Multiscale Wind Modelling (Mesoscale) for Wind Energy Applications: Challenges and Insights During LLJ events

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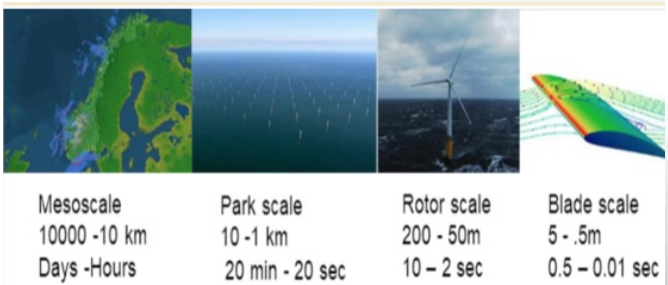
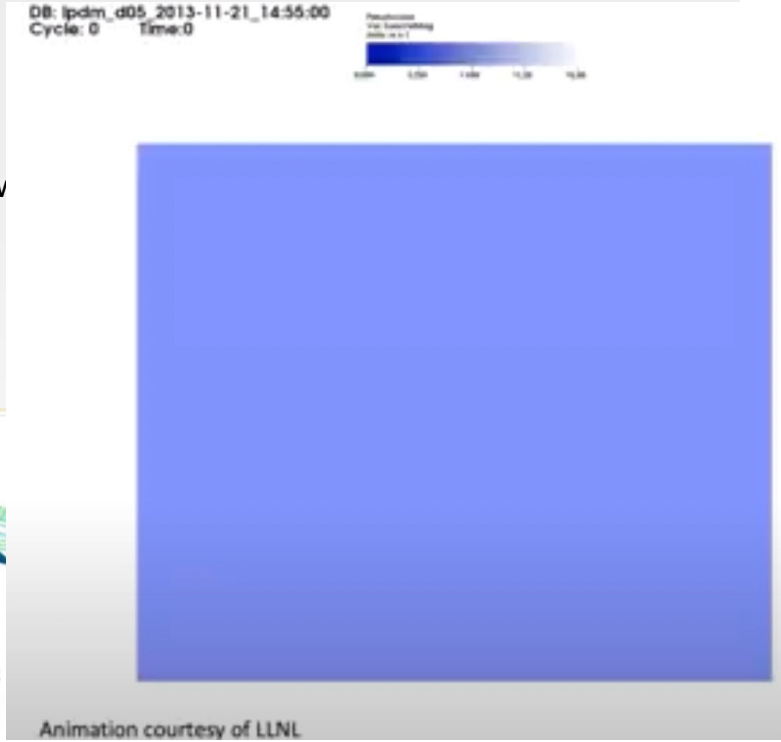
Motivation

- **Motivation**
  - Weather models are not able to resolve scales are important for the wind power plants, and microscale models cannot correctly resolve flow details with realistic forcing from mesoscale models





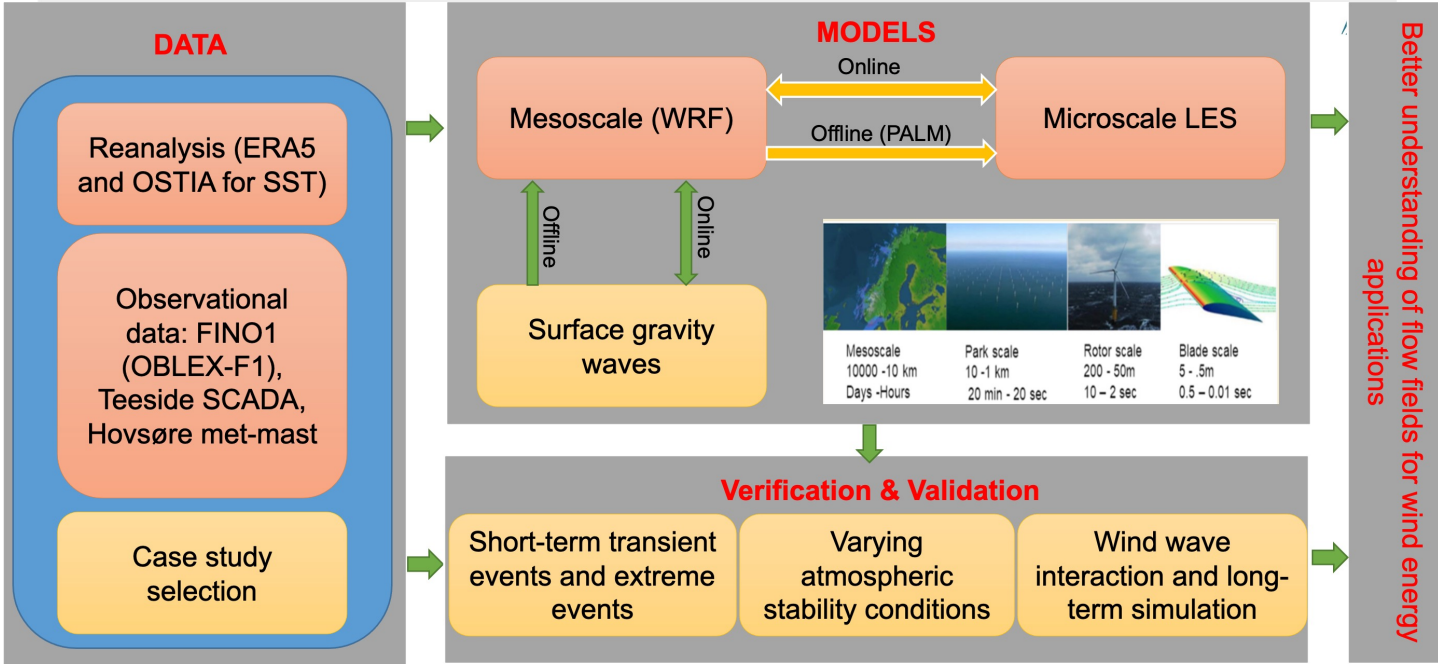
Mirocha, J. D., Kosović, B., Aitken, M. L., and Lundquist, J. K, 2014.

Outline

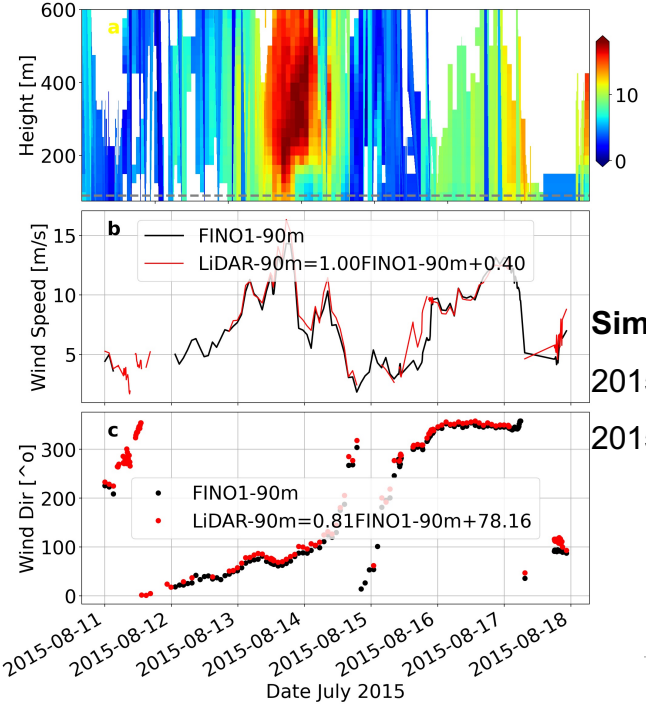
- Background of model chain diagram
- Observational data and a Low Level Jet (LLJ) event
- Multiscale mesoscale model framework

Modelling

- **Model chain**



Observational data: FINO1



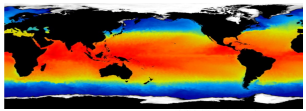
Simualtion period

2015-08-12 12:00:00 -

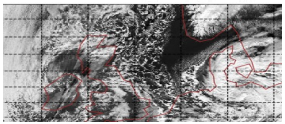
2015-08-14 12:00:00

- 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**).



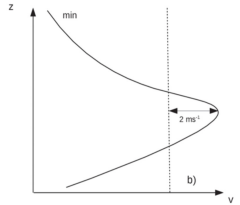
- Satellite cloud cover

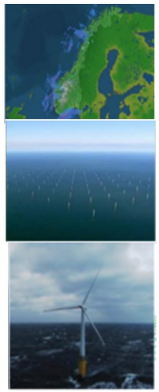


Modelling

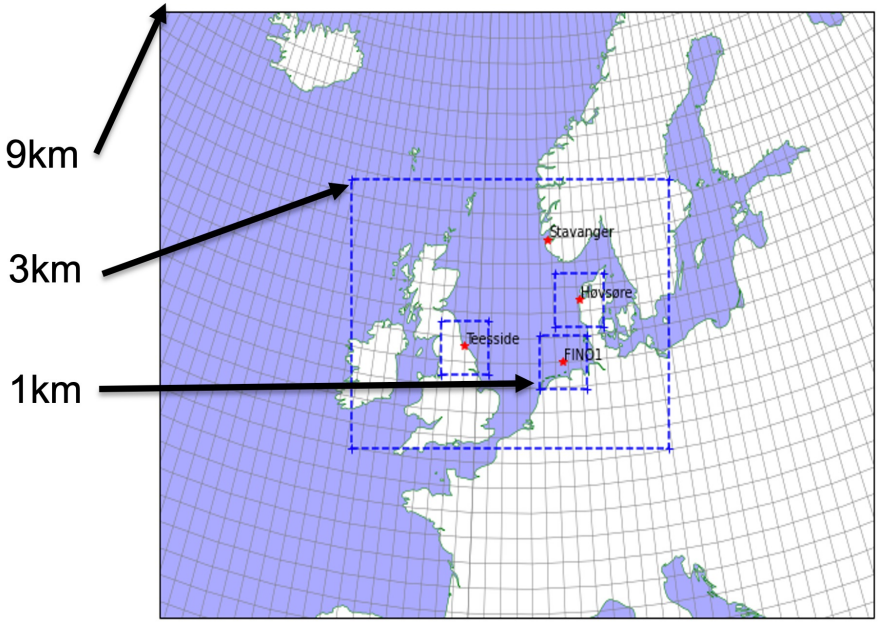
- **WRF simulation at FINO1 (**E6.588, N54.015)

The maximum below 518 m should be at least 2 ms^{-1} with a value 25% larger than the next minimum at higher heights (below 518 m).



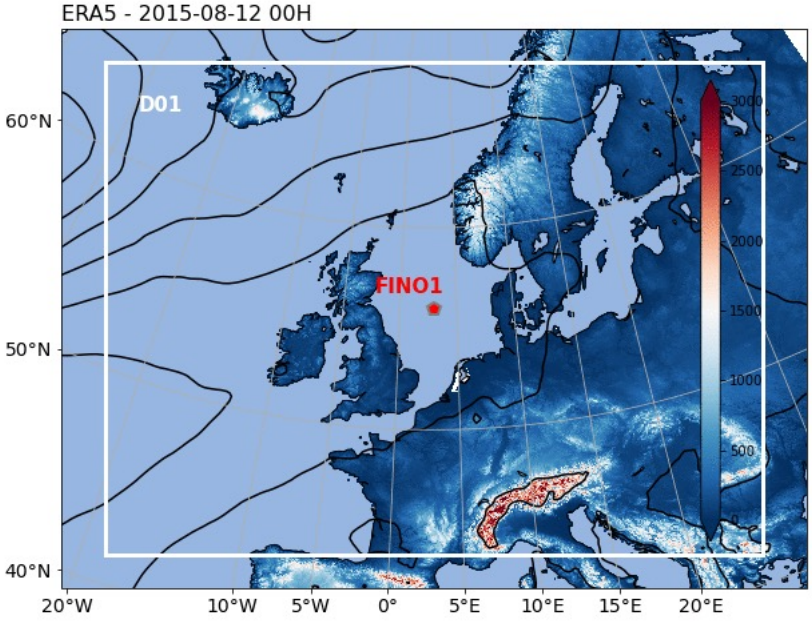


Rotor scale
200 - 50m
10 – 2 sec



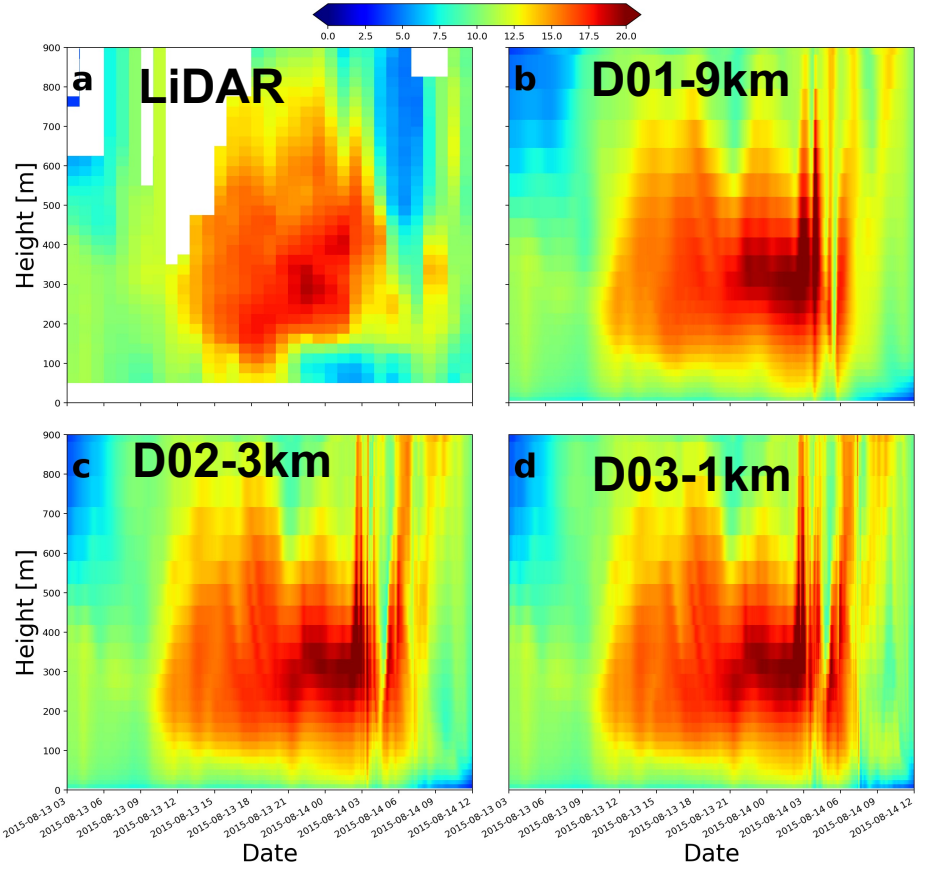
Model Result: Synoptic characteristics

- a well developed low pressure system (centered at South-West of Iceland).
- South of this weather system, there is a weak low.
- Norward passage warm front at the North Western Germany northwards leding to a southeasterly geostrophic wind.



Model results: General characteristics

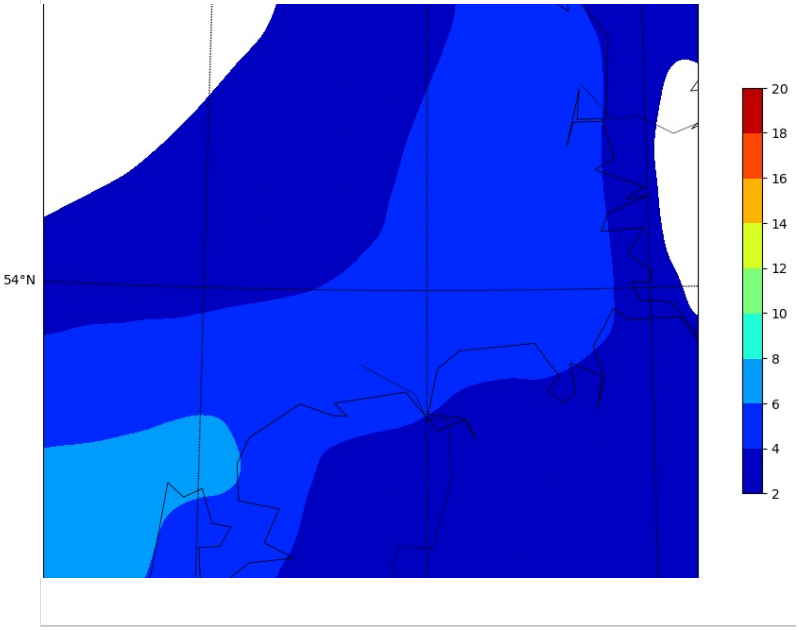
Comparisons between LiDAR (a) and WRF results At domain: (b) d01-9km; (c) d02-3km; and d03-1km.

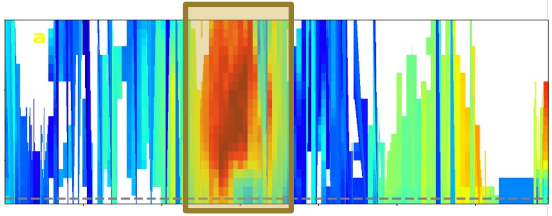


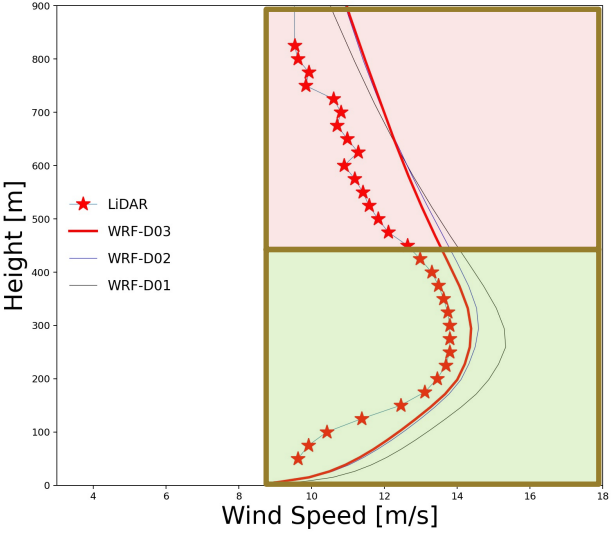
Model Results

Averaged horizontal wind speed profiles
Over the colored rectangle

Horizontal wind speedat 10m at domain d03

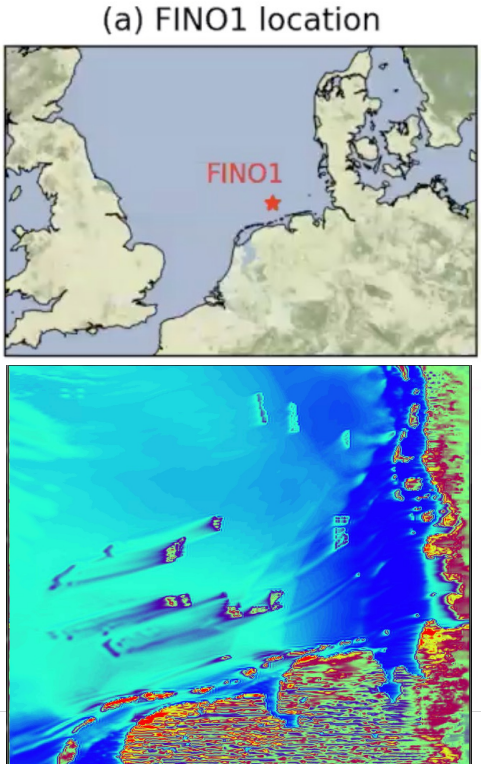




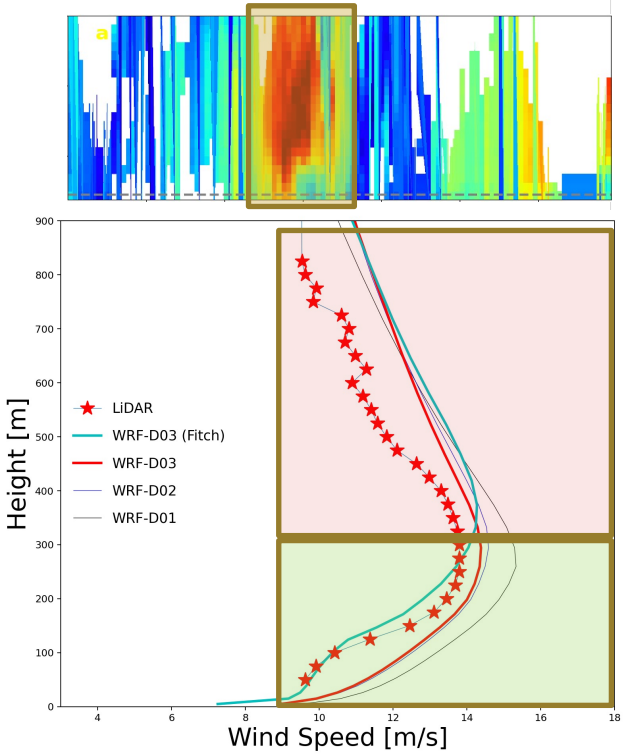


Model Results

Effect of cluster of wind farms in the Sourthern North Sea

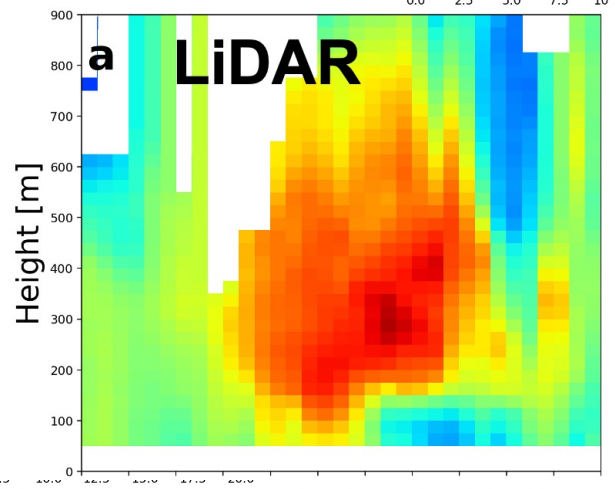


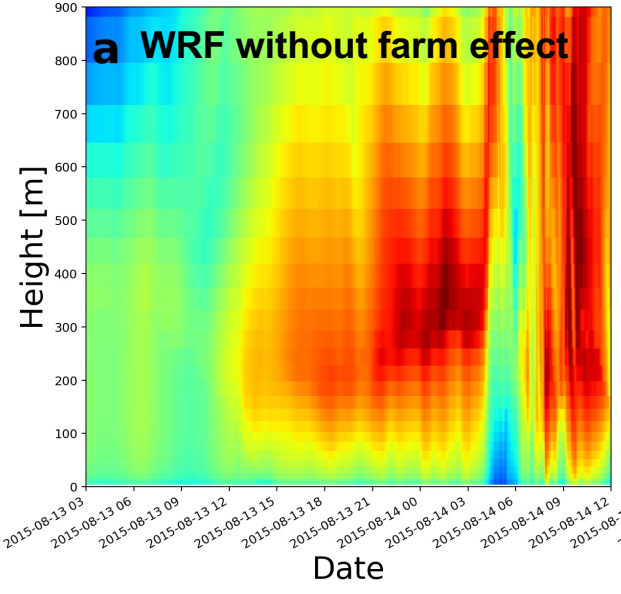
Averaged horizontal wind speed profiles Over the colored rectangle

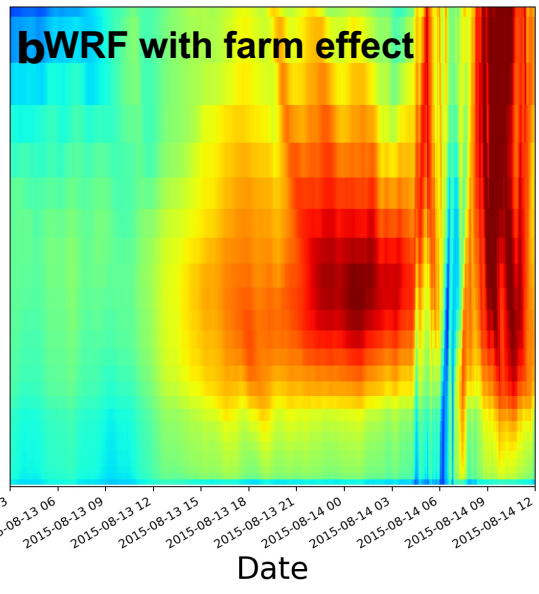


Model Results Effects of wind turbine

Effects of farms influence the vertical-spatial distribution of wind field

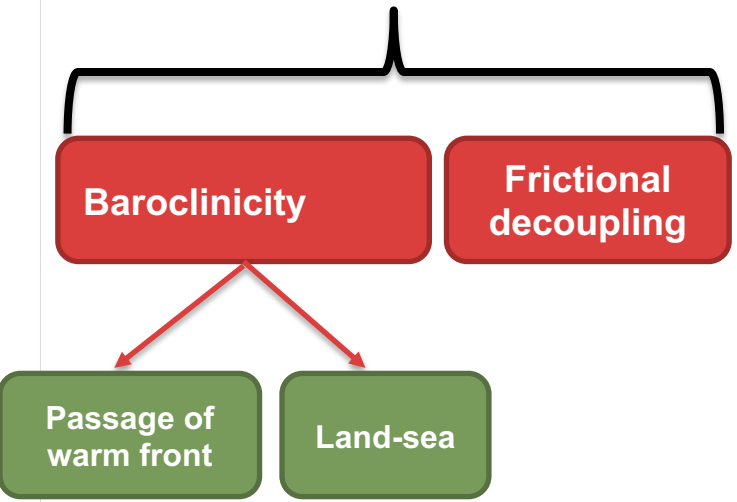




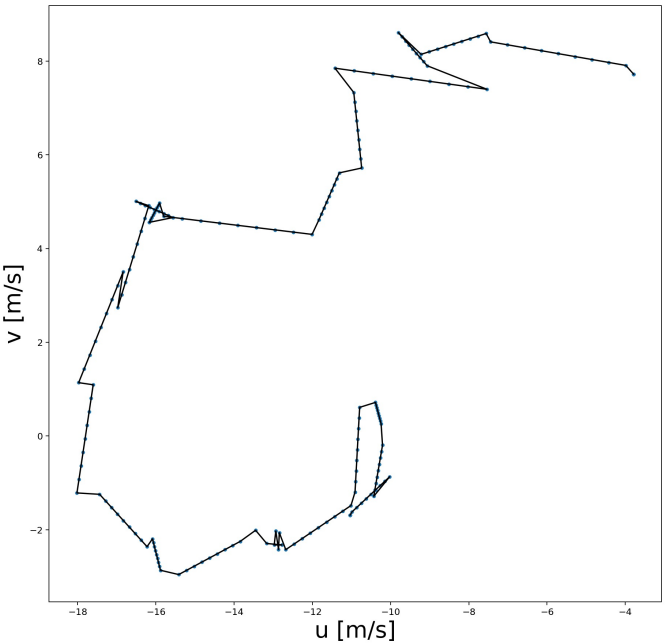


LLJ generation mechanisms

A combination of different processes are responsible for formation of this LLJ event. These mechanism are contributing together in generation process:



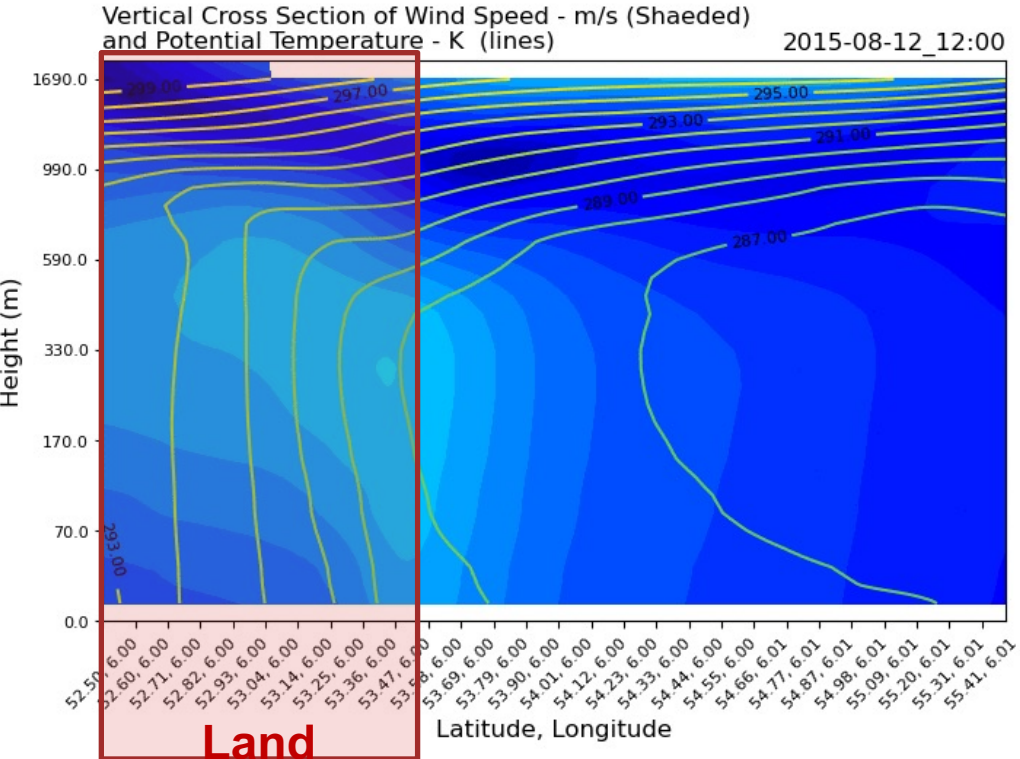
An **inertial oscillation** was observed from 0840 UTC 13 August to 0040 UTC 14 August.



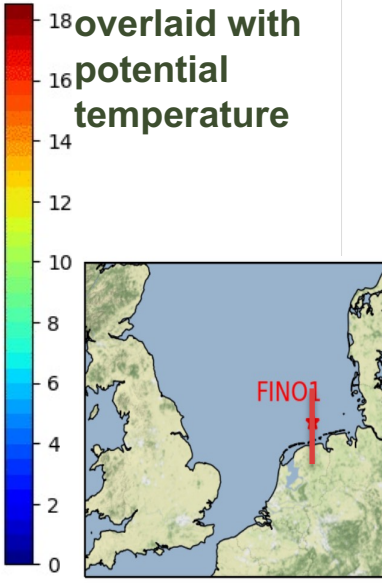
The cycle shows an elliptical shape typical for the IO, although the cycle is not closed.

LLJ generation mechanisms: Baroclinicity

Baroclinicity is state of flow that surfaces of constant temperature (density) are intersected by the surface of constant pressure.



Wind speed along the cross-section overlaid with potential temperature

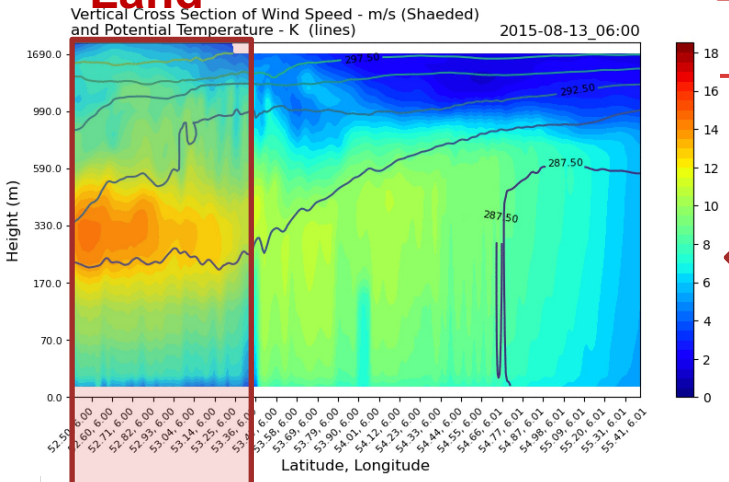


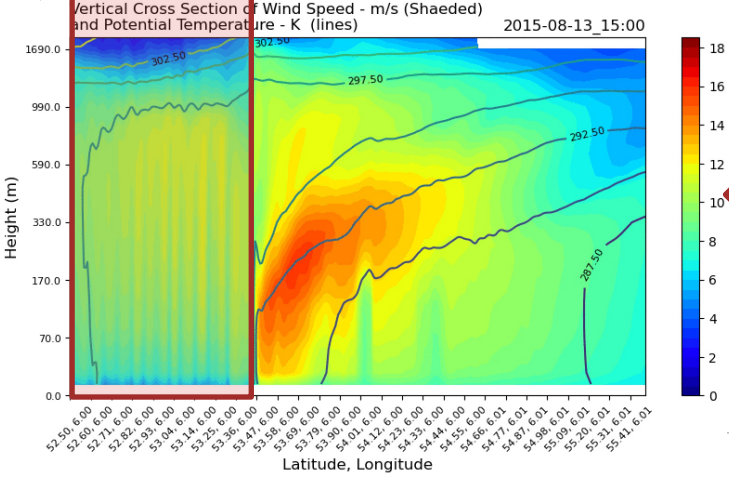
Cross-setion Passing FINO1

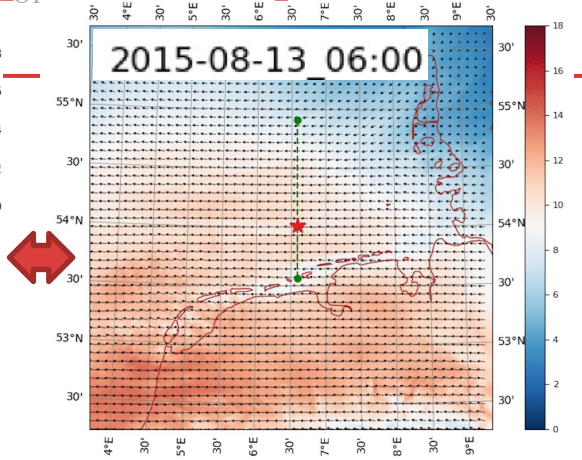
LLJ generation mechanisms: Baroclinicity

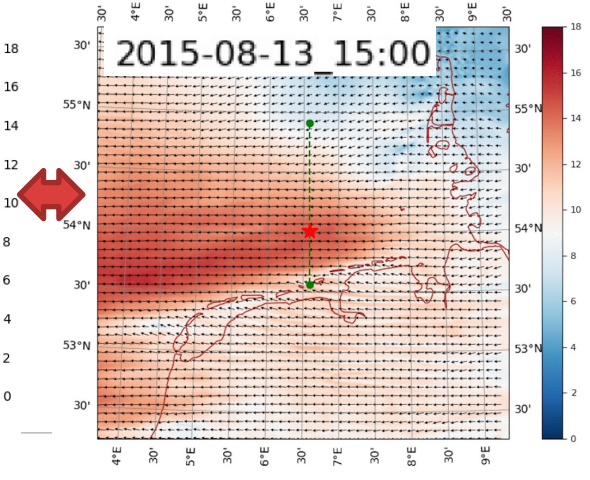
Land

connection of wind speed and temperature









Thermal wind formation

Conclusions

- **Present work**
  - We have studies meso-multiscale modelling of wind field at FINO1 using nested WRF model.
  - We checked the importance of accounting for the wind farms in the Southern North Sea
  - We investigated the formation mechanism of a LLJ event in which we have good LiDAR coverage..
- **Future work**
  - Use WRF and WRF-LES to complete the model chain. We will the conduct the load analysis based on high-frequency time series of WRF-LES.

References

[1] Wagner, D., Steifeld, G., Witha, B., Wurps, H., and Reuder, J., 2019 Low Level Jets over the Southern North Sea, Meteorol. Z., 28, 389–415.

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

Acknowledment

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

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