Multiscale modelling of low-level jet: Effects on aerodynamic load of offshore wind turbine

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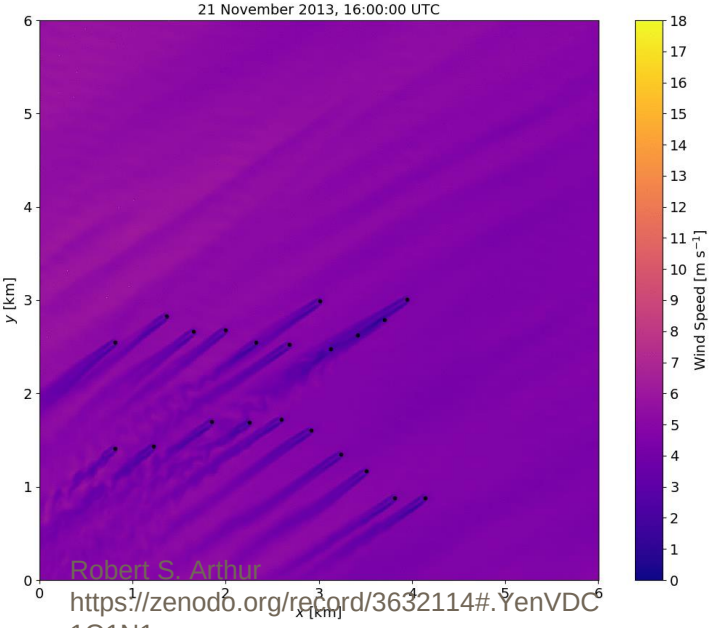
Motivation

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



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

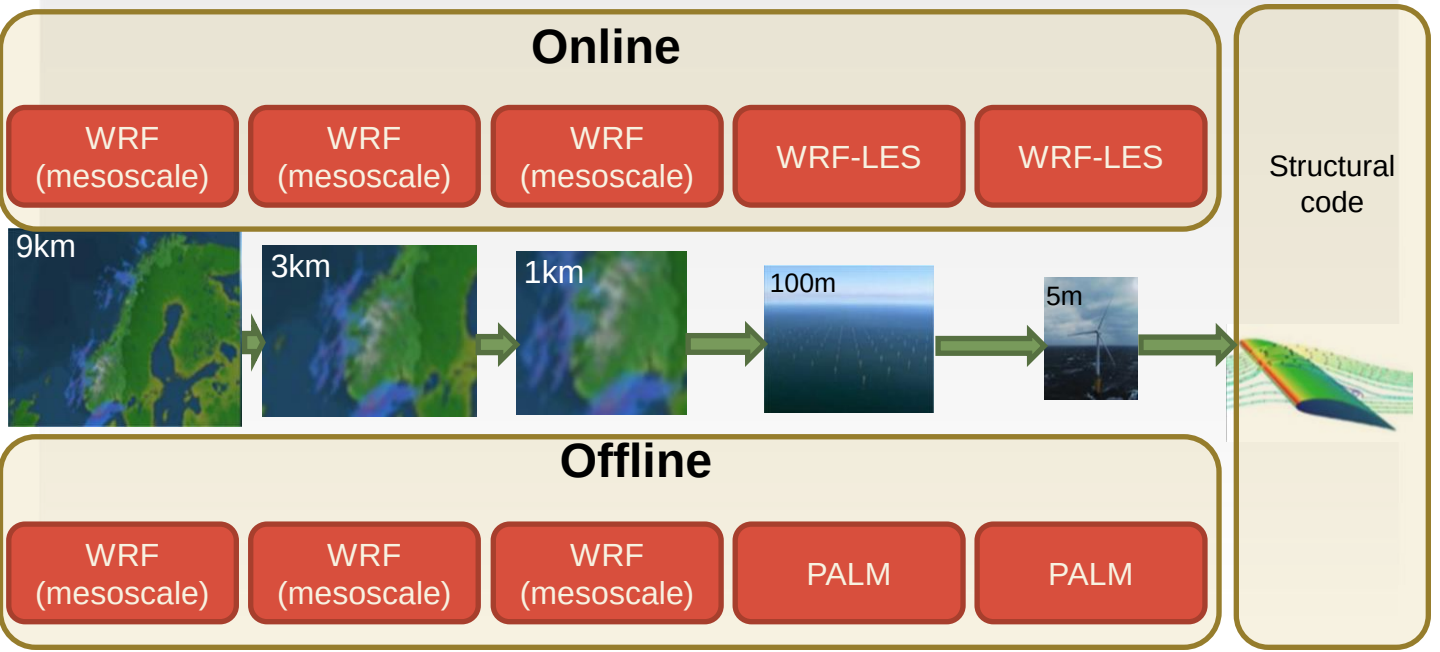
Outline

- Introduction to multiscale modelling frameworks
- Observational data (FINO1 & Alpha Ventus)
- Transient event modelling and measurement
- Results

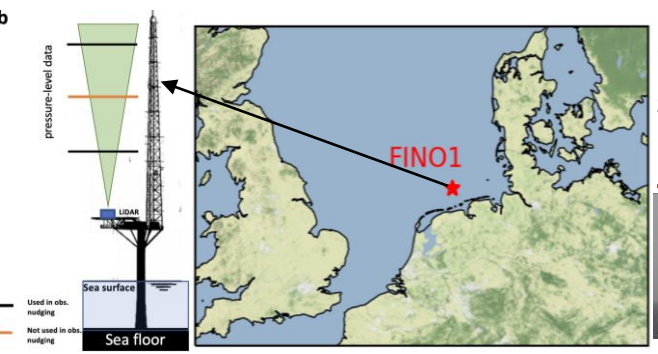
Multiscale modelling frameworks

Model components:

- Weather Forecasting and Research (WRF).
- Parallelized Large Eddy Simulation Model (PALM).
- WRF Large eddy Simulation (WRF-LES)



Read more in [1]



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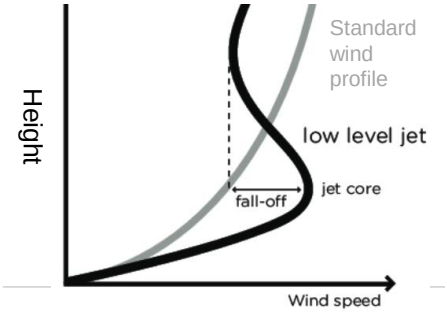
Measurements during Low Level Jets

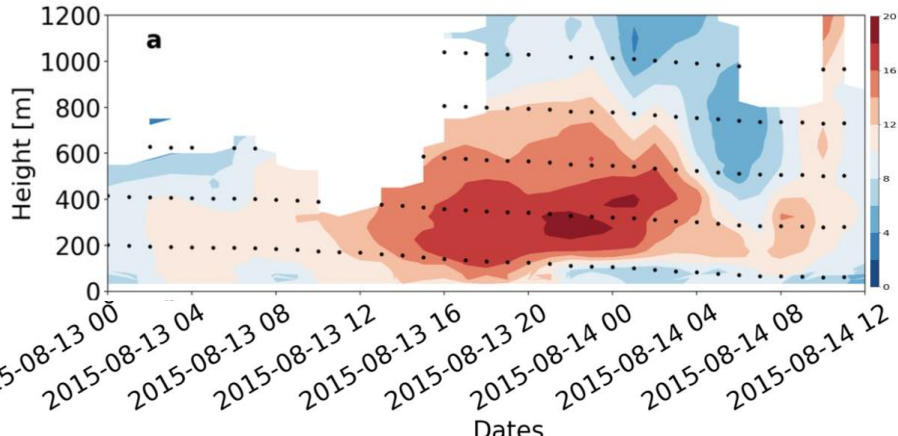
- Sonic anemometers at 15, 20, 40, 60, and 80m.
- Upward looking LDAR measurements. (OBLEX-F1 between 2015 and 2016)

Maximum detection height of 518 m LLJ profile should exist at least for 20 minutes.

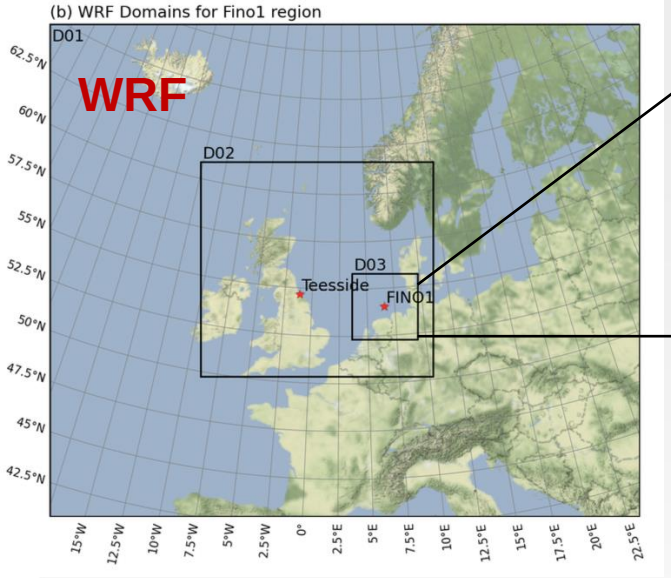
The maximum below 518 m should be at least 2 ms^{-1} with a value 25% larger than the next minimum at higher heights (below 518 m).

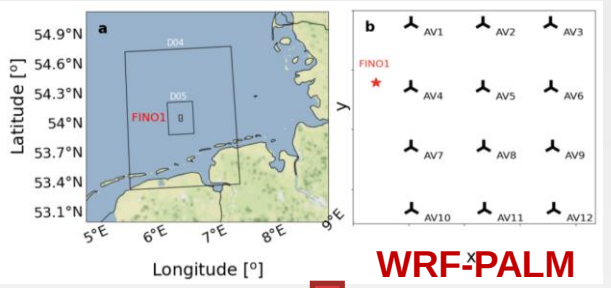


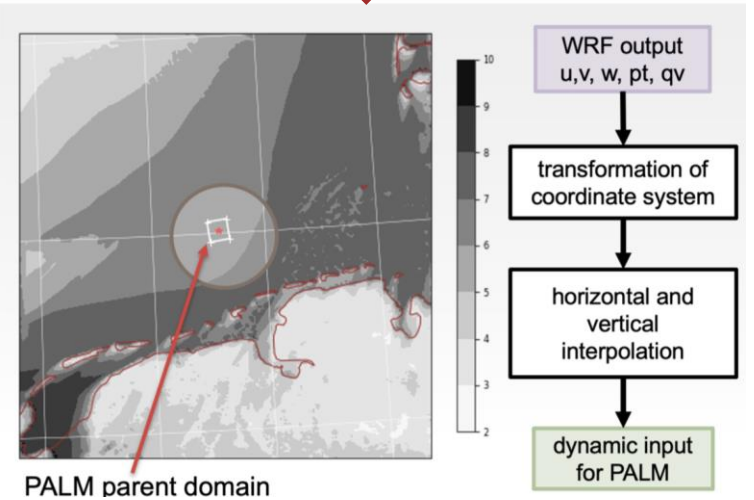
LiDAR measurements during a LLJ



Multiscale modelling: WRF and PALM domains and coupling(offline)





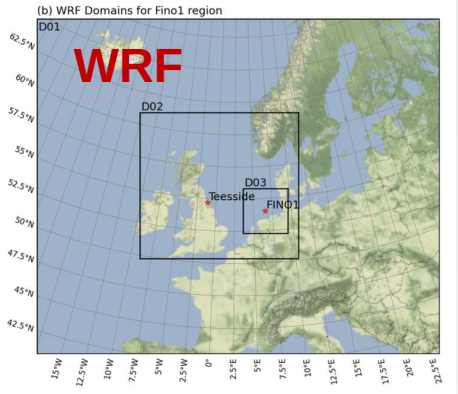


WRF fine resolution domain (i.e. D03 with 1 km horizontal resolution) and PALM outer domain with horizontal resolution of 270 m. The right-hand-side panel shows the flow chart corresponding to the offline WRF and PALM nesting.

Read more in [1,2,3]

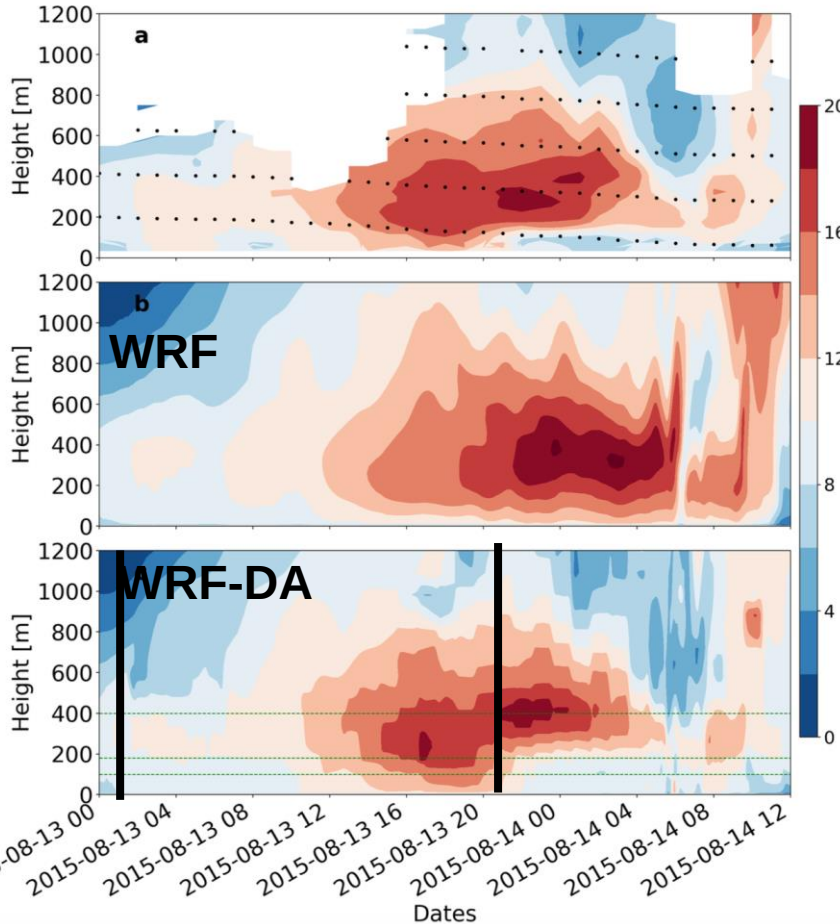
Results

Multiscale modelling: WRF modelling



(b) WRF without Observation nudging Analysis (OA); and (c) WRF with OA.

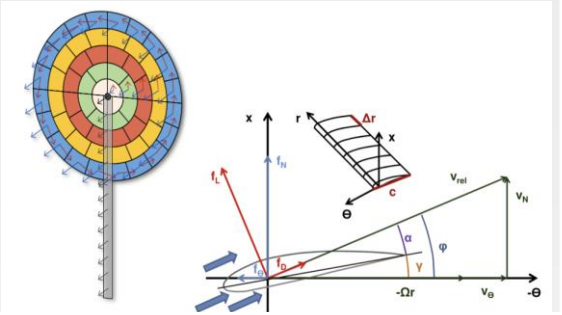
Vertical lines show start time of PALM simulations



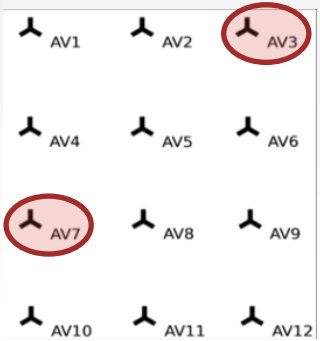
Read more in [1,4]

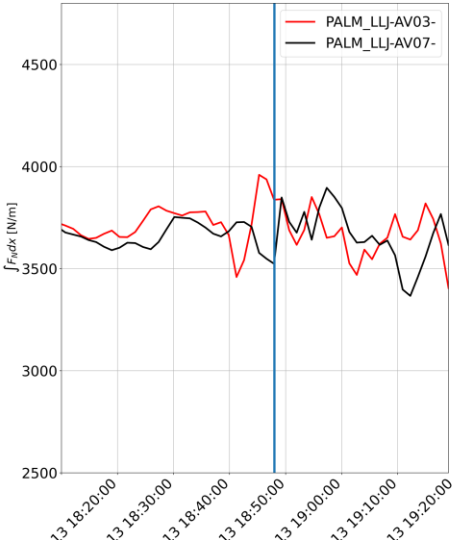
Meso-to-microscale (WRF-PALM): LLJ episode

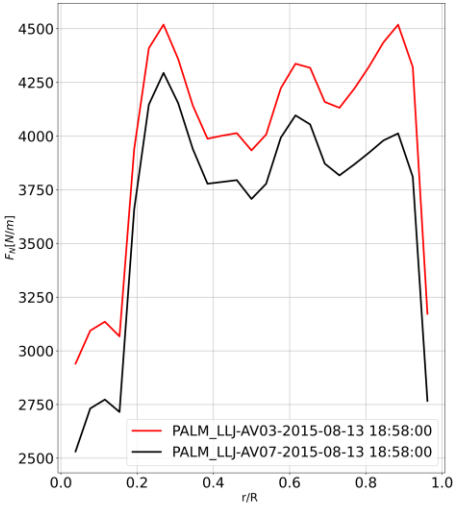
- Wake effects for this event due to dominance of thermal stratification won't induce turbulence from wake meandering or wake-added turbulence.
- AV03 and AV07 shows similar behaviour for this specific event (due to large recovery distance and the fact that AV07 does not reside in the wake of upstream turbines).



Time series of integrated thrust force during LLJ event for AV3 & AV7

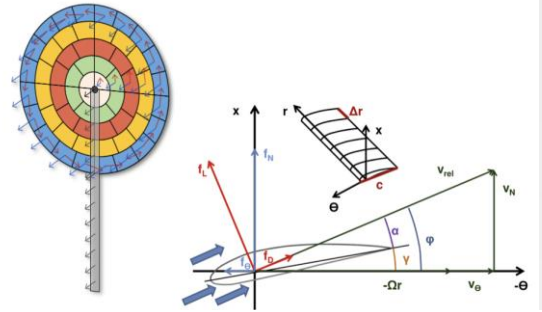






Meso-to-microscale (WRF-PALM): no LLJ (weak) episode

- We have less pronounced thermal stratification due to mixed stable-unstable conditions,
- wake recovery is fast.
- turbines induce wakes and turbulence.
- Further elaboration is required for verification versus LiDAR & interpretation of results.



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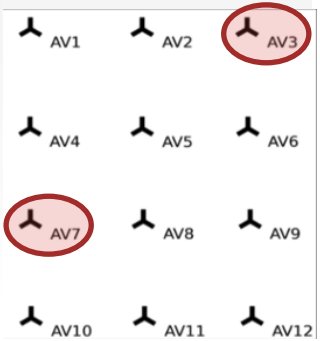

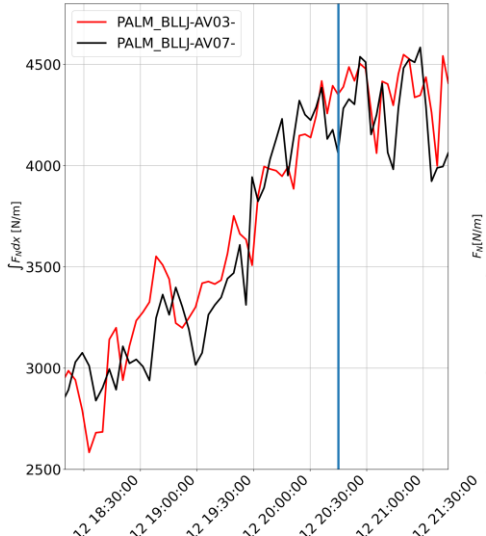

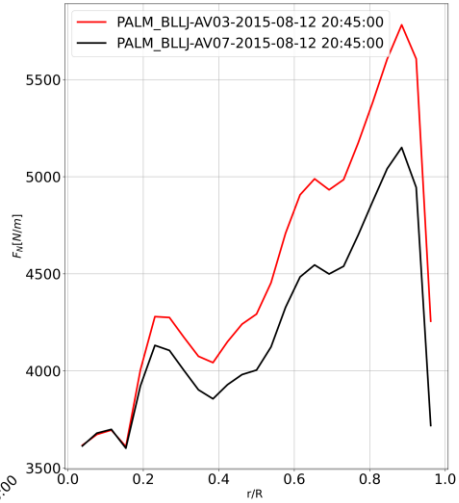

Conclusions

- We developed a multiscale frame work to model wind.
- Uncertainity of mesoscale model-chain was reduced through observational nudging.
- We showed the wake meandering and evolution using offline meso-to-microscale framework for two cases: before & during LLJ event.
- The aerodynamic thrust loads calculated using ADM-R in PALM for these two cases.

References

[1] M. Bakhoday-Paskyabi, H. Bui, M. Mohammadpour-Penchah, 2022, D2.1 - Atmospheric-Wave Multi-Scale Flow Modelling (2022), EU Horizon project delivery report, https://www.hiperwind.eu/publications .

[2] **Bakhoday Paskyabi, Mostafa; Krutova, Maria; Bui, Hai; Ning, Xu.** Multiscale Simulation of Offshore Wind Variability During Frontal Passage: Brief Implication on Turbines' Wakes and Load. *Journal of Physics: Conference Series (JPCS)* 2022 ;Volum 2362.

[3] **Bui, Hoang Hai; Paskyabi, Mostafa Bakhoday.** Mesoscale simulation of open cellular convection: roles of model resolutions and physics parameterizations. EERA DeepWind 2022 Conference; 2022-01-19 - 2022-01-21.

[4] **Bakhoday Paskyabi, Mostafa; Flügge, Martin.** A Mesoscale Model Sensitivity over the Southern North Sea: Comparison with Measurements and Impacts of Data Assimilation. Presentation; 2021-01-12 - 2021-01-15

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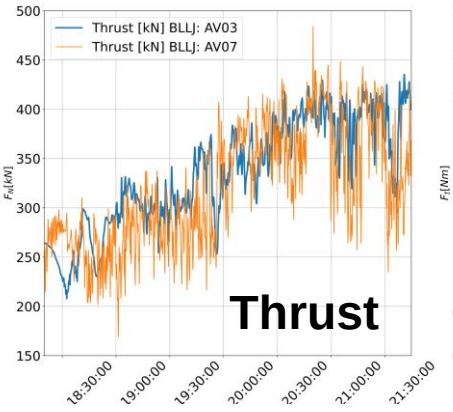
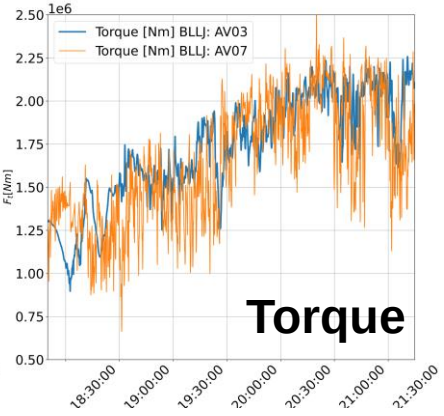
Meso-to-microscale (WRF-PALM): no LLJ (weak) episode

Time series of averaged thrust and torque during LLJ event for AV3 & AV7





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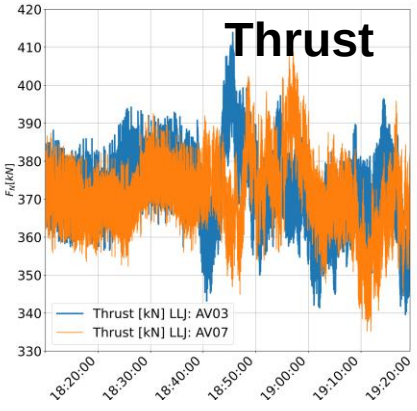
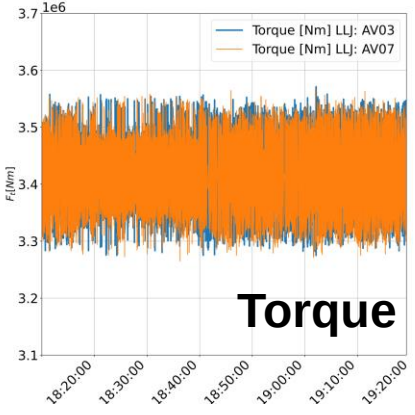
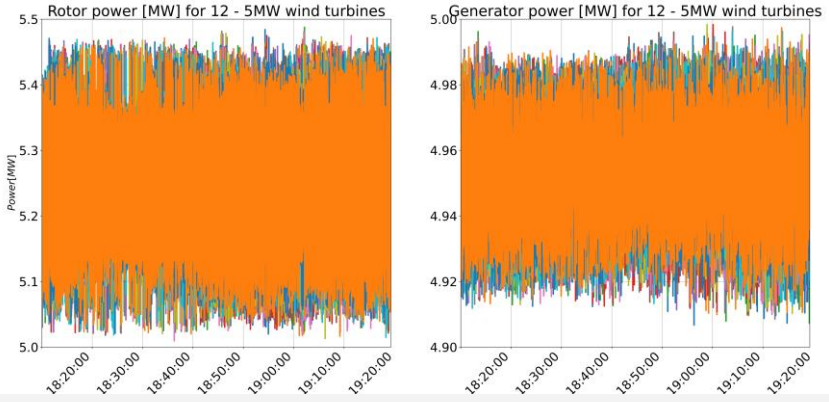




Meso-to-microscale (WRF-PALM): no LLJ (weak) episode

Time series of power production during LLJ event for all turbines



Time series of power production during BLLJ event for all turbines