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Significant wave height simulation using machine learning and remote sensing for offshore wind farms

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Objectives

- Significant Wave Height (SWH) is an important parameter for a variety of offshore operations
- In Offshore Wind (OSW) industry, SWH defines the accessibility of individual wind turbines
- High resolution sea state numerical simulation is computationally heavy for very small grids, but can have significant impact in operation and maintenance procedures
- Use of machine learning methodologies with remote sensing and buoy data to simulate sea state at a high resolution

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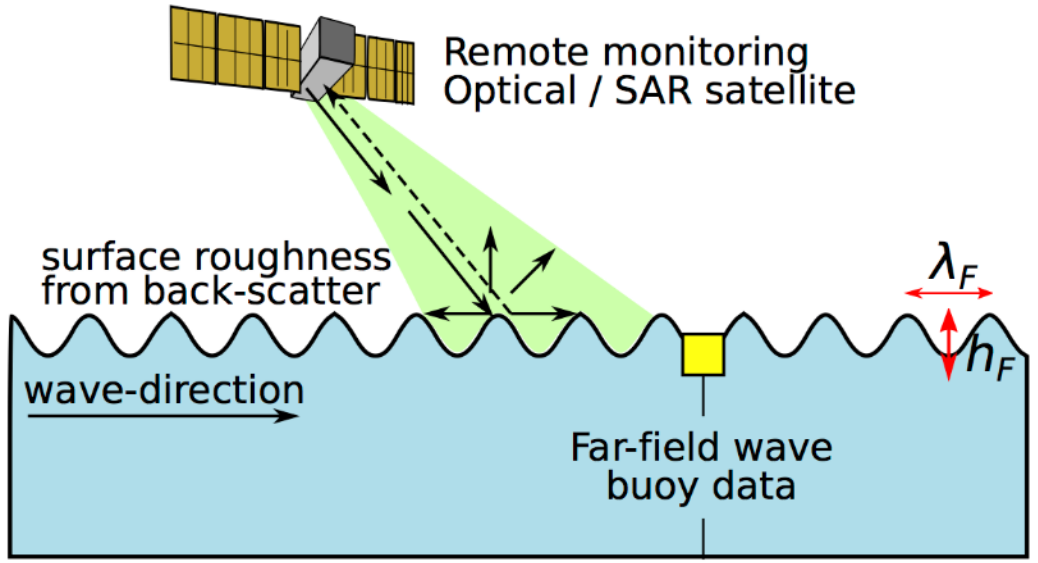
Satellite images

- Synthetic Aperture Radar (SAR) onboard Sentinel-1 satellites
- Advantages:
  - Unaffected by weather and cloud cover
  - Frequency
  - Availability
- Measures 2D surface backscattering
- Can provide information about the sea roughness and hence wave height



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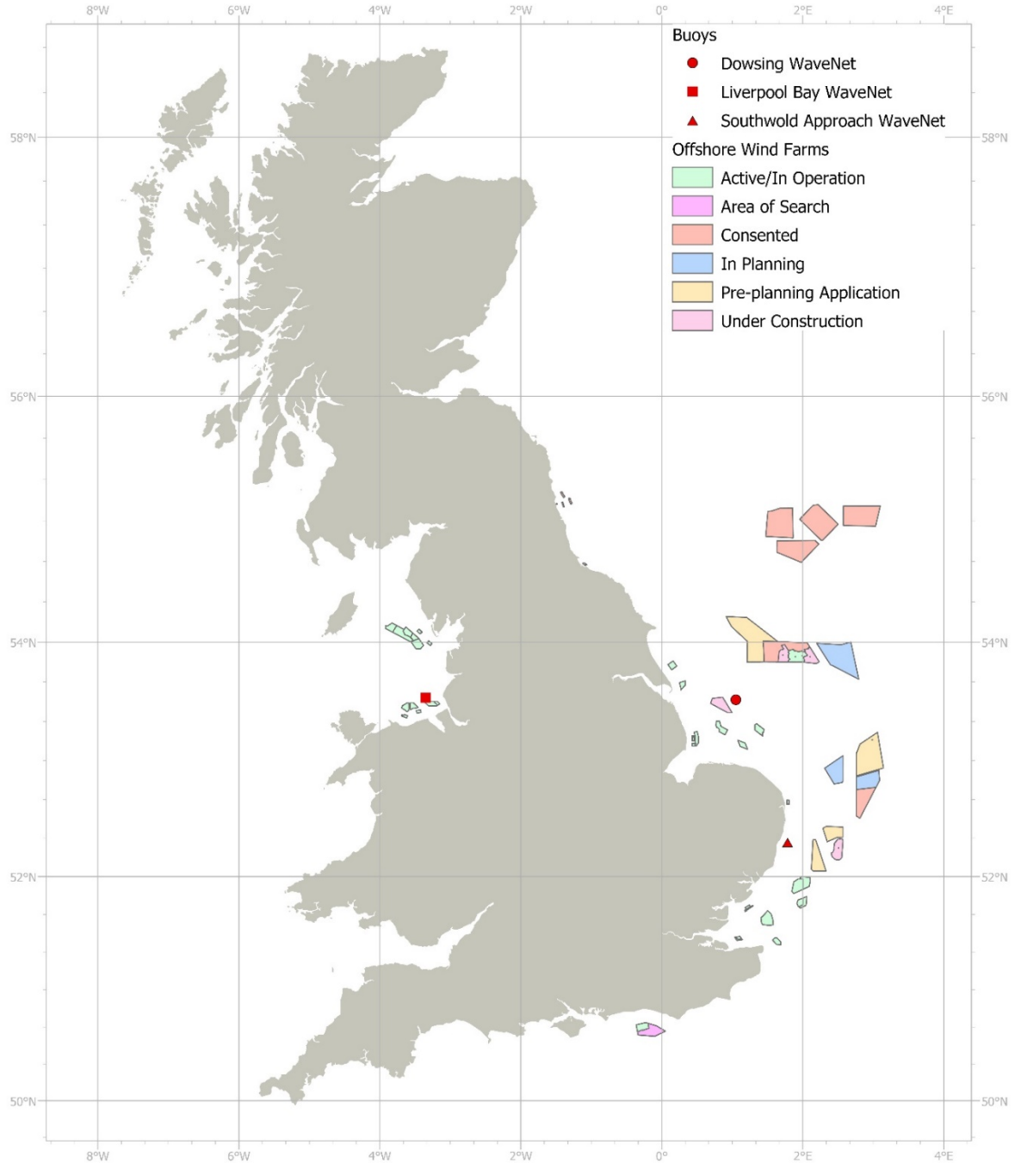
Data Availability

- In order to correlate satellite information with significant wave height → Real information are necessary
- Satellite images from 3 locations → different size of wind farms
- Buoy data available through Centre for Environment, Fisheries and Aquaculture Science (CEFAS) WaveNet
  - Liverpool Bay
  - Southwold Approaches
  - Dowsing



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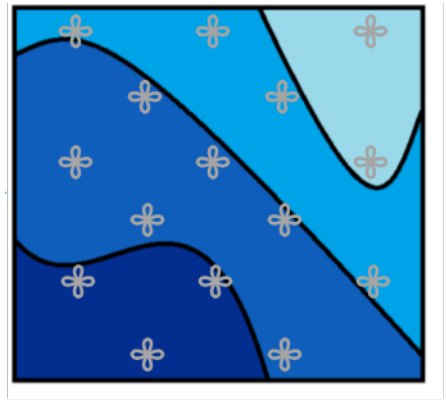
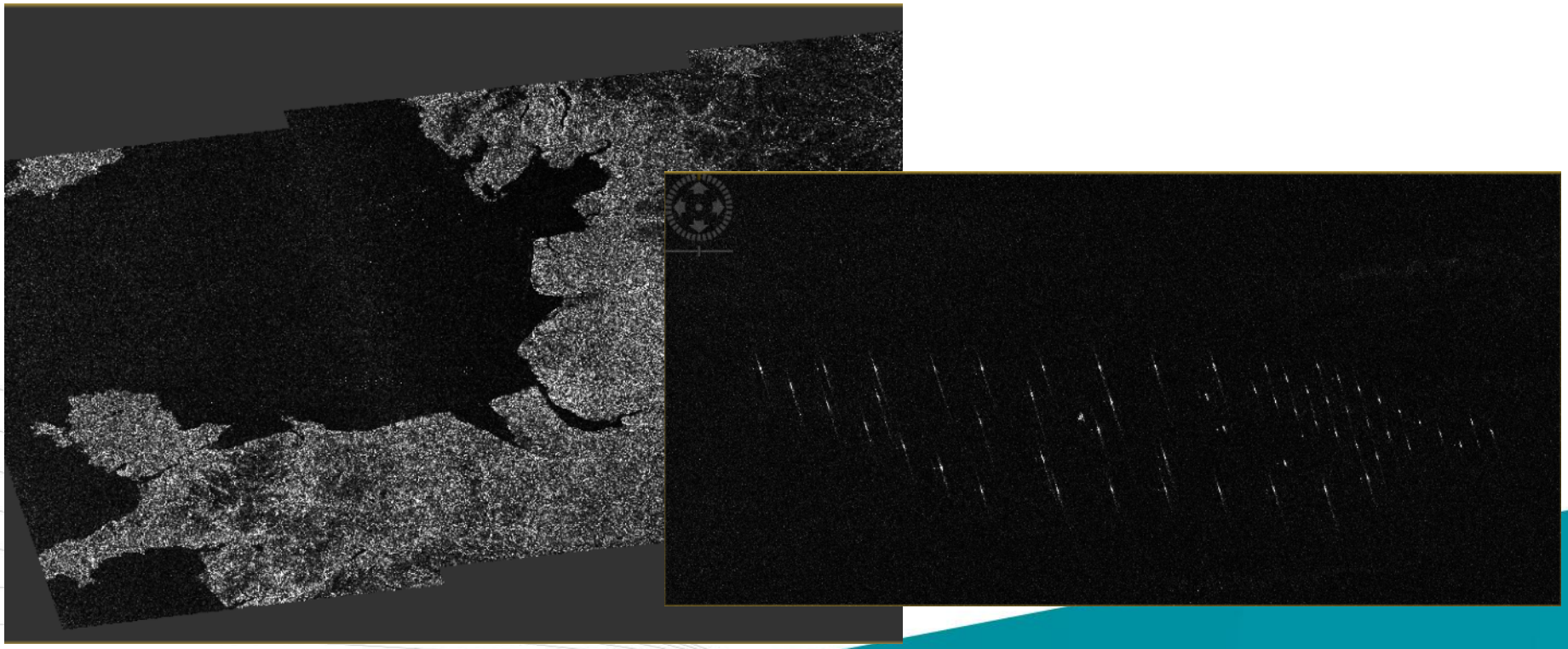
Methodology

Data Acquisition	Data processing	Artificial neural networks (ANNs)	Spatial distribution
1/6/2018 to 1/6/2019 • Sentinel 1 - SAR Images (220 images) • Buoy data	Initial processing, Extract parameters related to sea roughness, Different SAR bands	Correlate sea roughness parameters to buoy data	Apply ANNs to calculate significant wave height in multiple locations spatially





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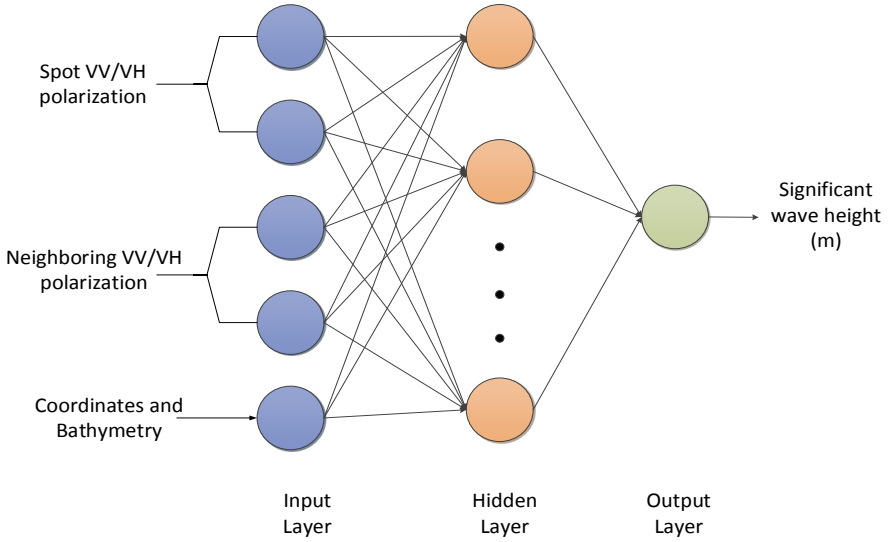
Model accuracy

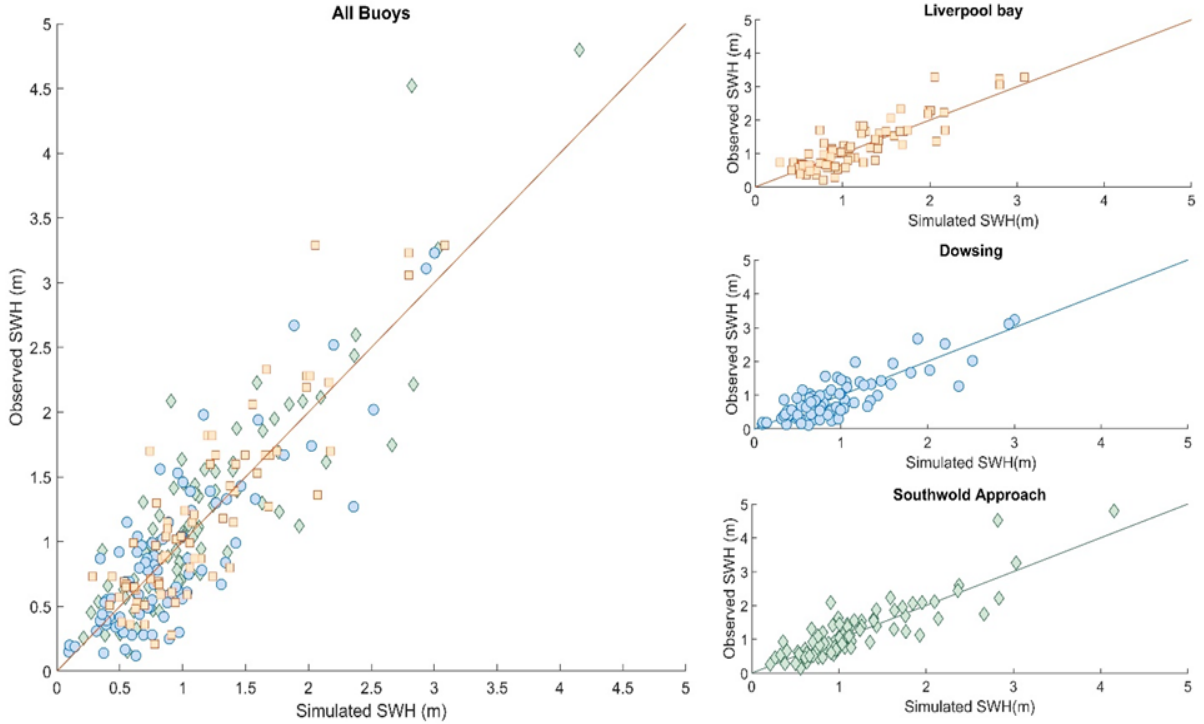
ANN training process:

- Different Architectures, optimal being Levenburg-Marquardt with 1 hidden layer (10 nodes)
- Ensemble of 100 trainings to reduce uncertainty (Monte Carlo procedure)
- Overall R^2=0.84
- Similar precision for ANN methodology (±0.24m) and CMEMS-NWS hindcast (±0.21m)



Advantages:

- Provide better spatial resolution than other hindcasts (5m resolution vs 1.5km)
- Localized information
- Small computational cost



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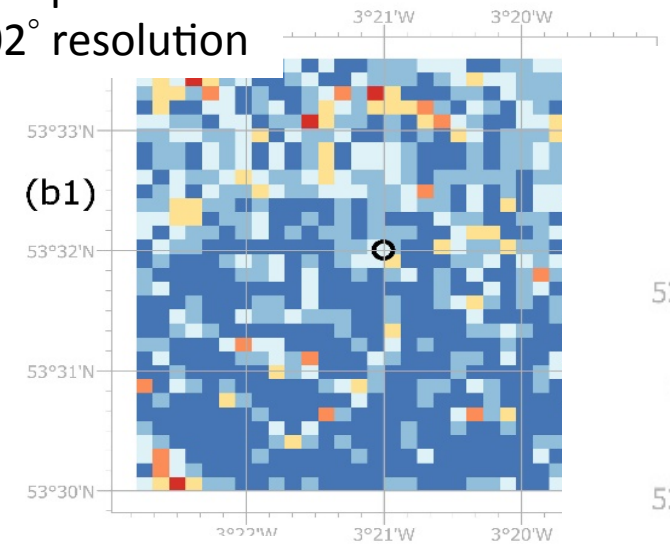
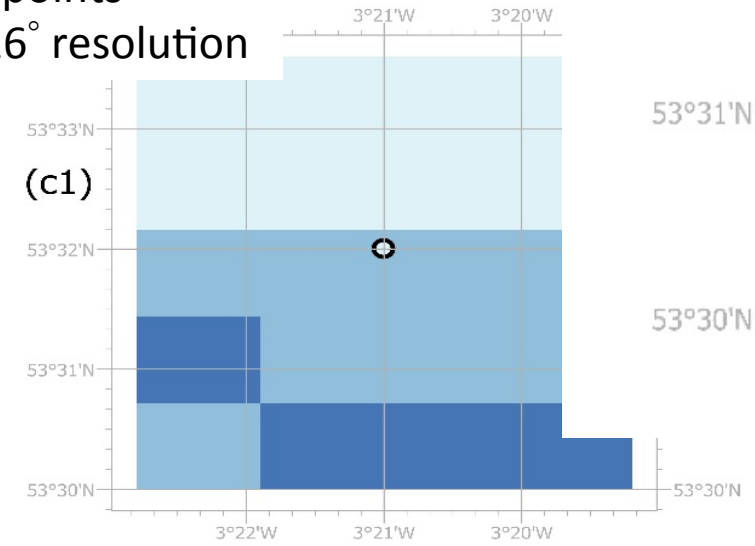
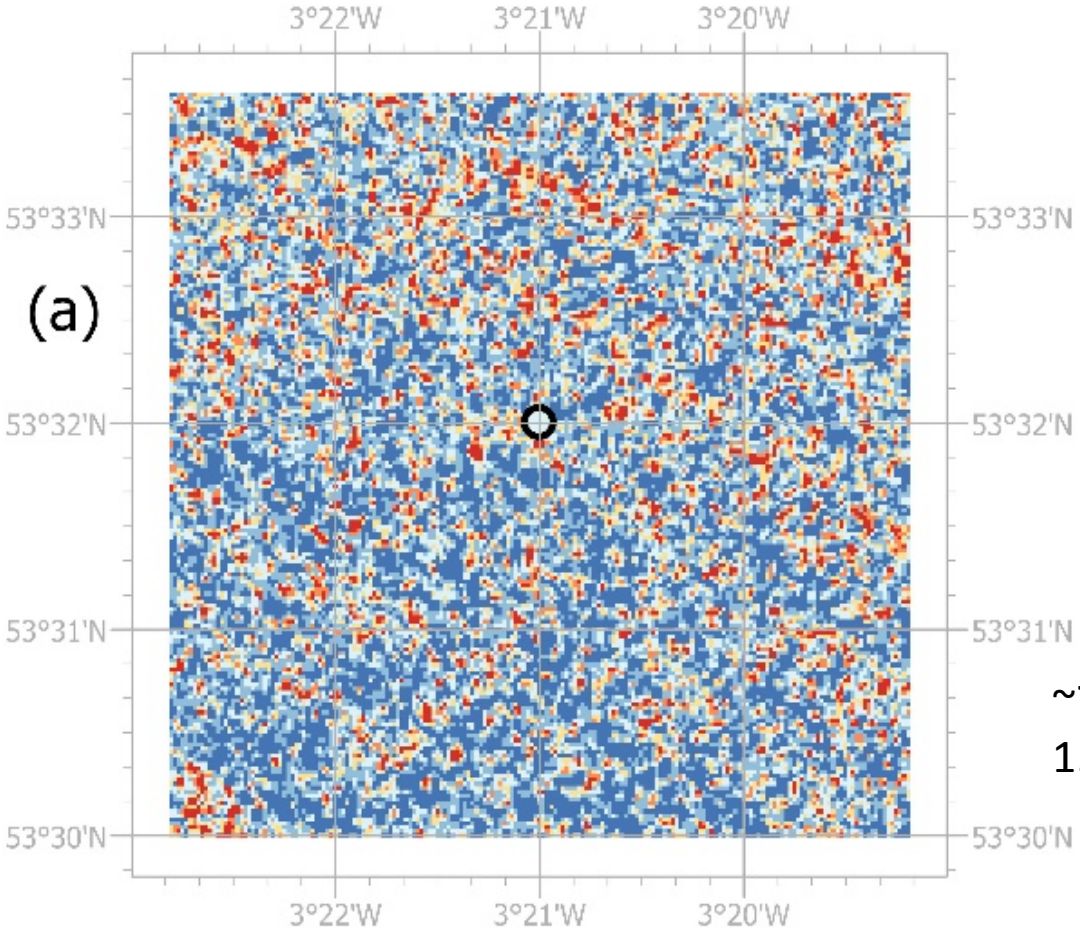
Define optimal spatial resolution

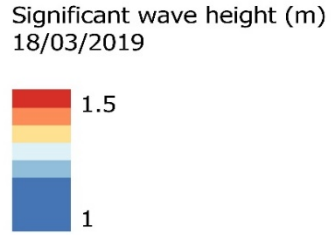
~3200 points
0.002° resolution



~60 points
0.016° resolution







Native resolution (a)

Averaging of native resolution image (b1/c1)

~792,000 points
1.25×10^{-4}° resolution

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Satellite images – Burbo Bank (Average significant wave height)

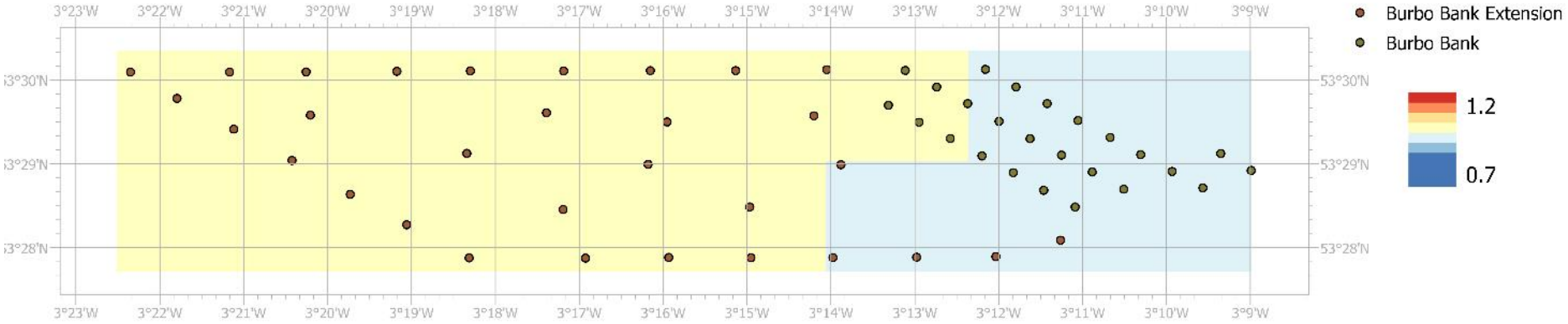
Comparison of Sea state conditions at 2/4/2019 06:32:16am

Buoy data: 0.89m (6:30am) – 1.07m (7:00am)

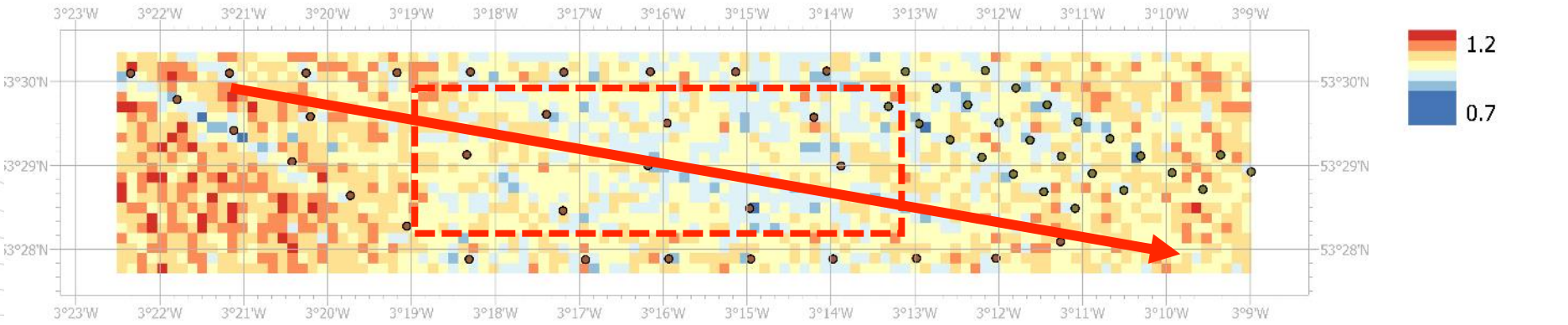
Numerical model at the buoy: 0.92m

ANN Ensemble: 0.95m

(a) CMEMS-NWS-0.016deg



(b) ANN Ensemble - 0.002deg



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Conclusions

The developed model provides:

- Equally accurate hindcast with the widely available Copernicus CMEMS-NWS
- Computationally efficient
- High-resolution hindcast

Results presented for Burbo Bank indicated wave wake effect in small/average significant wave heights which can be utilized for increased accessibility in some wind turbines

Reduction on maintenance costs linked to lost trips/wasted maintenance opportunities

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Thank you

Questions?

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