Anholt offshore wind farm wake investigated from satellite data and wake models

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Anholt offshore wind farm

Number of turbines: 111
Wind turbine capacity: 3.6 MW
Rotor diameter: 120 meters

Construction period: 2012-2013

SCADA data for analysis is from January 1st, 2013 to June 30, 2015 (2.5 years)

Courtesy: DONG Energy
Research question

How well can we quantify the wake effect from modelling and satellite?

Sub-task:

How large is the coastal wind speed gradient?
Data

- Supervisory control and data acquisition (SCADA)
- Satellite Synthetic Aperture Radar (SAR)
- Weather Research and Forecasting model (WRF)
- Reynolds-averaged Navier-Stoke model (RANS)
Location
Fetch and wind speed gradient

Anholt Offshore Wind farm
DONG Energy

~27 km

~15 km

18-20 km
Coastal wind gradient investigation
SCADA

Wind speed interval 8 to 10 m/s
Westerly flow from 210° to 320°

Wind speed along row A; $8 < U_{park} \leq 10$ m/s; $\Delta=10°$

Region with coastal effect

Each symbol is one of the 30 turbines in row A
European satellites with SAR

Envisat
2002-2012

Sentinel-1a/b
2014/2016-present
SAR wind data archive
SAR and WRF (without wind farm)
Mean wind speed at 10 m

SAR – 2002-2012

WRF – 2014
RANS and WRF (without wind farm)  
Wind speed at hub-height for 270° ± 5°
Results from RANS

Animation 1:
Wind speed at hub-height from RANS without wind farm.

Animation 2:
Normalized wind turbine power from RANS and SCADA.


Challenges in simulating coastal effects on an offshore wind farm

*IOP Visby wake conference 30 May - 1 June 2017* (in press)
RANS (without wind farm)
Wind speed at hub-height

Influence of coast line on inflow conditions at hub height of Anholt WF, wd=245.0

Horizontal wsp [m/s]

-80 -60 -40 -20 0 20 40 60
y [km]

-40 -20 0 20 40 60
x [km]

8.0 8.5 9.0 9.5 10.0
Horizontal wsp [m/s]

-5 -4 -3 -2 0 0.04 0.05 0.06
Relative wd [deg] Ti

WT number in row A

WT number in row A

WT number in row A
RANS, WRF and SCADA
Wind speed at Row A
(turbines from south to north)

Horizontal wind speed normalized by the wind speed at A15

- RANS 300 m
- RANS 600 m
- RANS 1200 m
- WRF
- SCADA

\[ \text{wd} = 250^\circ \pm 5^\circ \]

\[ \text{wd} = 260^\circ \pm 5^\circ \]

\[ \text{wd} = 270^\circ \pm 5^\circ \]

\[ \text{wd} = 280^\circ \pm 5^\circ \]
Wake investigation
RANS and SCADA wind turbine power (normalized)
Wakes in SAR wind map
SAR-based mean wind speed at 10 m

Selection
30 Sentinel-1a/b scenes
Wind direction from 250° to 270°
taken from the GFS data
Conclusions

There is significant wind speed gradient at Anholt offshore wind farm in particular for westerly flow.

SCADA, WRF, RANS and SAR confirm the wind speed gradient.

Wind farm wake from RANS and SCADA for specific wind speed and direction compare well.

Satellite SAR analysis indicate far-field wind farm wake.
Acknowledgements

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