Wind Farm Layout Optimisation Using a 3D RANS Wake Model

ProPlanEn Wind Energy Advisory

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Wake Superposition

In the development of large offshore wind farms, using a layout optimiser to minimise levelised cost of energy (LCoE) is a key step. As part of the process, a layout optimiser must predict the energy yield of the wind farm for many alternative wind farm layouts. Due to performance constraints, the wind farm energy yield is usually calculated using single turbine wake models coupled with an explicit analytical superposition of multiple wakes. However, previous studies show that none of these superposition methods provide accurate wind speed in both inline and offset wake cases [1]. This inaccuracy can lead to unconvincing optimal layouts with even very simple wind farm case studies.

ProPlanEn Ltd has developed WakeBlaster, a 3D RANS wake model based on eddy-viscosity turbulence closure. Its solver allows an implicit modelling of wake superposition, increasing the energy prediction accuracy in multiple wake cases.

In the figures below, the WakeBlaster double wake profile is compared against analytical superposition methods in three cases: (a) inline (b) partly offset (c) fully offset:

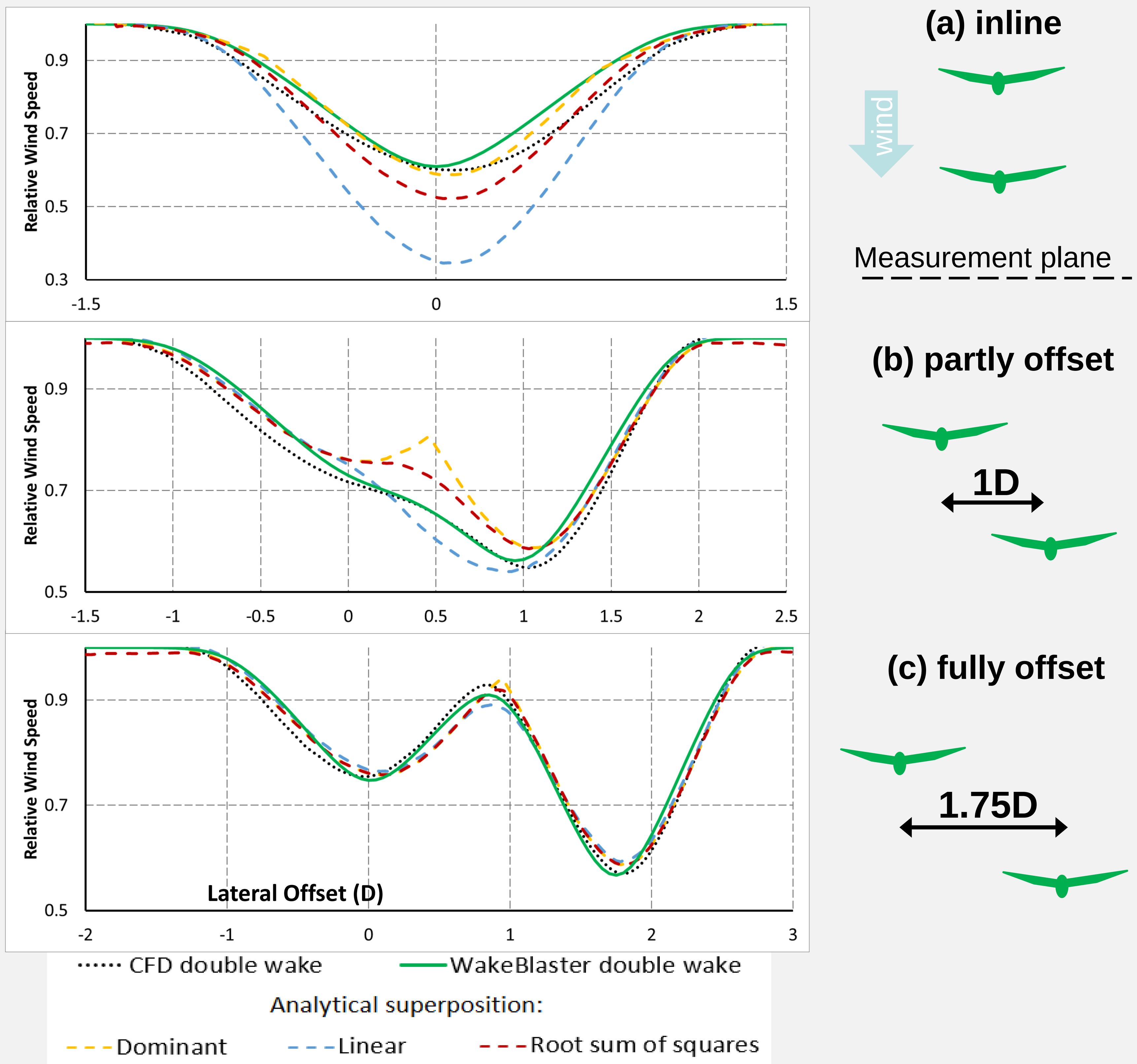


Figure 1: Comparison of wake profiles at a downstream measurement plane for CFD from [1], WakeBlaster and from different single wake analytical superposition models commonly implemented.

Simple Optimisation

When designing a wind farm layout to minimise LCoE, the optimiser must balance the discounted energy production against the discounted costs.

$$LCoE = \frac{\sum Discounted\ Costs}{\sum Discounted\ Energy}$$

The optimiser will find turbine locations that minimise the wake of upstream turbines on the blade face. This will increase the energy yield and drive down the LCoE (when associated location costs are comparable).

One of the dangers of any optimisation process is that a good optimiser will find weaknesses in the underlying model and exploit these to generate non-real world solutions. This can be illustrated by “optimising” the location of a third turbine in the (b) partially offset case.

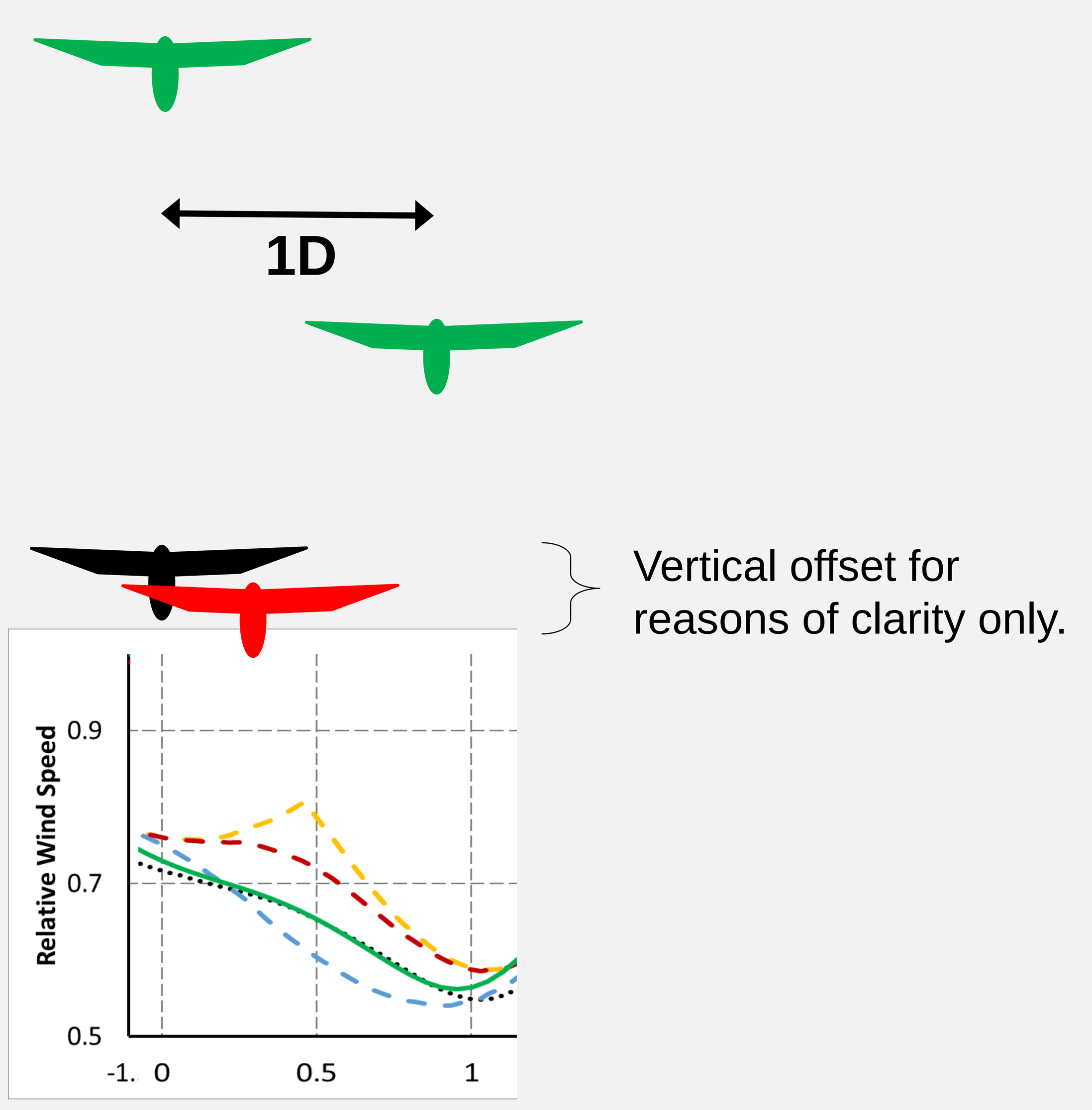


Figure 2: Illustrating how the choice of wake recombination impacts the “optimum” location of downstream wind turbines. The black turbine is the optimum location when using WakeBlaster. The red turbine is the optimum location when using analytical superposition of multiple wakes.

When combining the upstream turbine wakes using linear superposition the optimum position of the turbine is incorrectly displaced. This will result in:

a) Incorrect placement of turbines internally within the array

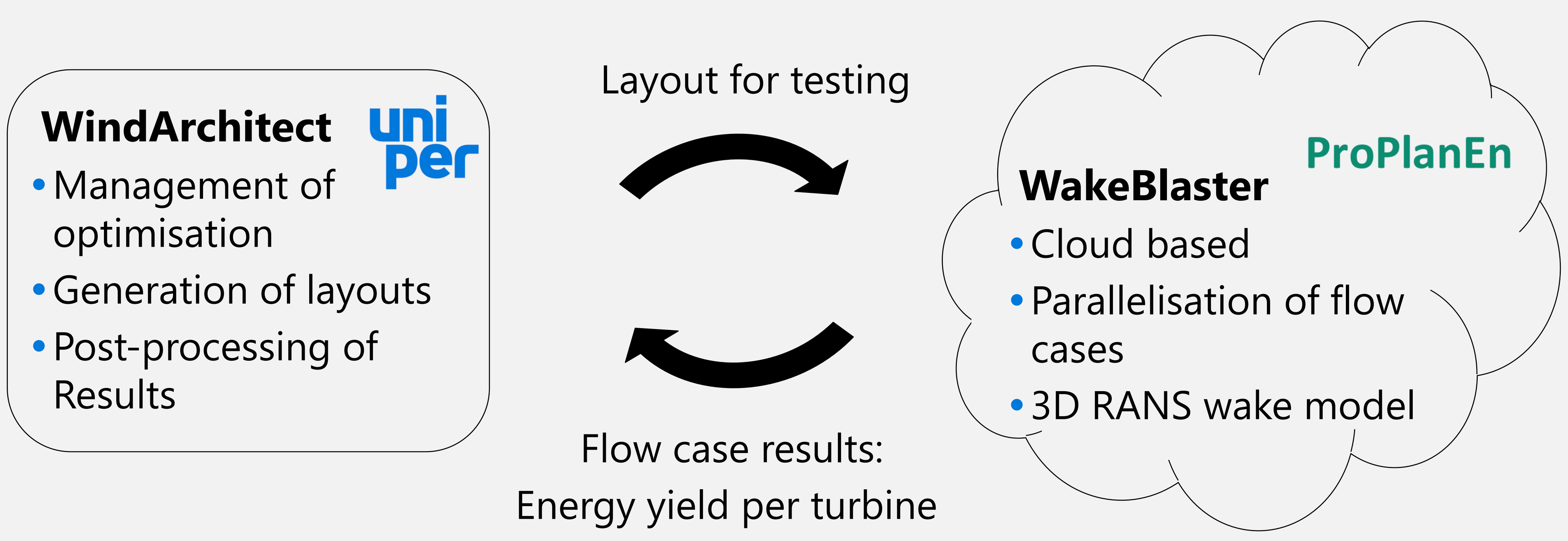
b) Real-world performance will not match energy assessment

c) LCoE delivered will be higher than that modelled

Wind Farm Layout Optimisation

WindArchitect™, Uniper’s wind farm optimisation software, has integrated an interface to ProPlanEn’s WakeBlaster online CFD wake model to enable accurate layout design in acceptable timeframes. Here WindArchitect provides the optimisation framework using various evolutionary and genetic algorithms to explore the design space and generate layouts for testing. These are then handed to WakeBlaster which calculates the flow cases in parallel in the cloud to assess the net yield.

This offers the industry the opportunity to undertake Levelised Cost of Energy optimisation with improved confidence in final layout design generated.



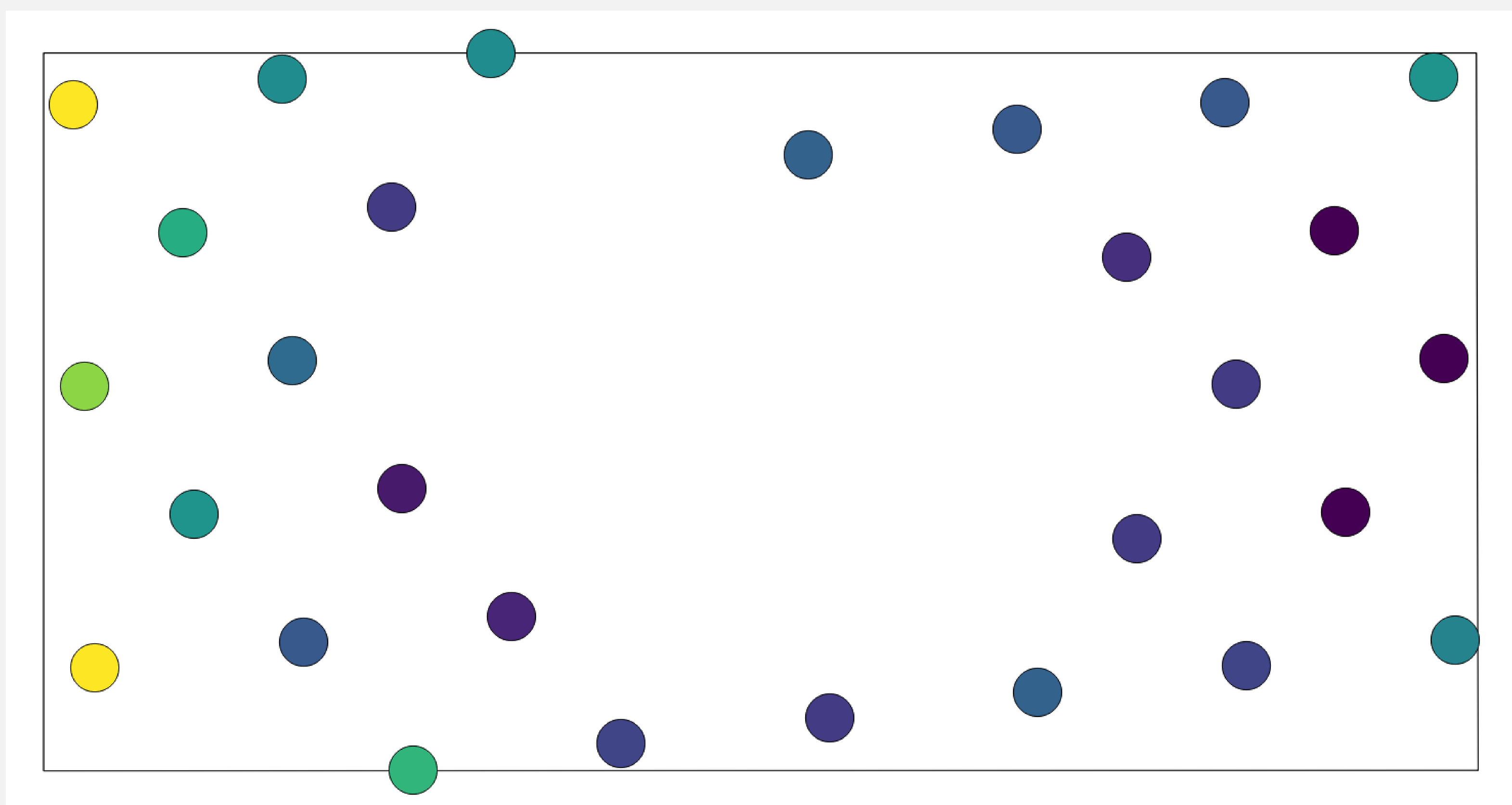


Figure 3 : An optimised layout generated using WindArchitect and WakeBlaster. Highest turbine energy yields shown in yellow and lowest turbine yields in purple

References

1. *K. Gunn et al* 2016 *J. Phys.: Conf. Ser.* **749** 012003