X-Wakes Public Workshop

Multi-fidelity wake model benchmark of external wake effects

Lukas Vollmer[1], Hauke Wurps[2], Martin Dörenkämper[1]

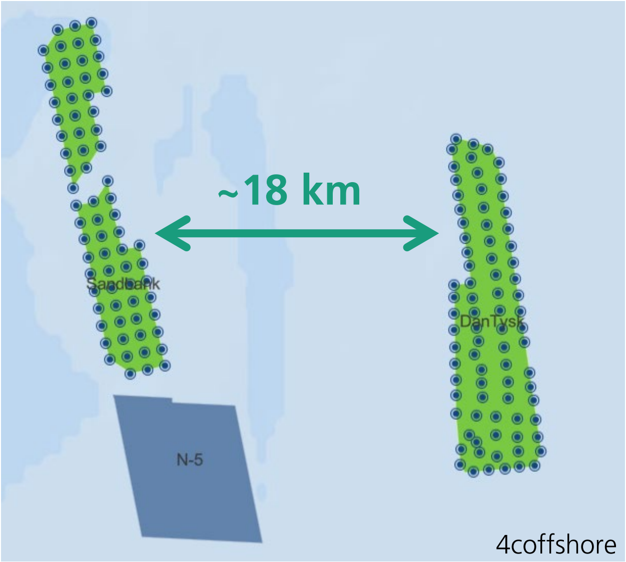
[1] Fraunhofer IWES
[2] ForWind – Universität Oldenburg

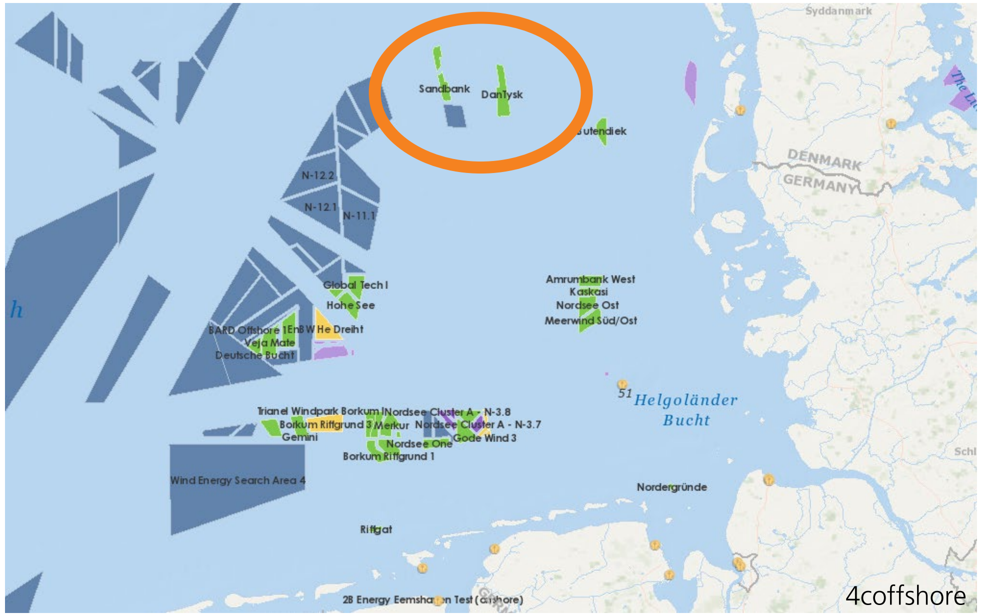
Benchmark idea

Isolating the far wake effect

Isolation of impact of long wakes between the two wind farms

- 4 years of concurrent data of Sandbank & Dan Tysk
- Availability and wind conditions at both farms available
- Additional meteorological information from WRF simulation





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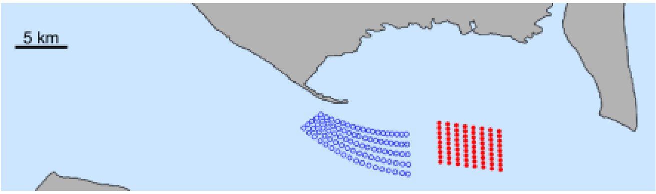
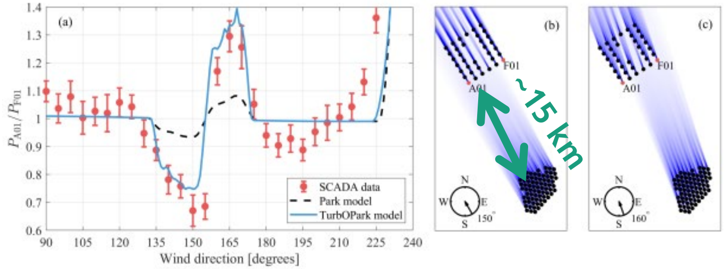
Comparable studies:

- Nysted – Rodsand(e.g. 1,2)
  - Small distance
  - Possibly large disturbance by land



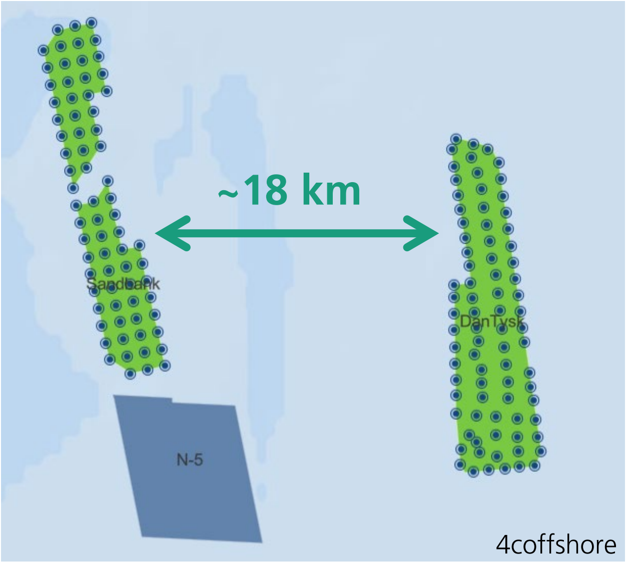
- Humber Gateway – Westermost Rough[3]
  - Only SCADA data from WMR



[1]Nygaard, 2016, [2]Fischereit, 2022, [3]Nygaard, 2020

Benchmark idea

Isolating the far wake effect



Isolation of impact of long wakes between the two wind farms

- 4 years of concurrent data of Sandbank & Dan Tysk
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Processing of data for the benchmark

Performance Filter

WS Filtering

Power Gap Filling

WD Bias Correction

WD Consistency Correction

Free Inflow Calculation

Comparison WRF and Met Mast

WS Bias Correction

Estimate Advection between Farms

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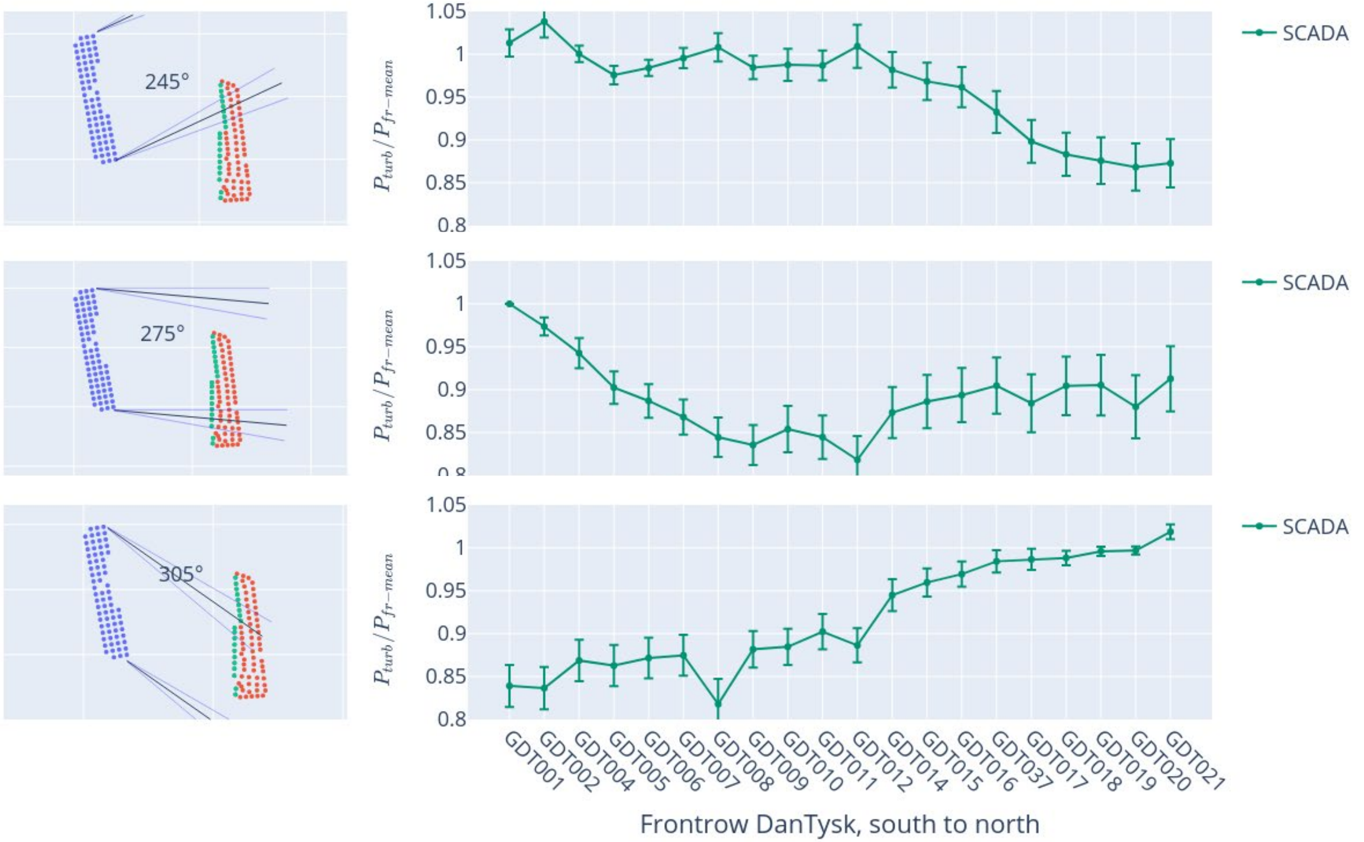
Benchmark idea

Reducing uncertainties

- Focus on relative production of first row of Dan Tysk
- Reducing influence of
  - Power curve biases, sensitivity to veer, shear, TI
  - Biases / uncertainties in free wind speed

- Benchmark input
  - Wind speeds / directions from front-most row of Sandbank
  - WRF parameters for filtering / as model input
    - TI
    - Obukhov length
    - Atmospheric boundary layer height



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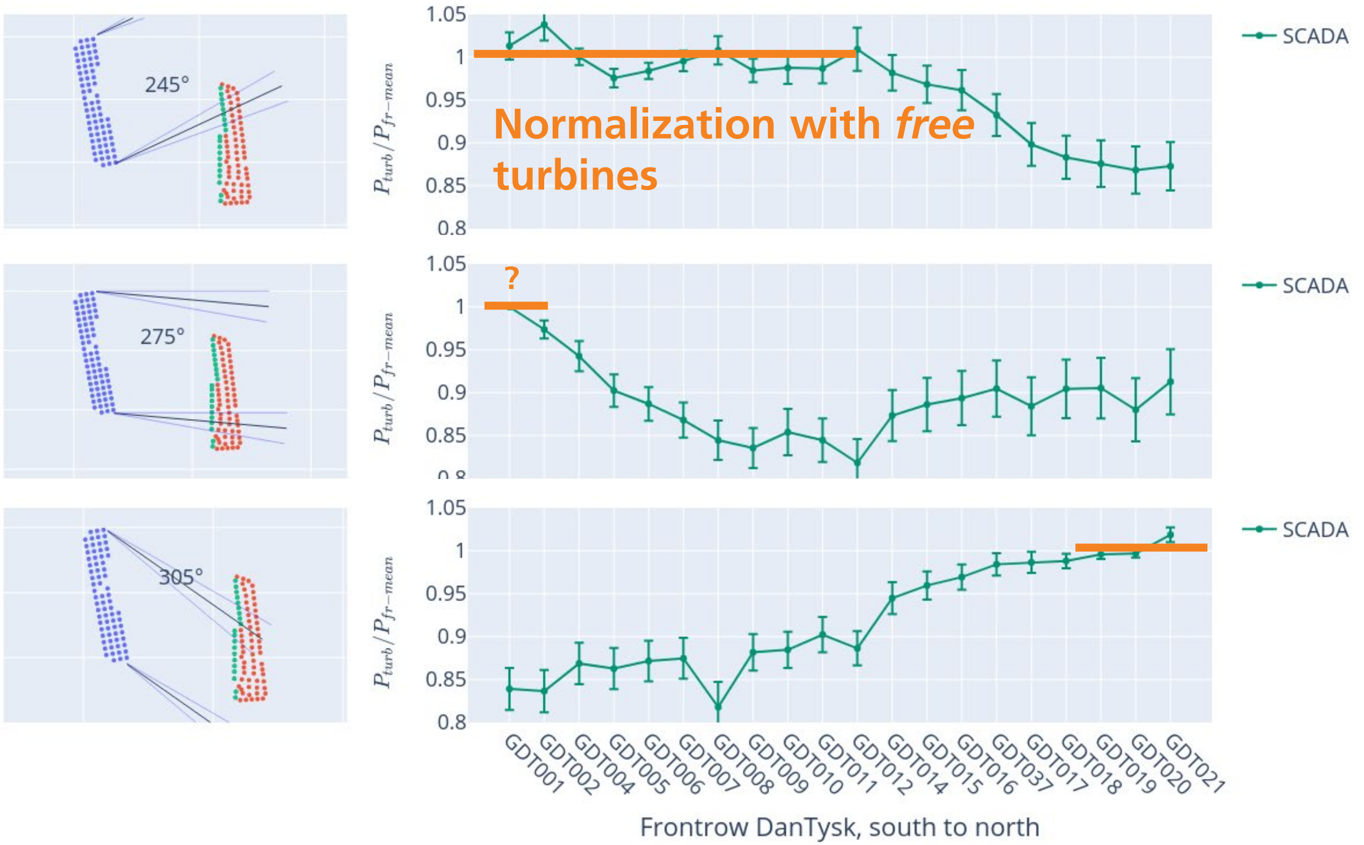

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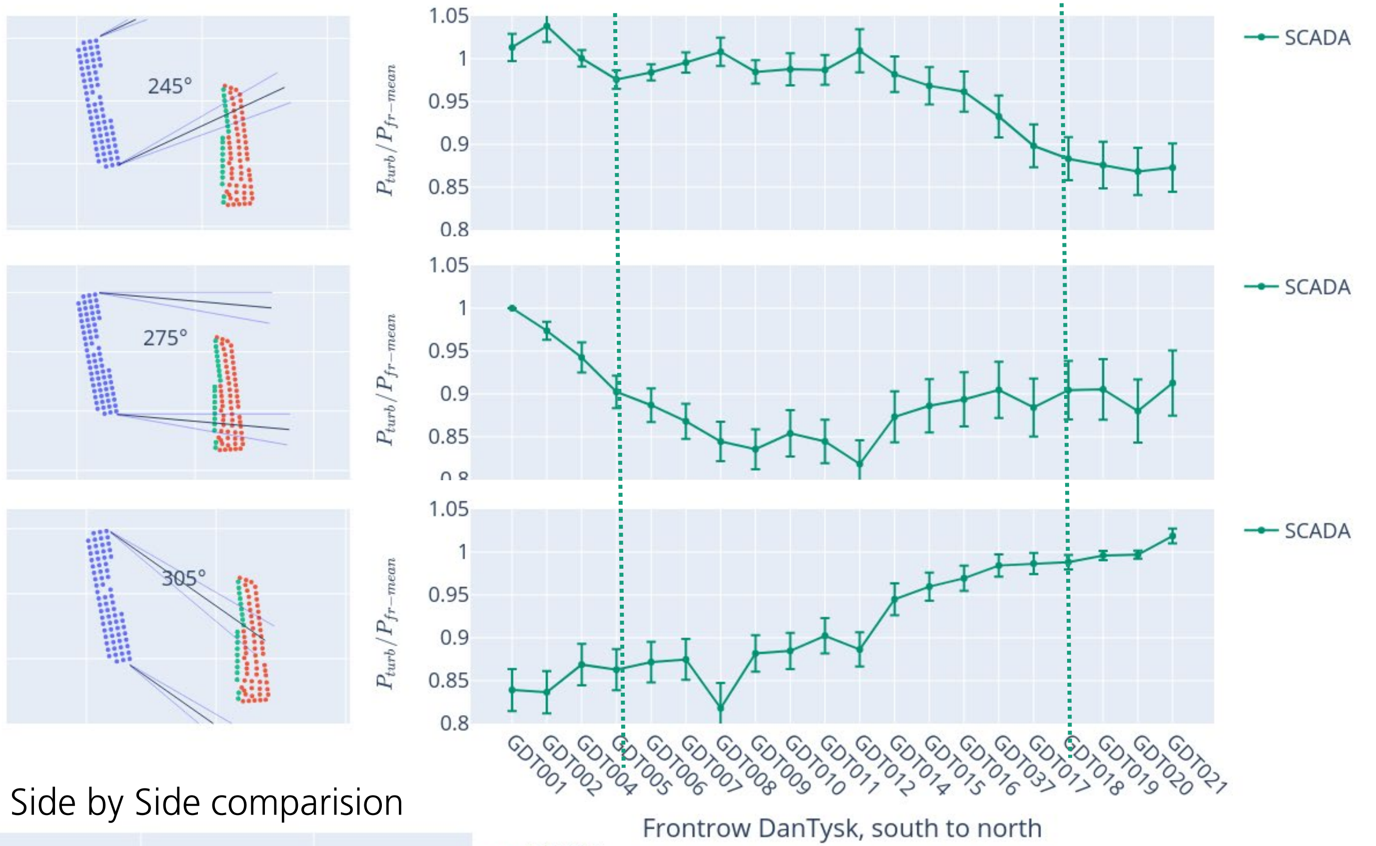
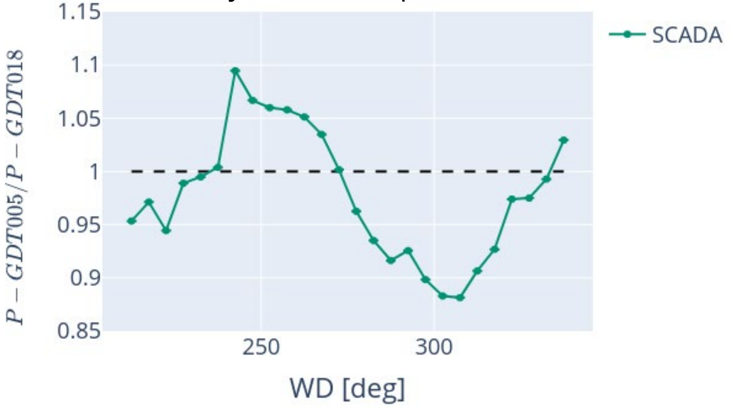


Side by Side comparision



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Model inputs

Low & High Fidelity

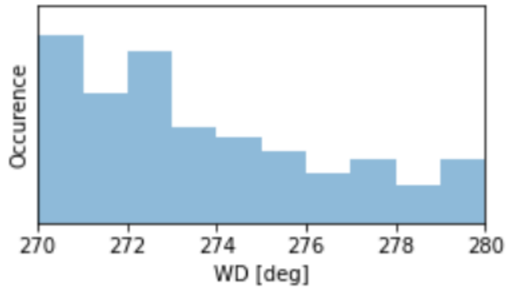
Low Fidelity

- Time series of met. conditions
- Binning of calculation results to increase statistical significance of comparison

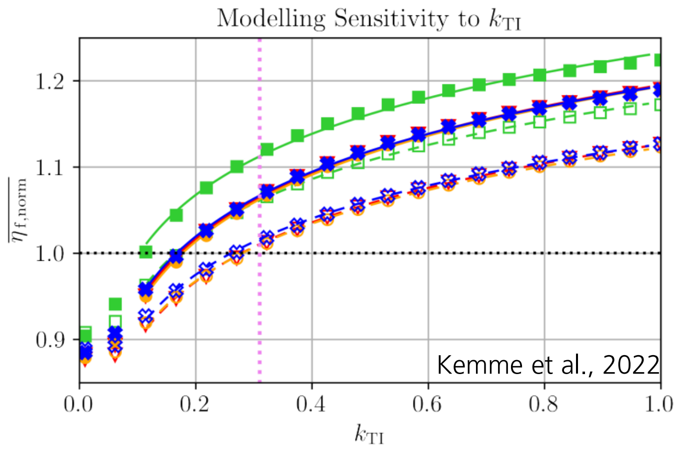
No.	WS-95	WD-95	TI-95	RMOL	PBLH
0	7.50	223.2	0.010	0.015	58
1	11.52	263.3	0.054	0.002	554
…					

Why time series?

- Align processing of production and model data
- Correlation of met. conditions is maintained
- Distribution within bins in maintained



- Wake losses non-linear to atmospheric input parameters



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Model inputs

Low & High Fidelity

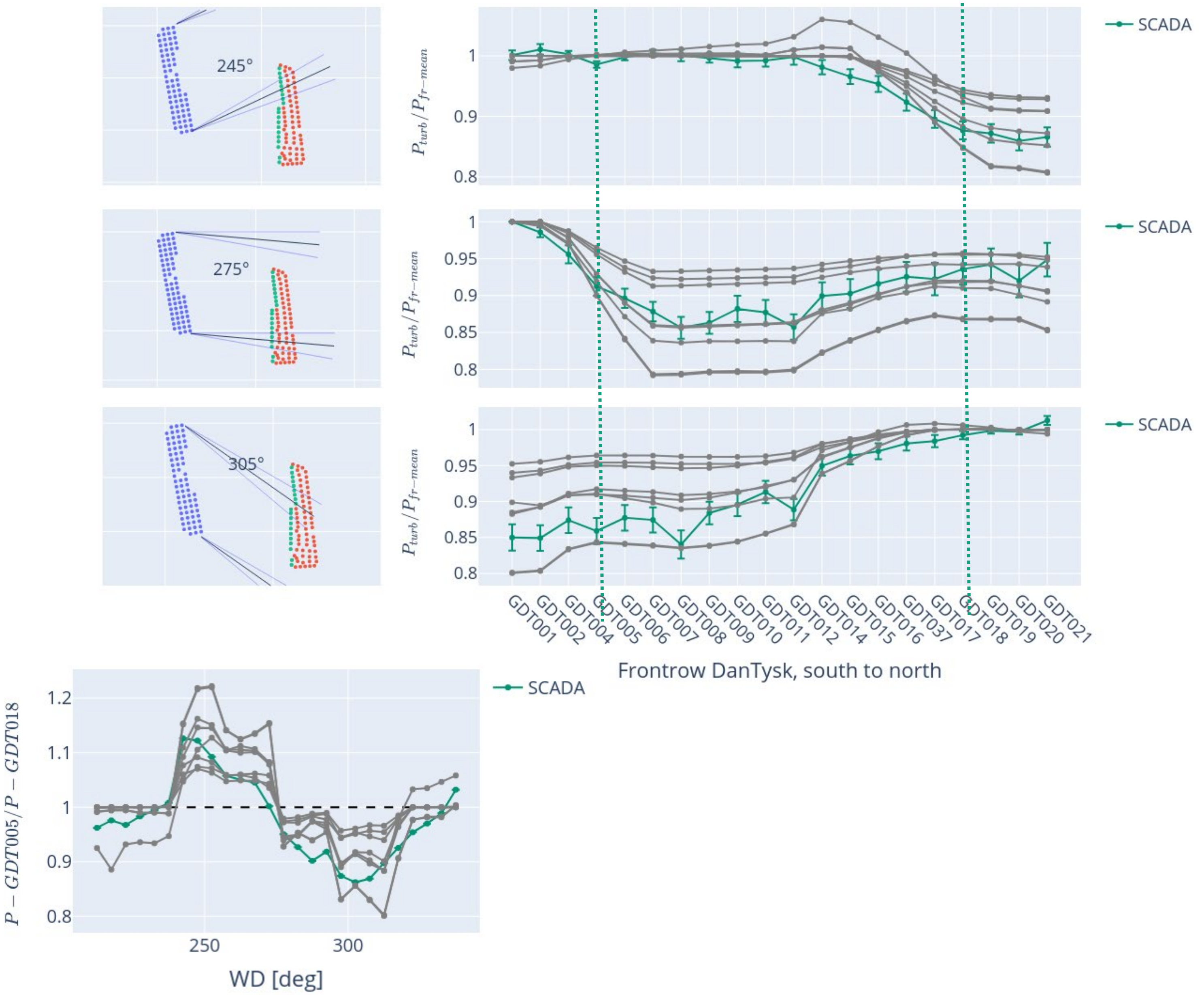
High Fidelity

- Selection of sectors, wind speed bins and stability conditions
- Multiple simulations for single wind directions to fill larger wind direction sector in the data
- RANS and LES simulations

	WS-95	TI-95	RMOL	PBLH
Neutral – 265	8	0.055	-0.006	993.672
Neutral – 305	8	0.066	-0.01	949.31
Stable – 265	8	0.024	0.006	329.309
Stable – 305	8	0.024	0.009	246.726

Results
Overall

Comparison with time series models
- Model simulations with foxes and contribution from project partners
- Significant spread in model results



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Results

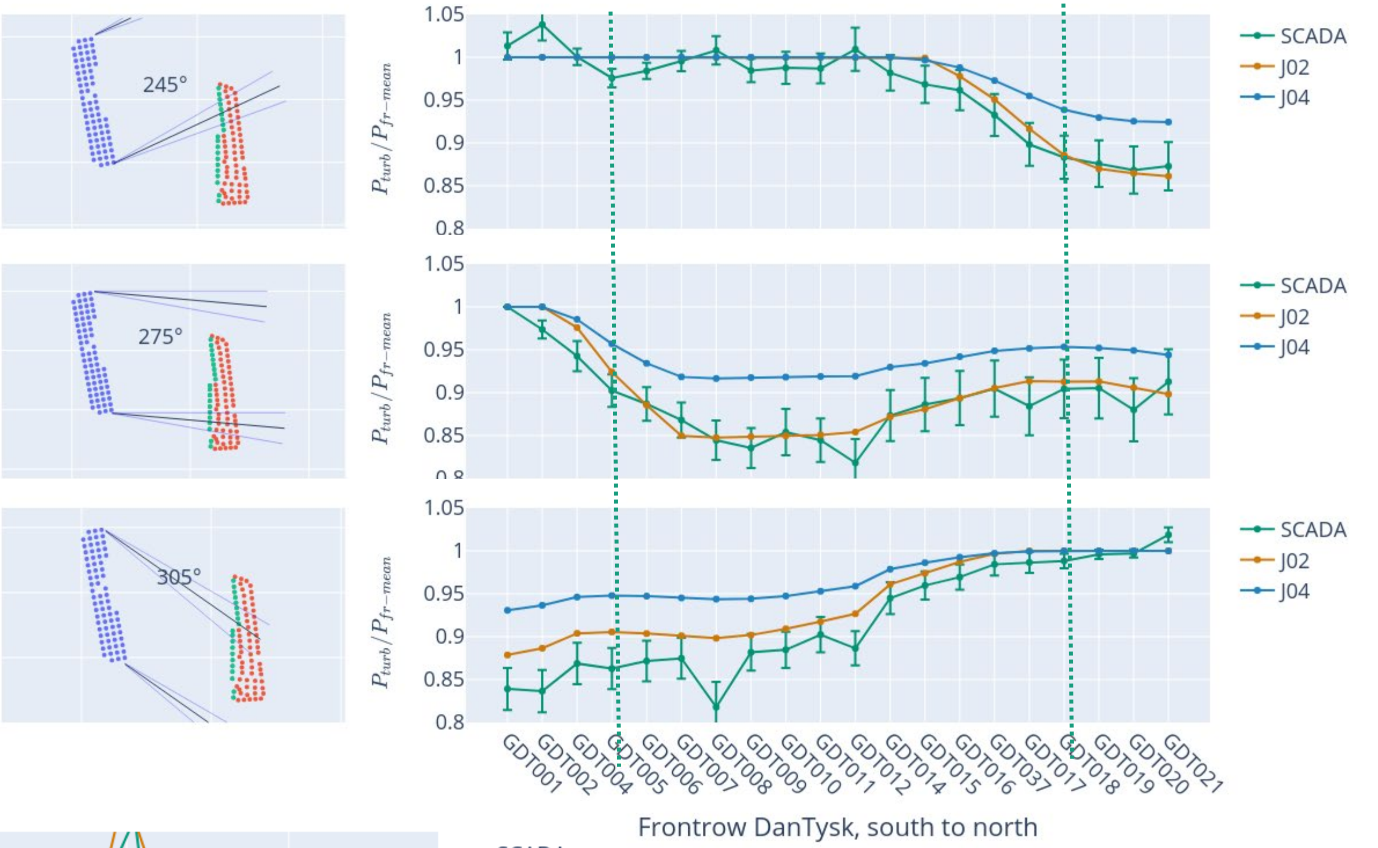
Overall

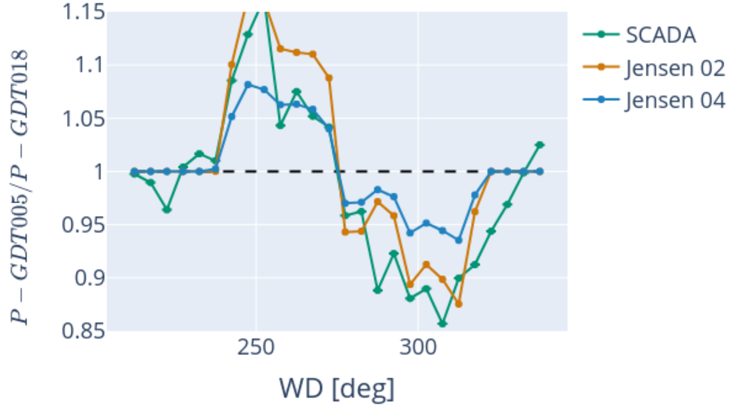
Comparison with time series models

- What can we already learn from standard approaches?

Jensen - wake decay k=0.04 / k=0.02

- Clear underestimation of external wake with *standard* approach





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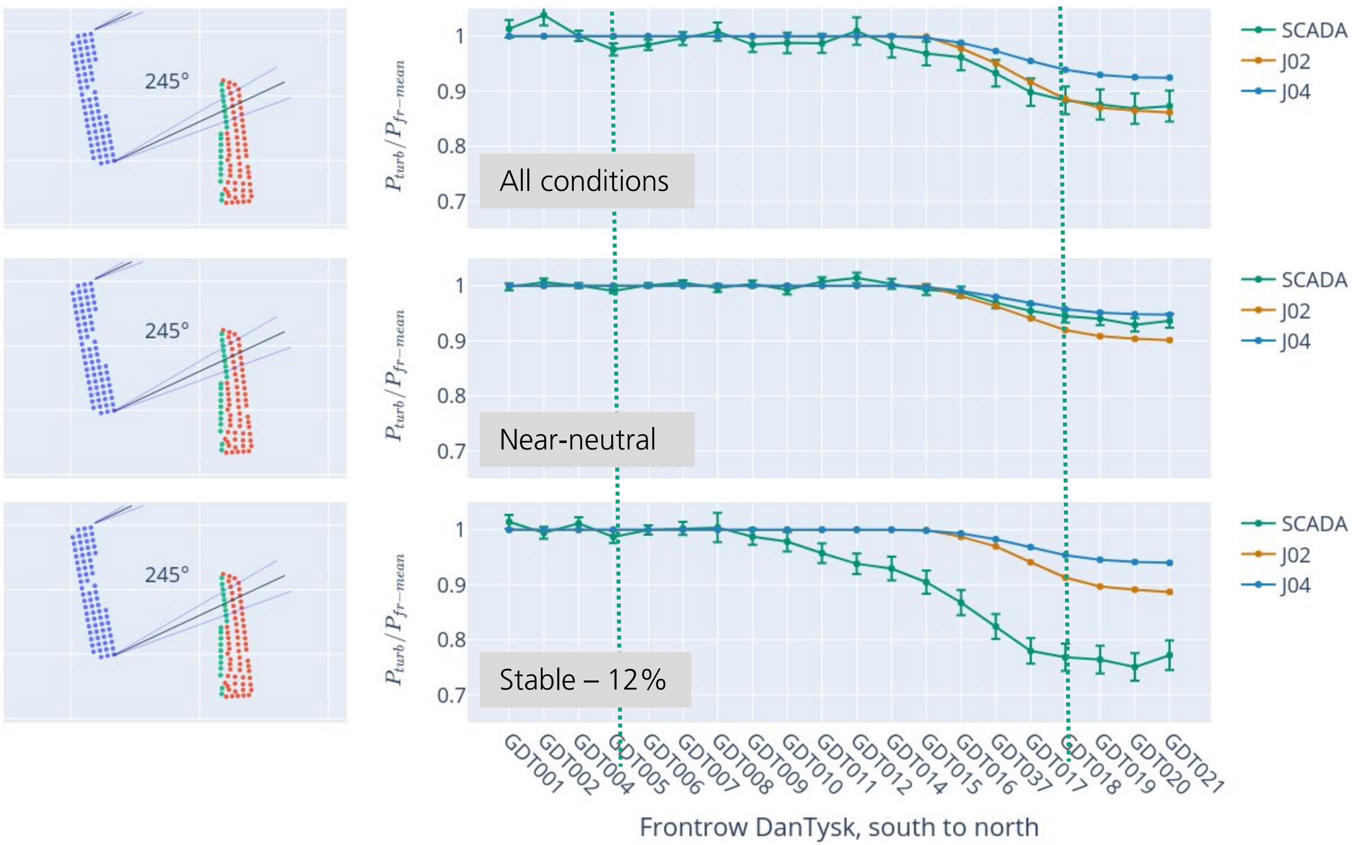
Results

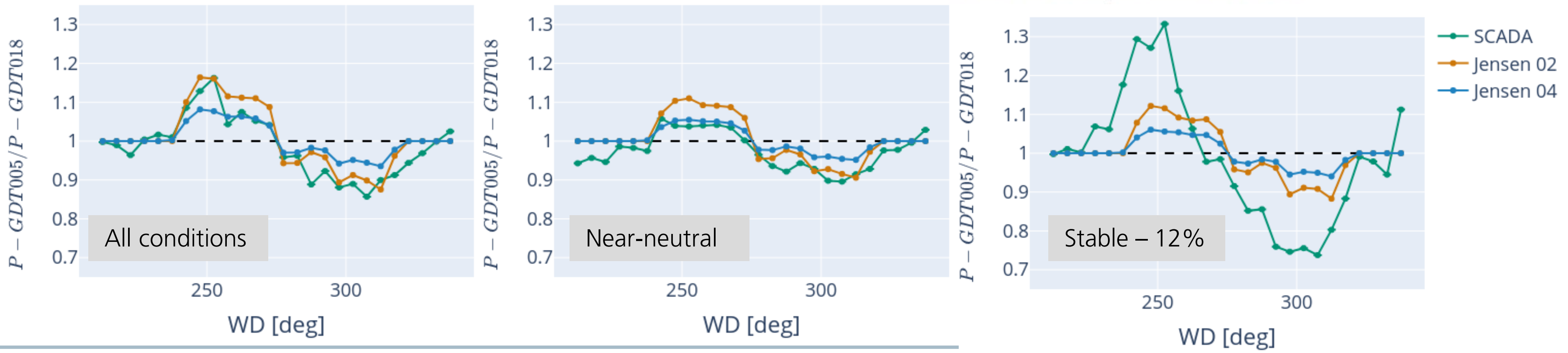
Dependency on meteorologic conditions

Comparison with time series models

- Slight overestimation for near-neutral conditions
- Large underestimation for stable conditions
- Asymmetry in the wake losses

	TI [%]	MOL [m]	PBLH [m]	VEER [deg]
ALL	6.1	-117	826	0.3
NN	6.4	-103	882	0.2
S	2.4	153	219	7.5





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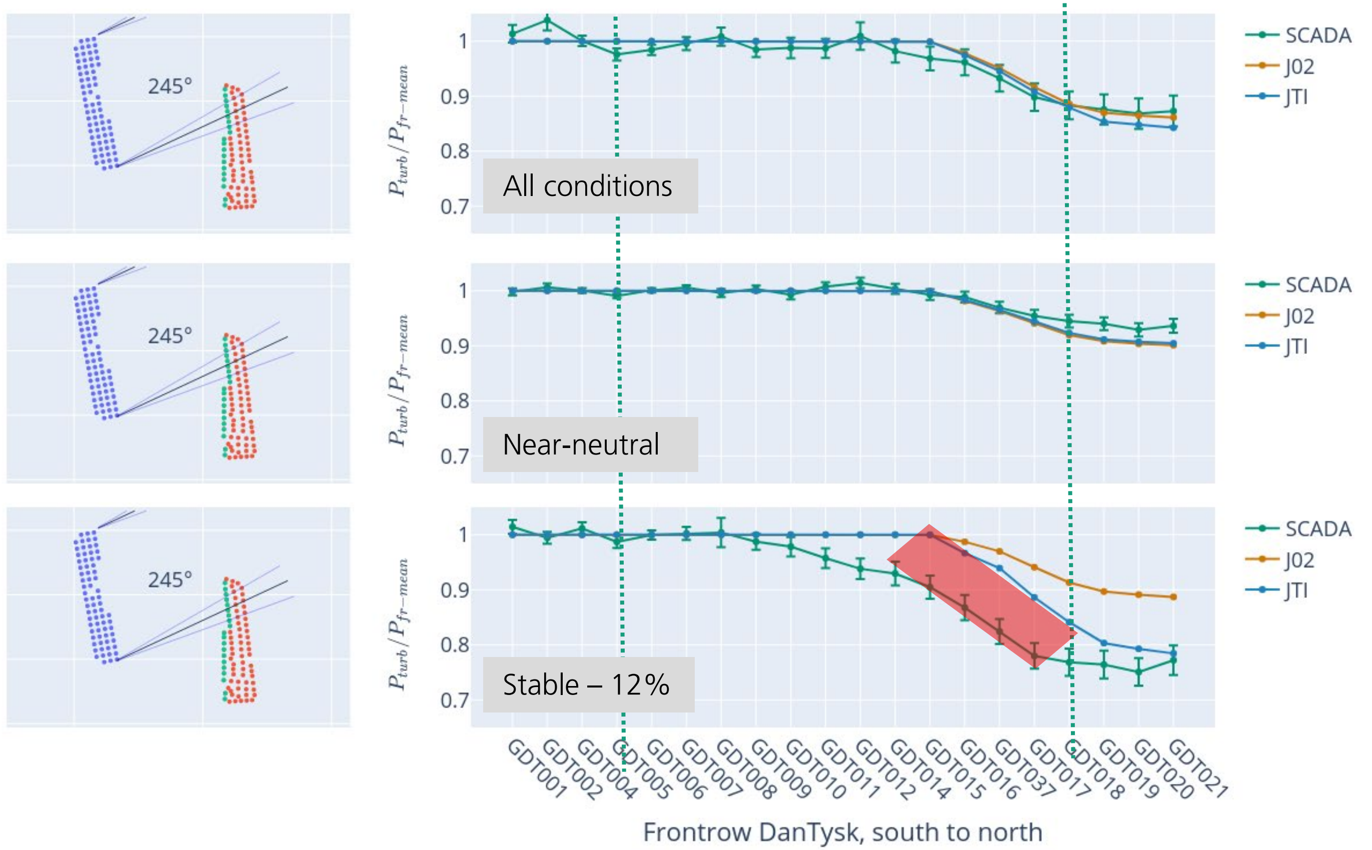
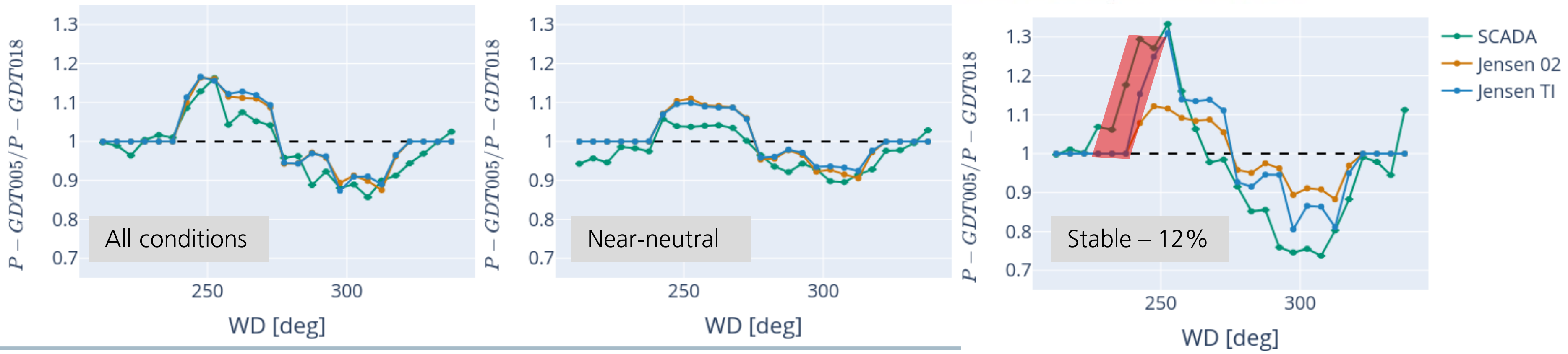


TI-dependency of wake decay

k = 0.4 TI

- Quite good representation of wake deficit
- Modelled wake not much wider



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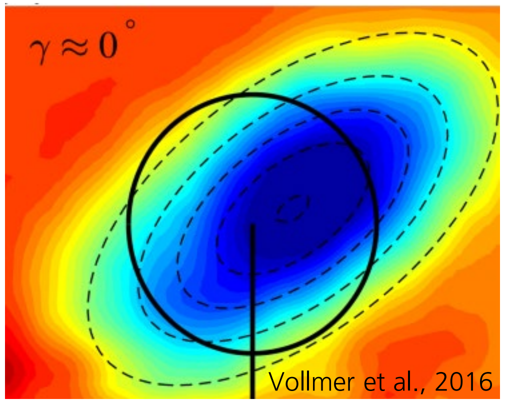
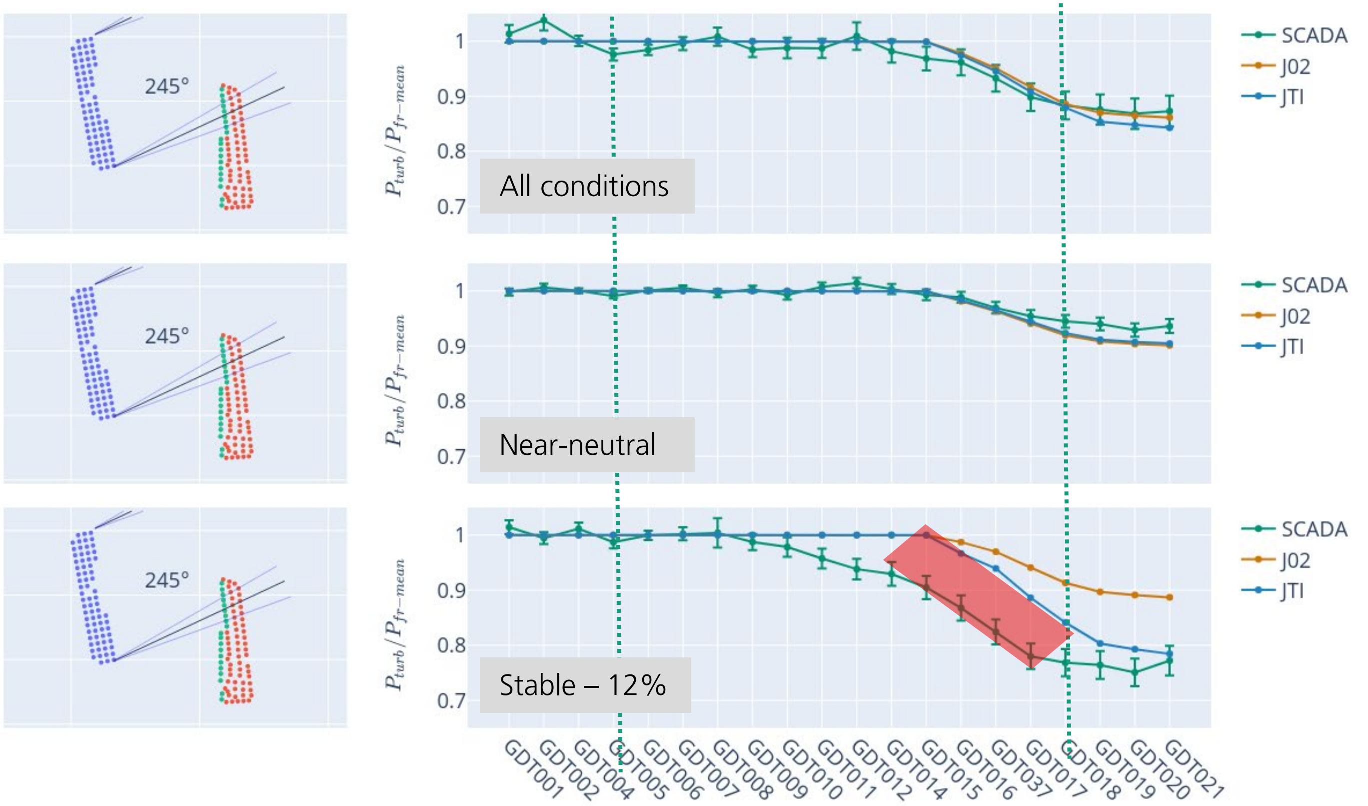
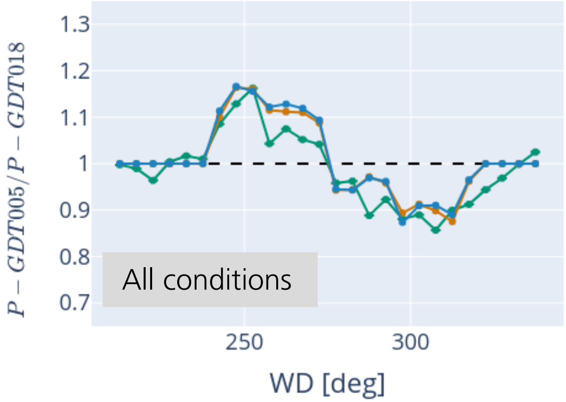
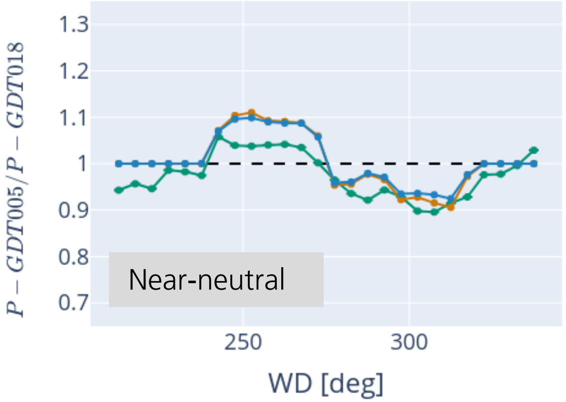
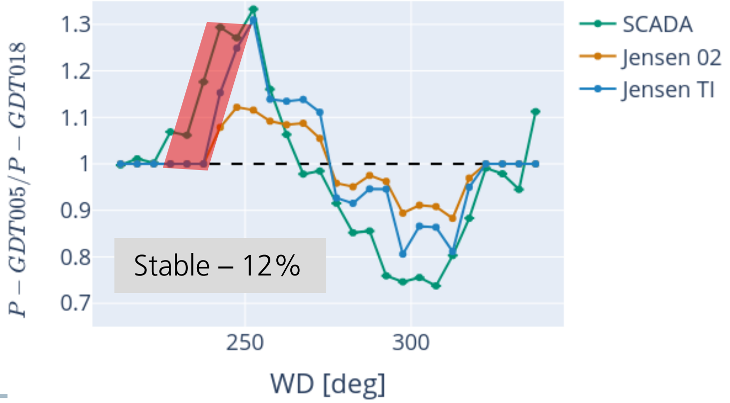




Frontrow DanTysk, south to north







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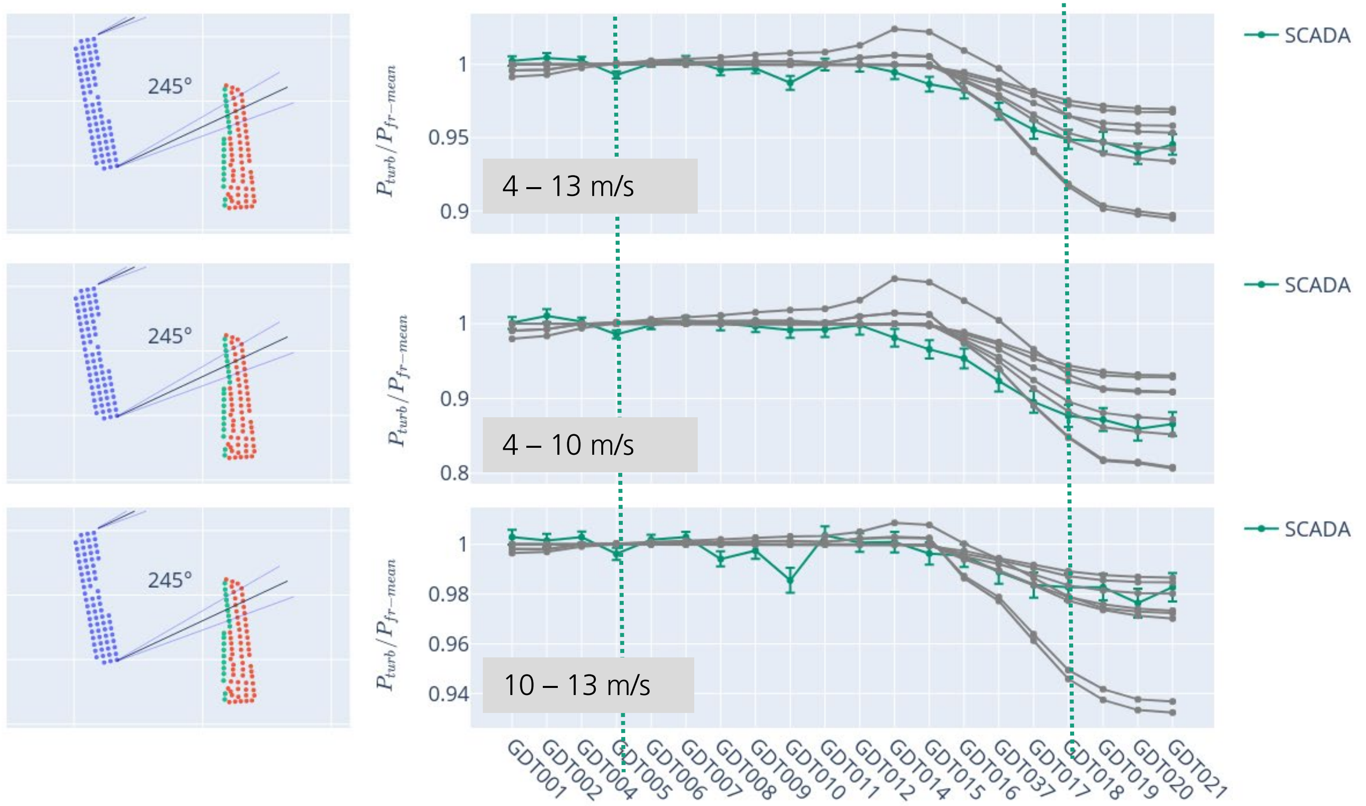
Results
Dependency on wind speed

- Split into constant ct and variable ct domain
- Some models are more sensitive to the change of domains

! Uncertainties and biases in inflow wind speed much more relevant in variable ct domain



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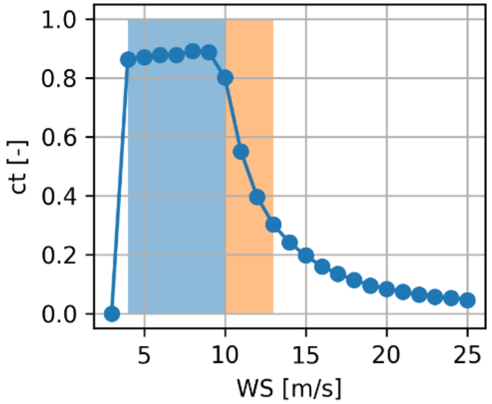

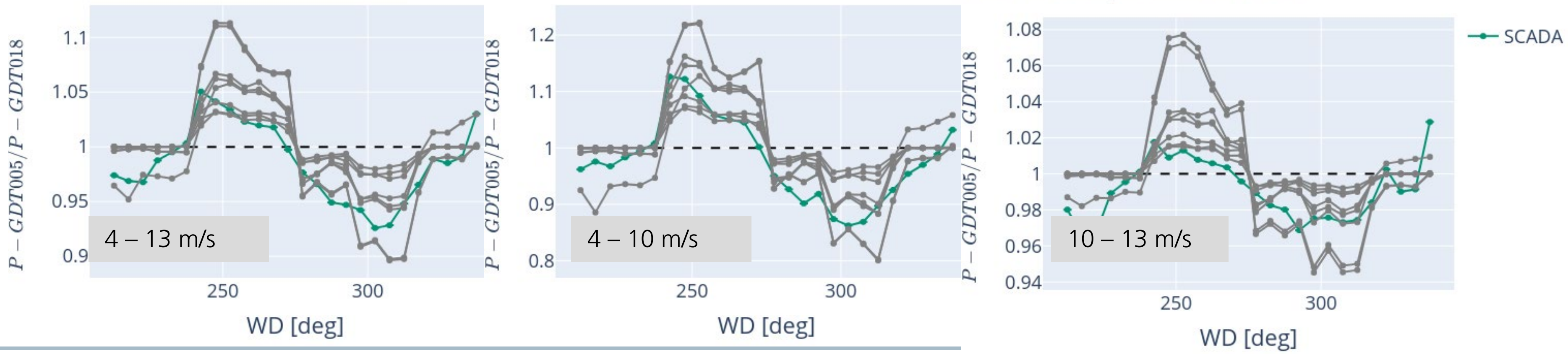

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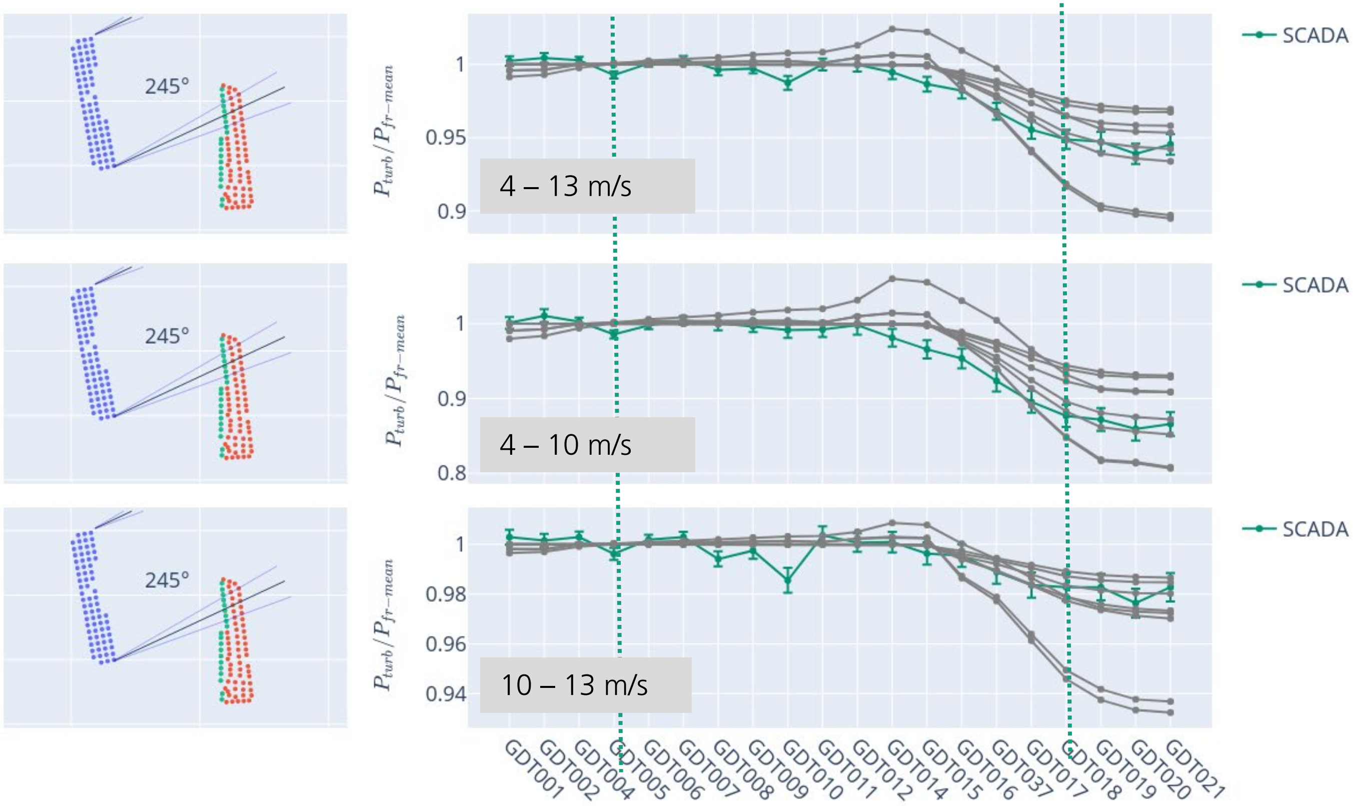

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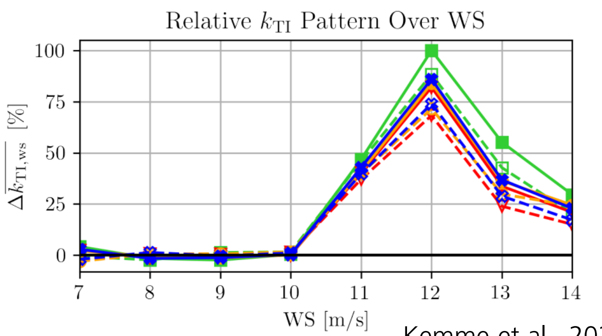
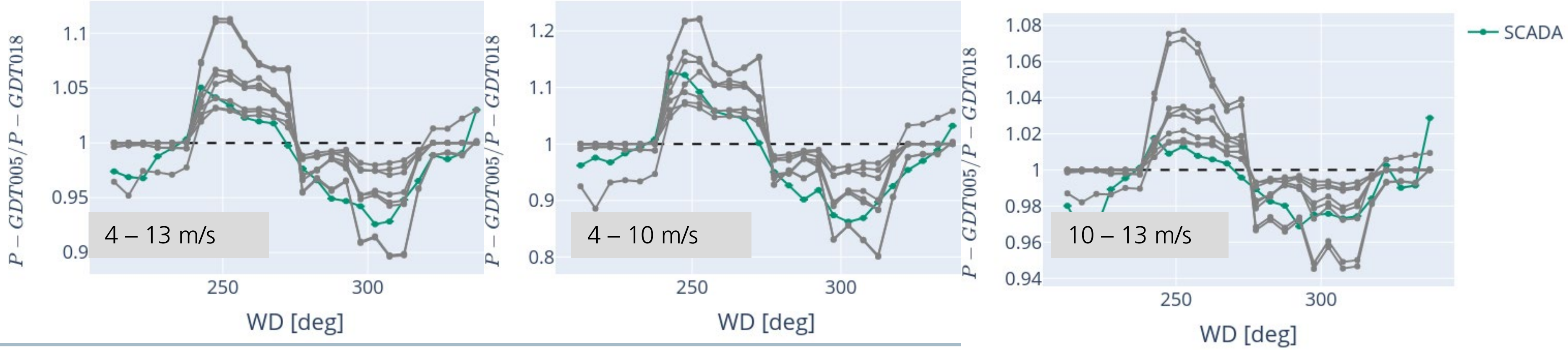


Kemme et al., 2022



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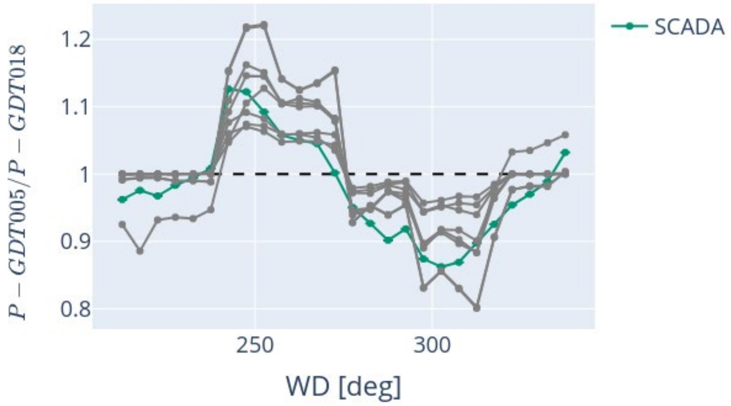
Take-aways

Modelling of long wakes

Generalization of results – what should we look for when validating models?

- Consistency over distance (Nygaard, 2022)
- Consistency over atmospheric conditions
- Consistency over wind speed / thrust coefficient

- Can ignored physics explain differences?



Outlook

- More model results to be included
- Extension to *high fidelity* models (LES, RANS, WRF)
- Analysis of internal wake losses

Contact

Lukas Vollmer
Numerical Site Assessment
Fraunhofer Institute for Wind Energy Systems IWES
Küpkersweg 70
26129 **Oldenburg**
Germany

lukas.vollmer@iwes.fraunhofer.de

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