2783

COMPARISON OF SIMULATIONS OF THE FAR WAKE OF ALPHA VENTUS AGAINST SHIP-BASED LIDAR MEASUREMENTS

Hauke Beck[1], Juan José Trujillo[1], Gerrit Wolken-Möhlmann[2], Julia Gottschall[2], Jonas Schmidt[2], Alfredo Peña[3], Vitor Gomes[4], Bernhard Lange[2], Charlotte Hasager[3], Martin Kühn[1],

[1]ForWind - University of Oldenburg, Germany, [2]Fraunhofer IWES, Germany, [3] DTU Wind Energy, Denmark, [4]CEsA, University of Porto, Portugal

KEYWORDS: *wind speed deficit, steady state simulations, remote sensing*

INTRODUCTION

The large investment in large offshore wind farms requires accurate analysis of the wind resource. In this respect, it is critical to take into account the energy yield penalty produced by the wake effects of neighbouring wind farms. For this, wind farm models are used which need to be thoroughly validated in far distances (>20D) from the wind farm. This poster shows analysis of simulations and measurements of the far wake of the offshore test field ‚alpha ventus‘. Three models have been applied, namely flapFOAM, VENTOS®/2 and WAsP. The simulations are compared against measurements performed by Fraunhofer IWES with a lidar vertical profiler installed on a ship moving through the far wake.

TEST CASE

Within the EU project EERA-DTOC the Fraunhofer IWES carried out a measurement campaign from 4th to 9th of October 2013 with a ship based VAD lidar system. The wind speed, wind direction and turbulence intensity haven been measured on the ship trajectory in heights from 40 m – 200 m.

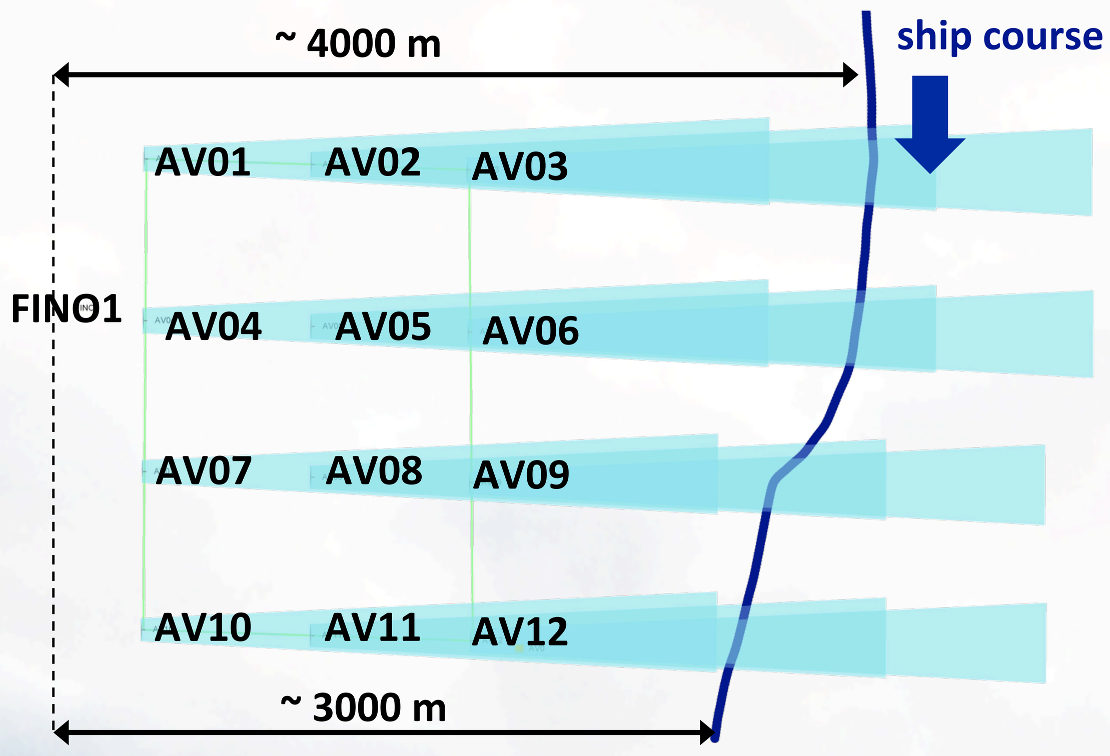

Fig. 1: Measurement coordinates on ship trajectory in the east of ‘alpha ventus’

In the time period from 5th of October from 9:50h till 10:30h the ship travelled the distance of ca. 4000 m from north east to south east of ‘alpha ventus’ with an average speed of 1.67 m/s. From the figures below it can be seen, that the conditions changed slightly within the 40min of measurement.

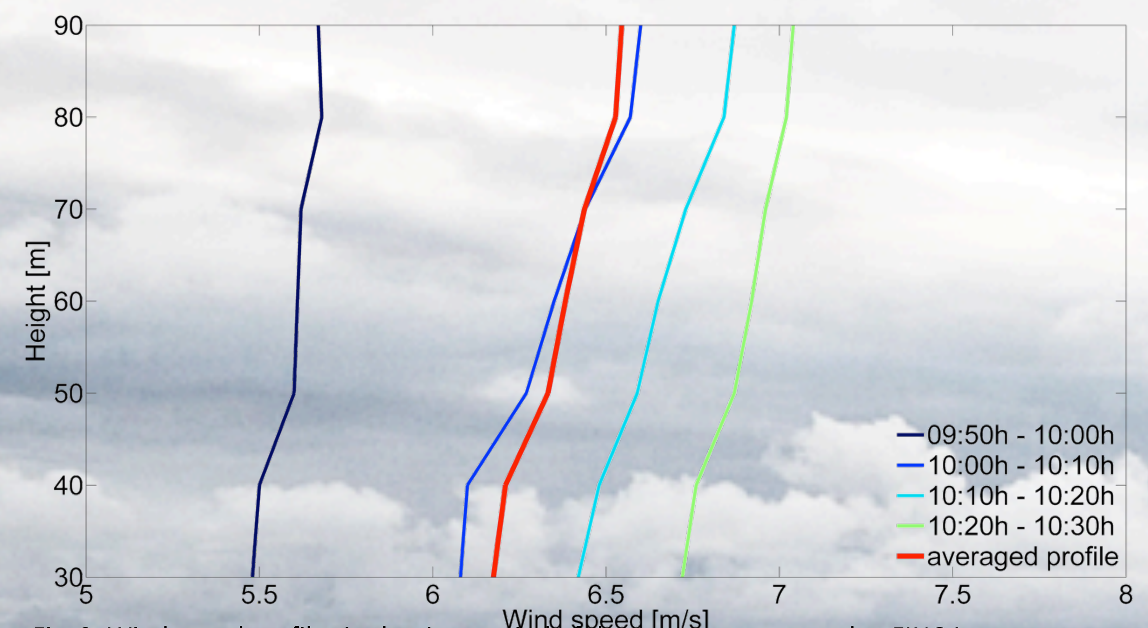

Fig. 2: Wind speed profiles in the time period of the test case measured at FINO1

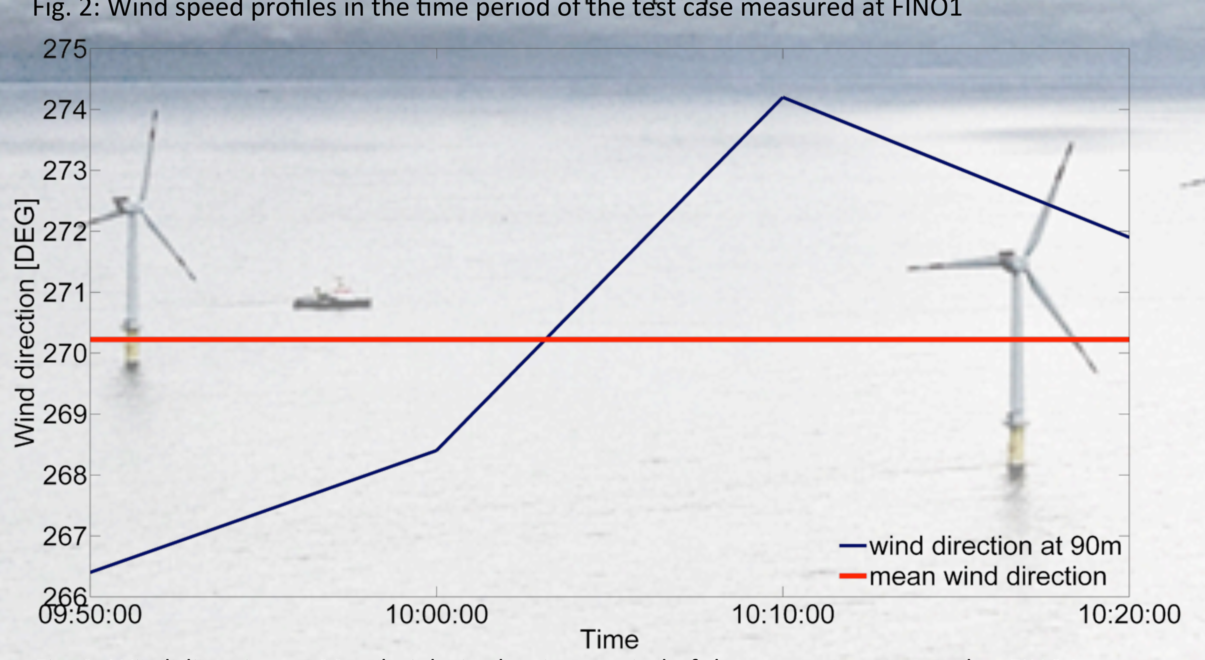

Fig. 3: Wind direction at 90 m height in the time period of the test case measured at FINO1

WAKE MODELS

The modified Park model (DTU)

A modified version of the Park wake model also implemented in the Wind Atlas Analysis and Application Program (WAsP) is here used for wake calculations. The main difference between this modified version and that in WAsP is that the former does not take into account the effects of the ‘ground reflecting back wakes’ and so it only takes into account the shading rotors both directly upstream and sideways.

flapFOAM (Fraunhofer IWES)

The flapFOAM model is intended to be used for wind farm modelling and layout optimisation. flapFOAM is based on OpenFOAM libraries. All implemented models are run-time selectable, and the code is easily extendable with new models. Similar to what is done in other wind farm modelling software, the local wind velocity at a point inside the wind farm is obtained by overlapping a background wind field and the wake deficits that arise from upstream turbines.

VENTOS®/2 (CEsA/FEUP)

The CFD code, VENTOS®/2, is a finite volume implicit solver for the Reynolds averaged Navier-Stokes (RANS) equations for non-stratified flows, with a two equation turbulence model k-ε turbulence model. Modelling the momentum drag associated with the presence of a wind turbine is done implicitly in VENTOS®/2, using a uniformly loaded actuator disk model. The wind turbine rotor’s span is first described in a fine cylindrical coordinate mesh, from which a smooth actuator disk is produced in the domain mesh by tri-linear extrapolation.

COMPARISON

40 min averaged comparison

In a first consideration averaged inflow conditions, like the wind speed profile, wind direction at 90 m height and atmospherically turbulence intensity at 90 m height, measured by the meteorological measurement mast FINO1 in the inflow were used as input parameters for the different simulations.

In this first approach the slightly changes of inflow condition were not taken into account and representative mean values were used instead.

4 x 10 min averaged comparison

In a second consideration time depended simulations have been performed. Therefore the time interval was divided into four 10 min segments for which each with input information based on the meteorological mast FINO1.

RESULTS

40 min averaged comparison

While the magnitude of the deficit can be simulated in average within a tolerance of 7 % for 40 m and 90 m heights, there are larger deviations up to 140 m height. The position of the wakes from the simulations show a trend for AV07 – AV12 to match the measurements in a better manner than AV01 – AV06. An average offset in the wake center of 3° can be observed between measurements and simulations.

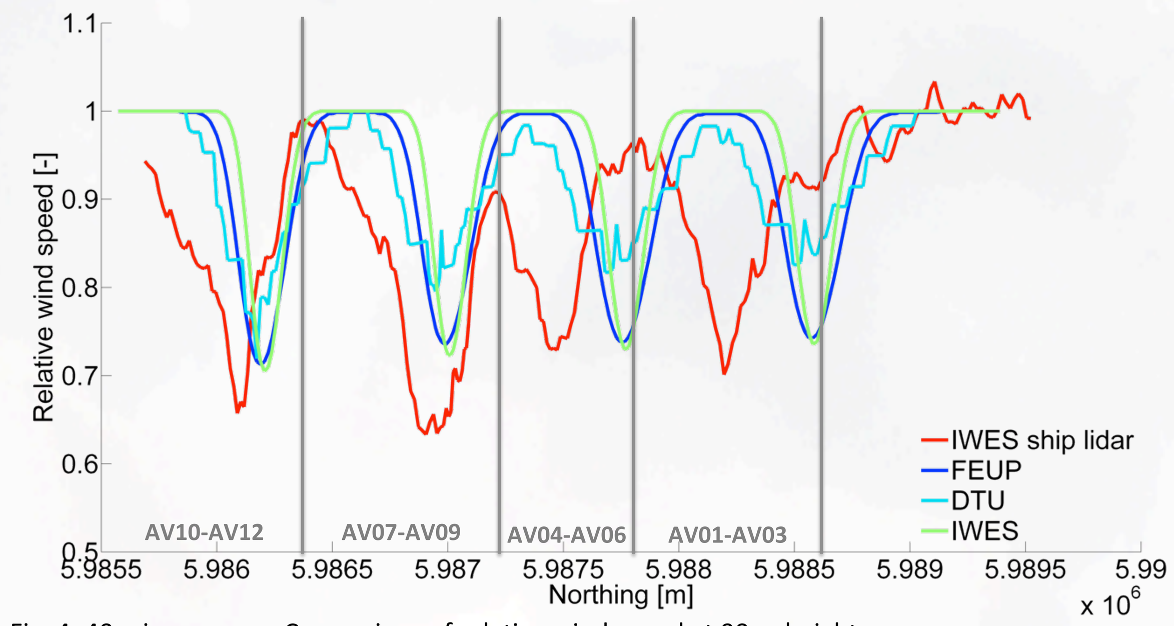

Fig. 4: 40 min average - Comparison of relative wind speed at 90 m height

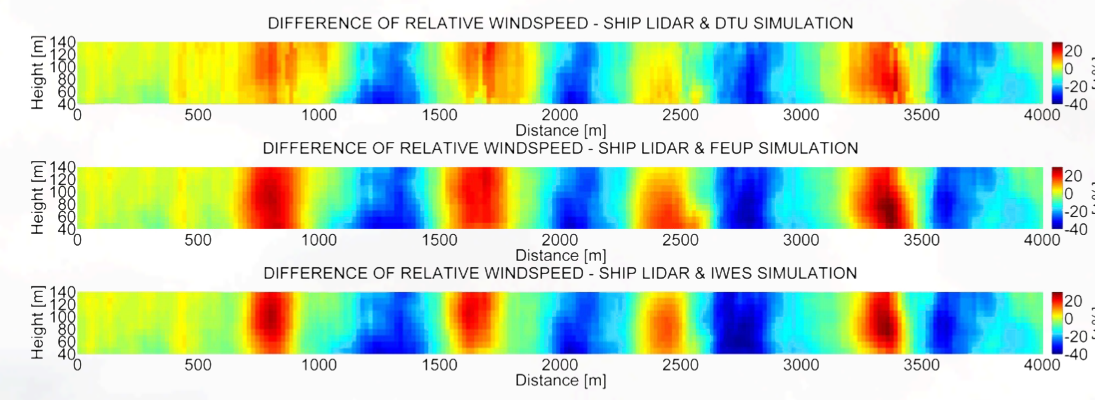

Fig. 5: 40 min average – Difference of relative wind speed

4 x 10 min averaged comparison

With respect to the first comparison the second simulations indicate a worse match of strength of the deficits. While the wake center position nearly stayed the same, no model can depict the overlapping of turbine row wakes in a good manner.

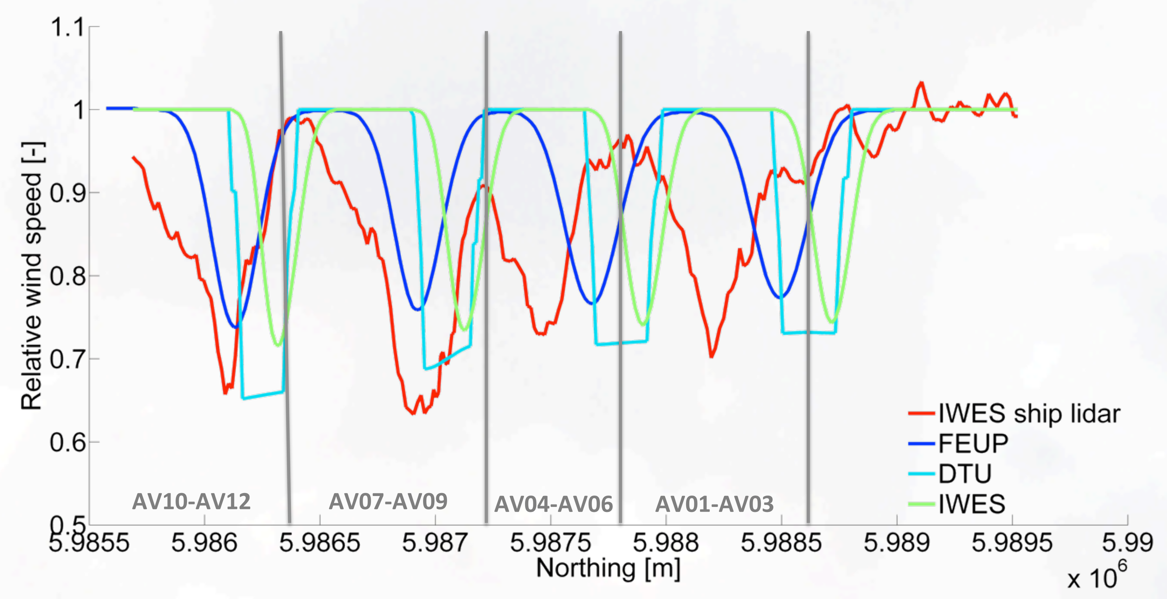

Fig. 6: 4 x 10 min average - Comparison of relative wind speed at 90 m height

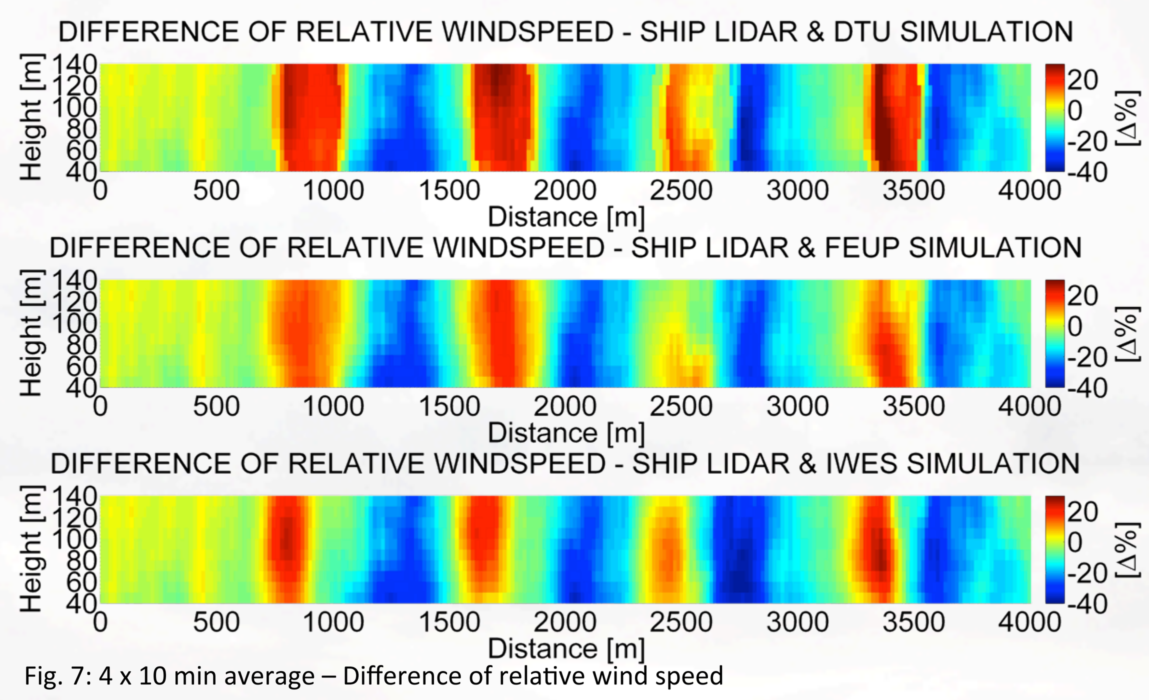

Fig. 7: 4 x 10 min average – Difference of relative wind speed

CONCLUSION

It is challenging to simulate the far wake of ‘alpha ventus’ turbines with engineering models in the range of 1500 m to 2000 m in downstream direction. Main influencing factors for the mismatches are most likely the lake of dynamic by averaging inflow conditions and the artificial thrust coefficient curve. While the magnitude of the wind speed deficits can be partly depicted in a appropriate manner, the positions of the wakes can not yet be simulated accurate with steady wake models.

ACKNOWLEDGEMENTS

The present work is funded within the framework of the EU project EERA-DTOC(n°282797) by the Seventh Framework Programme.