability of a foundation structure is required
  - Reliable scour prediction for a wide range of hydraulic conditions
- Marine environment is characterized by directional tidal current and sea states and combinations thereof
- Further optimisation of scour prediction is required as available approaches still have some shortcomings:
  - ➢ Simplification of hydraulic conditions, i.e. flow directionality
  - ➢ Concentration on near field (local) scour development and depth

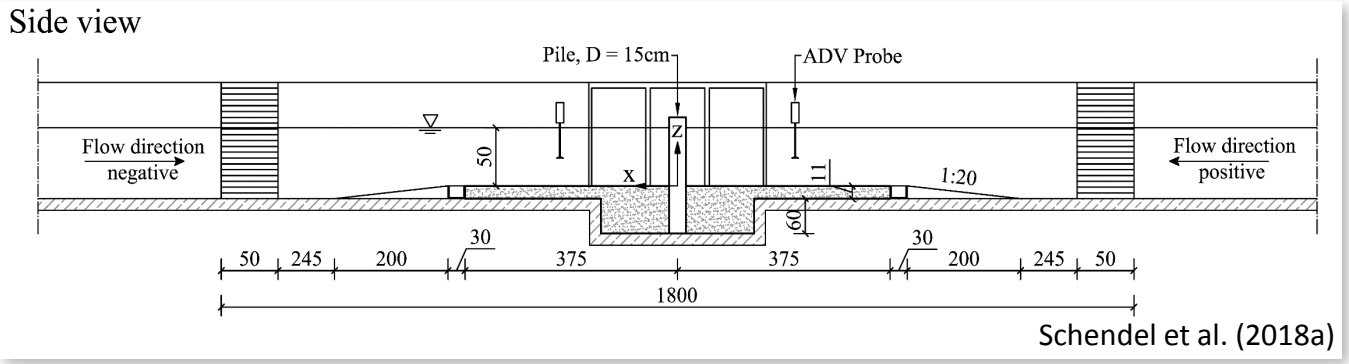
Schendel (2018)

Contents

1. Improvement of scour prediction by a more realistic representation of marine hydraulic conditions:
   - Scouring induced by unsteady tidal currents
   - Scouring in combined multidirectional waves and current conditions
2. Consideration of sediment displacement processes in the far field (global) of offshore structures:
   - Method to account for sediment displacement and transport budget around a jacket structure
3. Outlook on scour protection design
   - Improvement of scour protection design by new parametrization of damage

Schendel (2018)

Scour induced by tidal currents



Schendel et al. (2018a)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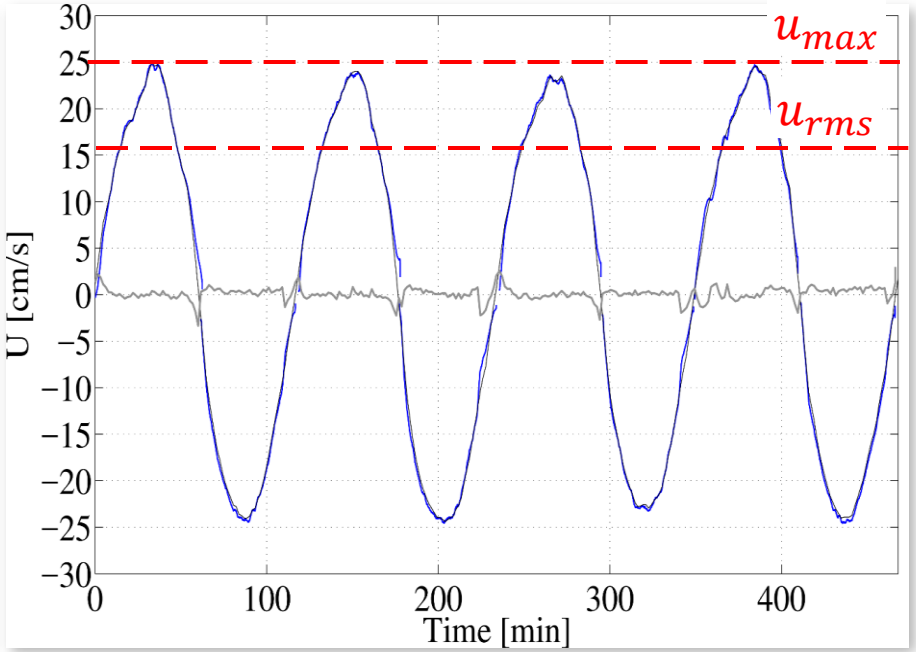
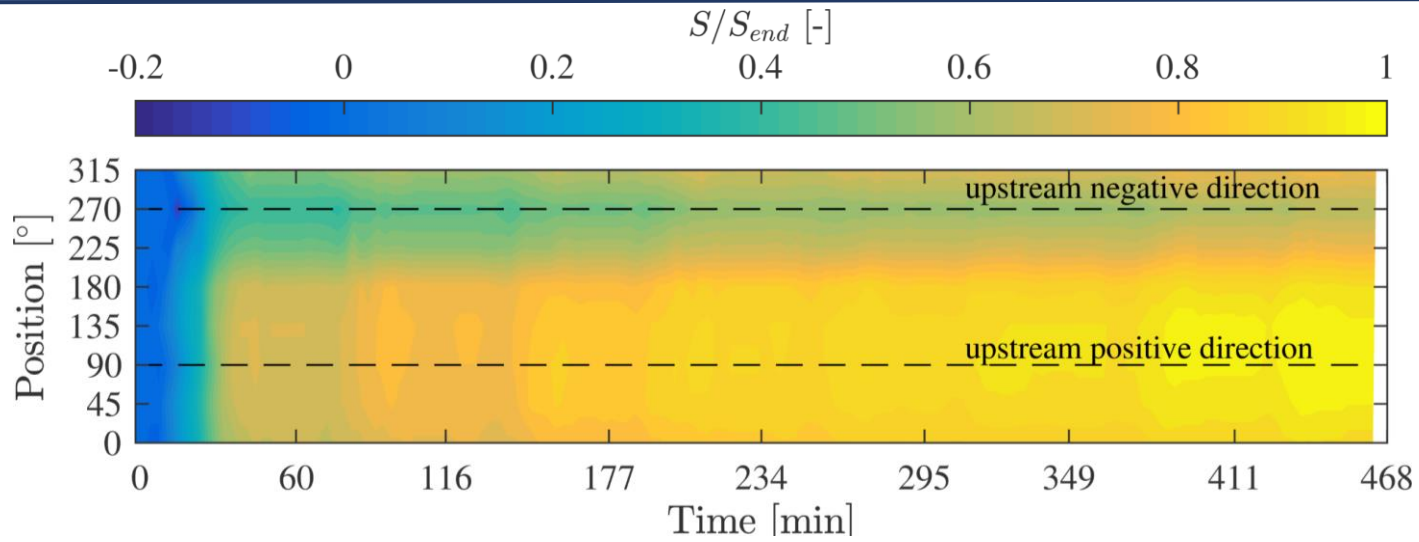


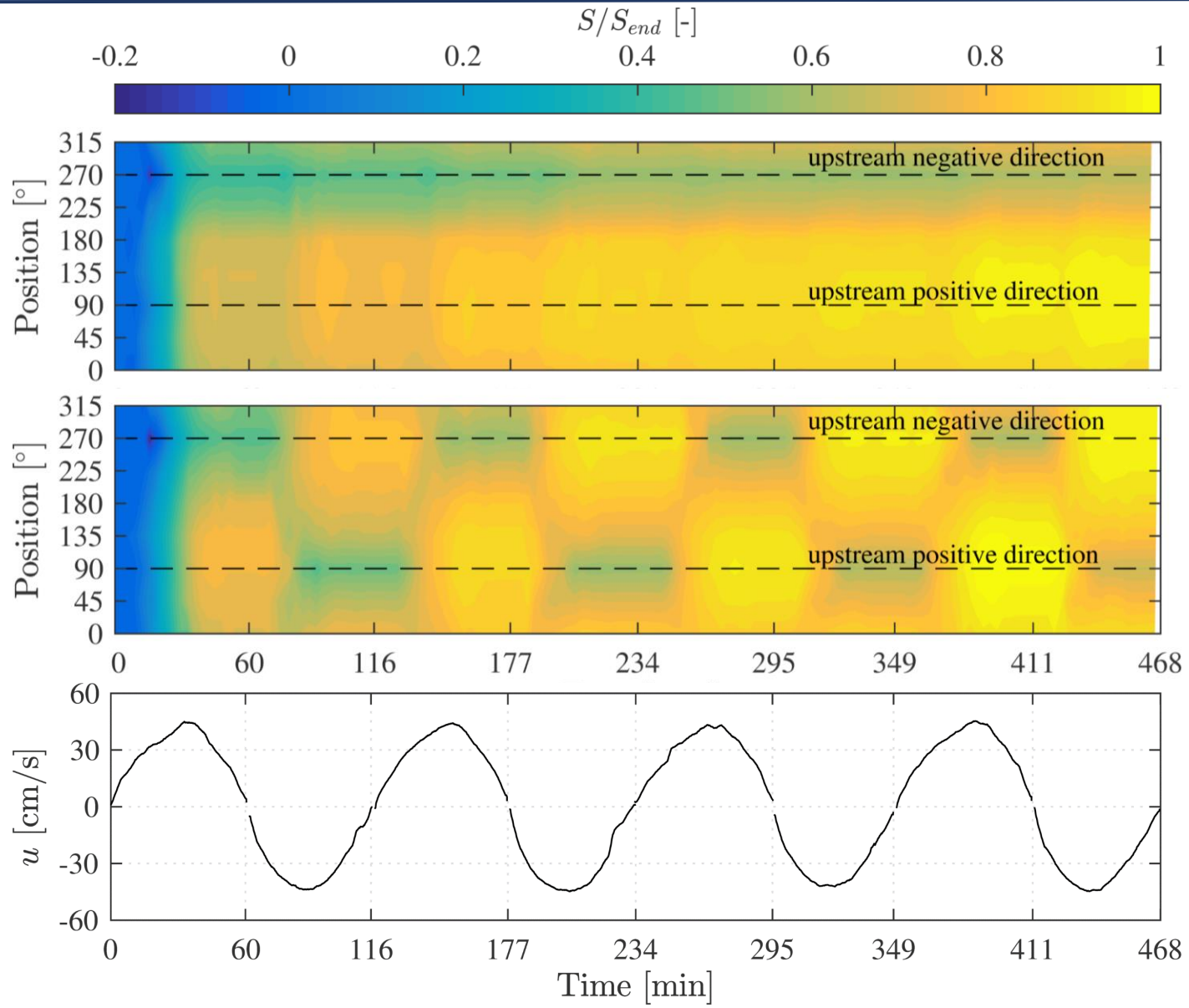
- Problem:
  - Main driver for the scour development in coastal, estuarine and offshore conditions
  - Comparability of available studies limited due to simplification of tidal currents
  - ➢ Uncertainty in the prediction of scour induced by tidal currents
  - ➢ Closed circuit flume, model scale 1:40, clear water and live-bed conditions, 4 tidal cycles
  - ➢ Realistic representation of tidal currents with scaled field measurements
  - ➢ Comparison of each tidal current test with 2 unidirectional current tests

Scour induced by tidal currents



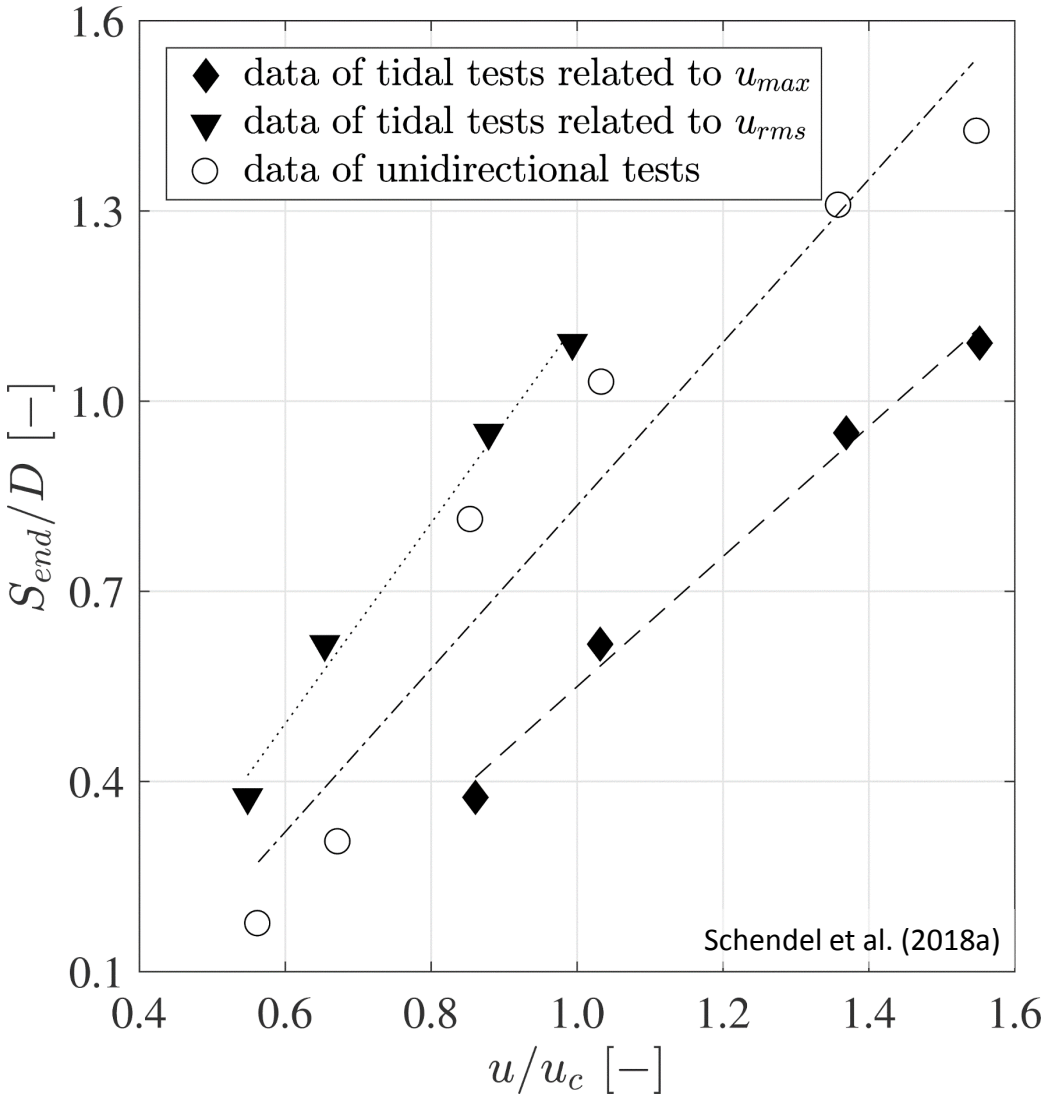
- Time development of scour depth
- Scour development around the whole circumference of the monopile as an interpolated scour pattern

Scour induced by tidal currents



- Time development of scour depth
- Scour development around the whole circumference of the monopile as an interpolated scour pattern
- Constantly varying sediment infilling and displacement processes
- Periodically returning scour scheme:
  - Stagnating scouring at times of changing flow direction
  - Resumption of the scouring process with the next tidal half cycle
  - Position of maximum scour alternates around the pile

Scour induced by tidal currents

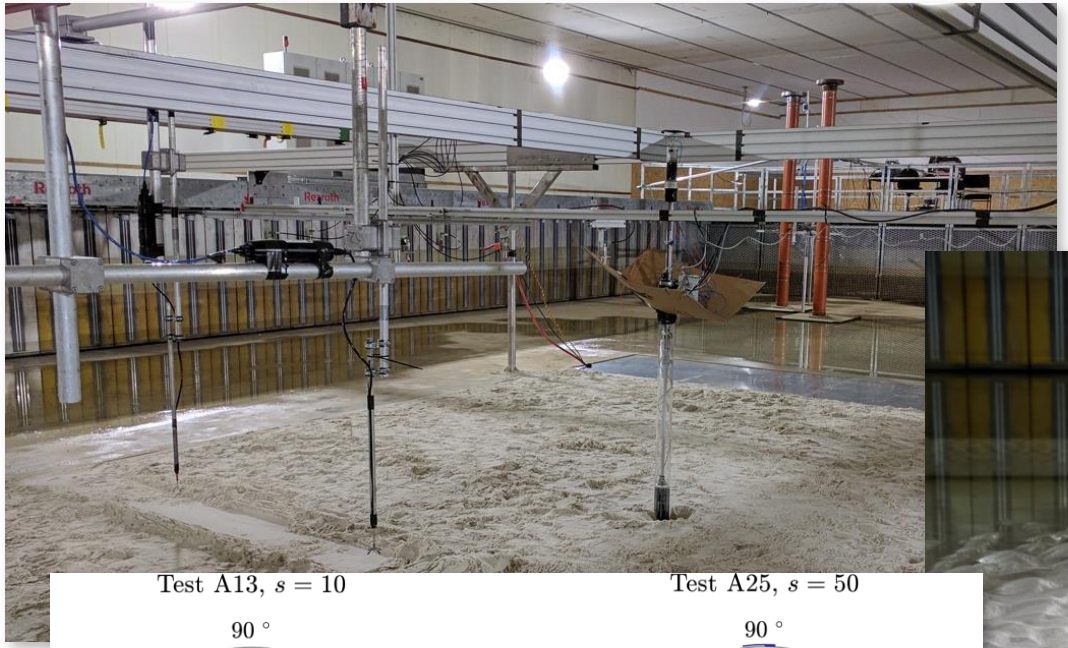


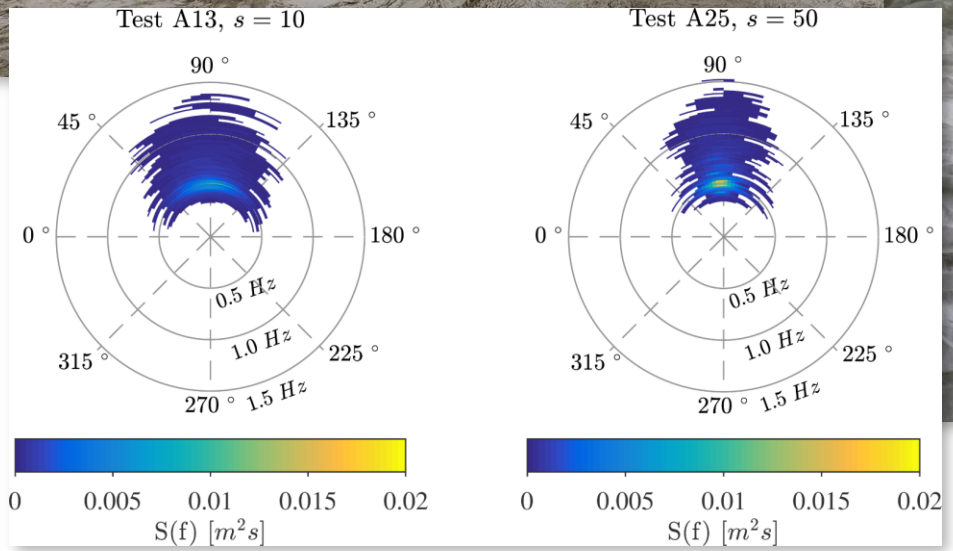
- Comparison based on maximum u_{max} or mean u_{rms} tidal velocity
- Maximum velocity:
  - Overprediction of scour depth by up to 62%
- Root mean square:
  - Up to 51% larger scour depths in tidal currents

➢ Importance of selection suitable flow velocities for the design of foundation structures against tidal scour

➢ Similar scour depths and progression by using a constant flow velocity close to $u_{max}/\sqrt{2}$ of the tidal current

Scour induced by multidirectional waves





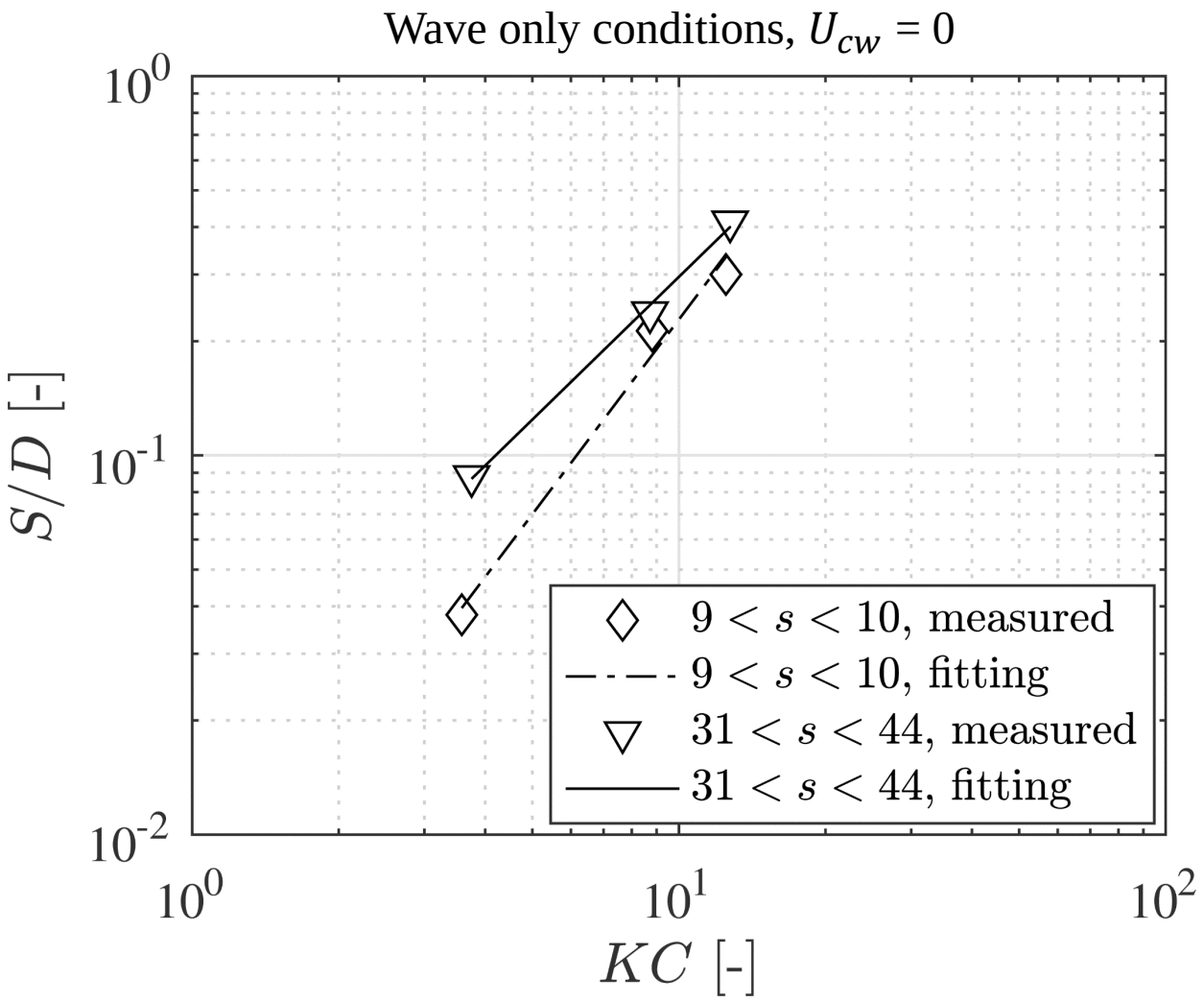
- Objectives:
  - Understanding of scouring process induced by multidirectional waves (and current)
  - Systematically investigate the influence of wave spreading on the scouring process
  - Improve the scour prediction by comparing the results to unidirectional wave induced scour

➢ JONSWAP spectra, model scale 1:75, stepwise increase of current velocity after 6000 waves

➢ Uni- and multidirectional wave spectra with identical total wave energy

➢ Different wave spreading based on Mitsuyasu-type (cos2s), s =10 and s = 40

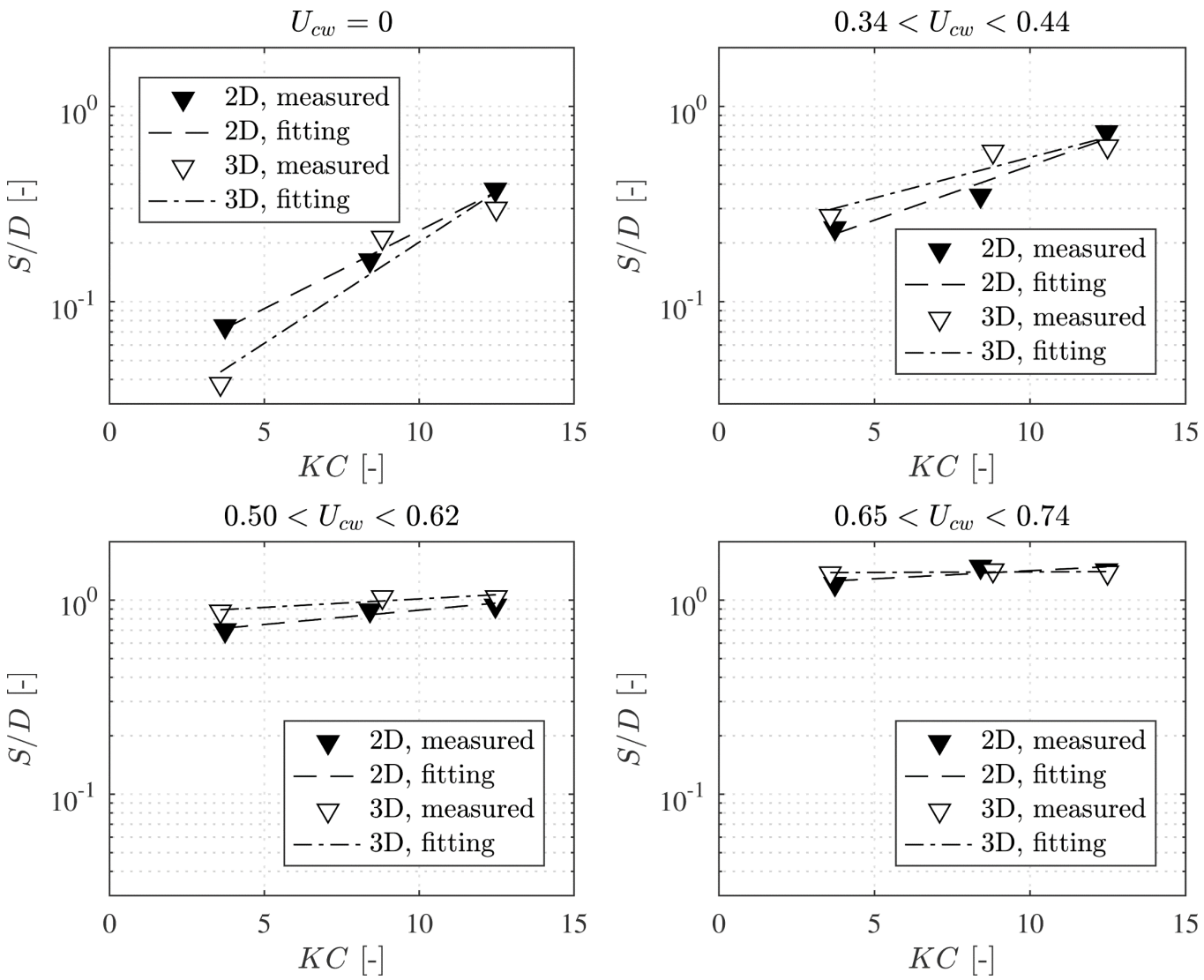
Scour induced by multidirectional waves



- Maximum scour depths obtained in wave only conditions, as a function of KC number and spreading parameter s
- Scour depths decrease with increasing wave spreading, particularly for small values of KC
- Only limited number of data points

→ Verification for additional spreading parameter needed

Scour induced by multidirectional waves



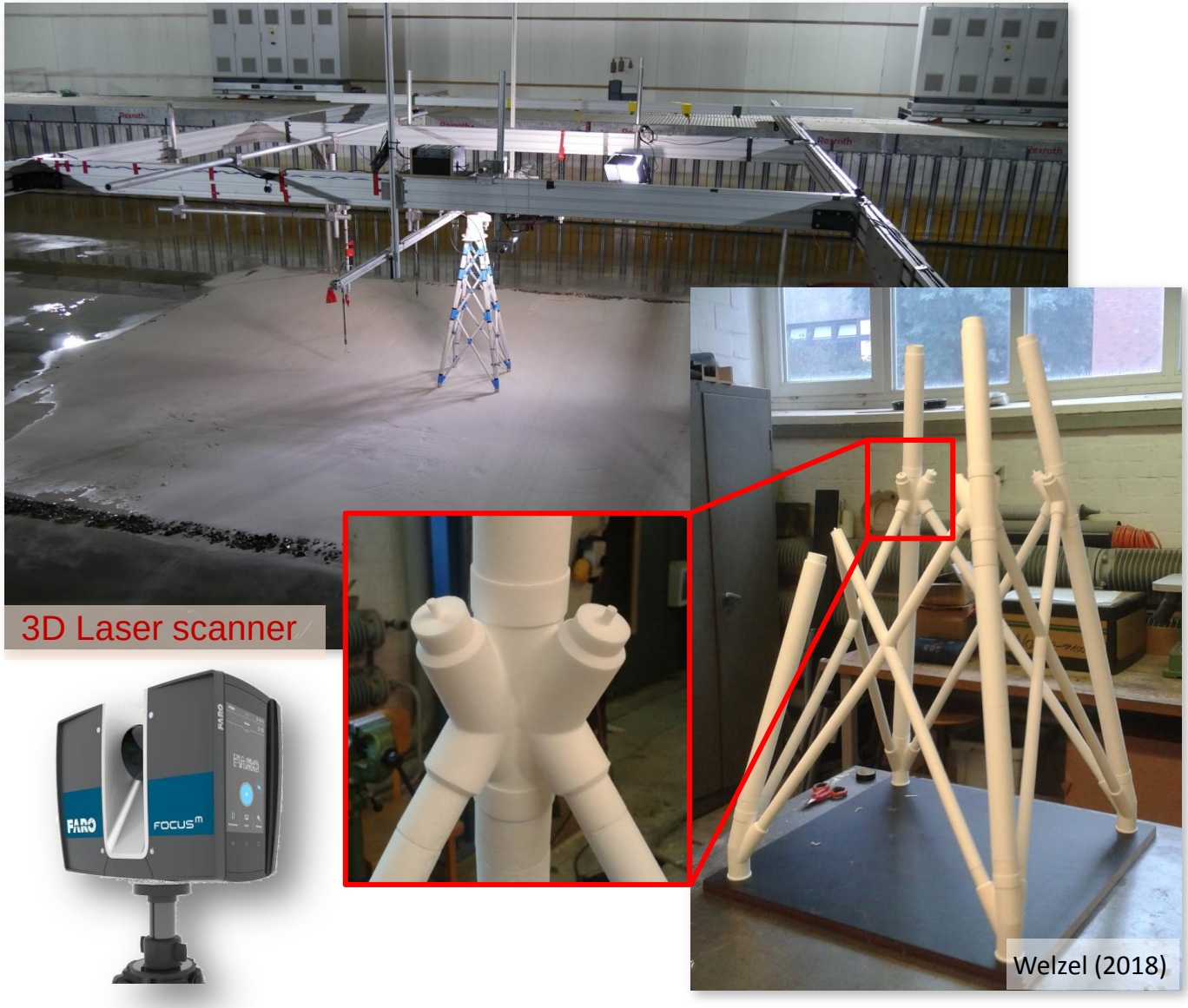
- U_{cw} = 0: On average 33% smaller scour depths in multidirectional waves
- 0 .3 < U_{cw} < 0.6: Wave directionality leads to slightly larger scour depths
- U_{cw} → 1: Differences in scour depths are declining

➢ Multidirectional waves are less dominant, resulting in:

→ increased influence of current

→ larger scour depths in combined conditions

Scour around a jacket structure

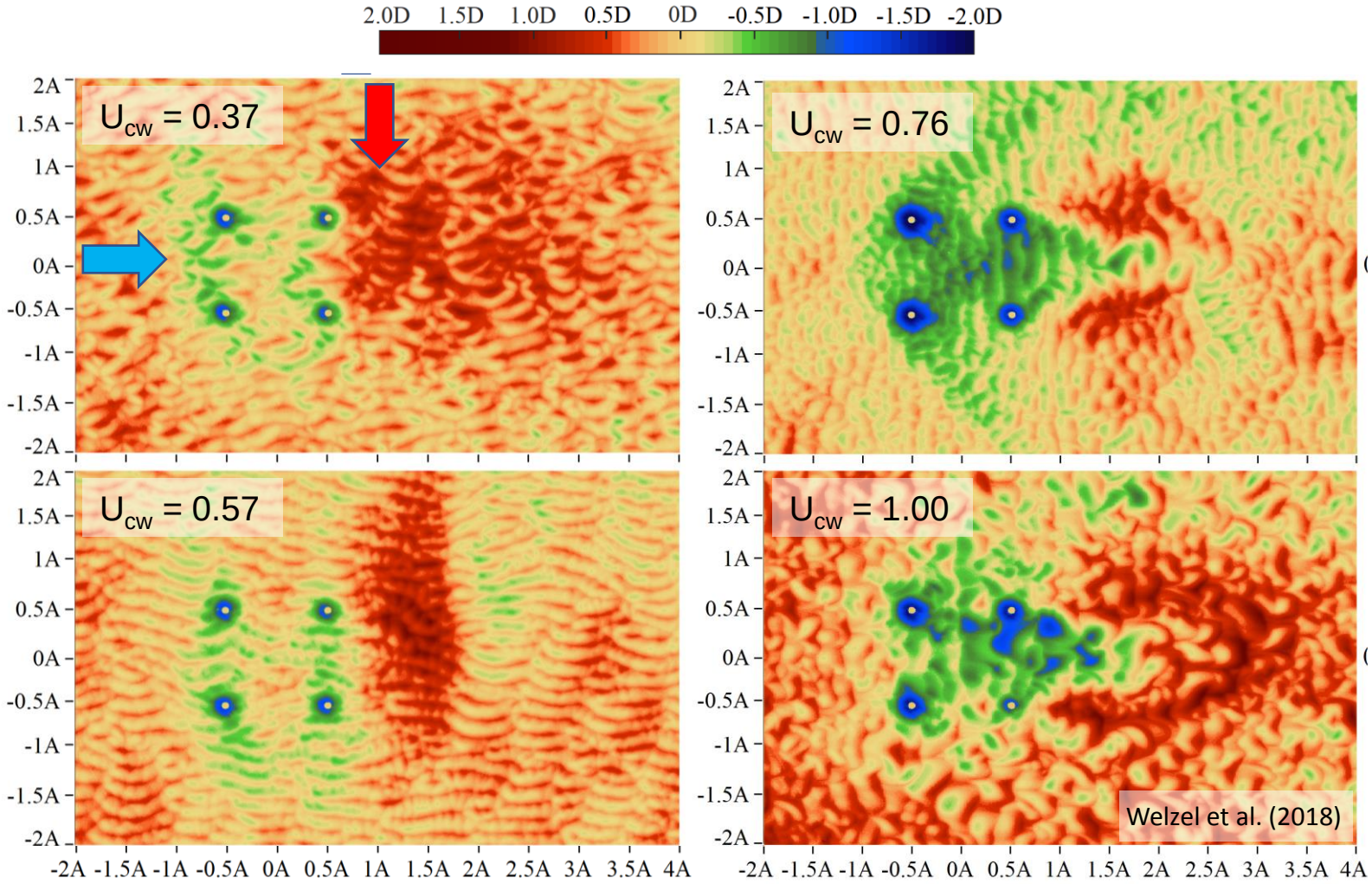


- Objectives:
  - Understanding of scouring processes and sediment displacement around complex structures
  - Systematically investigation of the amount and extent of sediment transport / displacement
  - Improvement of scour prediction with volume based assessment technique

➢ JONSWAP spectra, stepwise increase of current velocity after 6000 waves

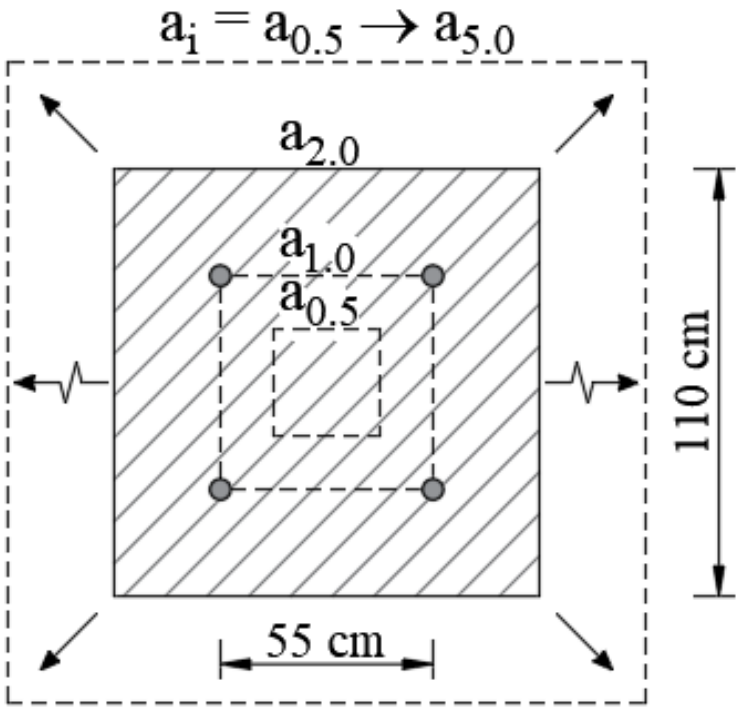
➢ 3D printed physical model of a jacket foundation, model scale 1:30

Scour around a jacket structure



- Detailed 3D scans of spatial scour development and sediment displacement
- Characteristics of morphodynamic processes depending on flow conditions
- Large influence of the structure on the surrounding seabed
- Pronounced wake effects downstream of the jacket structure
- ➢ Not hydrodynamically transparent despite a distance of 14D between piles

Scour around a jacket structure



Schematic sketch of increasing total areas a_i around the structure footprint for the example of $a_{2.0}$

Welzel et al. (2018)

$$V_{erosion} = \Delta z \cdot a_i$$

$$V_{D,i} = \frac{V_{erosion}}{D^3} \; [-]$$

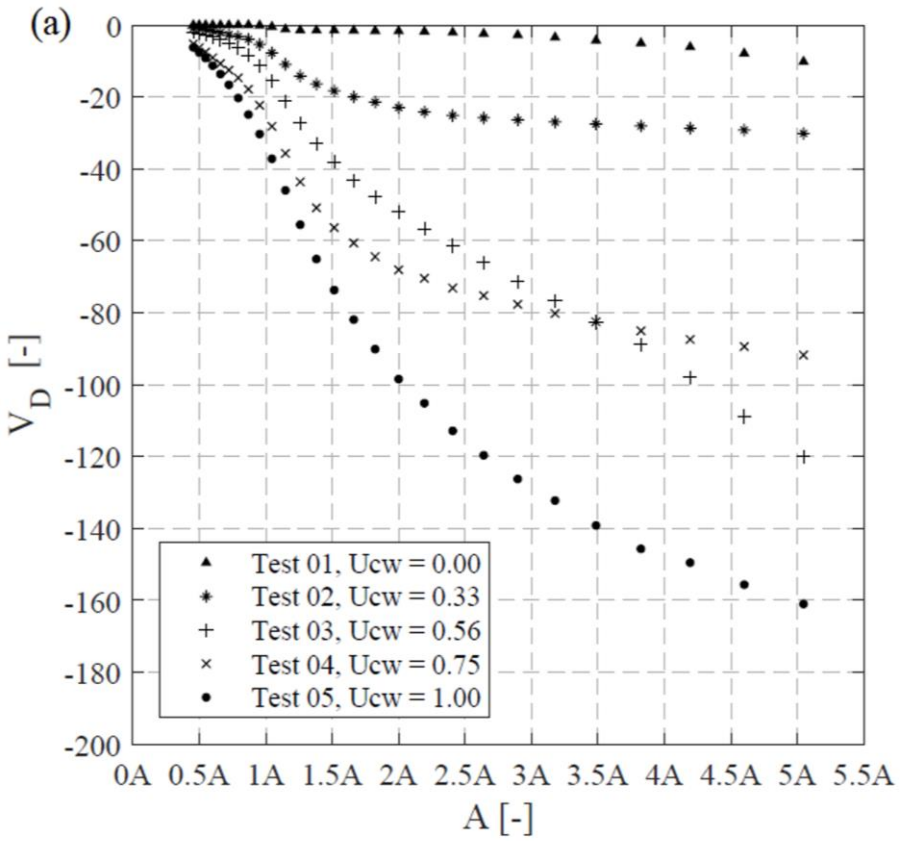
$$V_{A,i} = \frac{V_{D,i}}{A} \; [-]$$

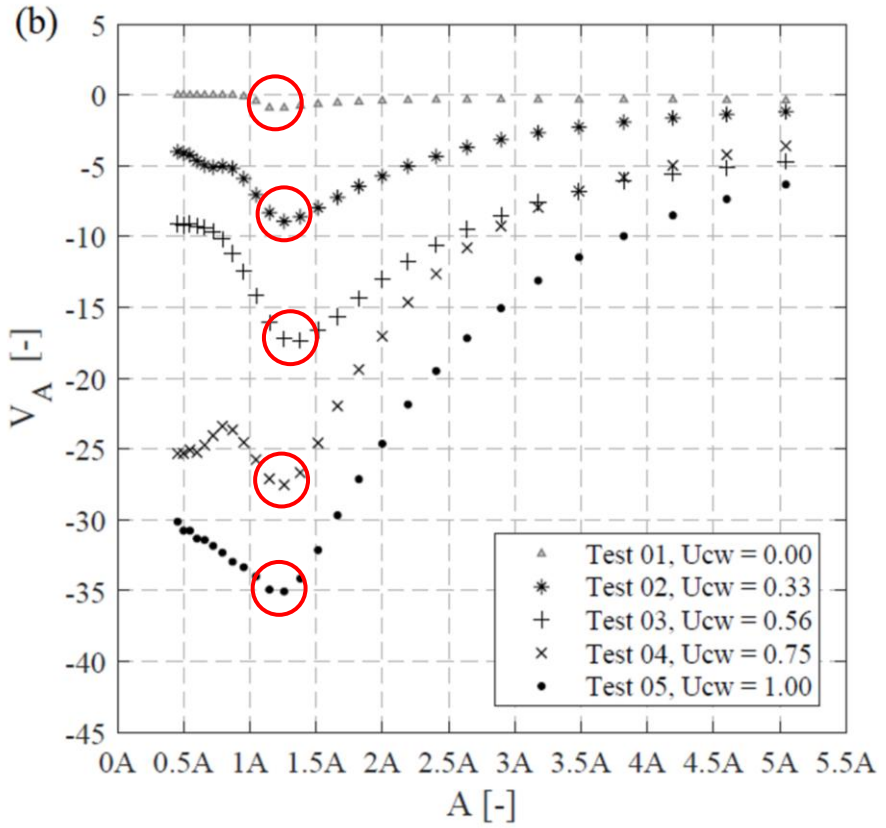
$$A = a_i / a_1 \; [-]$$

- Volume based assessment of erosion process
- Erosion volume $V_{erosion}$ will depend on considered area
- Erosion volume related to the pile diameter and the multiplies of the footprint of the structure
- Adaptable for different types of foundation structures

Scour around a jacket structure

Development of erosion volume for increasing area





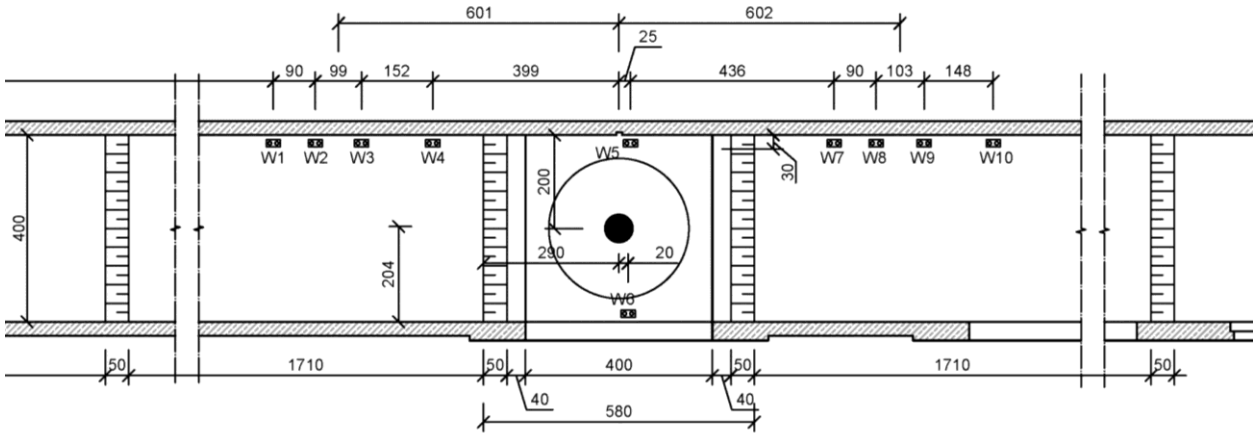
- Increase of erosion volume with increasing current velocity and considered area

- Maximum erosion volume at 1.25A

$$V_{A,max}(U_{cw}) = -1.3 \cdot (0.1 + \exp(-4.6 \cdot U_{cw}))^{-1.5}$$

Scour protection design

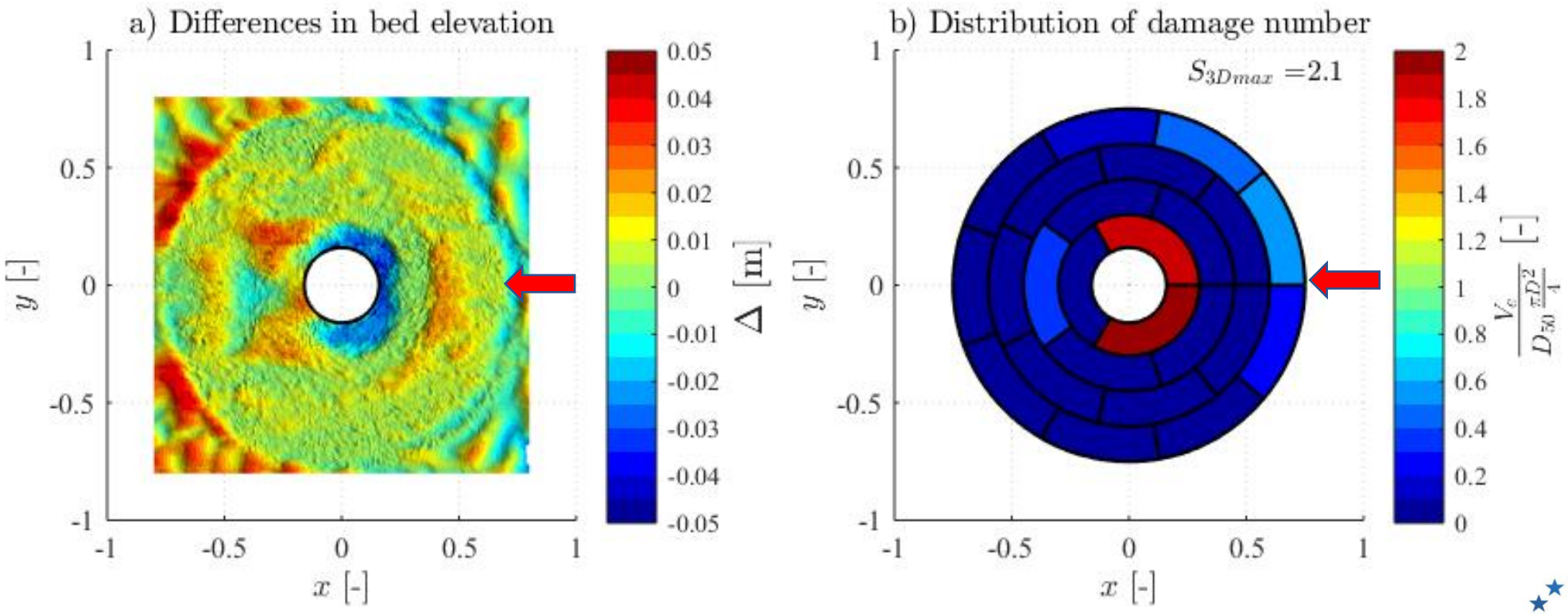
- PROTEUS: “Large scale experiments to improve monopile scour protection design adapted to climate change”
- European Joint Project between University of Ghent, University of Porto, IMDC, University of Hannover and HR Wallingford
- <u>Objectives:</u>
  - Creating a benchmark dataset by performing intermediate scale and large scale experiments
  - Creating a specific dataset of model tests using both narrow-graded two layer and wide-graded single layer scour protection
  - Improved design approach for dynamically stable scour protection by new damage characterization



Scour protection design

Dynamically stable scour protection design (De Vos et al., 2012)

- Quantification of damage based on an eroded volume over an sub area equal to the cross-section of the pile

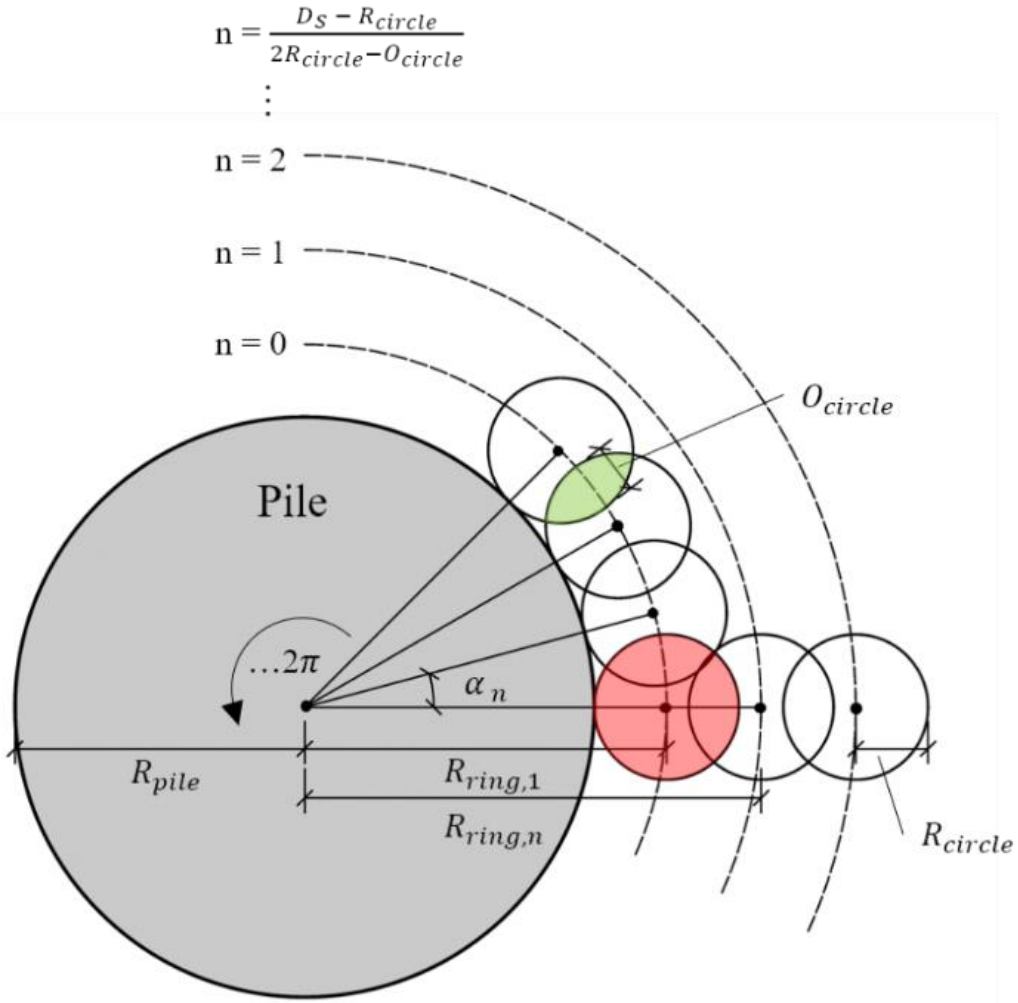


Scour protection design

Dynamically stable scour protection design (De Vos, 2012)

- Overcome shortcomings of current approach:

  1. Adjust the size, shape and arrangement of sub areas
  2. Add statistical analysis to increase certainty
  3. New damage / failure characterization



Scour protection design

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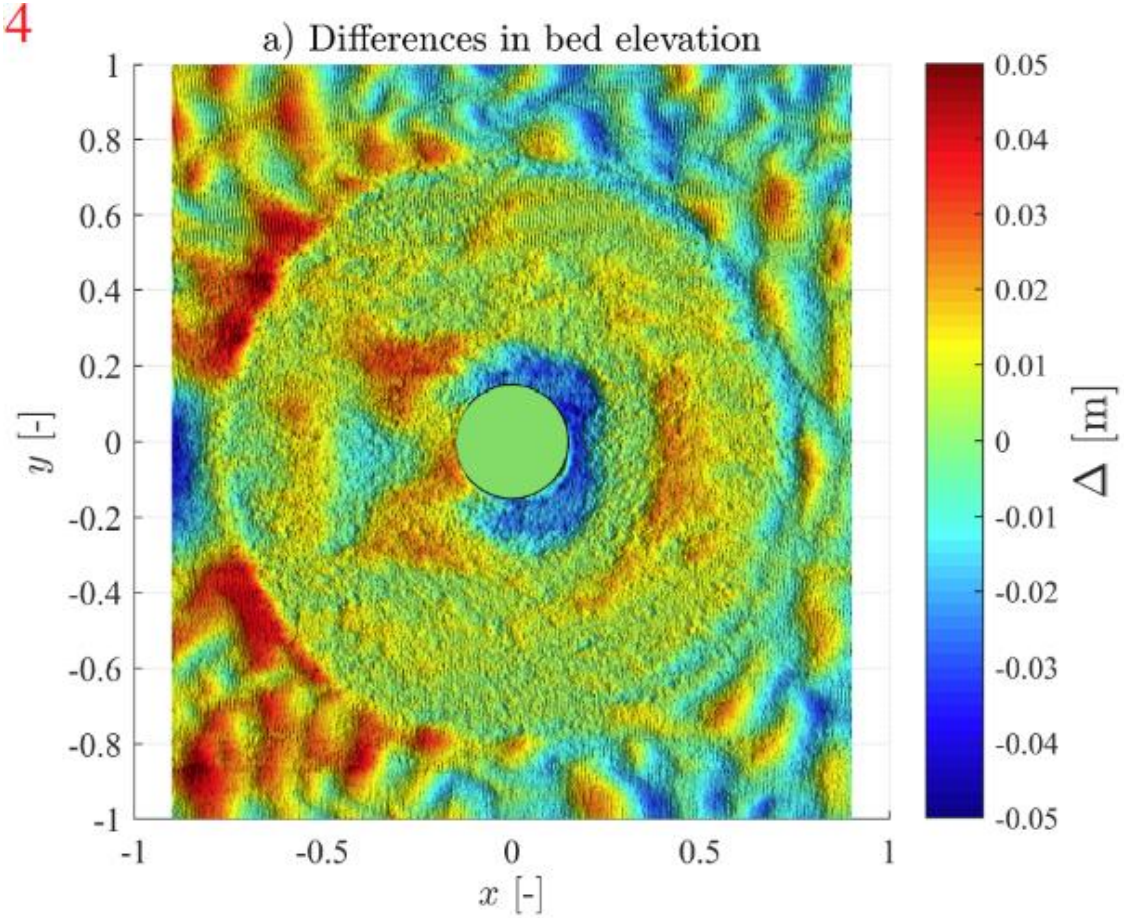

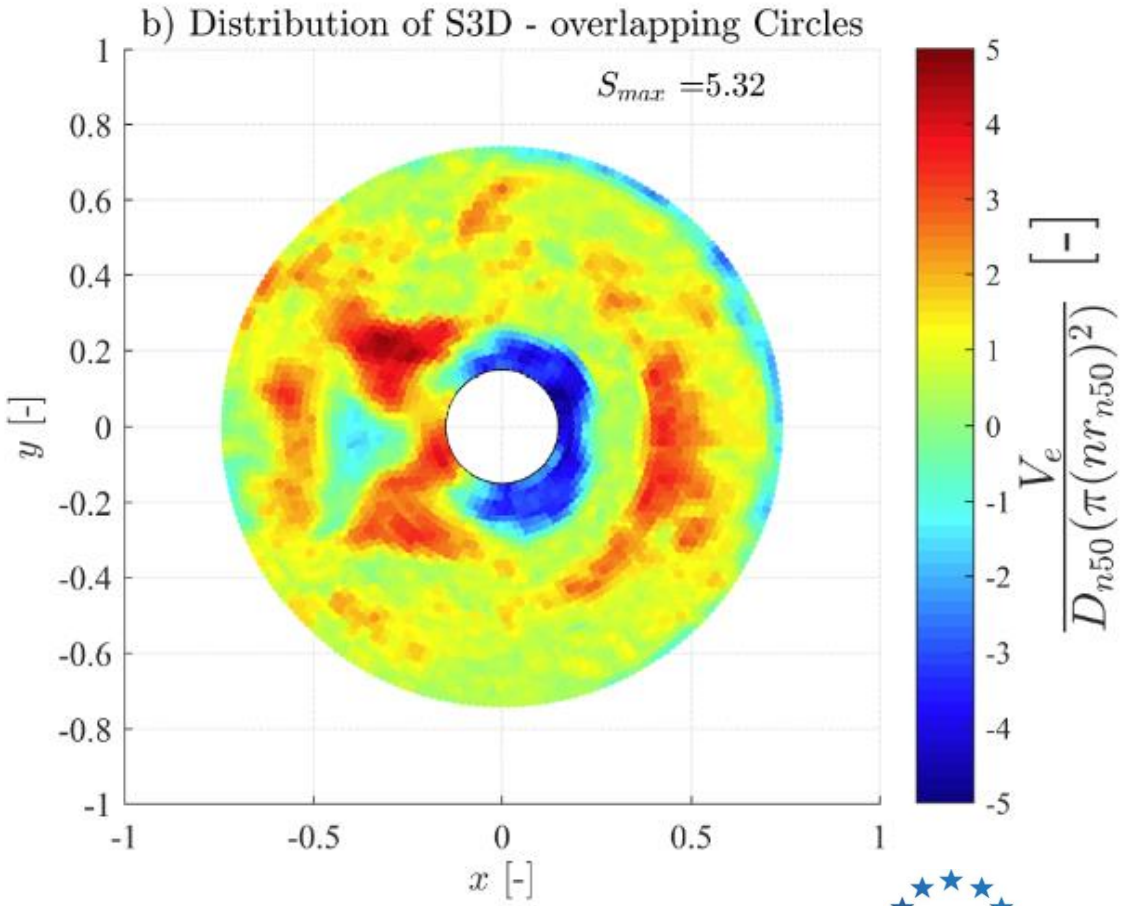


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