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C. RODAWAY [1], K. GUNN [1], G. SMITH [2], D. DUNSMORE [2], K. SINCLAIR [2], C. MONTAVON [2], E. TRAIGER [3],

1. RWE Renewables UK Ltd, Swindon, United Kingdom
2. DNV Services UK Ltd, London, United Kingdom
3. DNV Energy USA Inc, Medford, United States of America

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Big cluster & far-field wakes - an assessment of multi-fidelity models against North Sea wind farms' SCADA data

BACKGROUND

With the steady build-up of wind farms in the North Sea and US Eastern Seaboard, the impact of cluster wakes on wind farm annual energy production (AEP) increases over time. Wake effects over large distances / clusters is an increasingly emergent risk to LCoE.

The effect of cluster wakes is investigated for the object wind farms of Amrumbank West (ARB) and Triton Knoll (TK), operating in different parts of the North Sea.

OBJECTIVE

- Better understand (and reduce) uncertainty and bias of turbine interaction losses for tomorrow's wind farms.
- Assess the suitability of a range of wake models (from fast engineering models for wakes and blockage to higher fidelity CFD) in their ability to capture pattern of production (PoP) seen in SCADA data
- Focus on wind directions where the object wind farm is partly in the wake of an operating wind farm.

METHODS

- Carefully process (clean, filter) SCADA data from two wind farms operating in the North Sea.
- Filter 10 minutes records for high windfarm availability (100% for ARB, 95.6% for TK of the turbines operating)
- From the filtered time series, derive PoP from the average power of each individual turbine.
- Compare (with SCADA) the PoP obtained from models such as the EVM + LWF [1], VV [2], and DNV and RWE CFD solutions [3, 4].

RESULTS

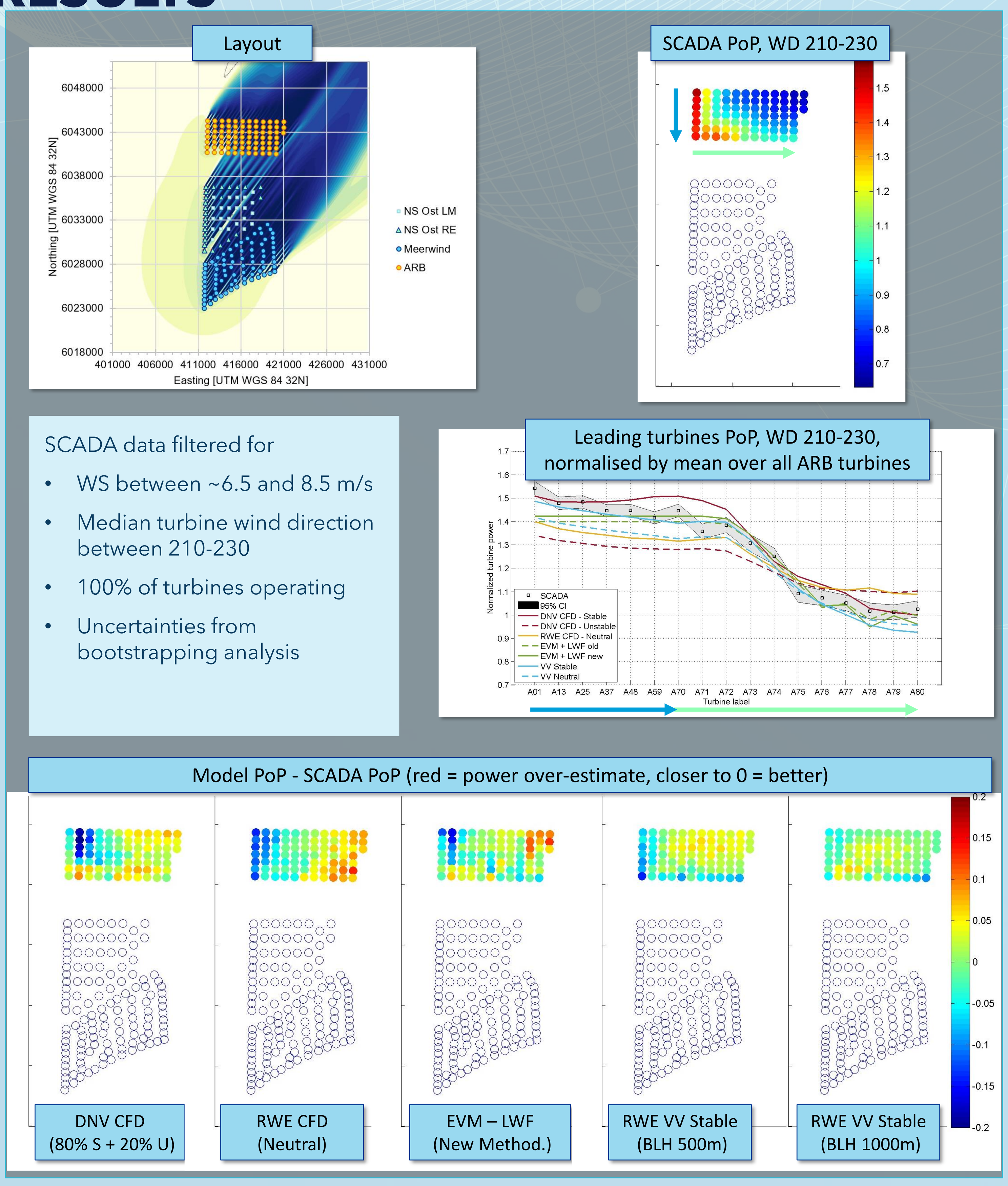

Figure 1: Amrumbank West results

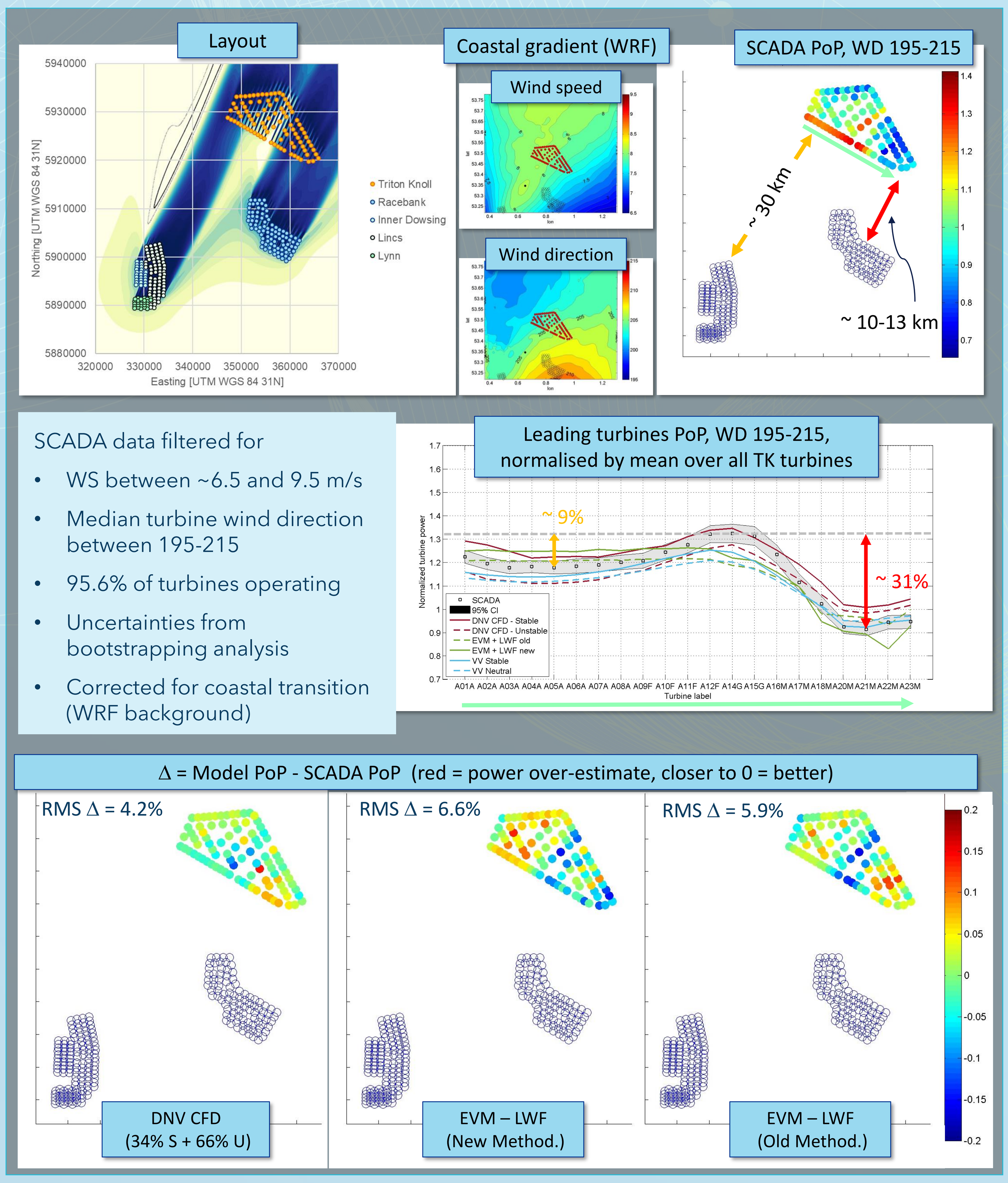

Figure 2: Triton Knoll Results

RMS Δ = root mean square of difference between model and SCADA PoP

CONCLUSIONS

While it was known from previous work that wind farm wakes can persist for distances over 50 km, when atmospheric conditions are stable, the current work demonstrates that cluster wakes can be detected in the SCADA data of offshore wind farms, without limiting the investigation to stable conditions. At TK, on the plateau of the thrust curve, the effect leads to a variation in turbine power of approximately 31% for leading turbines, when the distance between TK and the upstream cluster varies between 10-13 km (65 – 85 rotor diameters) **. For the larger distance of roughly 30 km, the variation in power across the leading turbines is approximately 9%. The magnitude of the effects will be significantly less once aggregated over the site wind speed distribution.

The EVM + LWF model appears to capture the wakes from the neighbours reasonably well for the leading turbines (improved after the methodology change [5]), but despite this, still tends to under-estimate the wake effects deeper in the array. RWE's VV model shows very good agreement with the measured PoP when set up with stable conditions (Obukhov length of 125 m) using a boundary layer (BL) height of 1000 m. The high-fidelity CFD models can capture the PoP with good accuracy for the leading turbines and throughout the array, when driven with appropriate boundary conditions.

Both the CFD and VV also reveal high sensitivity of the results to modelled stability conditions (surface stability, boundary layer height). To feed these high-fidelity models with the required inputs, there is a need to develop/test robust methodologies (either from meso-scale models or new measurement campaigns) to characterise the site stability conditions and boundary layer height.

The validation and the assessment of the effect in AEP terms is ongoing.

** Latest results removing effects in the SCADA data at TK that can be attributed to coastal gradients.

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CONTACT

Elizabeth.Traiger@dnv.com
Christiane.Montavon@dnv.com
Kennett.Sinclair@dnv.com
David.Dunsmore@dnv.com
Gordon.Smith@dnv.com
Kester.Gunn@rwe.com
Christopher.Rodaway@rwe.com