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Wakes between offshore wind farms

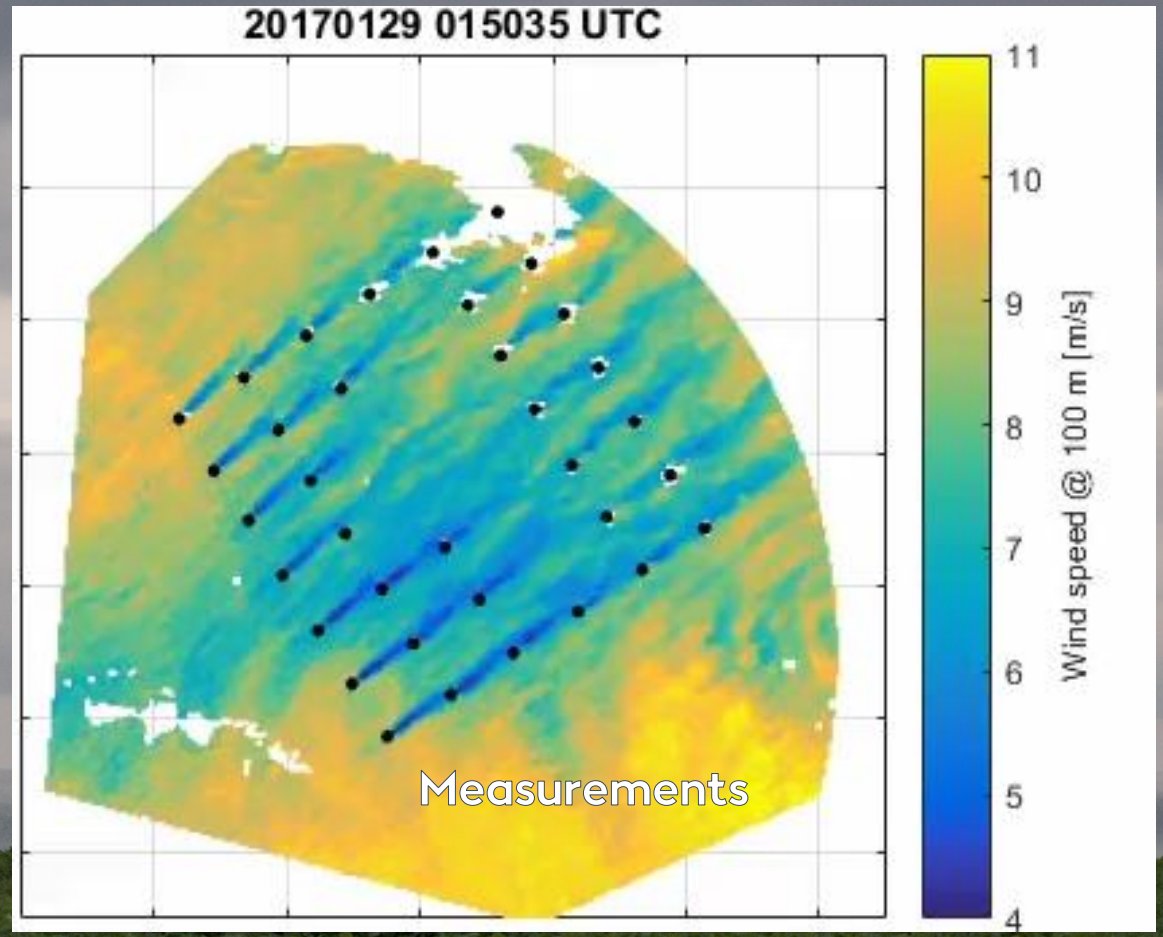
A technical background

01 December 2023

Nicolai Gayle Nygaard

Dual-Doppler radar measurements

Unique insights on wake characteristics



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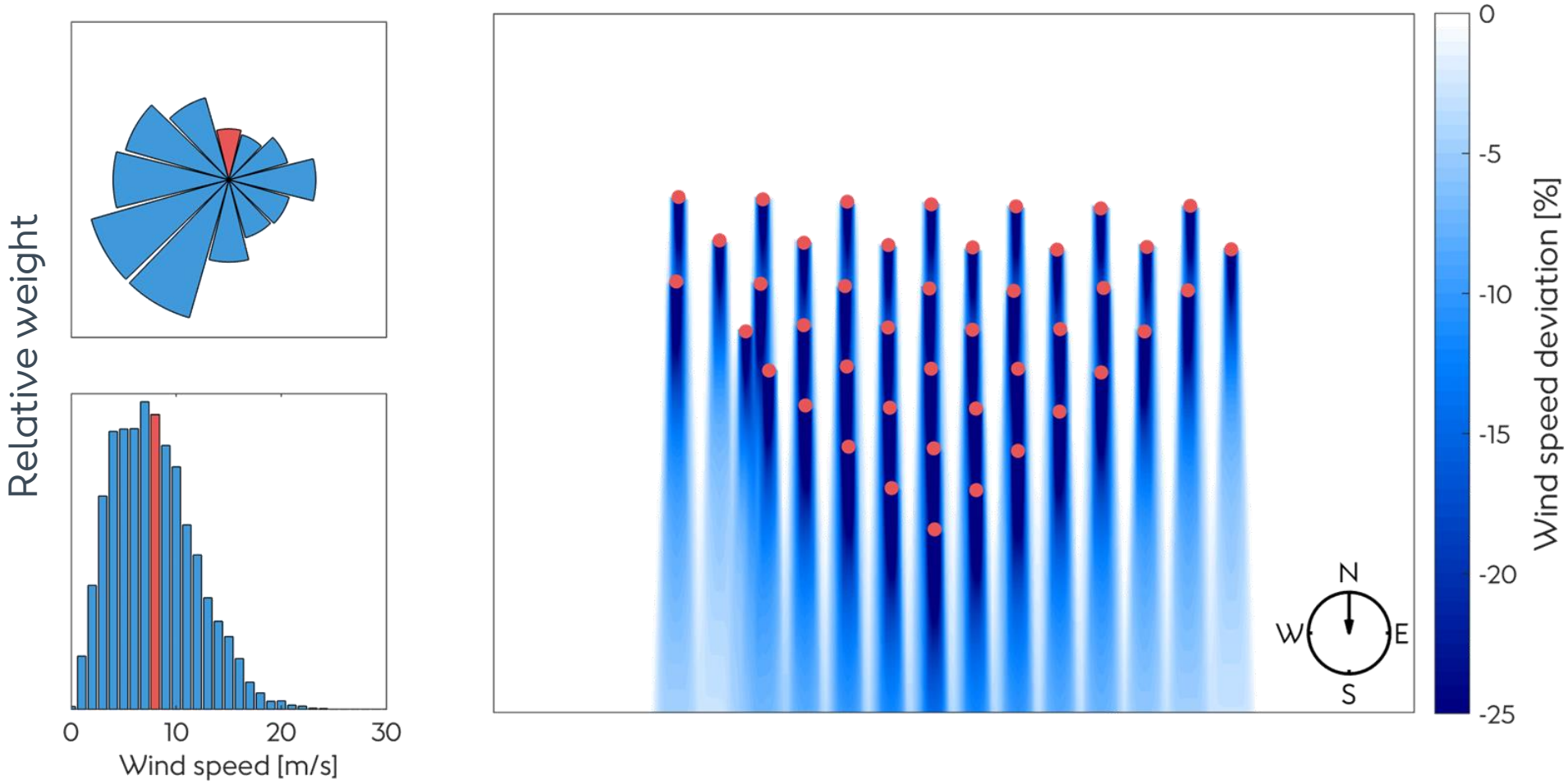
Wakes depend on wind direction

Orientation relative to the wind rose matters



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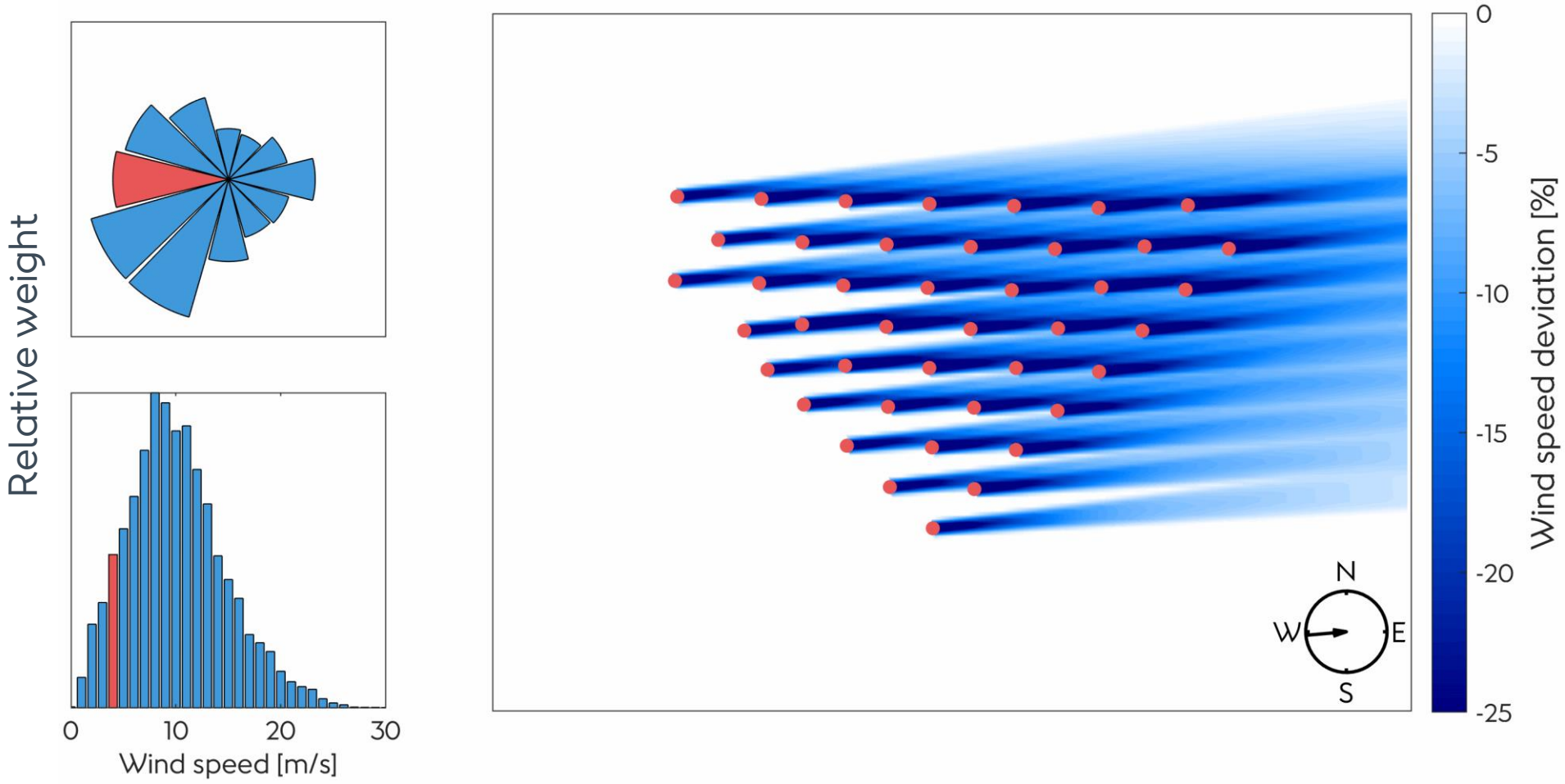
Wakes depend on wind speed

Wakes are more severe at lower wind speeds



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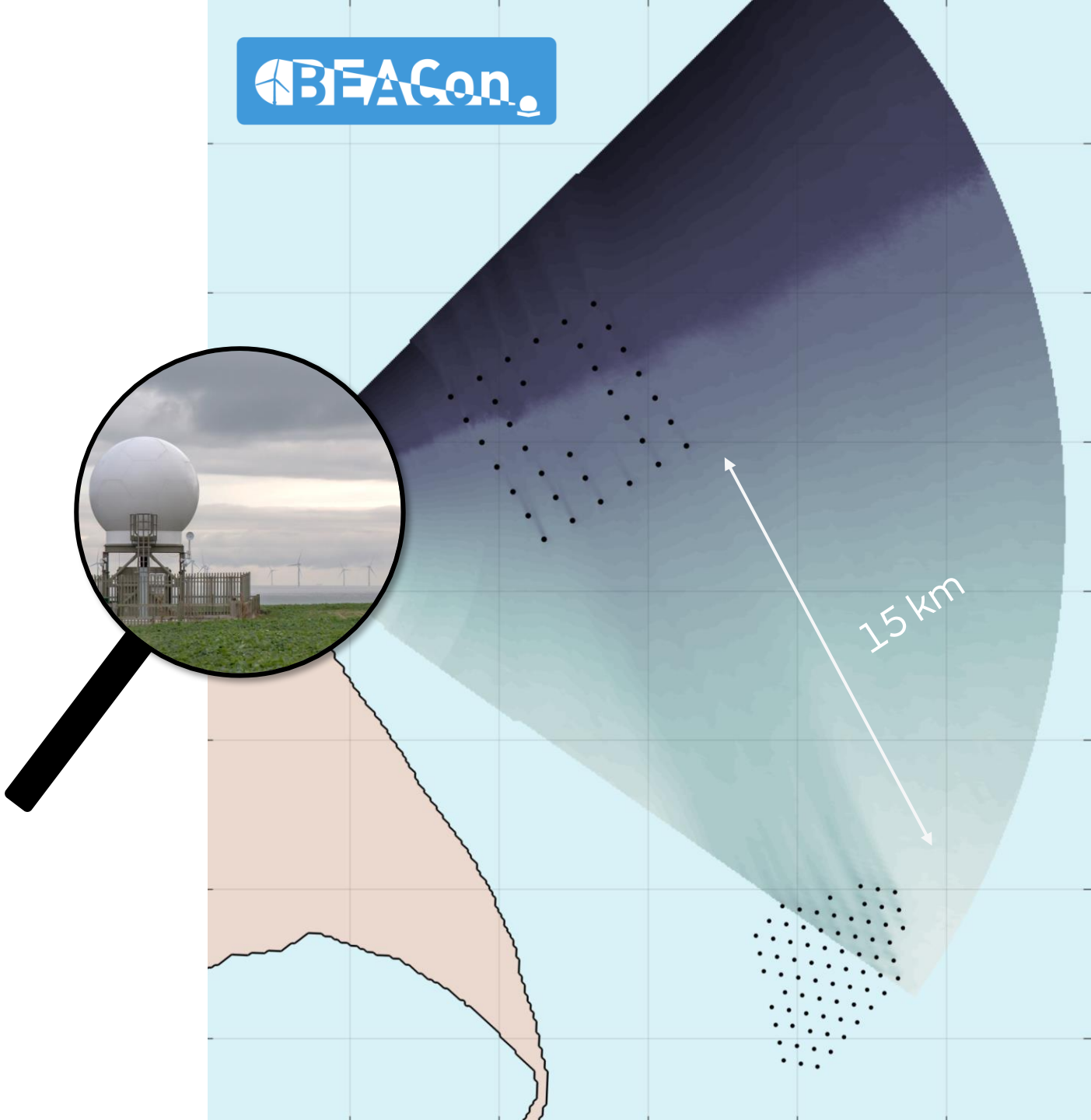
Wakes between wind farms

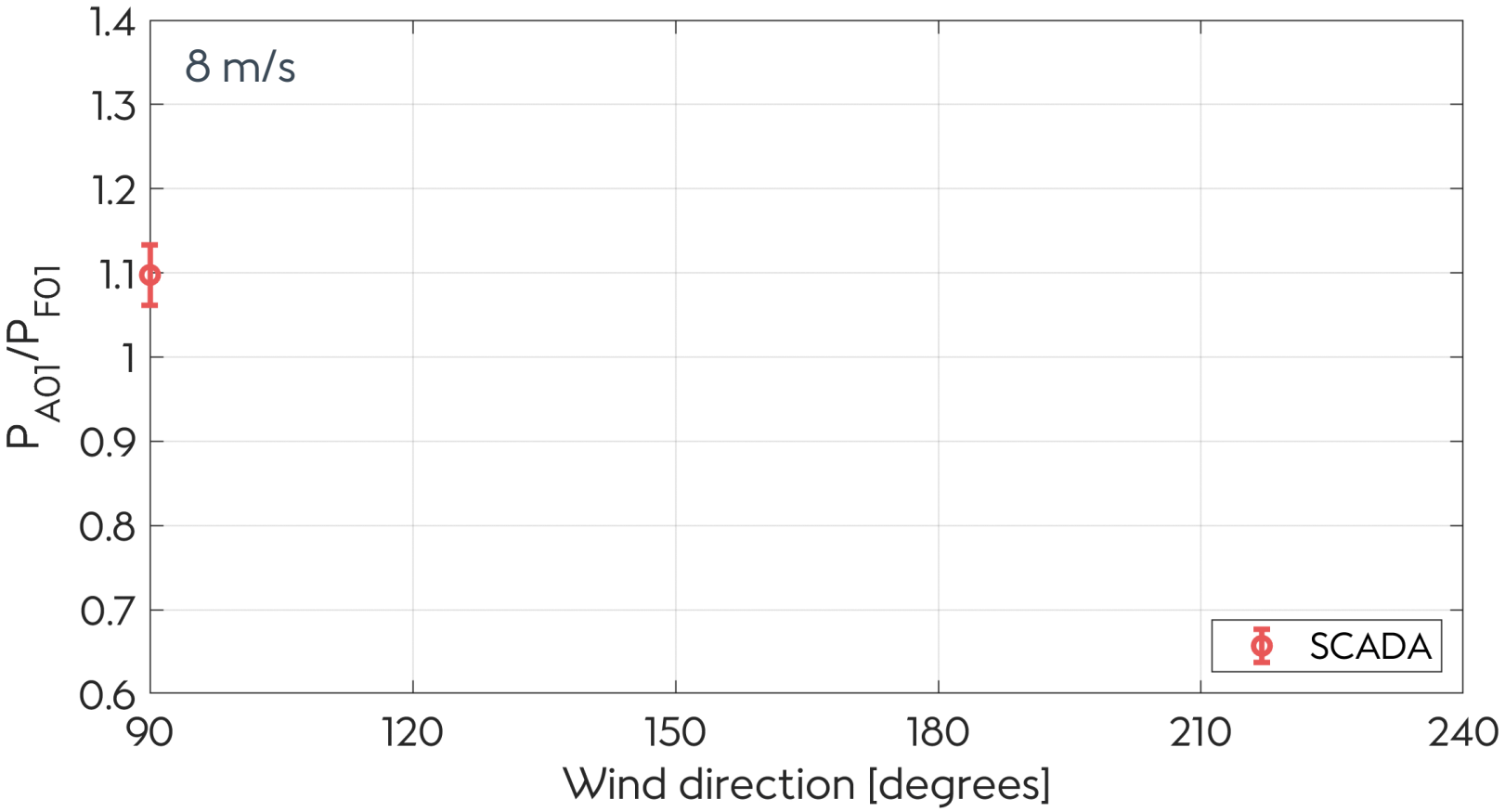
Observed with dual-Doppler radar

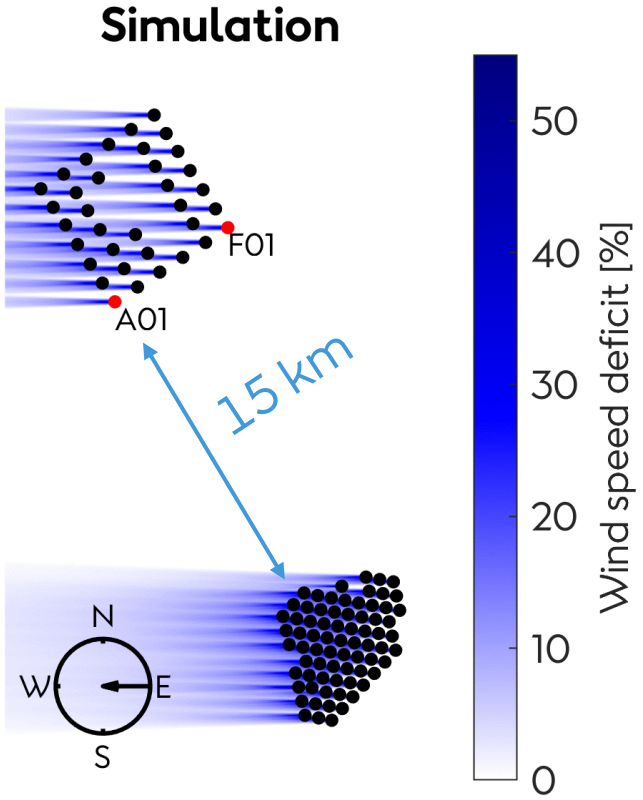
- Two-hour average
- Wind farms separated by 15 km
- Wakes traced from single-turbine origins to merged wind farm wake



Revealing wake impact on front row turbines

Turbines in the neighbour wind farm wake produce less





Not indicative of impact on full energy production

- *Single wind speed only*
- *Only few wind directions affected*
- *Results only shown for front row turbines*

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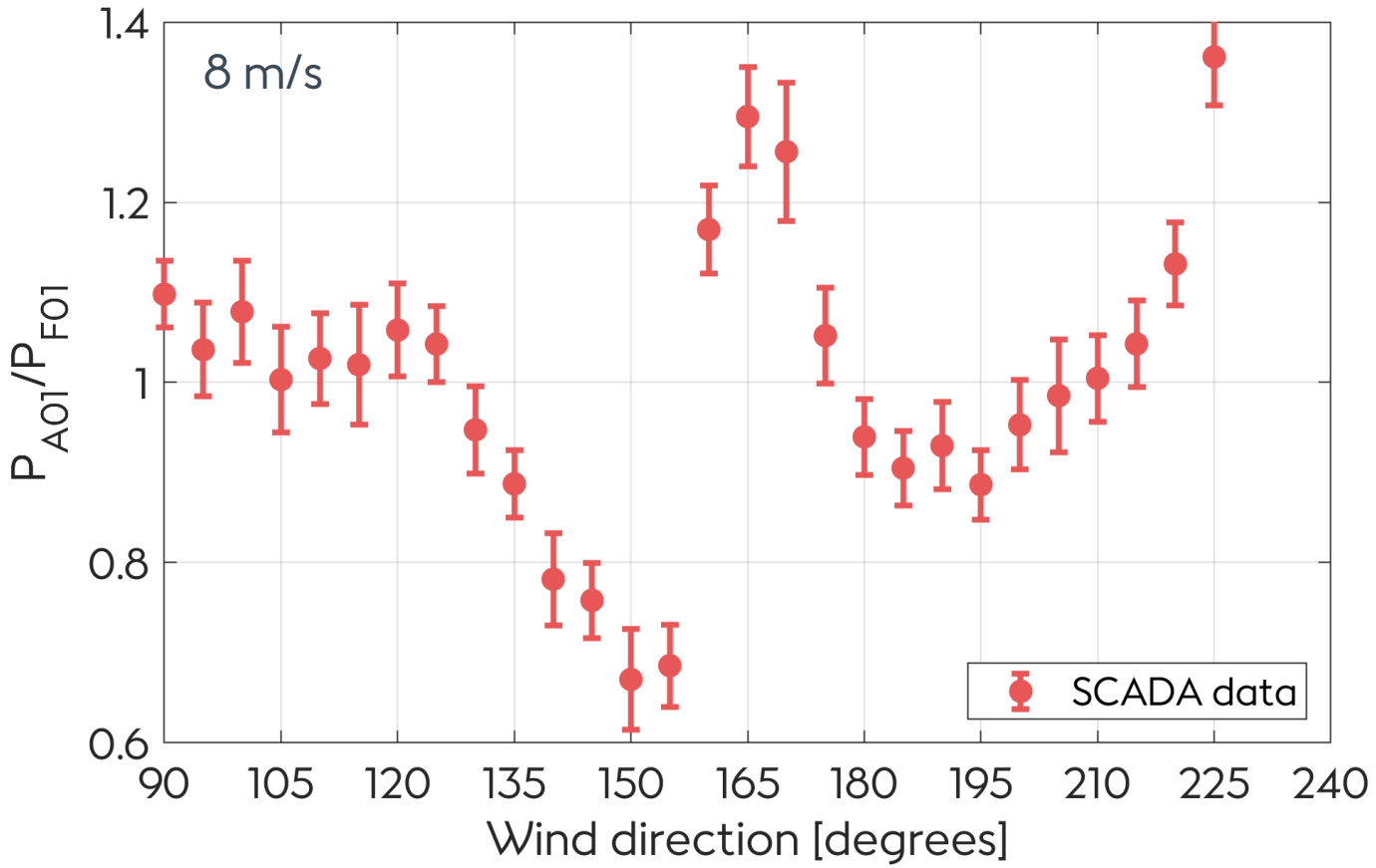
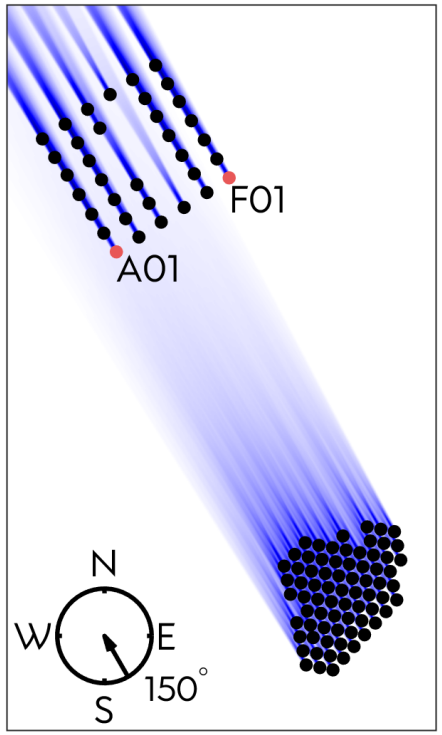
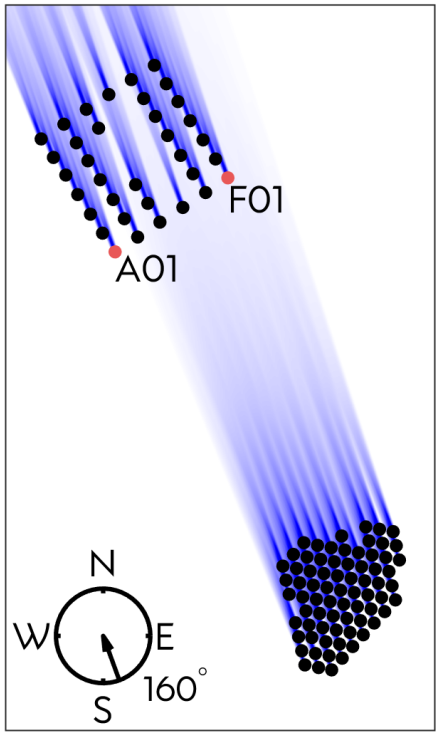
Revealing wake impact on front row turbines

Characteristic pattern of power ratio vs. wind direction







Not indicative of impact on full energy production

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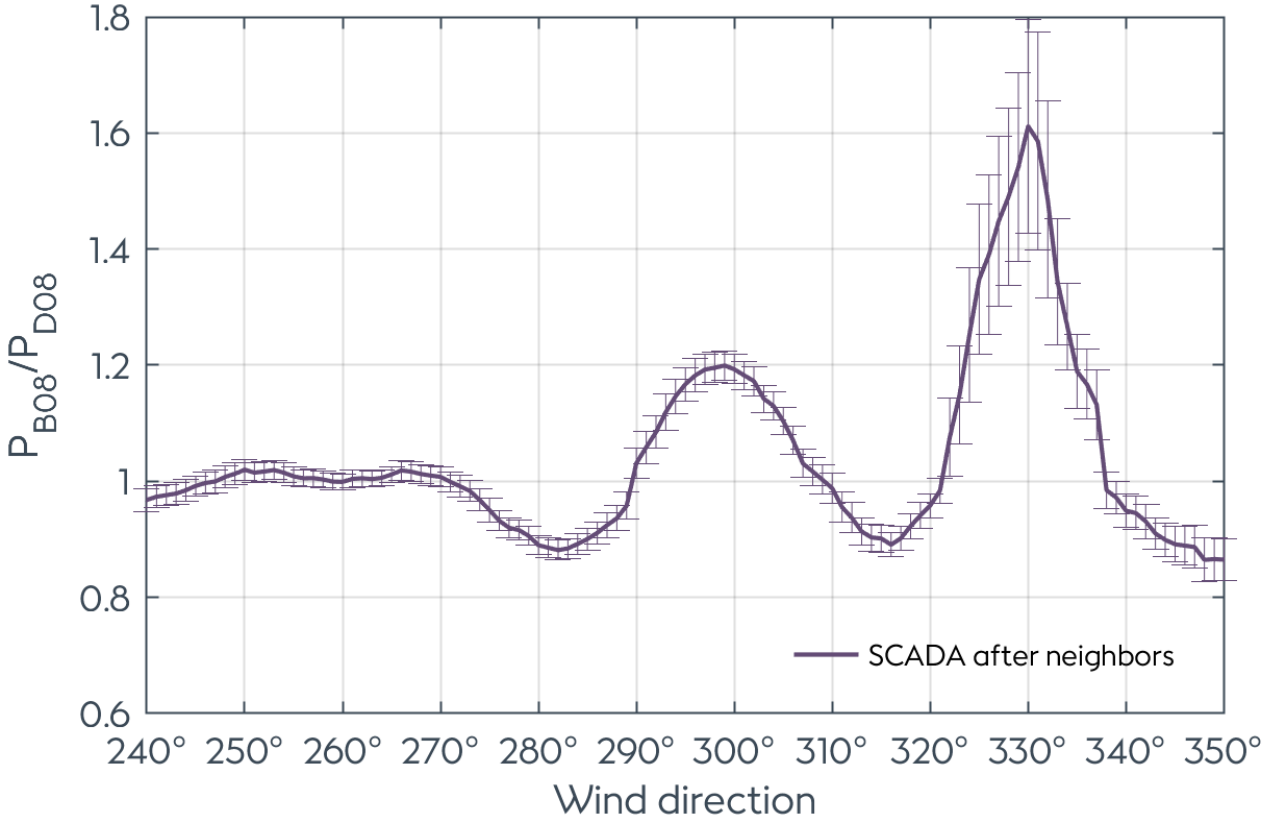
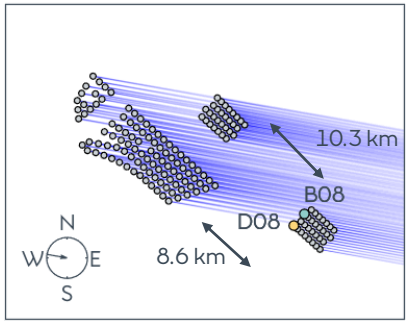
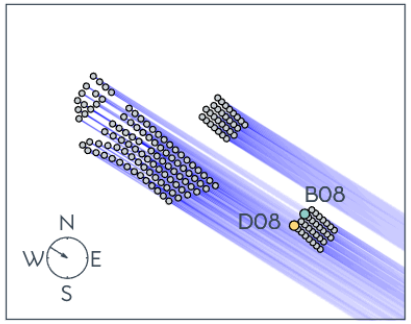
A more complicated example

Two neighbour wind farms result in a double pattern

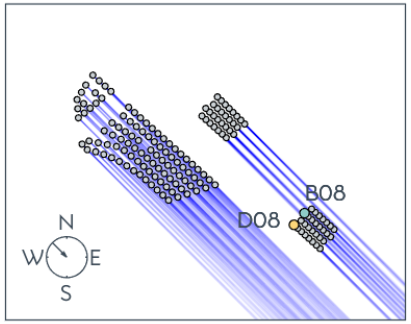




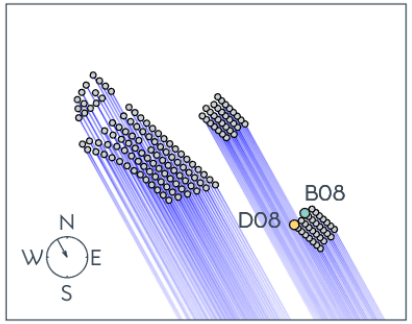
Model @ 280°



Model @ 302°



Model @ 315°



Model @ 331°

Not indicative of impact on full energy production

- *Single wind speed only*
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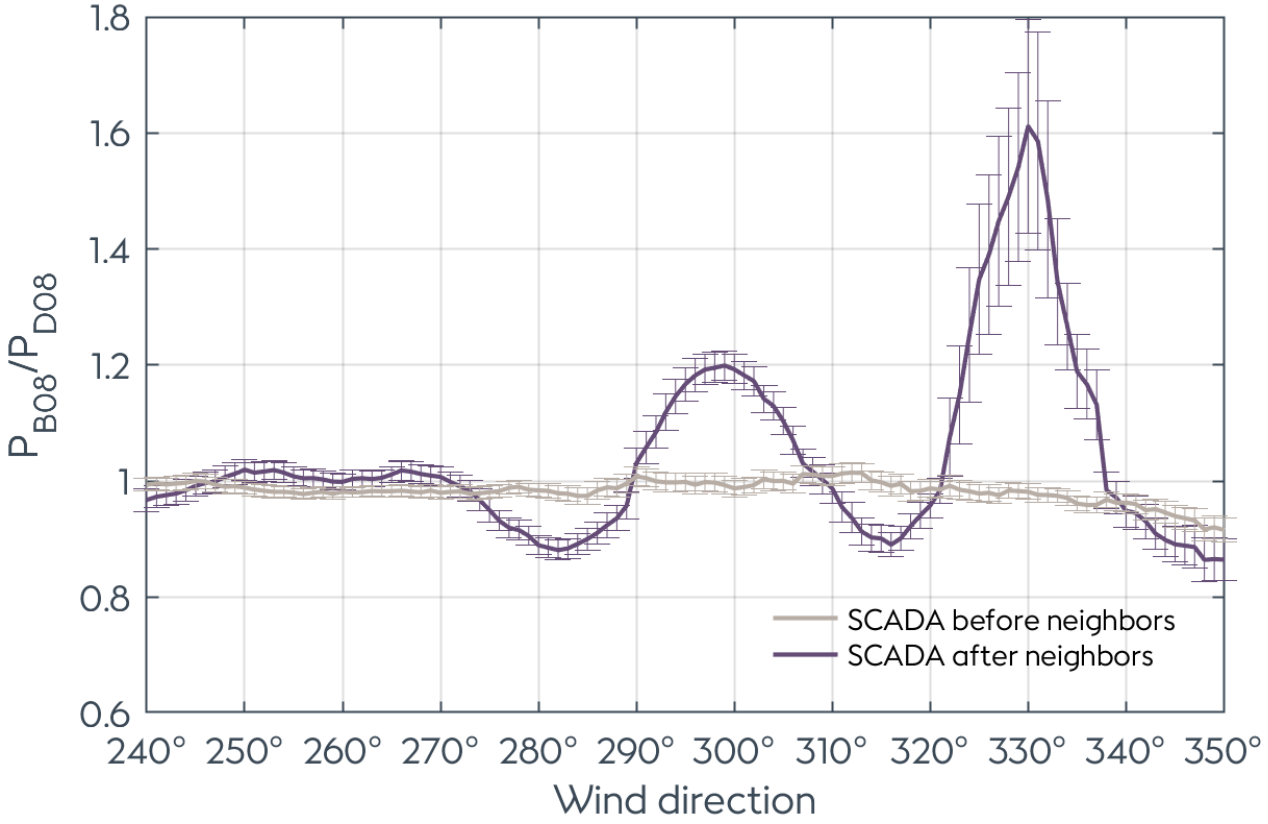
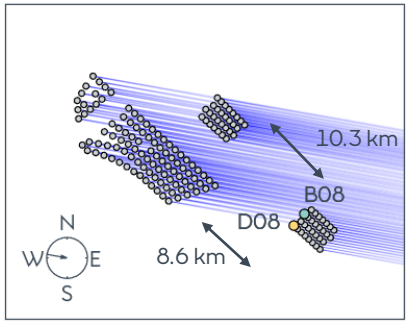
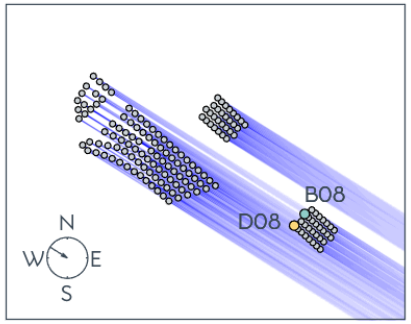
These are really wakes!

The effect is absent before the neighbors were built

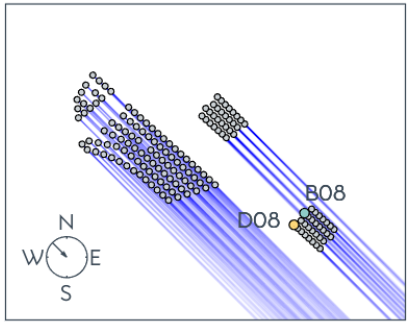




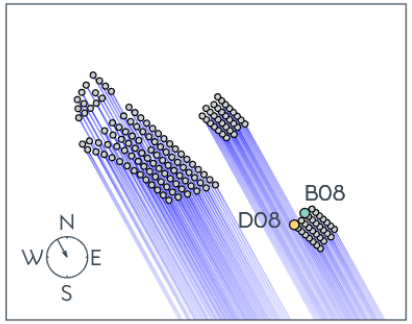
Model @ 280°



Model @ 302°



Model @ 315°



Model @ 331°

Not indicative of impact on full energy production

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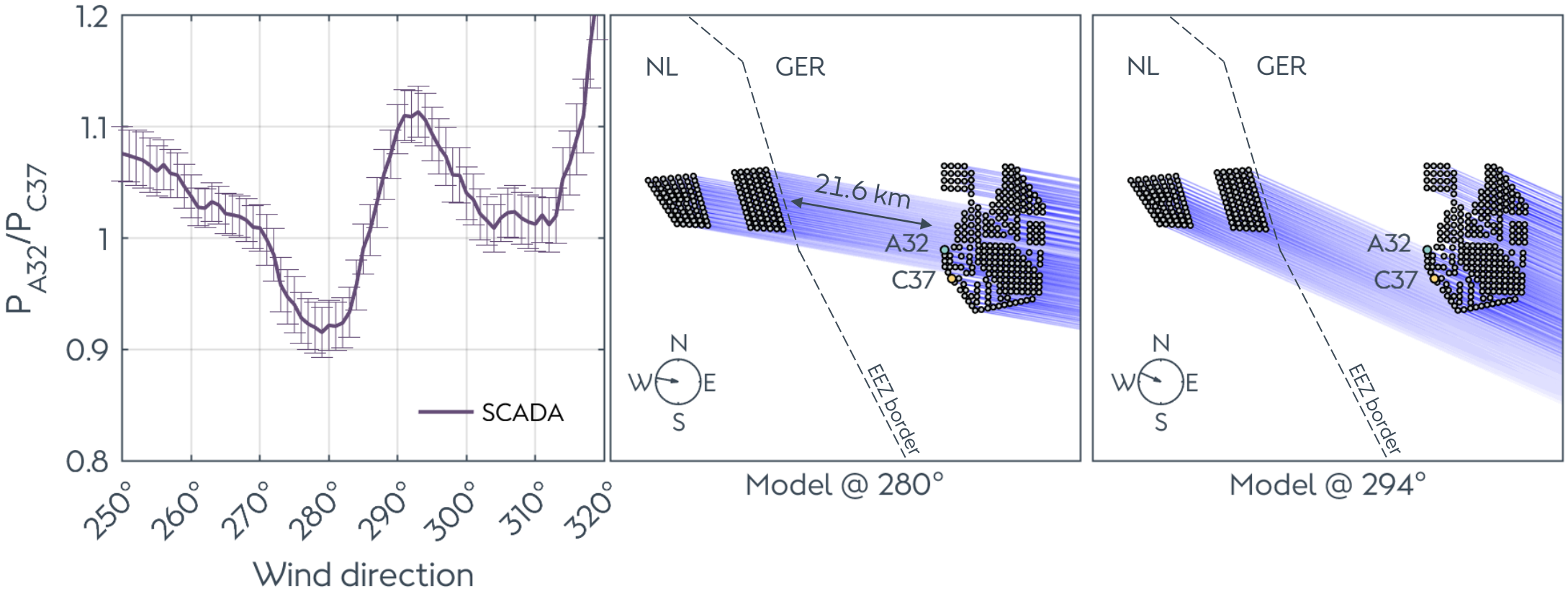
Wakes transcend national borders

Cross-national coordination needed



Not indicative of impact on AEP

- *Single wind speed only*
- *Only few wind directions affected*
- *Results only shown for front row turbines*

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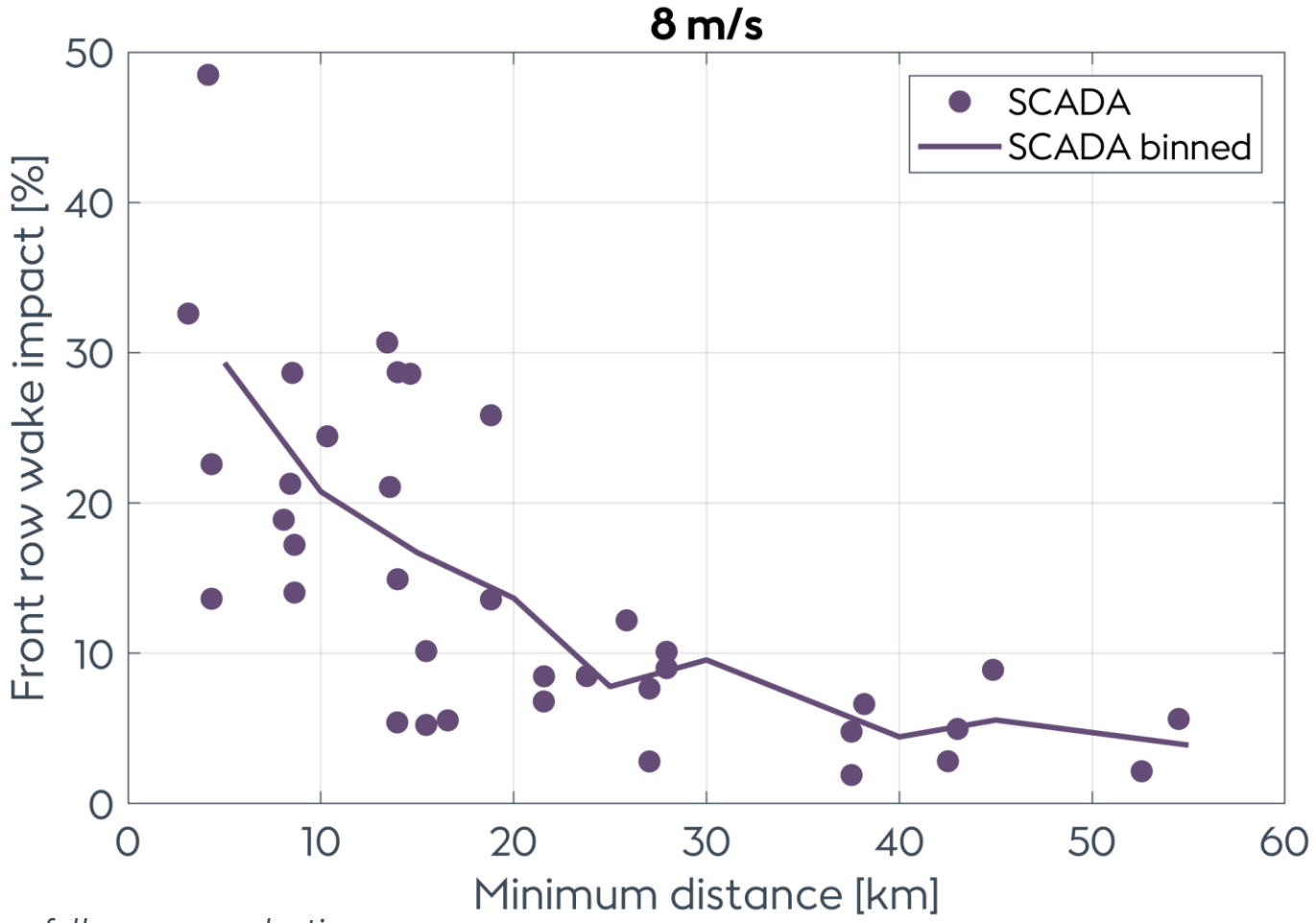
Dependence on distance

Neighbour wake impact decreases at larger distances



Not indicative of impact on full energy production

- *Single wind speed only*
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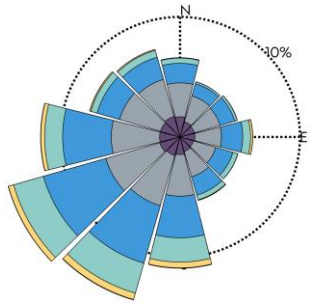
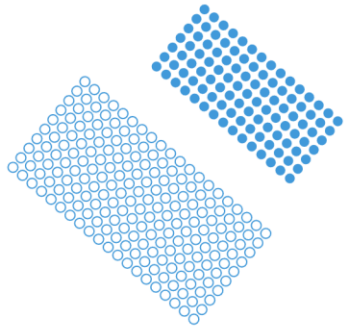
Impact on annual energy production

3 hypothetical examples

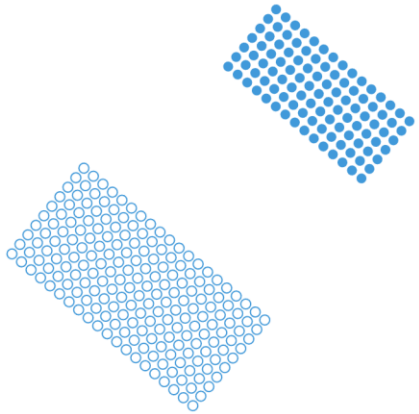


1



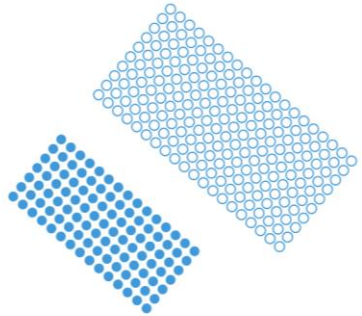
Separation 5 km
External wake loss 7.8%

2



Separation 15 km
External wake loss 3.8%

3



Separation 5 km
External wake loss 3.4%

Target wind farm

Neighbour wind farm

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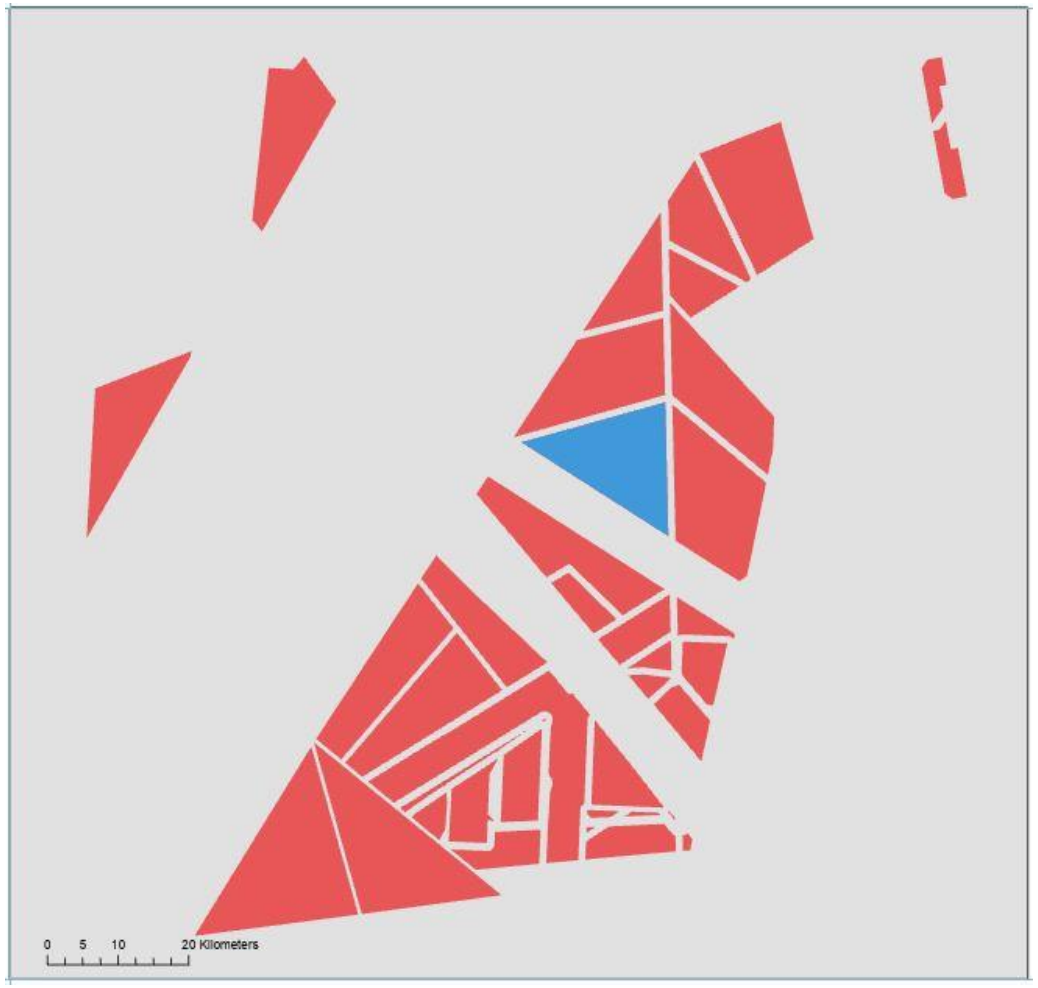
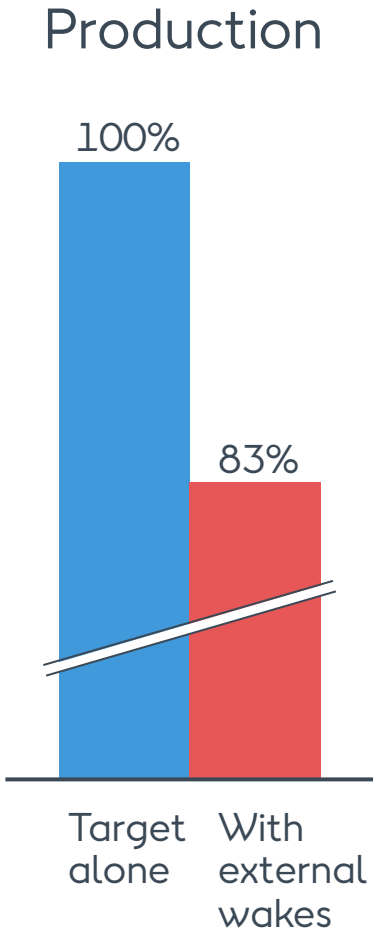
A real world example

Neighbour wake loss in the German Bight



Target

Neighbours



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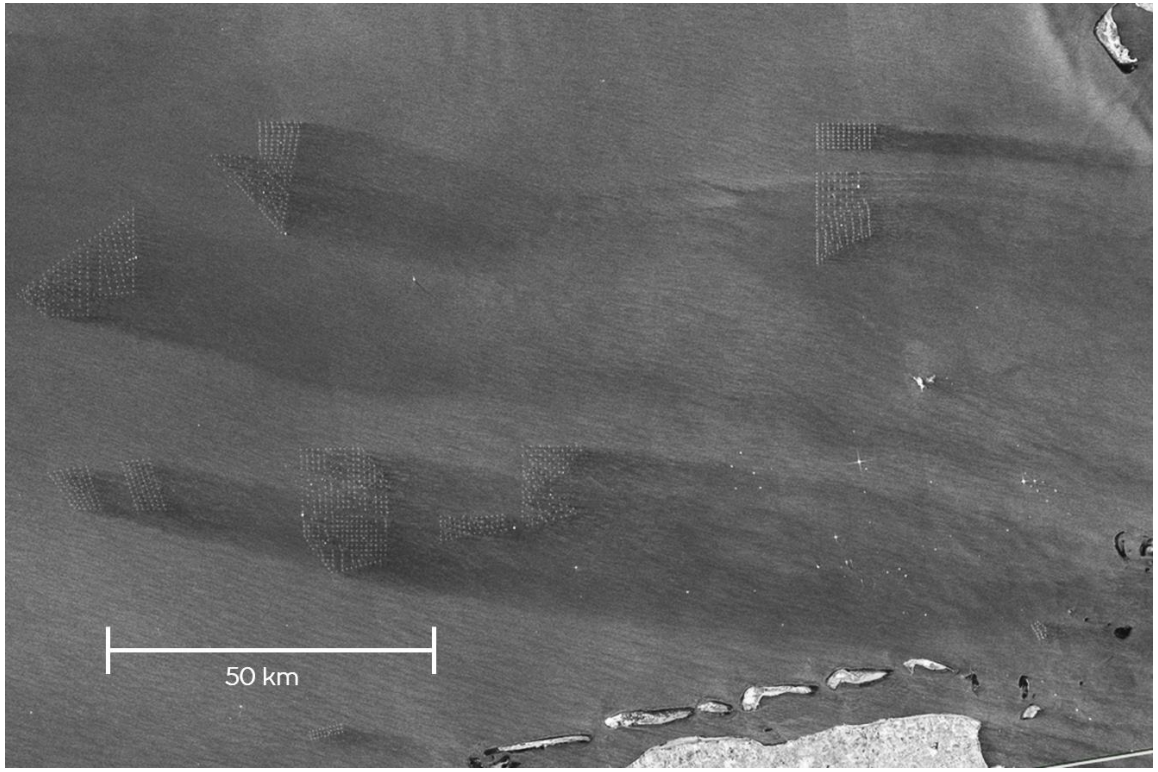
Conclusions

As a developer

- More wind farms = more green electrons
- Wakes cannot be avoided
- Use an unbiased wake model[1]
- Model all relevant neighbour wind farms
    - Distance and likelihood of being built

For governments

- Wakes do not respect national borders
- Mitigate developer risks
    - Clear pipeline of future buildout
    - Locations, sizes, timing
    - Coordination and collaboration
- Discussion of framework for resource sharing



Sentinel-1 satellite image, 1 April 2020
Ocean Virtual Laboratory

[1]Ørsted uses TurbOPark
https://github.com/OrstedRD/TurbOPark
Pedersen *et al*, J. Phys. Conf. Ser.: **2265**, 022063 (2022)

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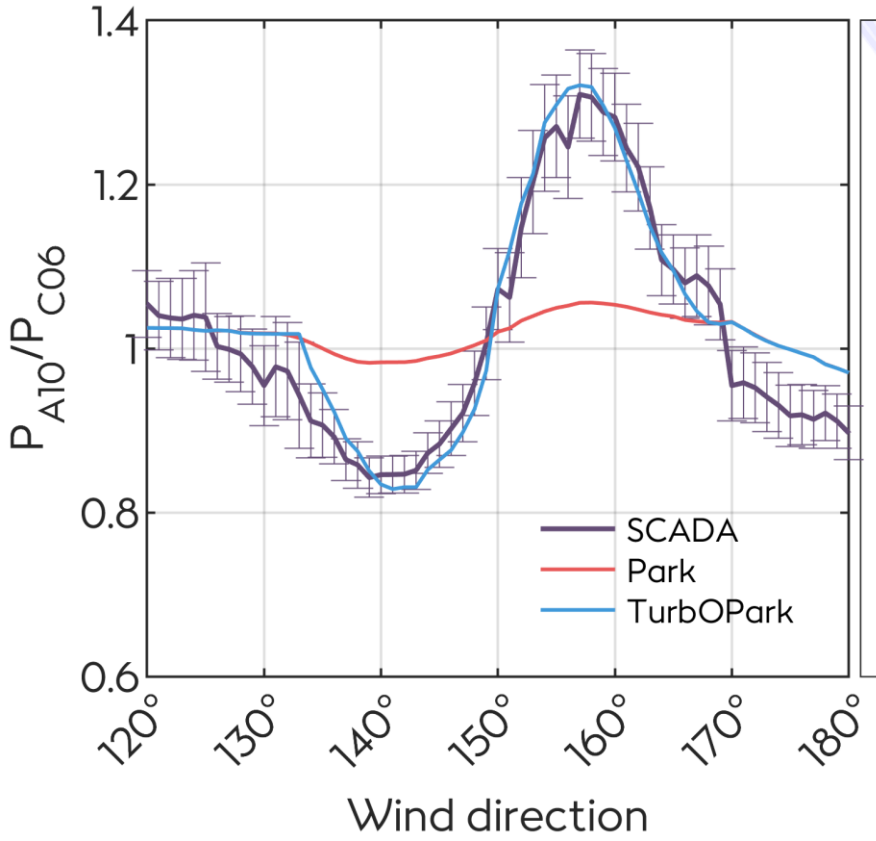
Thank you for listening!

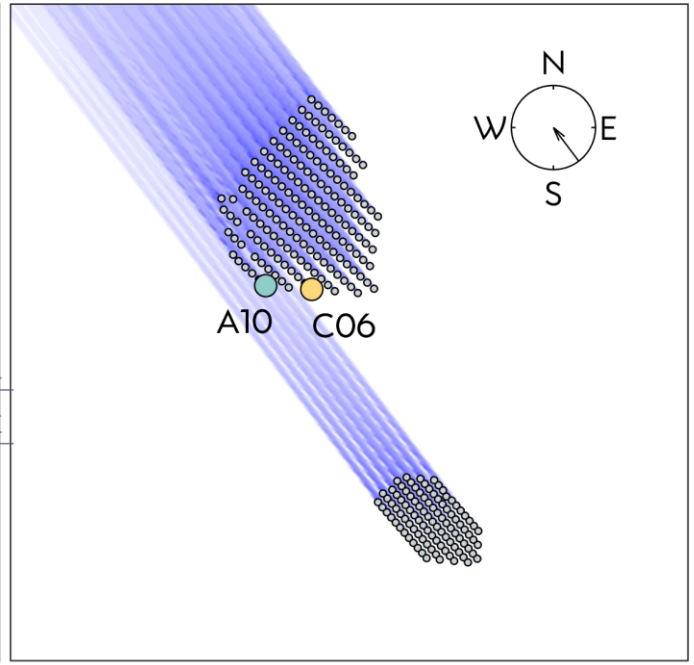
nicny@orsted.com

Backup slides

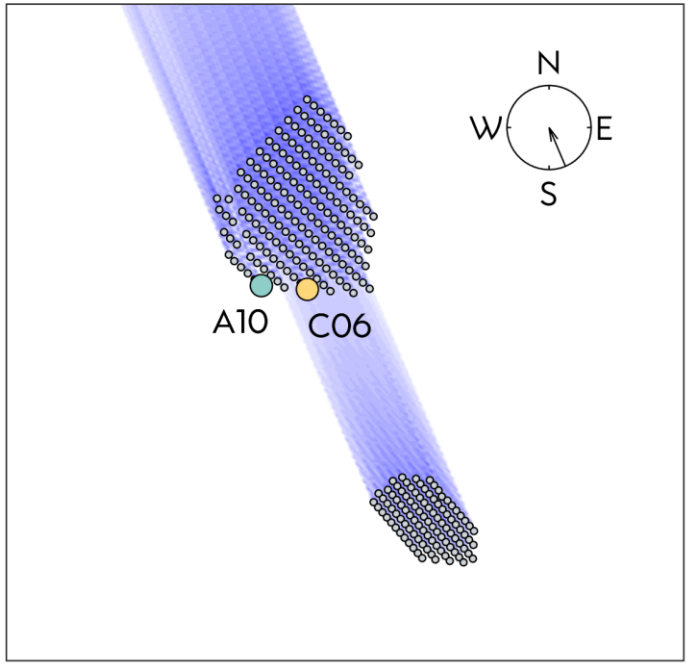
Observed vs. modelled neighbor wake impact

TurbOPark better captures long-distance wakes





Model @ 143°



Model @ 157°

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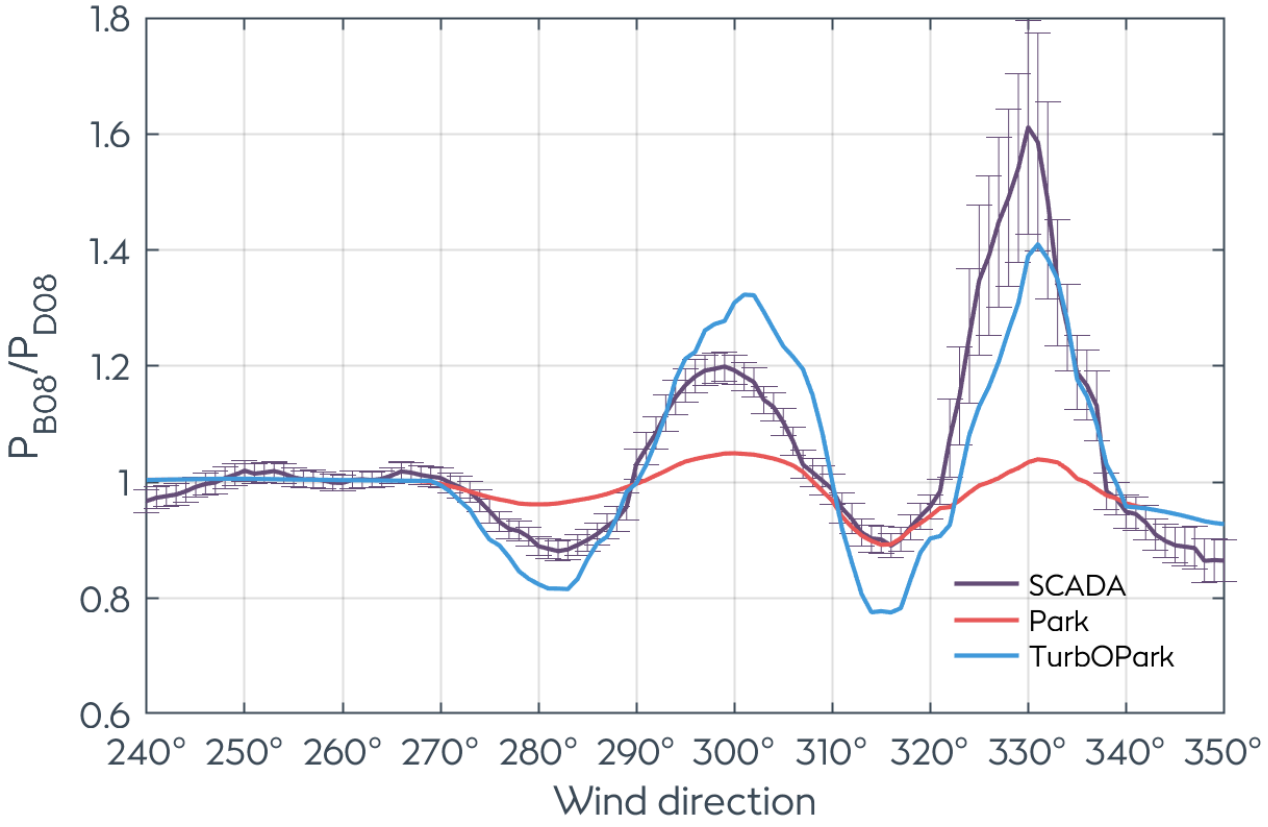
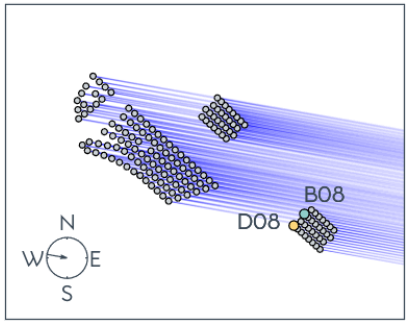
Observed vs. modelled neighbor wake impact

TurbOPark better captures long-distance wakes





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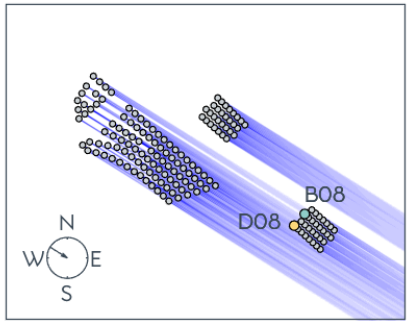
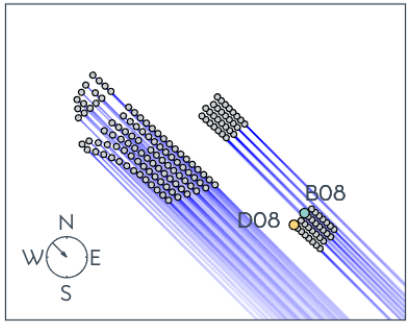
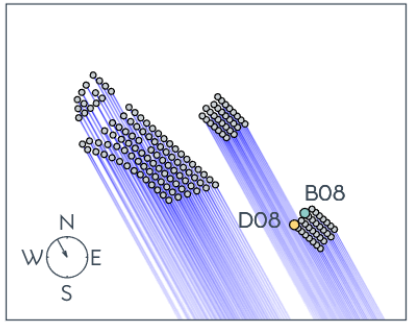


Model @ 302°



Model @ 315°



Model @ 331°

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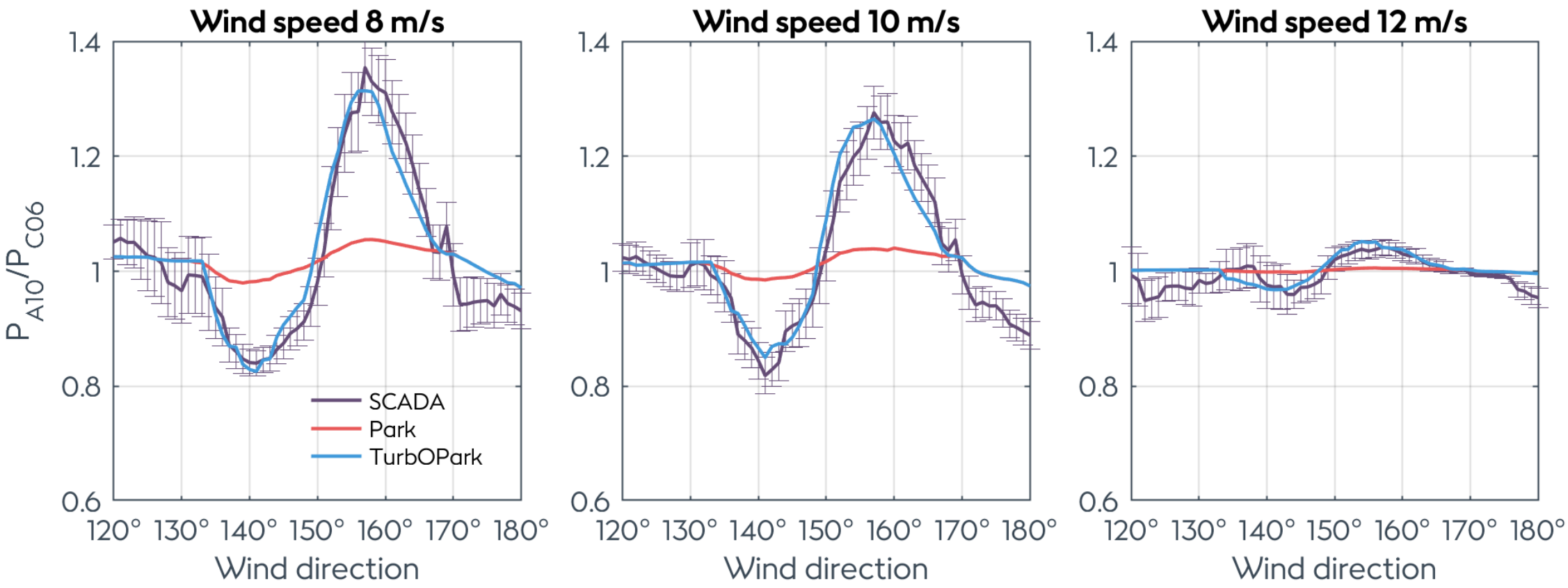
Wind speed dependence

Higher wind speeds reduce the neighbor wake impact



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