

Nonlinear coastal wave prediction with a hybrid approach using phase-resolving models and machine learning

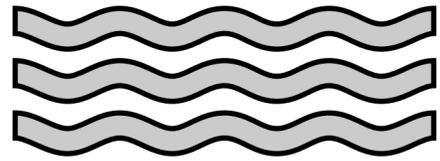
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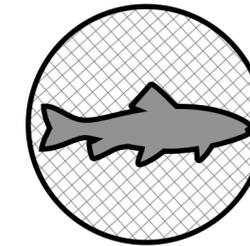
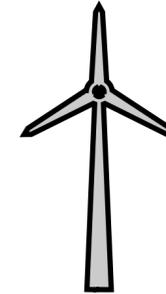
The Question



Offshore wave



- Bathymetry changes
- Coastlines
- Wave transformation
- Coastal nonlinearity



Structure

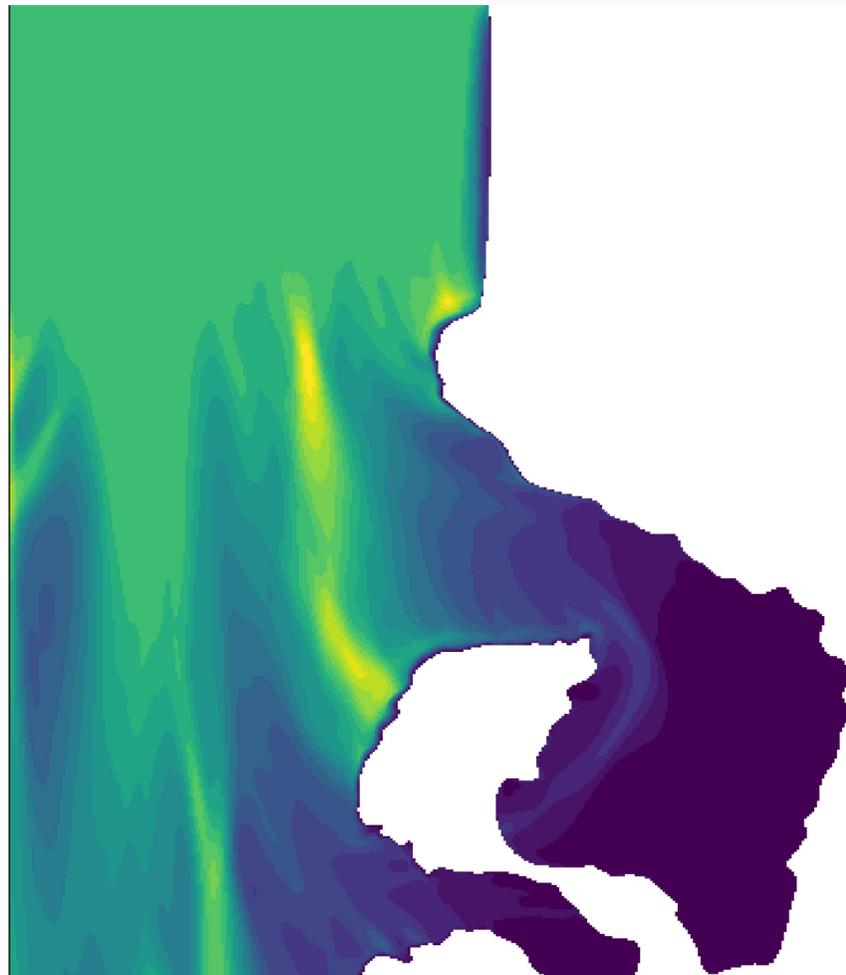
JONSWAP

H_s, T_p

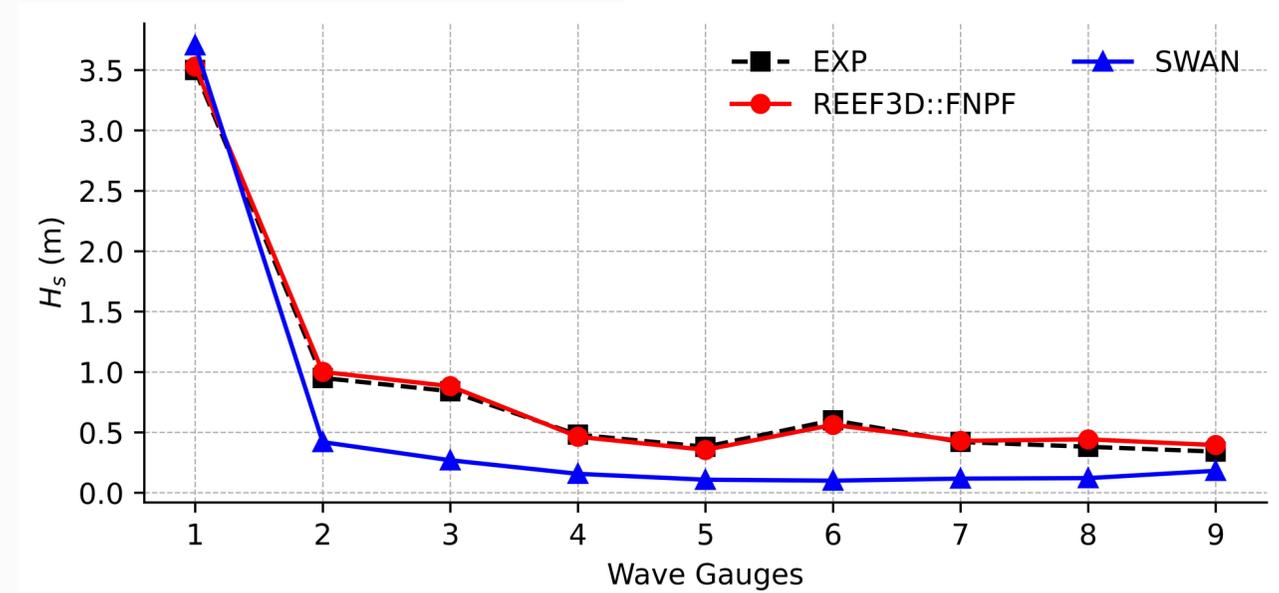
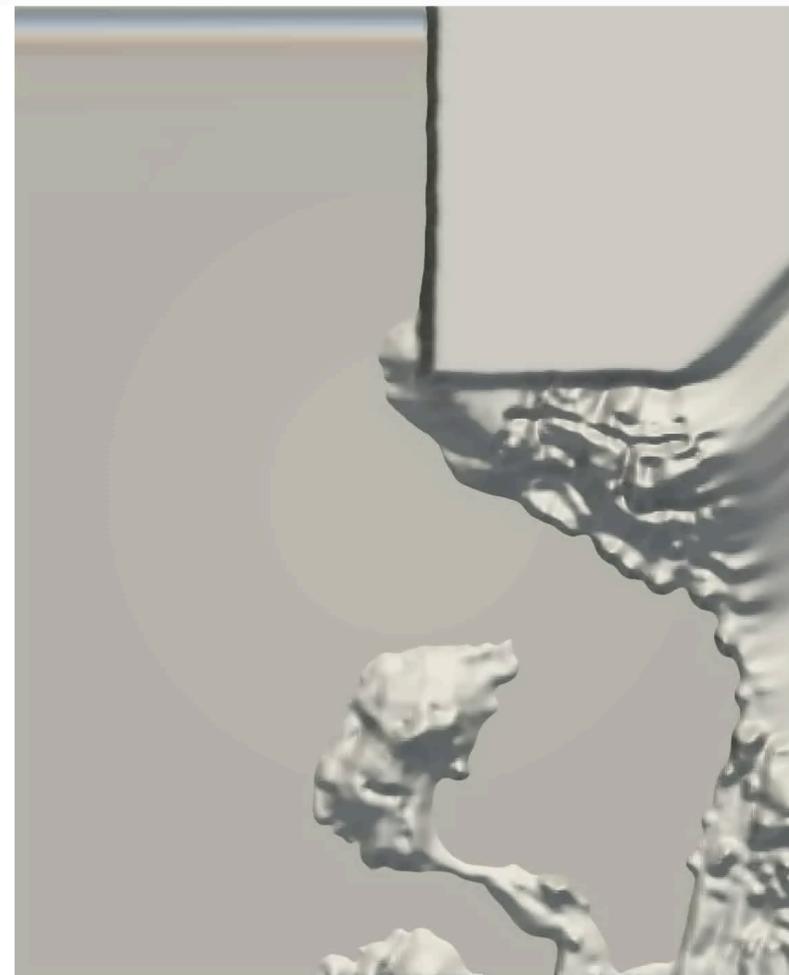


Wave modeling approaches & coastal nonlinearity

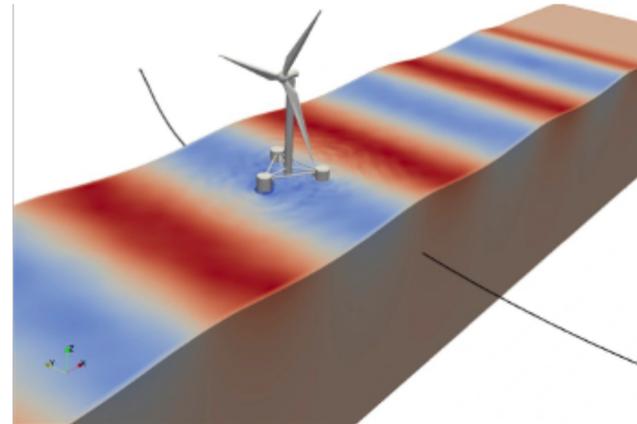
Phase-averaged



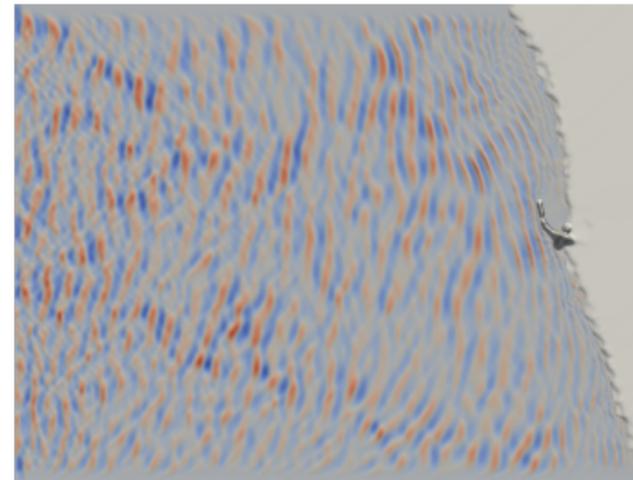
Phase-resolved



REEF3D — open-source hydrodynamics

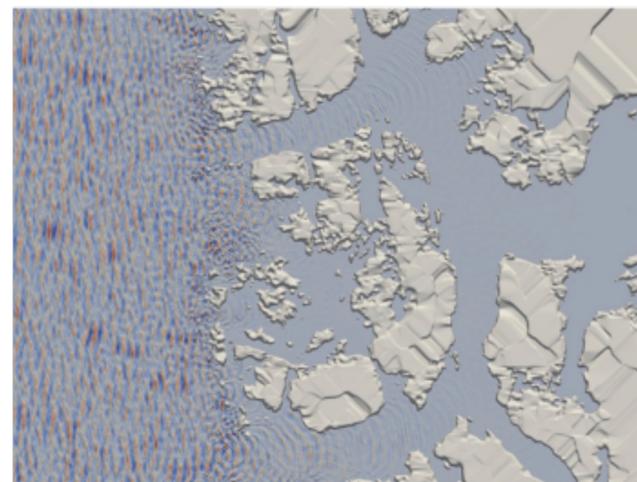
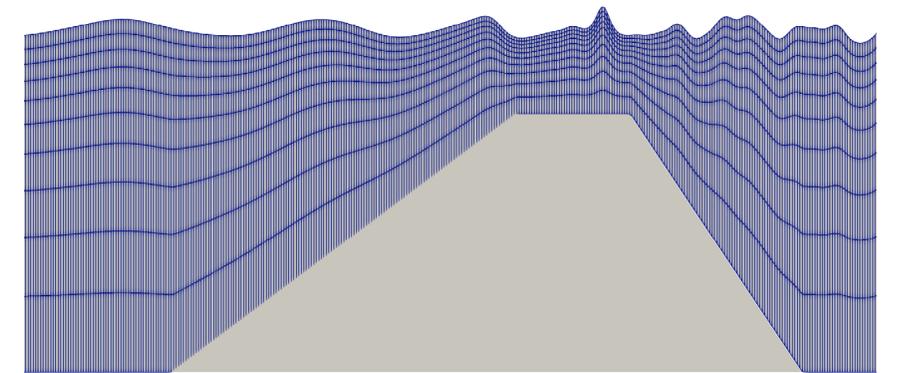


CFD Two-Phase Navier-Stokes Equations

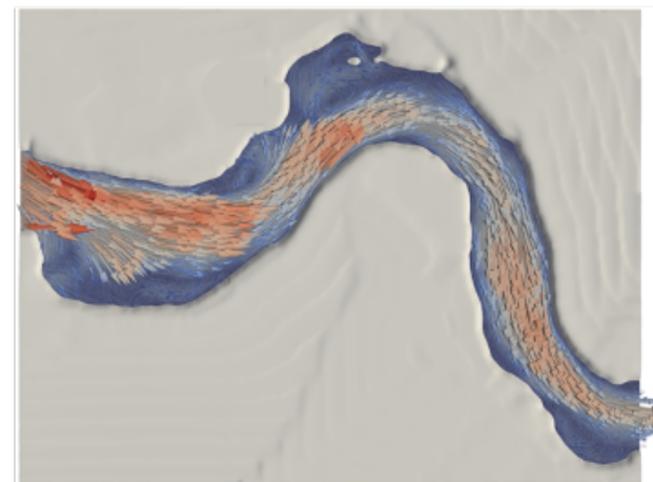


NHFLOW Non-hydrostatic Navier-Stokes Equations

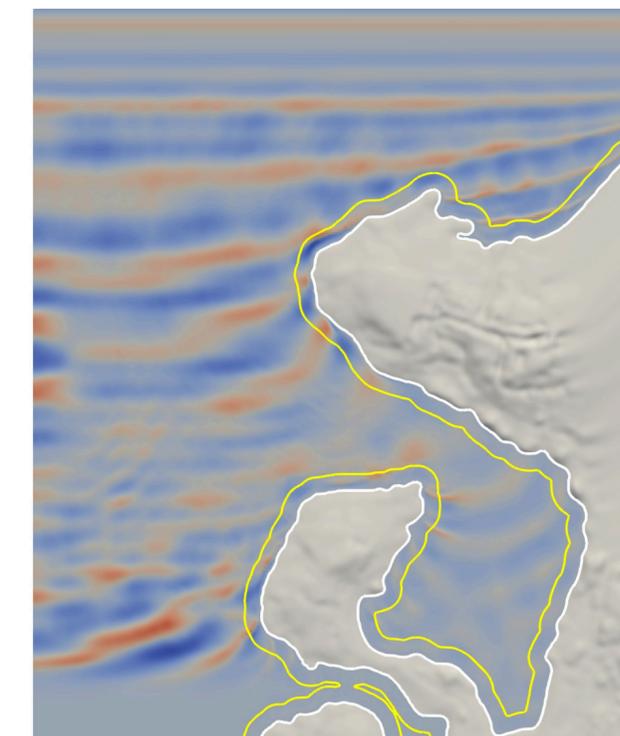
REEF3D::FNPF



FNPF Fully Nonlinear Potential Flow

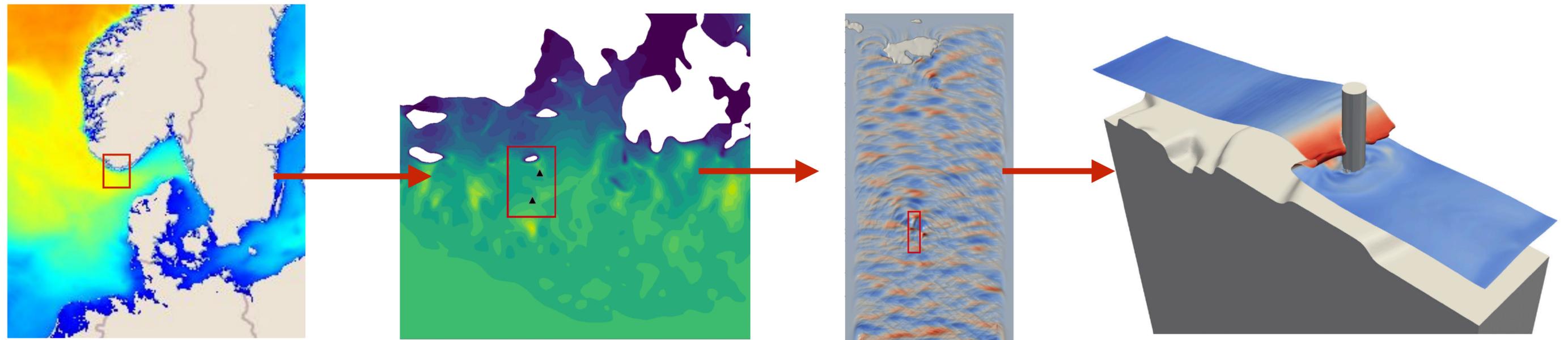
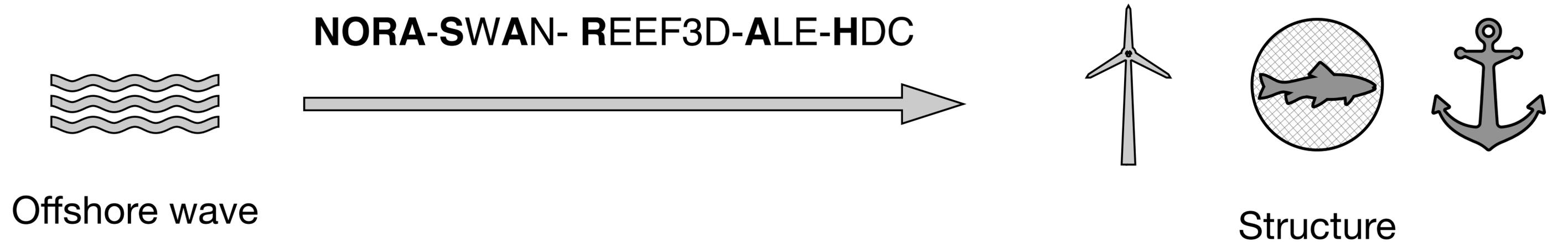


SFLOW Non-hydrostatic SWE

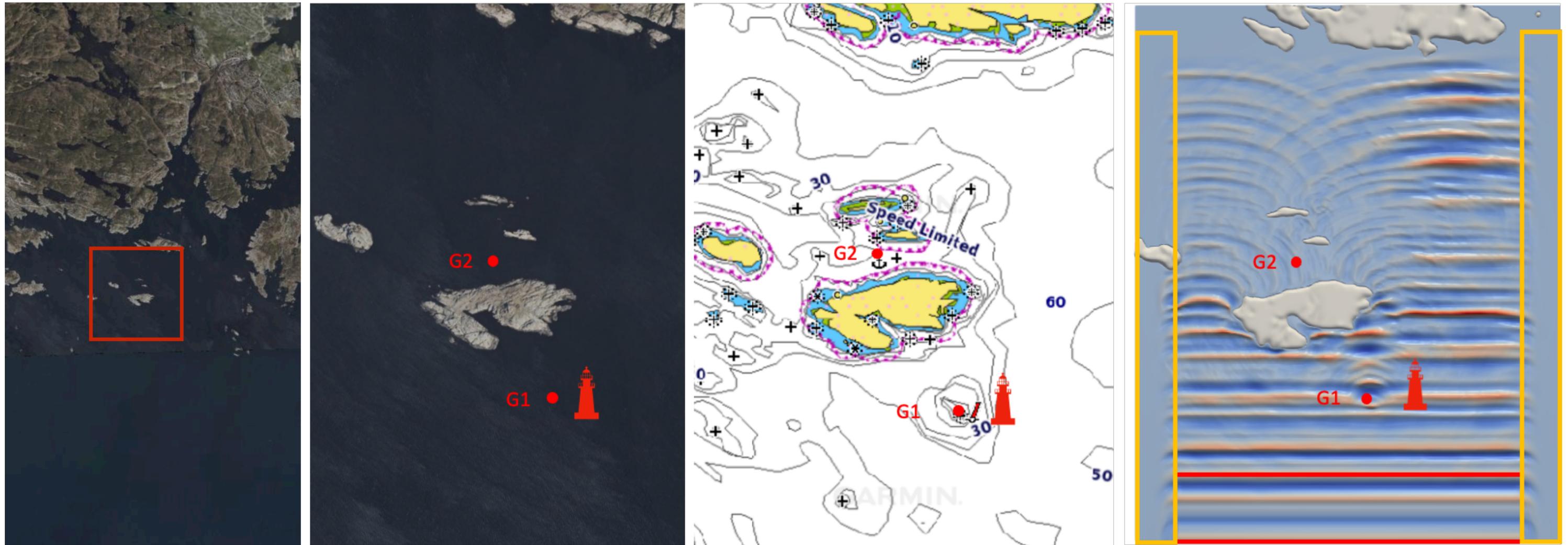


- Laplace
- MPI
- Breaking
- Dispersive
- Coastline

NORA-SARAH — down-scale coastal wave modeling



Case study — Store L yngholmen, Southern Norway



Artificial Neural Networks

Feedforward Neural Network (FNN)

$$a^{(1)} = \sigma(Wa^{(0)} + b)$$

2 Dense layers

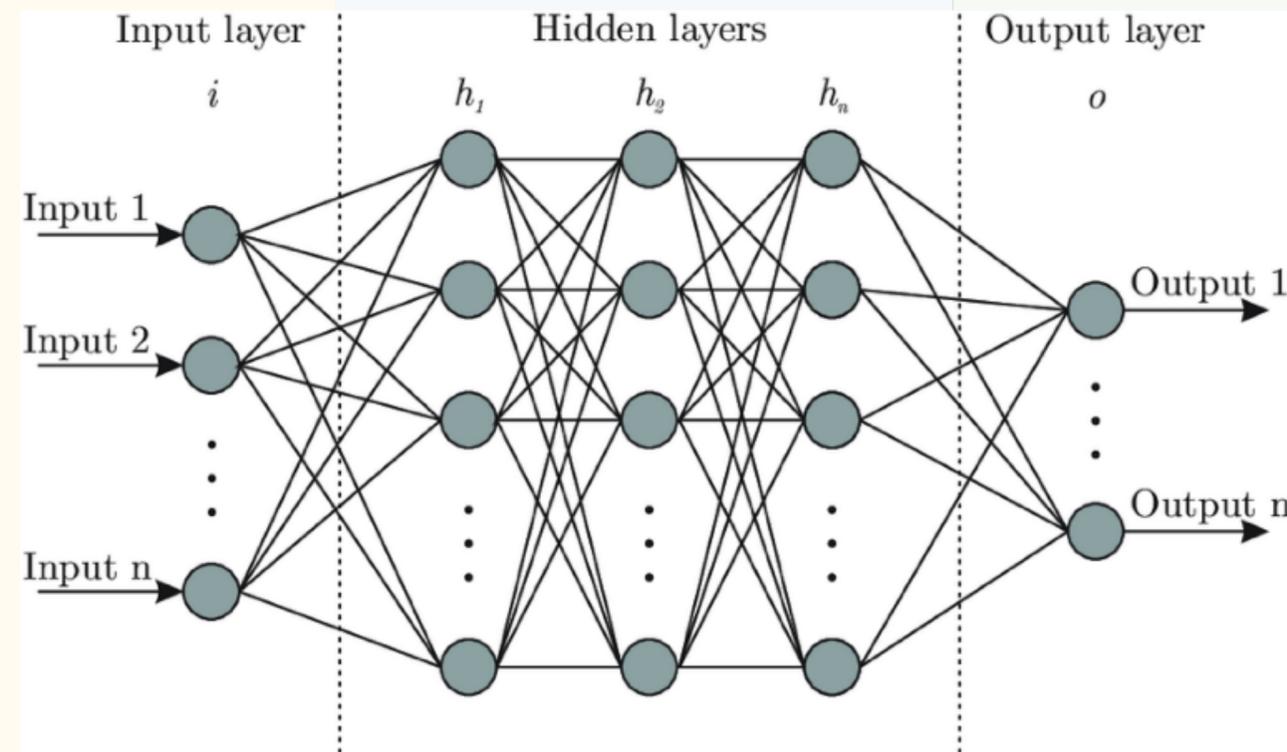
64 + 32

ReLU + MSE + ADAM

100 x H_s

Split 80%+20%

MinMax scaling



Loss function

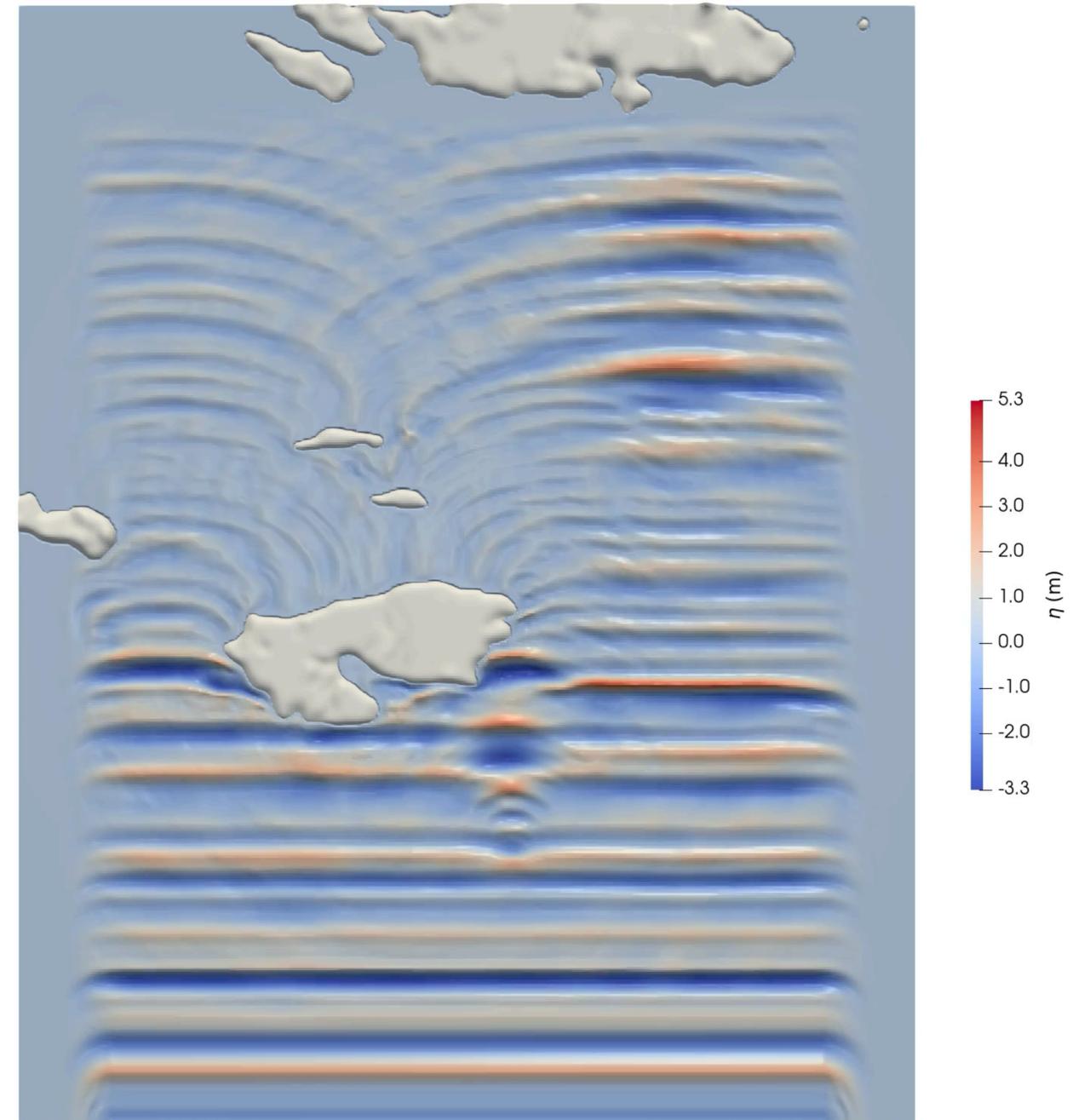
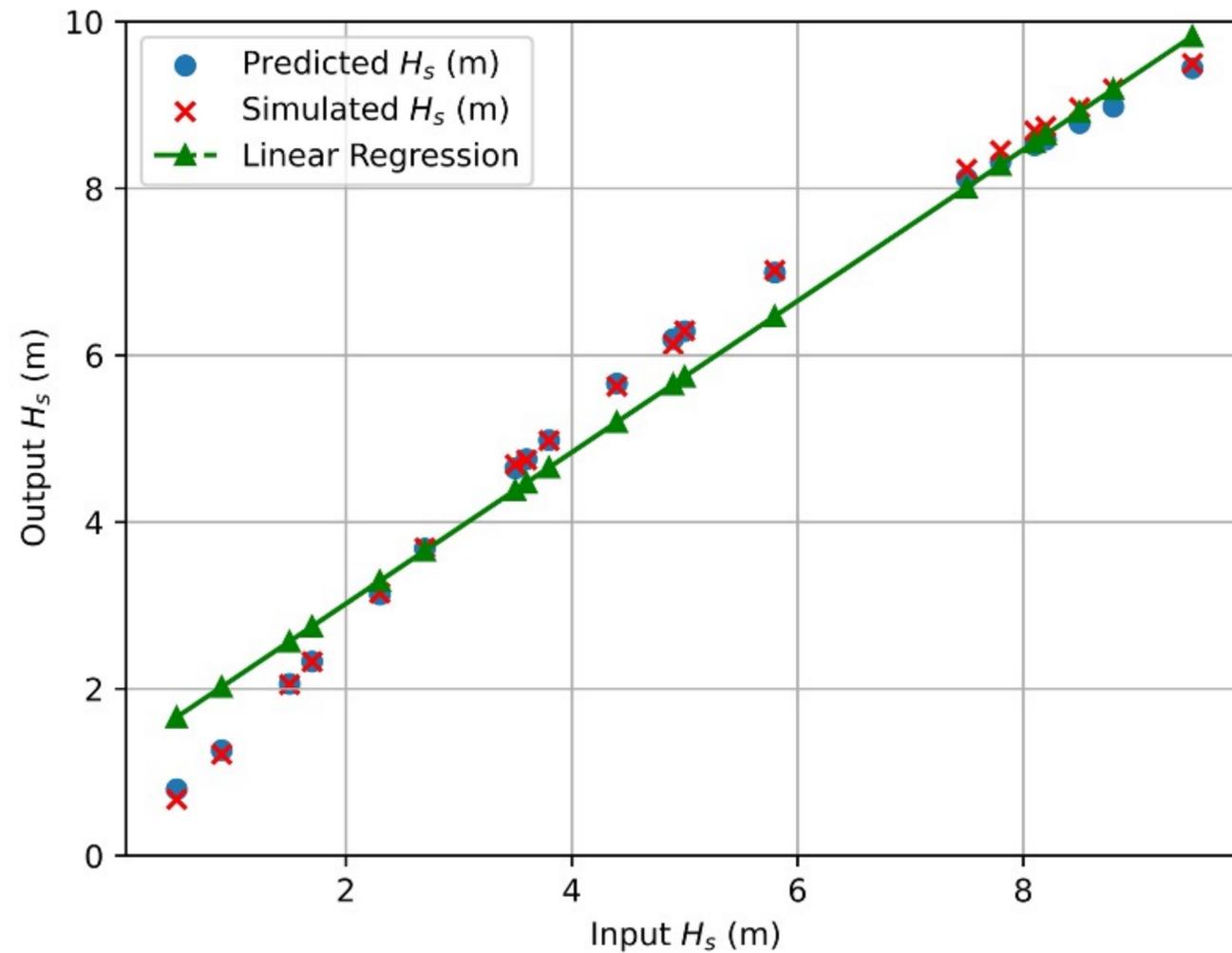
H_s & F_{\max}

Coastal wave prediction - shoaling

Input variables $H_s = 0.5:0.1:10.5$ m; $T_p = 12$ s

G1

Training time = 2.6 s

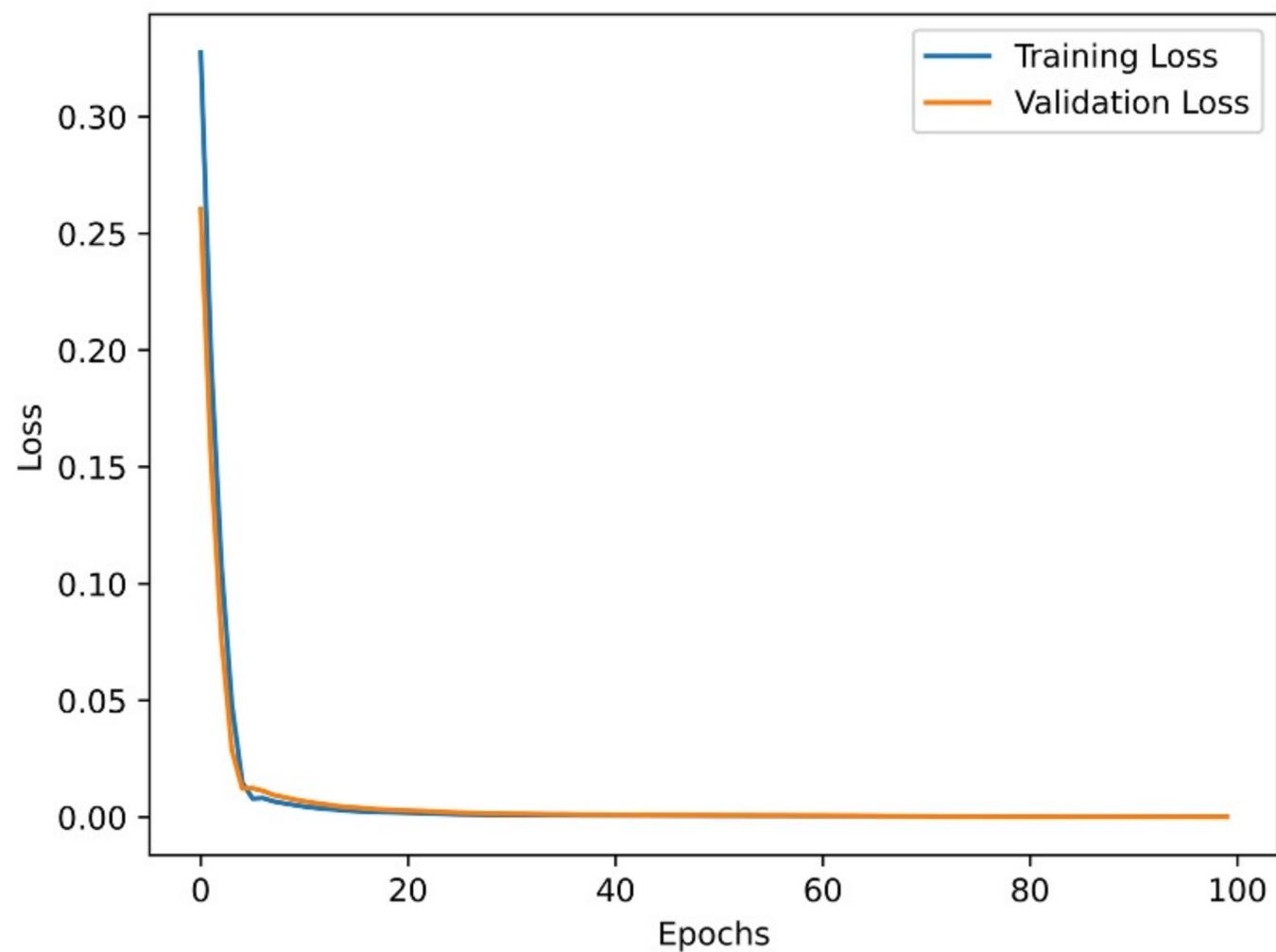
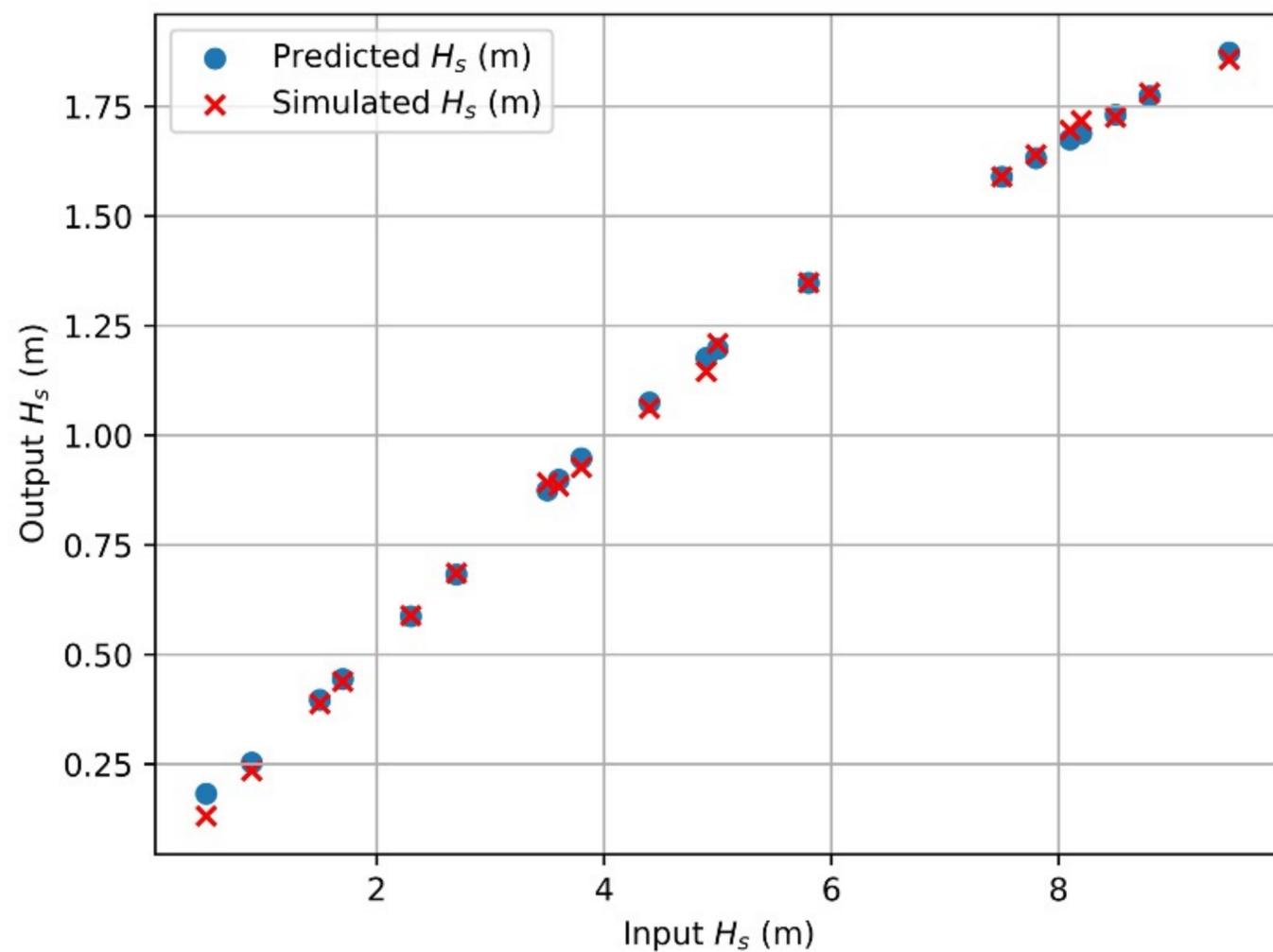


Coastal wave prediction - diffraction

G2

Training time = 2.53 s

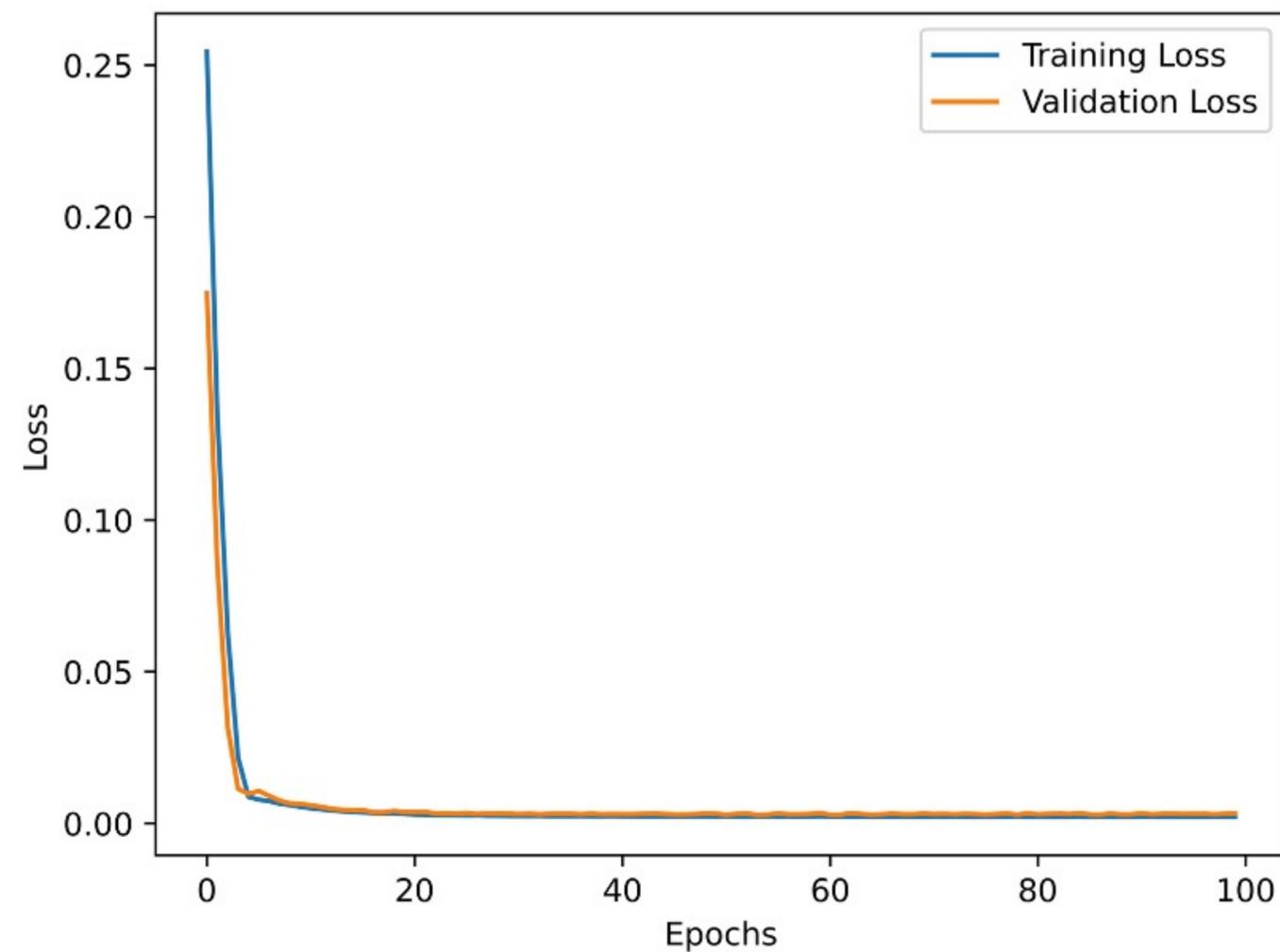
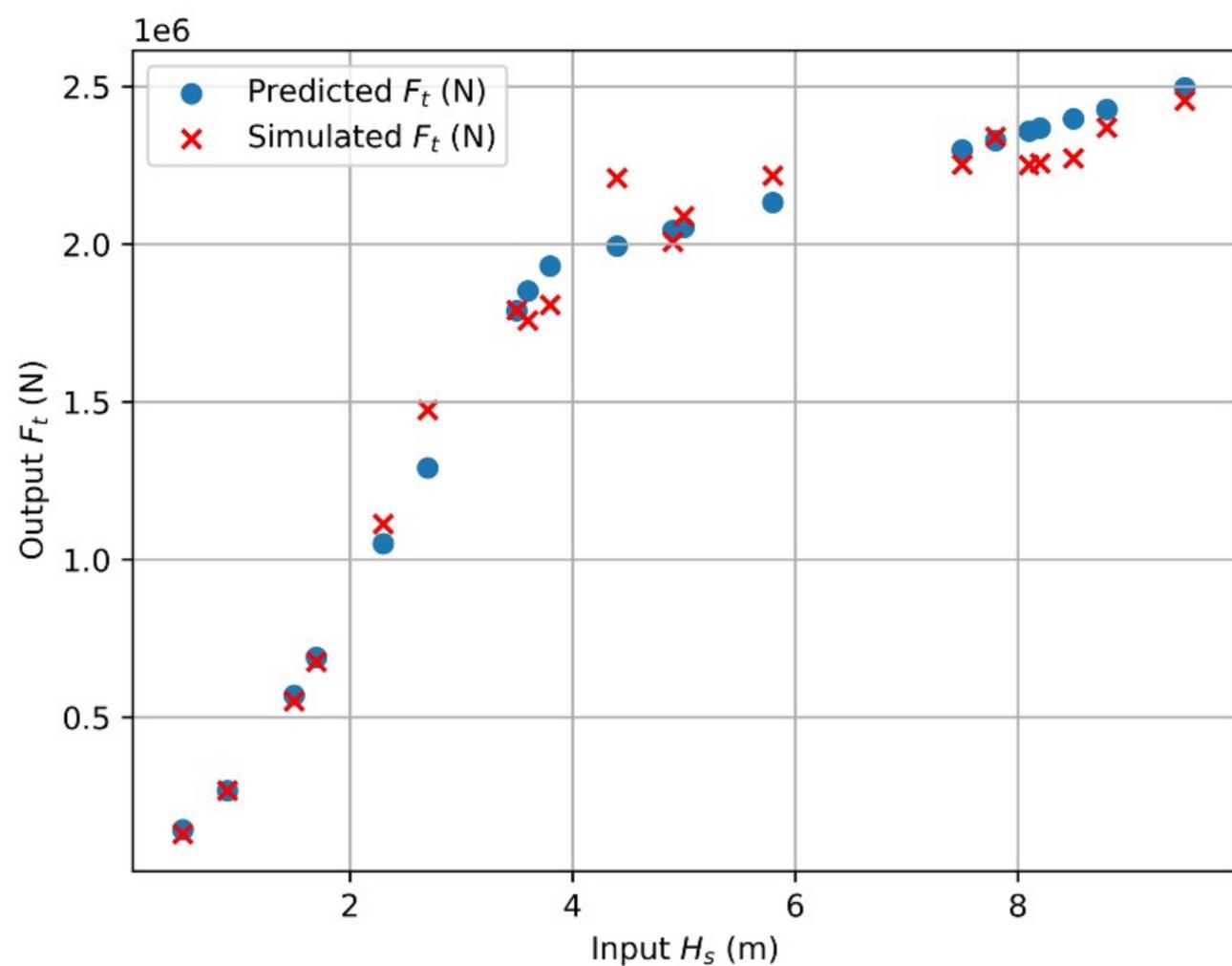
$R^2 = 0.9988$



Coastal wave prediction - force

G1, max total force

$R^2 = 0.9988$



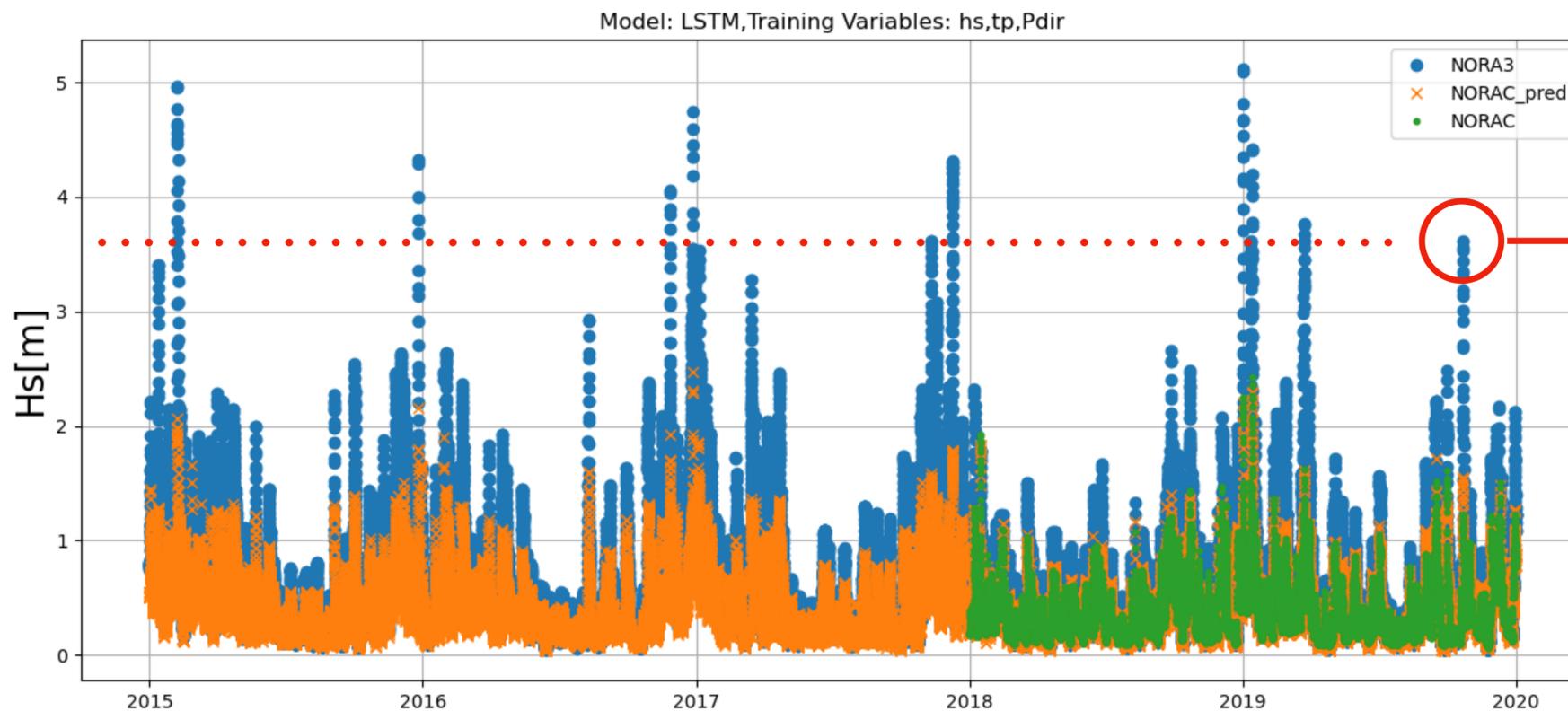
Machine learning framework

Offshore wave forecasting

LSTM

(Long-term short-term memory)

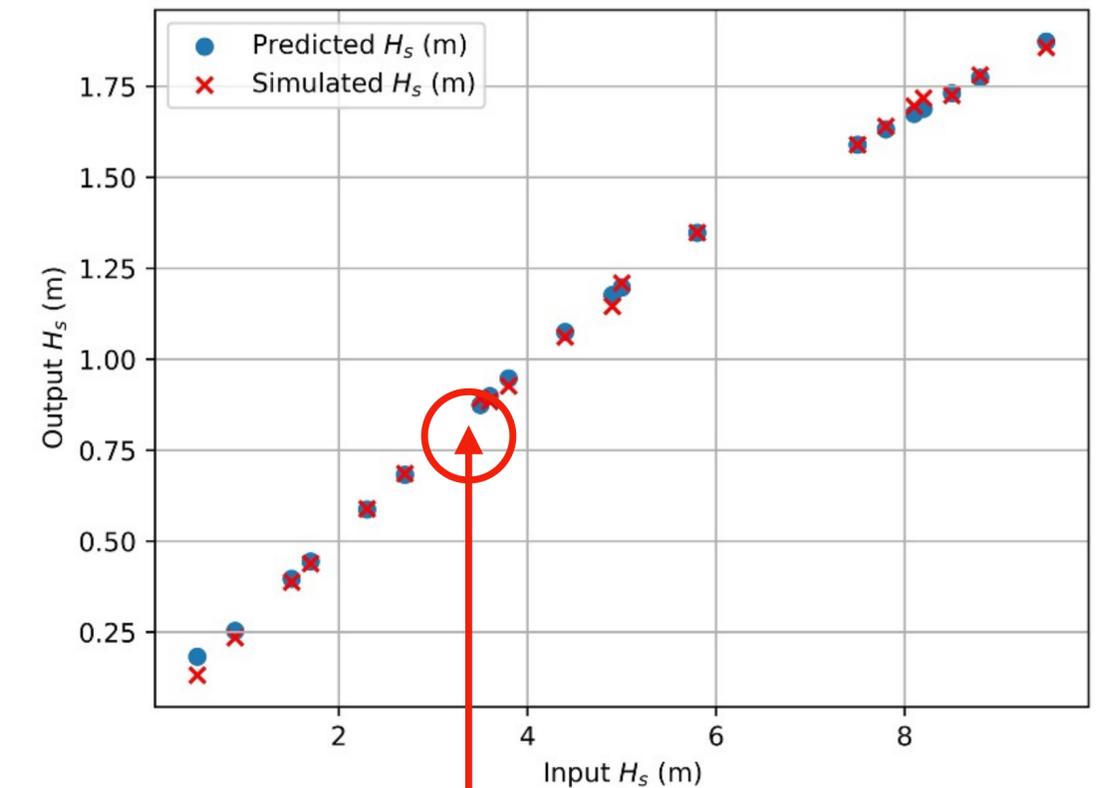
Metocean-ml (MET) : time series forecast offshore



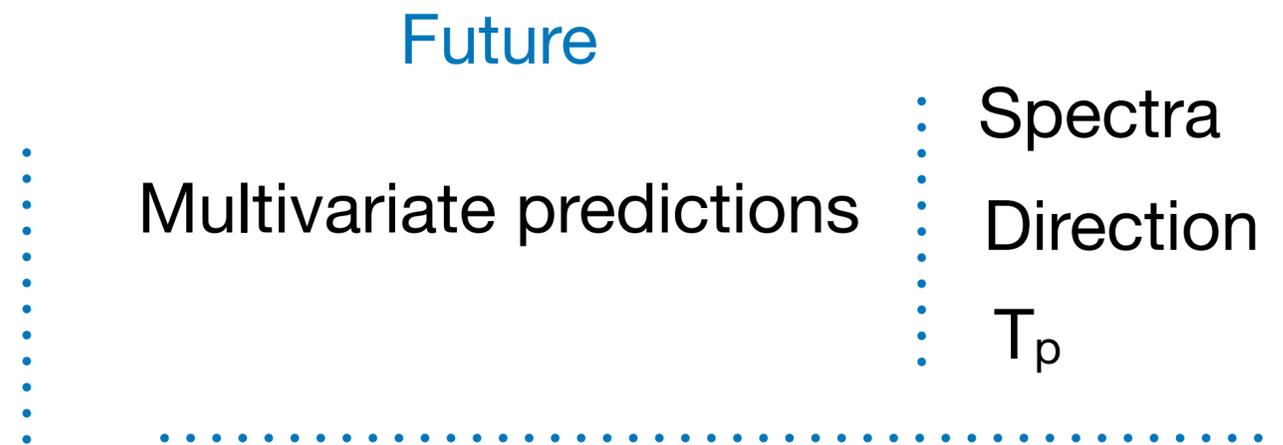
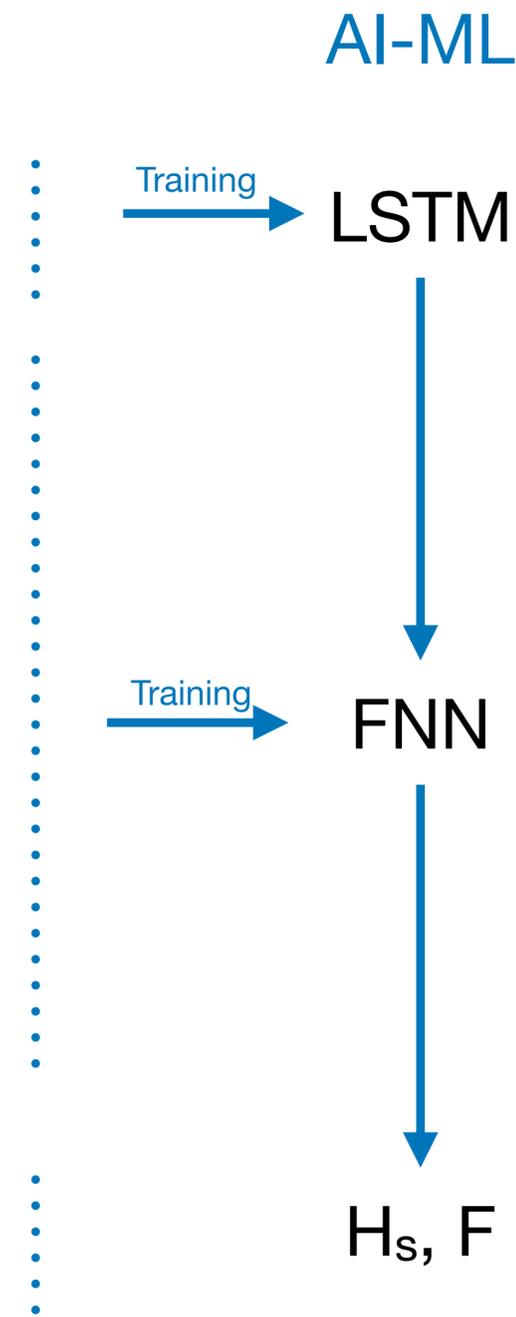
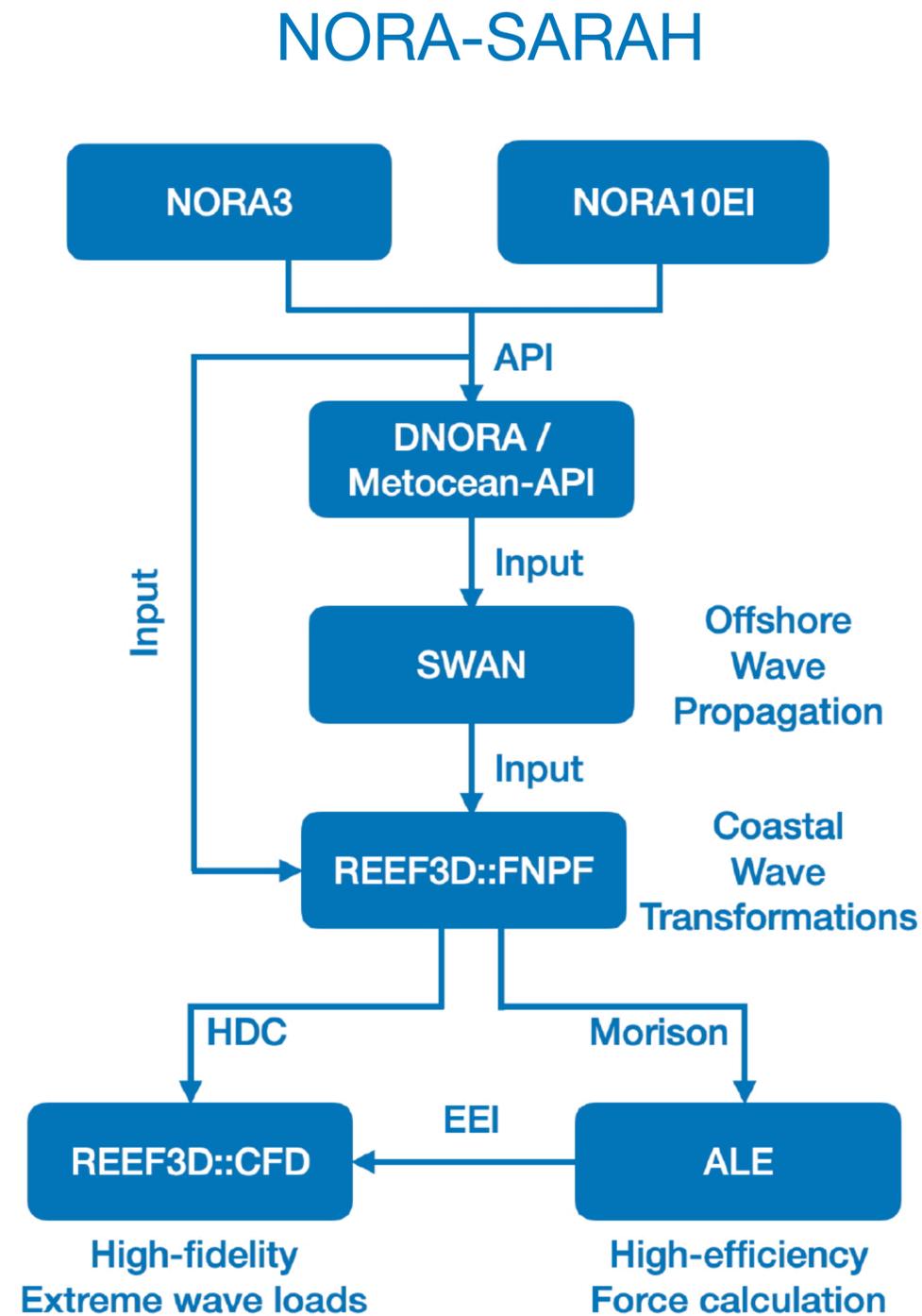
Offshore-Coast correlation

FNN

(Feedforward Neural Network)



Machine learning framework



Thank you!

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PARTRES