

# WINDRIFT: influence of offshore wind farms to sea ice dynamics and winter navigation

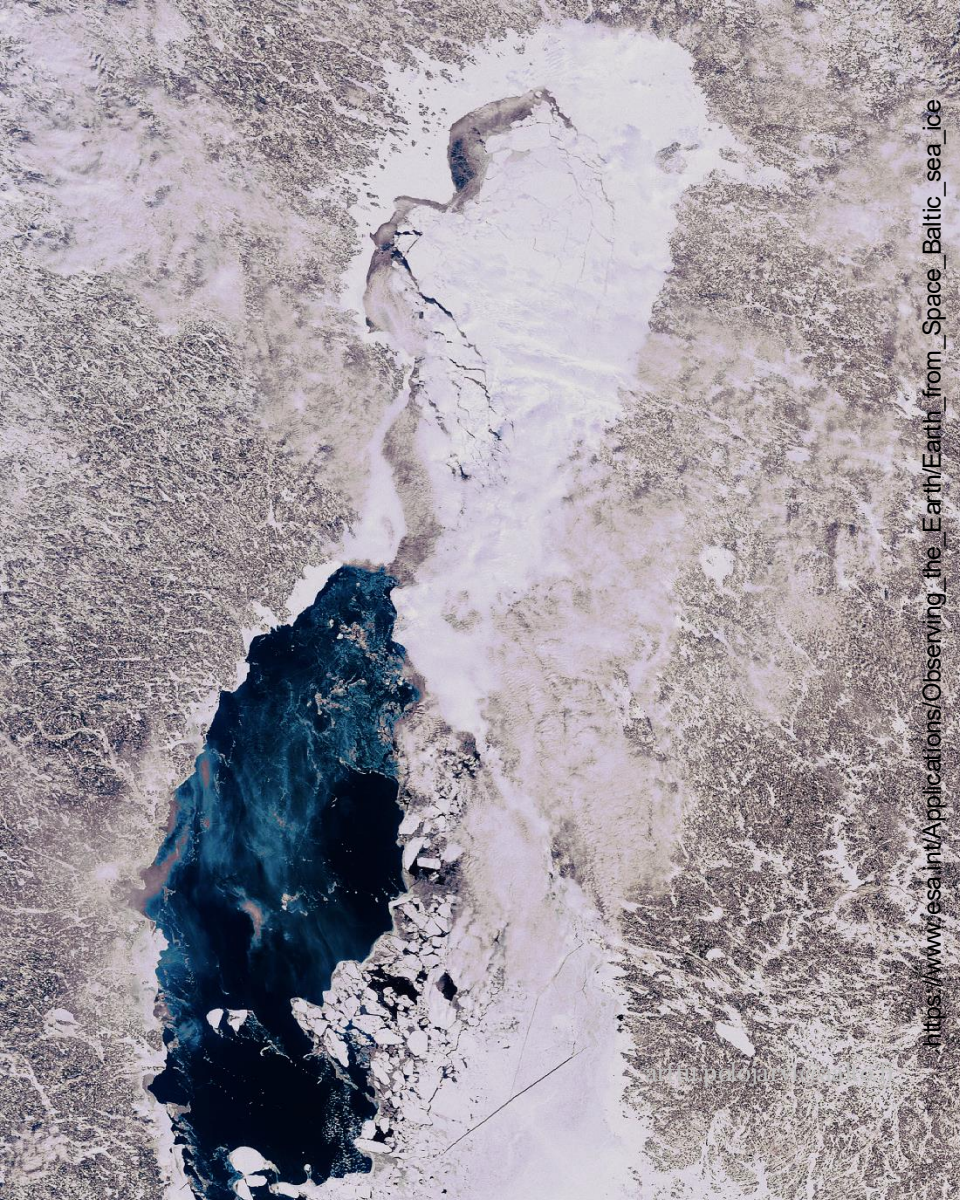
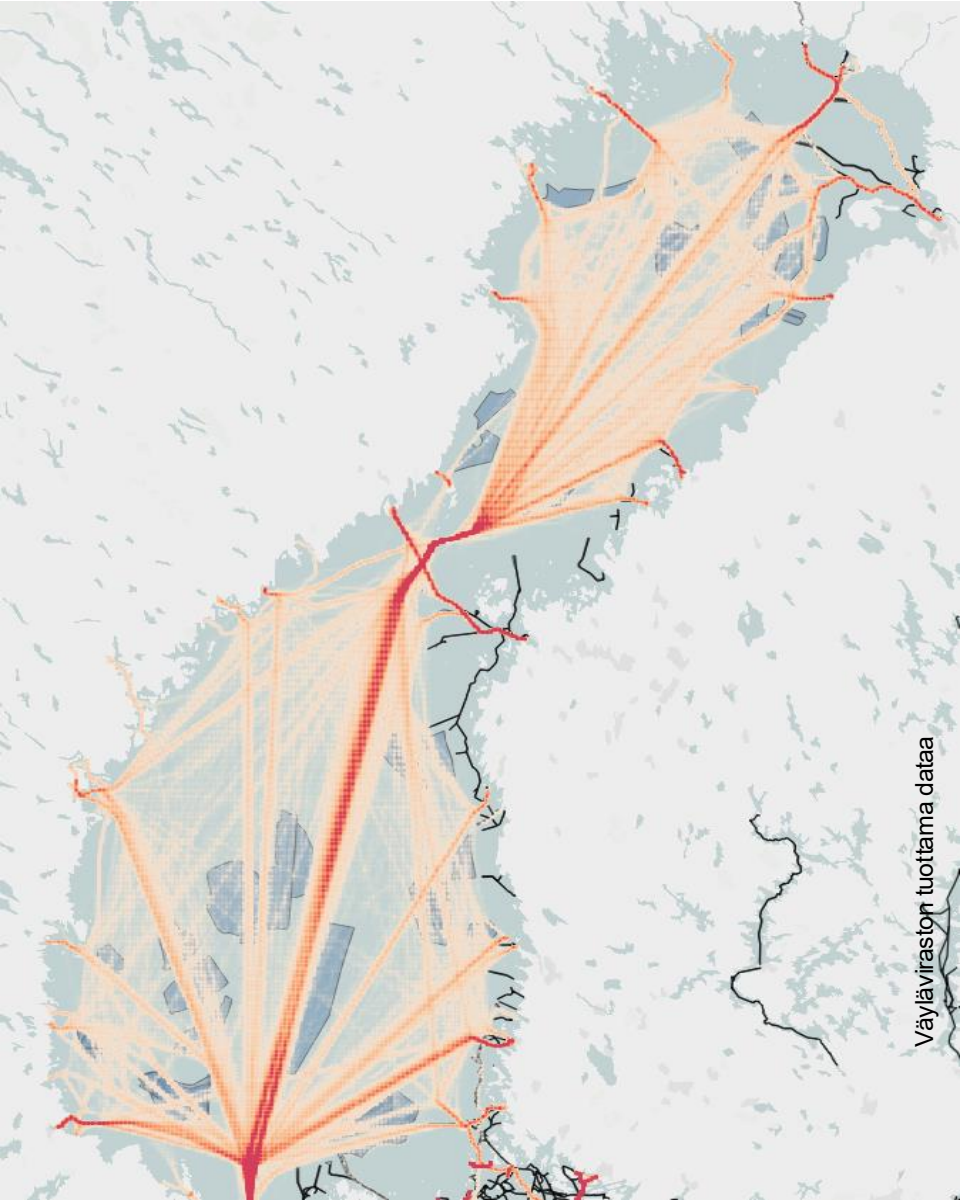
Results from WINMOS 3 on ice modelling related to windfarms and shipping

Arttu Polojärvi  
Associate Professor of Ice Mechanics  
Aalto University

C2B2 Ice conference  
March 17, 2026  
Luleå



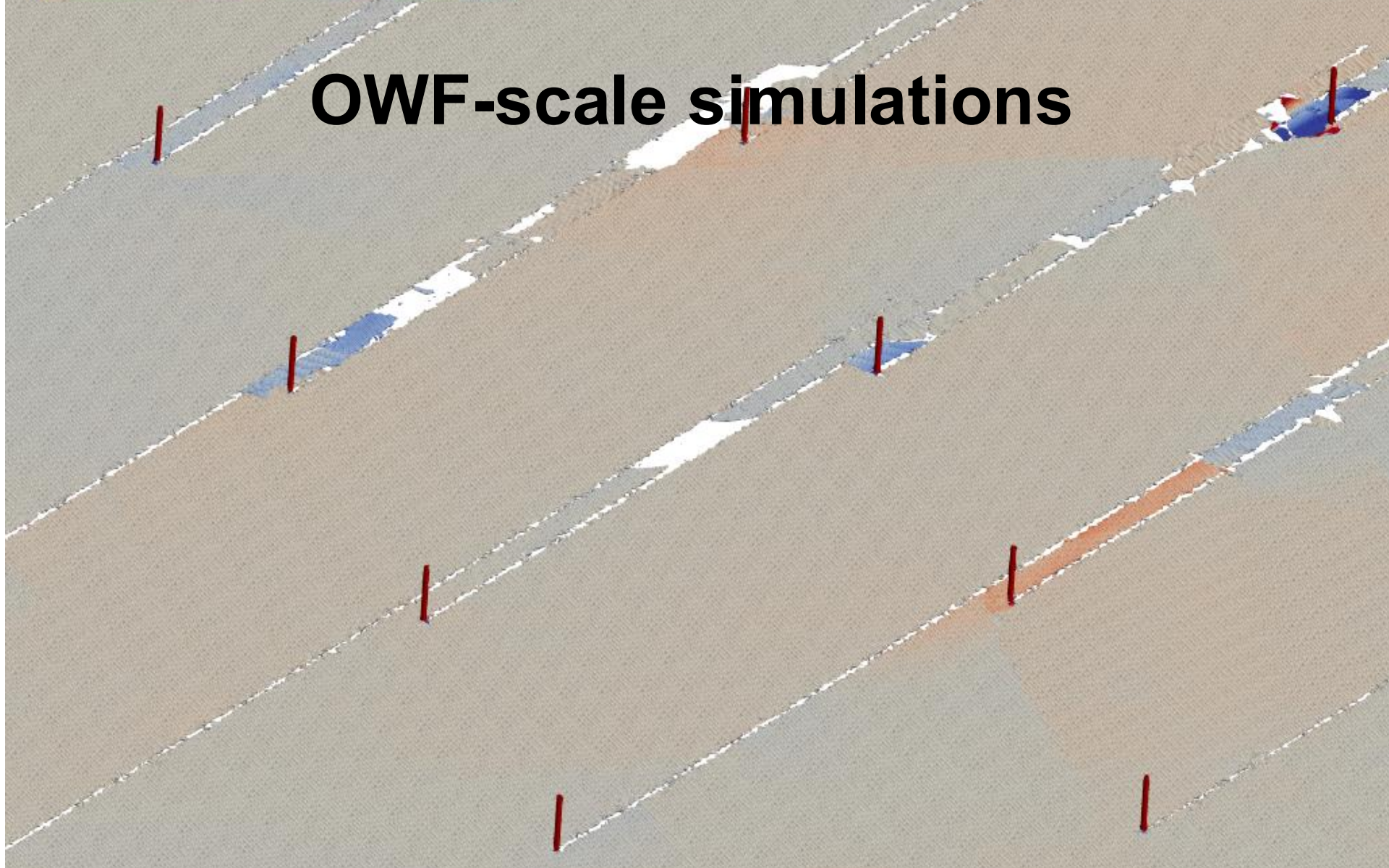
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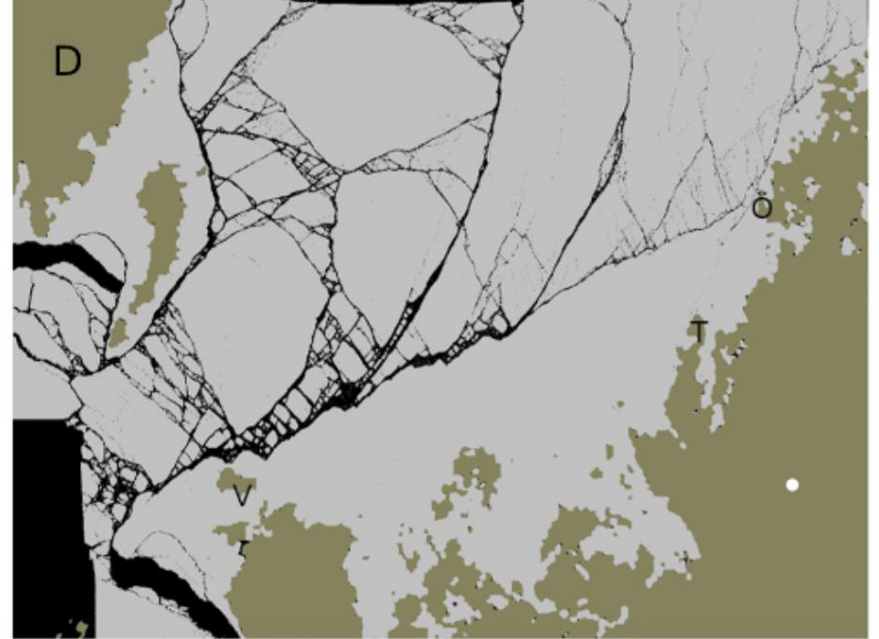
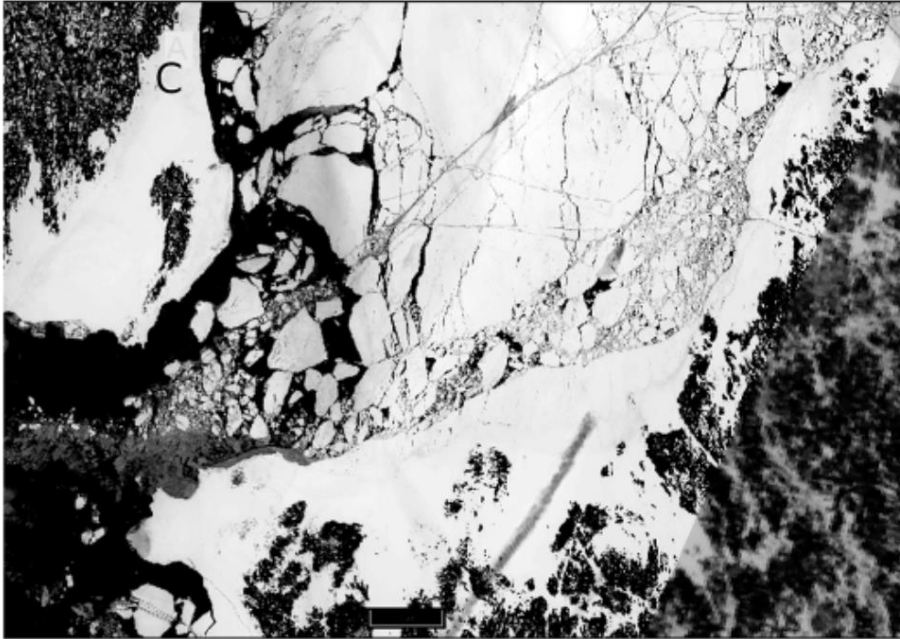
# WINDRIFT background

- Consortium: Aalto University (coordinator), FMI, VTT, and CSC → strong expertise in developing and applying numerical tools for sea ice
- Foundation for WINDRIFT: RCF-funded project *WindySea* (2021–2024) a digital twin framework for studying OWF-sea ice interactions.
- Hybrid modeling combining three-dimensional discrete element method (DEM) at the wind farm scale and continuum modeling at the basin scale.
- Funding from the Finnish Transport Infrastructure Agency and funded by the European Union through the CEF Infrastructure Project WINMOS III.

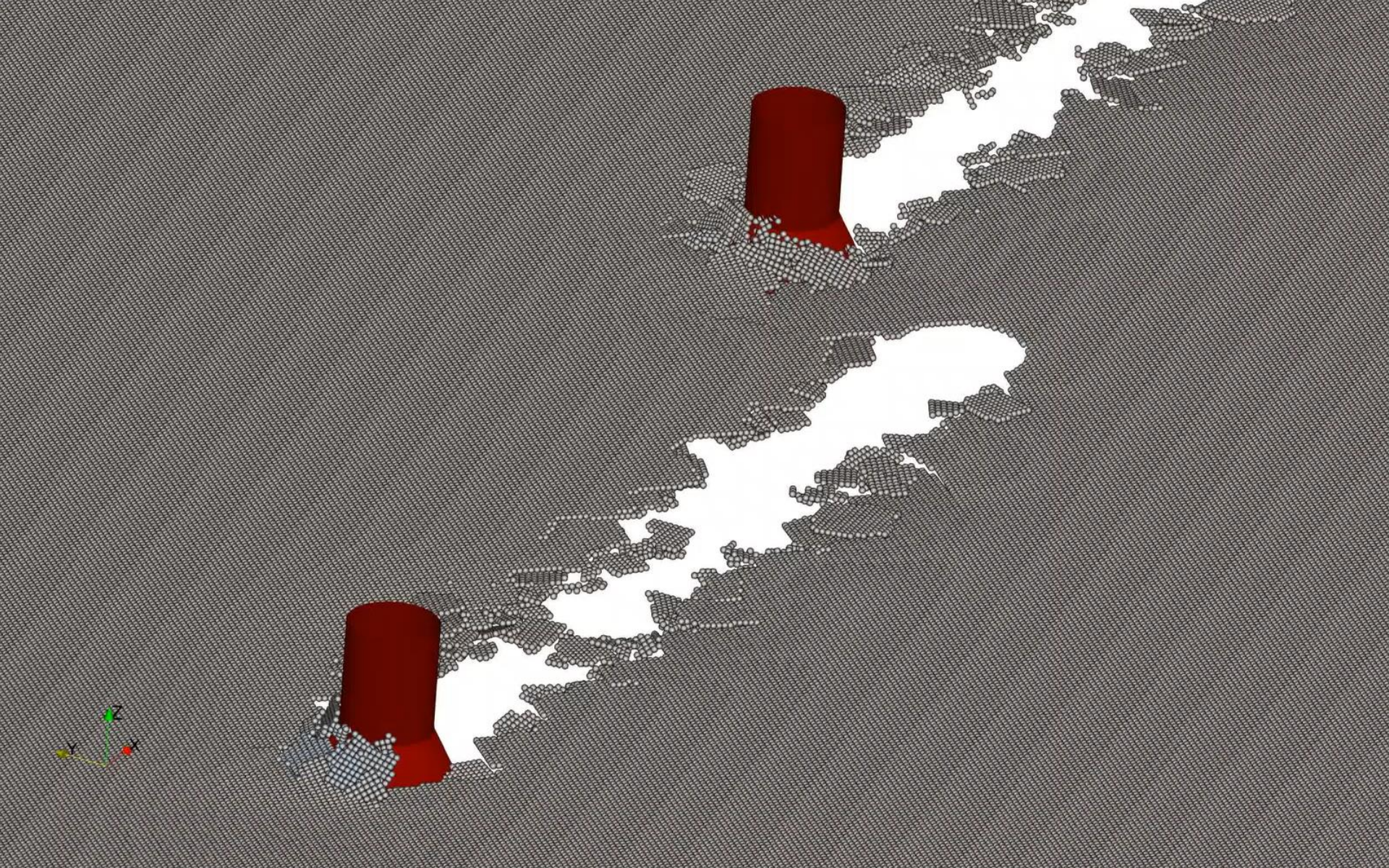
# OWF-scale simulations



# High-resolution large-scale DEM

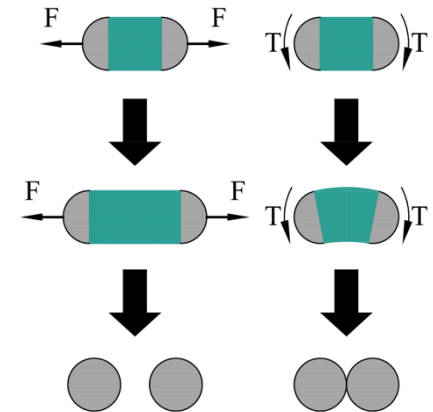
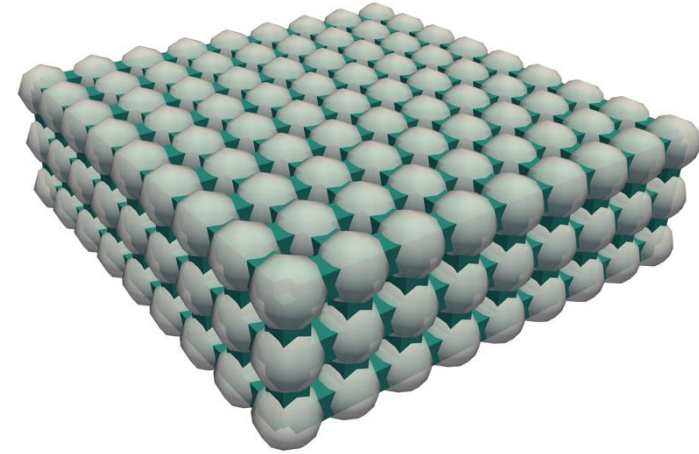


Åström, J., Robertsen, F., Haapala, J., Polojärvi, A., Uiboupin, R., and Maljutenko, I. (2024) A large-scale high-resolution numerical model for sea-ice fragmentation dynamics, *The Cryosphere*, 18, 2429–2442, <https://doi.org/10.5194/tc-18-2429-2024>



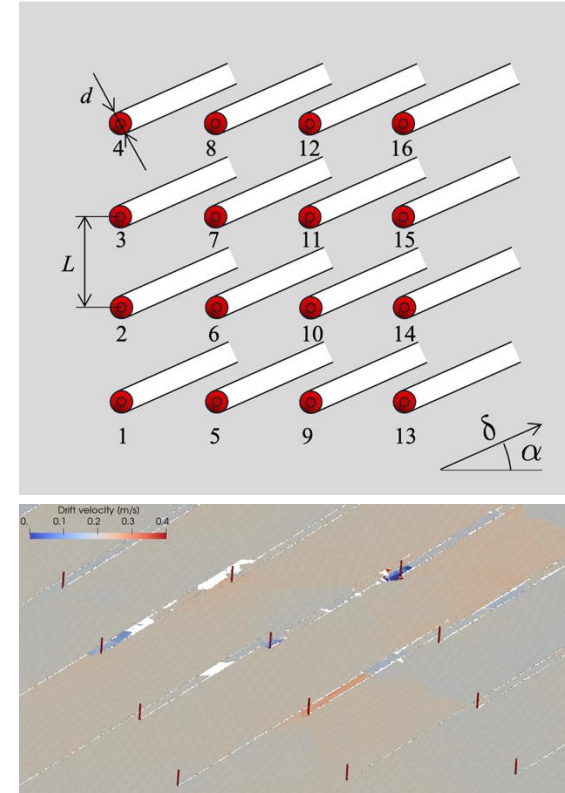
# High-resolution large-scale DEM

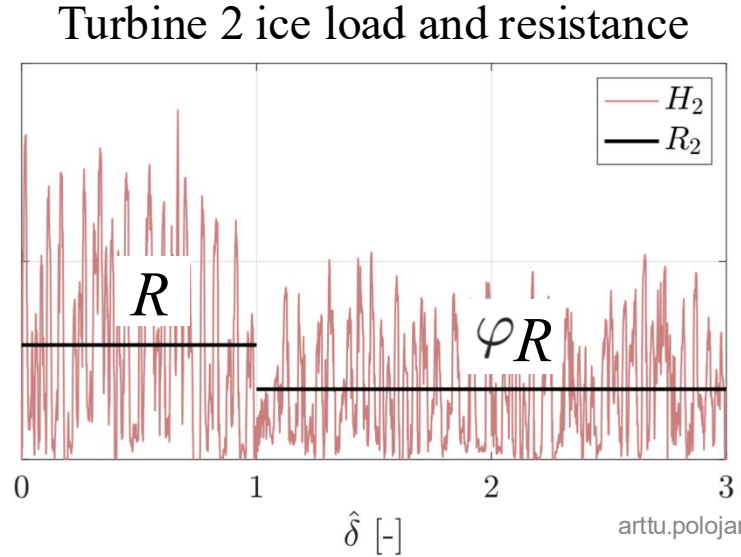
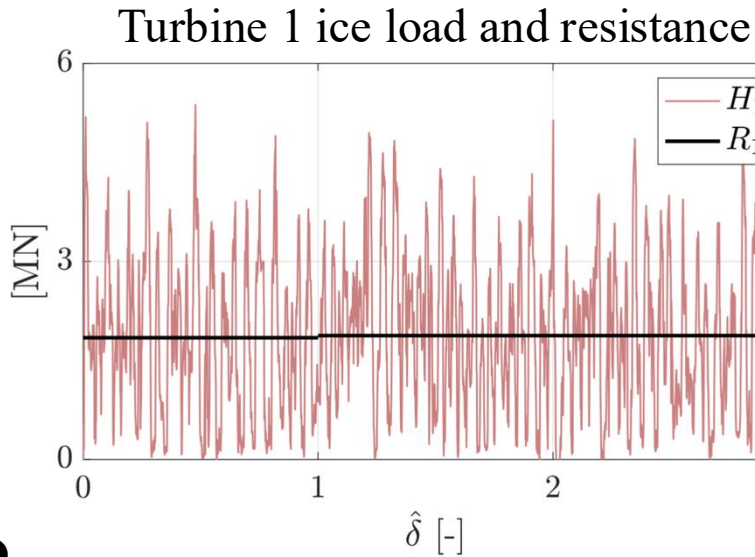
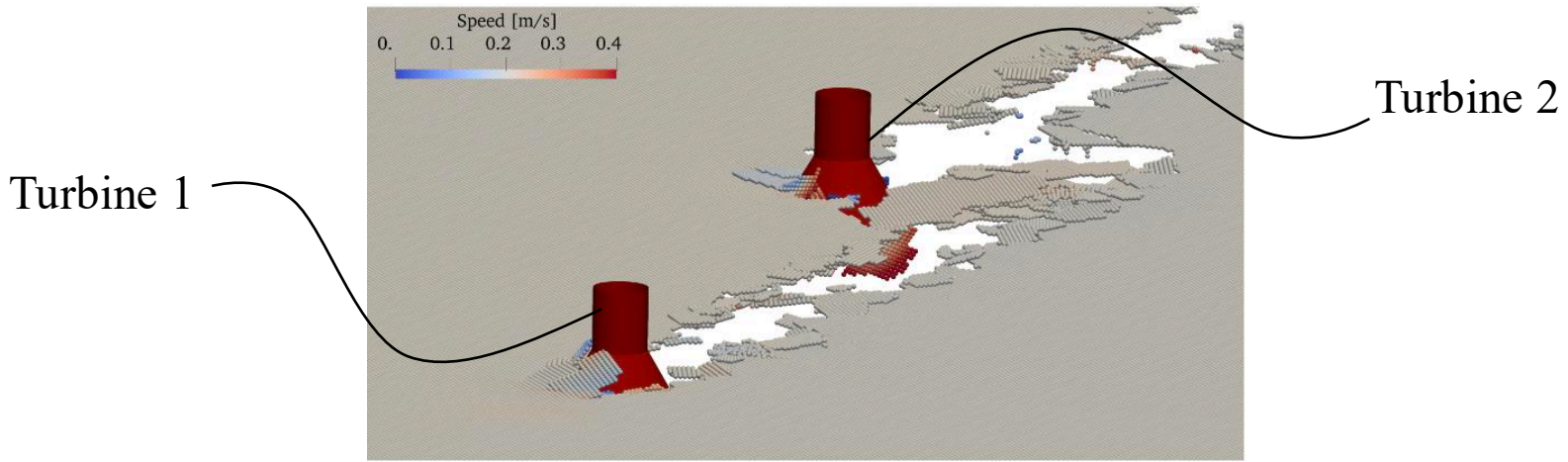
- Spherical discrete elements connected by Euler-Bernoulli beams.
- Simplified friction and wind and fluid drag; cohesive softening upon ice failure.
- Small time steps due to high stiffness, high resolutions, and low density of sea ice.
- Parallelization: MPI with offloading computations to GPUs via CUDA.

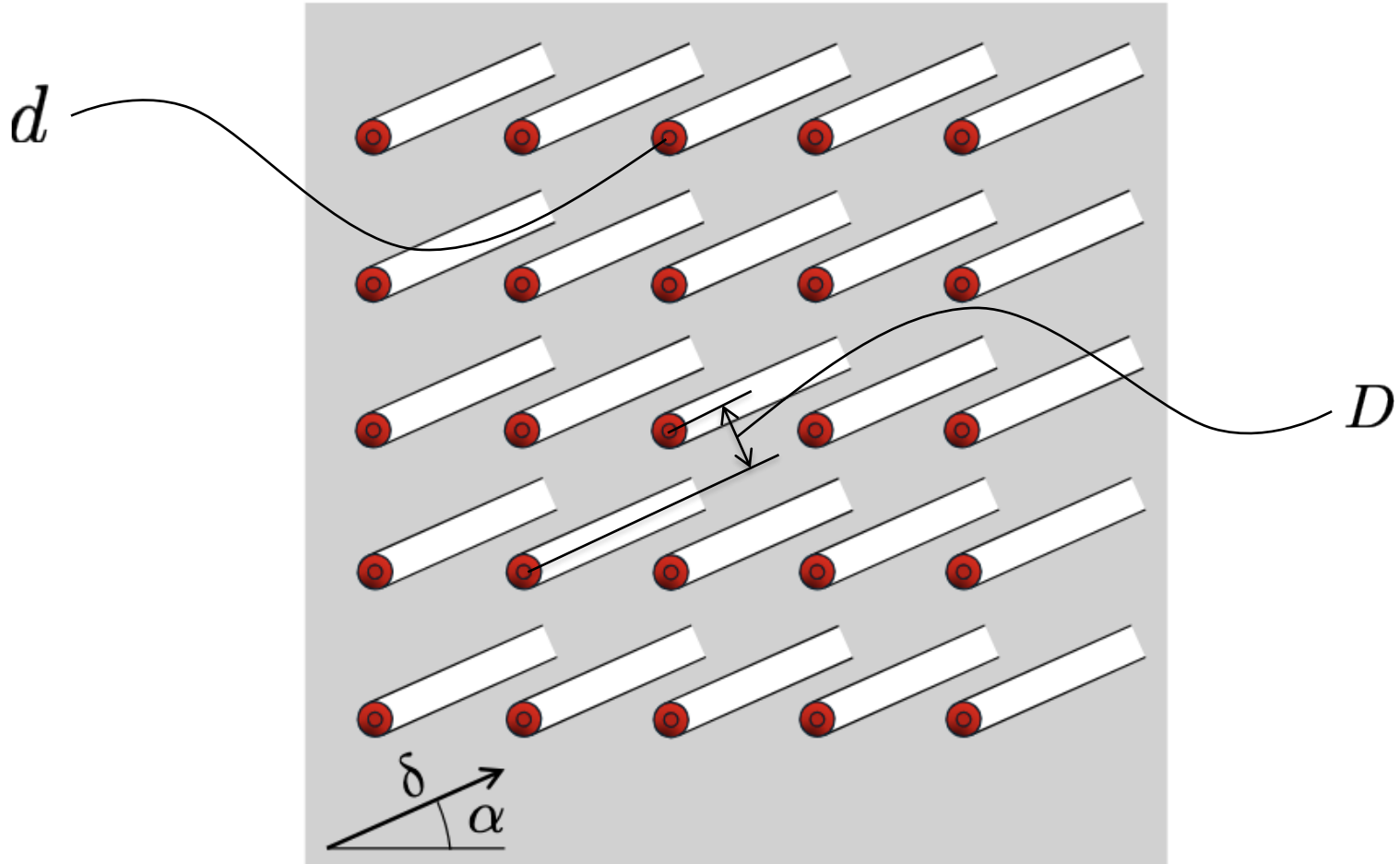


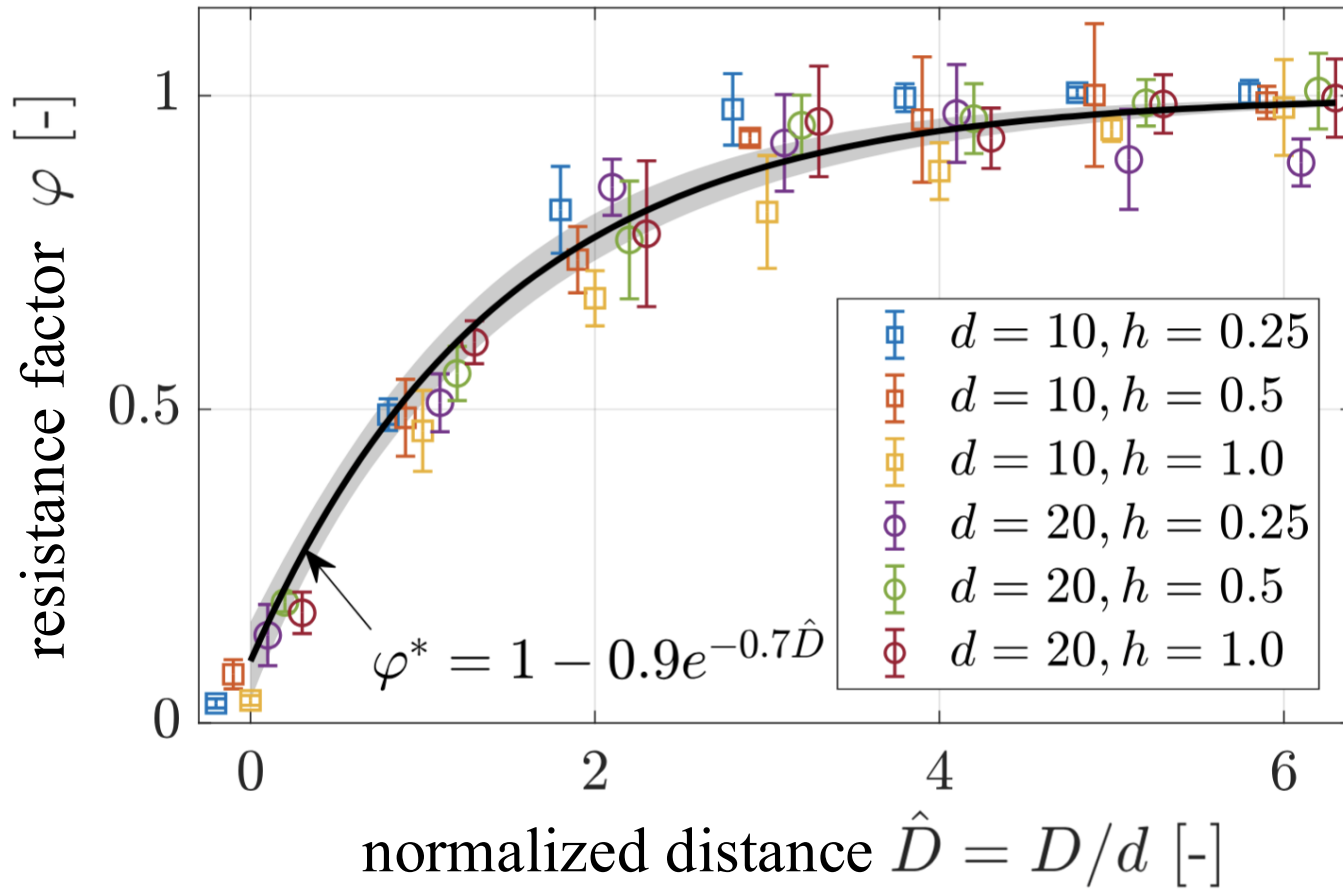
# Level ice resistance of a wind farm

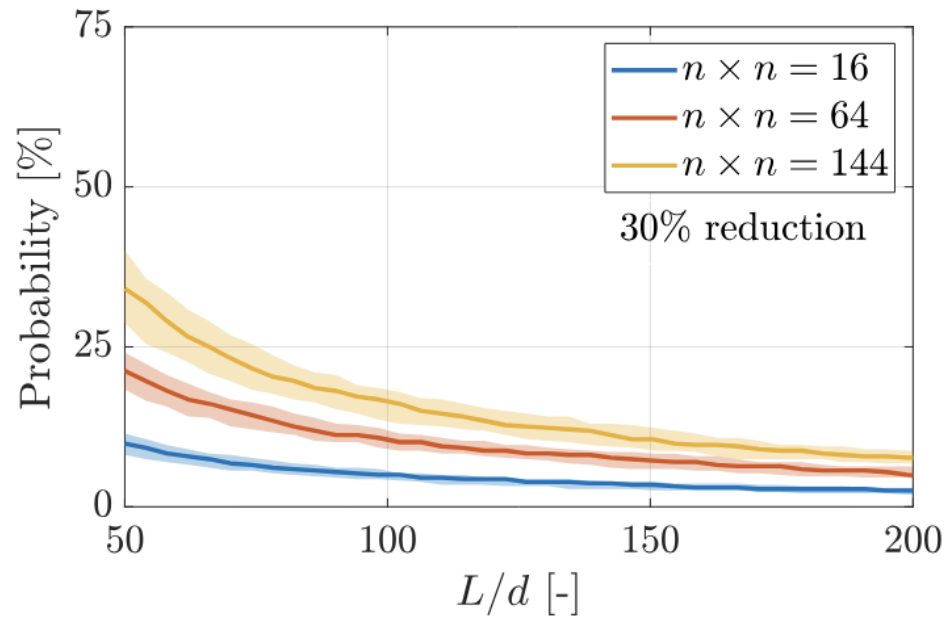
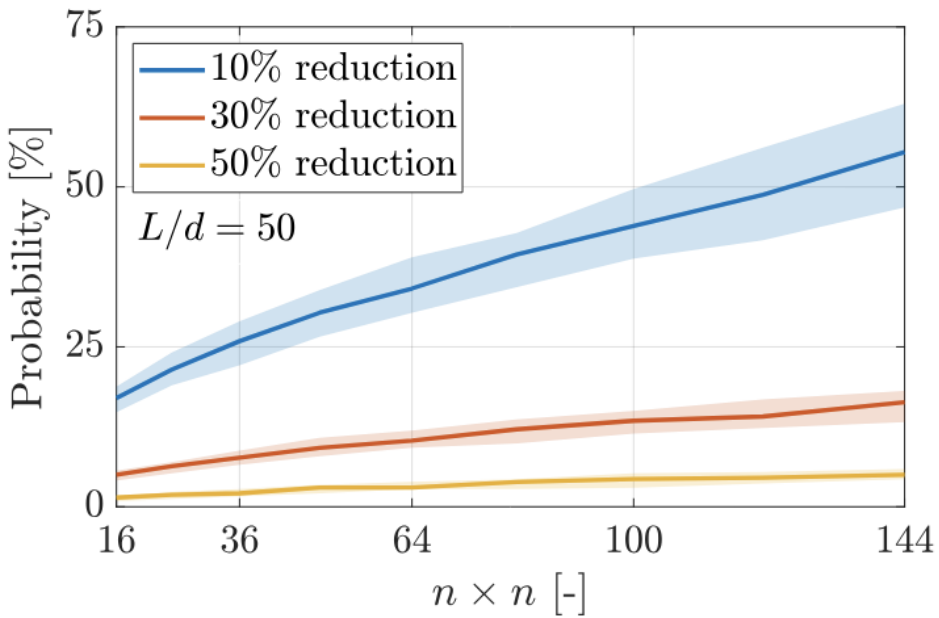
- Ran on EuroHPC LUMI supercomputer using 2–4 GPU for about two days.
- About  $50 \times 10^6$  particles connected by approximately  $150 \times 10^6$  beams.
- Inhomogeneity introduced by removing 20 % of the beams.
- $6 \times 6 \text{ km}^2$  ice sheet, 0.5 m thickness, velocity  $0.2 \text{ ms}^{-1}$ , pushed 3 km (about 4 h).



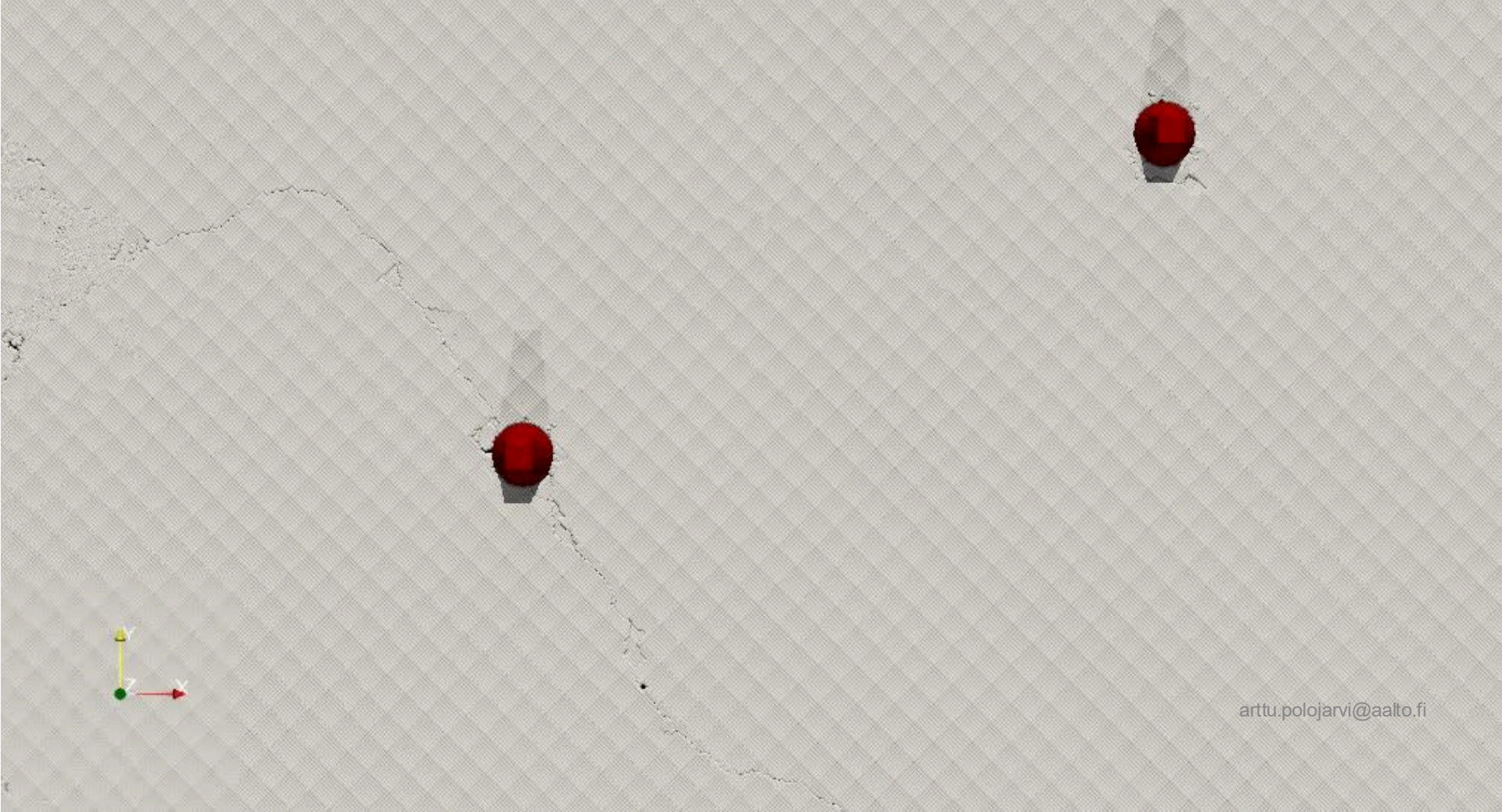




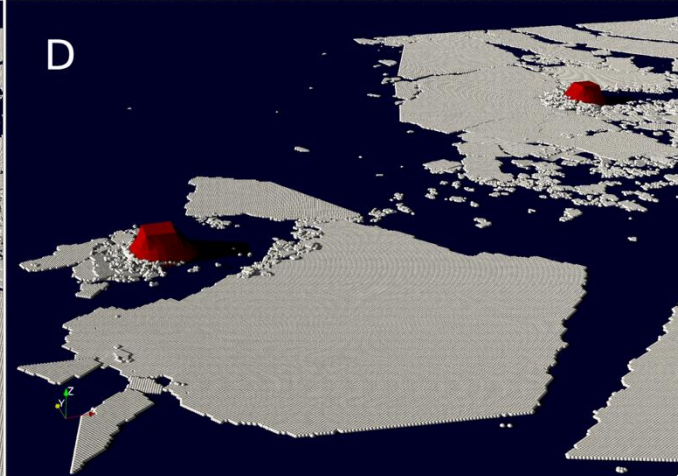
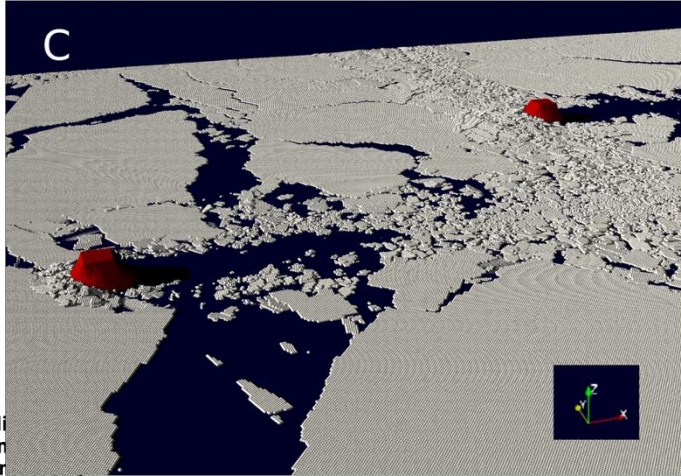
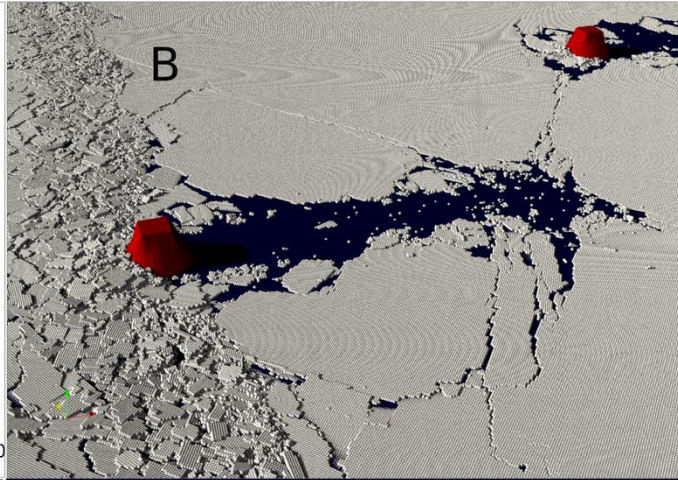
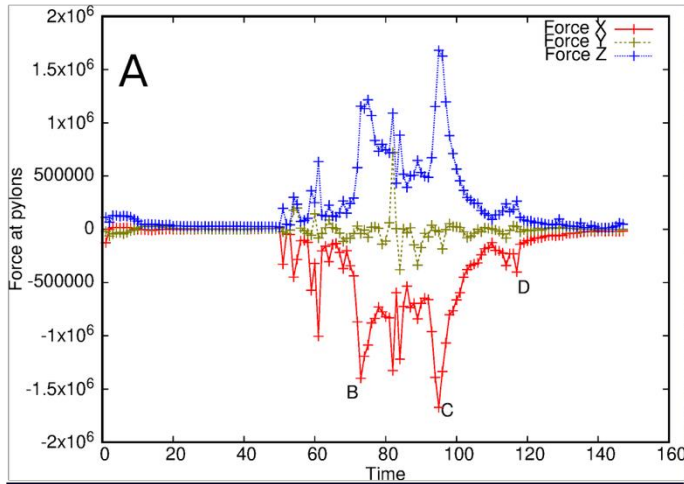




# Deformed ice resistance

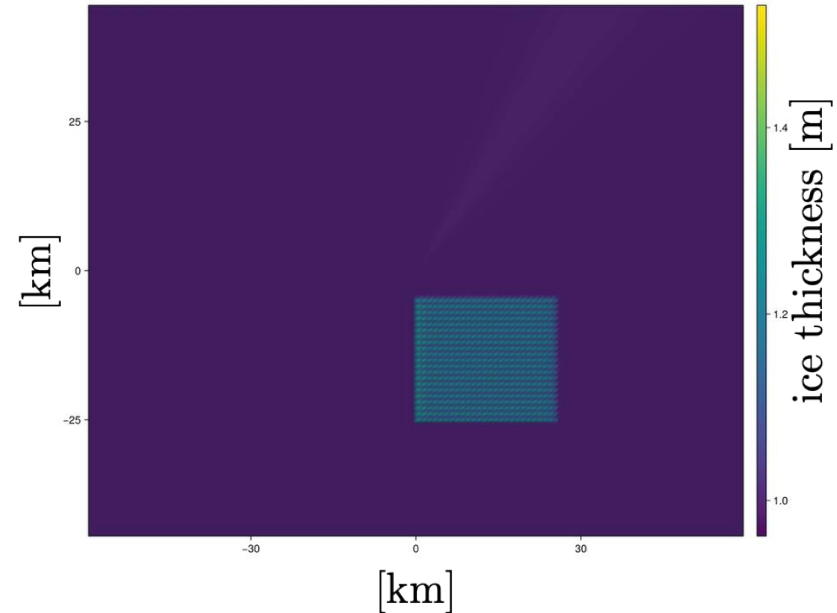


# Deformed ice resistance



# Hybrid modeling for large scales

- Continuum basin scale model: NEMO-SI3 (high-resolution:  $\sim 0.5$  km).
- Model parameterization done based on OWF-scale DEM results.
- Goal: model the effects on the scale of Baltic sea over one ice season.



**Thank you!**

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*Polojärvi, A., Prasanna, M., & Åström, J. A. (2025). Level ice resistance of a wind farm. Geophysical Research Letters, 52, e2025GL115284.*

*Polojärvi, A., Prasanna, M., and Åström, J. (2025). Ice loads on wind turbines of a wind farm. Proceedings of the 28th International Conference on Port and Ocean Engineering under Arctic Conditions, POAC'25.*

*Åström, J., Robertsen, F., Haapala, J., Polojärvi, A., Uiboupin, R., and Maljutenko, I. (2024) A large-scale high-resolution numerical model for sea-ice fragmentation dynamics, The Cryosphere, 18, 2429–2442*

*Åström, J., & Polojärvi, A. (2024). High-resolution fracture dynamics simulation of pack-ice and drift-ice formation during sea ice break up events using the HiDEM2.0 code. Geophysical Research Letters, 51, e2024GL110552.*

*Prasanna, M., Vuollekoski, H., Polojärvi, A., Haapala, J., Lensu, M., & Åström, J. (2024). Multi scale modelling of interaction between pack ice and offshore structures. In Proceedings of the 27th IAHR International Symposium on Ice. Gdańsk, Poland, 9–13 June, 2024.*

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**Co-funded by  
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