Multiscale Prediction of Offshore Wind Energy During Frontal Passage: Implication on Turbines' Wakes

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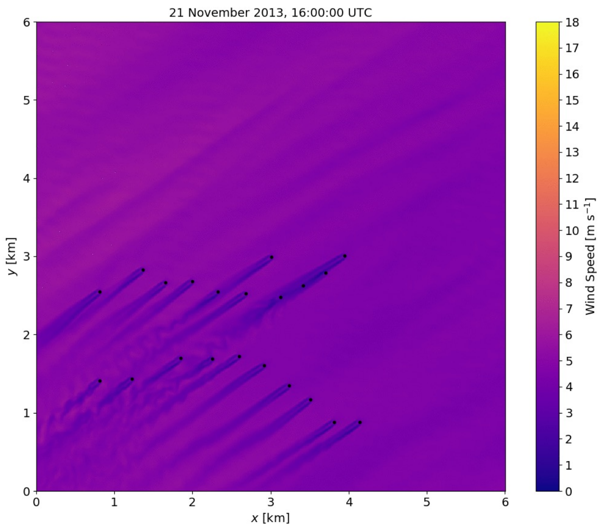
HIPERWIND

UNIVERSITY OF BERGEN

Motivation

Engineering wake models to model wind turbine wakes are useful and fast. However, they can just provide limited information associated with the flow.

- We account for wind farm wake impacts in multiscale modelling in a target study site (FINO1).



- Here we simulated wind turbines/farm wakes using different model configurations with available meteorological observations.

Source : Robert S. Arthur
https://zenodo.org/record/3632114#.YenVDC1Q1N1

Outline

- Background of model chain diagram
- Observational data and multiscale modelling of OCC
- Microscale high fidelity PALM model
- Multiscale model framework: effect of wind park

Outline

*LES explicitly resolves the large-scale energy containing motions and models the small-scale turbulent motions through the so-called **subgrid-scale (SGS) closures**.*

Microscale and meso to microscale strategies

Nomeso. nestting (PALM)

- Initial boundary conditions are provided for each atmospheric stability conditions
- Turbulence is generated either by precursors or by synthetic turbululence box model.
- Need several tuning to mach with observations.
- An actuator disk model with rotation has been combined with model

Nested: Online

- The WRF-LES coupling system can model flow field for a range of scales from mesoscale to microscale.
- It needs to be combined with actuator disk model for turbine for example.

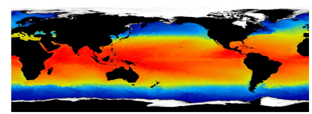
Nested: Offline (WRF-PALM)

- A coupler has been used to do all horizontal/vertical interpolations as well as other conversions.
- Conservation of mass along the nested boundaries need to be checked.
- PALM self nesting as well as offline nesting need to be verified

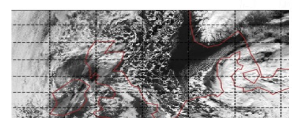
Observational data: FINO1

- Sonic anemometers at 15, 20, 40, 60, and 80m.
- Upward looking LDAR measurements.
- SCADA data
- Wave buoy measurements.

- Meteorological data (ERA5 and NORA3).
- Static geographical data.
- The Operational Sea Surface Temperature and Ice Analysis (**OSTIA**).

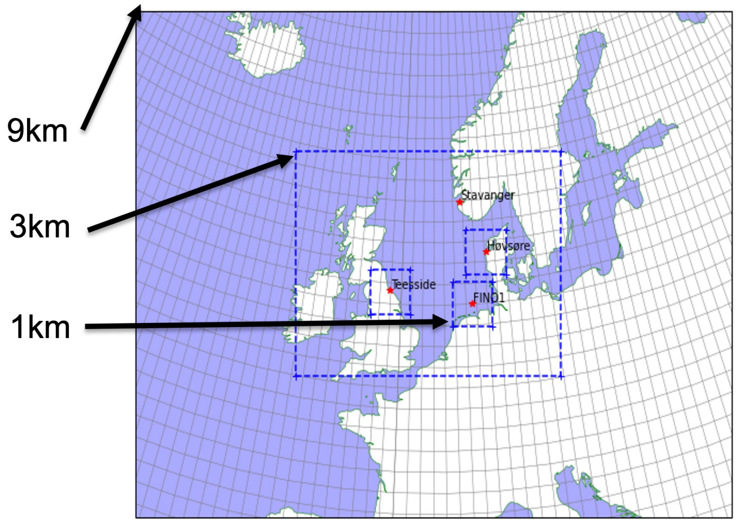


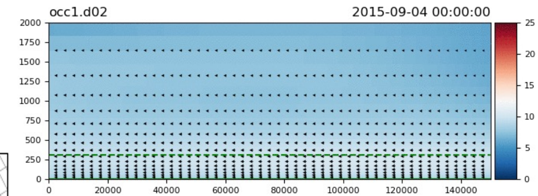
- Satellite cloud cover

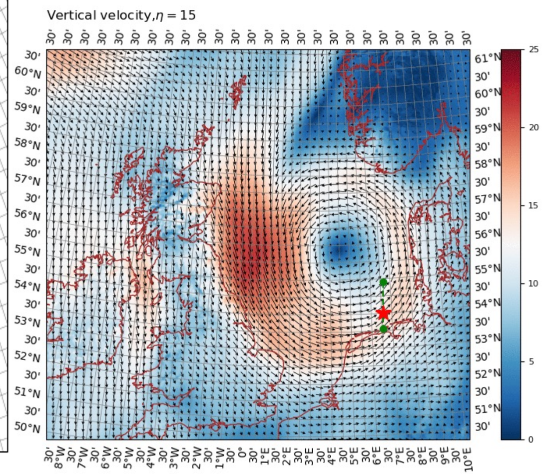


Modelling: Mesoscale

- **WRF simulation at FINO1 (**E6.588, N54.015)

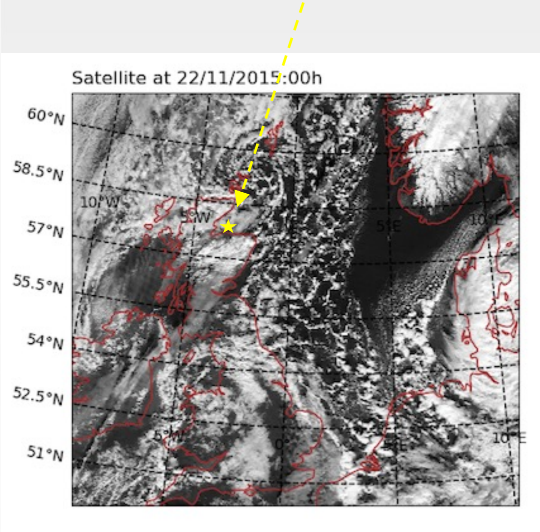






We use WRF-LES with two horizontal resulutions: 200m and 40m. Since we have no wind turbine implementation on LES model component of WRF-LES, we will focus on offline nesting

Physical processes: Open Cellular Convection (OCC) 1



- Open cellular convection (OCC) is a common phenomenon over the North Sea, where it often associates with the cold air outbreak and appears as honey comb-like pattern in cloud images.

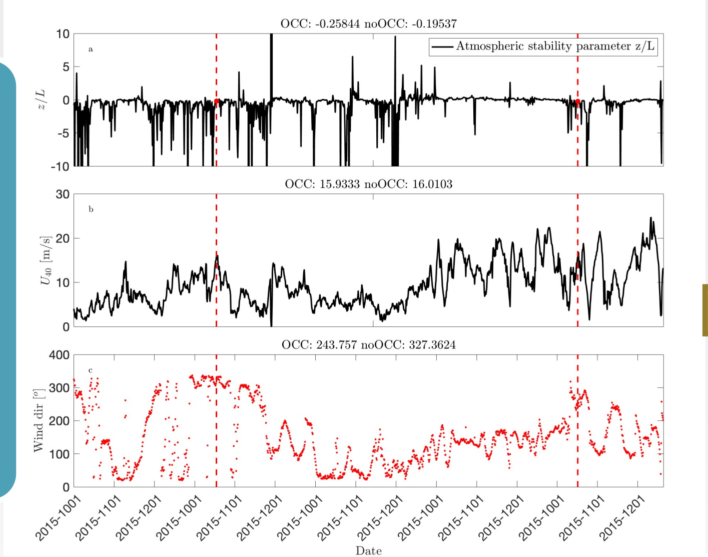
- The OCC is accompanied by large fluctuations of wind speed with a short time scale of minutes to hours.

- Such fluctuations contribute significantly to the wind speed variability over the wind farms and greatly affect the wind energy operations.

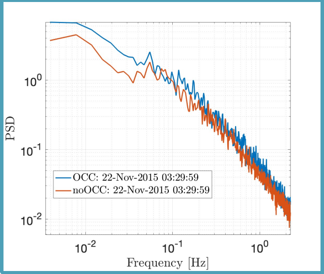
- Thus, reliable numerical simulations and forecasts of OCC events have great importance for offshore energy.

Multiscale modelling: Whether OCC event is important for small scale turbulence

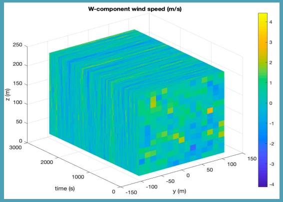
Met data from sonic anemometers mounted on FINO1



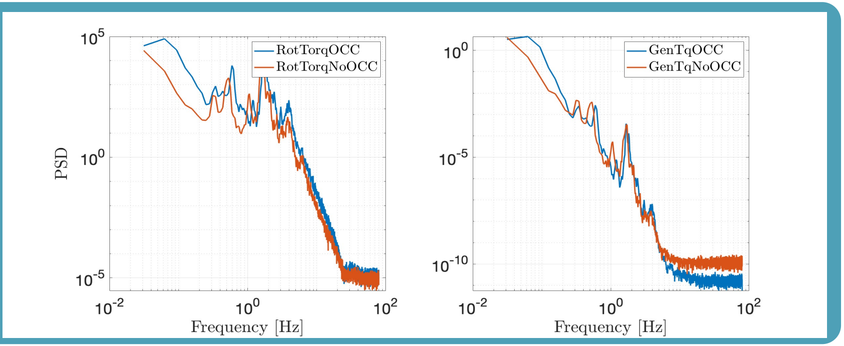
Sonic spectra of OCC versus noOCC evernts



TurbSim



NREL FAST



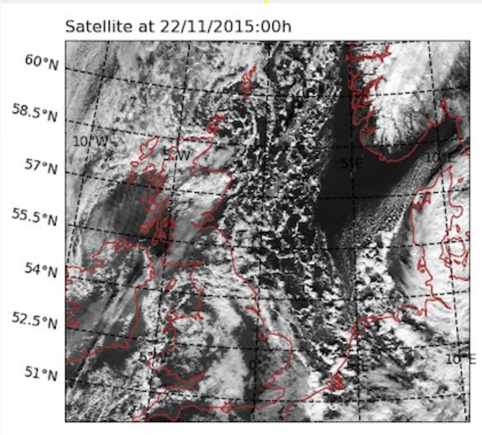
WRF results: Open Cellular Convection (OCC) 1

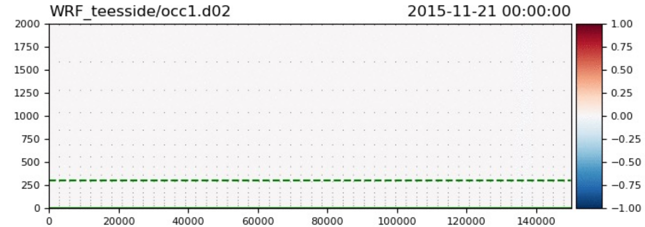
WRF d02 cross-section results

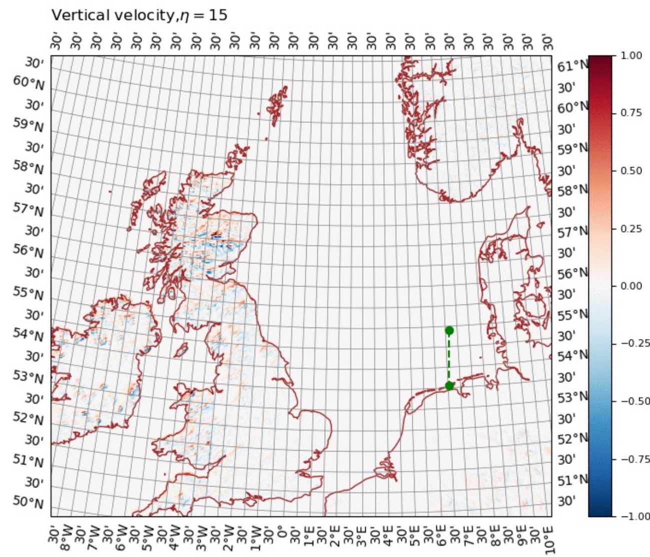
Simualtion period

2015-11-21 00:00:00 -

2015-11-23 00:00:00



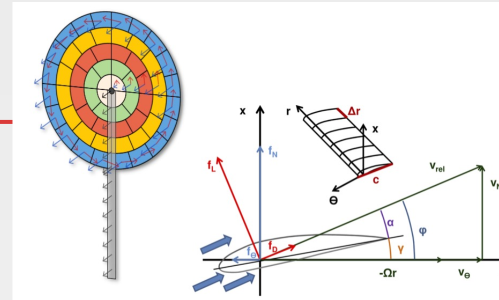




- The physics parameterizations play the key role and must be careful selected.

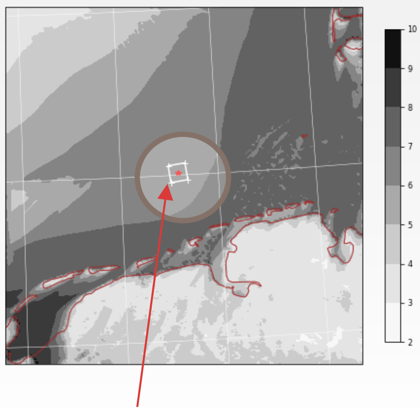
Modelling: Microscale (PALM)

- We use Paralleized Large Eddy Simulation Model (PALM) combined with actuator disk model with rotation



In this presentation we just use PALM with 1 domain

WRF 1km domain



PALM parent domain

WRF output u,v, w, pt, qv

↓

transformation of coordinate system

↓

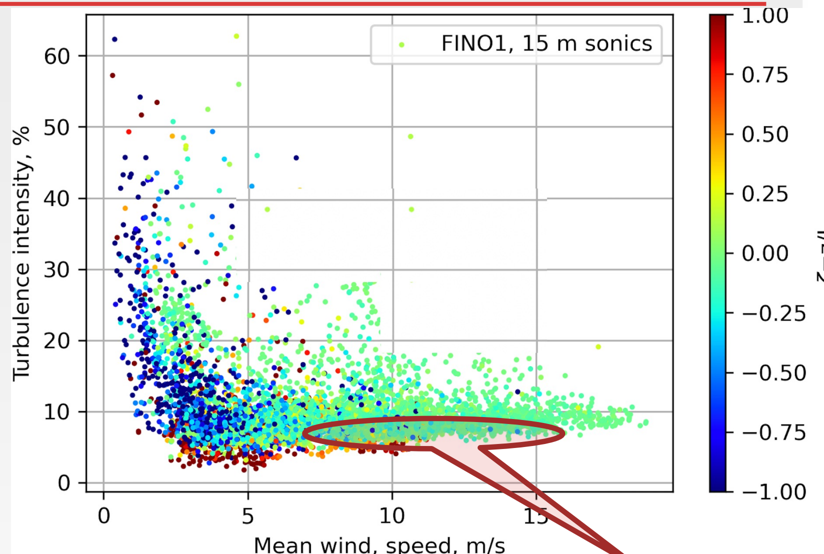
horizontal and vertical interpolation

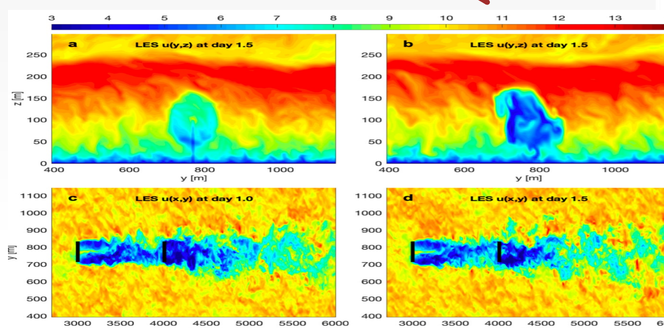
↓

dynamic input for PALM

Modelling: Microscale (PALM alone)

The relationship between atmospheric stability and TI in FINO1 (during June-August 2015)



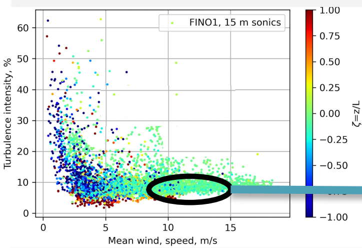


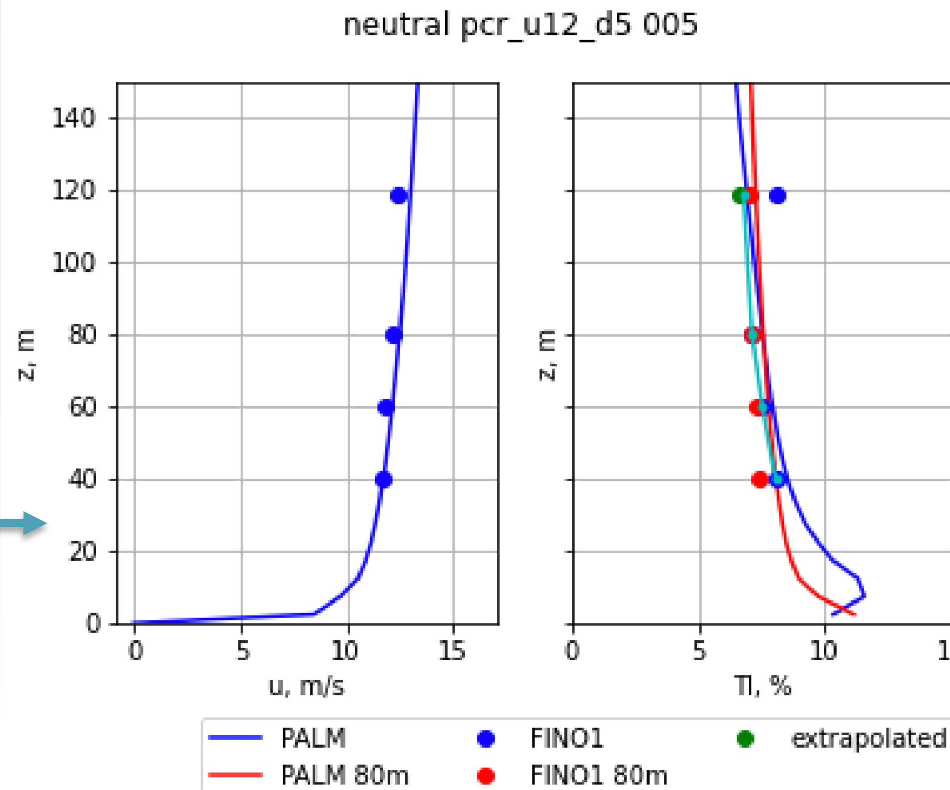
Snapshots of the LES data for the stream-wise u velocity field: (a,b) in the yz-plane in the xy-plane at hub height and t = 1 day; and (c,d) in the xy-plane at hub height and t = 1.5 day.

Small TI (stable ABL)

Modelling: Microscale (PALM alone example for stable ABL)

Compare versus observations at FINO1 mast at different heights



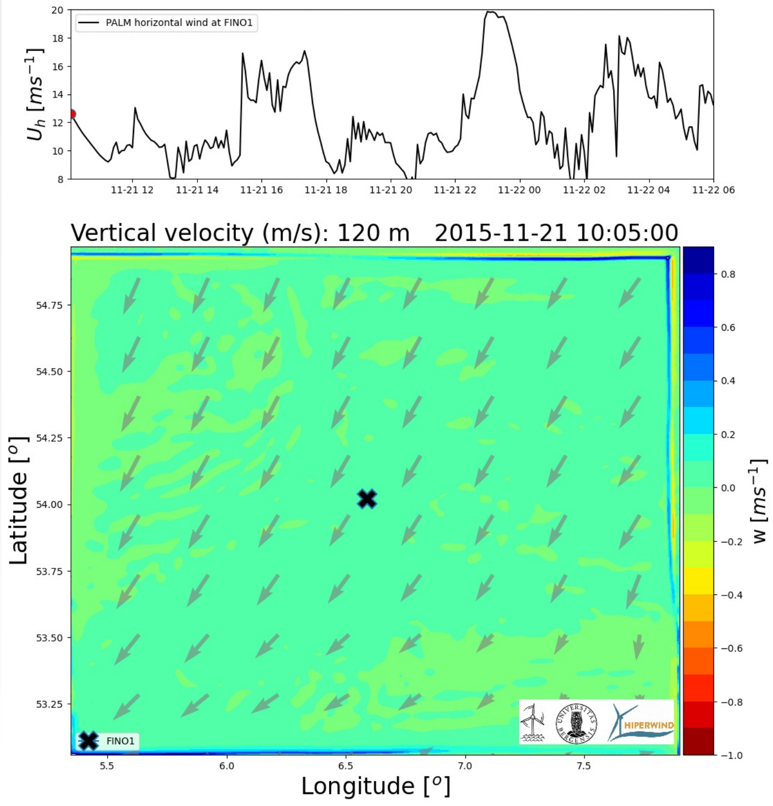


Source: Maria Kurtova

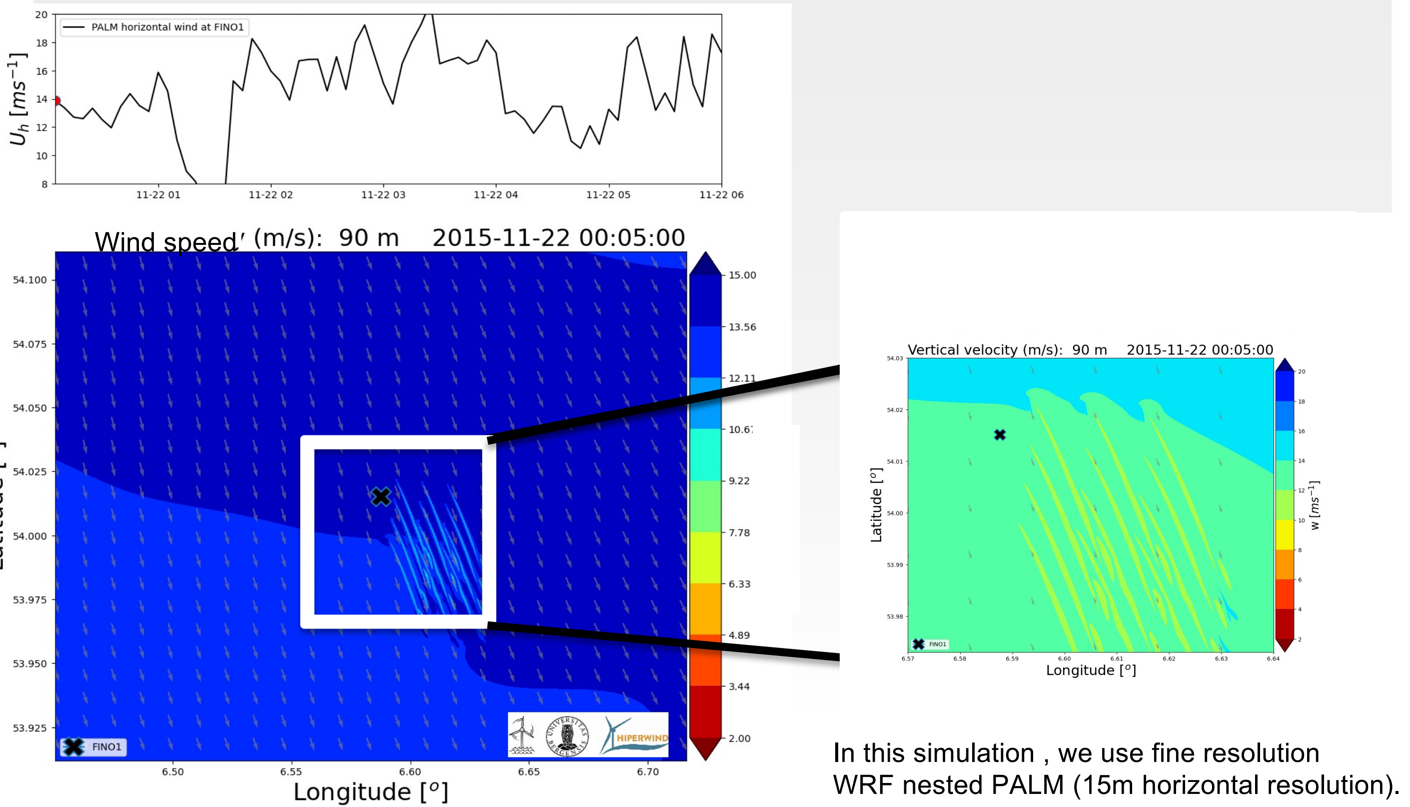
Multiscale modelling: WRF-PALM (no farm effect – 375m resolution)

Horizontal grid size is 375m and with now wind turbine OCC features are clear in the model domain.

No wind turbine



Multiscale modelling: WRF-PALM (with farm effect- 15m resolution)



In this simulation , we use fine resolution WRF nested PALM (15m horizontal resolution).

Conclusions

- **Present work**
  - We have studies meso-multiscale modelling of wind field at FINO1 using nested WRF model coupled offline with PALM microsscale model.
  - We implemented technically the wake model using WRF-PALM setup.
  - We investigated whether OCC event can influence small scale turbulence.

- **Future work**
  - Conducting a series of validation and verification scenarios based on LiDAR and sonic measurements
  - Using WRF-PALM high frequency data to conduct the load analysis.

References

[1] Bakhoday Paskyabi, M., and Flugge M., 2021
Predictive Capability of WRF Cycling 3DVAR: LiDAR Assimilation at FINO1,
J. Physics,

Acknowledgment

HIghly advanced Probabilistic design and Enhanced Reliability methods for high-value, cost-efficient offshore WIND (HIPERWIND)

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