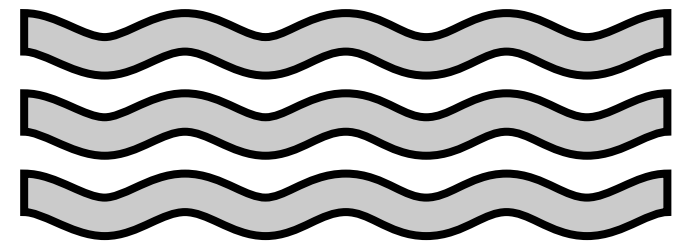


Down-scale wave hydrodynamic analysis for marine structures - the NORA-SARAH approach

NordPIANC 2024
Svolvær, Lofoten

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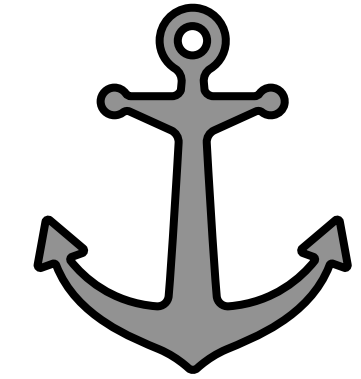
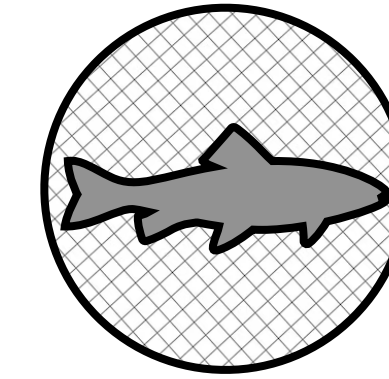
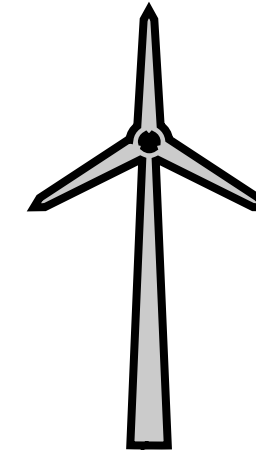
The Question



Offshore wave



- Bathymetry changes
- Coastlines
- Wave transformation
- Coastal nonlinearity



Structure

JONSWAP



The Challenges in Norway



Andenes, Versterålen Archipelago

- **Deepwater**
- **Rapid water depth variations**
- **Strong diffraction**

Limitations to commonly used numerical wave models

Spectral models

e.g. SWAN

Diffraction

Shallow water models

e.g. FUNWAVE

Water depth

$kd \sim 4$

Mild-slope model

e.g. CGWAVE

Depth gradient

Slope < 1:3

REEF3D

- Developed at the Department of Civil and Environmental Engineering

Multiscale Framework:

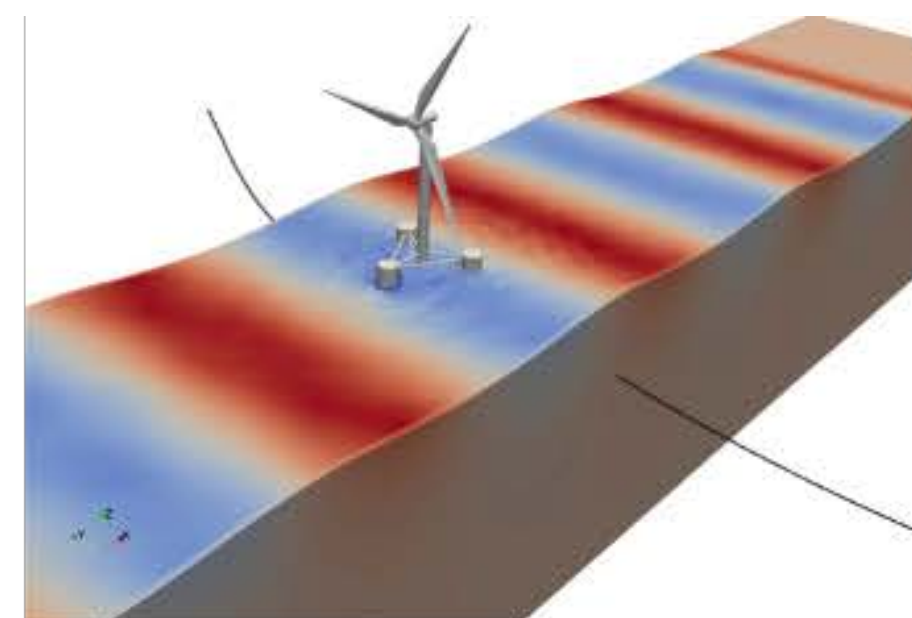
- high-order discretization (FDM)
- mesh with immersed boundary
- high-performance solvers
- consistent parallelization (MPI)
- hydrodynamic coupling

Multiphysics for Hydraulic, Coastal, Offshore:

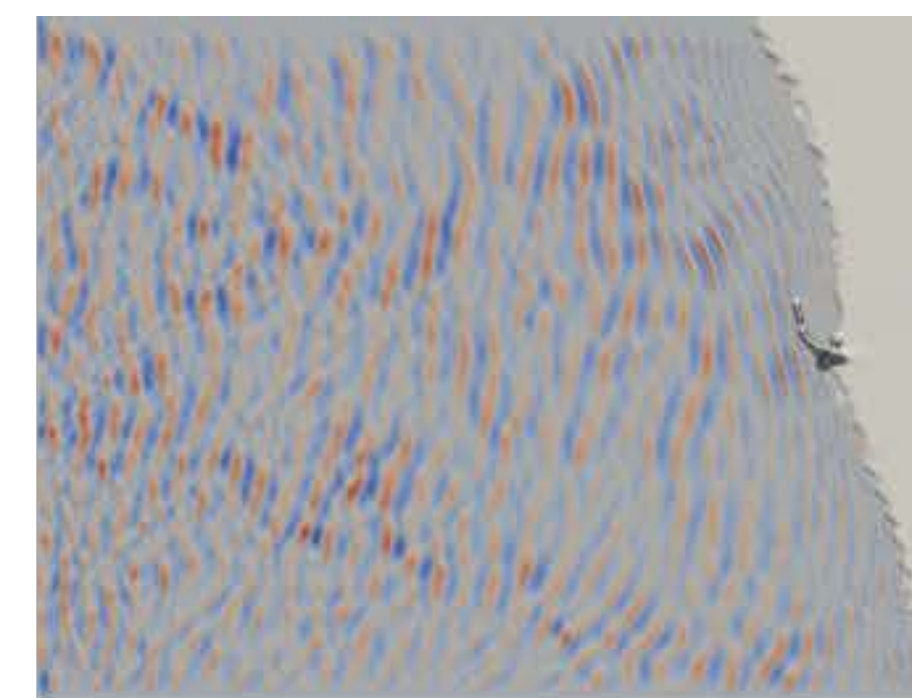
- sediment transport
- floating bodies
- porous structures
- vegetation
- stratified flow

- Published under GNU GPL v3

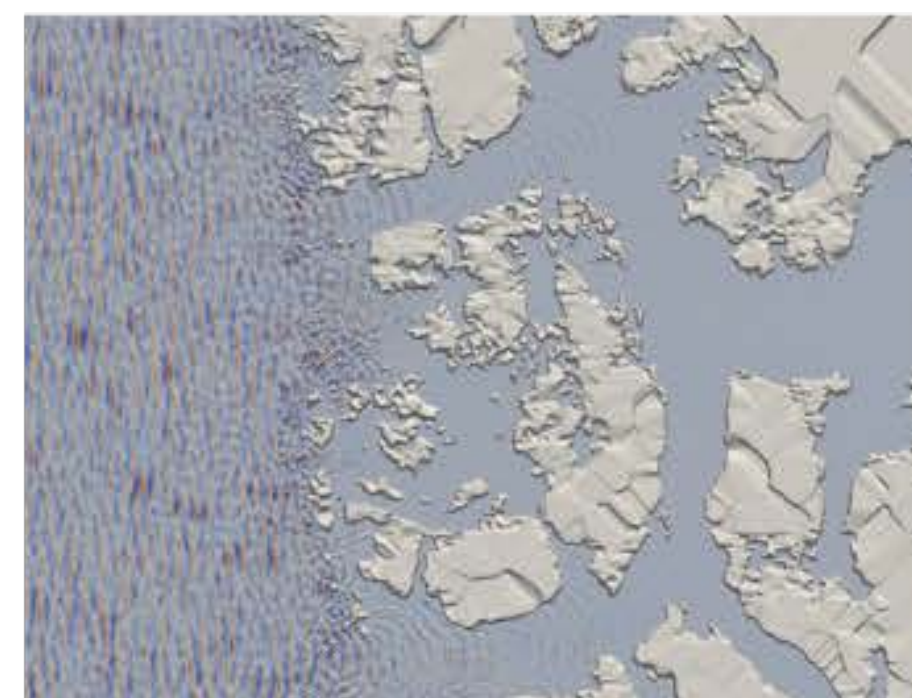
www.reef3d.com



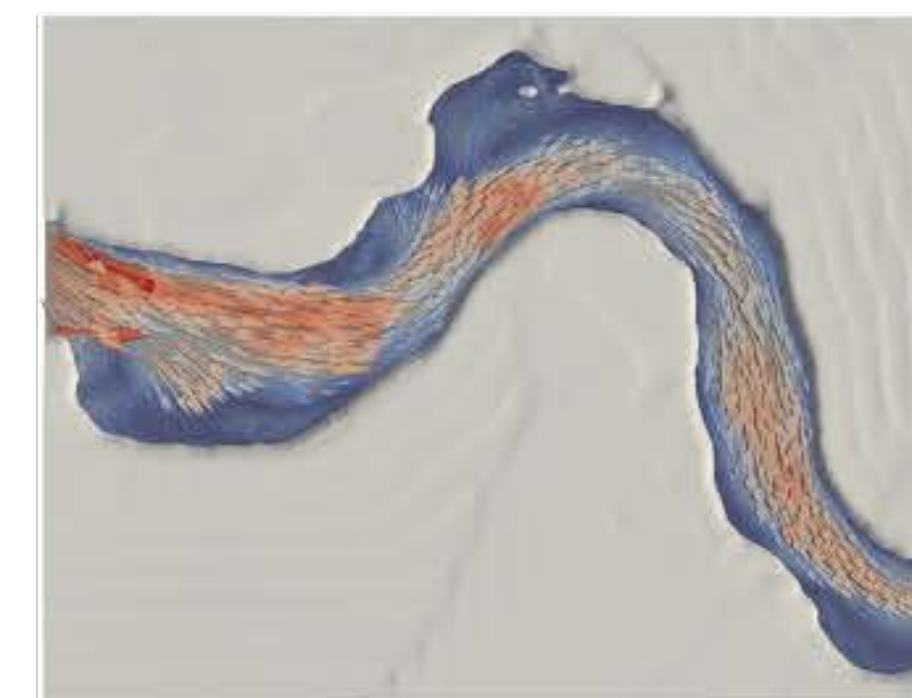
CFD Two-Phase Navier-Stokes Equations



NHFLOW Non-hydrostatic Navier-Stokes Equations

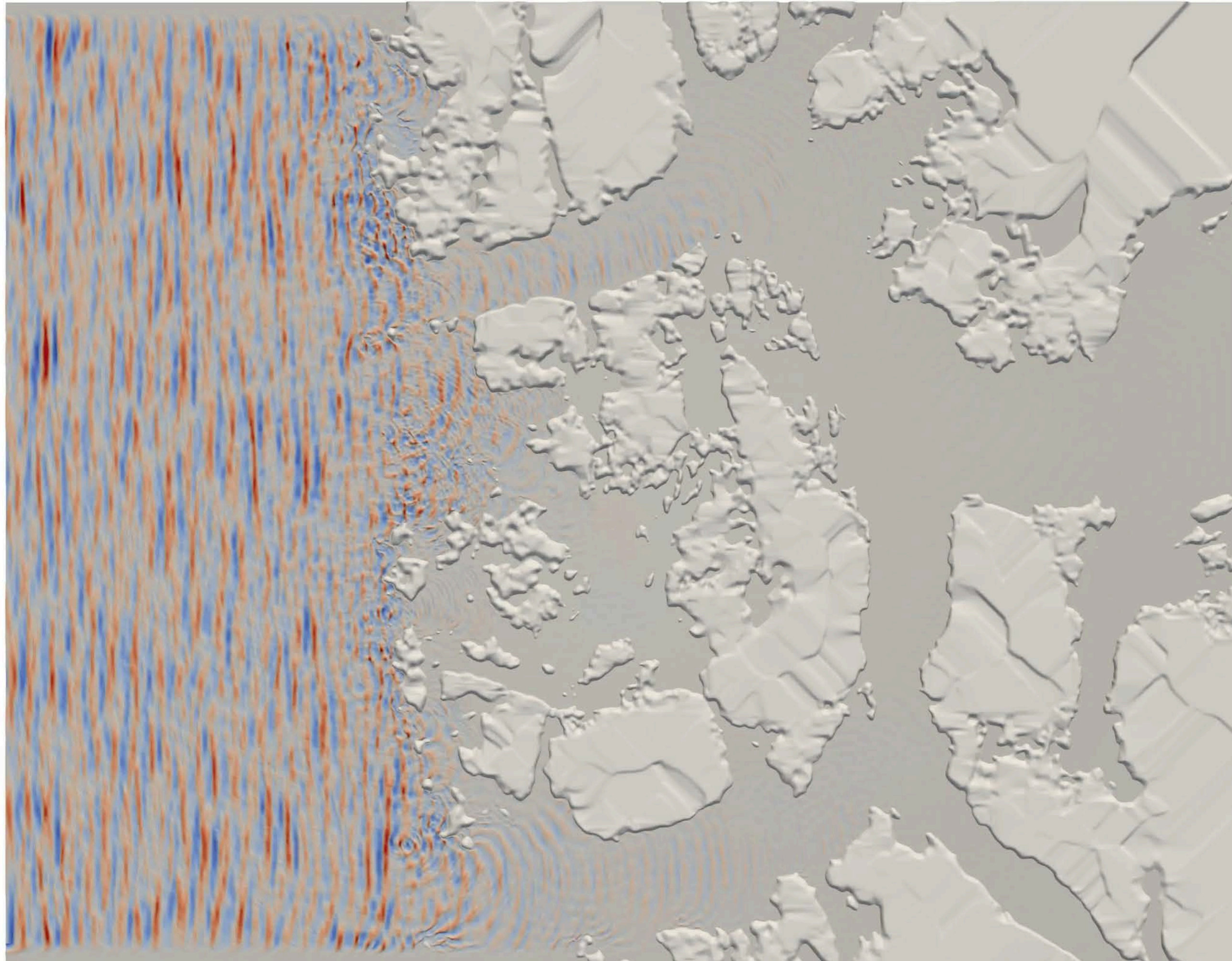


FNPF Fully Nonlinear Potential Flow



SFLOW Non-hydrostatic SWE

REEF3D:FNPF



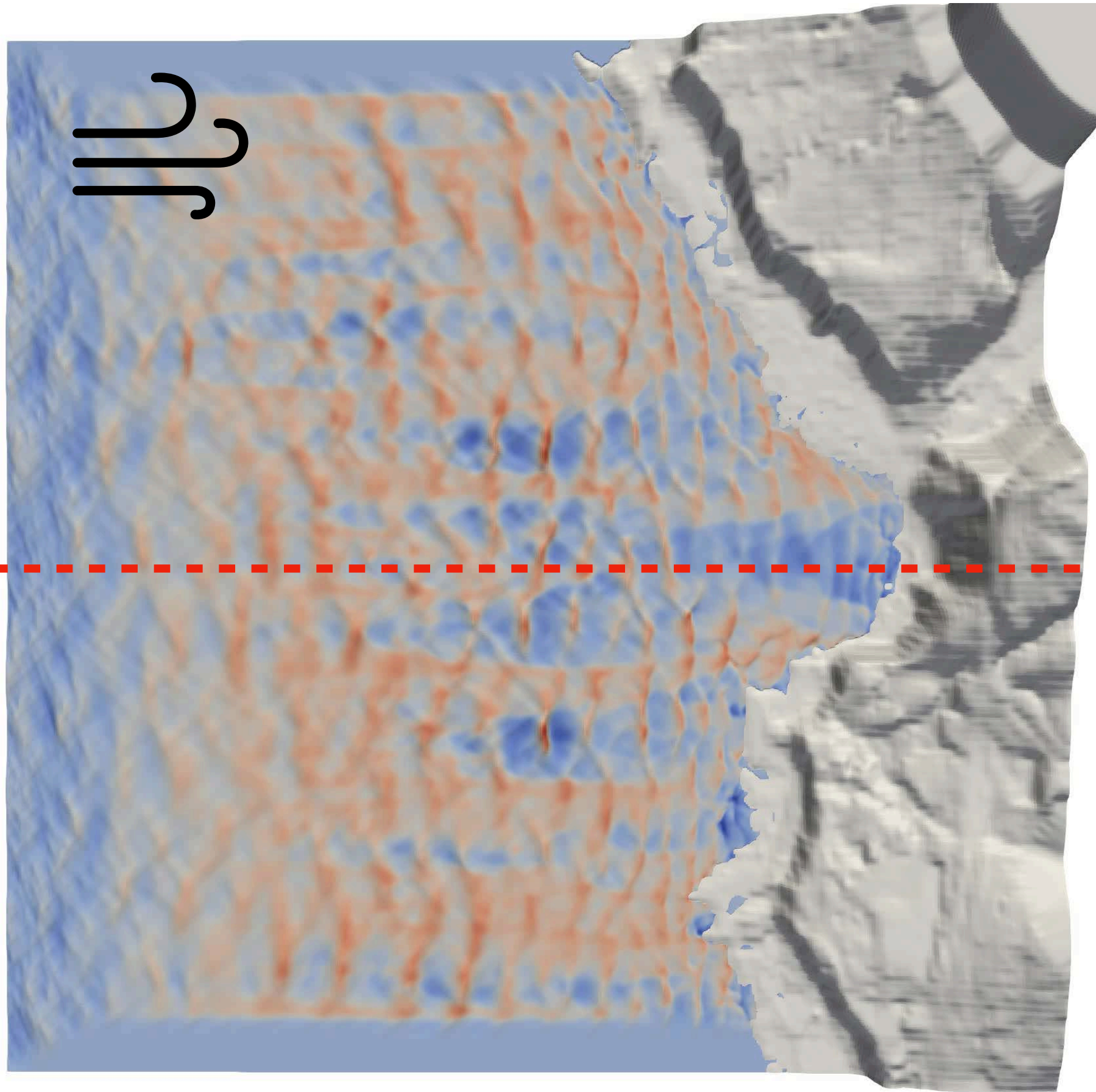
REEF3D::FNPF

- Fully-non linear potential flow
- stable and accurate for steep and breaking waves
- **from deep to shallow water** (bathymetry effects included)
- coastline algorithm for irregular boundaries

Bjørnafjord 45 km x 35 km

REEF3D::NHFLOW

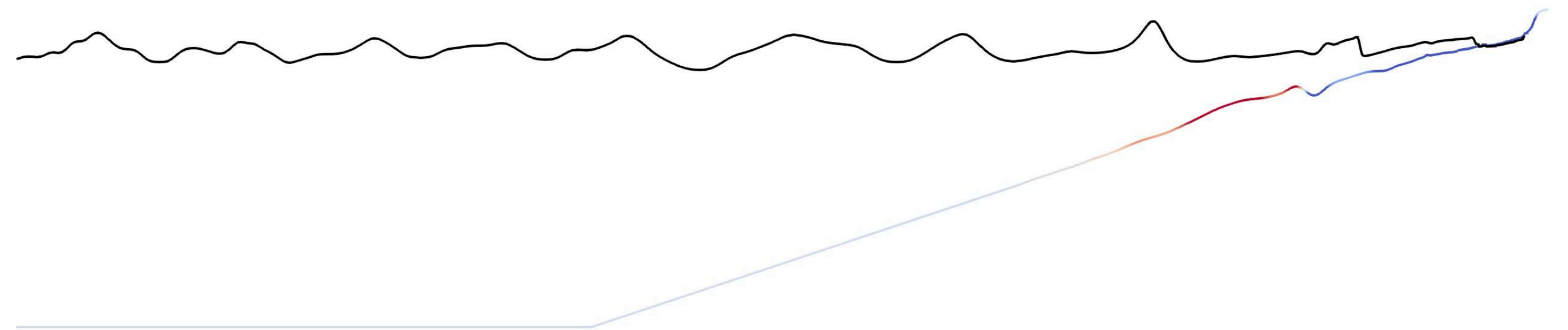
Coastal dynamics



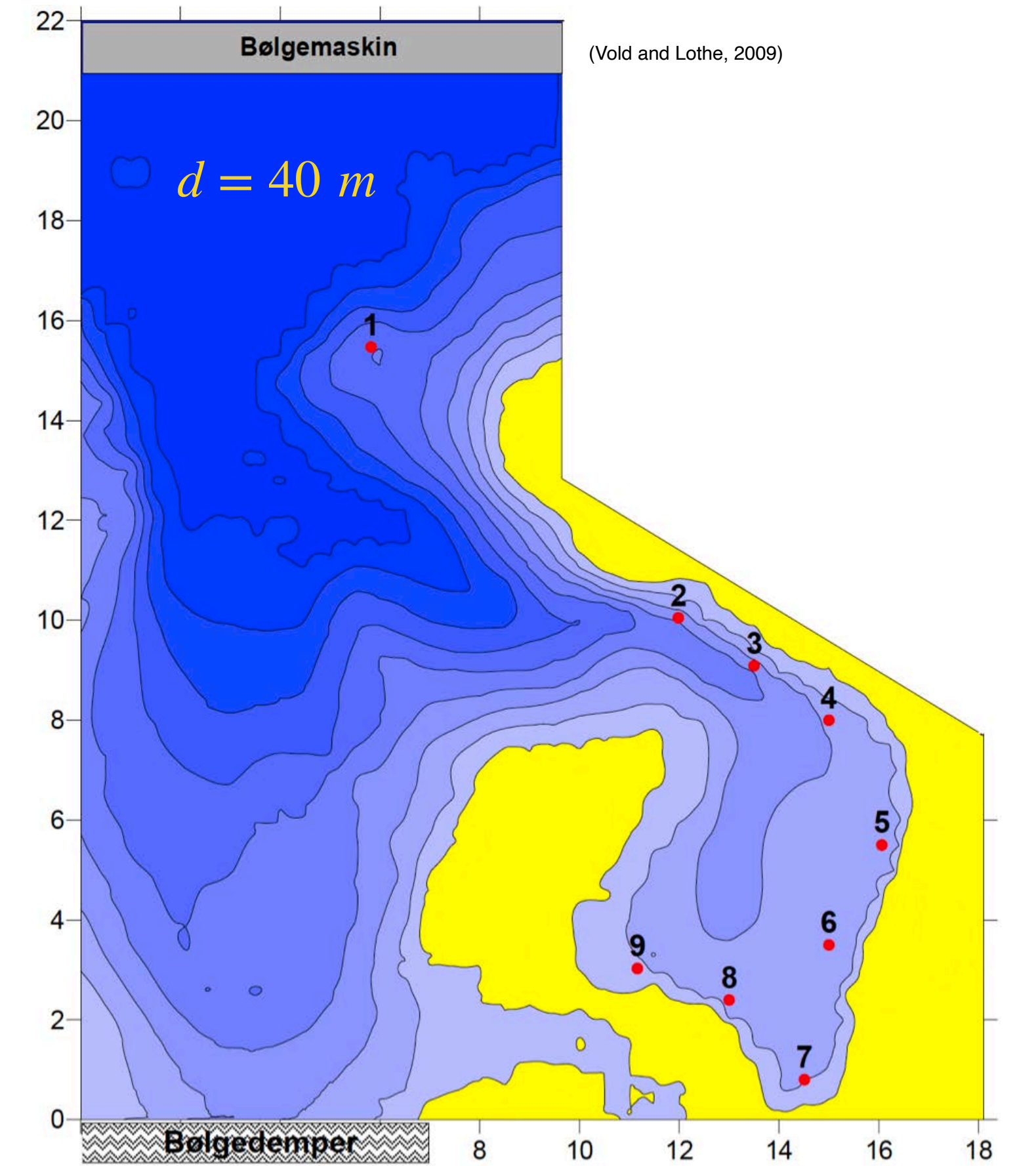
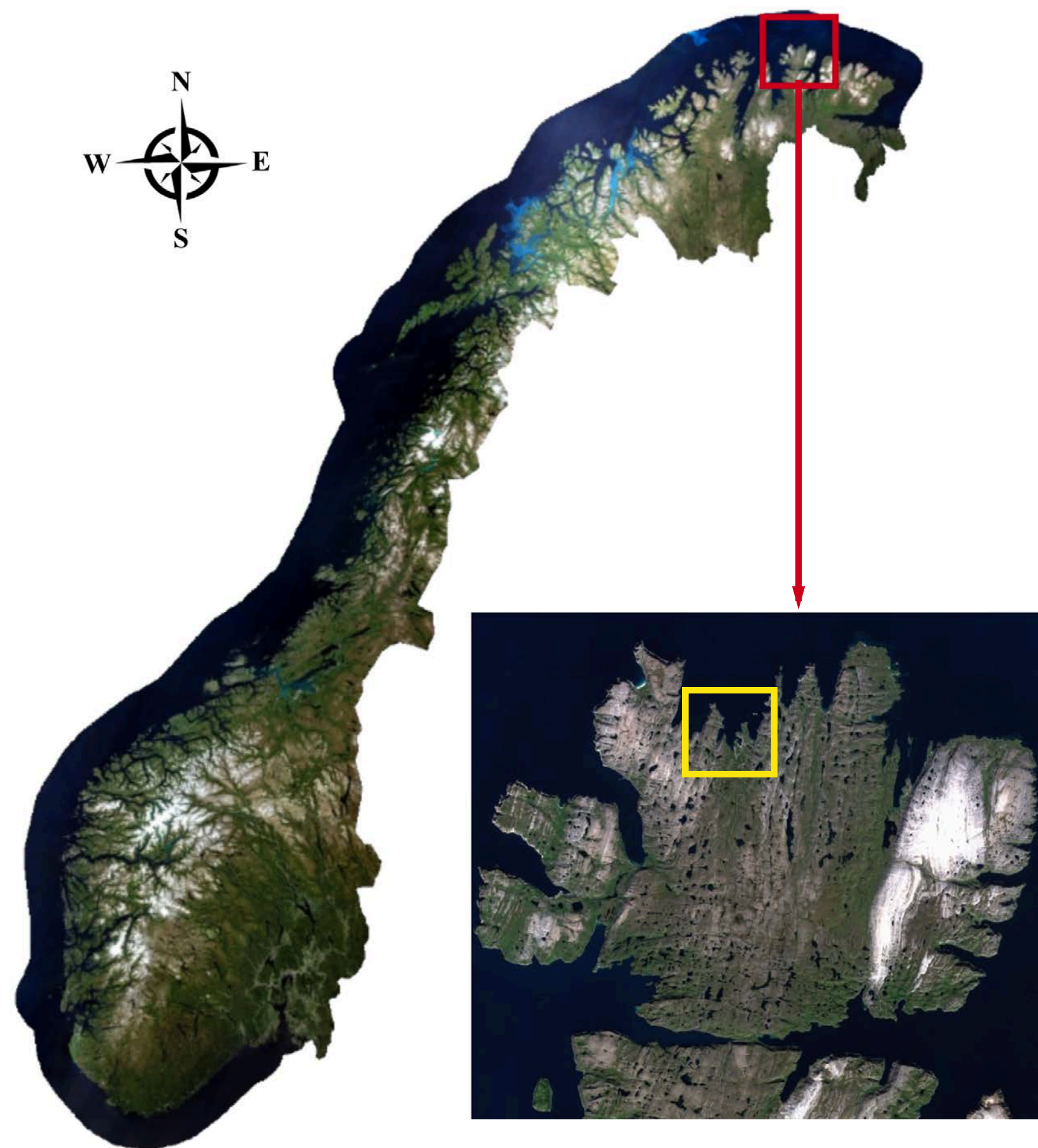
REEF3D::NHFLOW

- Non-hydrostatic model
- wave features similar to FNPF
- **includes coastal processes** e.g:
 - current
 - turbulence
 - wind
 - sediment

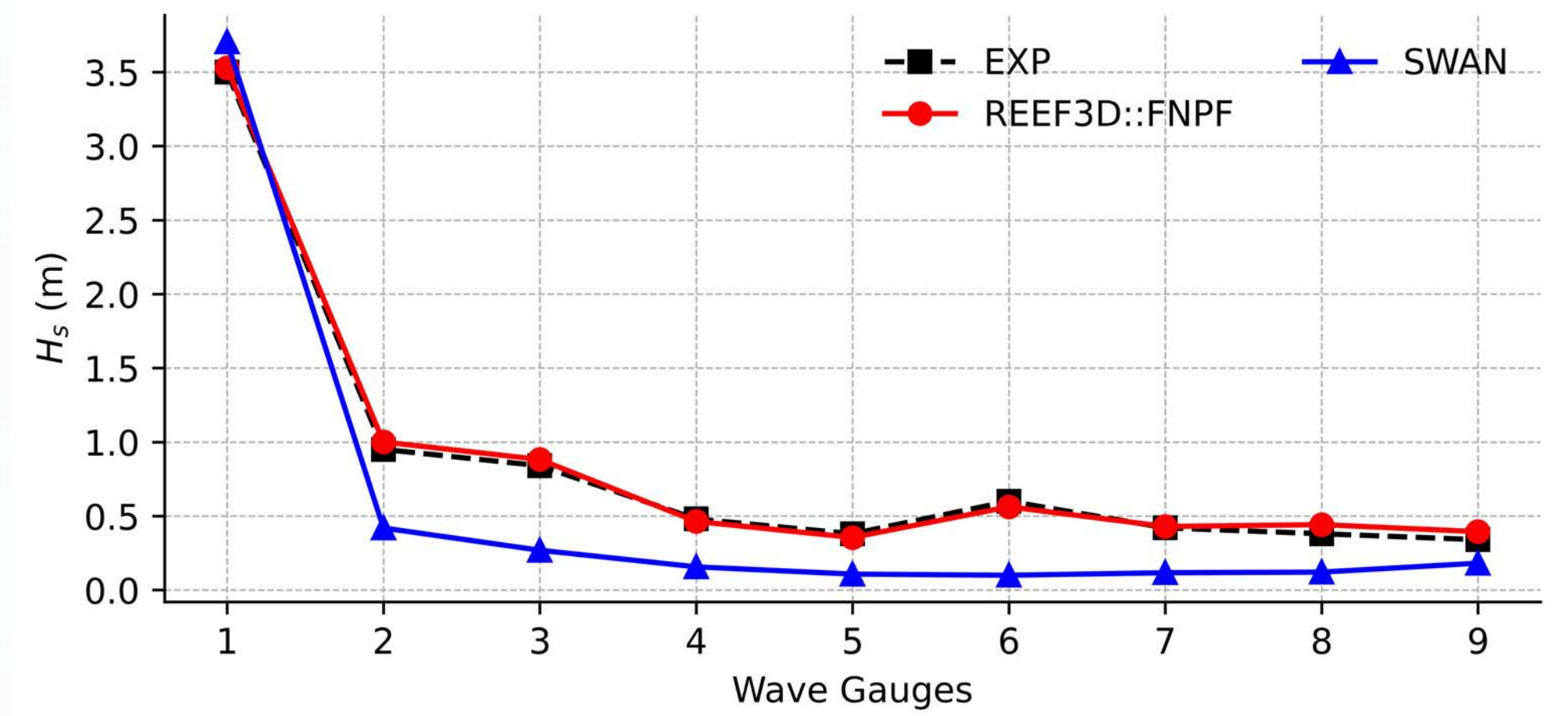
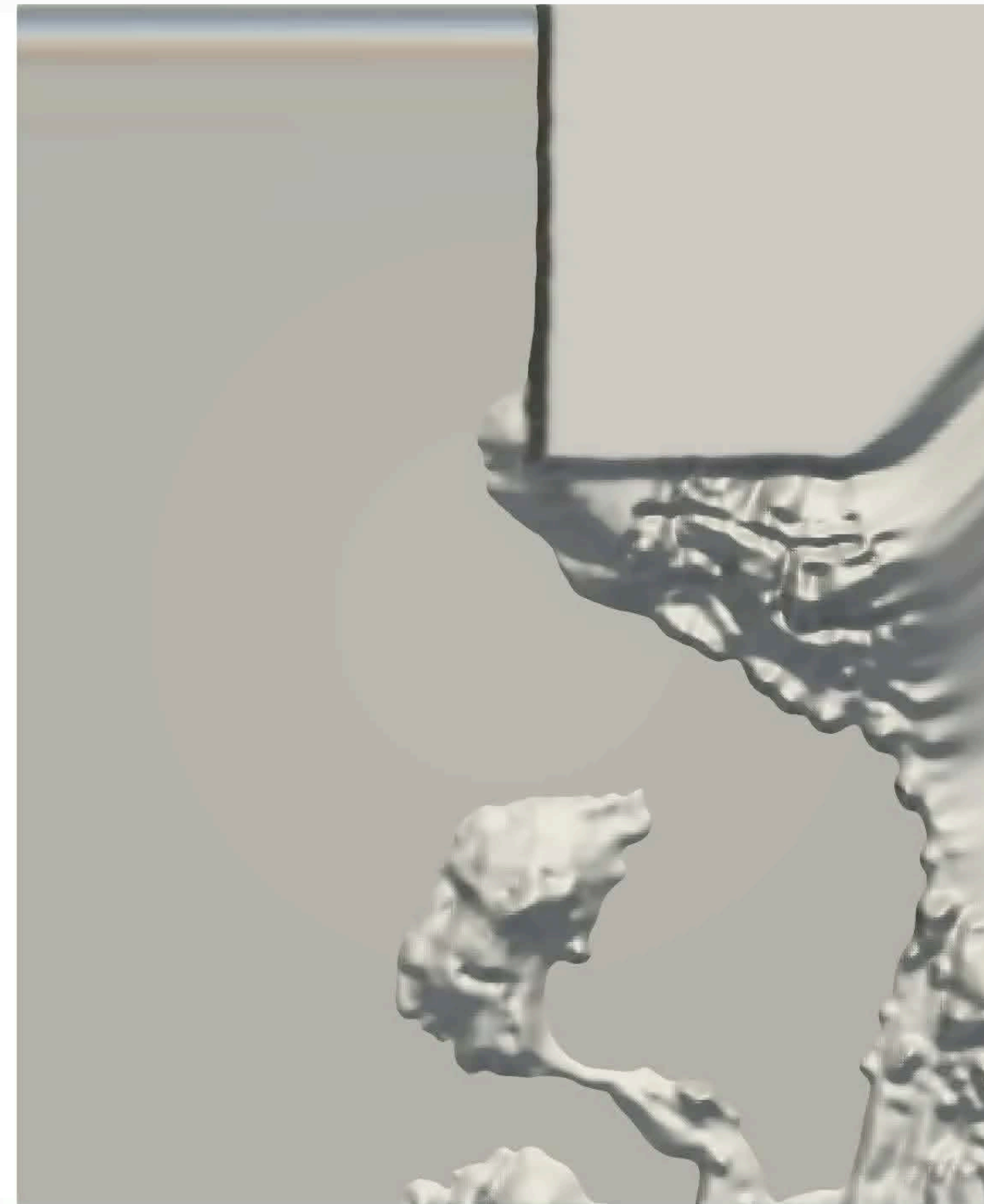
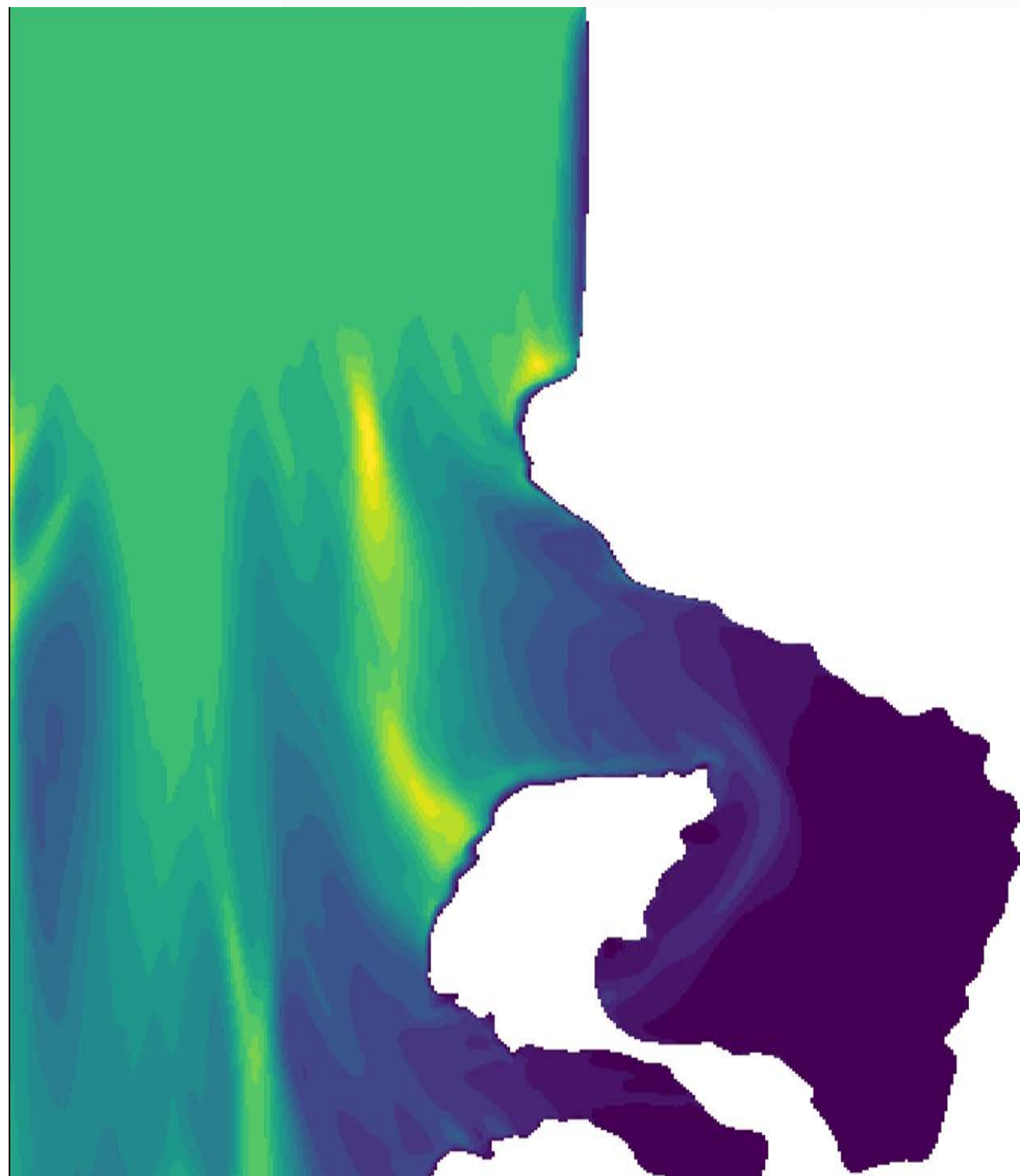
Wind + Current + Sediment



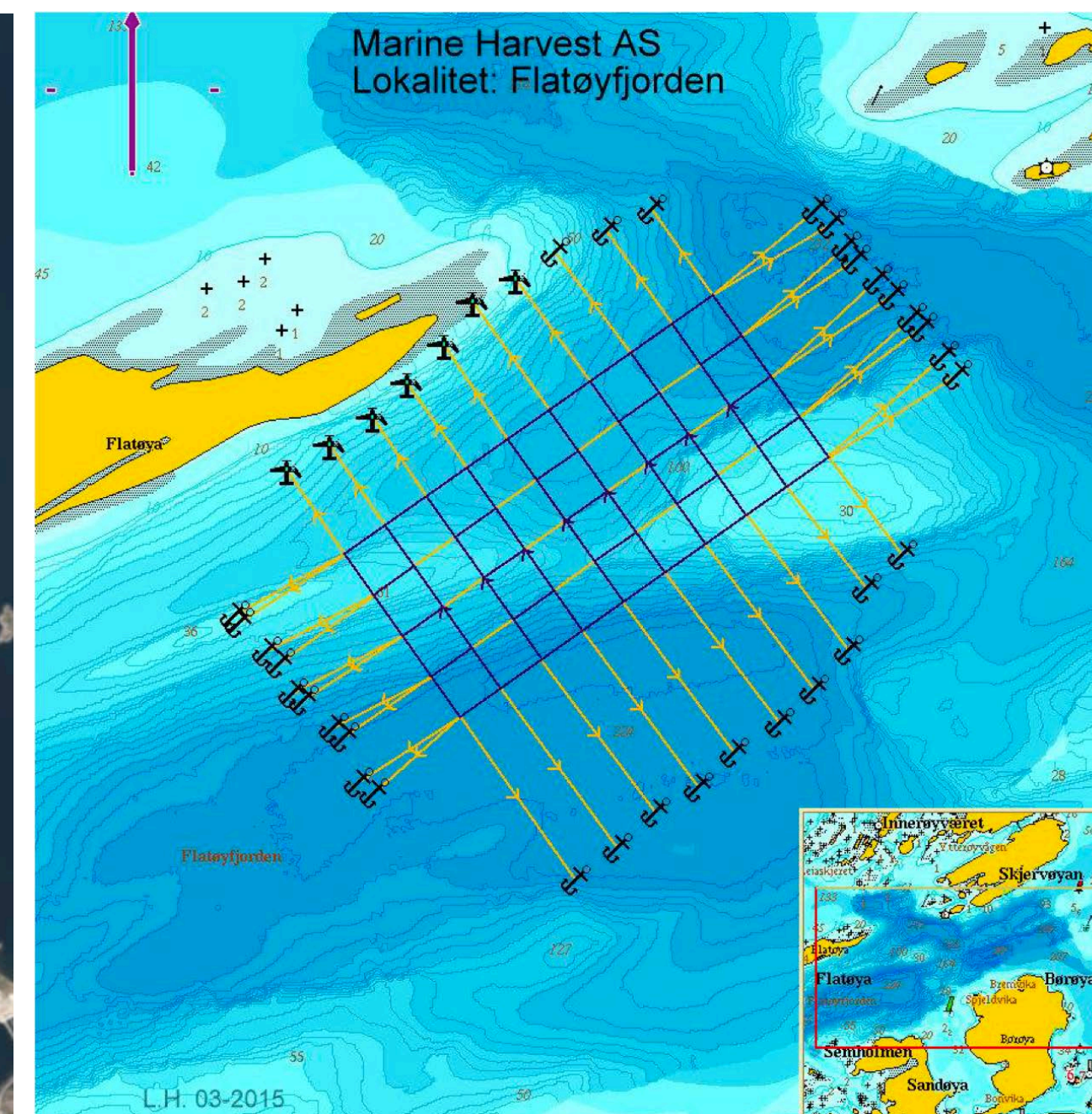
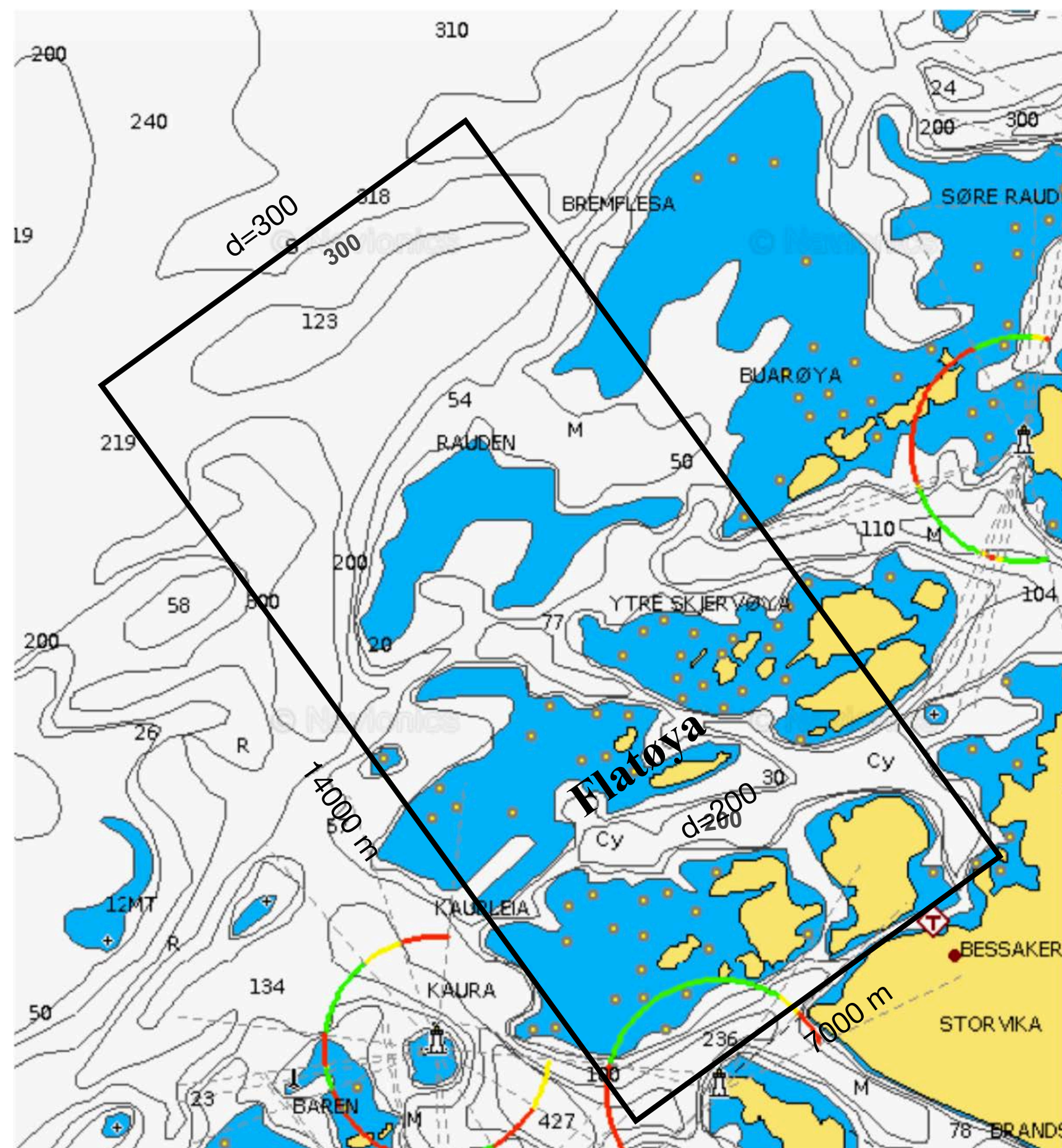
Mehamn



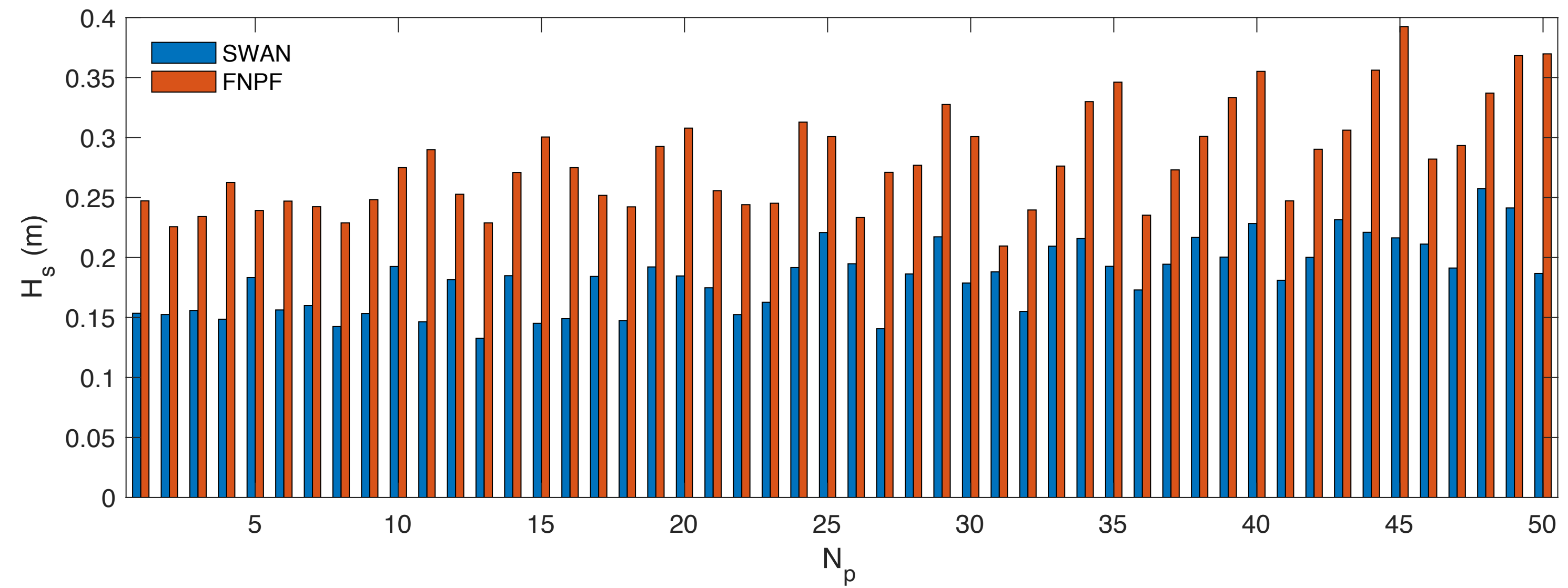
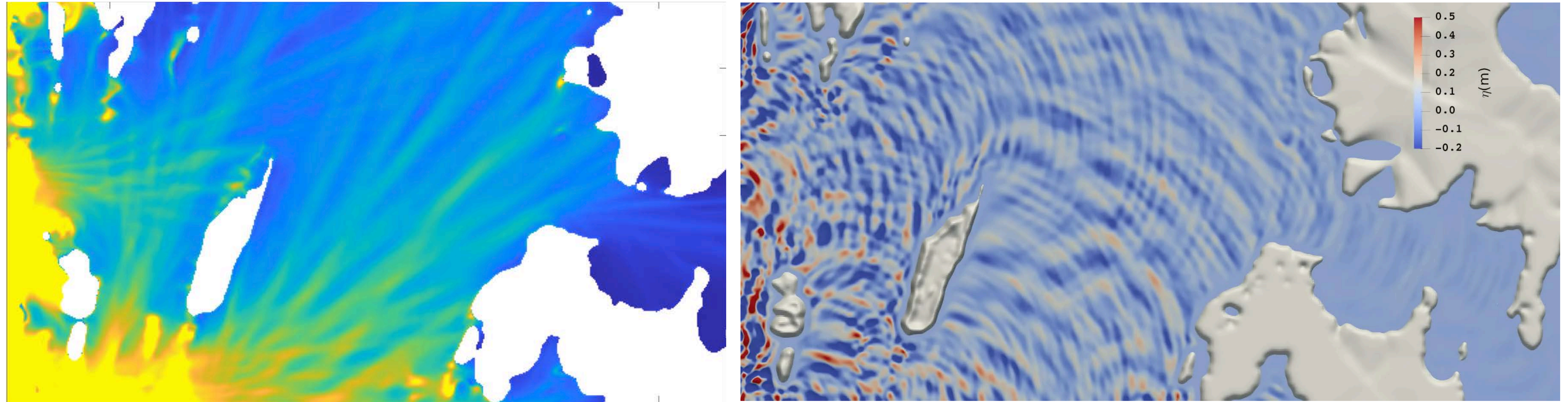
Mehamn



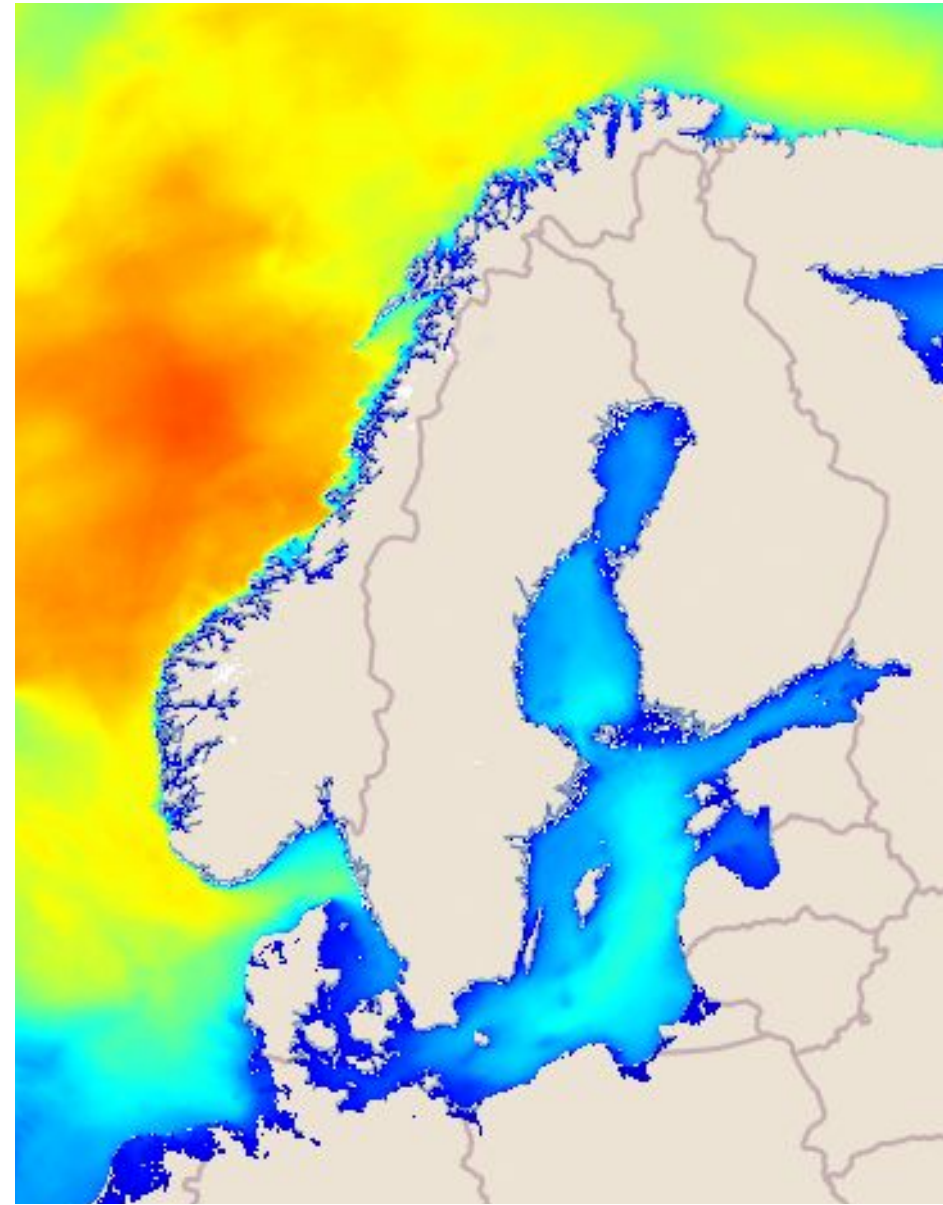
Flatøya



Flatøya

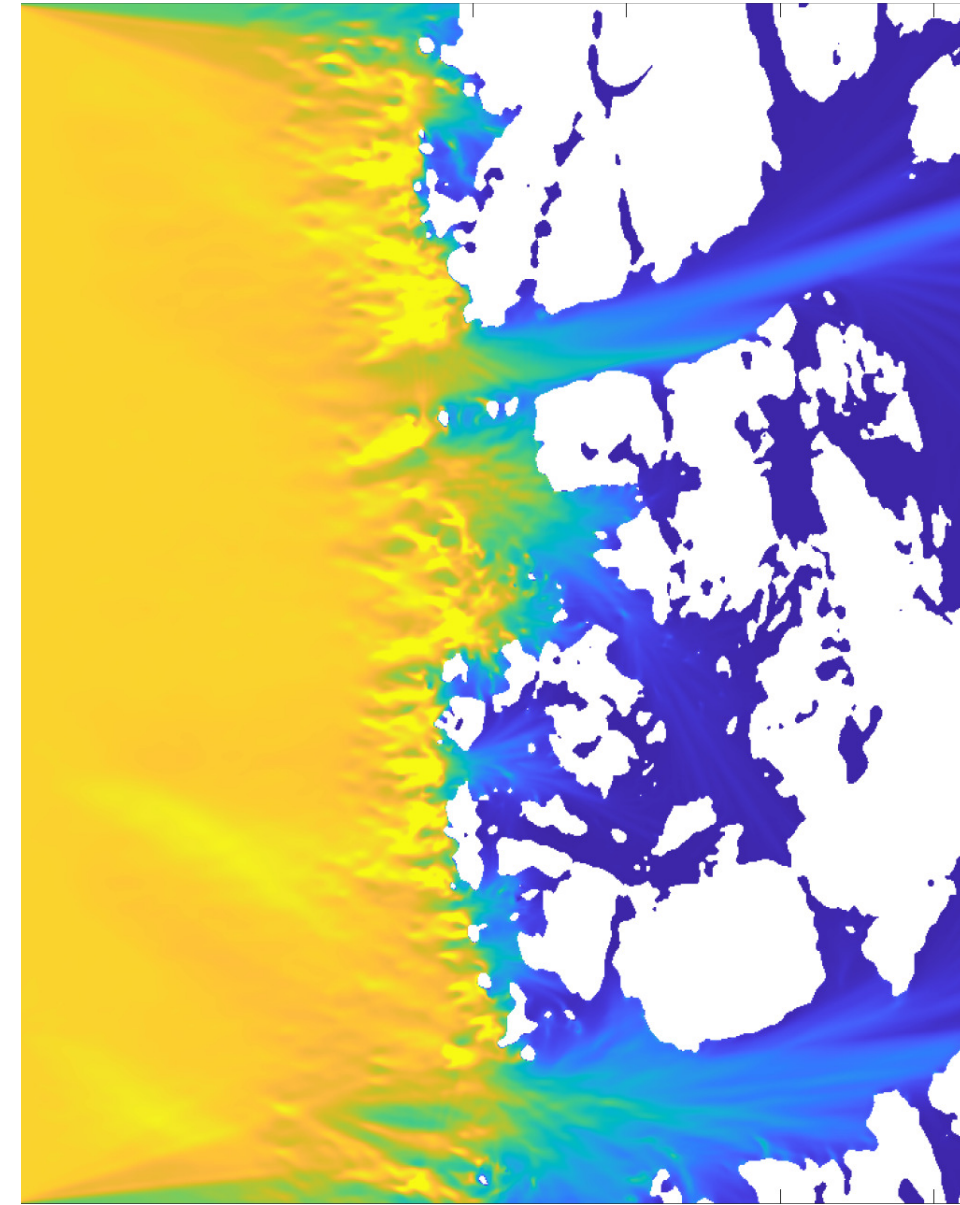


NORA-SARAH



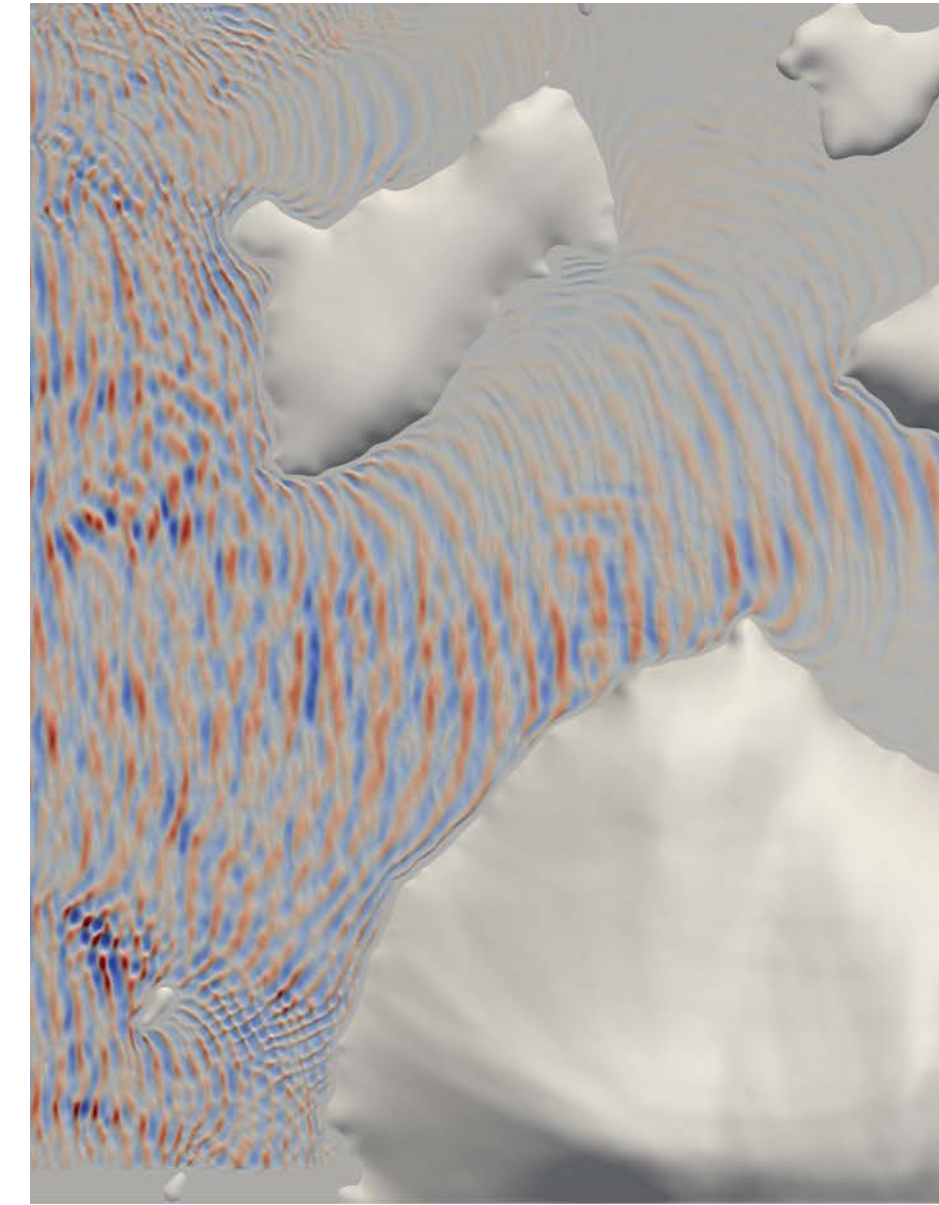
Met-Ocean data

e.g. NORA3
NORA10
DNORA



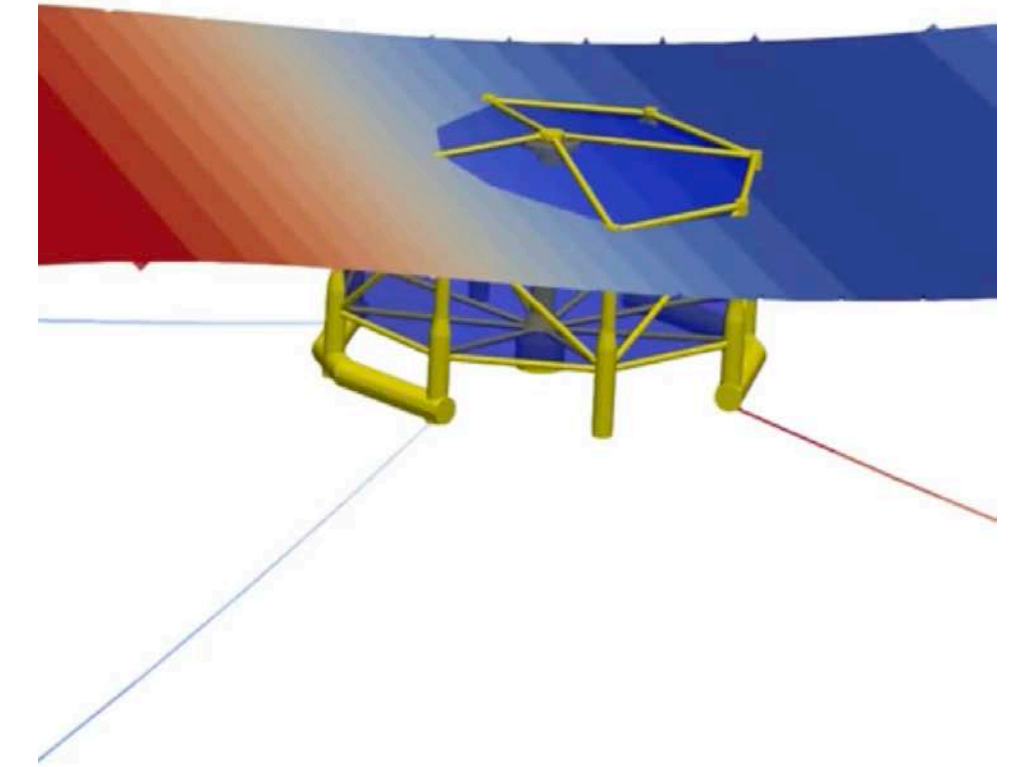
Phase-averaging
wave model

e.g. SWAN



Phase-resolving
wave model

e.g.
REEF3D::FNPF
REEF3D::NHFLOW



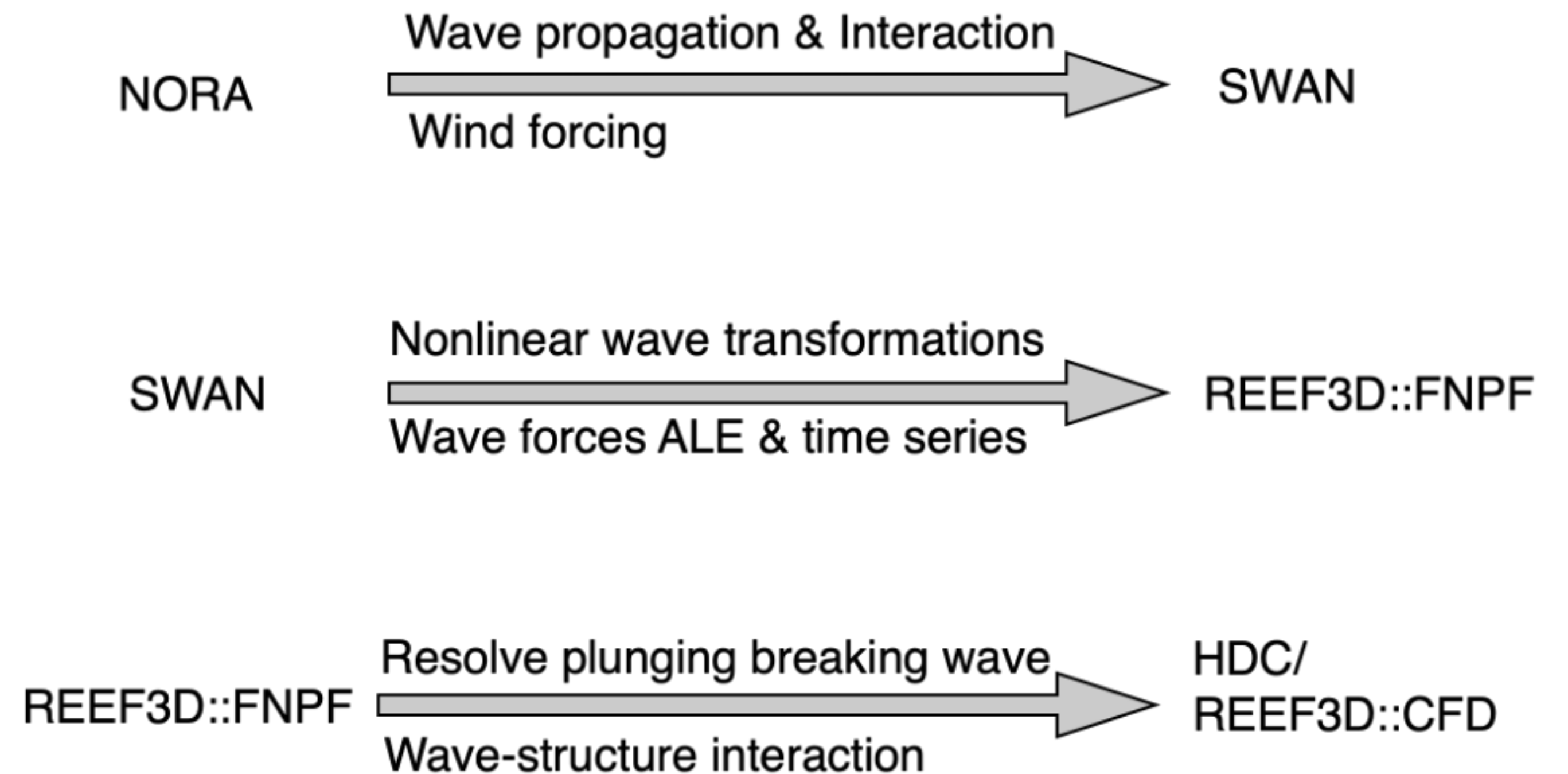
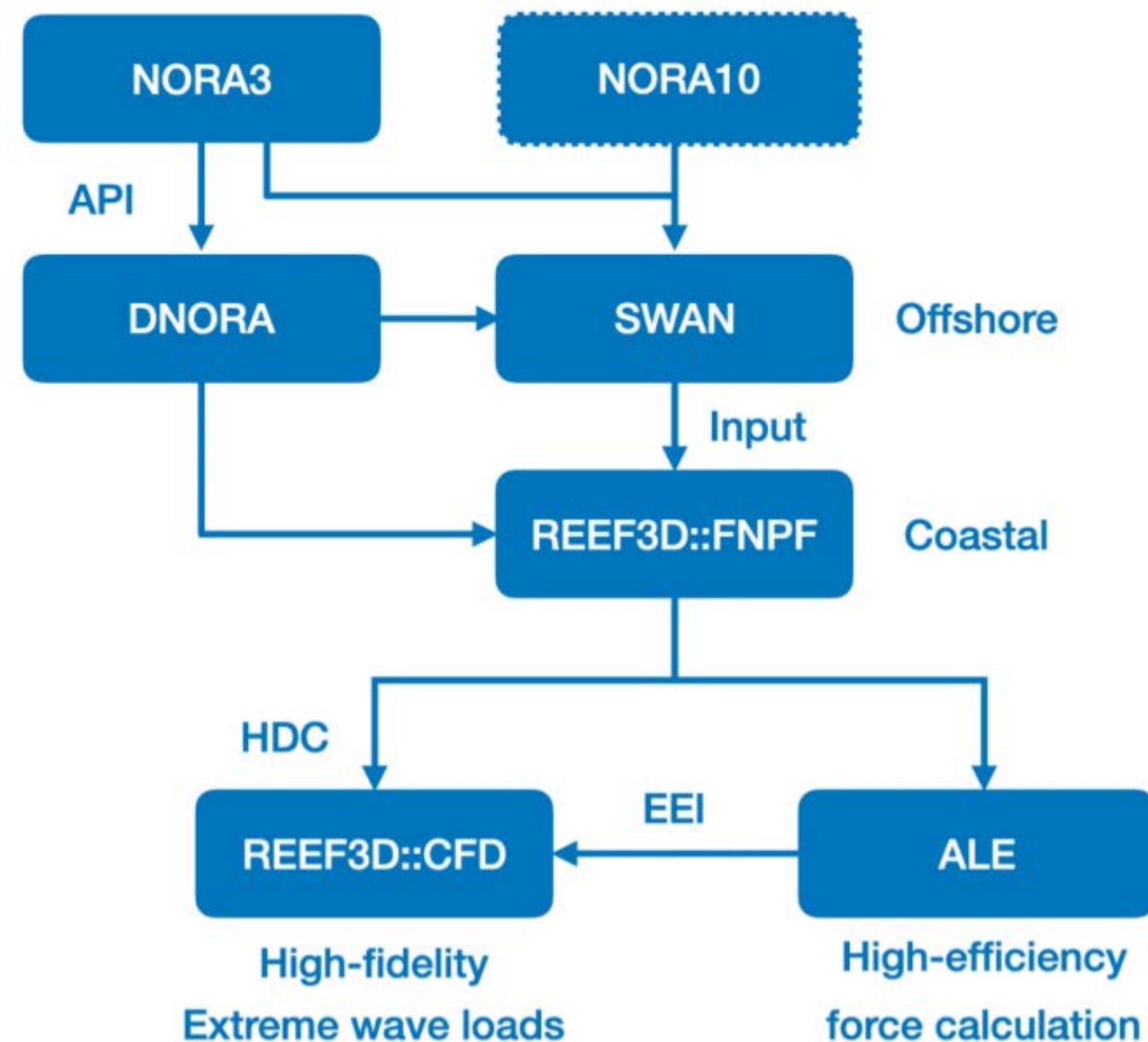
Computational fluid
dynamics (CFD)

e.g.
REEF3D::CFD

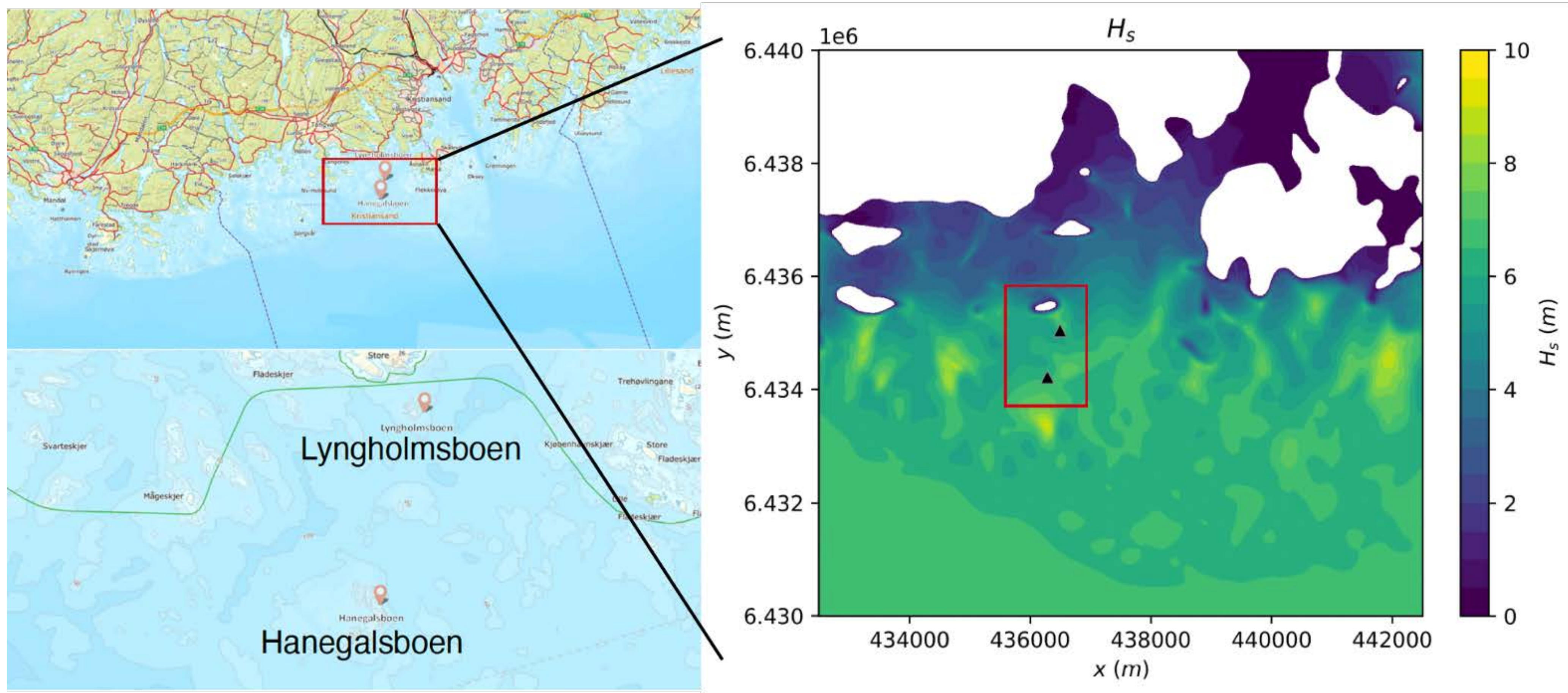
NORA-SARAH

NORA-SWAN-REEF3D-ALE-HDC

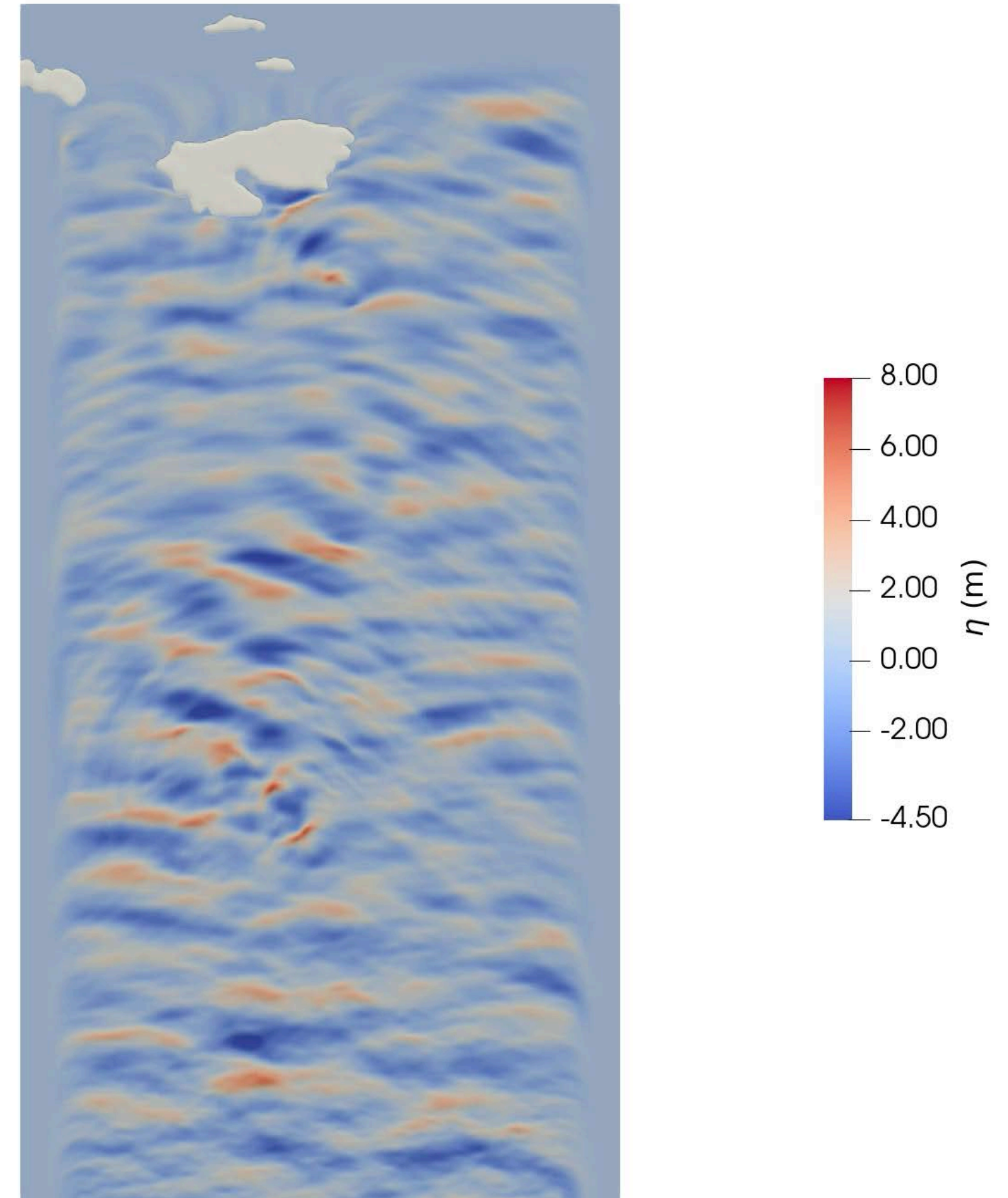
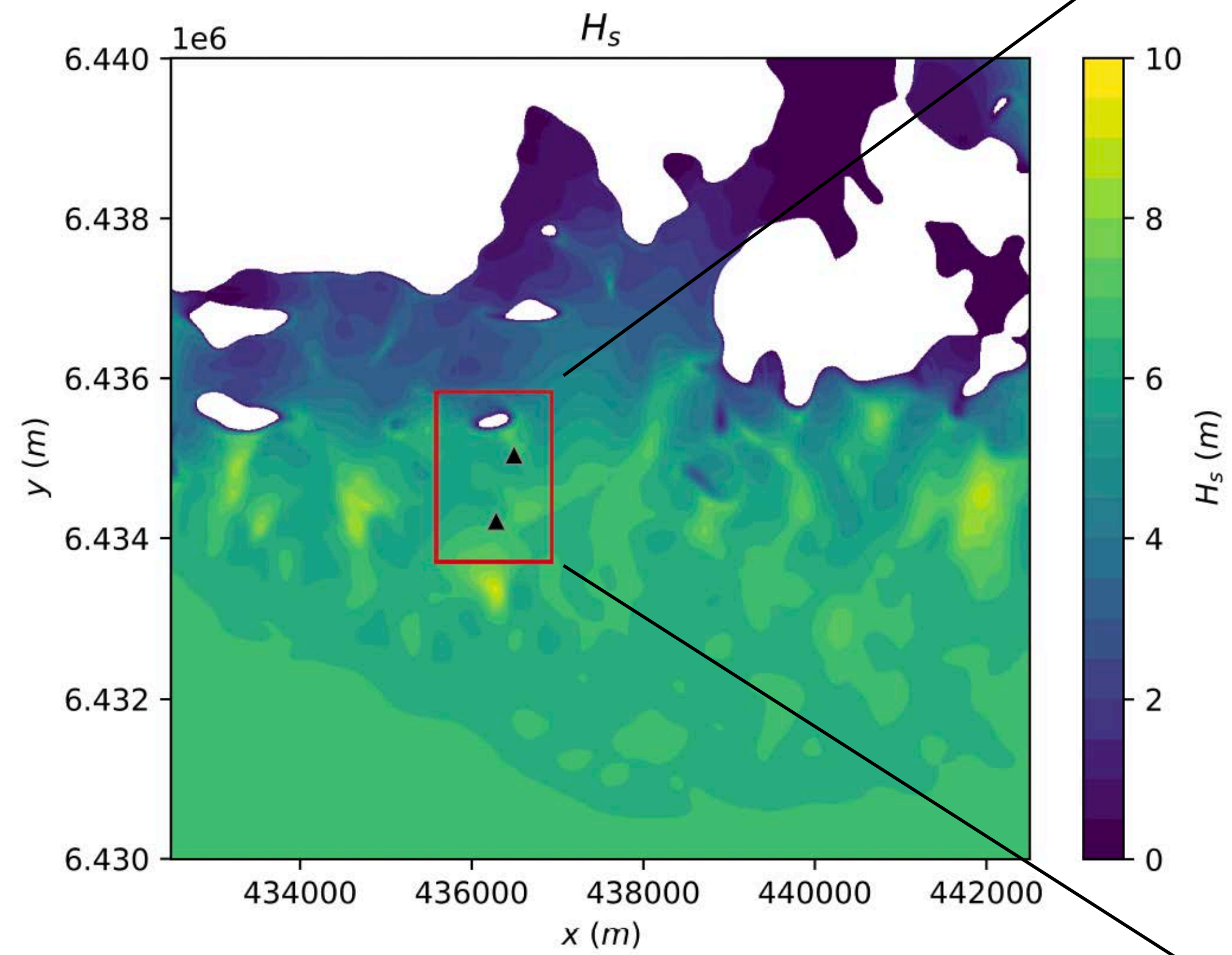
All codes open-source / All data open-access



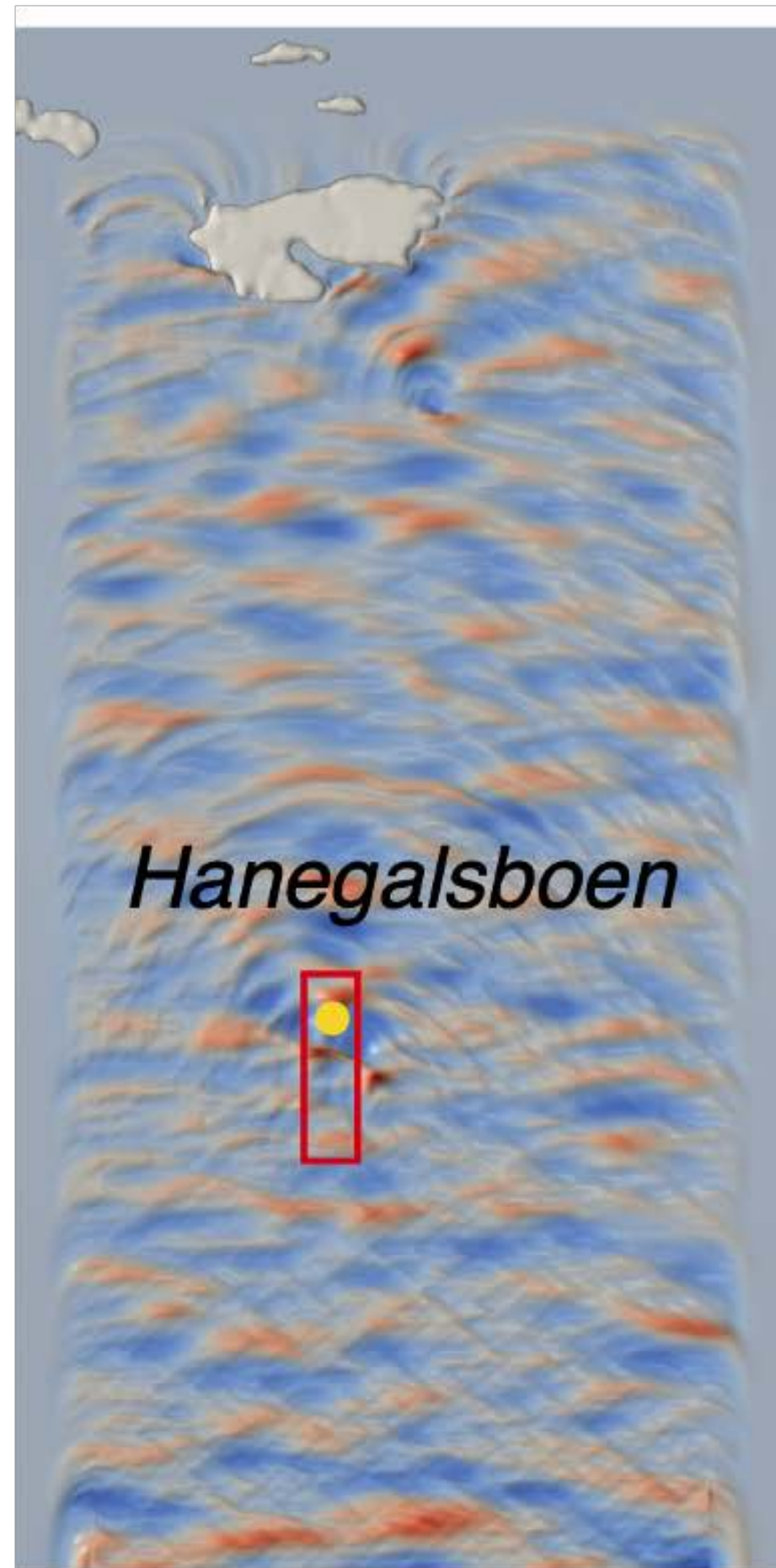
NORA-SARAH



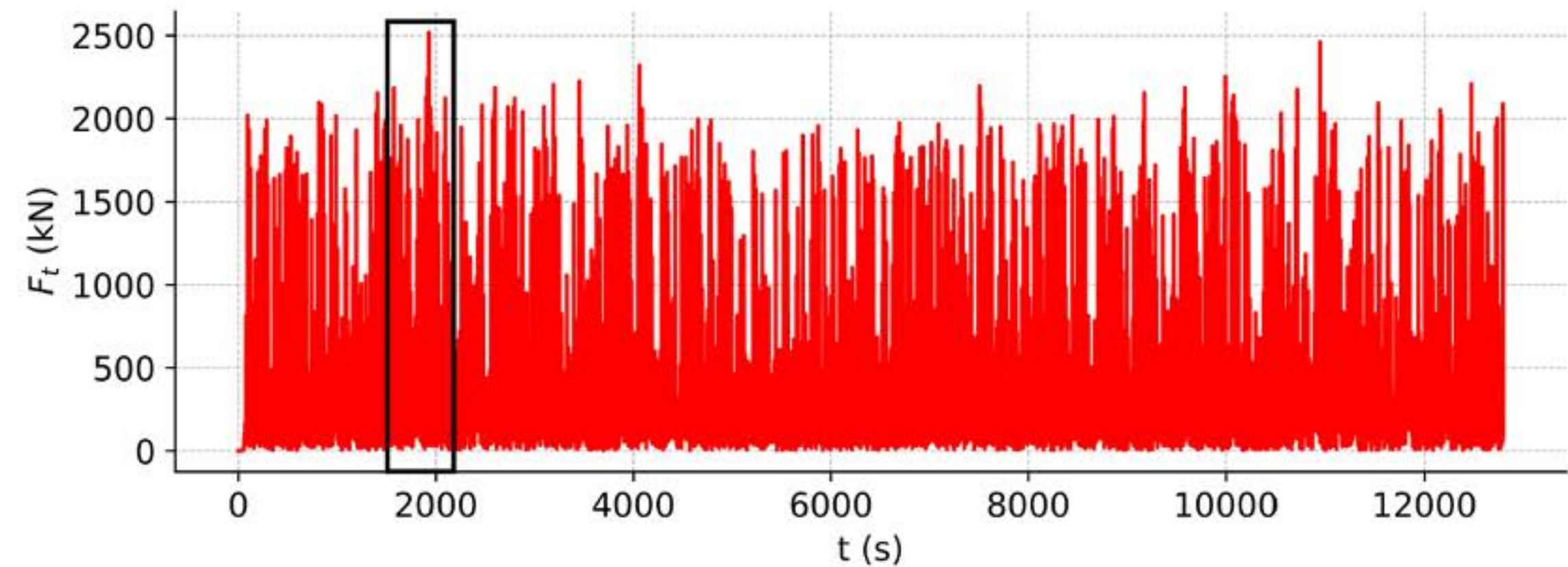
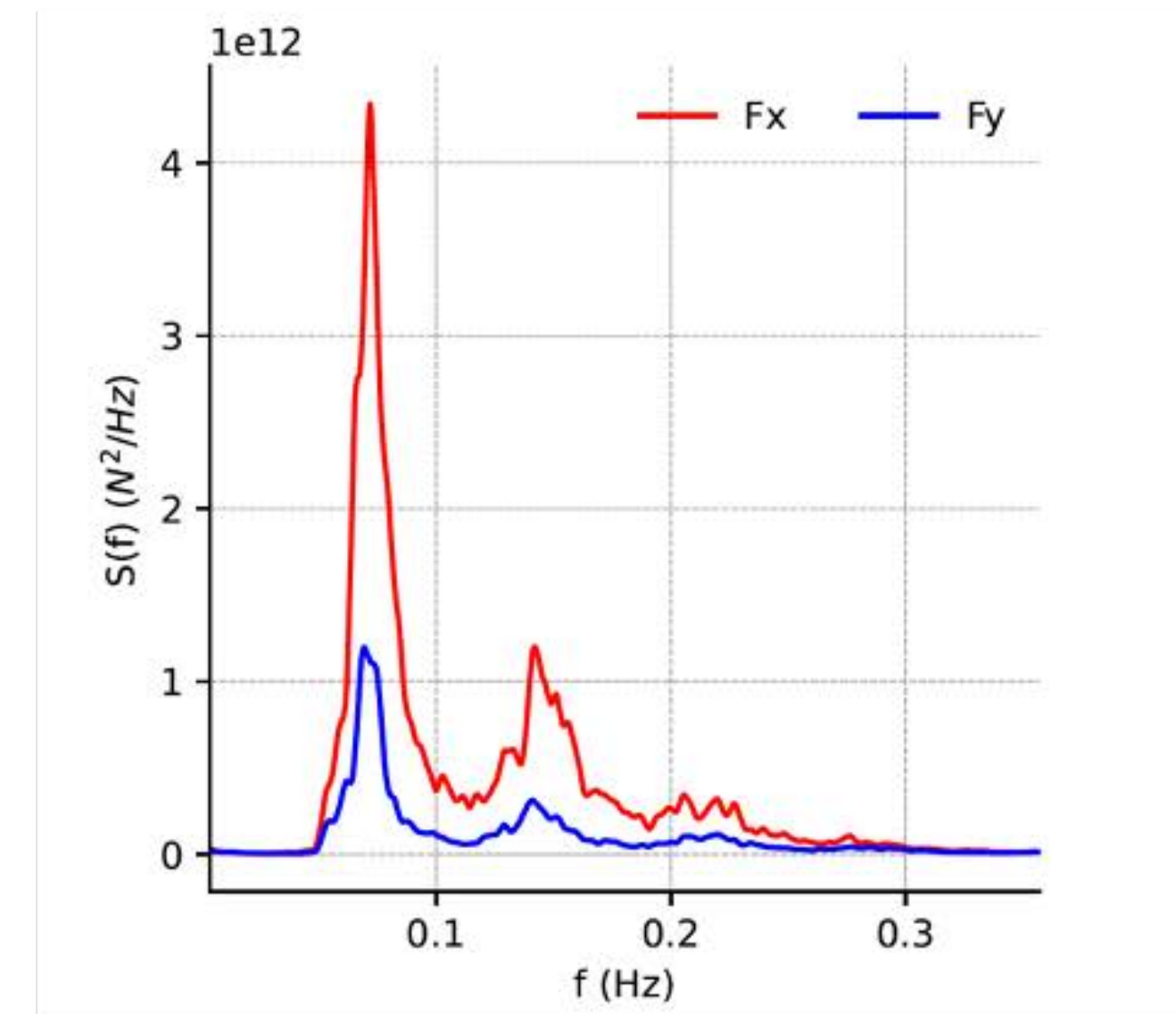
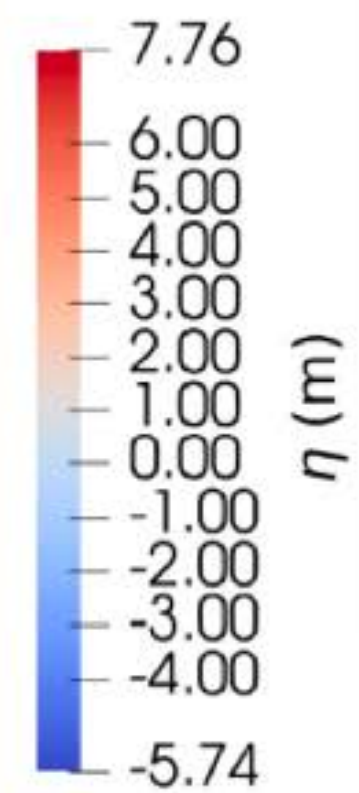
NORA-SARAH



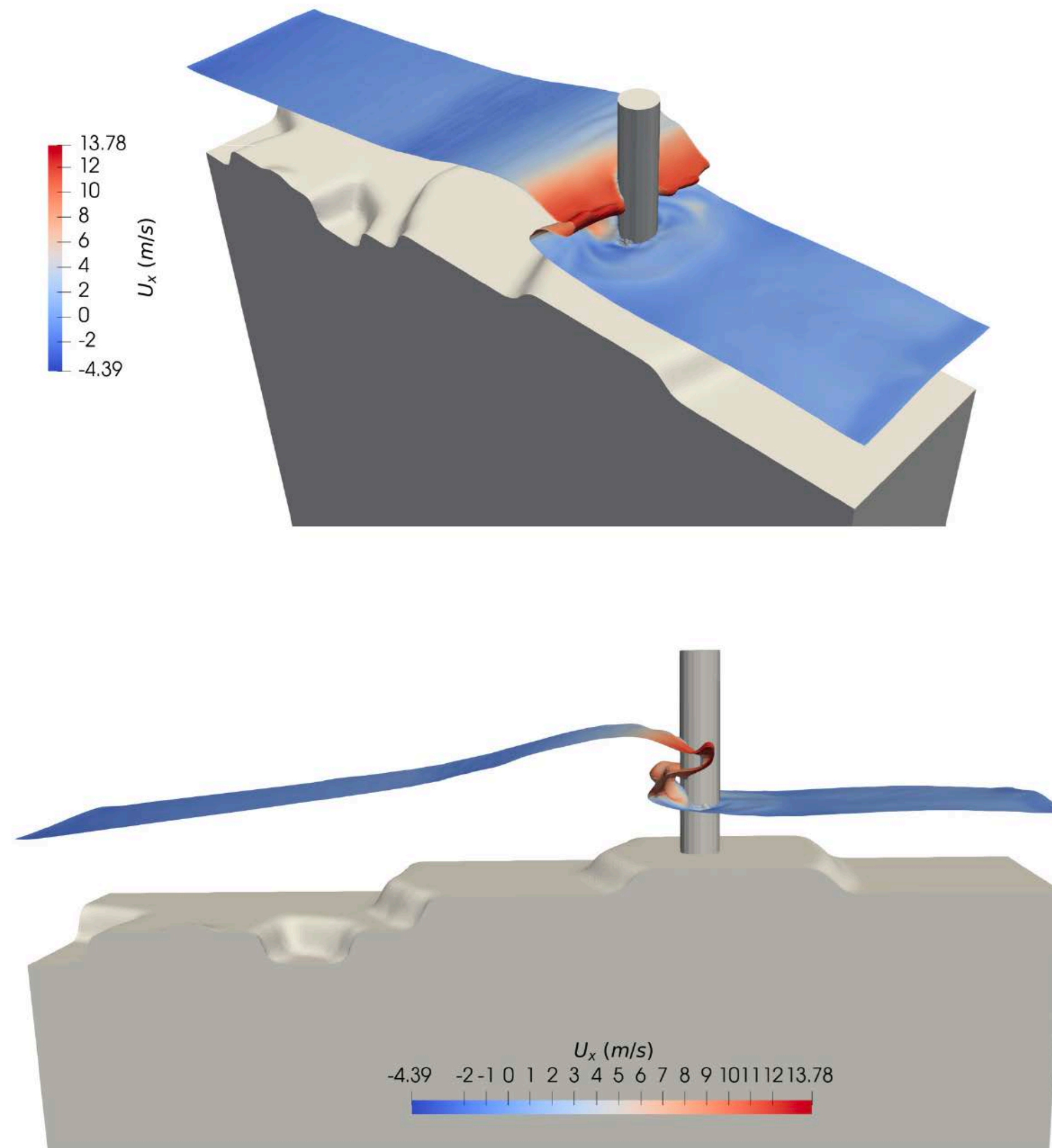
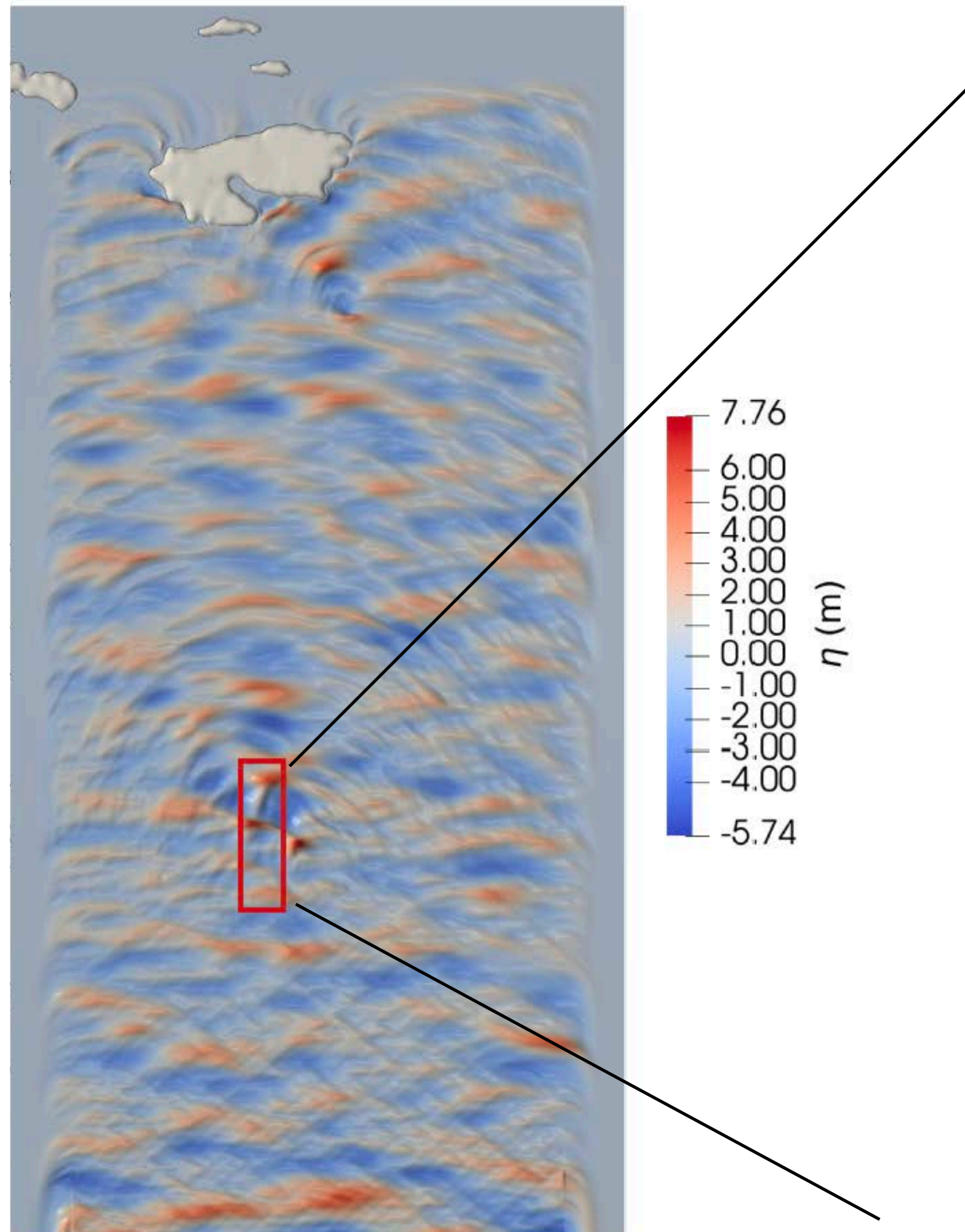
NORA-SARAH



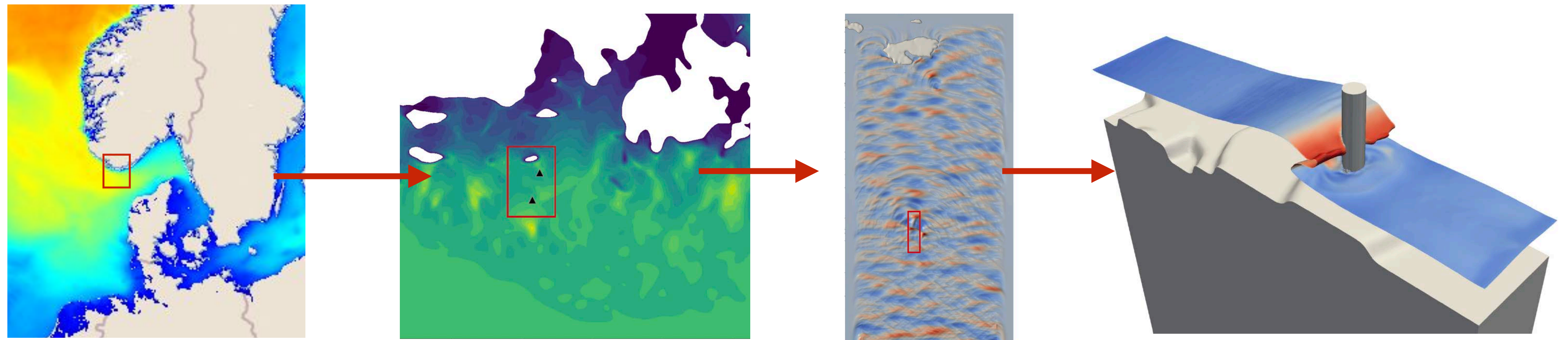
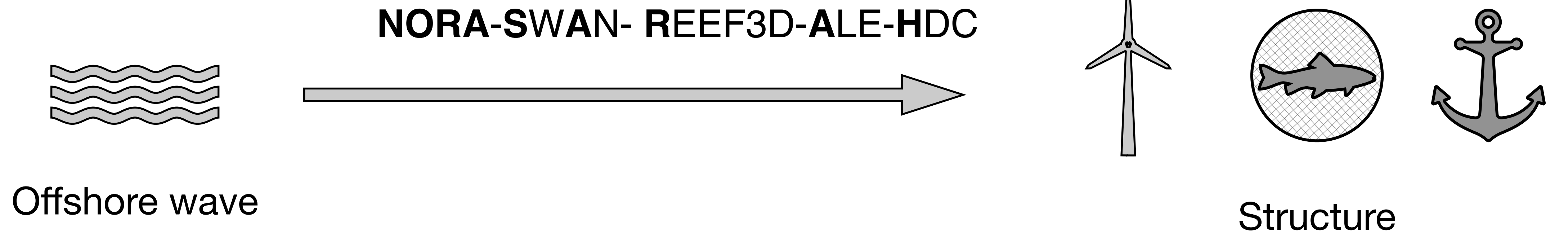
3.56 h simulation
256 cores
4.9 h completion



NORA-SARAH



NORA-SARAH

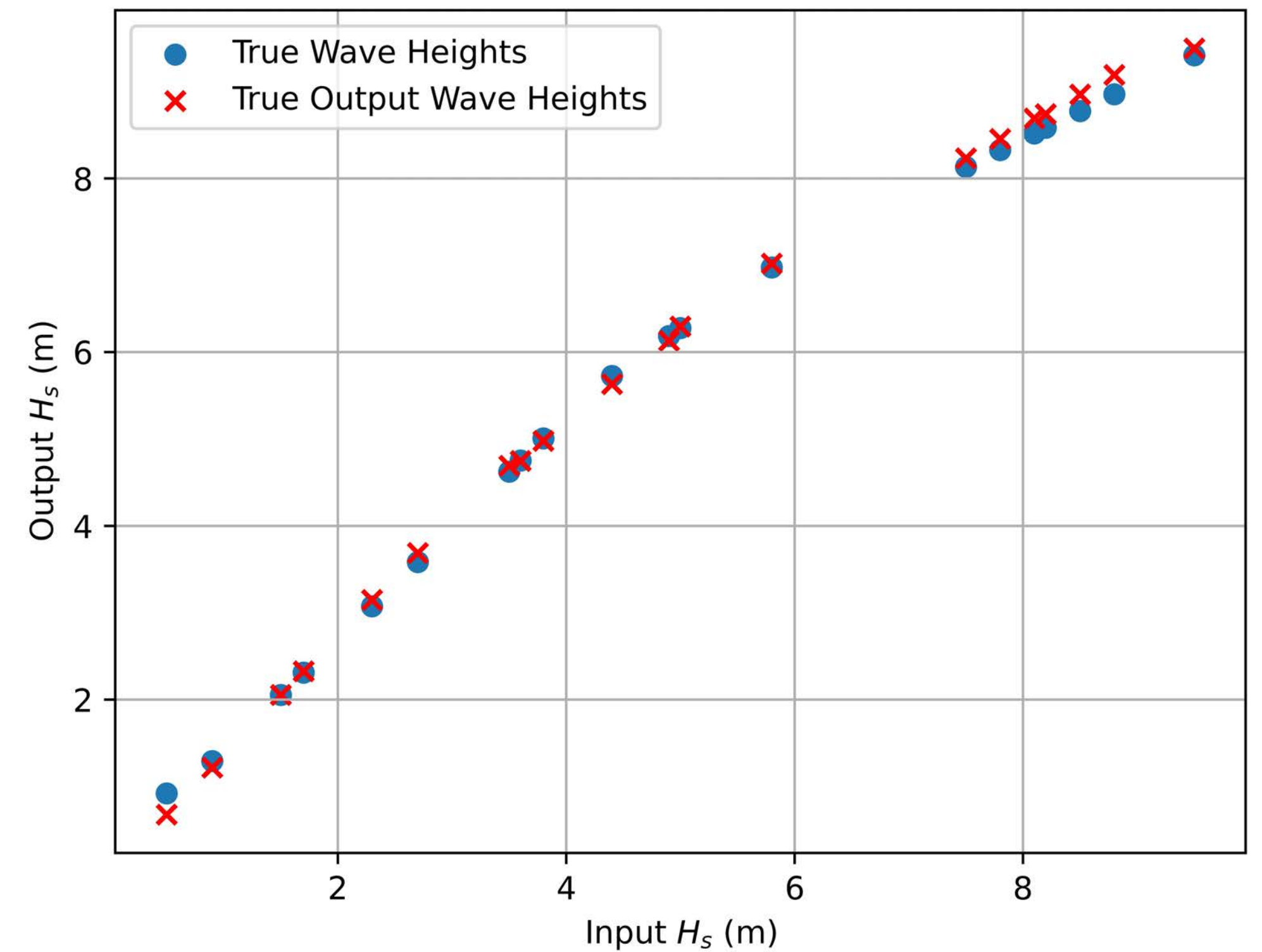
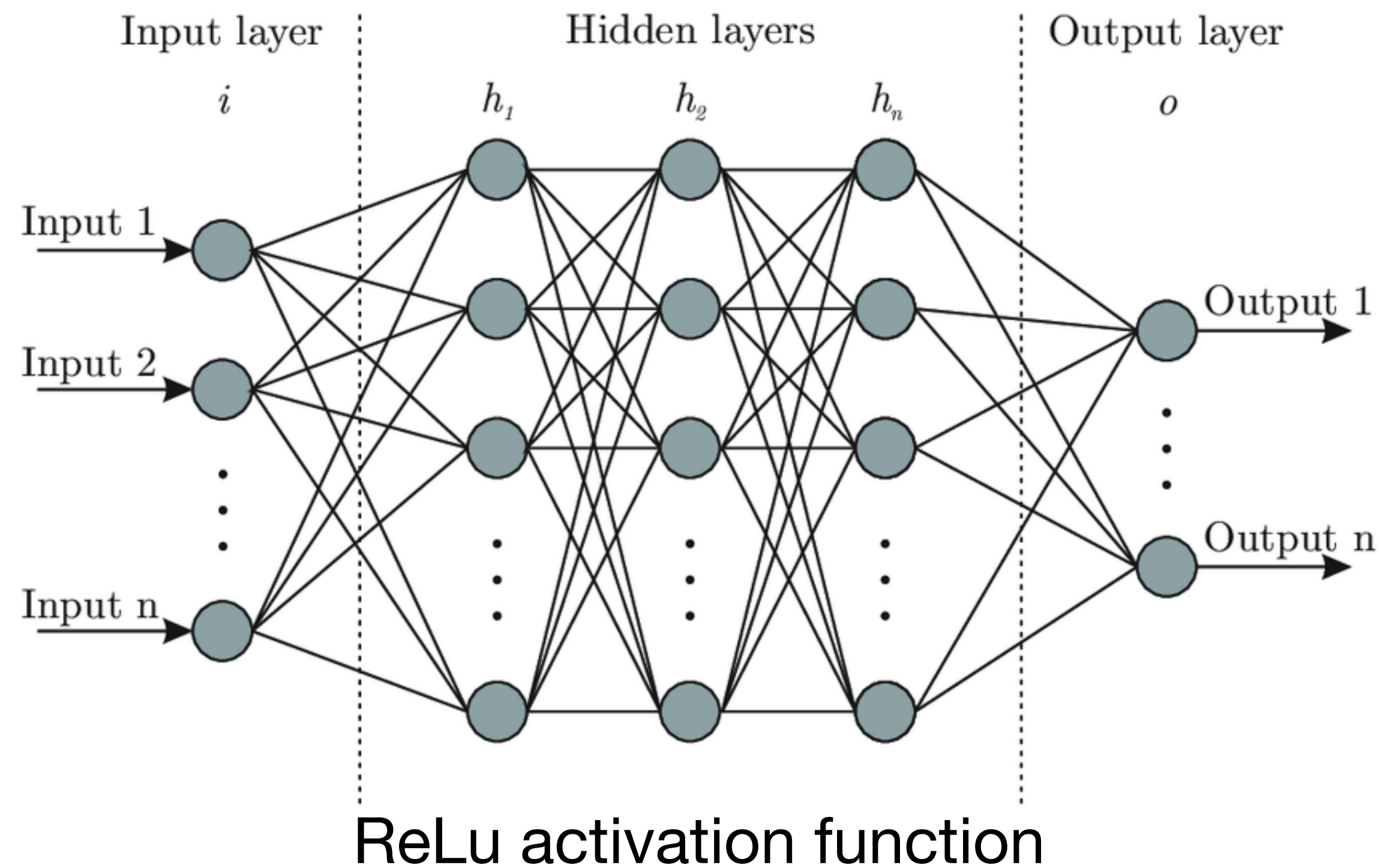


- Open
- Automatic
- AI-powered

NORA-SARAH.AI

Machine Learning (ML) prediction of shoaling wave height (To be presented in ICCE 2024)

100 simulations (Hs & Tp) Feed-forward ML Hs at Hanegalsboen
3 hidden layers



REEF Consulting



- **REEF3D:** unique framework solution with coastal, marine and offshore engineering
- open source!

- **Growing demand** for phase-resolved large-scale wave modeling and wave-structure interaction
- **Growing demand** for commercial REEF3D collaboration

- **Innovation:** making cutting edge knowledge available for industry usage

- **This presentation:** examples of previous REEF3D applications highlights the model capabilities

