



# Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight



Kjell zum Berge – University of Tübingen

Gabriele Centurelli - ForWind - Center for Wind Energy Research - University of Oldenburg

Martin Dörenkämper - Fraunhofer IWES

Supported by:



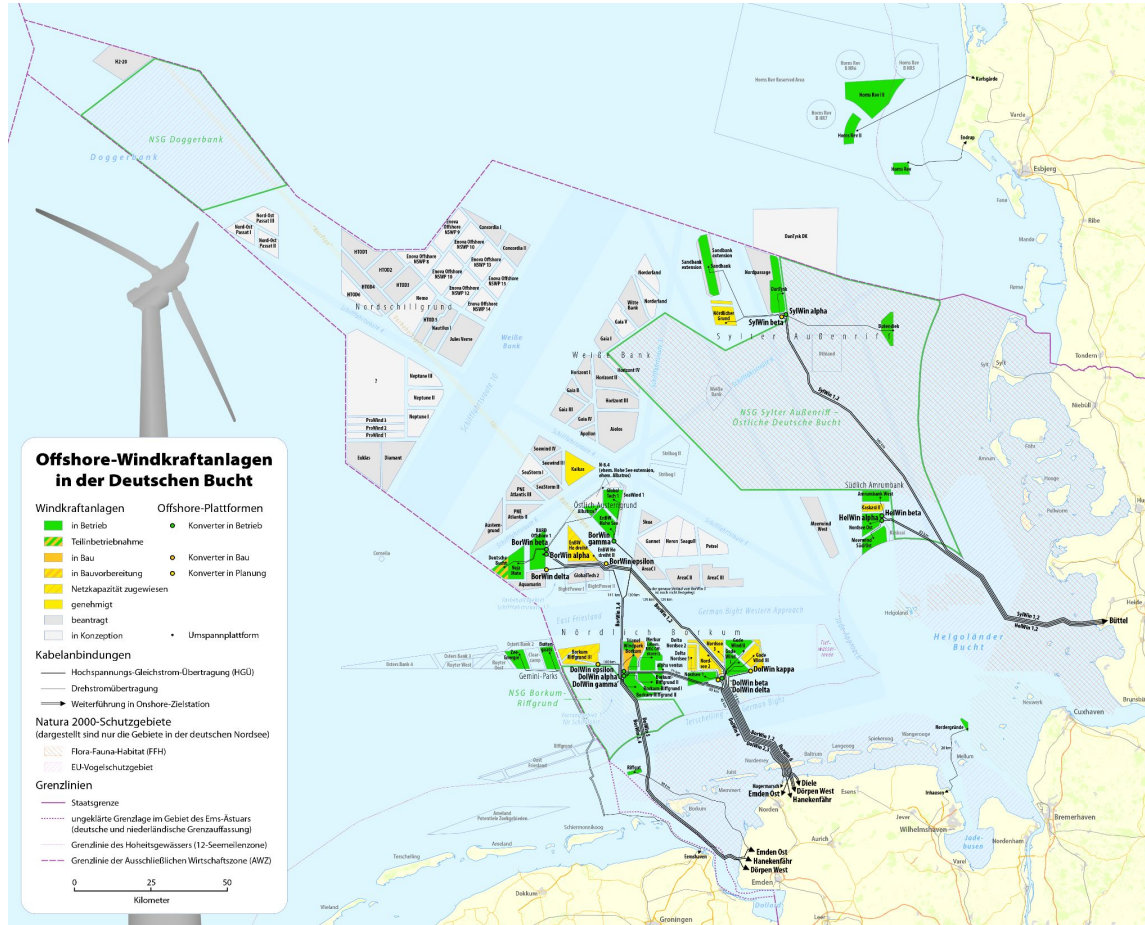
on the basis of a decision  
by the German Bundestag

[X-Wakes Workshop | 26.06.2023](#)



# Overview

## Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight



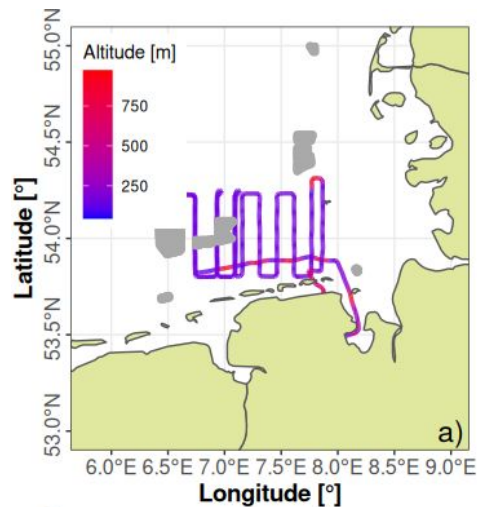
- The increasing demand for renewable energy will increase the amount of wind turbines/farms/clusters in the German Bight
- This leads to less space between the farms resulting in more wakes impacting downstream farms
- For the use of Engineering Models (EM) to estimate the yield of wind farms, the capabilities to simulate (long) wakes are beneficial



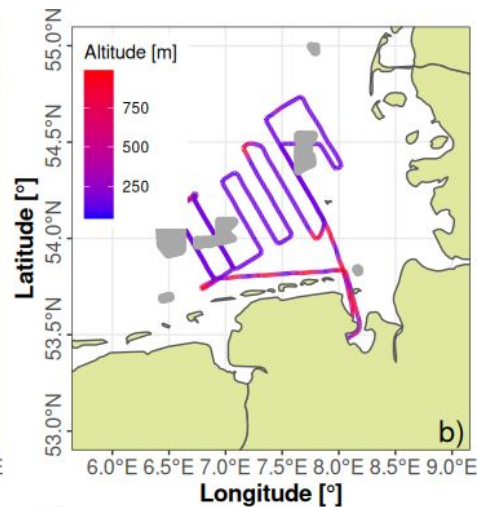
# Flight Data

Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight

14.07.2020

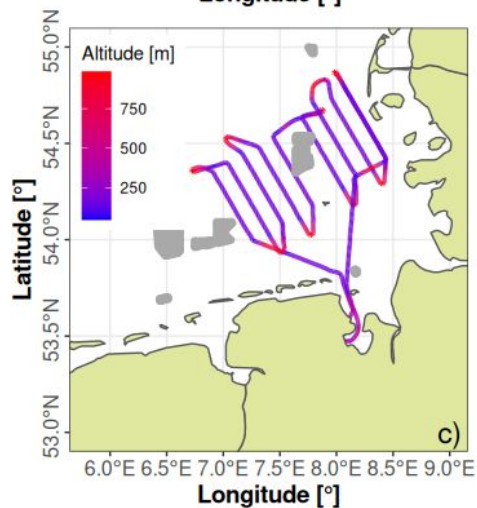


23.07.2020

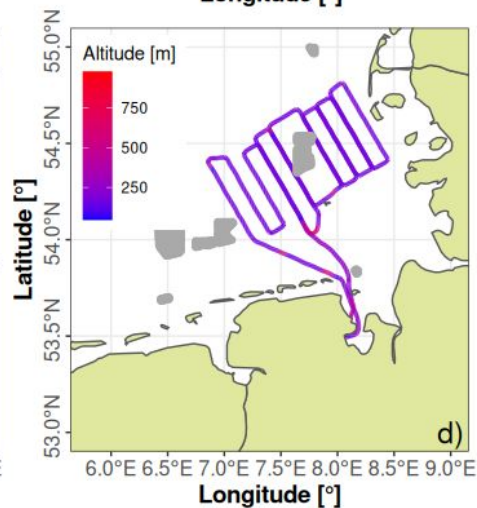


Date	Wind Speed [m/s]	Wind Dir [°]
14.07.2020	7	270
23.07.2020	10	225
27.07.2021	10	240
30.07.2021	10	240

27.07.2021



30.07.2021



# Flight Data

Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight

Date	Wind Speed [m/s]		Wind Direction [°]	
	SCADA	Flight Data	SCADA	Flight Data
14.07.2020	6.8	7.4	268.6	266.4
23.07.2020	9.2	9.9	233.0	221.3
27.07.2021	6.5	10.2	233.9	235.5
30.07.2021	9.4	10.7	238.1	238.1

- SCADA data: Mean of first row depending on wind direction
- Flight data: Mean of outer 10% of each flight leg

Date	Lapse Rate $\leq$ Hub Height	Lapse Rate $>$ Hub Height	Thermal Stratification
14.07.2020	0.18	0.23	Stable
23.07.2020	0.31	0.14	Stable
27.07.2021	0.43	0.31	Stable
30.07.2021	0.14	0.27	Stable

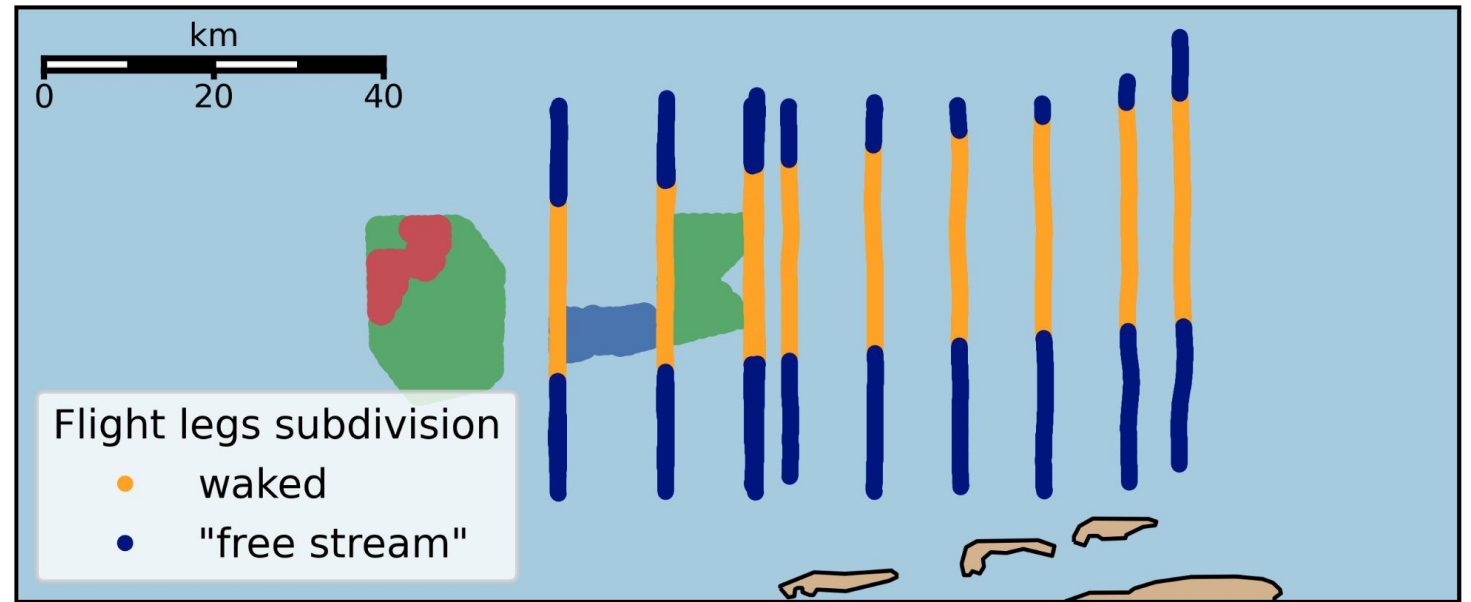
- $\gamma < - 0.04$ : unstable
- $- 0.04 \geq \gamma \geq 0.04$ : near-neutral
- $\gamma > 0.04$ : stable

Platis et al. (2021)

# Engineering model setup: Inflow

Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight

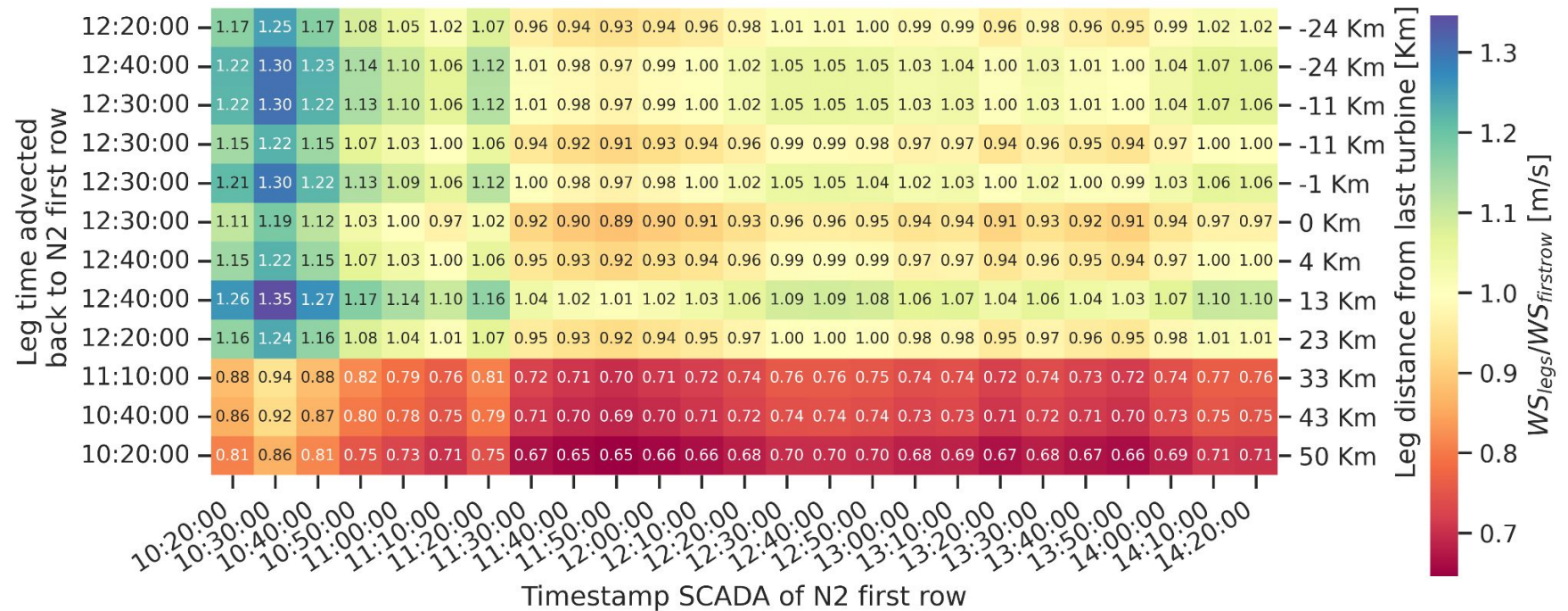
- Free stream velocity identified on the legs  
-> Leg wise comparison
- Assumption on the lateral extent of the cluster wake
- No shear at the sea surface, velocity homogeneous with height. Comparisons only at hub height



# Engineering model setup: turbine status

Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight

- SCADA in 10 min average
- All turbines considered, a curtailment coefficient between 0 and 1 applies, to partialize or to shut down turbines
- The time at which SCADA are considered for one leg is chosen advecting the leg back in the middle of the farm

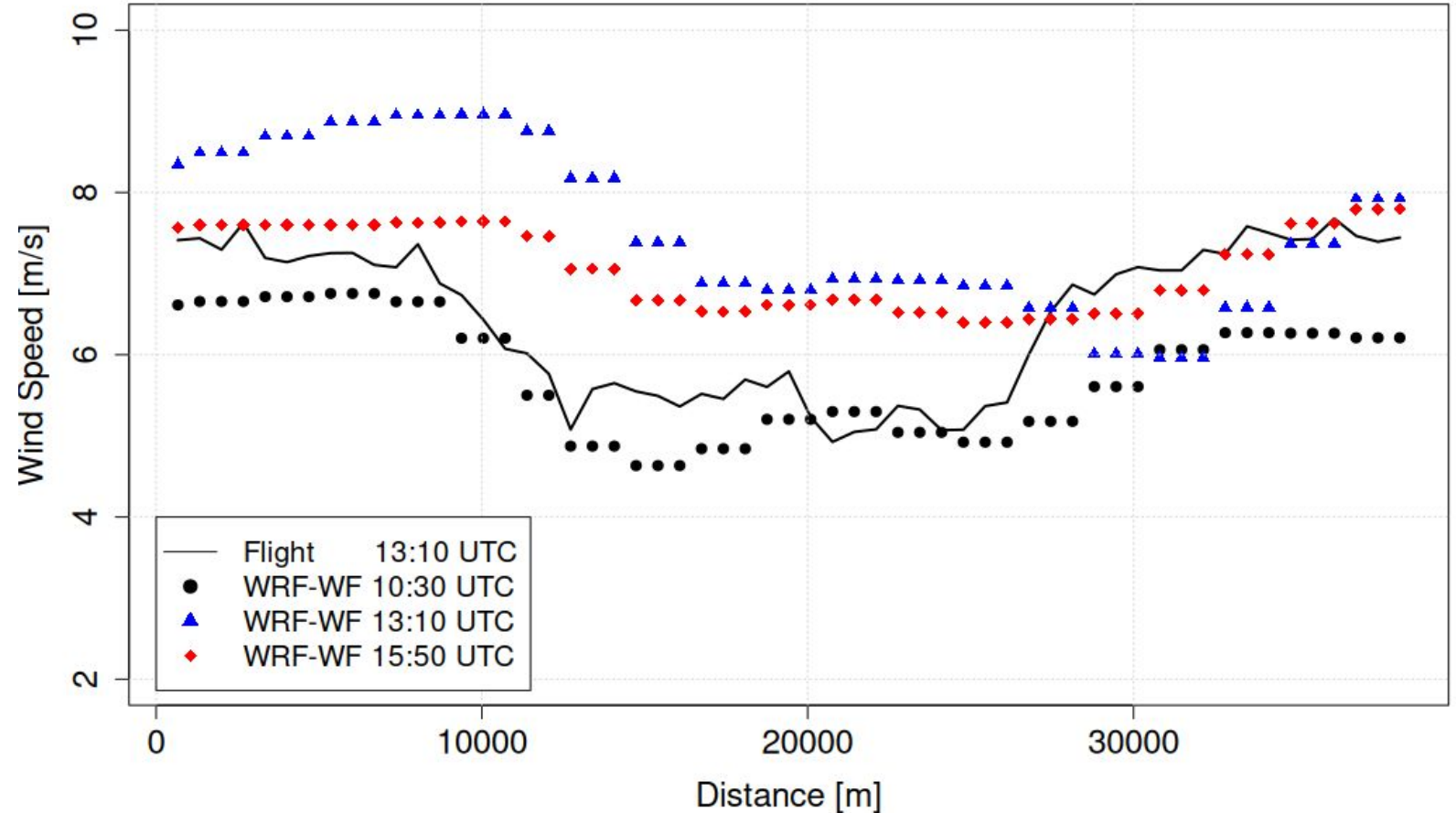




# WRF Timeshift

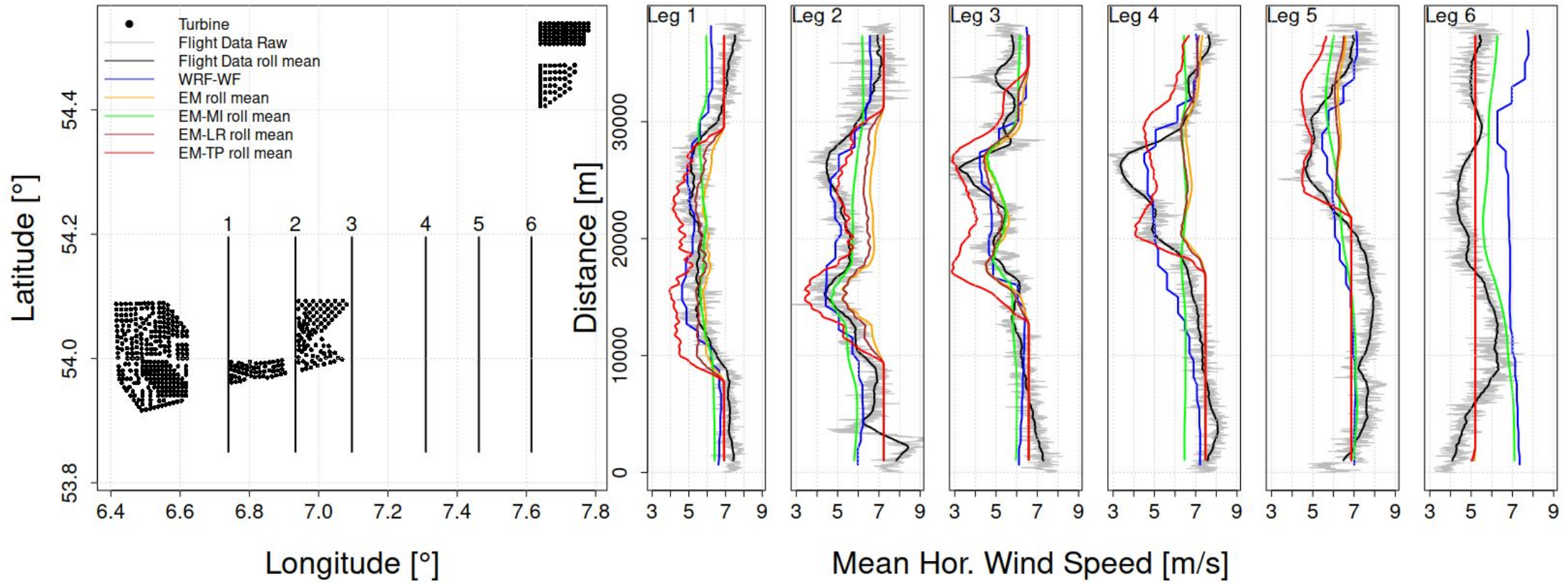
## Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight

- Based on the sensitivity studies in the framework of the NEWA project
- The model's boundary conditions for the atmospheric variables were prescribed by the ERA5 dataset and with OSTIA dataset
- Wind turbines were parameterized with the Fitch wind farm parametrization
- Driven every 6 hours



# Results – 14.07.2020

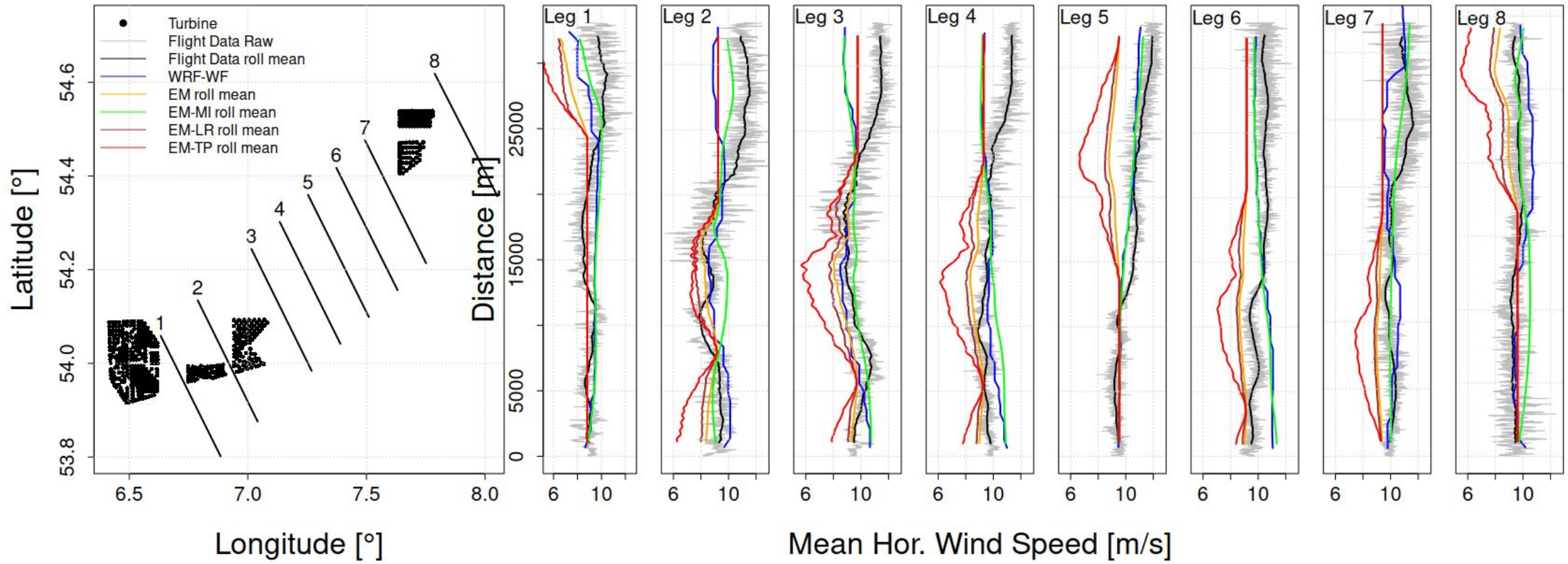
Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight





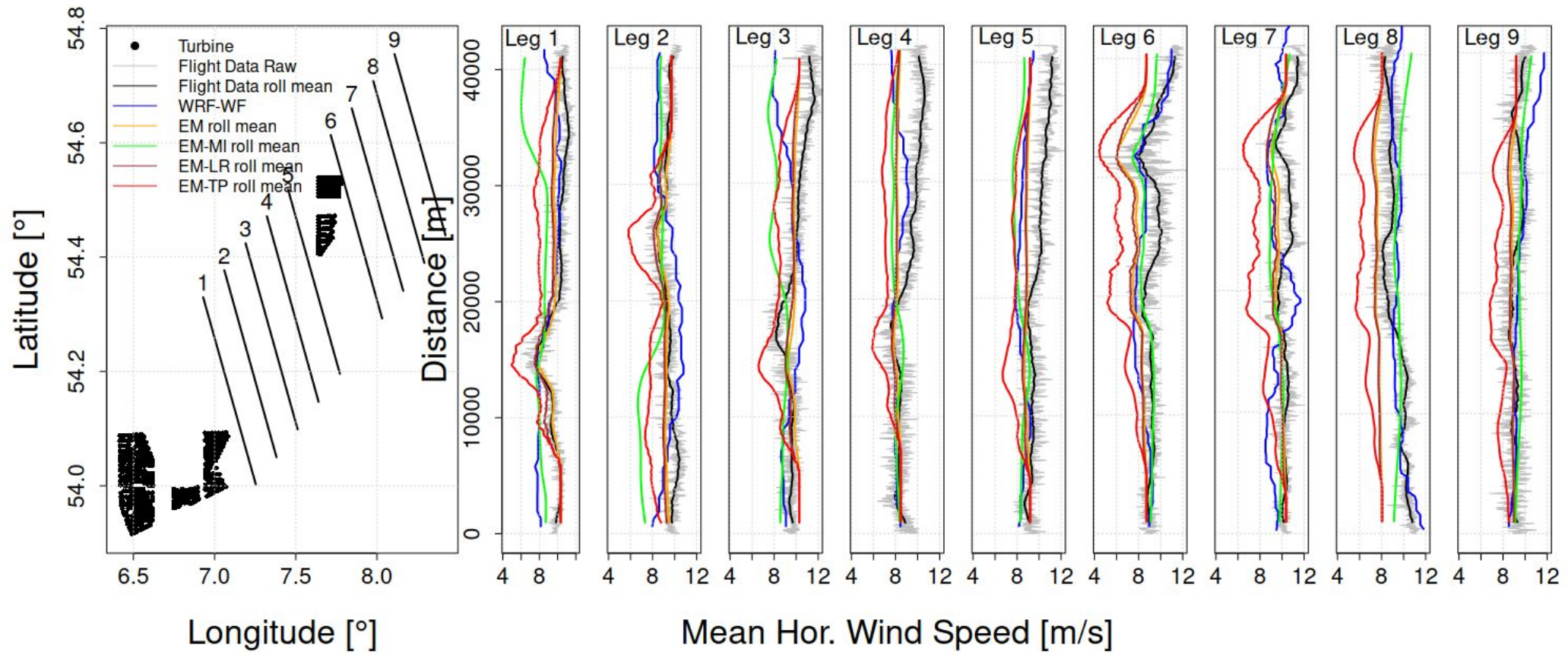
# Results – 23.07.2020

Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight



# Results – 27.07.2021

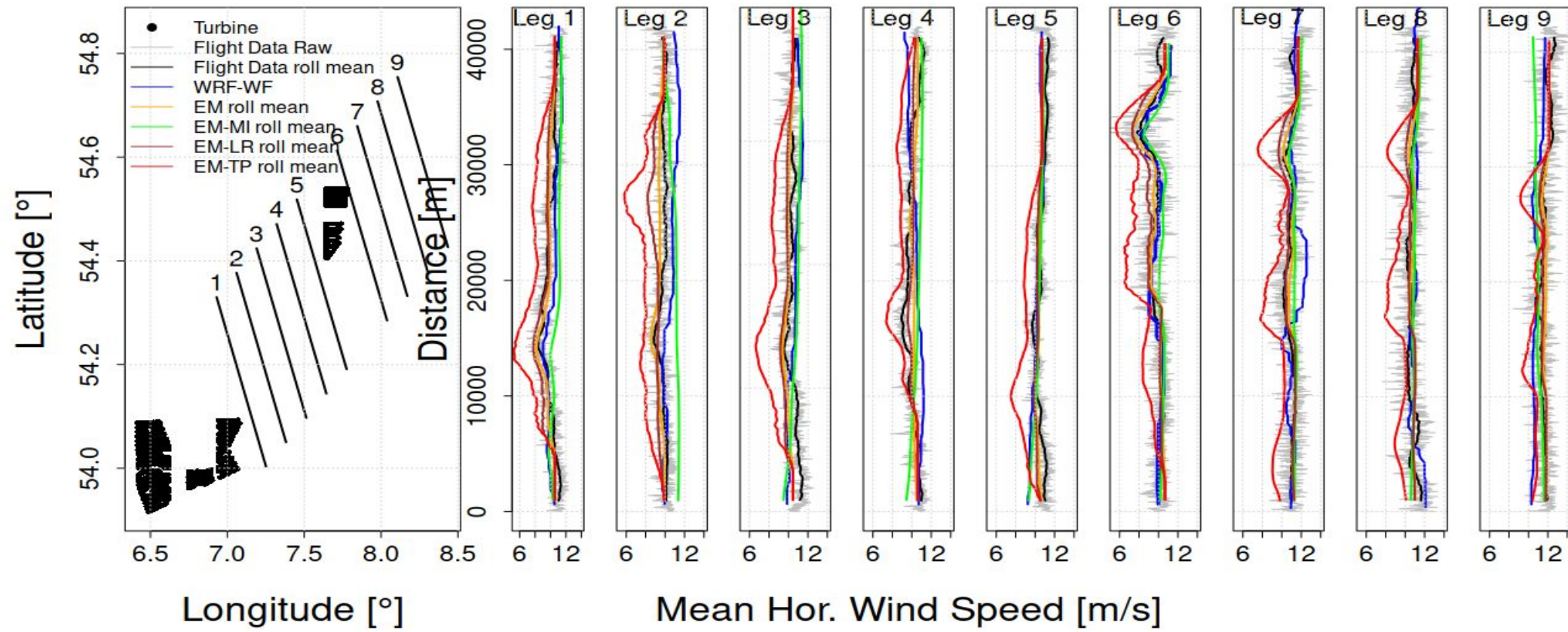
Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight





# Results – 30.07.2021

Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight





# Conclusion

## Comparison of Modelled Cluster Wakes to Aircraft Data in the German Bight

- The models perform convincingly in representing the near wake.
- At distances larger than 10 km or more the models already underestimate/overestimate the velocity deficit of the farm/cluster.
- Comparing WRF and EM to in situ data of an aircraft is challenging due to the short time span of measurements. Uncertainties in the comparison makes it difficult to isolate the better industry model calibration.
- This approach is a first test on how EM can be improved to serve as a tool to simulate long wakes of large wind farm clusters within an ever increasing amount of offshore wind energy.

Thank you for your attention!

**Acknowledgment for the  
provided SCADA Data**

 Orsted

 RWE

 MERKUR  
OFFSHORE

 Trianel