The Importance of Adding the Temporal Component to Wake Losses – a Verification Study

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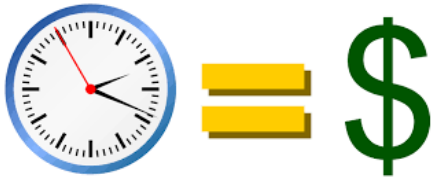
Motivation

- We have seen umpteen validation of wake models and umpteen interpretation of the result
- Most validations concentrate on the total number and not on the temporal behaviour
- Spot market: Time is money



- Wake losses depend on stability, thus time of the day
- But how much does the park efficiency vary with time of the day?
- How can we model that?

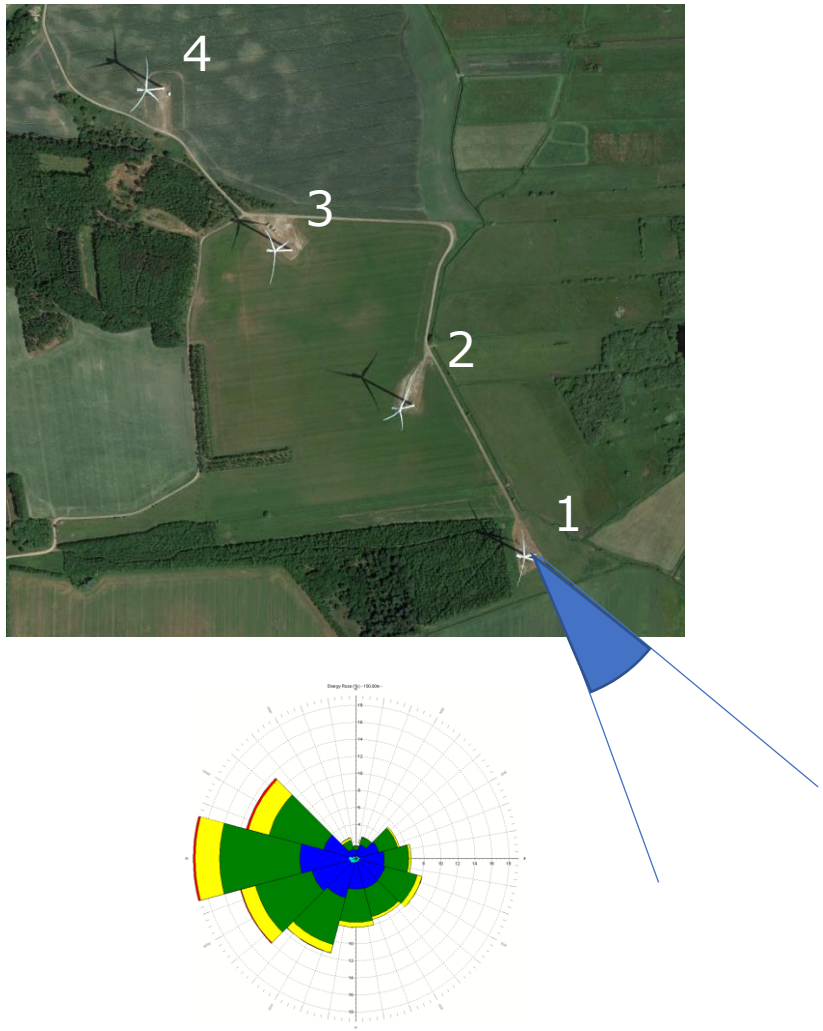
Setting the scene

- Ultimate truth: production data (10-minute SCADA data)
- Data filtering:
  - WTG operates flawless: no error or sub-optimal events
  - Exclude wind speeds near cut-in and rated wind speed
  - Only data where all WTGs operate
- Focus on wake sector

The Sites (1/3)

"Onshore – single row"

- Denmark: Krogstrup Enge
- 4 WTGs
- 3D distance
- Input to model:
  - nacelle wind speed WTG1

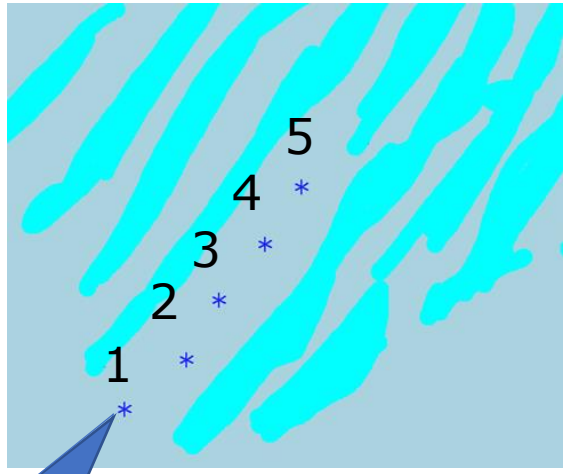


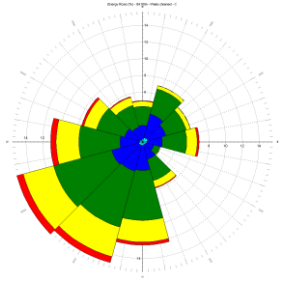
The Sites (2/3)

"Offshore"

- > 60 WTGs, 4.5 D apart downwind
- Special aspect: 5 WTGs are equipped with an iSpin *
- Consequently we know:
  - Real production
  - Real wind speed
  - Real turbulence intensity

  At 5 positions
- Wind speed at WTG 1 will be used



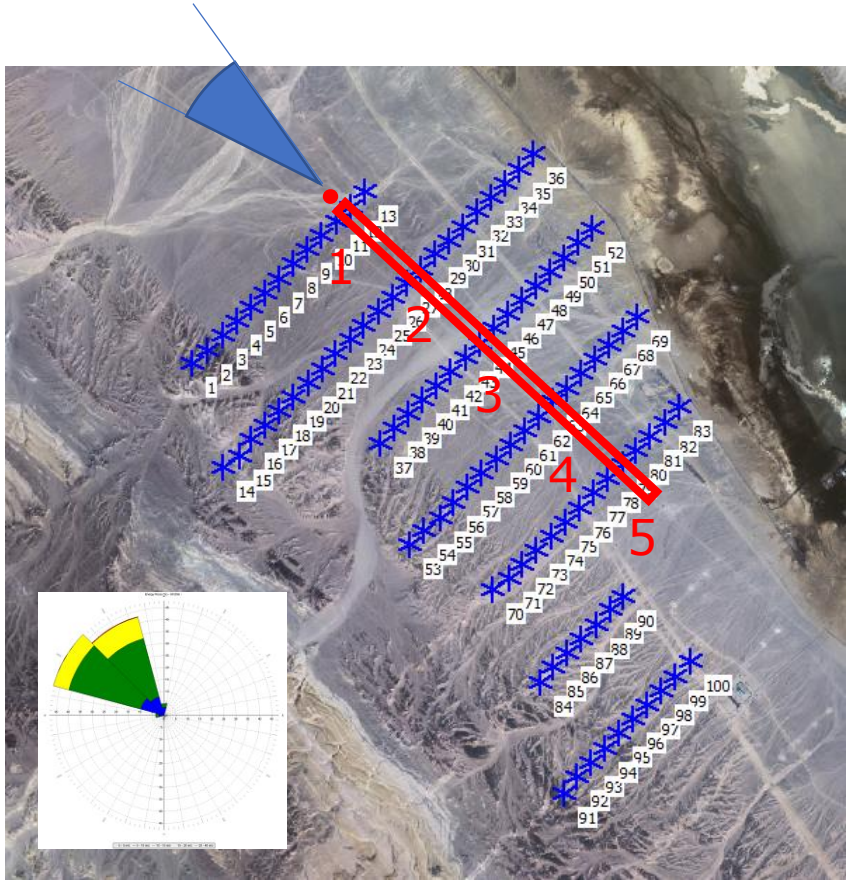


* Spinner anemometer, see https://www.romowind.com/

The Sites (3/3)

"Onshore – multiple row"

- Egypt: El Zayt
- 100 WTGs, 3 x 14 D
- Upwind mast used as model input



The wake model set-up

All calculations are time-varying driven by:

- Site 1: Nacelle ws
- Site 2: iSpin WTG1
- Site 3: mast

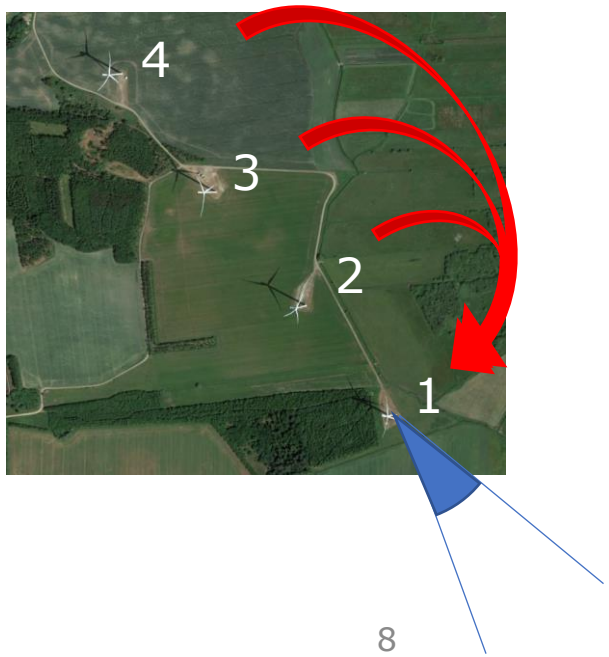
The configuration of the NO Jensen model varies:

1. Omni-directional fixed WDC (wake decay constant)
   - WDC 0.075 onshore / 0.04 offshore (DTU recommendation)
   - WDC adjusted to average TI (based on roughness and HH)
2. Time-varying WDC adjusted to TI per time-step
   - WDC = 0.4 TI
   - Site 1 (Krogstrup Enge, DK) only: Experimental WDC = 0.8 TI plus adjusting changing WDC per row

What to look for?

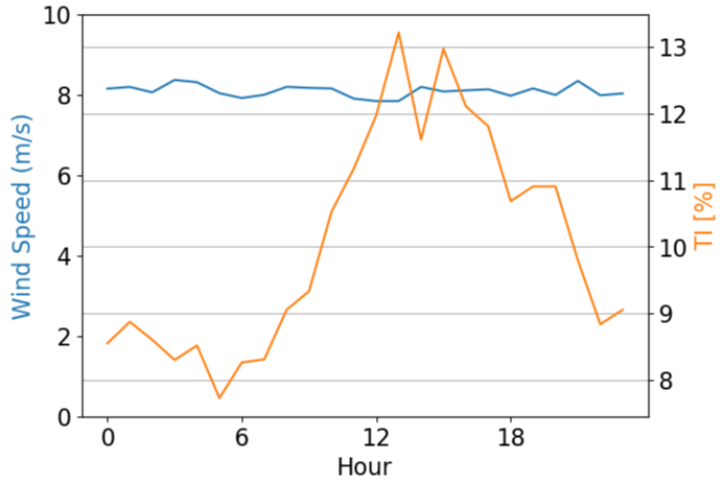
Step 1: Do we see diurnals?

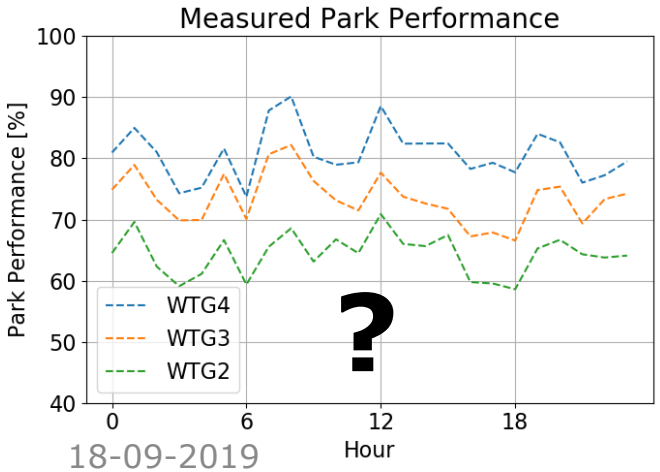
- Wind speed, turbulence
- Measured park performance: Production of downwind WTG normalized to production of free WTG - *per time stamp*



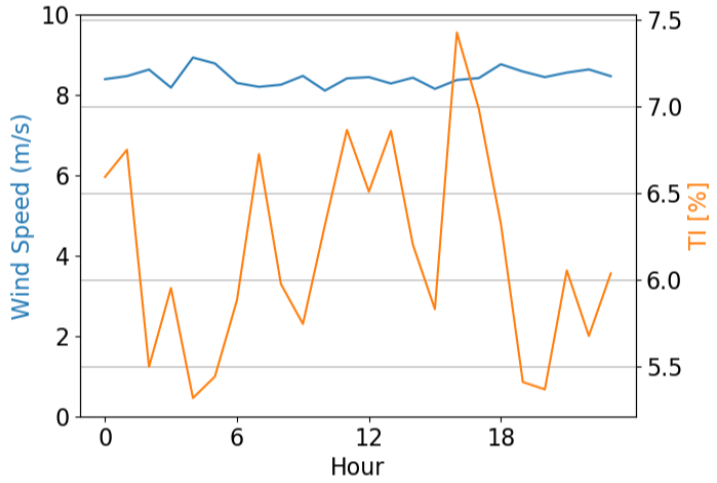
Step 1: Sanity Check

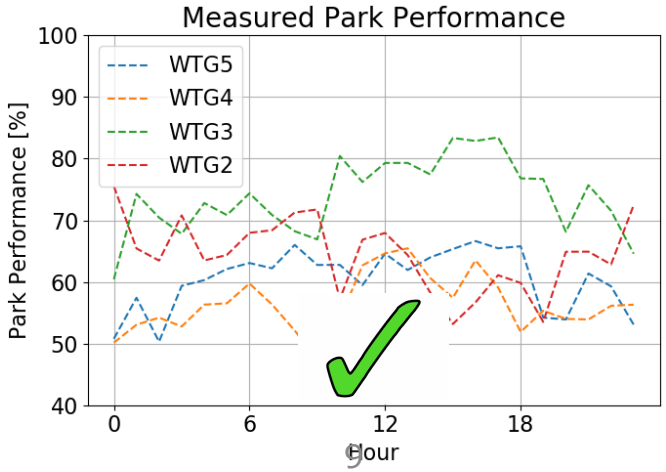
Site 1: Onshore single row



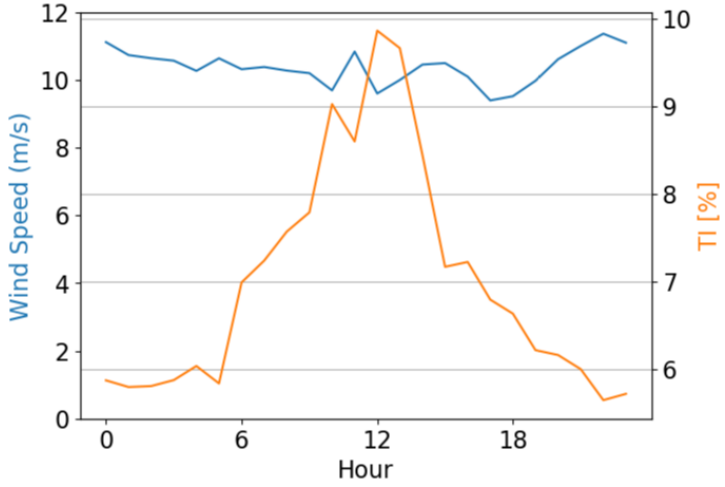


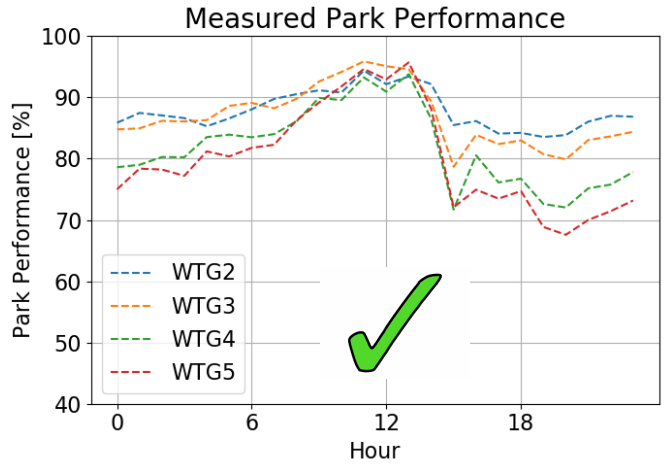
Site 2: Offshore





Site 3: Onshore multiple row





What to look for?

Step 1: Do we see diurnals?

- Wind speed, turbulence
- Measured park efficiency

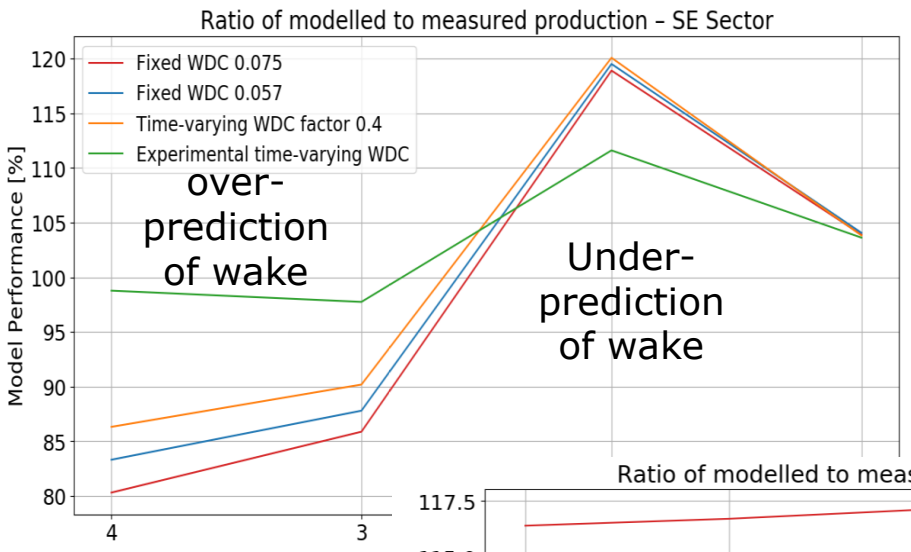
But we do not necessarily see diurnals in park efficiency

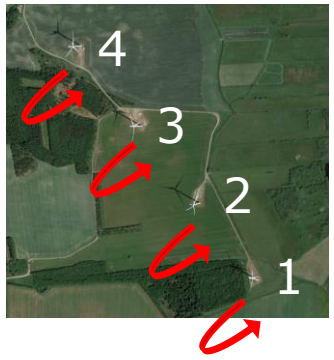
Step 2: Can we model?

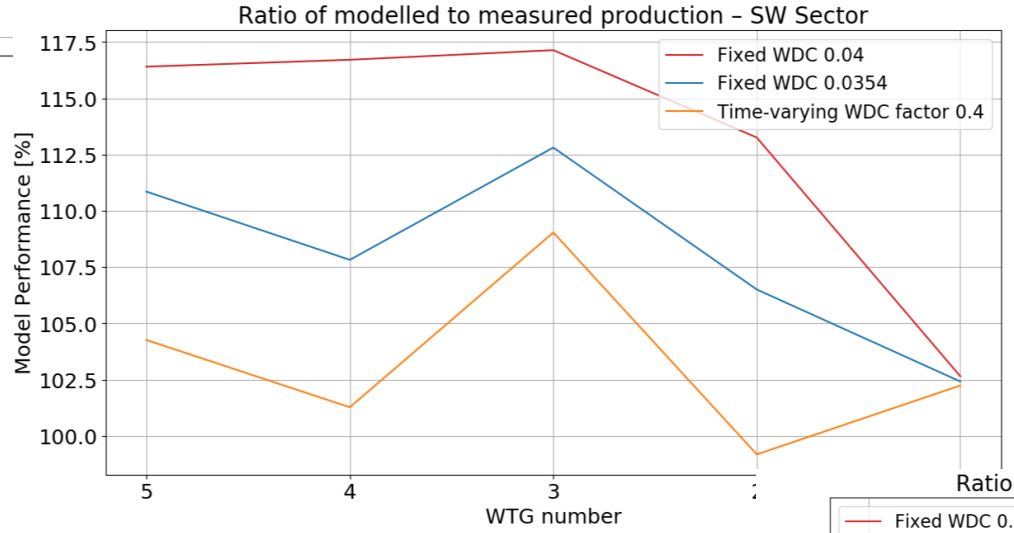
- In terms of absolute production
- In terms of diurnals

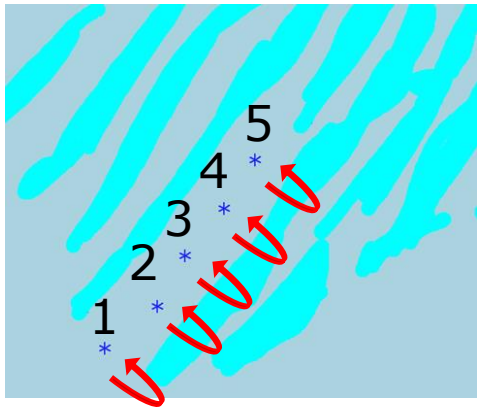
Model performance:

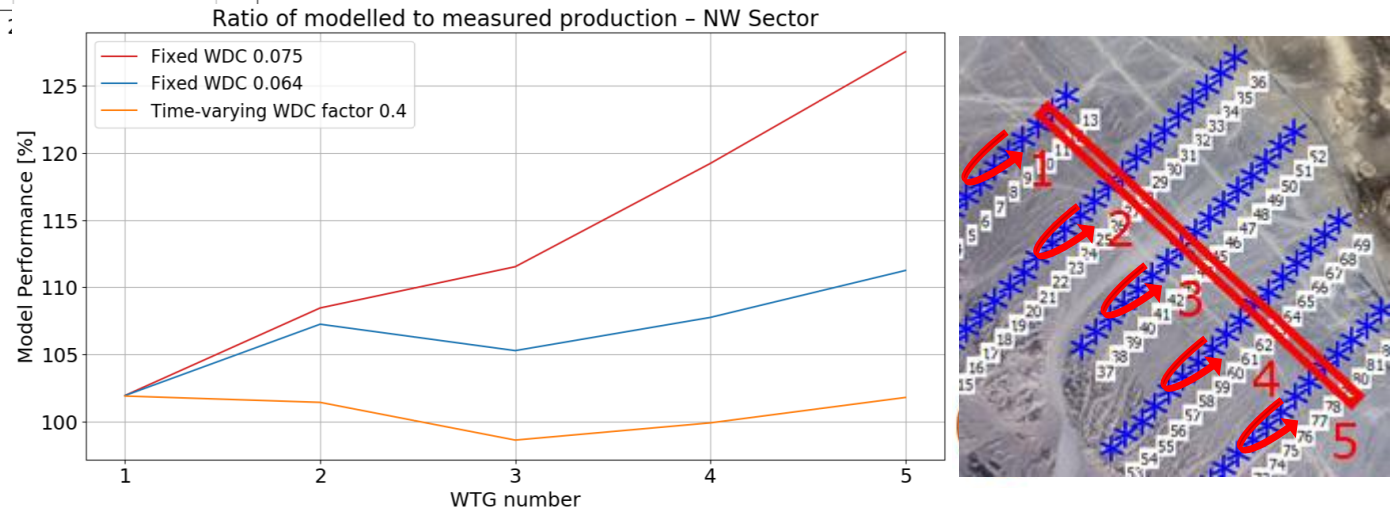
ratio of modelled to measured production on WTG level



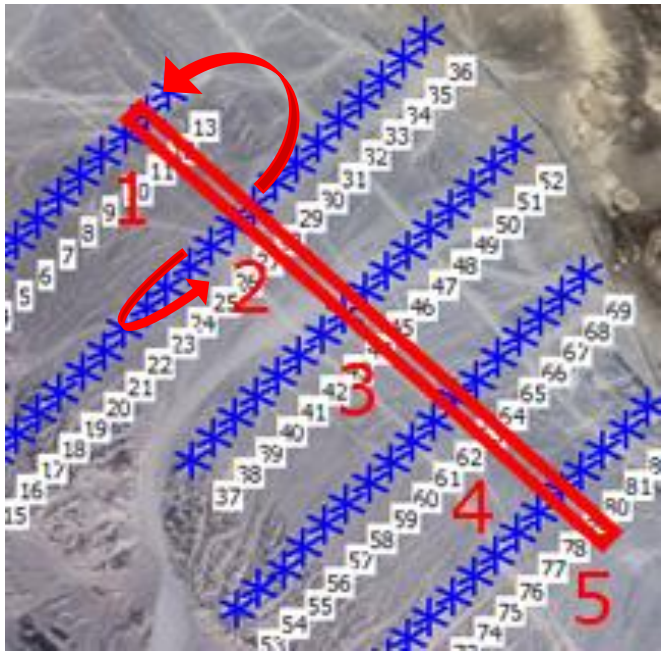


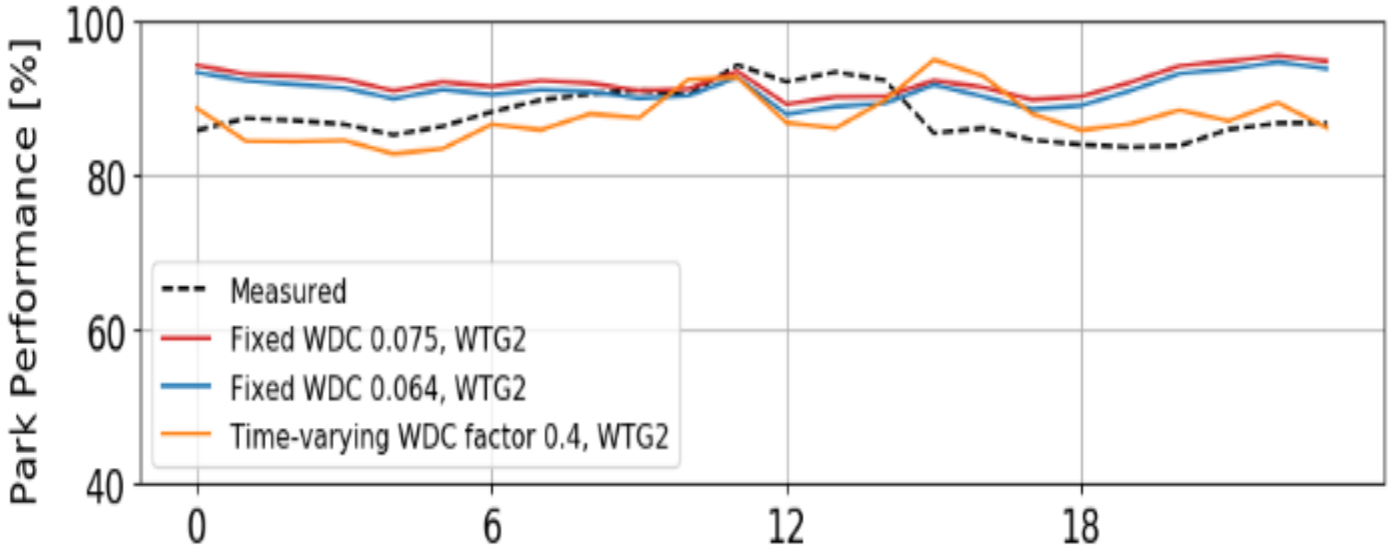


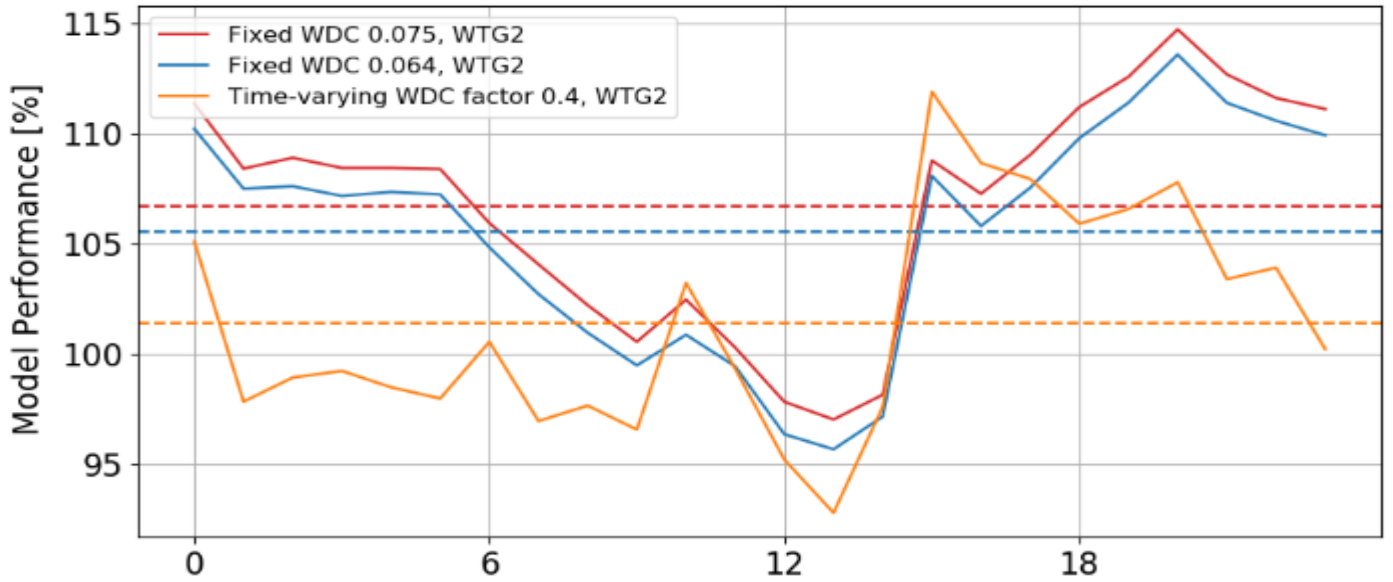




Modelling Diurnals: Site 3 El Zayt







What to look for?

Step 1: Do we see diurnals?

- Wind speed, turbulence
- Measured park efficiency

Step 2: Can we model?

- In terms of absolute production
- In terms of diurnals

Step 3: What does that mean in terms of money?

Financial implication

- Site 2 – offshore: Nord Pool spot market
- Only production in waked sector is analyzed
- Comparing modelled to measured production

	Deviation from measured earning
Fixed WDC 0.04	7.8%
Fixed WDC 0.0354	4.1%
Time-varying WDC	0.7%

Conclusion

- Clearly time-varying WDC best on all sites
- Clear financial impact can be shown
- Site 1 (single row) can be solved with experimental solution
- Diurnal TI pattern not necessarily a proxy for production diurnals

- Of course: More projects needed for validation! WP3 projects (with 10-minute SCADA data) will be analyzed

Contact Detail

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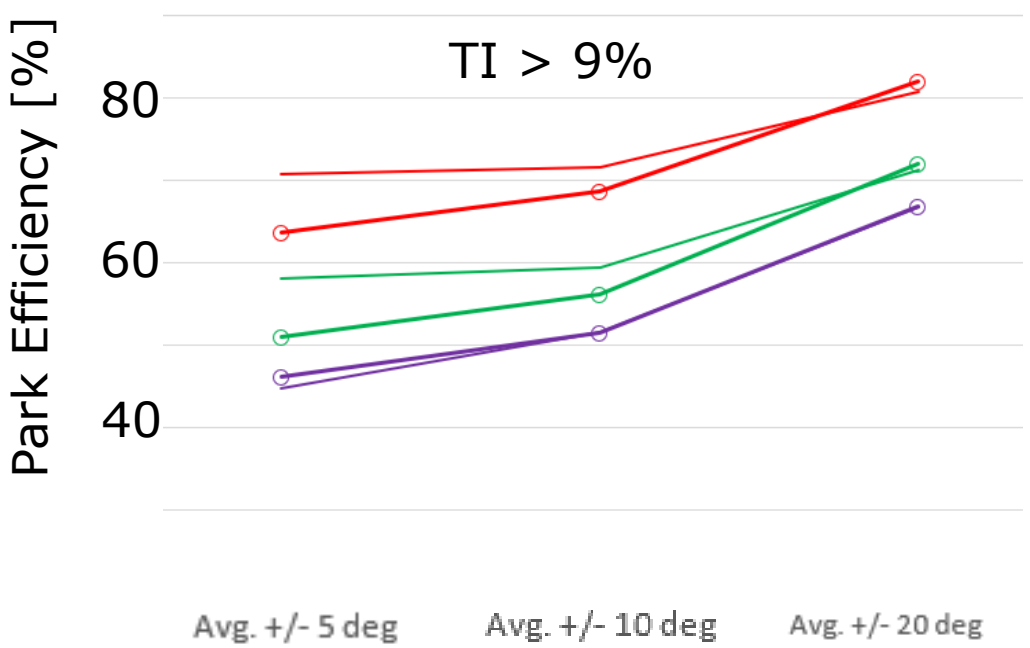
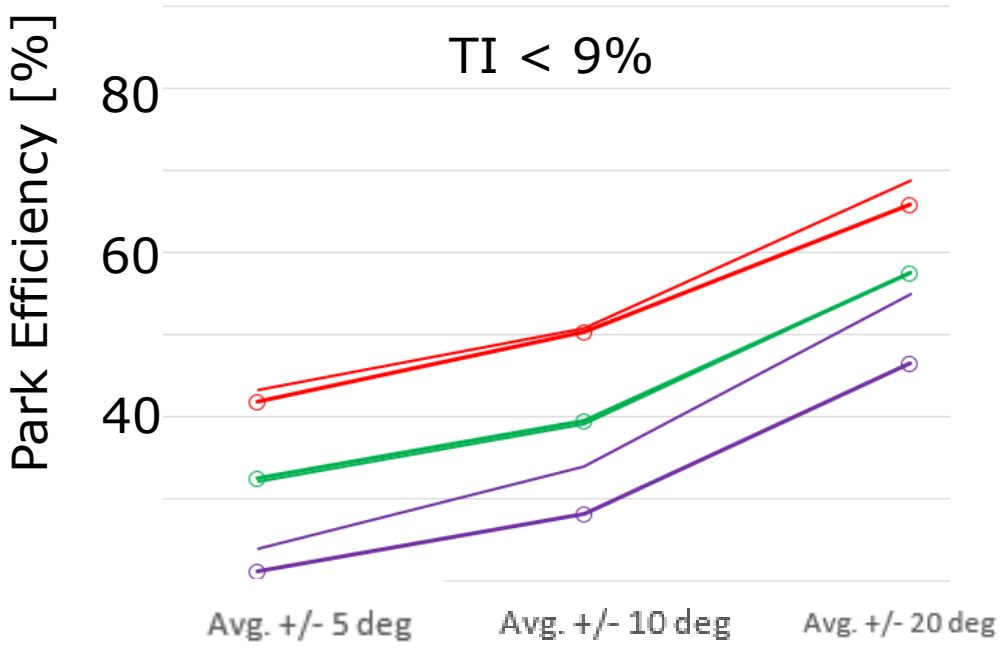
Backup slide: Direction-dependency

- Yes, wake losses are dependent of the width of the sector
- Yes, we did (some) analysis – example Site 1 (single row)





Meas_WT1 Meas_WT2 Meas_WT3
Calc_WT1 Calc_WT2 Calc_WT3