MSc thesis in Geomatics

The effects of beach house configurations on dune-ward sediment transport

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TU Delft

CONTENTS

1. MOTIVATION

- Background
- Problem statement

Importance of dunes

- Protection against flooding
- Biodiversity
- Drinking water
- Recreation

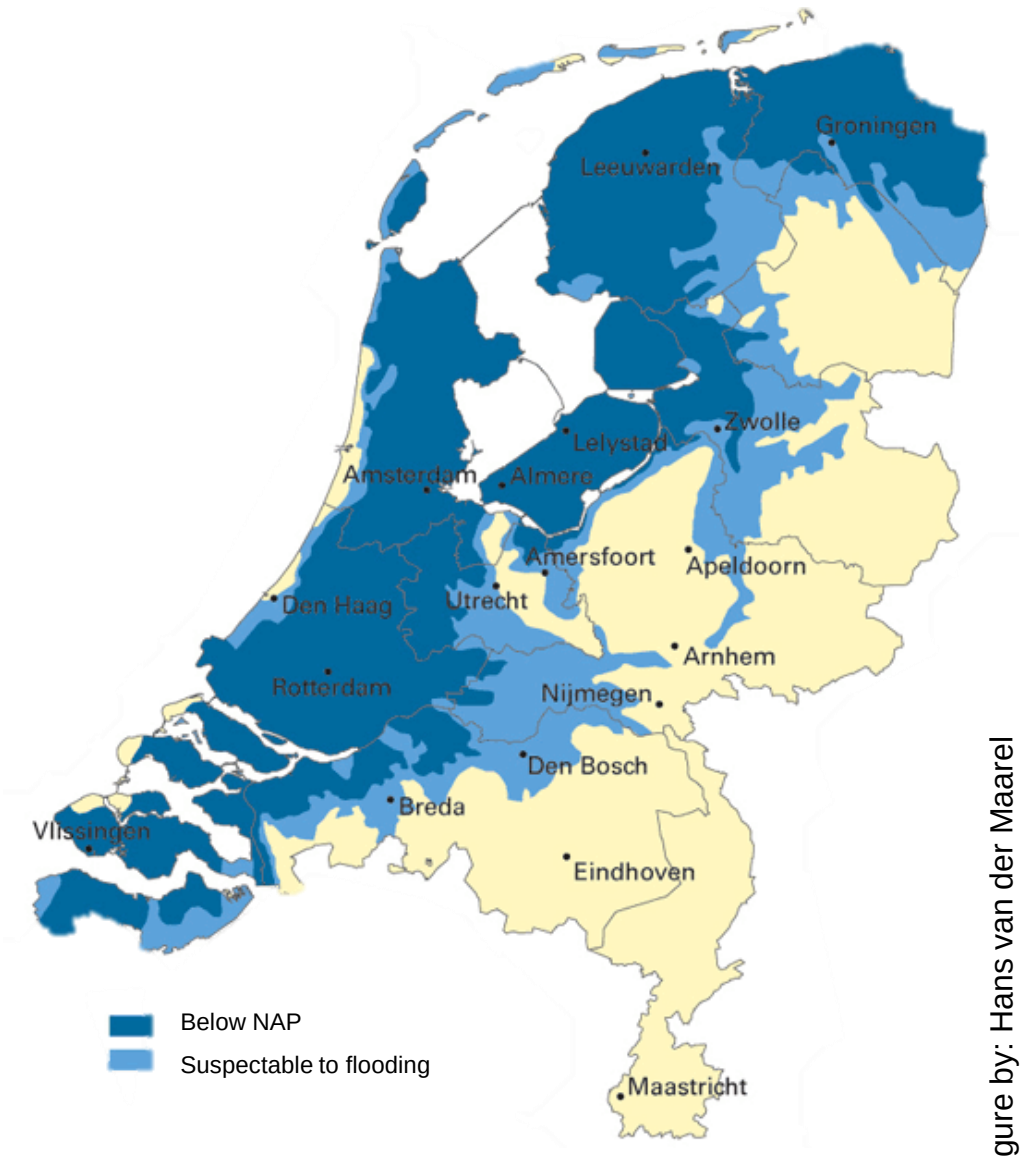


Figure by: Hans van der Maarel

Increase in dune erosion

- Climate change[1]
  - Sea level rise
  - Increase in storms
- Human activities[2]

Photo by: Omroep Zeeland (2020)

1. De Winter, R. C., & Ruessink, B. G. (2017). Sensitivity analysis of climate change impacts on dune erosion: case study for the Dutch Holland coast. Climatic Change, 141(4),
2. Nordstrom, K. F. and Jackson, N. L. (2013). Foredune restoration in Urban Settings. Springer Series on Environmental

Sand nourishments

- Artificial reinforcement in the form of sand nourishments
- Sand nourishments depend on aeolian sediment transport

(Own photo)

Limiting effect of beach houses

- The buildings on the beaches can limit the amount of aeolian sediment transport [1-3]

Photo by: strandhuisjeszeeenzon.nl

1. de Klerk, R. P. (2019). The influence of buildings on aeolian coastal dune development. Msc thesis, TU Delft.
2. Hoonhout, B. and Waagmeester, N. (2014). Invloed van strandbebouwing op zandverstuiving. Deltares.
3. van Westen, B. (2019). Invloed strandbebouwing op duinontwikkeling. Deltares.

Computational Fluid Dynamics (CFD)

- Numerical methods to simulate fluid flow
- Calculations to model flow around obstacles

Advantages:

- Relatively fast
- Adjustable environmental conditions
- Detailed information

- Previous study by van Onselen (2018)[1]

1. van Onselen, E. (2018). Analysing measures to improve beach - dune interaction in the presence of man - made structures using computational fluid dynamics (CFD). Msc thesis, Utrecht University.

ShoreScape

- Interdisciplinary research project
- Aim to ensure coastal safety without harming the natural environment

Photo by: Janneke van Bergen (2020)

Problem statement

- Limited knowledge about the effects of changing beach house configurations on aeolian sediment transport
- Unknown (long-term) effects of beach houses configurations using varying seasonal wind conditions
- Potential of lowering the limiting effect on dune-ward sediment transport

2. OBJECTIVES

Objectives

- Simulate wind around beach houses using Computational Fluid Dynamics (CFD)
  - Creating different beach house configurations
  - Using varying seasonal wind conditions
- Determine dune-ward sediment transport
- Create a database storage system

Research question

"What are the effects of different beach house configurations on dune-ward sediment transport?"

Case study: Noordwijk

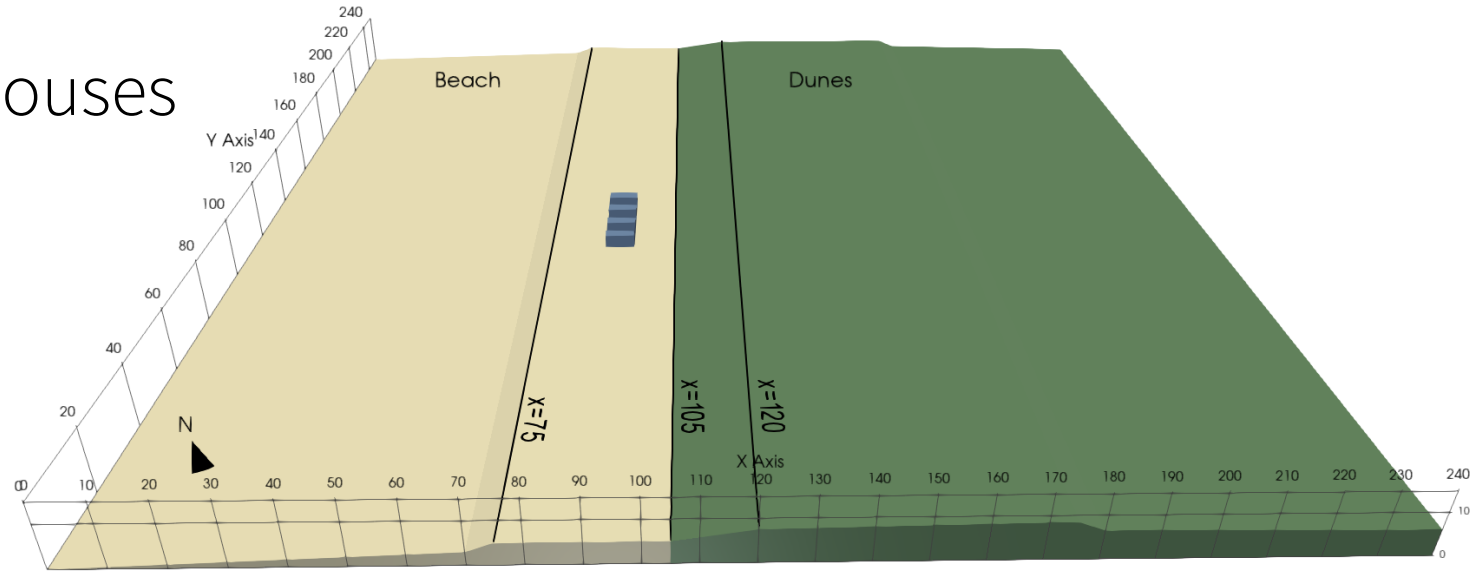
3. METHODOLOGY

- Running a CFD simulation
- Creating different scenarios
- Automation and database storage

Running a CFD simulation: OpenFOAM

Pre-processing:

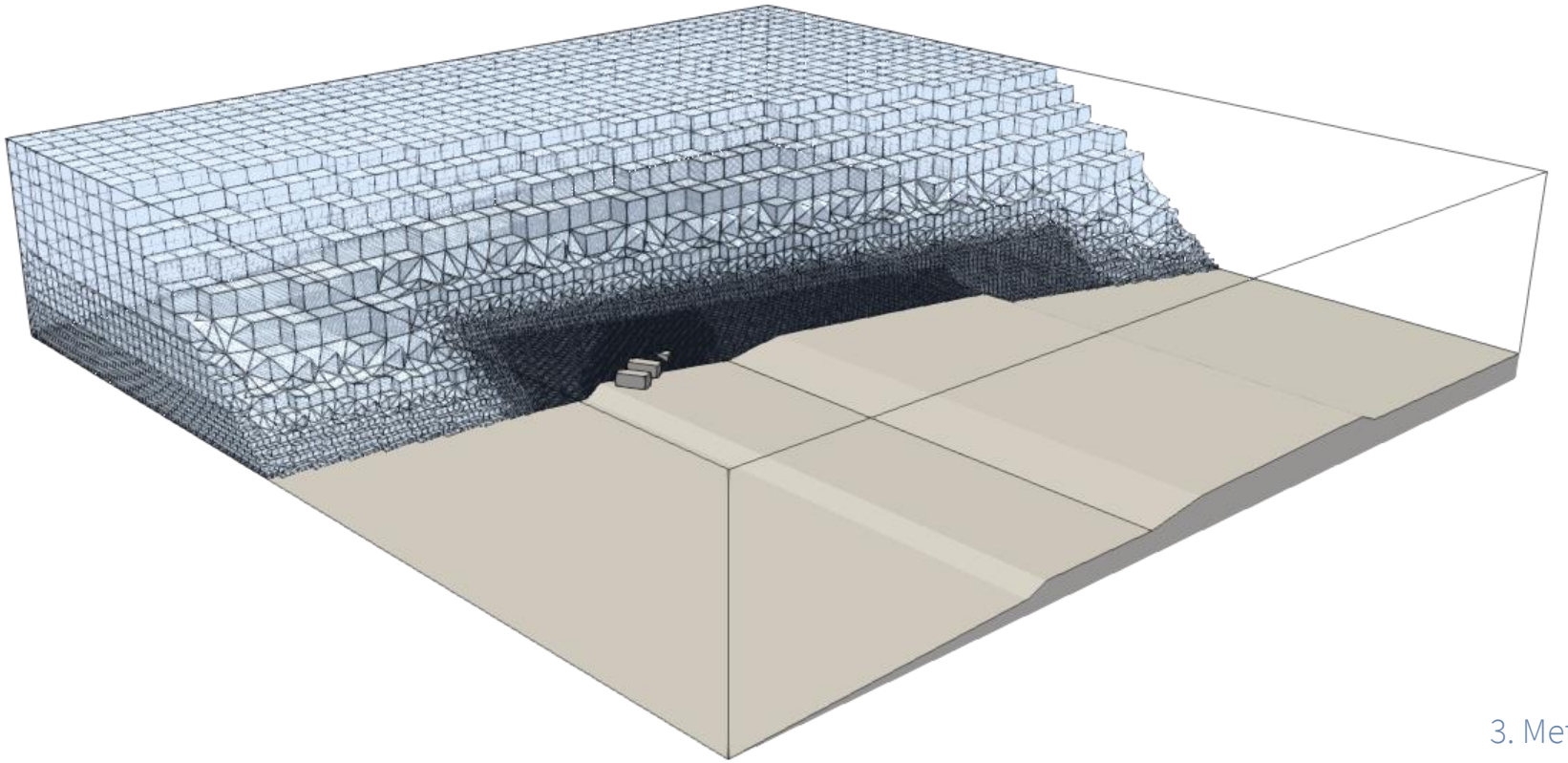
1. 3D model: beach + houses



Running a CFD simulation: OpenFOAM

Pre-processing:

1. 3D model: beach + houses
2. Create mesh

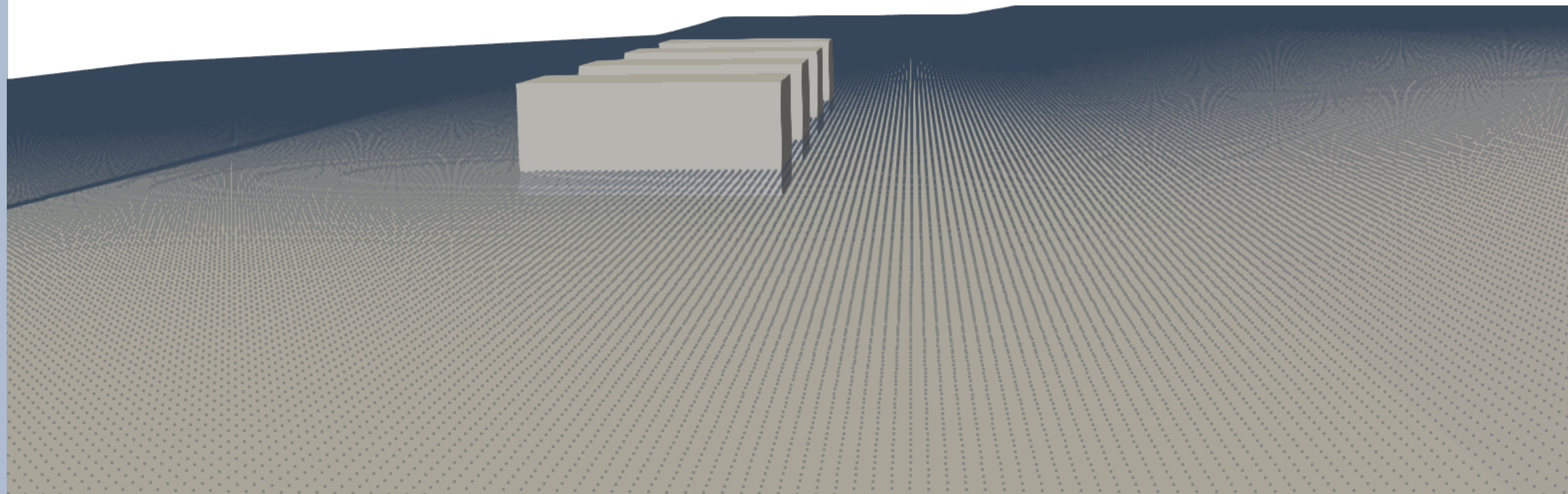


Running a simulation: OpenFOAM

3. Set parameters
   - Wind speed/direction
   - Boundary conditions
   - Turbulence
   - Etc.
4. Run solver
   - simpleFoam

Running a simulation: OpenFOAM

5. Postprocessing
   - Extract plane
   - Calculate sediment transport



Calculate sediment transport

Sediment transport[1]:

$$q = 1.8\left(\frac{\rho}{9.81}\right) u_*^3 \left(\frac{d}{0.25}\right)^{\frac{1}{2}}$$

Dune-ward sediment transport[2]:

$$Q_D = 0.1\ \mathrm{q}\ \cos(\alpha)$$

1. Bagnold, R. A. (1937). The Transport of Sand by Wind. *The Geographical Journal*, 89(5):409–438.
2. Davidson-Arnott, R. G. and Law, M. N. (1996). Measurement and prediction of long-term sediment supply to coastal foredunes. *Journal of Coastal Research*, 12(3):654–663.

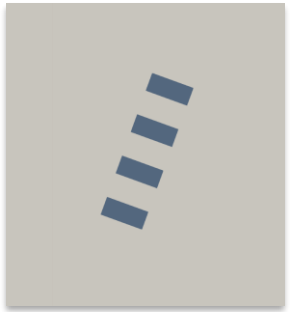
Creating different scenarios

Beach house configurations

Group 1

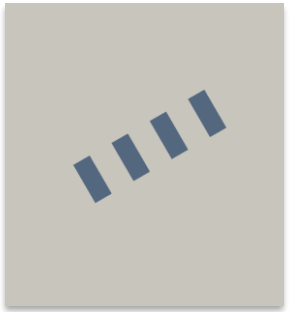
A. 0°

B. 20°



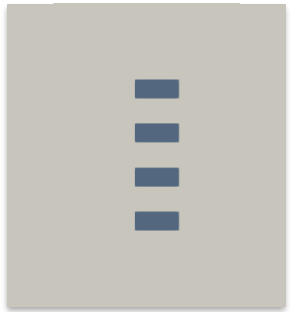
C. 40°

D. 60°

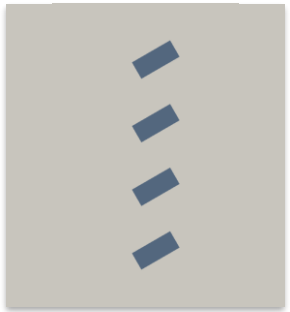


Group 2

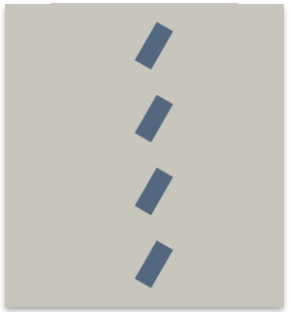
A. 0°



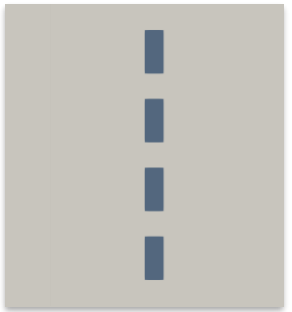
B. 30°



C. 60°

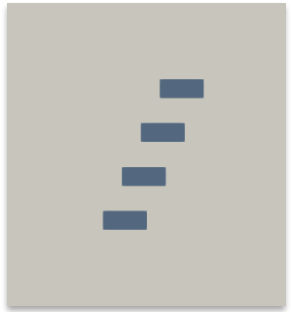


D. 90°



Group 3

A. 0°



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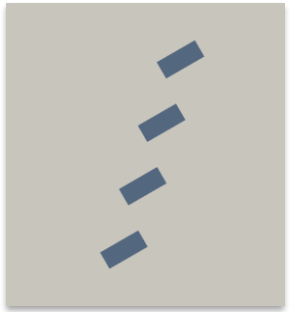

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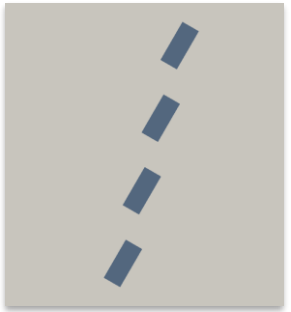
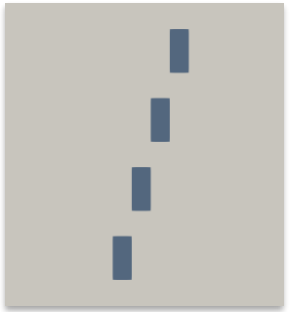


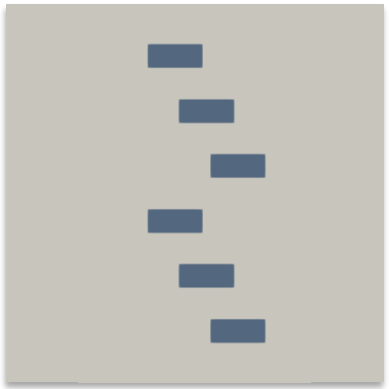
D. 90°

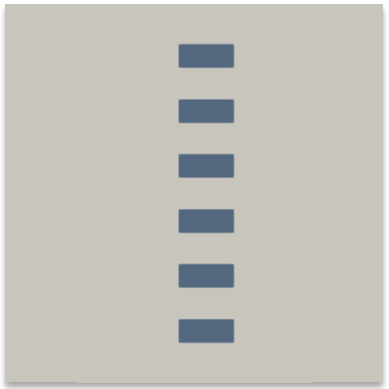


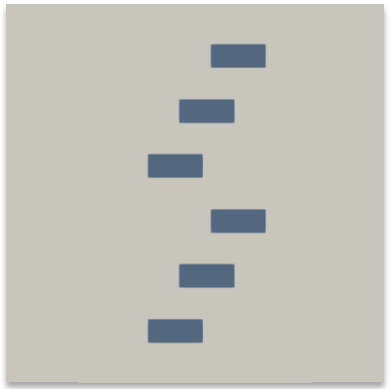
Creating different scenarios

Beach house configurations

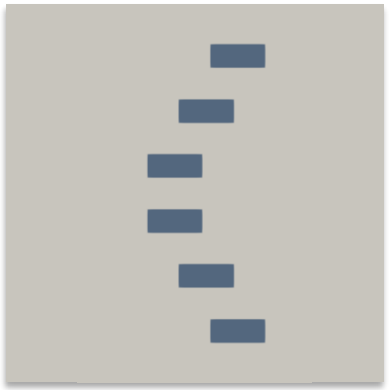
Group 4

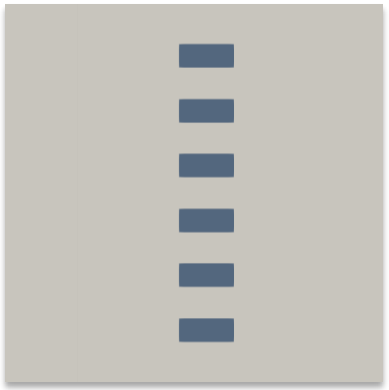
A. 

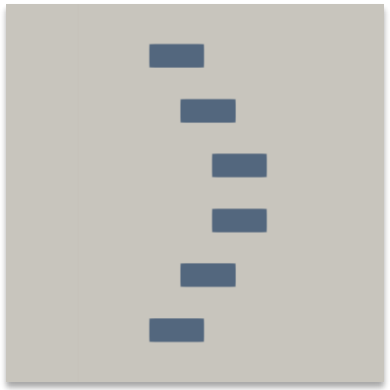
B. 

C. 

Group 5

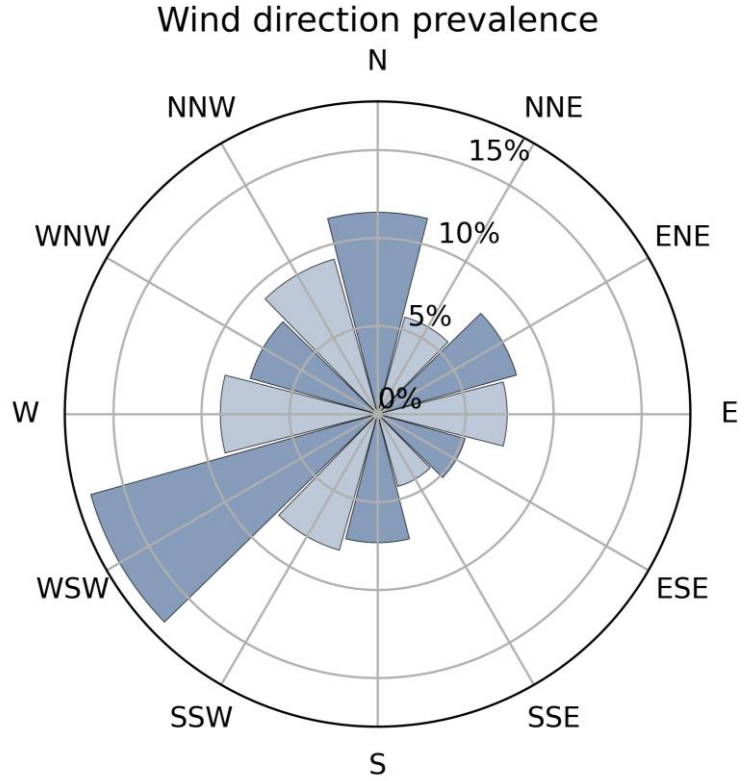
A. 

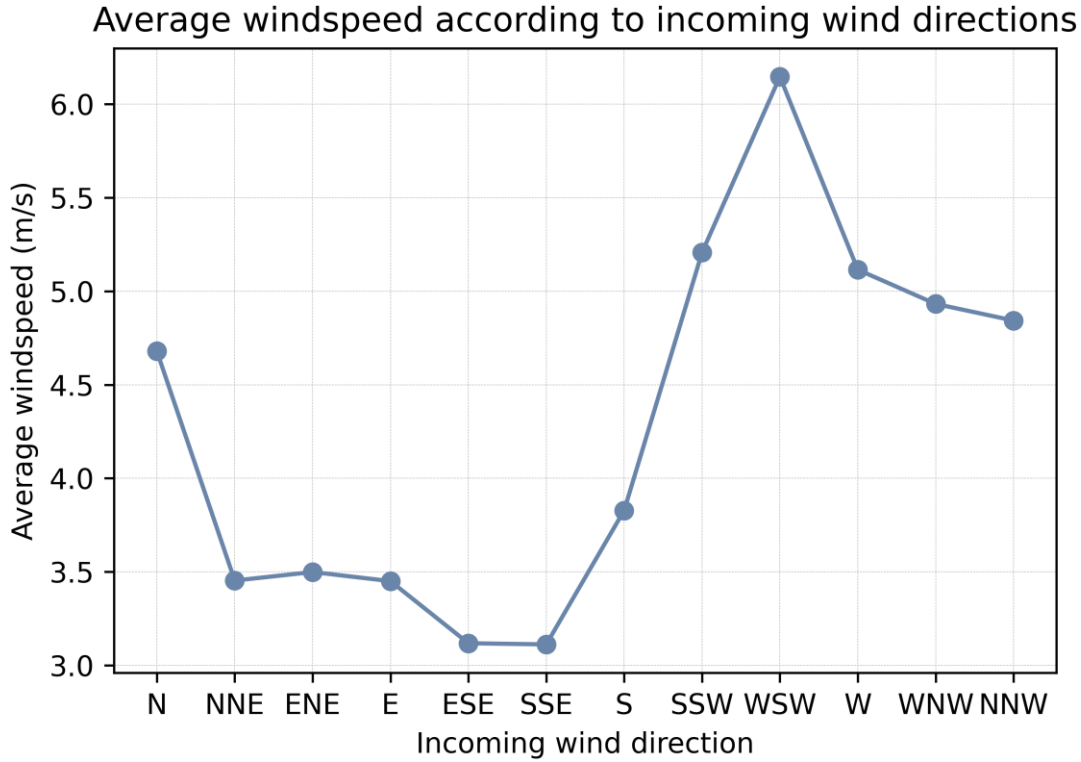
B. 

C. 

Creating different scenarios

Seasonal wind conditions



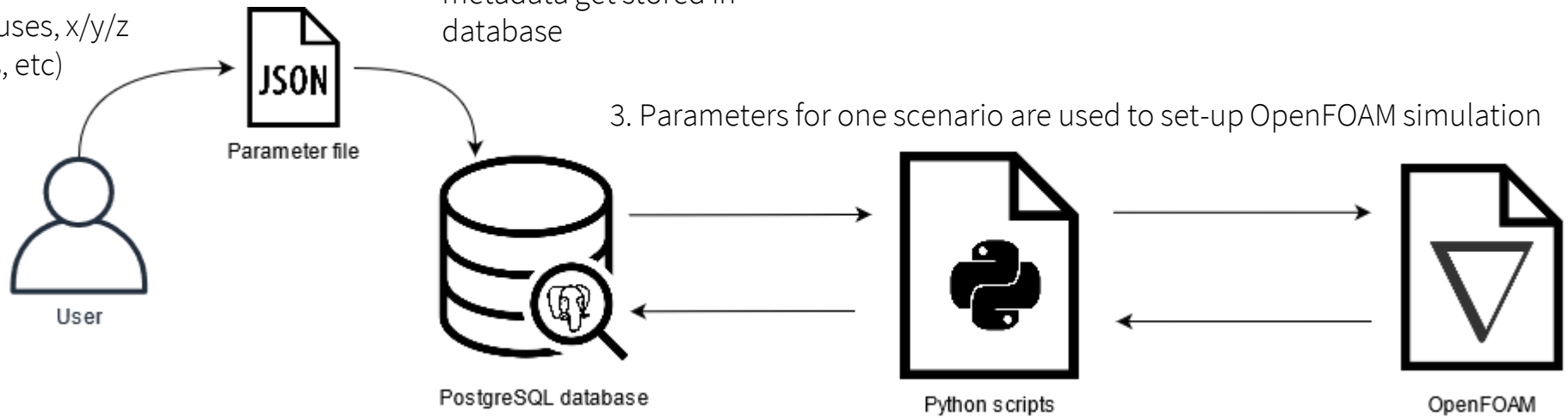


Automation

1. User enters beach houses parameters (e.g. # of houses, x/y/z coordinates, etc)

2. Parameters and metadata get stored in database

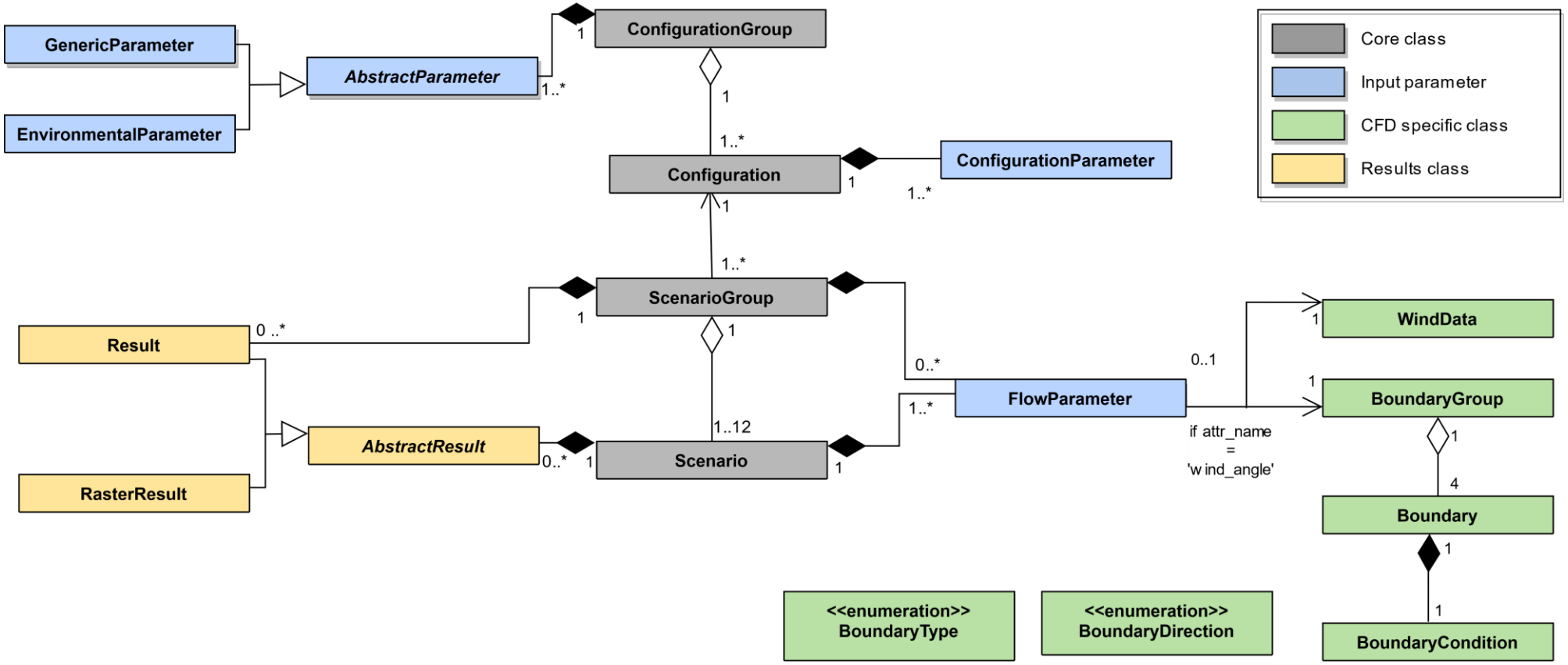
3. Parameters for one scenario are used to set-up OpenFOAM simulation



5. Calculated sediment transport values are stored in the database

4. After running the simulation results of extracted plane are returned

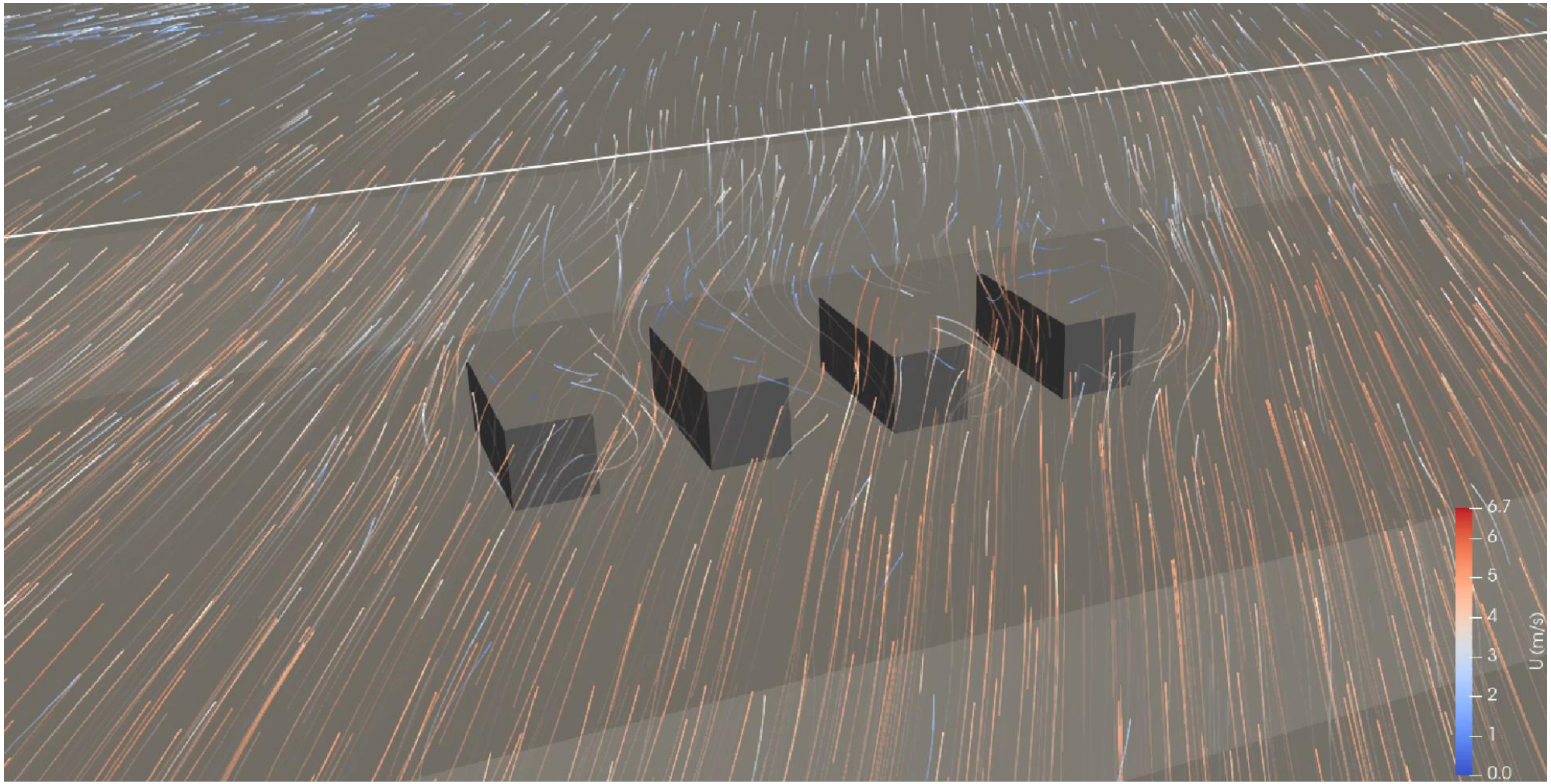
Data storage



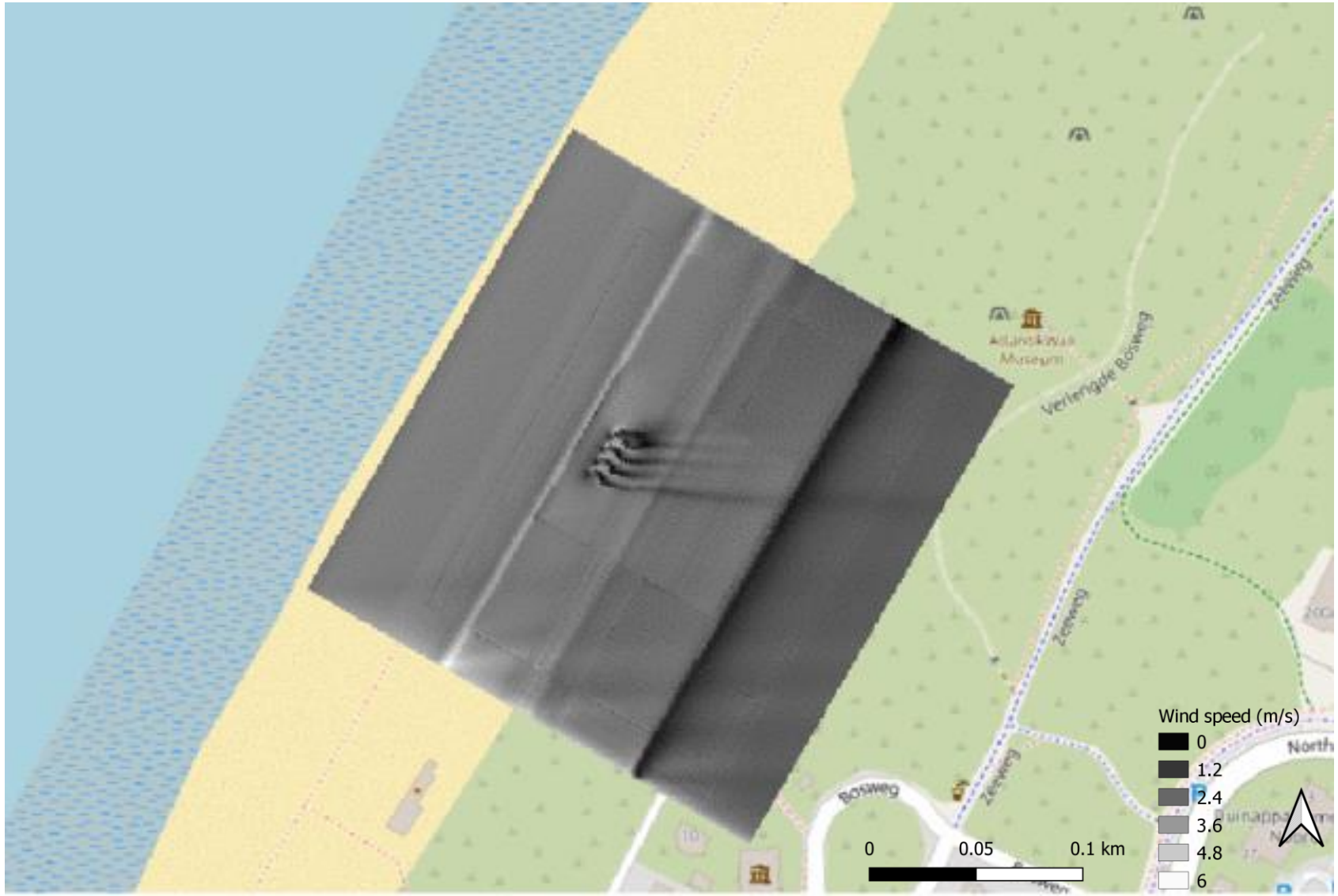
4. RESULTS

- Wind flow
- Varying wind conditions
- Beach house configurations

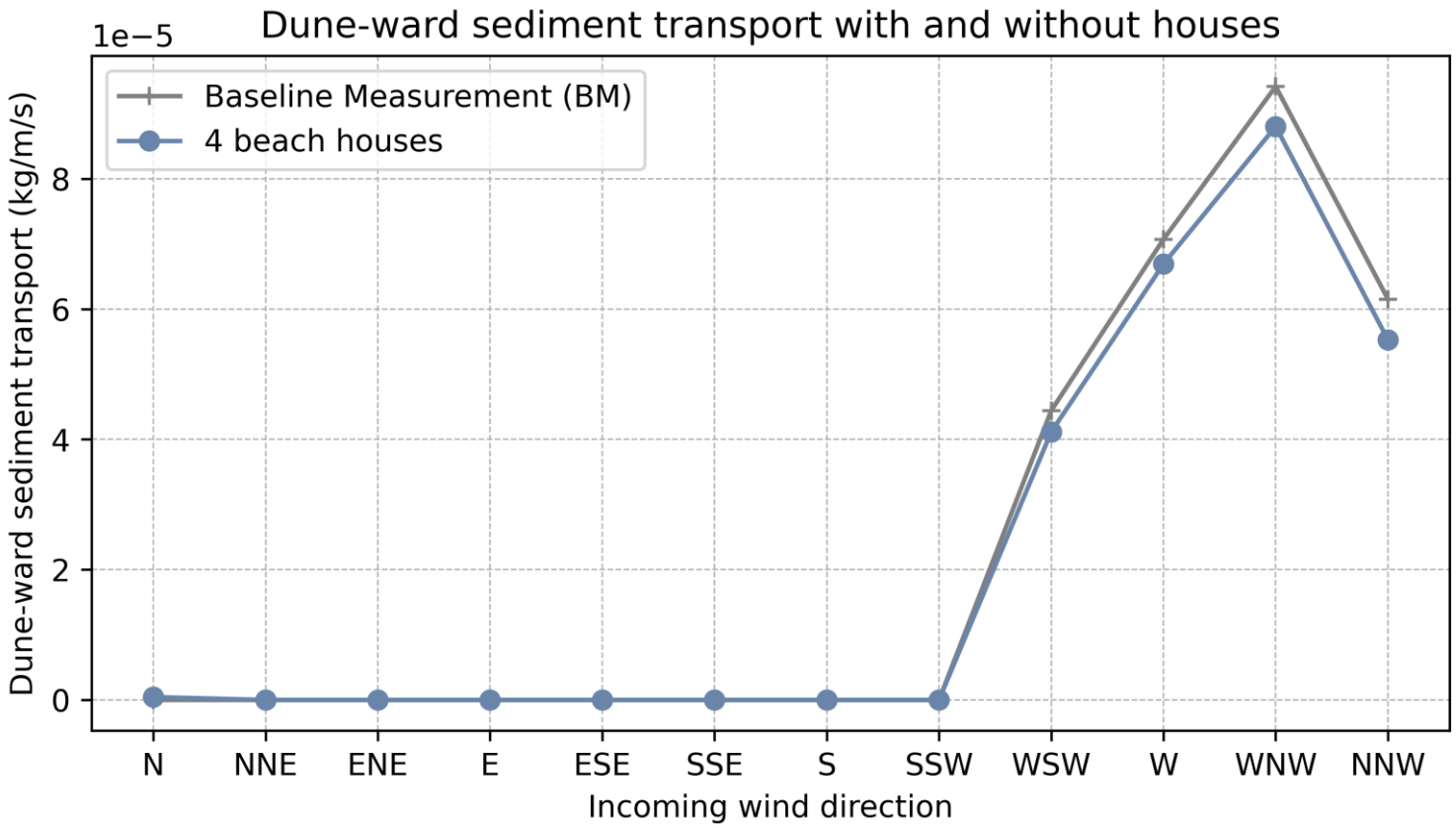
Wind flow



Varying wind conditions

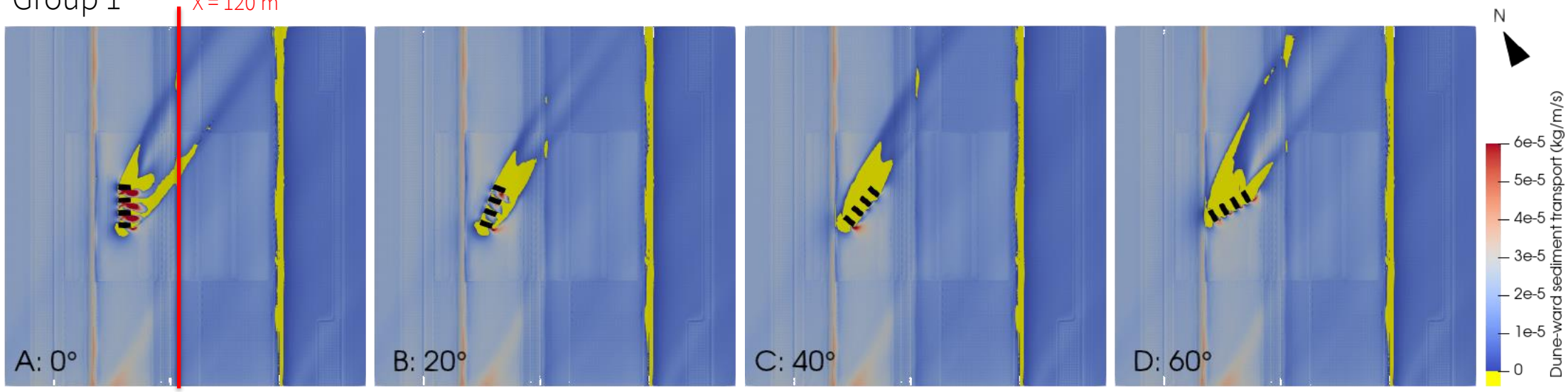


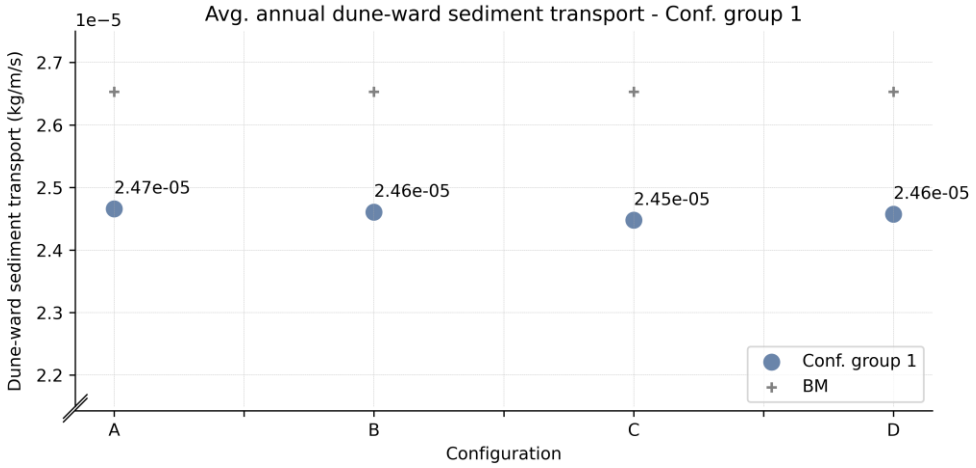
Varying wind conditions

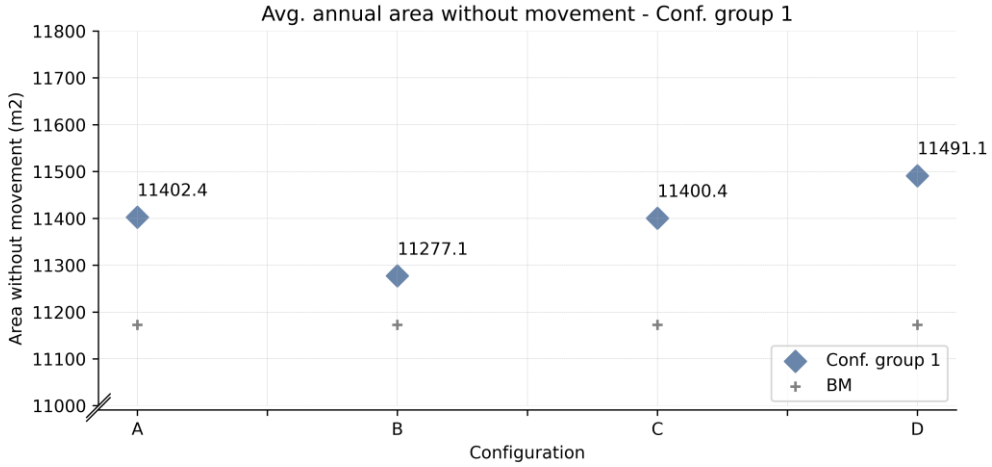


Beach house configurations

Group 1

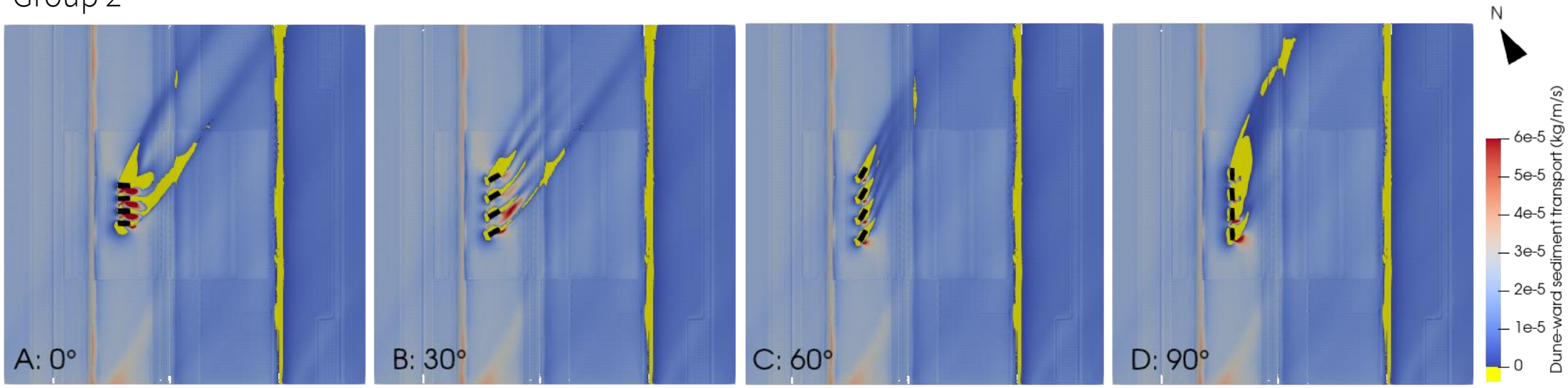


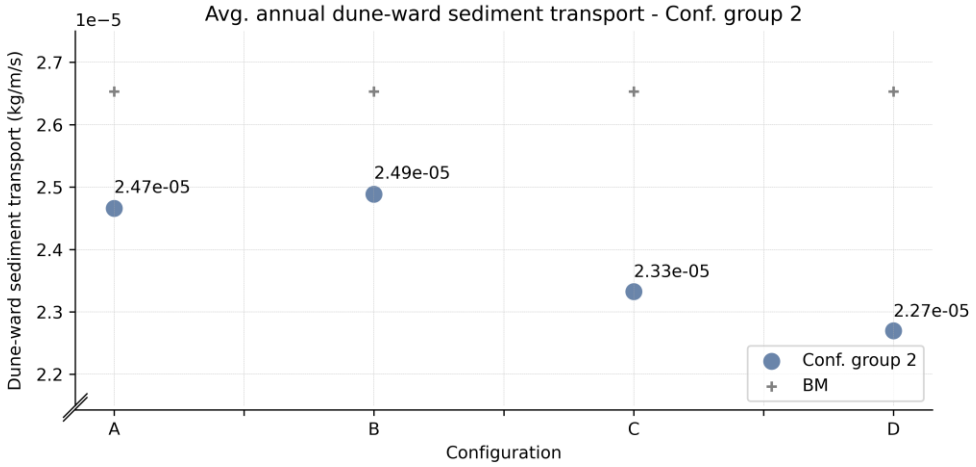


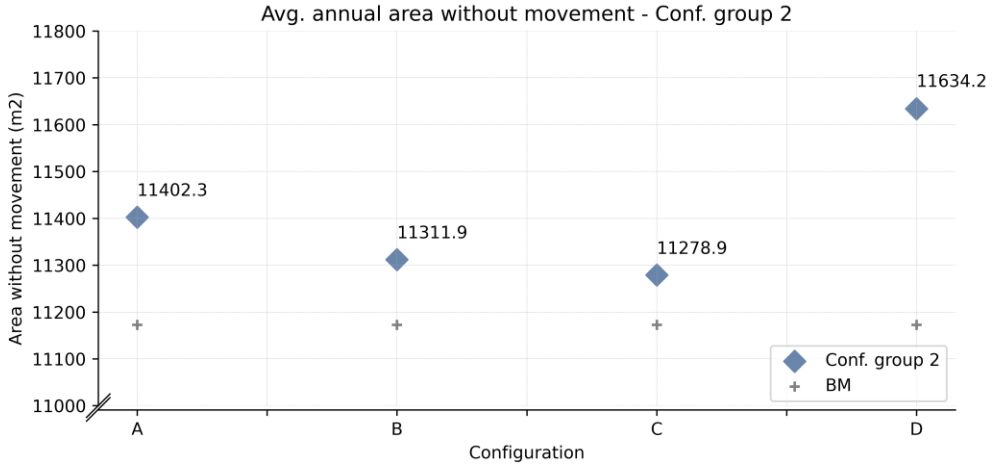


Beach house configurations

Group 2

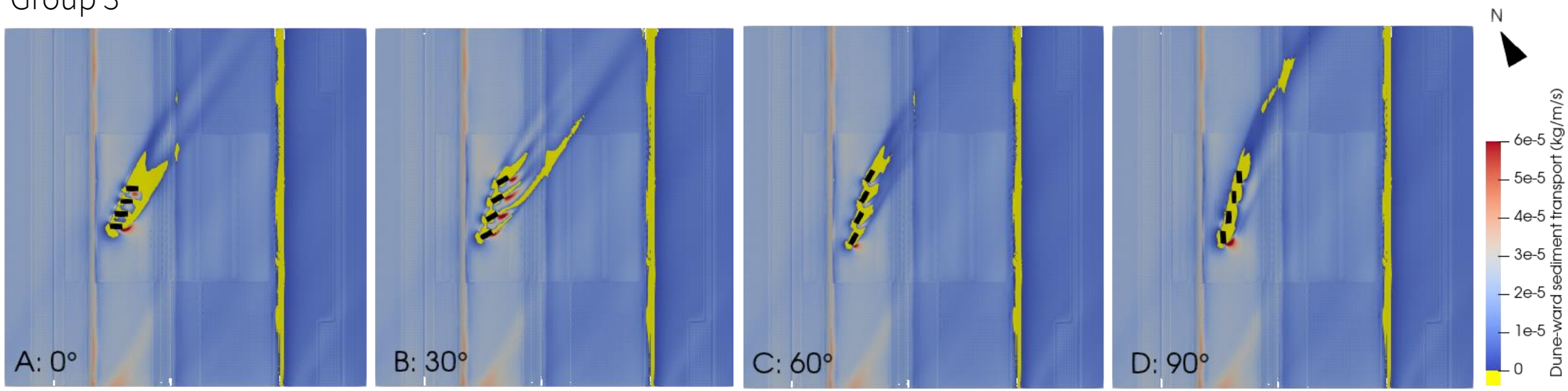


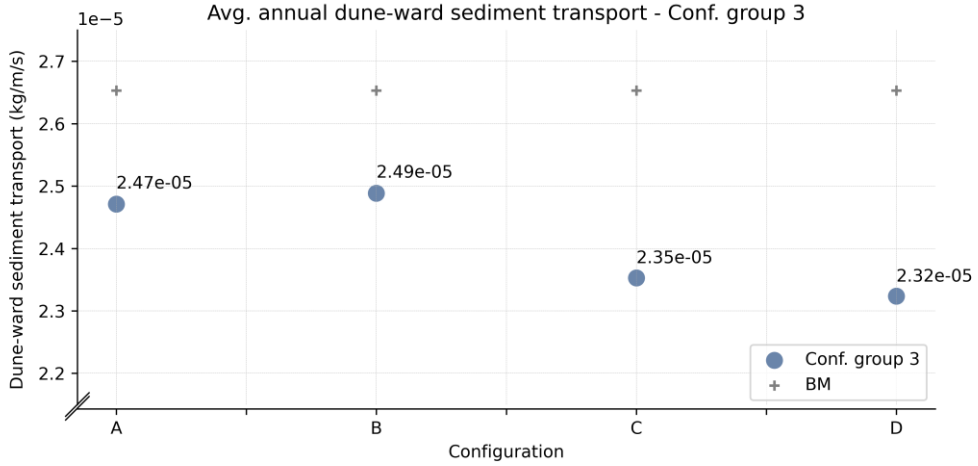


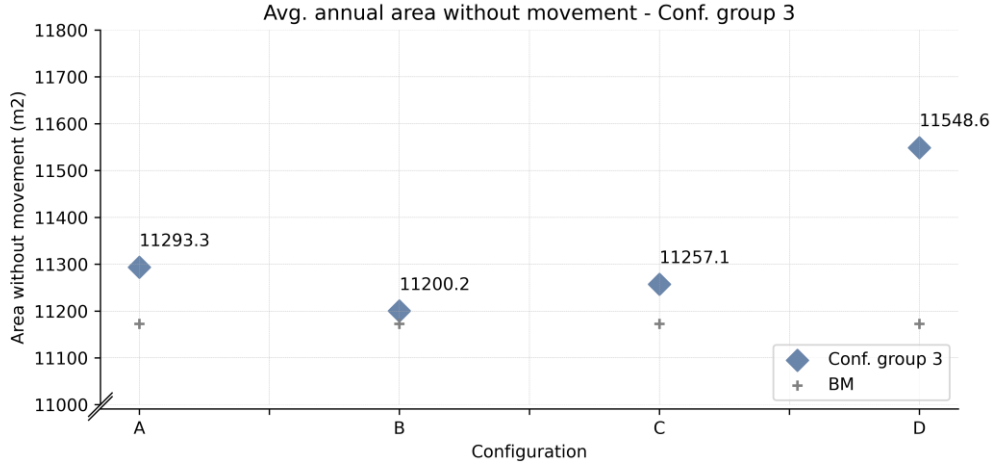


Beach house configurations

Group 3

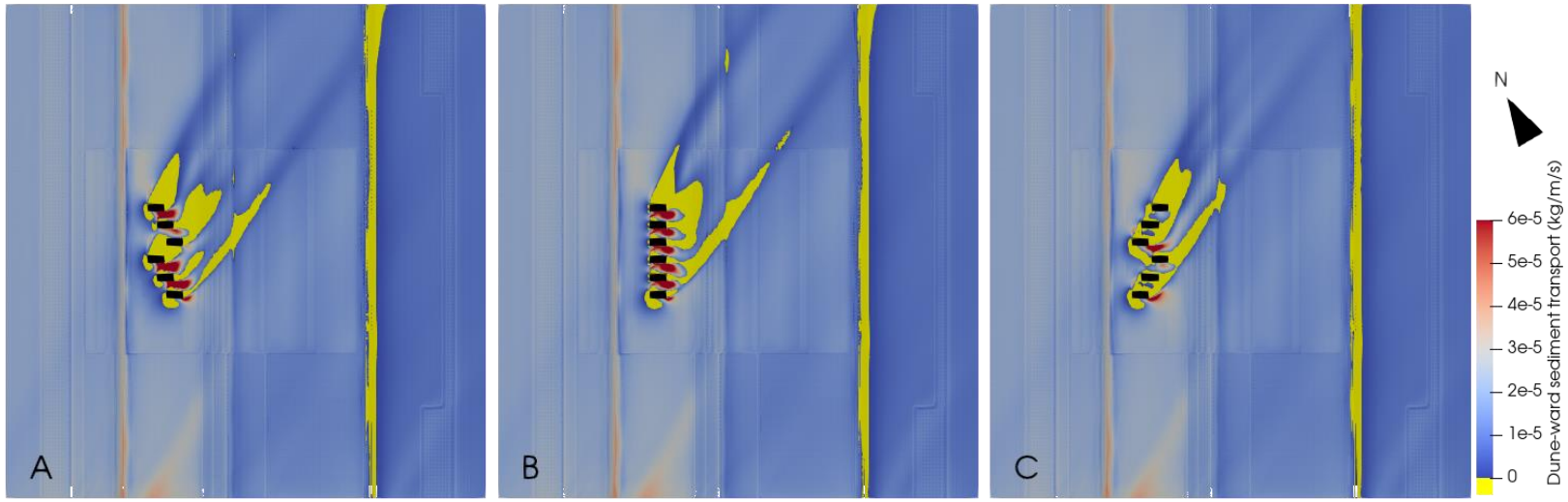


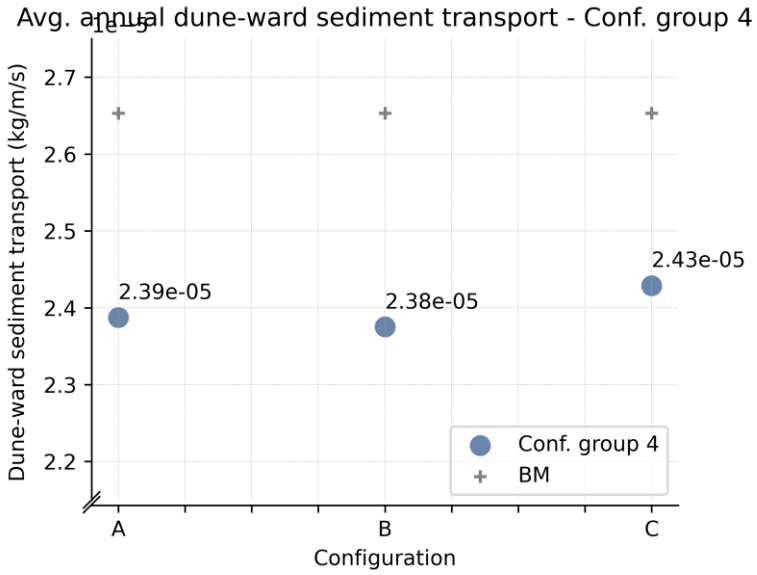


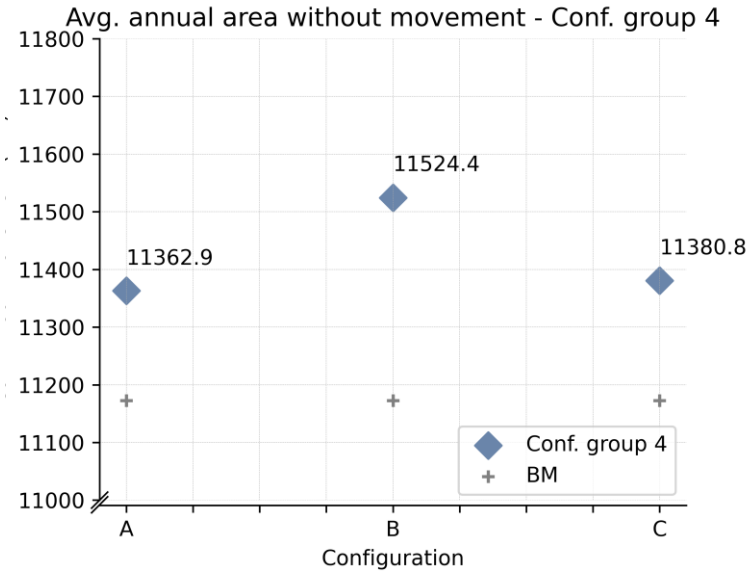


Beach house configurations

Group 4

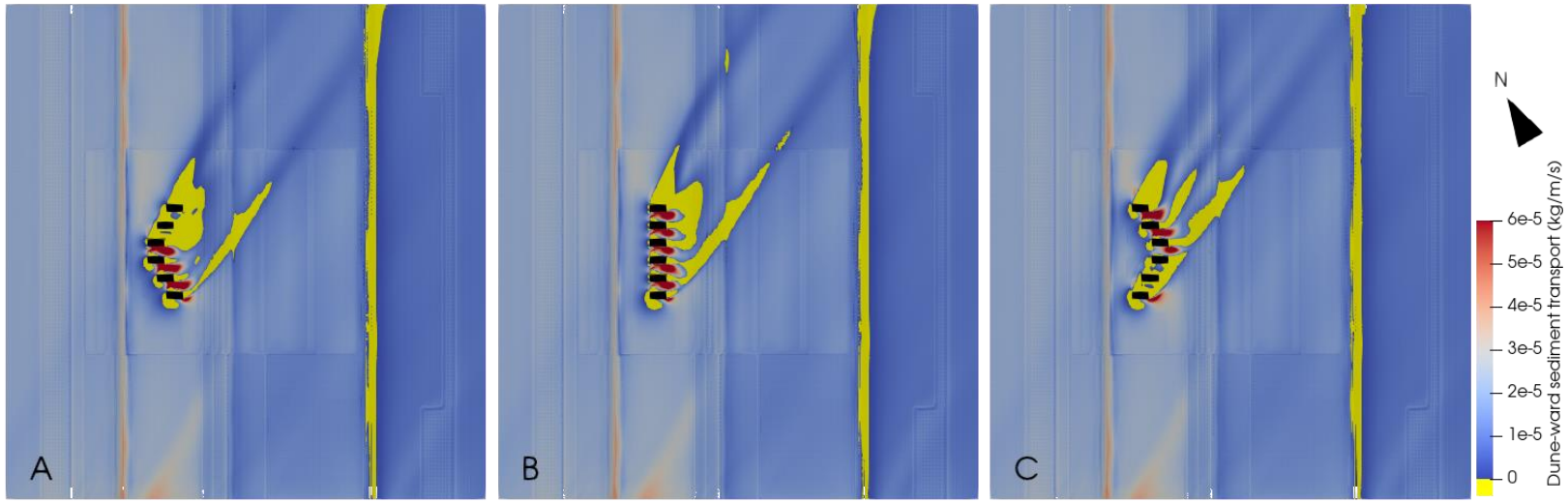


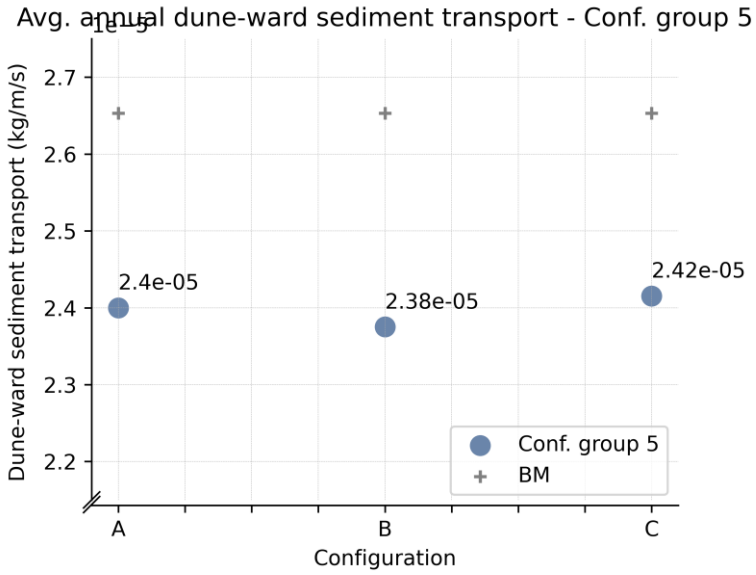


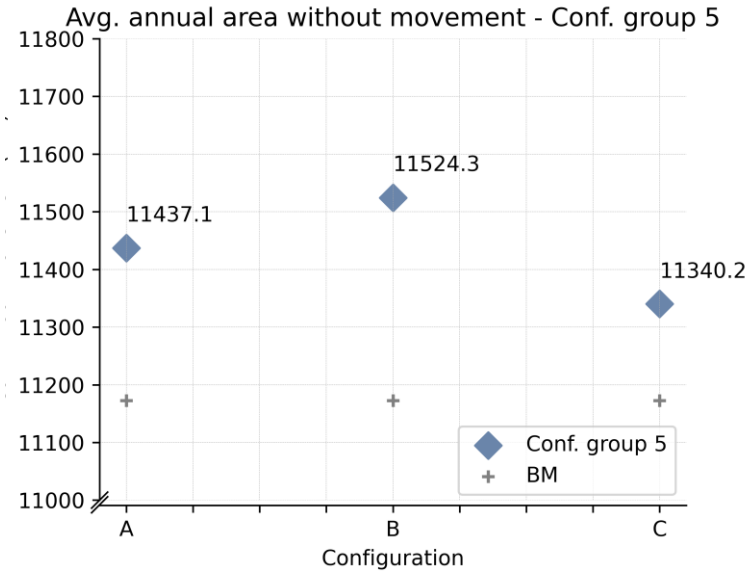


Beach house configurations

Group 5







5. DISCUSSION

- Limitations
- Future work

Limitations

- Not taken into account: moisture, fetch, temperature, etc
- Simplified 3D model

Future work

- Scale models, wind tunnels
- Improve data management

6. CONCLUSION

Conclusion

"What are the effects of different beach house configurations on dune-ward sediment transport?"

- The wind coming from WSW is responsible for most sediment transport.
- Rotating a whole row of houses has only small effects
- Rotating individual houses towards prevalent wind shows increase in dune-ward sediment transport and limits the stationary area
- V/funnel shape shows promising result to increase the dune-ward sediment transport

Thank you!

- Questions?

Extra slides