Benchmarking of wind farm scale wake models in the EERA-DTOC Project

EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

P.-E. Réthoré, K.S. Hansen, R.J. Barthelmie, S.C. Pryor, G. Sieros, J. Prospathopoulos, J.M.L.M. Palma, V.C. Gomes, G. Schepers, P. Stuart, T. Young, J.S. Rodrigo, G.C. Larsen, T.J. Larsen, S. Ott, O. Rathmann, A. Pena, M. Gaumond and C. B. Hasager

Support by

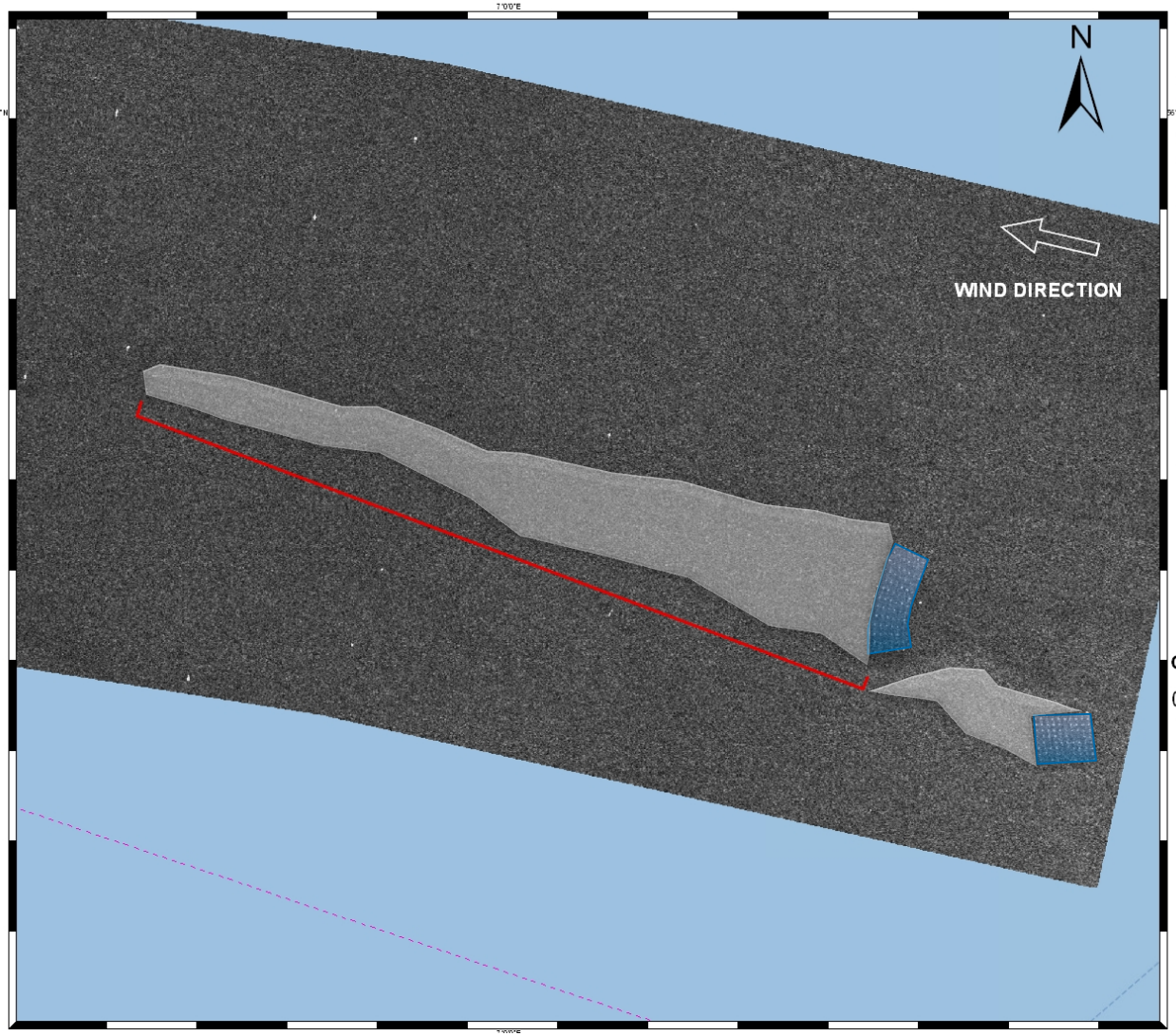
SEVENTH FRAMEWORK PROGRAMME

Outline

- Vision
- EERA-DTOC
- Wind Farm Scale Wake Benchmark
- Effect of wind direction uncertainty
- Summary

The Challenge

Cluster scale wake satellite pictures



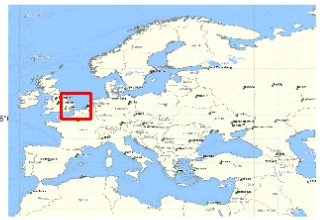


IMAGE 1
HORNS REV 1 & 2

Legend

EEZ

length

Comments

RADARSAT-1 image

Feature: Wake

Length: 88 km
Width max: 10 km

Cartographic informations

0 5 10 20 30
Kms

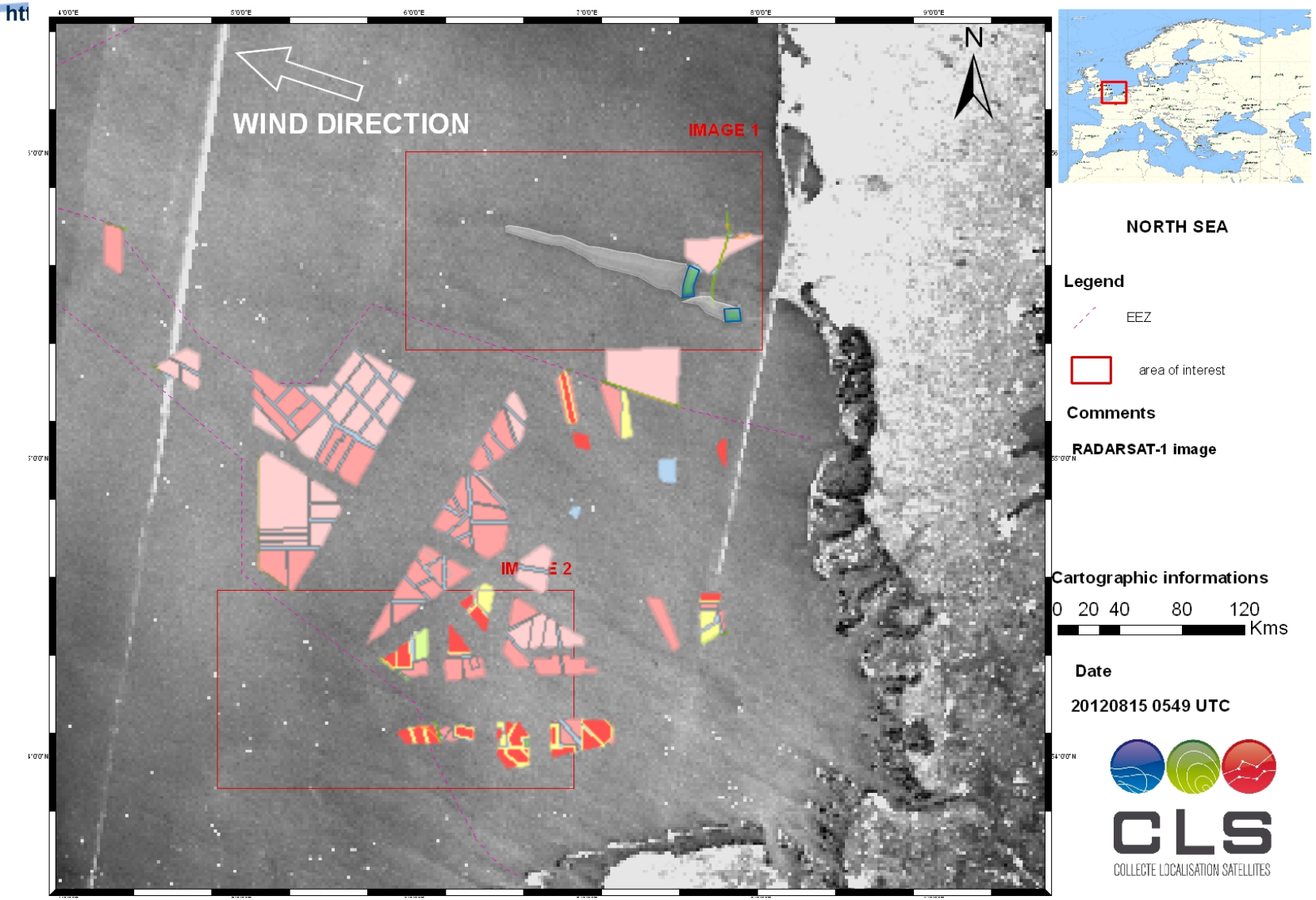
Date

20120815 0549 UTC

CLS
COLLECTE LOCALISATION SATELLITES

The Challenge

Cluster scale wake satellite pictures

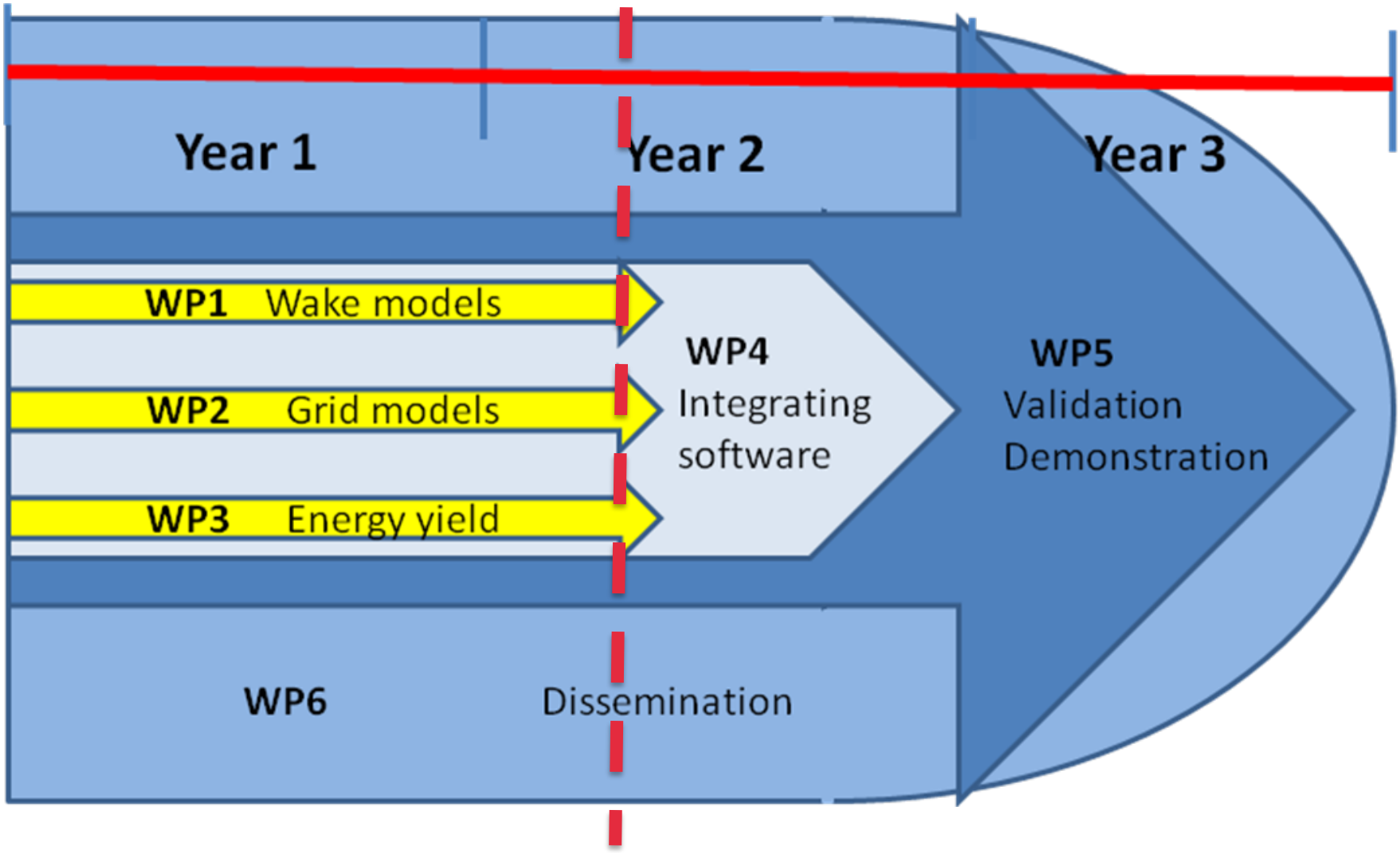


EERA-DTOC
Main Ideas

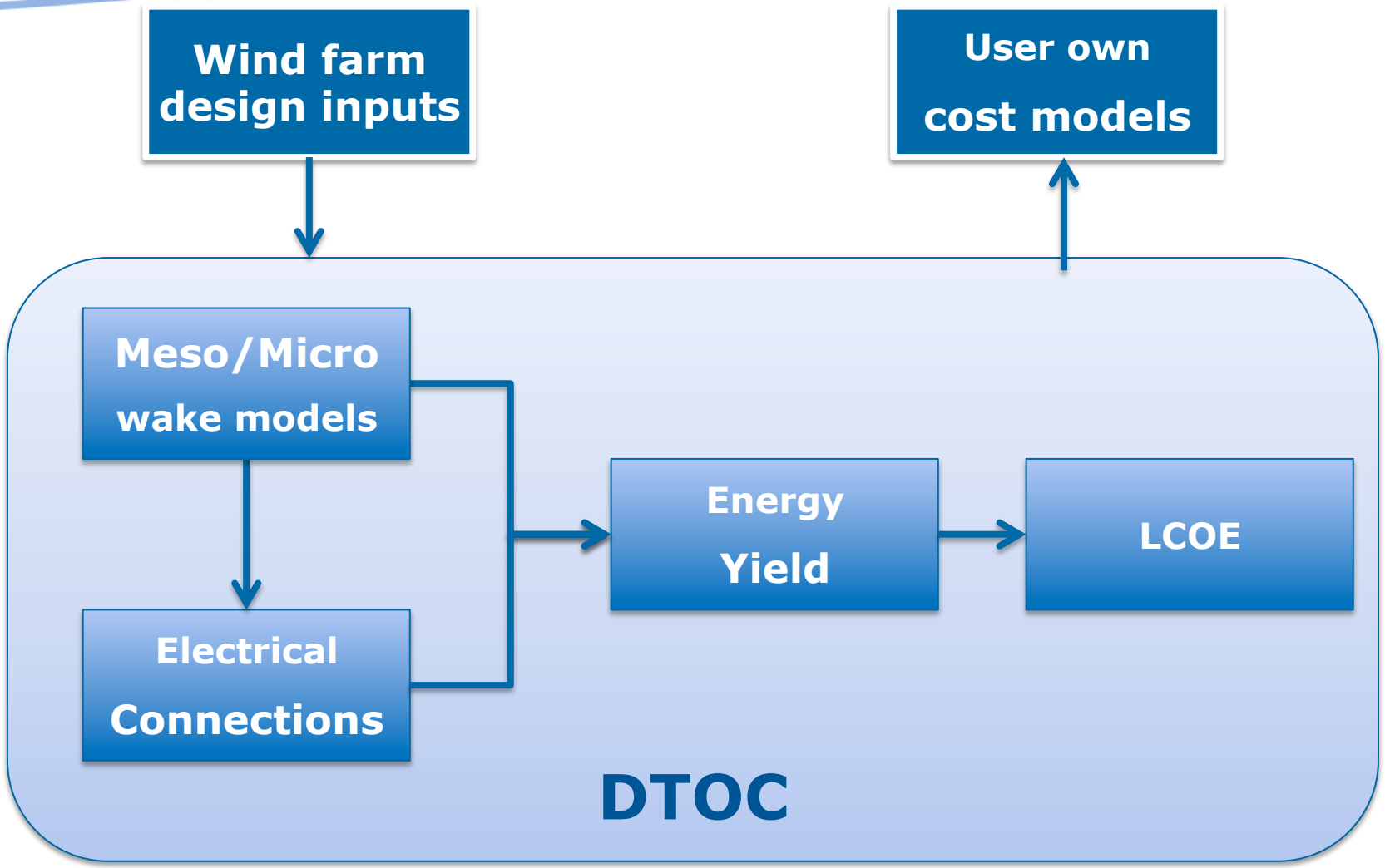
EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

- European Energy Research Alliance
- **DTOC: D**esign **T**ool for **O**ffshore (wind farm) **C**lusters
- EU-FP7 funded project, 2012-2015
- Focus on designing wind farm **clusters** considering:
  - Inter wind farms **wake losses**
  - Inter wind farms **electrical cabling**
- Work is underway to deliver an integrated tool for the design of individual wind farms and clusters of wind farms
- The tool is composed of existing models as available throughout Europe
- The tool will be available in December 2014

WP Structure

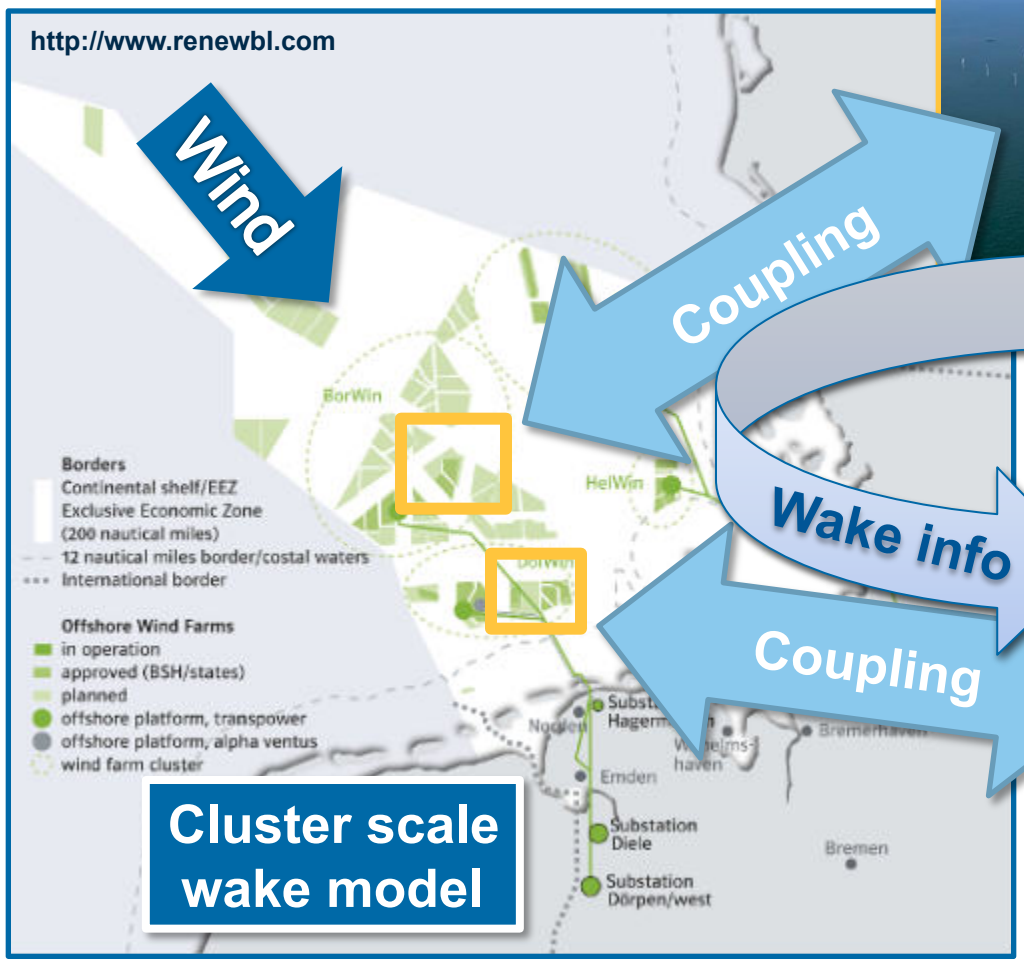


EERA-DTOC
System Global Overview



Introduction

The “big wake” picture



Coupling

Wake info

Coupling

Introduction

The “big wake” picture

Tuesday, 8:55
Jake Badger:
“*Wake modeling combining mesoscale and microscale models*”

Wednesday, 9:15
Patrick Volker:
“Wind farm parametrisations in mesoscale models”

Purpose

*"**Identify, benchmark,** provide **guidelines** for and **couple** the **existing wake models** that can operate over **wind farm scale** and **cluster scale.**"*

Wind farm scale wake models

DTU

DWM

FUGA

GCL

NOJ

INDIANA UNIVERSITY

WASP/ NOJ

U.PORTO

RANS

CRES flowNS

res power for good

Ainslie

ECN

FarmFlow

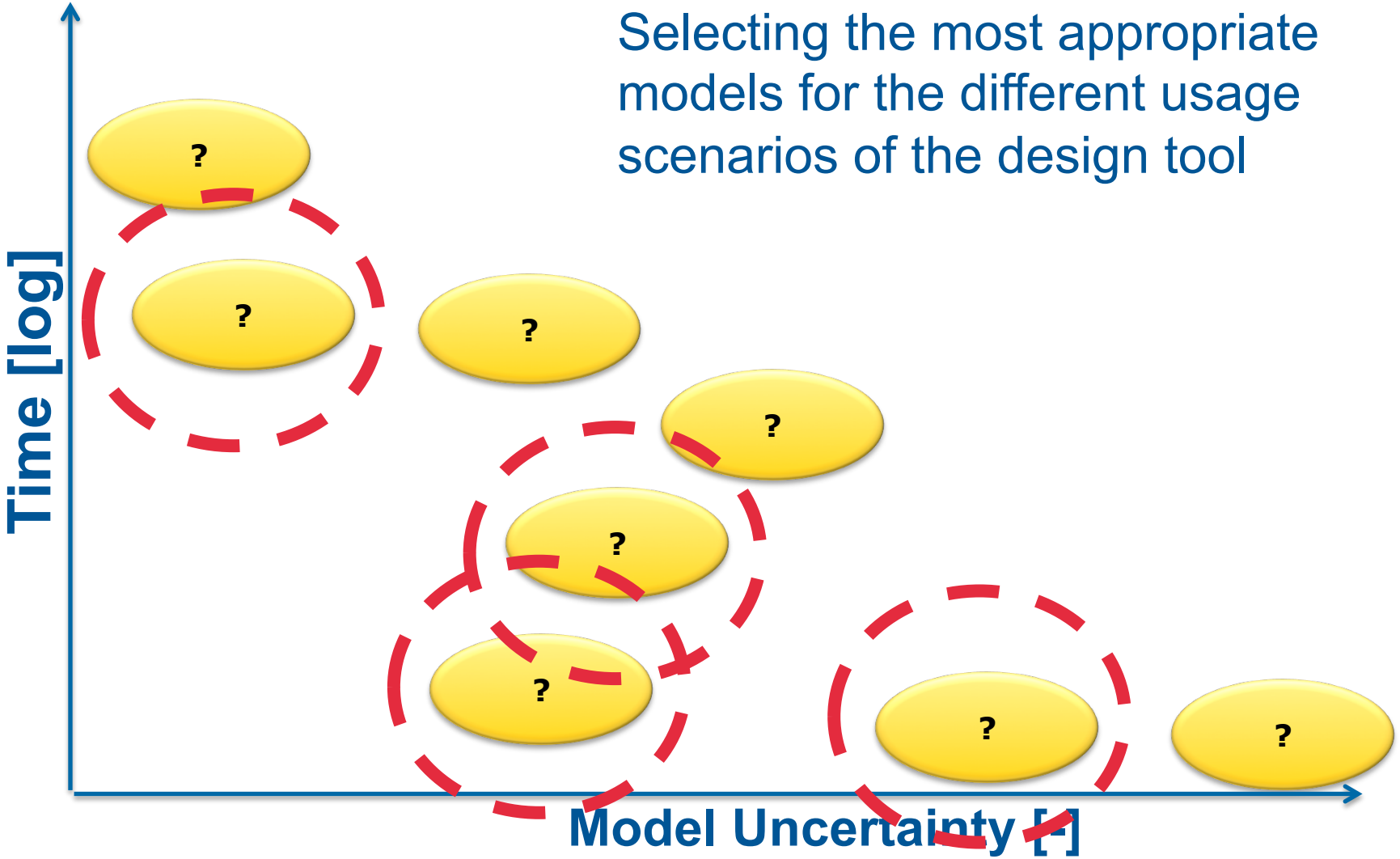
Enginneering

Simplified CFD

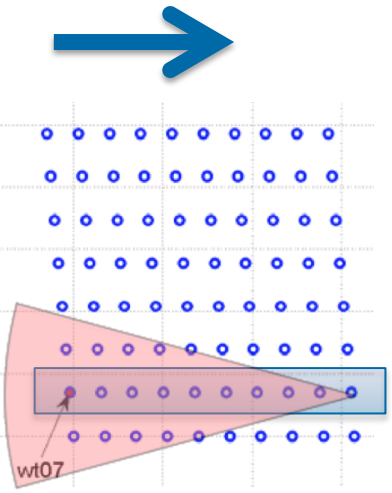
Full CFD

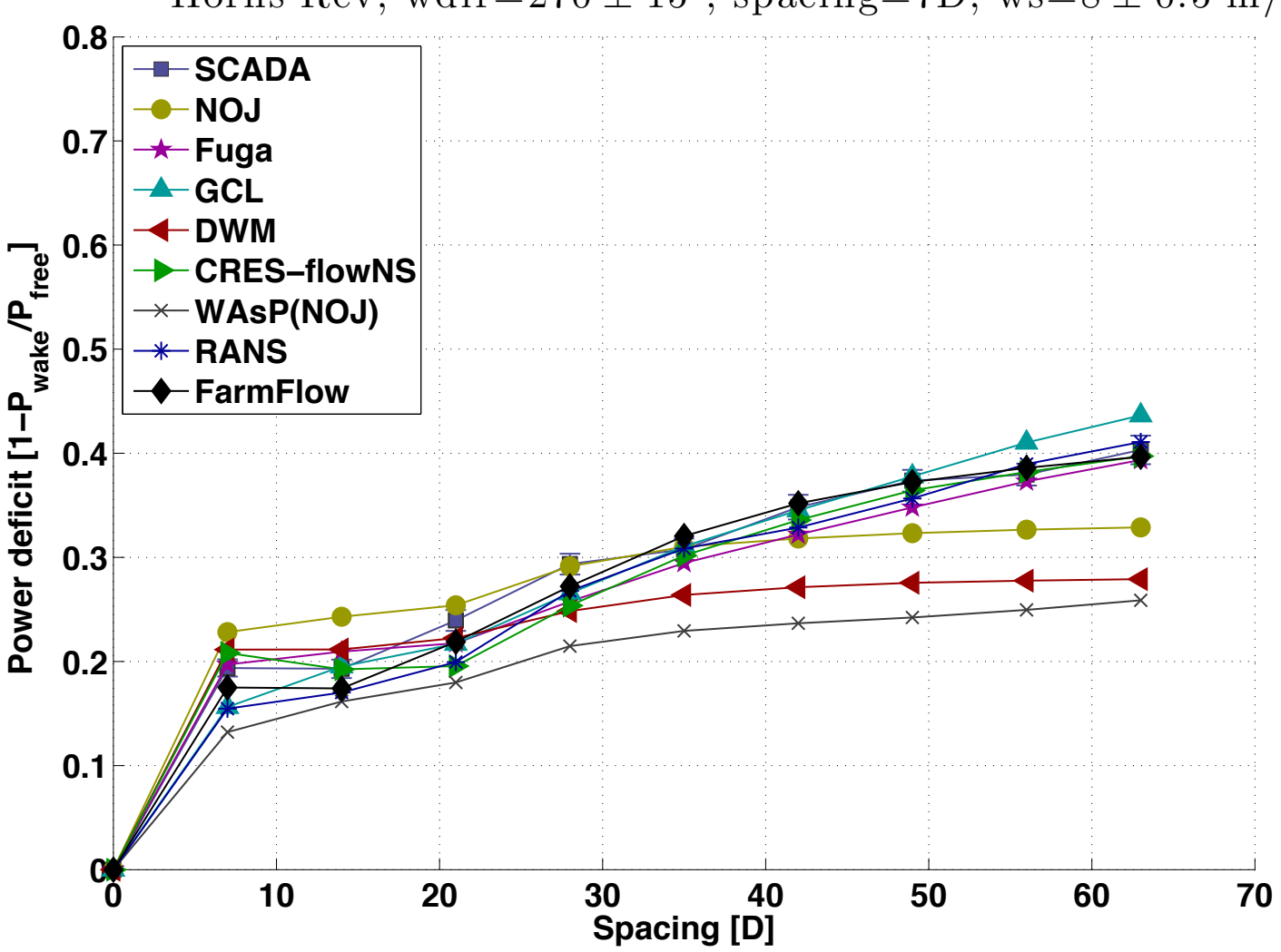
Benchmarking purpose

Selecting the most appropriate models for the different usage scenarios of the design tool

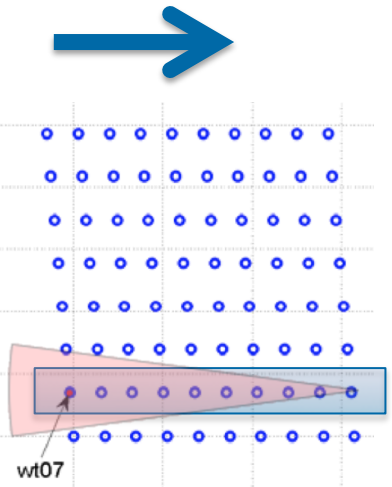


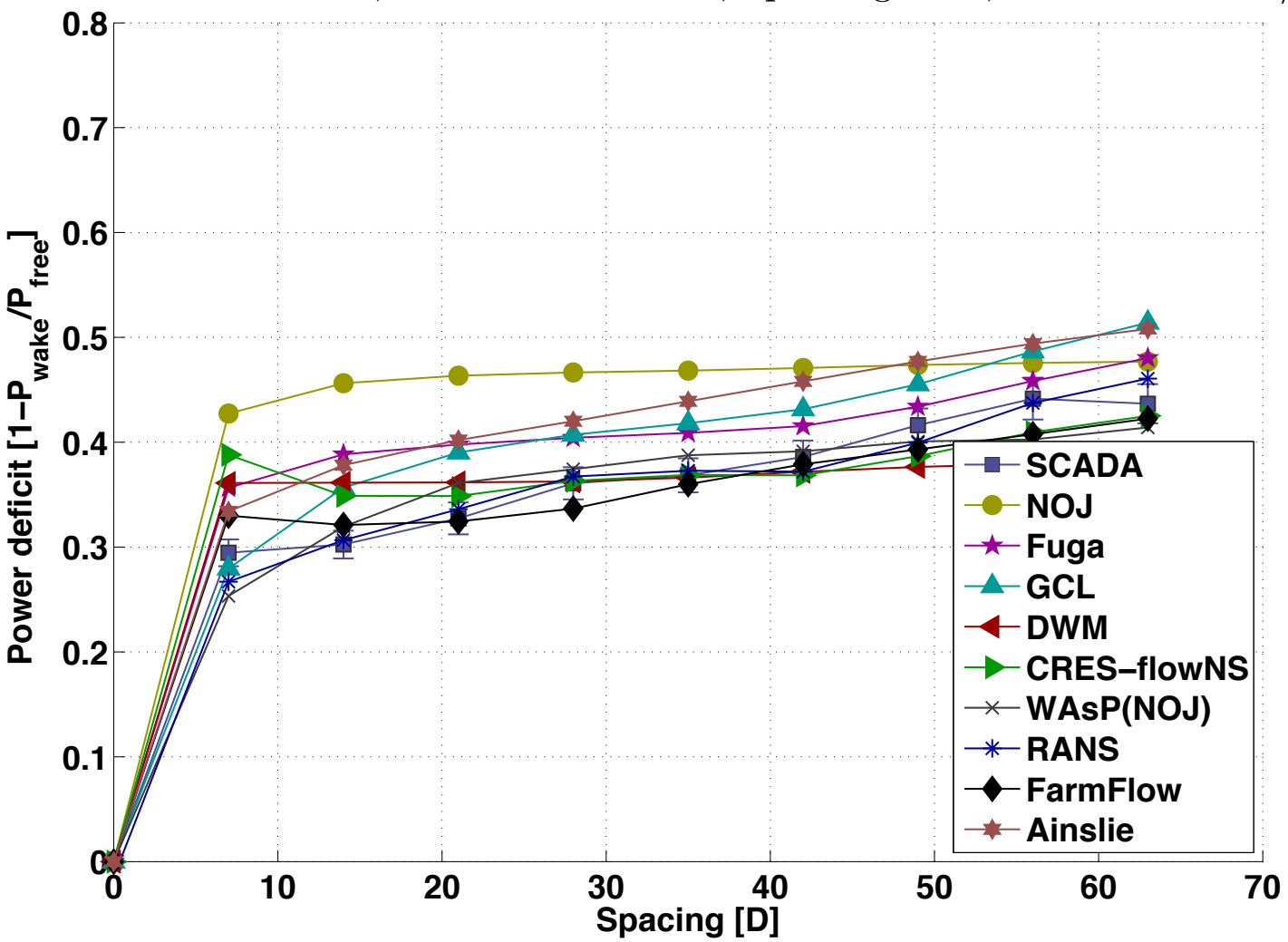
Benchmark preliminary results: Power deficit along a line of turbines





Benchmark preliminary results: Power deficit along a line of turbines





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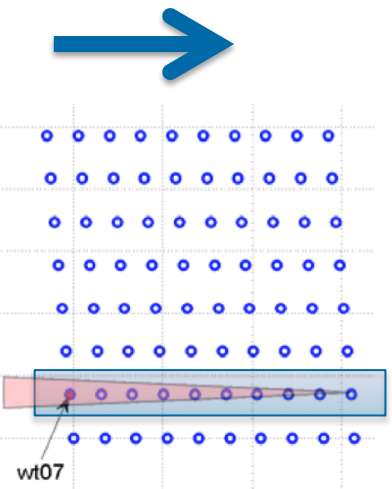
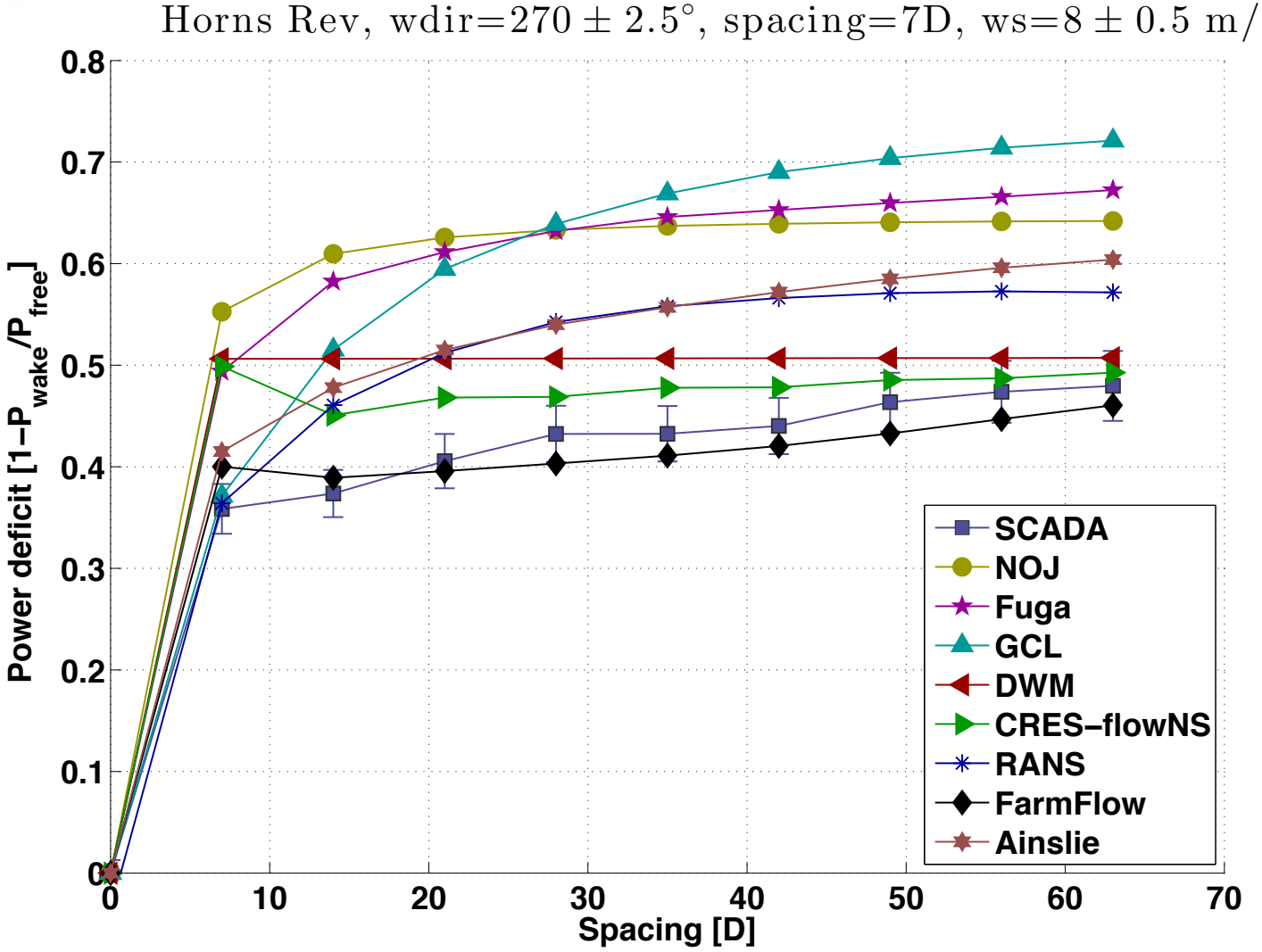
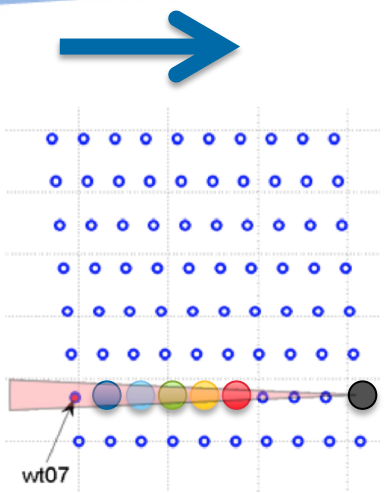
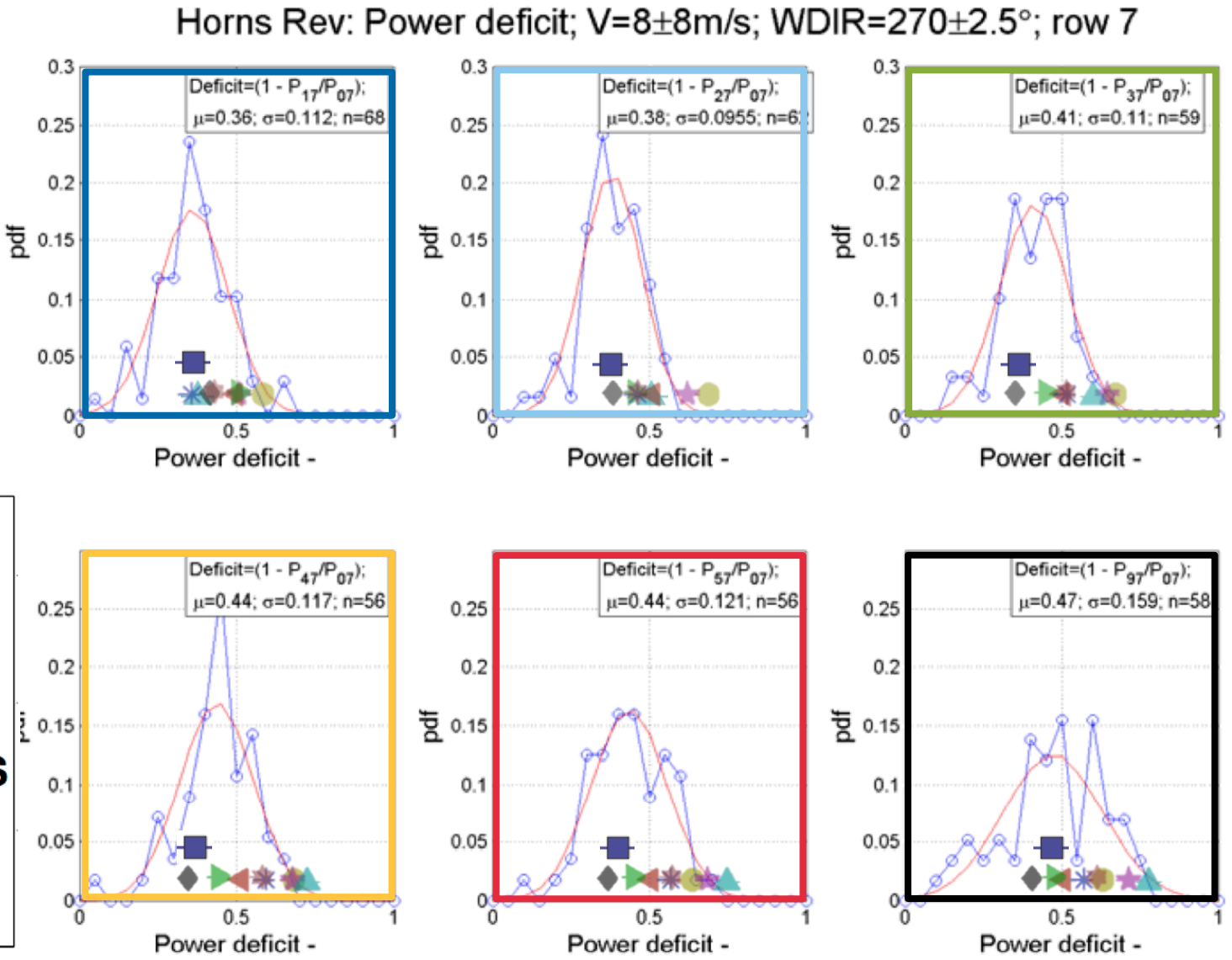


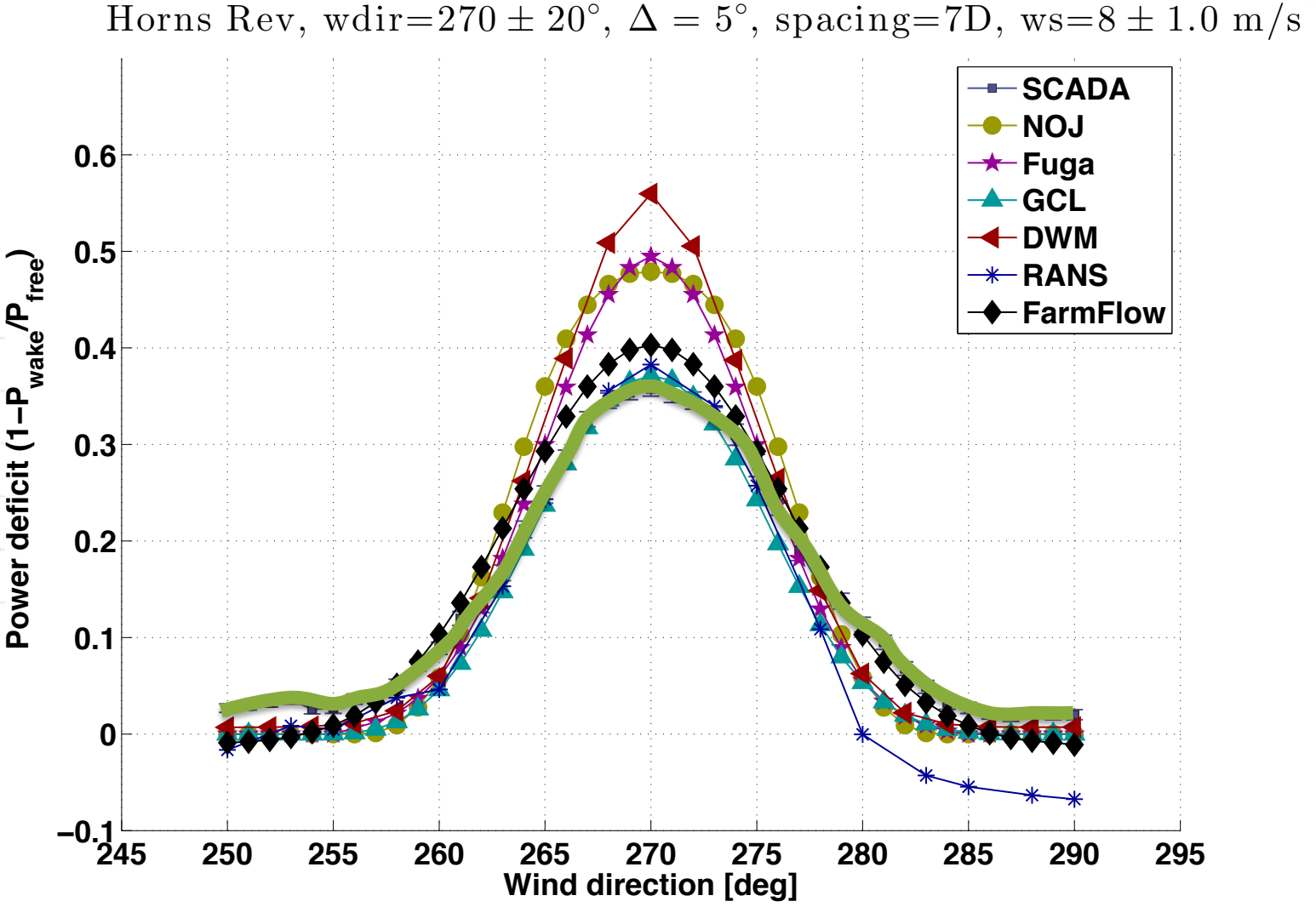


Challenge: Very noisy datasets!

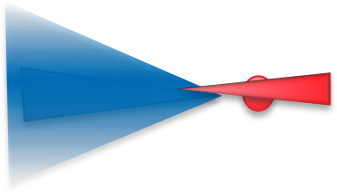


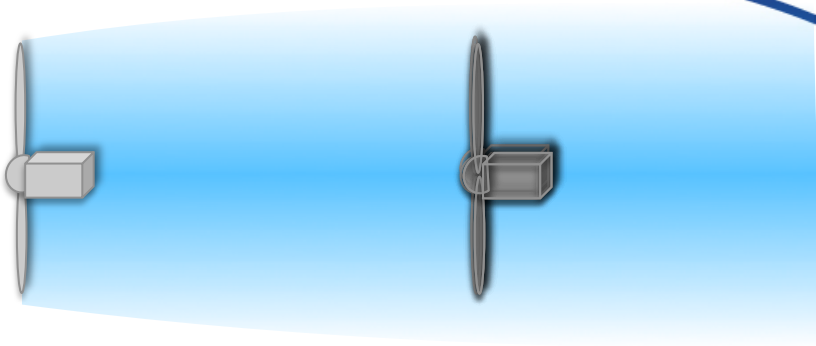


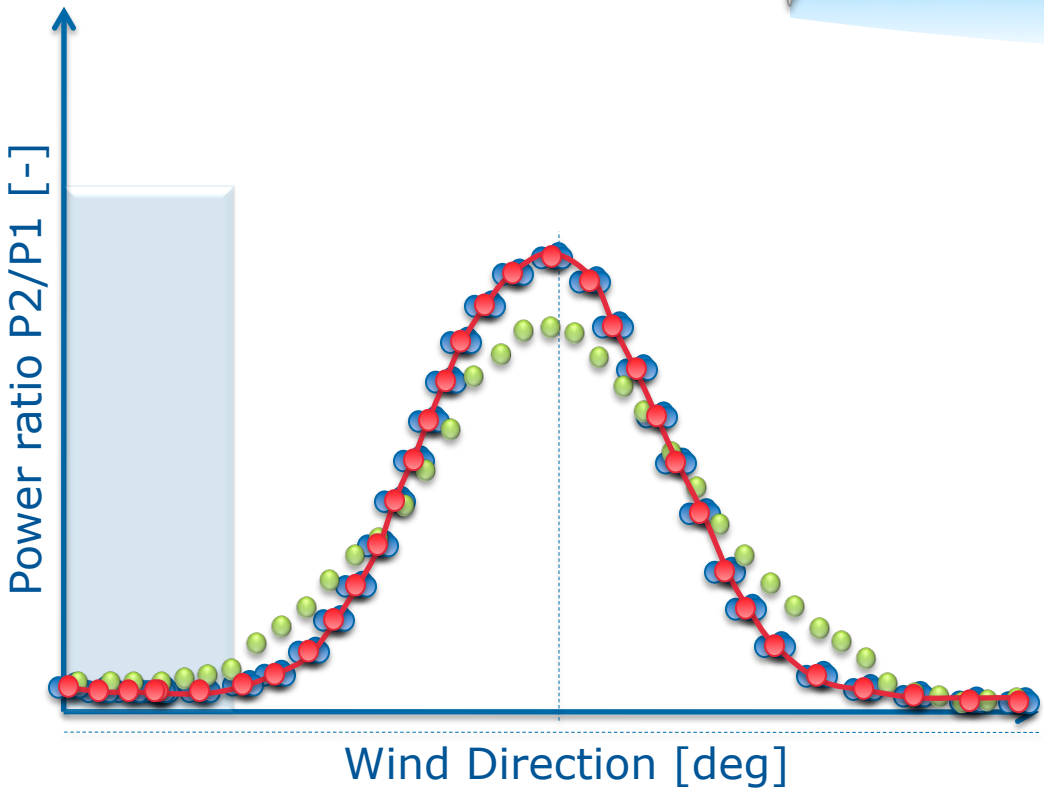
Benchmark preliminary results: Power deficit distribution vs wind direction



The effect of wind direction uncertainty on wind farm wake measurement



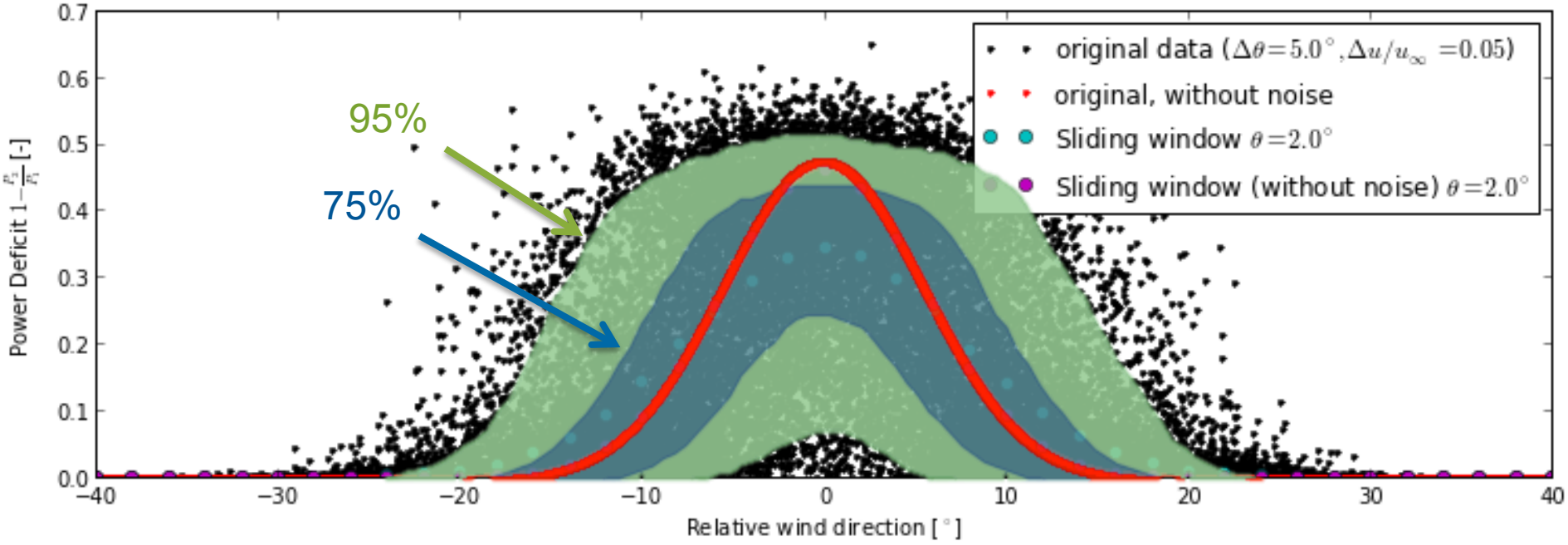




Measurements

Models

Artificial dataset demonstration



- Generate a random error in wind direction (5o) and power deficit (0.05)
- Apply the sliding window averaging (2o)
- Compare with sliding window on original
- Characterize envelop for 75% and 95% of the data

Sources of wind direction uncertainty

- Random/temporal bias from the measurement device
  - Yaw misalignment (when yaw sensor is used to measure direction)
  - Time drift of the calibration
  - Birds?
  - Temperature?
- Atmospheric turbulence
  - Small scale turbulence (sub 10-minute)
    - This *should* be accounted by the models
  - Large scale turbulence (i.e. wind directional trends, over 10-minute)
- Wind direction coherence
  - Spatial variability of the wind direction
  - Different time-control volume averaging

Proposed method for modelling uncertainty

- M. Gaumont et al. Wind Energy 2013
- M. Gaumont MSc thesis, DTU 2012

RESEARCH ARTICLE

Evaluation of the wind direction uncertainty and its impact on wake modelling at the Horns Rev offshore wind farm

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[2]Department of Mechanical Engineering, Technical University of Denmark, 2800 Kgs Lyngby, Denmark

ABSTRACT

Quantifying accurately wind turbine wakes is a key aspect of wind farm economics in large wind farms. This paper introduces a new post-processing method to address the wind direction uncertainty present in the dataset of the Horns Rev offshore wind farm. This new technique replaces the traditional simulation performed with the 10-minute average wind direction by a weighted average of several simulations covering a wide span of directions. The weights are based on a normal distribution to account for the uncertainty from the yaw misalignment of the reference turbine, the spatial variability of the wind direction inside the wind farm and the variability of the wind direction within the averaging period. The results show that the technique corrects the predictions of the models when the simulations and data are averaged over narrow wind direction sectors. In addition, the agreement of the simulations is improved for the shape of the power deficit in a single wake situation. The robustness of the method is verified using the Jensen model, the Larsen model and Fuga, which are three different engineering wake models. The results indicate that the discrepancies between the traditional numerical simulations and power production data for narrow wind direction sectors are not caused by an inherent inaccuracy of the current wake models, but rather by the large wind direction uncertainty included in the dataset. The technique can potentially improve wind farm control algorithms and layout optimization because both applications require accurate wake predictions for narrow wind direction sectors.

KEYWORDS

wind farms; offshore; wakes; power deficits; wind direction

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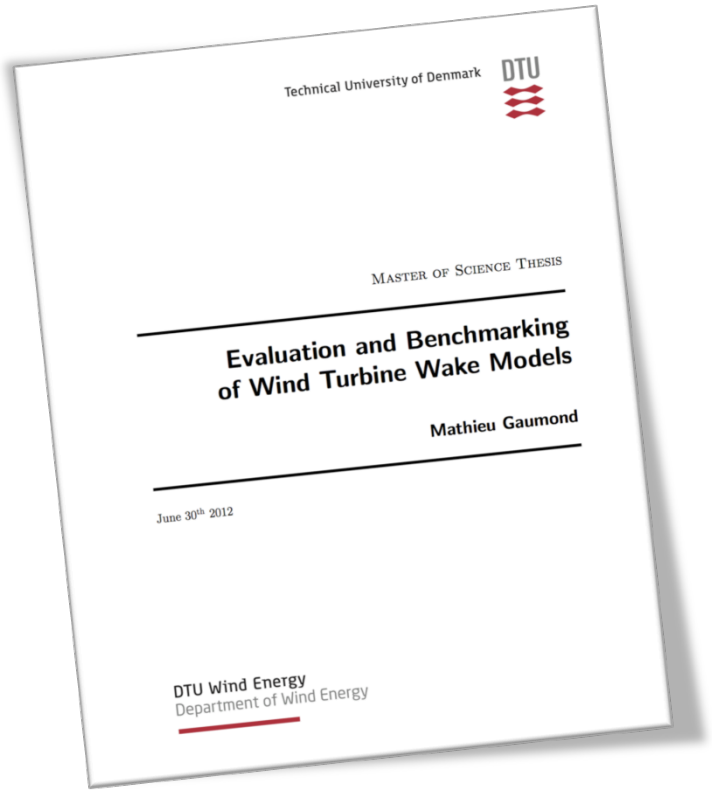
DOI: 10.1002/we



Technical University of Denmark

DTU

MASTER OF SCIENCE THESIS

Evaluation and Benchmarking of Wind Turbine Wake Models

Mathieu Gaumond

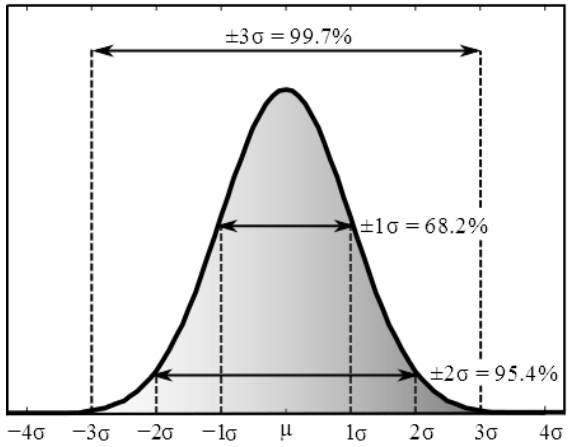
June 30th 2012

DTU Wind Energy
Department of Wind Energy

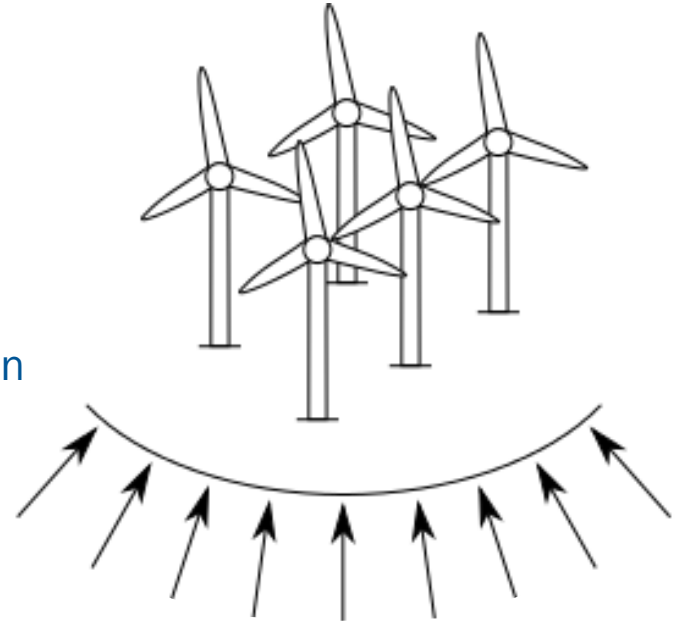
Wind Direction Uncertainty

The proposed method

- **Step 1:** Run simulations with fixed and homogeneous wind direction
- **Step 2:** Apply a weighted average based on the probability function of a normal distribution on the interval ±3 $\sigma \downarrow a$



- **Step 3:** Apply a linear average to reproduce the data post-processing



Wind Direction Uncertainty

- Overview of the proposed post-processing technique

	270 ± 2.5°	270 ± 15°
Power Data	64.7%	73.9%
NOJ, Baseline	-20.9%	+0.4%
GCL, Baseline	-20.9%	-0.1%
Fuga, Baseline	-21.7%	-0.3%
NOJ, σ=3.5°	-11.6%	+0.0%
GCL, σ=3.5°	-8.2%	-0.2%
Fuga, σ=3.5°	-8.5%	-0.2%
NOJ, row-specific	-3.1%	+0.1%
GCL, row-specific	-0.7%	-0.2%
Fuga, row-specific	-0.8%	-0.2%

Future work: How to benchmark the models?

- Processing the wind farm data in another way
  - Good ideas are welcome!
- Post-processing the models to account for wind direction uncertainty
  - Uncertainty propagation to the outputs
- Additional benchmarks within EERA-DTOC:
  - Lillgrund (in collaboration with WakeBench)
  - Rødsand II

Conclusion

- EERA-DTOC is designing a tool for planning offshore wind farm clusters
- The wind farm models seem to over predict the wake deficit, but it might be an artifact of the wind direction uncertainty
- Don’t tune your model to match the 2.5^{o} bins!
- Modelling the uncertainty gives lower discrepancy
- We need more datasets with higher quality wind direction sensors to move forwards

Thank you very much for your attention

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