Impact of long-distance wakes between offshore wind farms

Assessed using operational data

Technology Workshop 2023 Nicolai Gayle Nygaard

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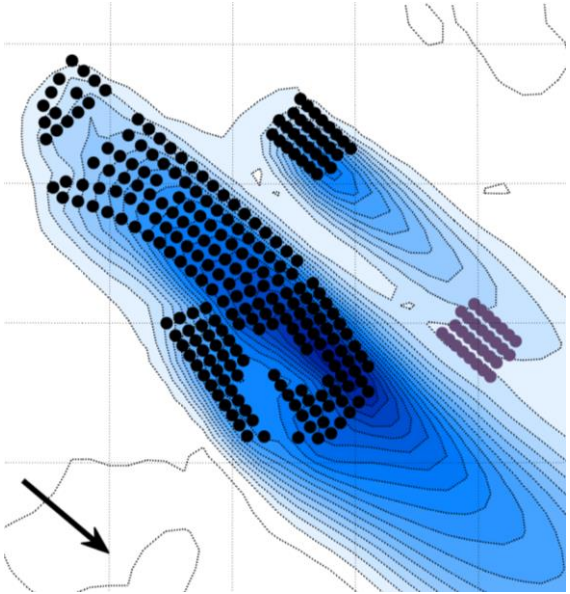
Wakes between wind farms



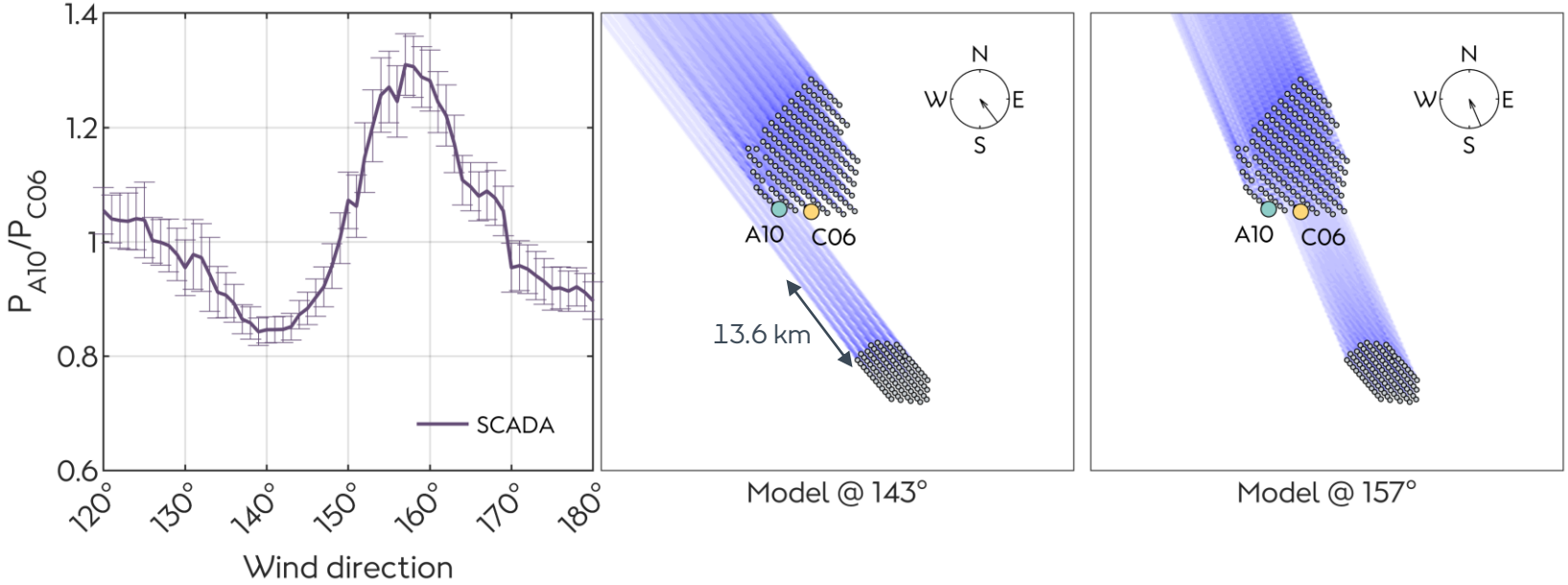
WRF modelling by Lina Poulsen, MSc thesis

In collaboration with
SmartWind Technologies
and Texas Tech University

15 km

Detecting long-range wind farm wakes

Using power ratio of front-row turbines



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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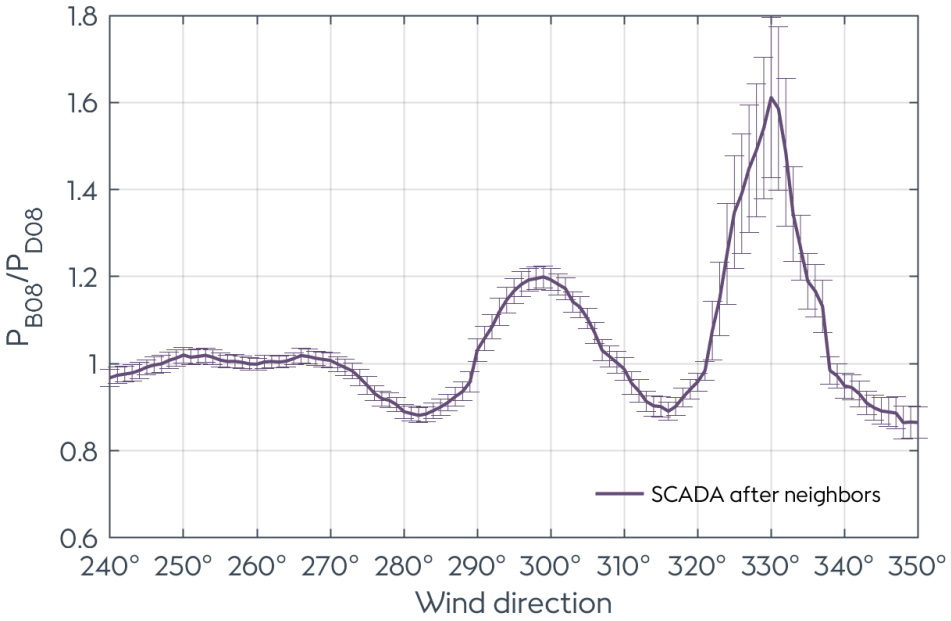
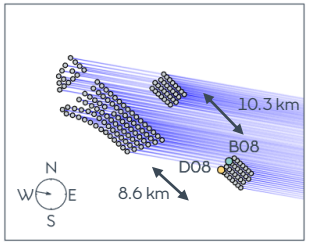
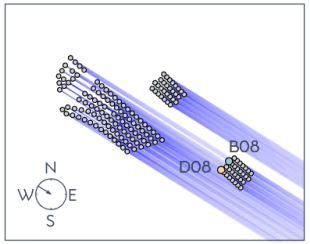
These are really wakes!

The effect is absent before the neighbors were built

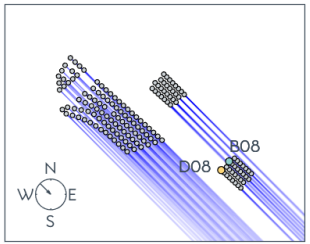




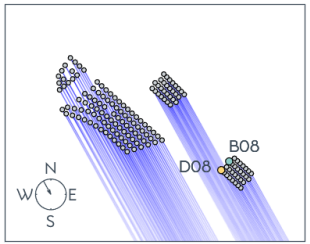
Model @ 280°



Model @ 302°



Model @ 315°



Model @ 331°

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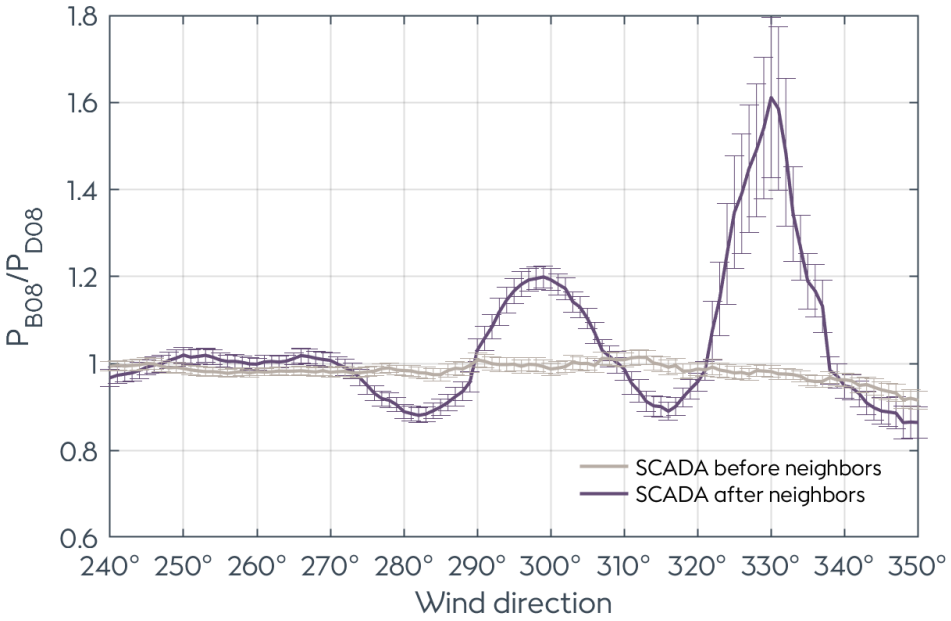

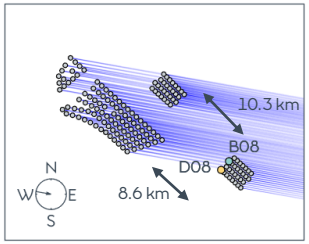

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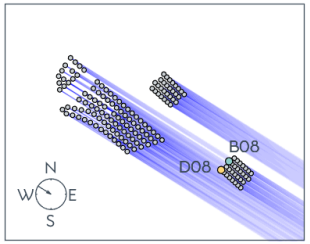
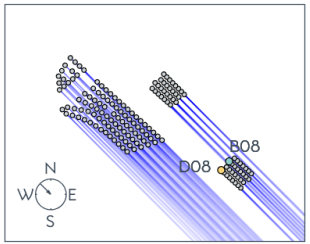


Model @ 302°



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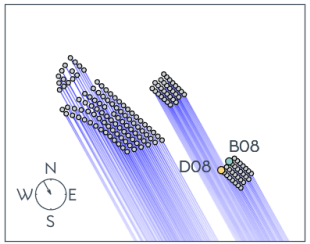

Model @ 331°

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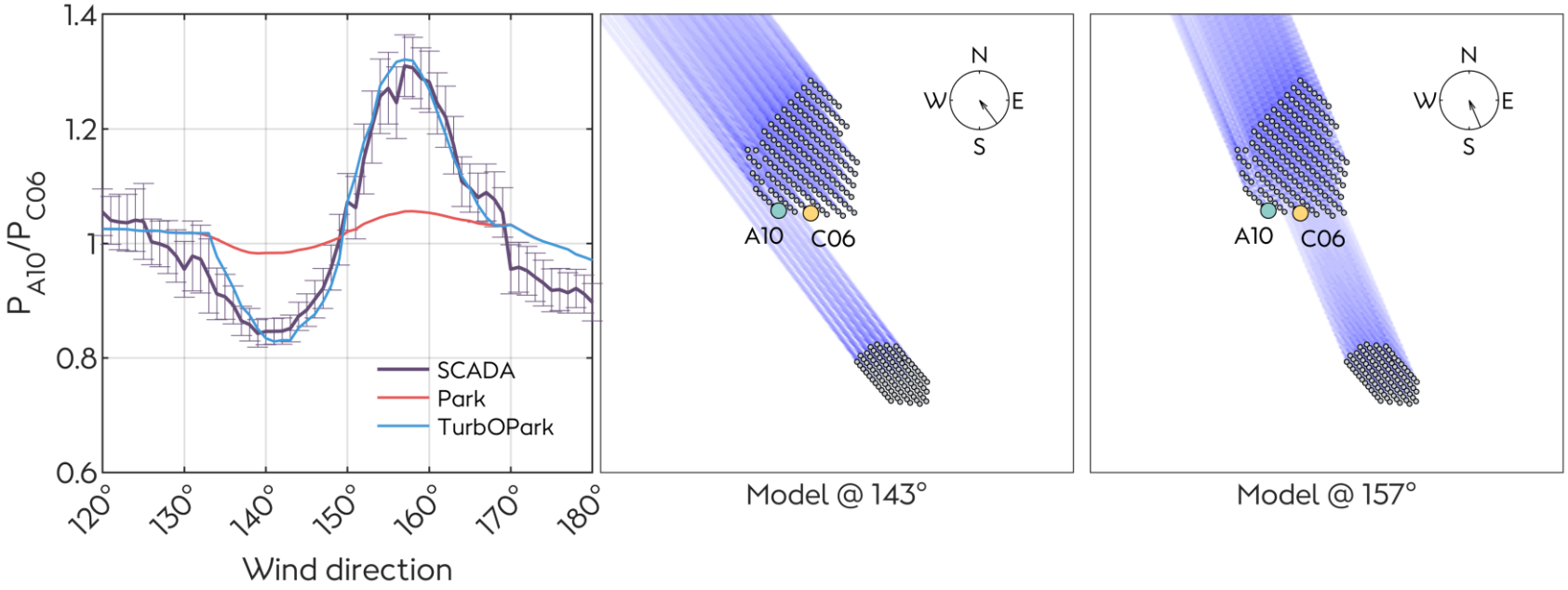
Observed vs. modelled neighbor wake impact

TurbOPark better captures long-distance wakes



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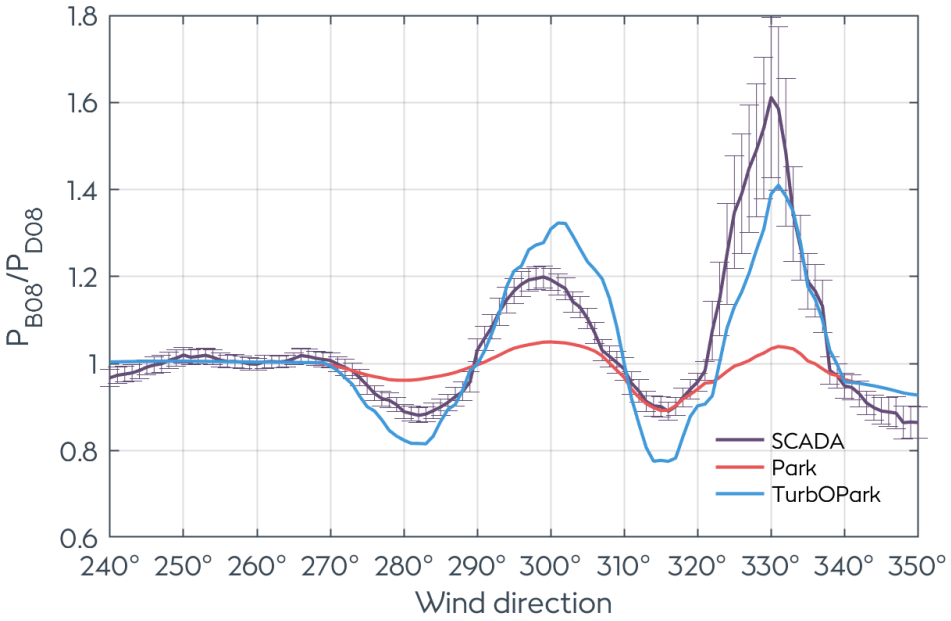

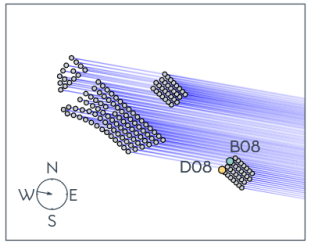

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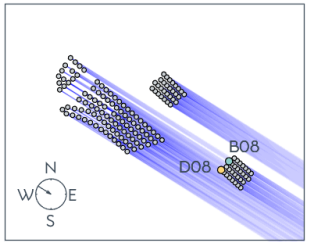

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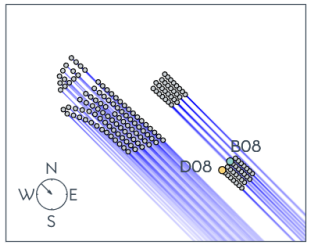

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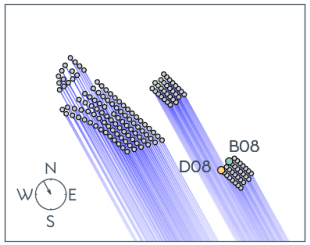

Model @ 331°

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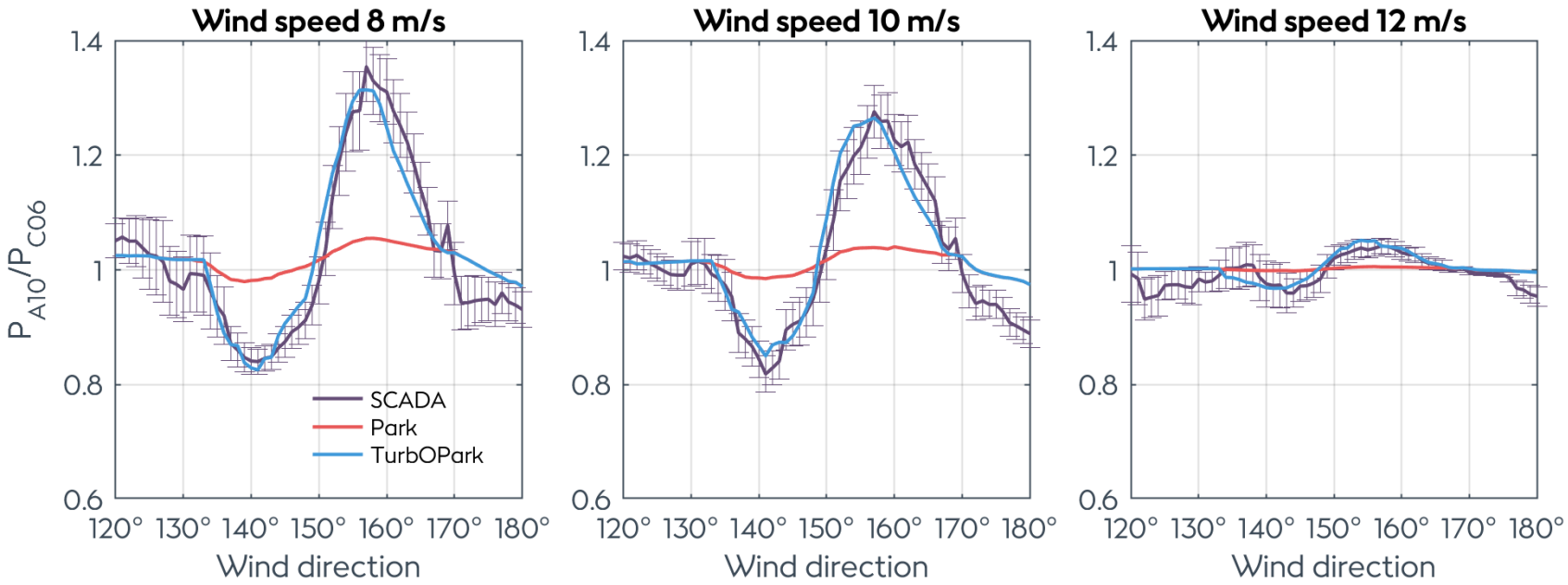
Wind speed dependence

Higher wind speeds reduce the neighbor wake impact



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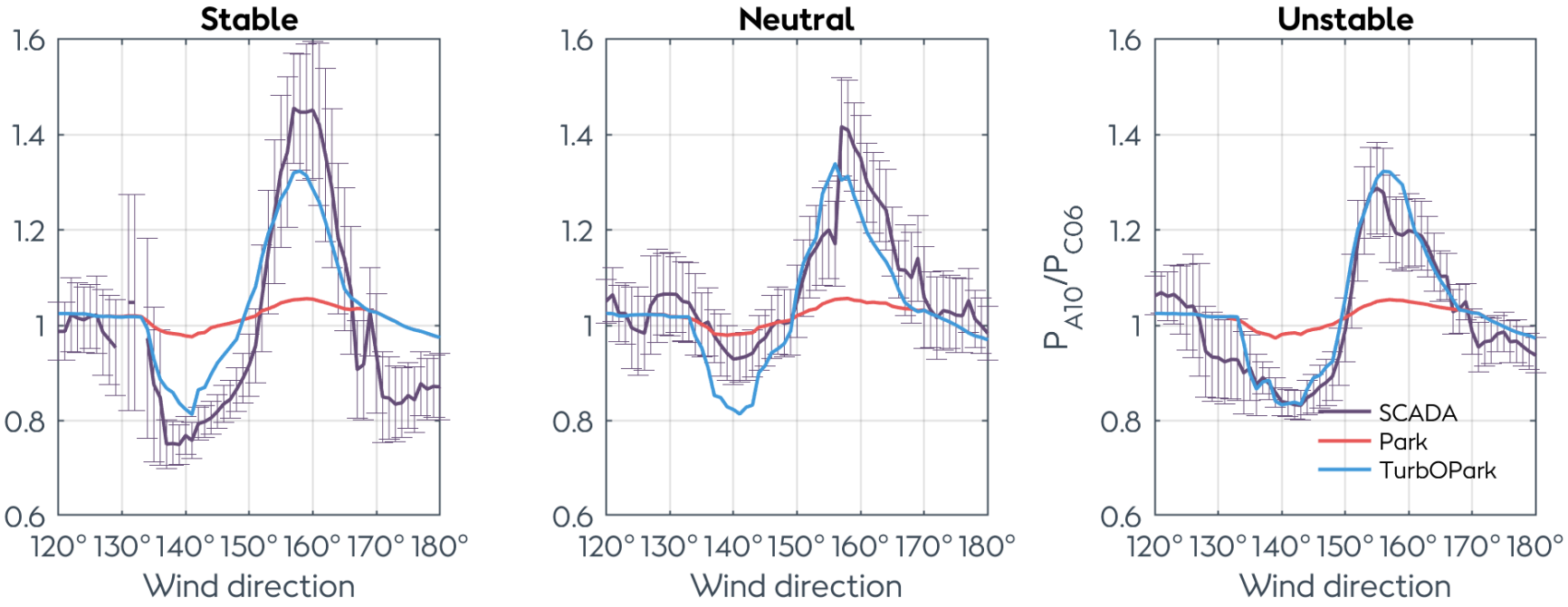
Stability dependence @ 8 m/s

With Monin-Obukhov length estimated from ERA5 data



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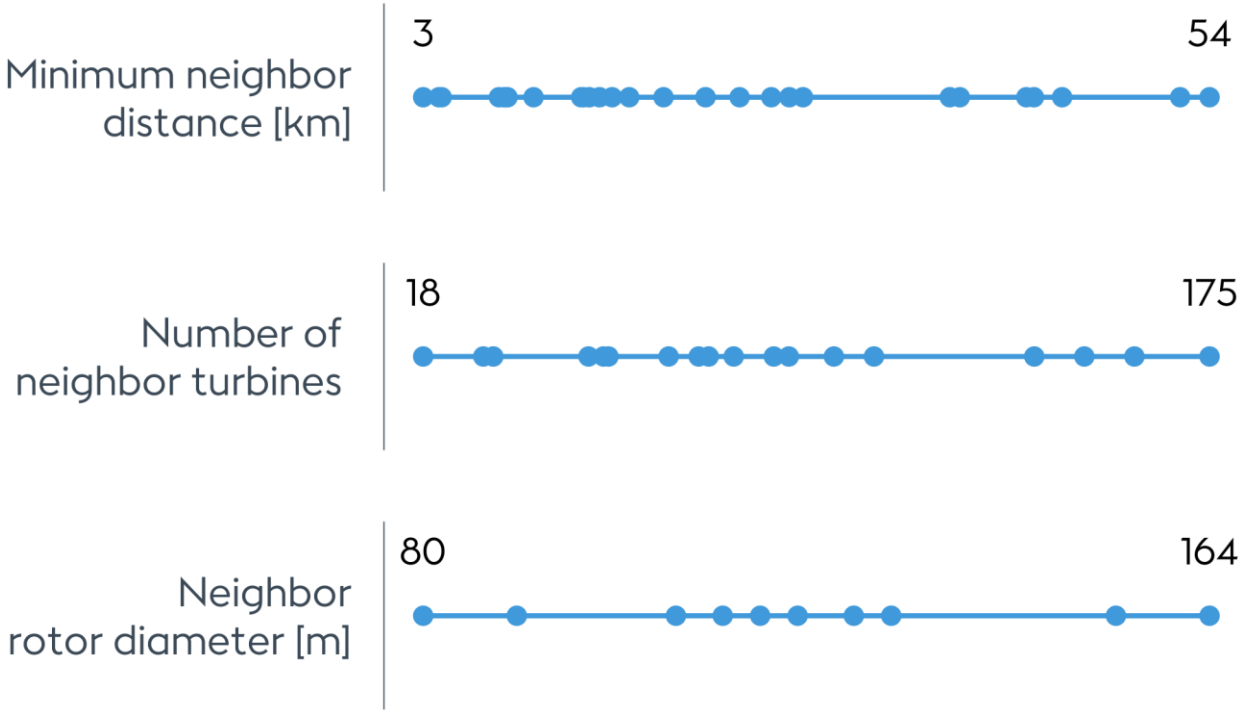
Generalizing to multiple cases

37 neighbor wind farms in Northern Europe



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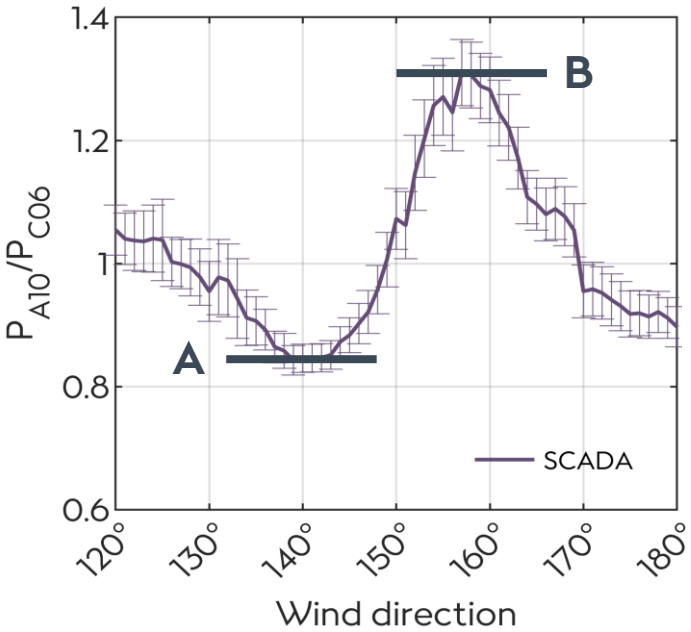
Calculating the wake impact from the neighbor

Only front row, only single wind speed



- Front row wake impact = $1 - 0.5(A + B^{-1})$
- Determine this for
  - All 37 wind farm pairs
  - SCADA data
  - Park model
  - TurbOPark model

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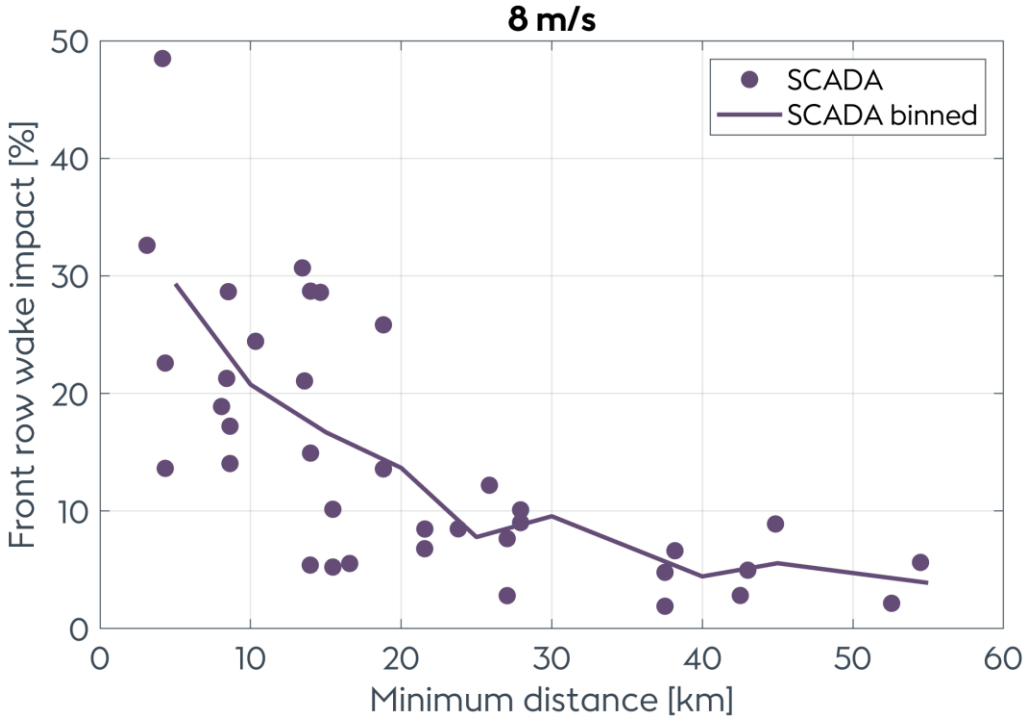
Dependence on distance

Neighbor wake impact decreases at larger distances



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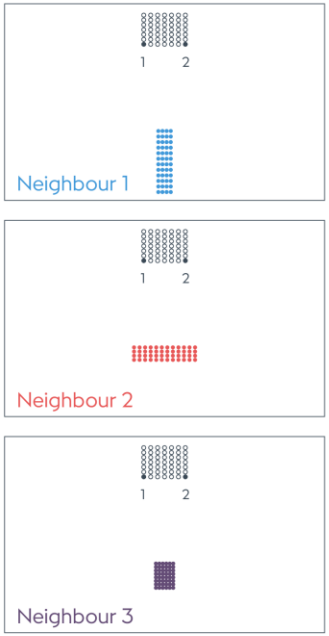
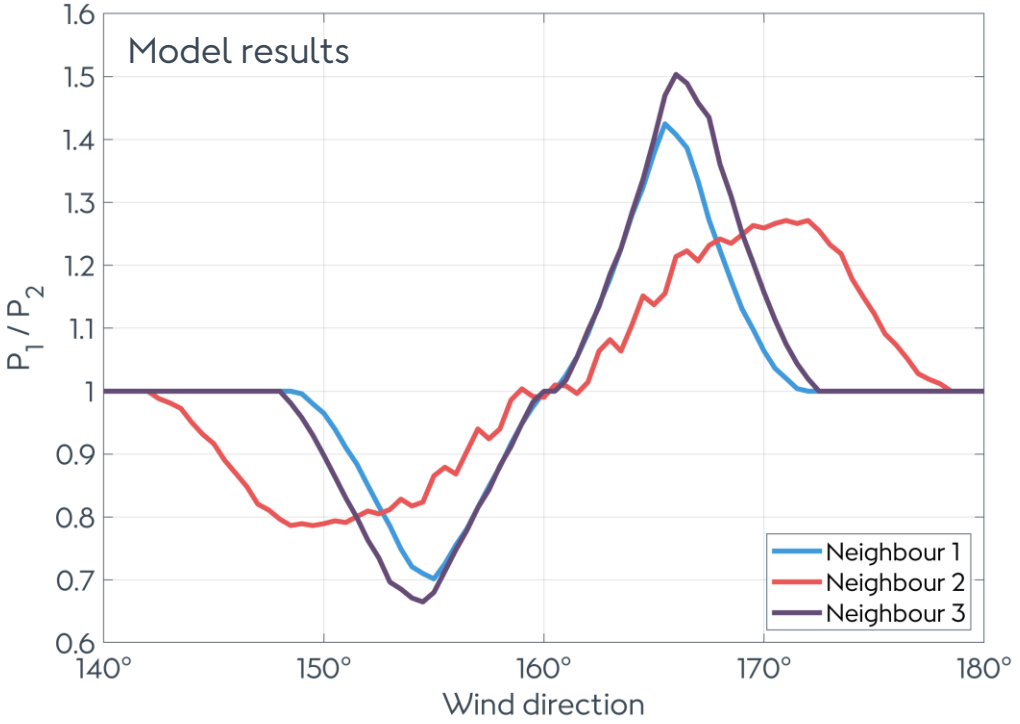
Sensitivity to neighbour configuration

Same turbines, same distance, different shapes





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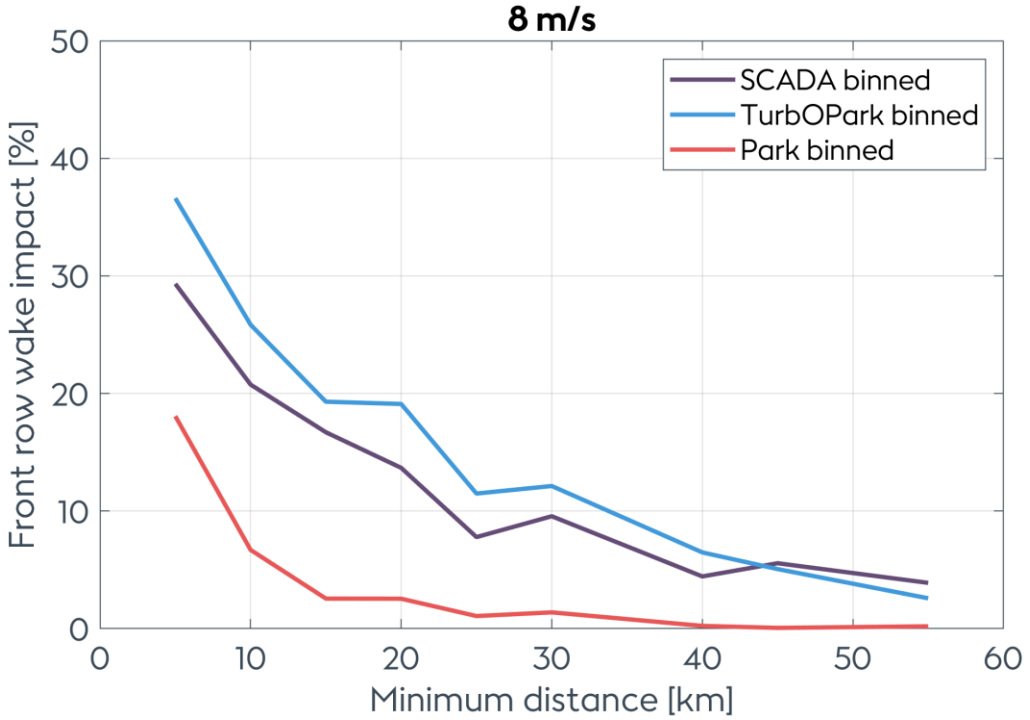
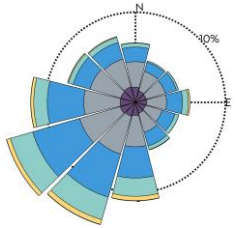
Dependence on distance

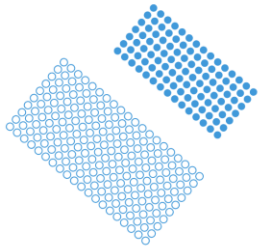
TurbOPark agrees well. Park underestimates the impact



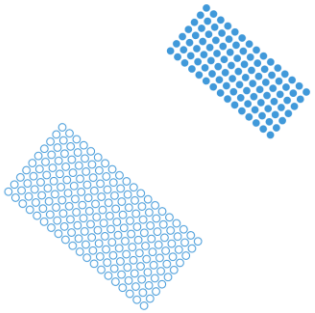
Impact on annual energy production

Hypothetical example

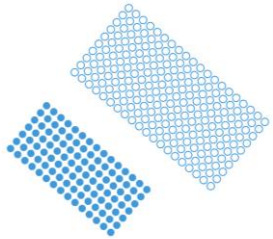




Separation 5 km
External wake loss 7.8%



Separation 15 km
External wake loss 3.8%



Separation 5 km
External wake loss 3.4%

Target

Neighbour

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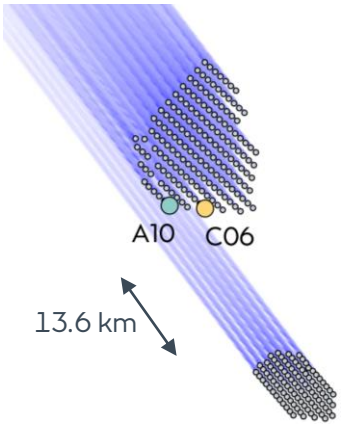
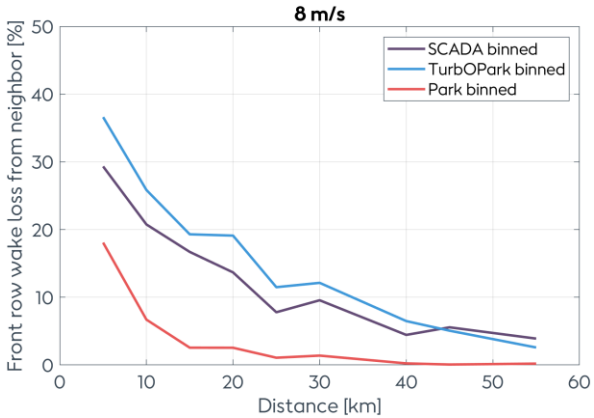
Conclusions





Wind speed

Stability

Neighbour configuration

Wind rose

Cluster wakes detected

Cluster wakes extend >50 km

Cluster wake dependencies

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Thank you for listening!

[redacted]