X-Wakes

Measurements and Modelling of Large-Scale Wind Farm Effects in the German Bight

Martin Dörenkämper, Fraunhofer IWES Oldenburg

and the X-Wakes Consortium

Supported by:

Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

Monday, 26.06.2023 | Final Public Project Workshop

Fraunhofer IWES

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Agenda

Morning

- 10:10-10:30 X-Wakes – Project Overview
- 10:30-10:50 Bughsin' Djath (Hereon) – Study of Coastal Effects Using Spaceborne Synthetic Aperture Radar (SAR)
- 11:10-11:30 Andreas Platis (University of Tübingen) - Uncrewed aircraft systems for offshore wind energy research
- 11:30-11:50 Beatriz Canadillas (UL, TU Braunschweig) - Offshore wind farm cluster wakes as observed by long-range-scanning wind lidar measurements and mesoscale modeling
- 11:50-12:10 Astrid Lampert (TU Braunschweig) - Coastal influence on wind speed in the North Sea based on wind lidar, airborne measurements and ERA5 data
- 12:10-12:30 J. Paulsen & J. Schneemann (ForWind OL) – Long-range Lidar to investigate low level jets and cluster wakes

Agenda

Afternoon

- 13:00-13:20 Gabriele Centurelli (ForWind) - Large-eddy simulations of wind farm clusters for the further development of industry models
- 13:20-13:50 Richard Foreman (UL) - Cumulative Interactions between the Global Blockage and Wake Effects as Observed by an Engineering Model and Large-Eddy Simulations.
- 13:50-14:10 Kjell zum Berge (Tübingen) - Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight
- 14:10-14:30 Lukas Vollmer (Fraunhofer IWES) - Multi-fidelity wake model benchmark of external wake effects from the X-Wakes research project
- 14:30-14:50 Martin Dörenkämper (Fraunhofer IWES) – Modelling the future wind farm expansion - an application of X-Wakes results for area development planning

Participation

Workshop Rules

- Presentations will be 12-15 min + 5 min discussion

- Please ask questions directly in the chat and throughout the workshop

- Feedback to the workshop is very welcome. Please use chat or write us an e-mail:

  x-wakes-workshop@iwes.Fraunhofer.de

X-Wakes: Project Introduction

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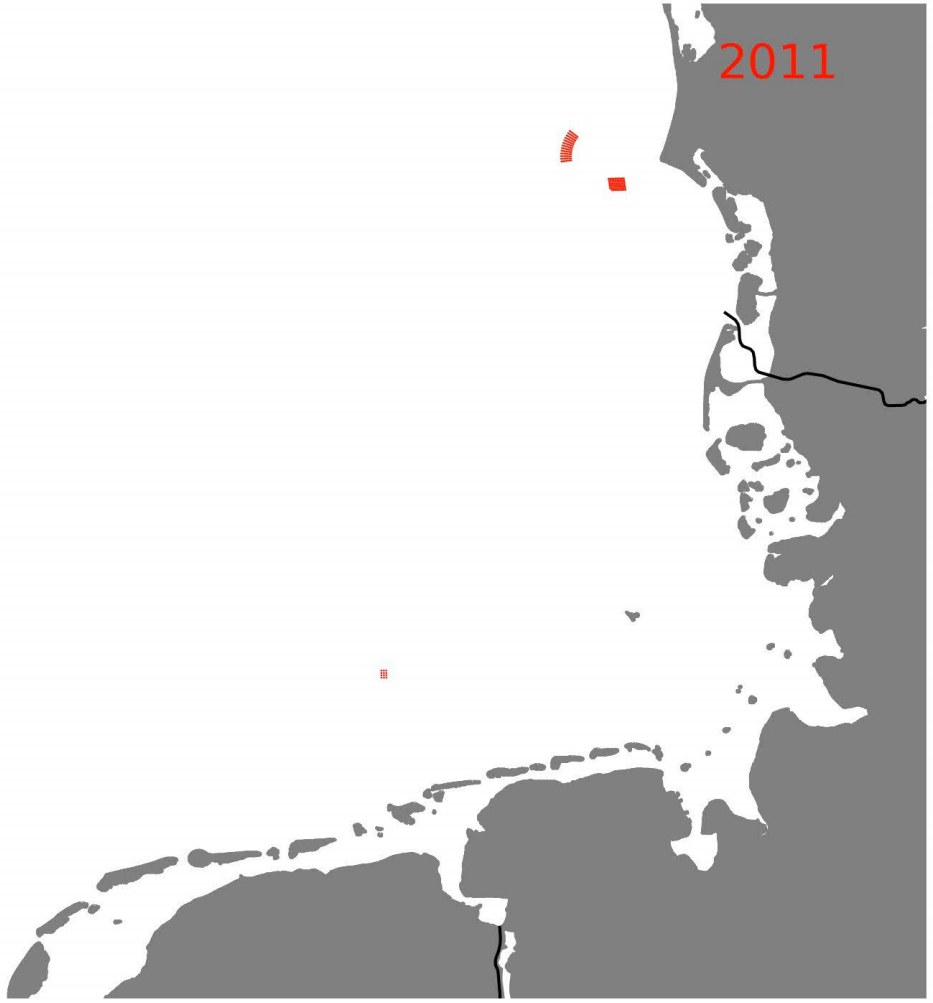
Motivation

Offshore Wind Energy in the German Bight

- Germany currently has second largest capacity of offshore wind farms connected to the grid

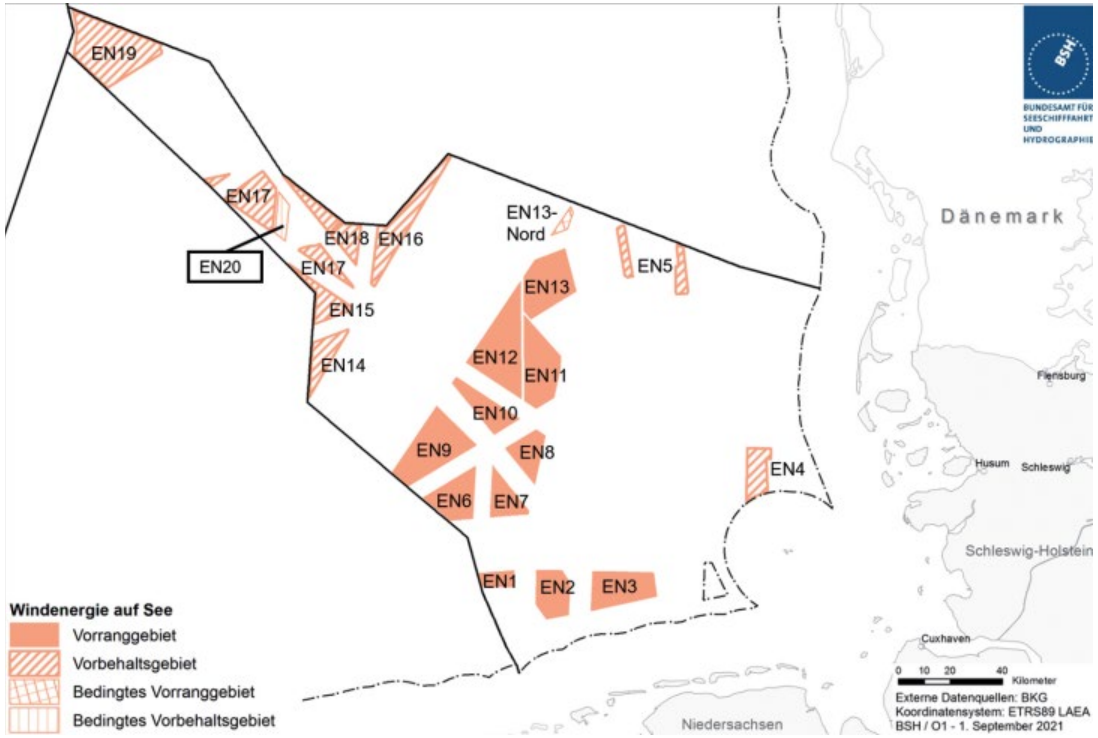
- Currently 7.7 GW out of which 6 GW are located in the German Bight



Motivation

Offshore Wind Energy in the German Bight

- Germany currently has second largest capacity of offshore wind farms connected to the grid
- Currently 7.7 GW out of which 6 GW are located in the German Bight
- Current long-term goals of the German government:
  - 2030 - 30 GW installed capacity
  - 2035 - 40 GW installed capacity
  - 2045 – 70 GW installed capacity
- One of the most densely areas of offshore wind globally

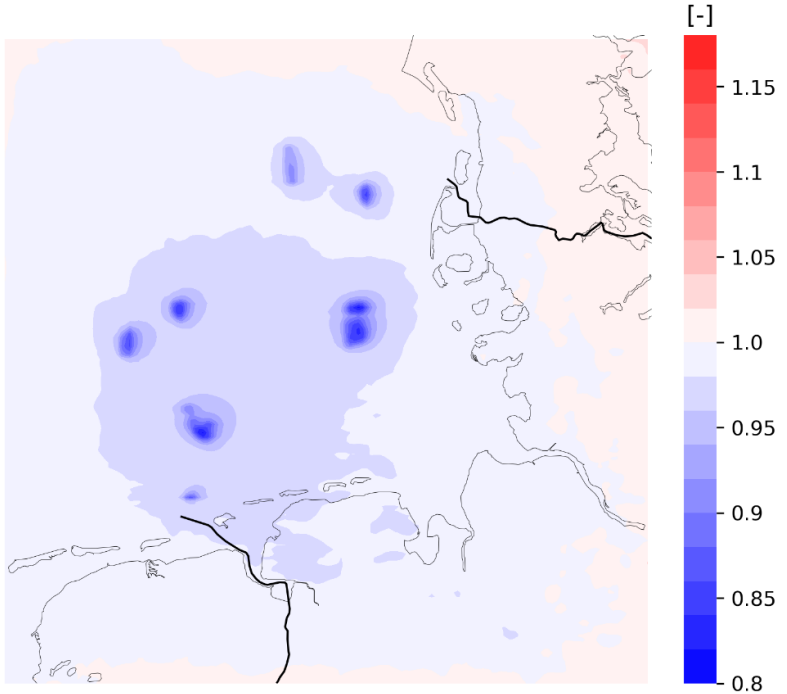


[source: BSH.de]

Past Cluster Wake Research

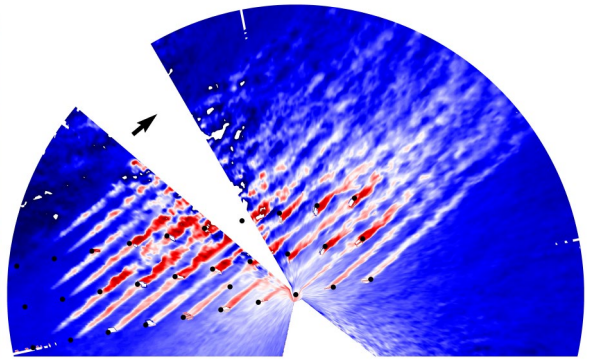
GW-Wakes (2012-2017)

- **Methods:**
  - Scanning LiDAR measurements in a small (12 WT) and a larger (30 WT) offshore wind farm
  - Mesoscale and LES modelling of wind farm wake effects, development of industry methods
  - SCADA data analysis



[Kühn et al., 2019; Vollmer et al.]

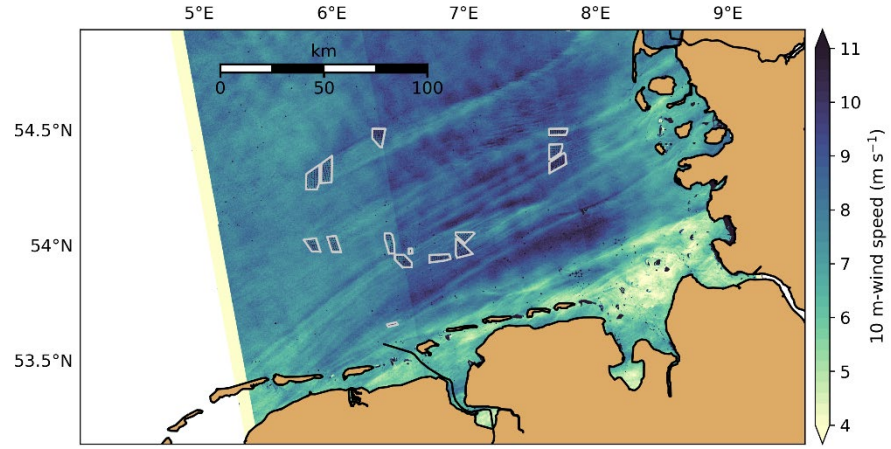
- **Key results:**
  - Small wind farms: wakes not grown together, after about 5 turbines in a row → a wind farm wake rather than single wakes
  - Mesoscale scenarios: strong reduction of the wind resource even for the expansion plans for 2025, is that true?



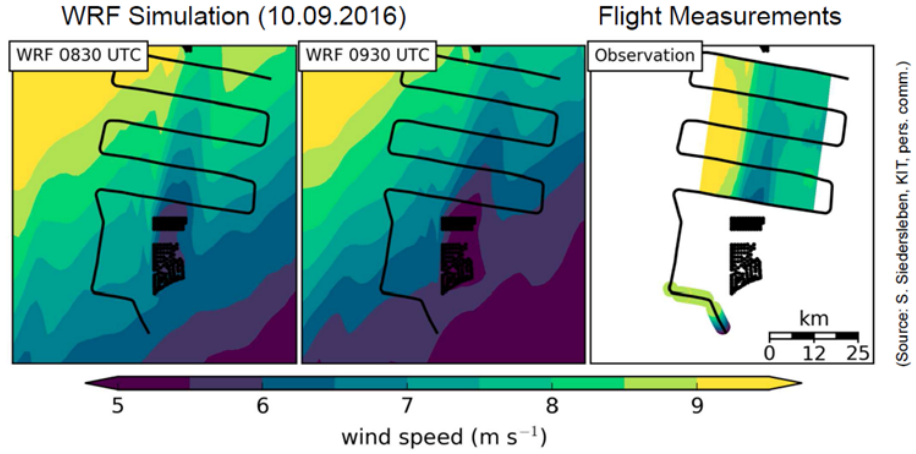
Past Large-Scale Wake Research

WIPAFF (2015-2019)

- **Methods:**
  - Manned aircraft and measurements
  - Profiling lidar and satellite data analysis
  - Mesoscale and industry modelling and validation of large-scale wake effects



- **Key results:**
  - Wake lengths of up to 100 km measured in stable conditions
  - Mesoscale models are capable in correctly simulating wake effects but have issues with coastal effects
  - Industry models need to be tuned to represent stable conditions correctly



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Goals of the Project

- Research Question: How do large wake effects and their interaction with the atmosphere affect the real-life wind farm operation?

- Quantification of the impact of wakes and other large-scale effects on yields:
  - Impact of **Coastal Effects** on Wind Farm Wakes
  - Interaction of **Single Wind Farm Clusters** with the Marine Atmospheric Boundary Layer
  - Interaction of **Several Wind Farm Clusters** with each others and the Marine Boundary Layer

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The Project

- Budget: 4.3 Million Euro public funding by Ministry of Economic Affairs and Energy (BMWi)
- Duration: 01.11.2019 – 30.04.2023
- Coordination: Fraunhofer IWES (modelling) and TU Braunschweig (measurements)
- Funded partners: Research institutions / universities of former projects GW-Wakes and WIPAFF, UL International
- Associated partners: seven wind farm operators and the federal maritime and hydrographic agency (BSH)

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Measurement & Modelling Activities

Measurements:

- Flight data (2 manned research aircrafts & UAV)
- Satellite Data Analysis (Sentinel-1A/B)
- Stationary measurements in windward, center and leeward of wind farm clusters with scanning and profiling lidars
- SCADA data analysis

Modelling:

- Engineering Models (Commercial and Research)
- Large-Eddy-Simulations [PALM]
- Mesoscale Modelling [WRF]

FOXES
Farm Optimization and eXtended yield Evaluation Software
Fraunhofer IWES

WRF
Weather Research & Forecasting

Openwind
Most advanced software for creating & optimizing turbine layouts

palm

➔ **Improved understanding of atmospheric processes and model validation for scientific and industrial applications**

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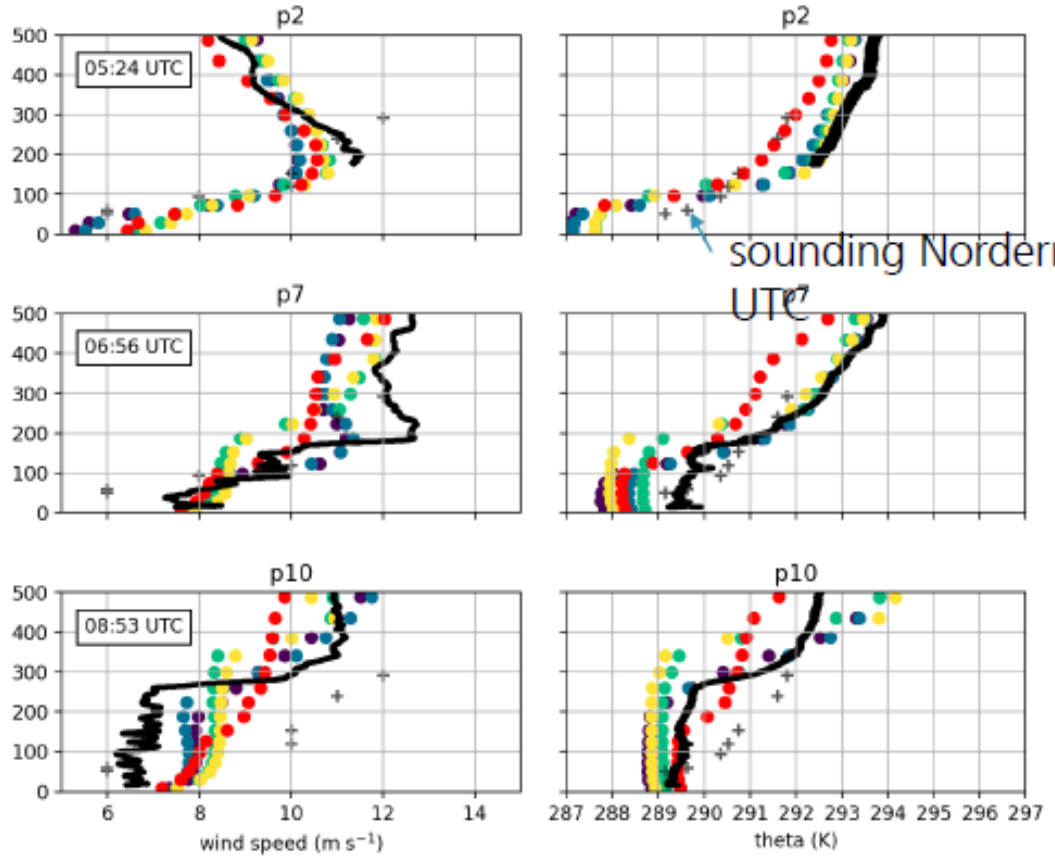
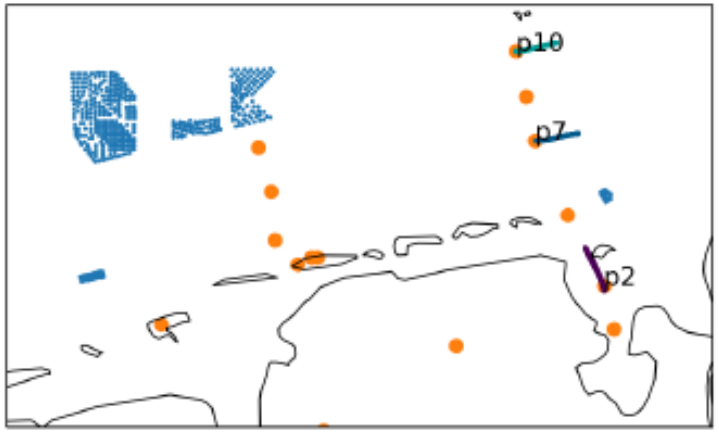
Results – Mesoscale Modelling of Coastal Effects





- SST (291K) is warmer than the advected air
- Stable stratification from the onshore night time inversion

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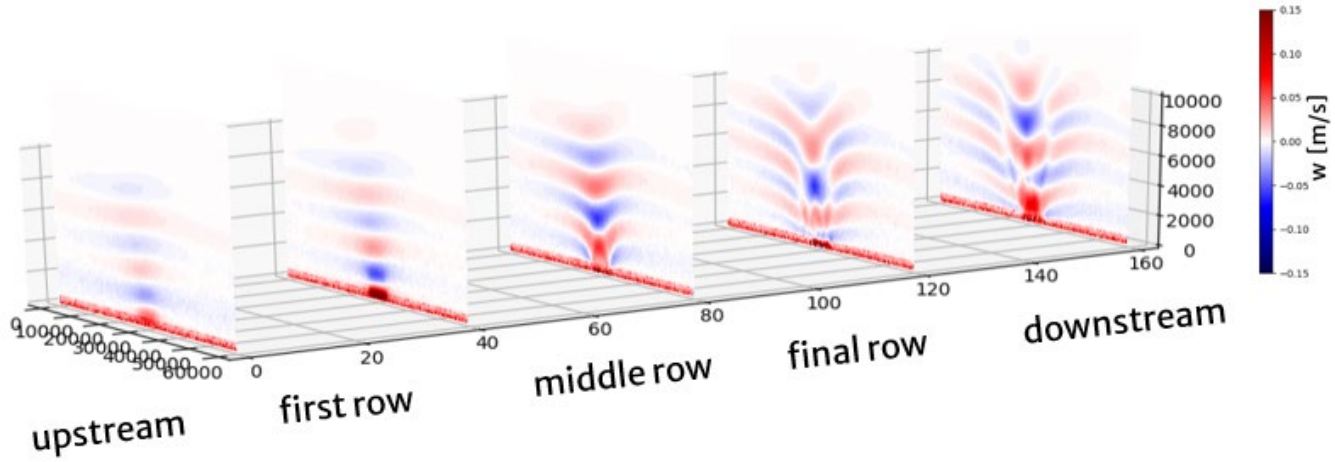
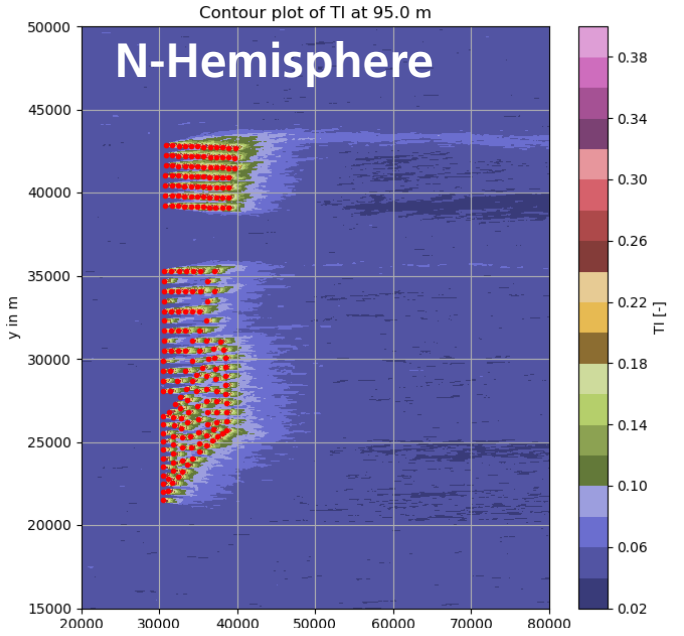
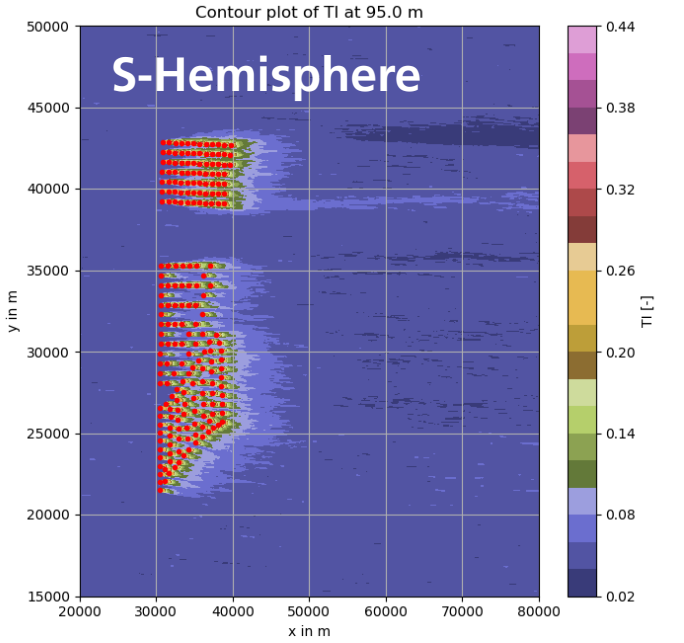
Results – Cluster Wake and Blockage Modelling

- Origin of streaks at wind farm edges investigated: Coriolis force is key ingredient

- Large Eddy-Simulations of wind farm clusters used for development of fast engineering model, e.g. for global blockage modelling







Acknowledgements

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Questions?