Artificial Intelligence for long range wake estimates in varying atmospheric conditions

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Introduction

As the wind farm plant sizes grows and the wind industry continues to expand, especially in North America, accurately predicting energy production is critical for maximizing efficiency and minimizing financial risks.

Turbine aerodynamic interactions upstream, within and downstream of a wind farm are highly dependent on atmospheric state. Vertical profiles of temperature and turbulence are among the main drivers of the differences. These profiles are used in high fidelity CFD models, but they are neglected from established rapid wake modelling approaches used for wind farm design. We updated the CFD.ML v2 model to include these inputs and tested the performance.

Methods

1. Turbine interaction loss factors were simulated using DNV's high fidelity WRF-to-CFD model at 118 wind farms.
2. Flow case simulations were tagged with their site-specific atmospheric conditions to create training data. The validation sites presented here were excluded from the training set.
3. A graph neural network was trained to replicate the turbine interaction loss factors, creating the WindFarmer "CFD.ML v2" model.

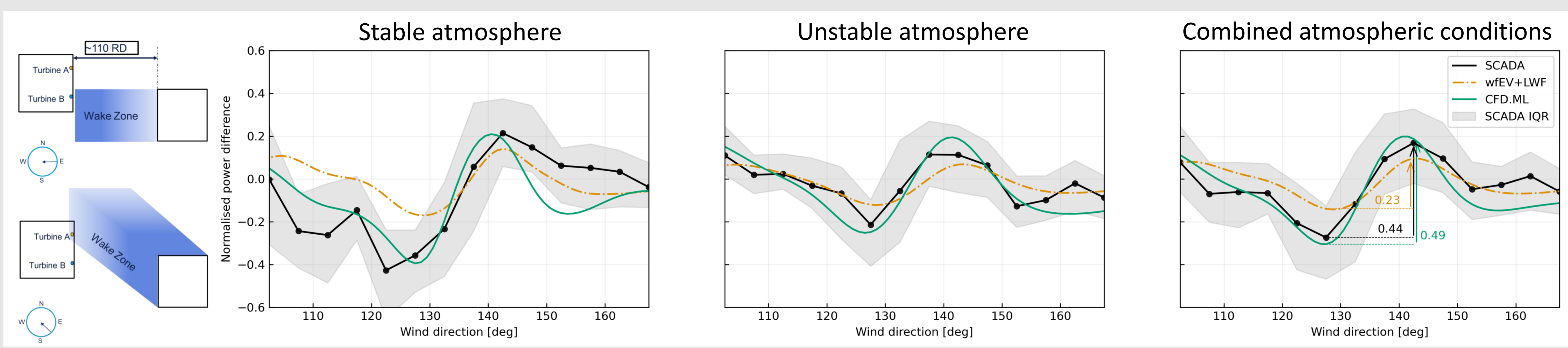
Results

Farm 1: Measured power differences between two corner turbines at Farm 1, that experience a direction-sweeping upstream wind farm wake, are well captured by the CFD.ML v2 model in both stable and unstable atmospheric conditions.

Farm 2: CFD.ML V2 emulates pattern of production results well, seen in CFD across the entire cluster, and SCADA power data at the Hohe See - Albatros Wind Farm. showing long range wakes emanating 25km upstream can be modelled effectively by CFD.ML v2 across a range of atmospheric conditions.

WindFarmer CFD.ML v2 resolves **turbine interaction effects** from **stable to unstable** atmospheric conditions, onshore and offshore

Farm 1:



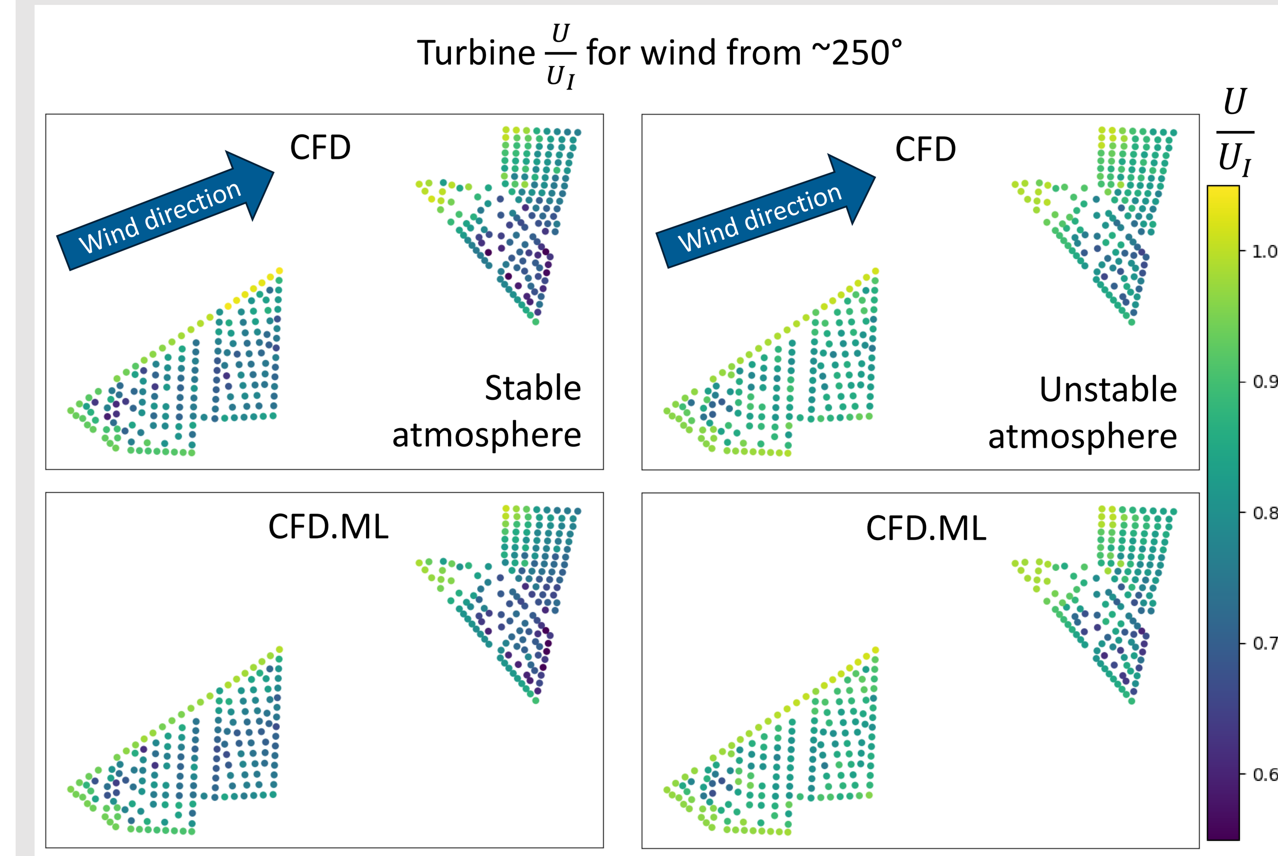
Power differences between two corner turbines at an offshore wind farm vs. wind direction where an upstream wind farm wake sweeps across at ~8m/s. CFD.ML v2 captures the measured signal well for stable, unstable and combined conditions. The WindFarmer EV+LWF underpredicts the magnitude of the signal, especially in stable conditions. CFD.ML v2 predicts more than double the peak wake deficit predicted by WFEV+LWF (less discrepancy is expected when considering a full wind speed distribution.)

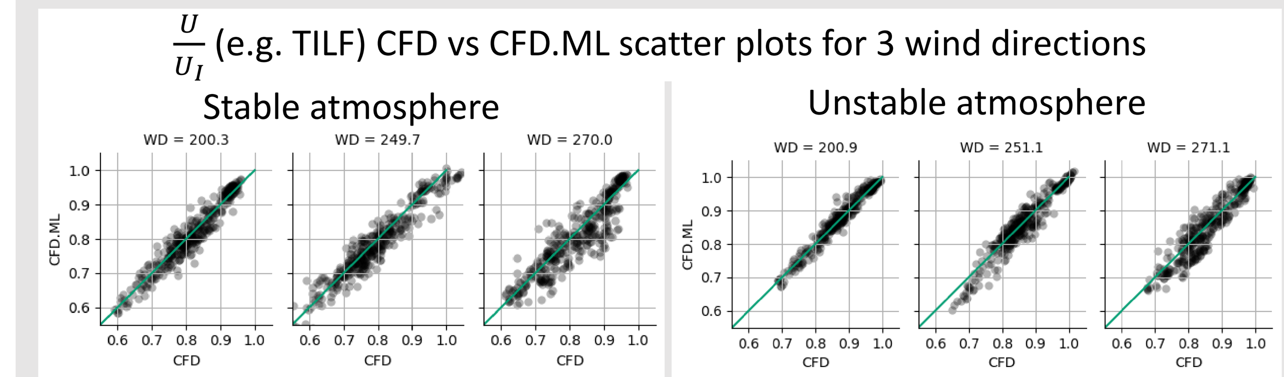
Download detailed reference material here:

Farm 2: Hohe See-Albatros, North Sea

Verification vs. CFD

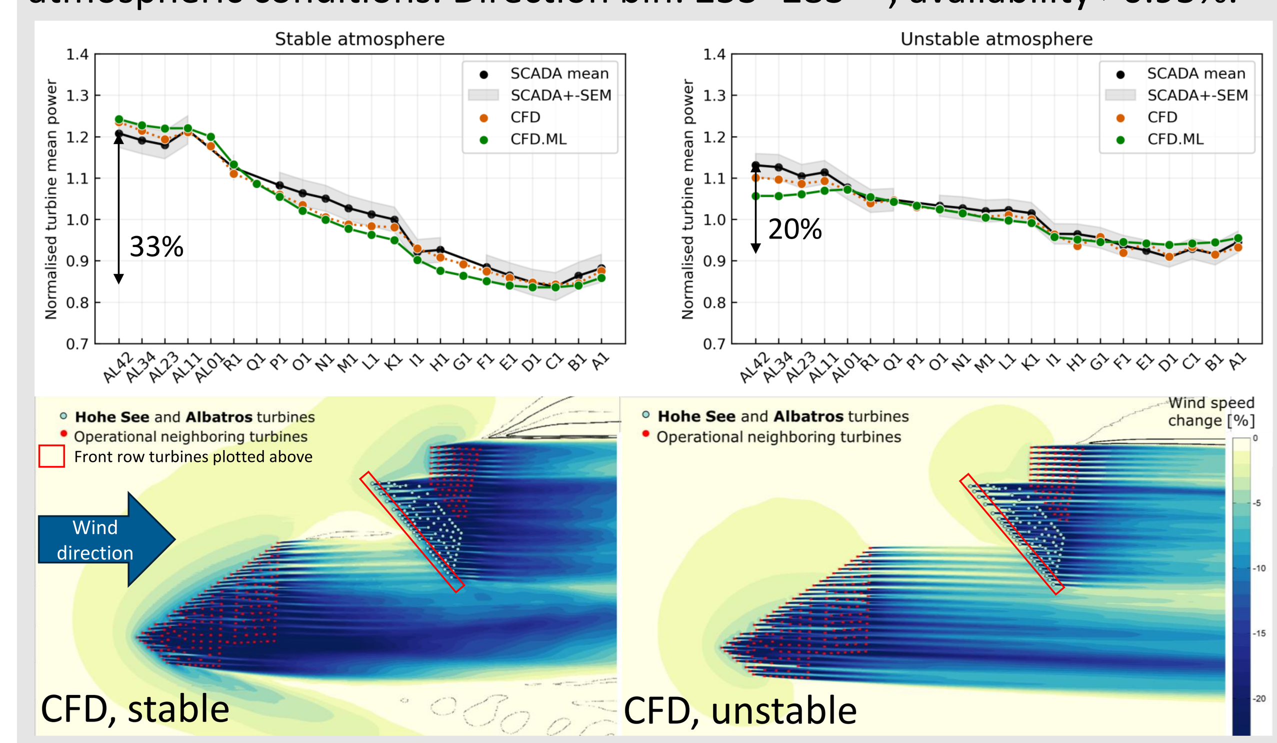
CFD.ML v2 emulates the pattern of production predicted by WRF-to-CFD well, despite never having been trained on simulations of this wind farm cluster. Stronger wakes are predicted in stable atmospheric conditions.





Validation vs. SCADA

CFD.ML captures well the measured turbine power trend across a front row partly waked by an upstream farm in both stable and unstable atmospheric conditions. Direction bin: 253- 283°, availability >0.95%.



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