

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

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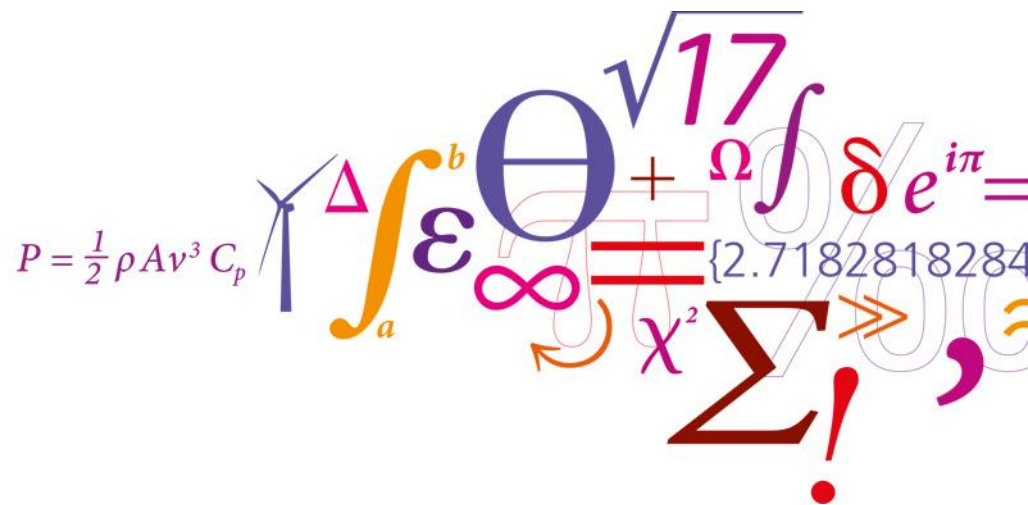
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# Anholt offshore wind farm wake investigated from satellite data and wake models

Charlotte Hasager  
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 Kurt S. Hansen  
 Alfredo Peña  
 Søren Ott  
 Patrick Volker  
 Paul van der Laan  
 Tobias Ahsbahs



# Anholt offshore wind farm



# Research question

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

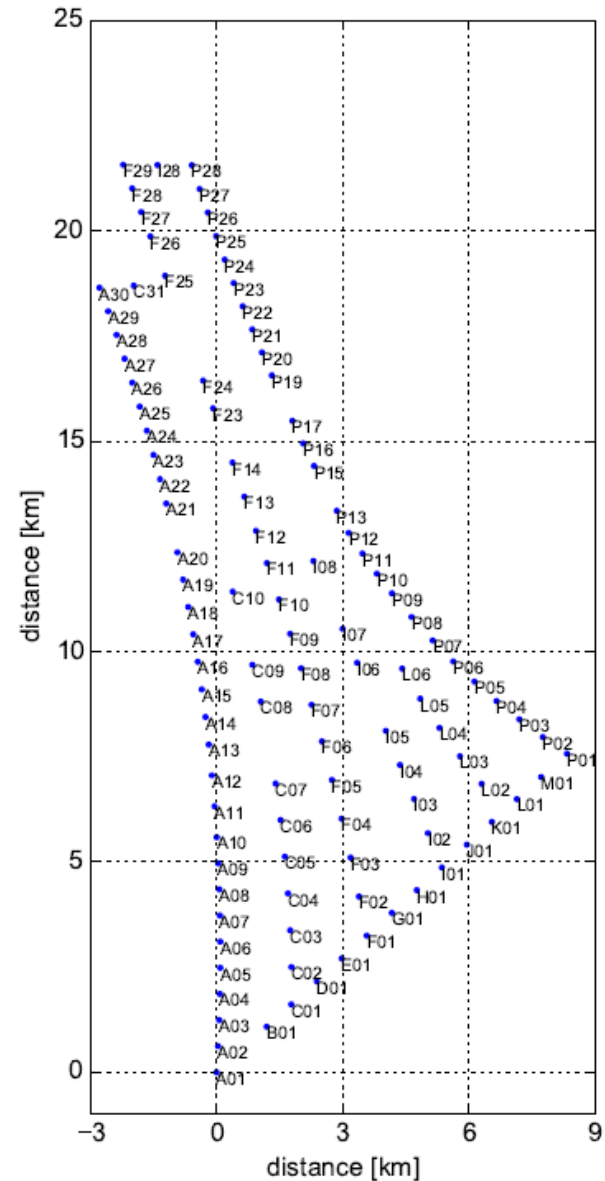
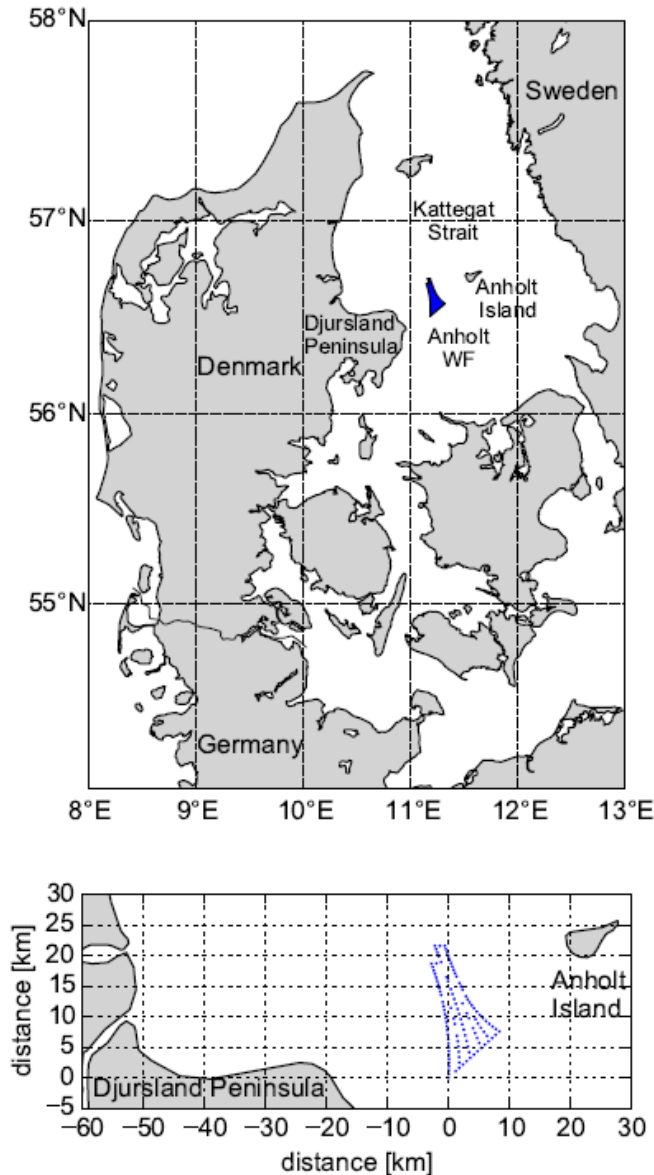
Sub-task:

How large is the coastal wind speed gradient?

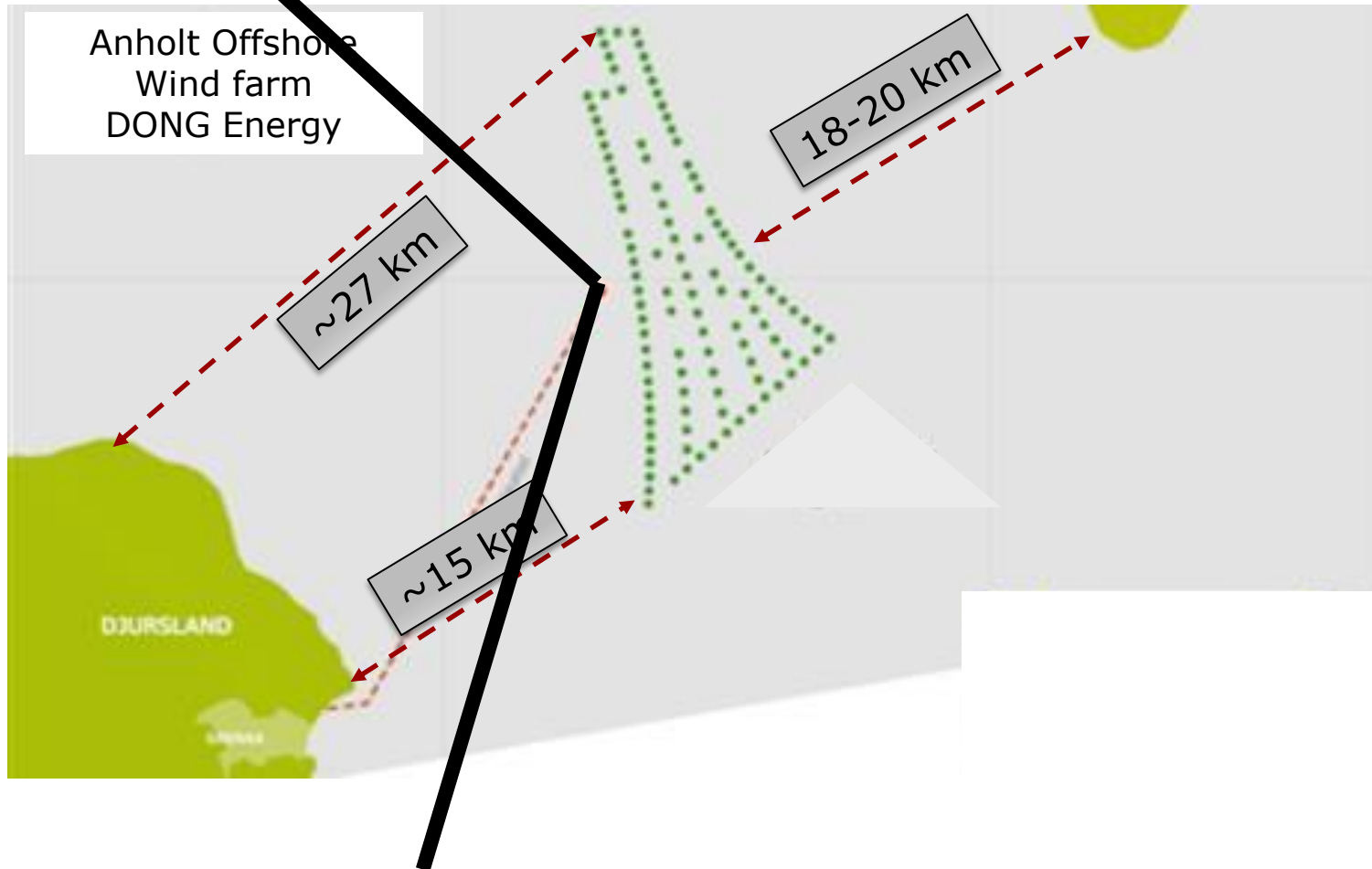
# Data

- 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



# Coastal wind gradient investigation

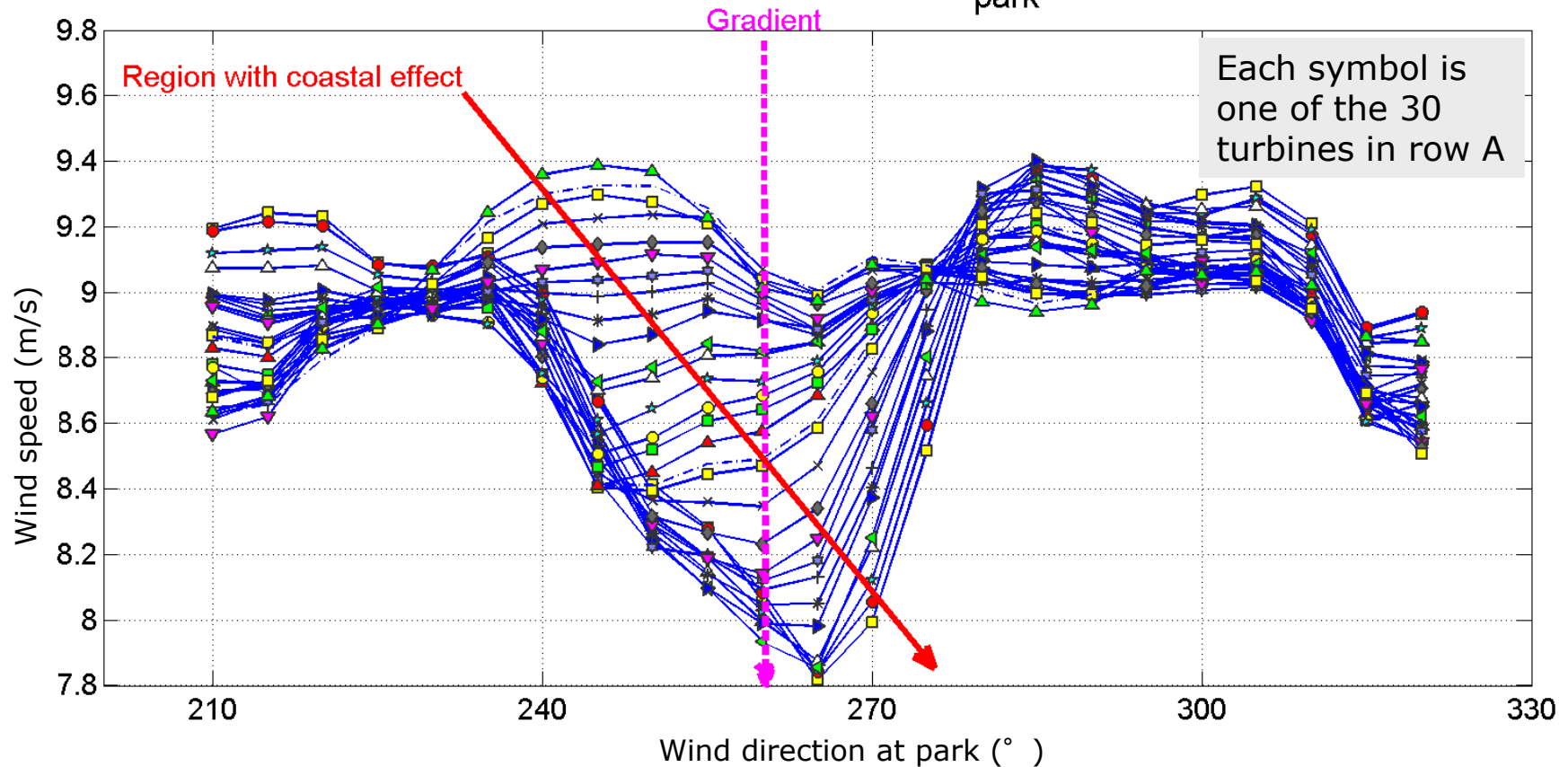


# SCADA

## Wind speed interval 8 to 10 m/s

### Westerly flow from 210 ° to 320 °

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

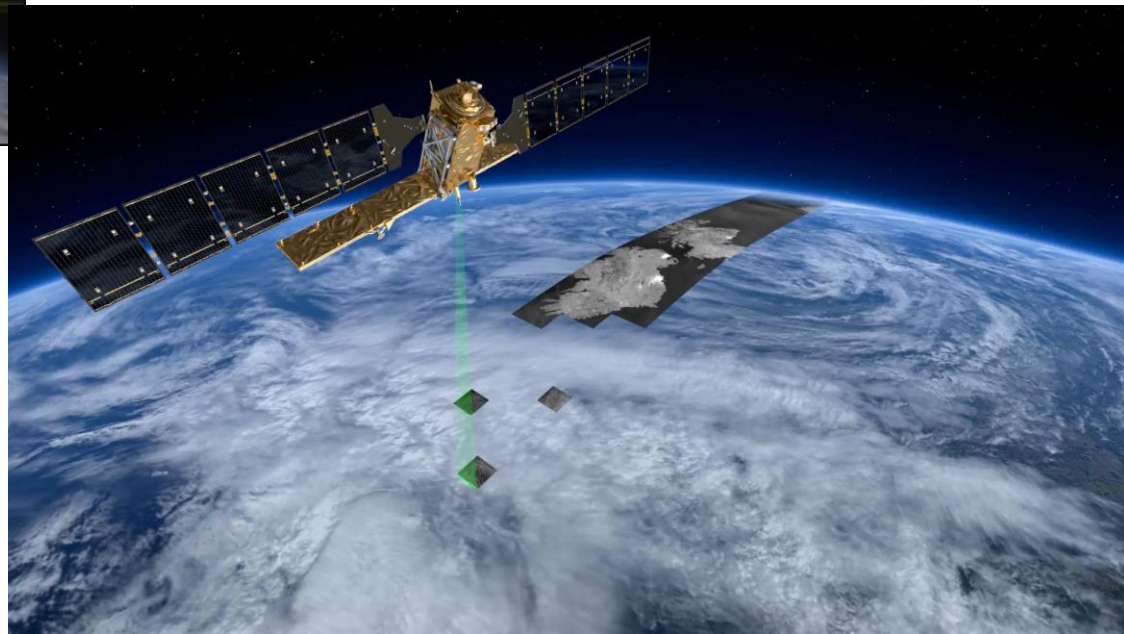


# European satellites with SAR



Envisat  
2002-2012

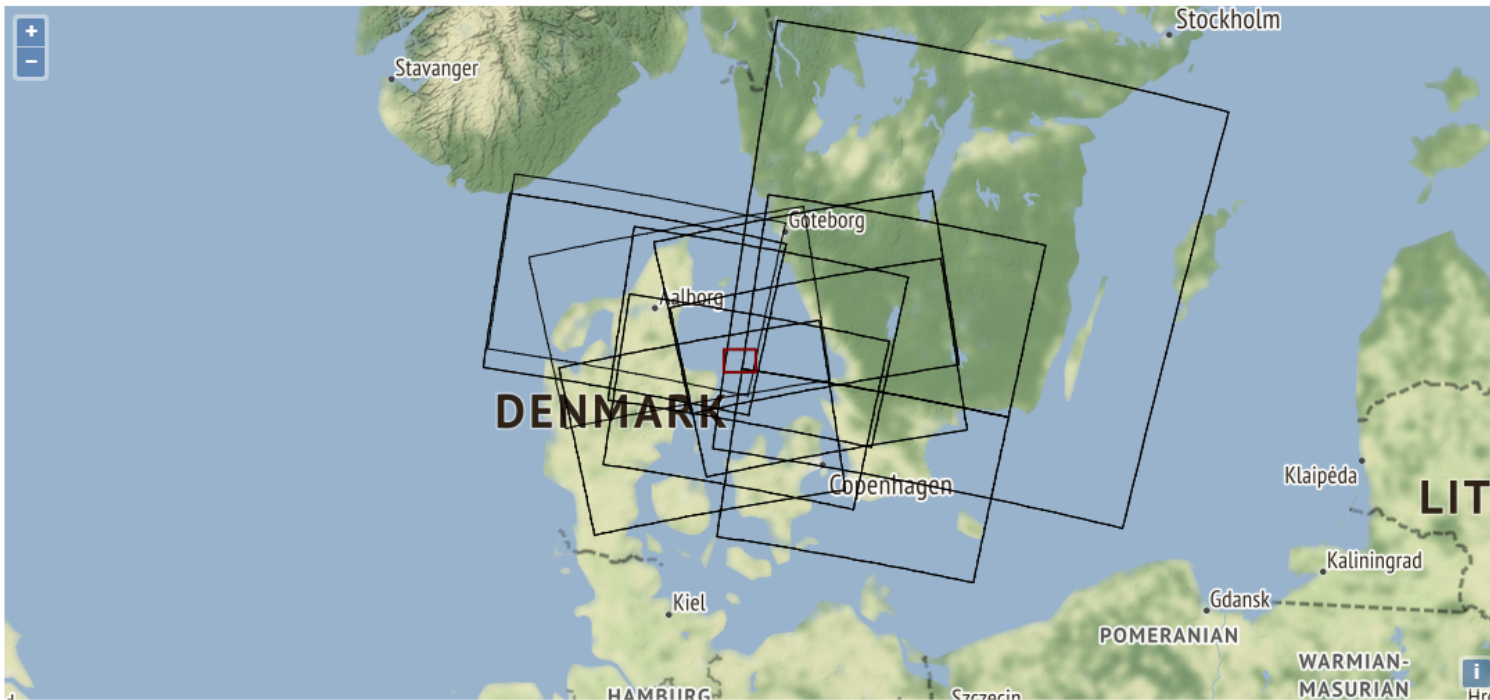
Sentinel-1a/b  
2014/2016-present



# SAR wind data archive

## DATA STATION

Home [Satellite winds](#)



You can select/adjust area of interest by holding CTRL key and drawing a bounding box

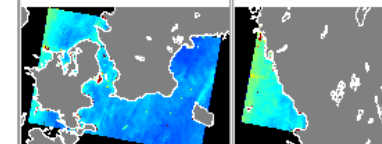
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<p>File: S1A_ESA_2017_02_27_05_24_21_0541488261_13.16E_55.59N_VV_C11_GF5025CDF_wind_Level2.nc  <a href="#">Download</a>          Date: 27.02.2017 05:24:21          SWASP-ID: 113774</p>	<p>File: S1A_ESA_2017_02_27_05_24_21_0541488236_13.65E_57.08N_GF5025CDF_wind_Level2.nc  <a href="#">Download</a>          Date: 27.02.2017 05:23:56          SWASP-ID: 113787</p>
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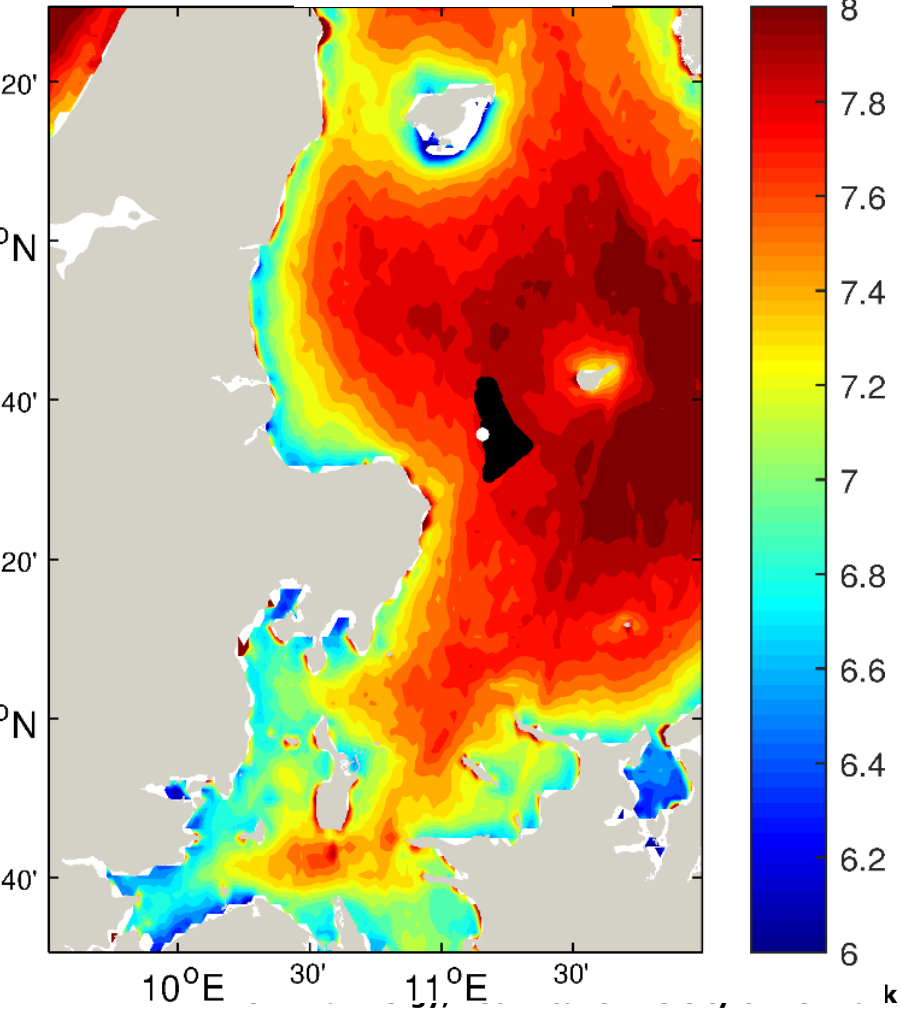
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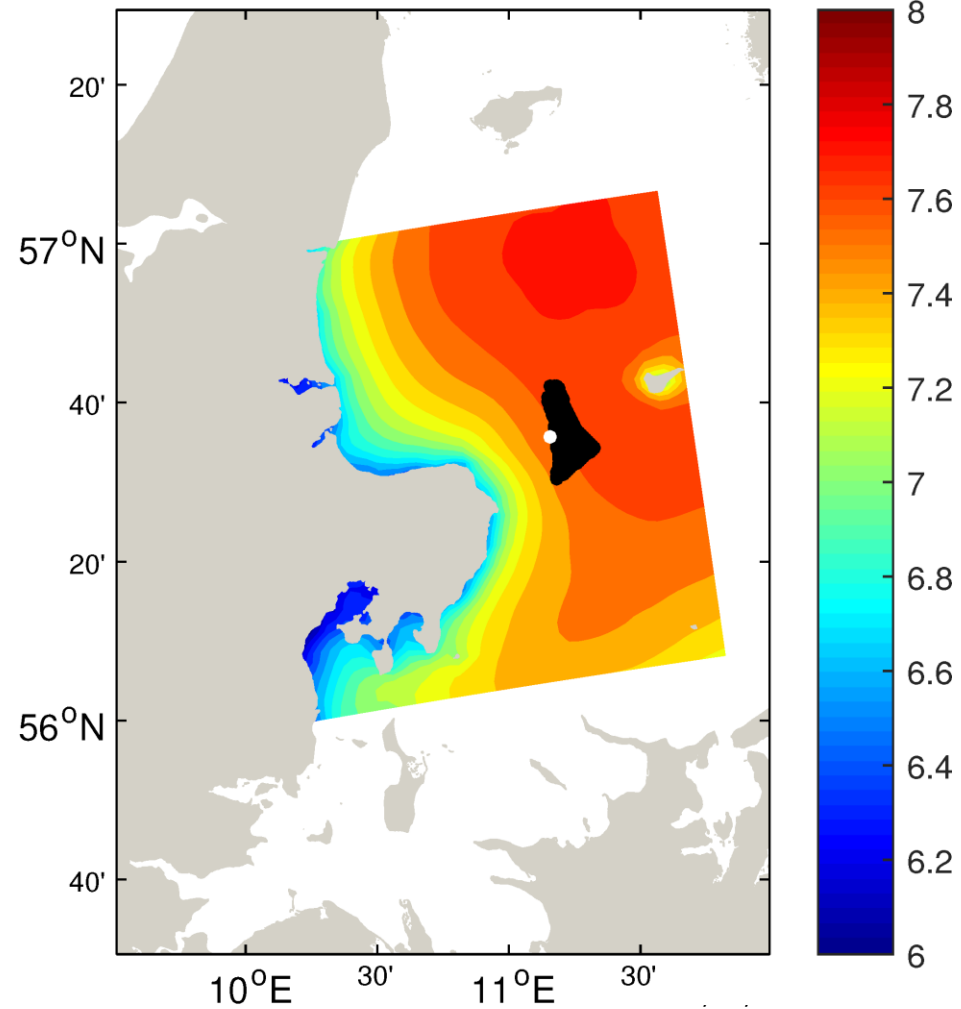
# SAR and WRF (without wind farm)

## Mean wind speed at 10 m

SAR – 2002-2012

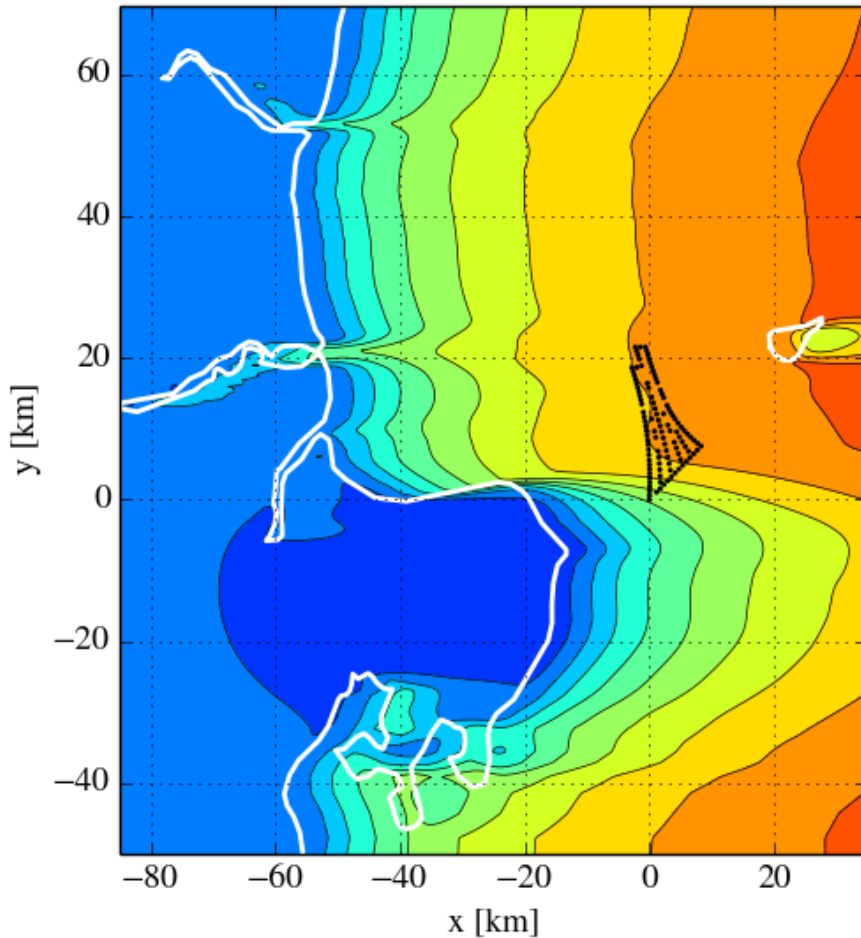


WRF – 2014

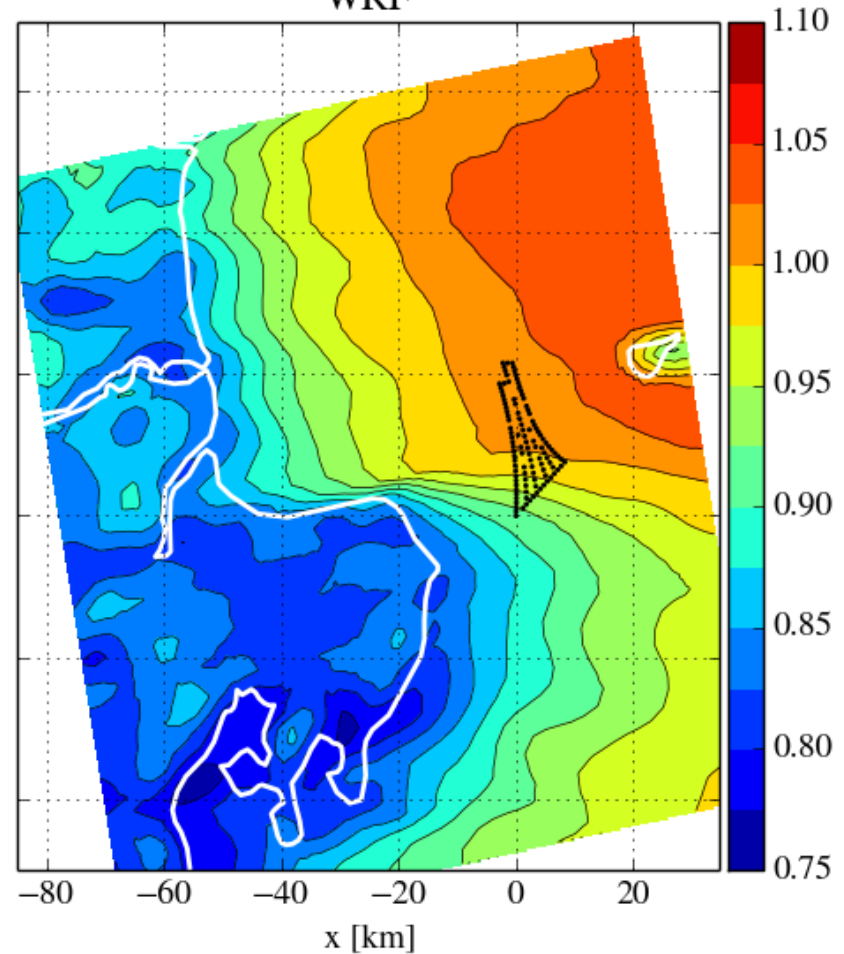


# RANS and WRF (without wind farm) Wind speed at hub-height for $270^\circ \pm 5^\circ$

RANS



WRF



# 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.

M. P. van der Laan, A. Pena, P. Volker, K. S. Hansen, N. N. Sørensen, S. Ott, C. B. Hasager.

Challenges in simulating coastal effects on an offshore wind farm

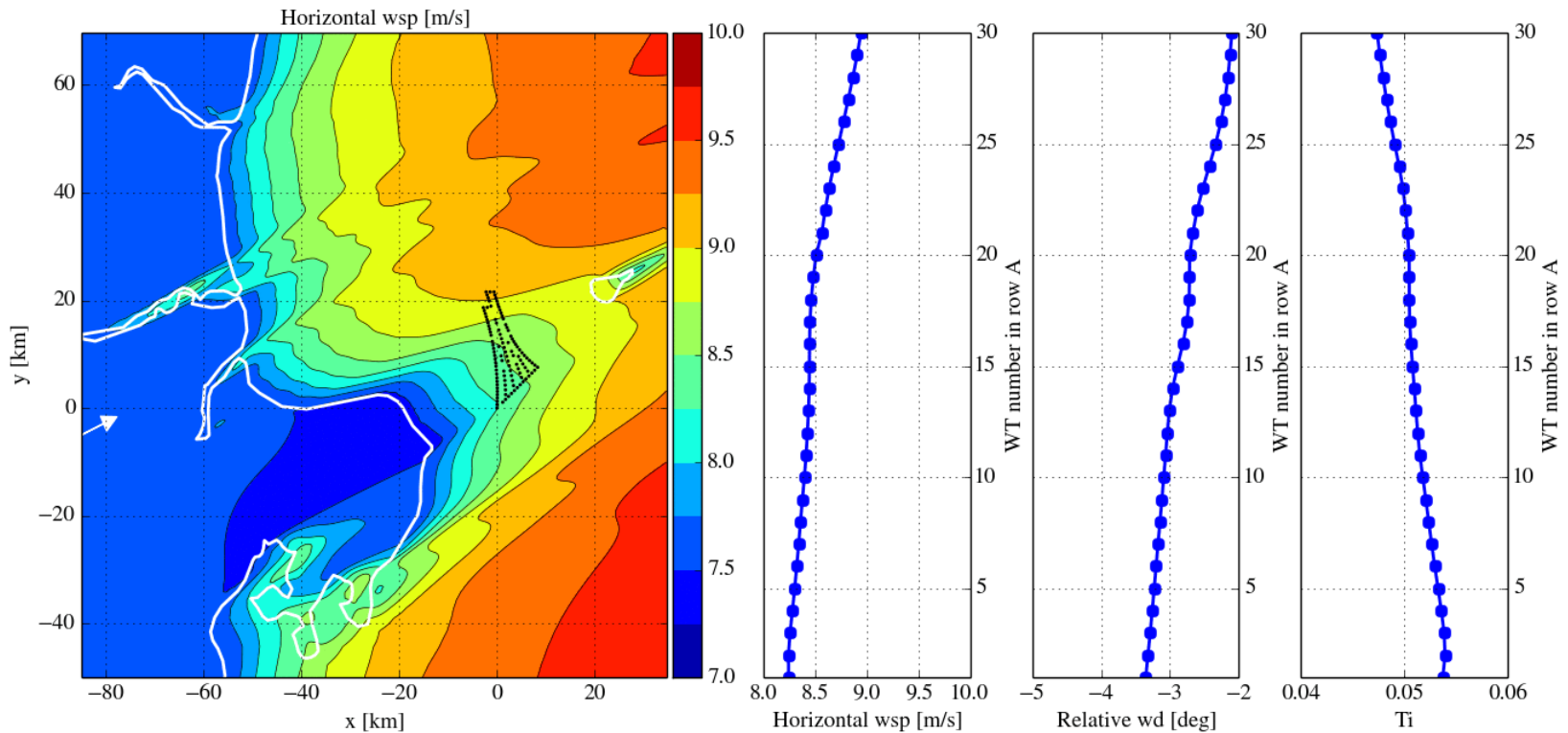
*IOP Visby wake conference 30 May - 1 June 2017 (in press)*



# RANS (without wind farm)

## Wind speed at hub-height

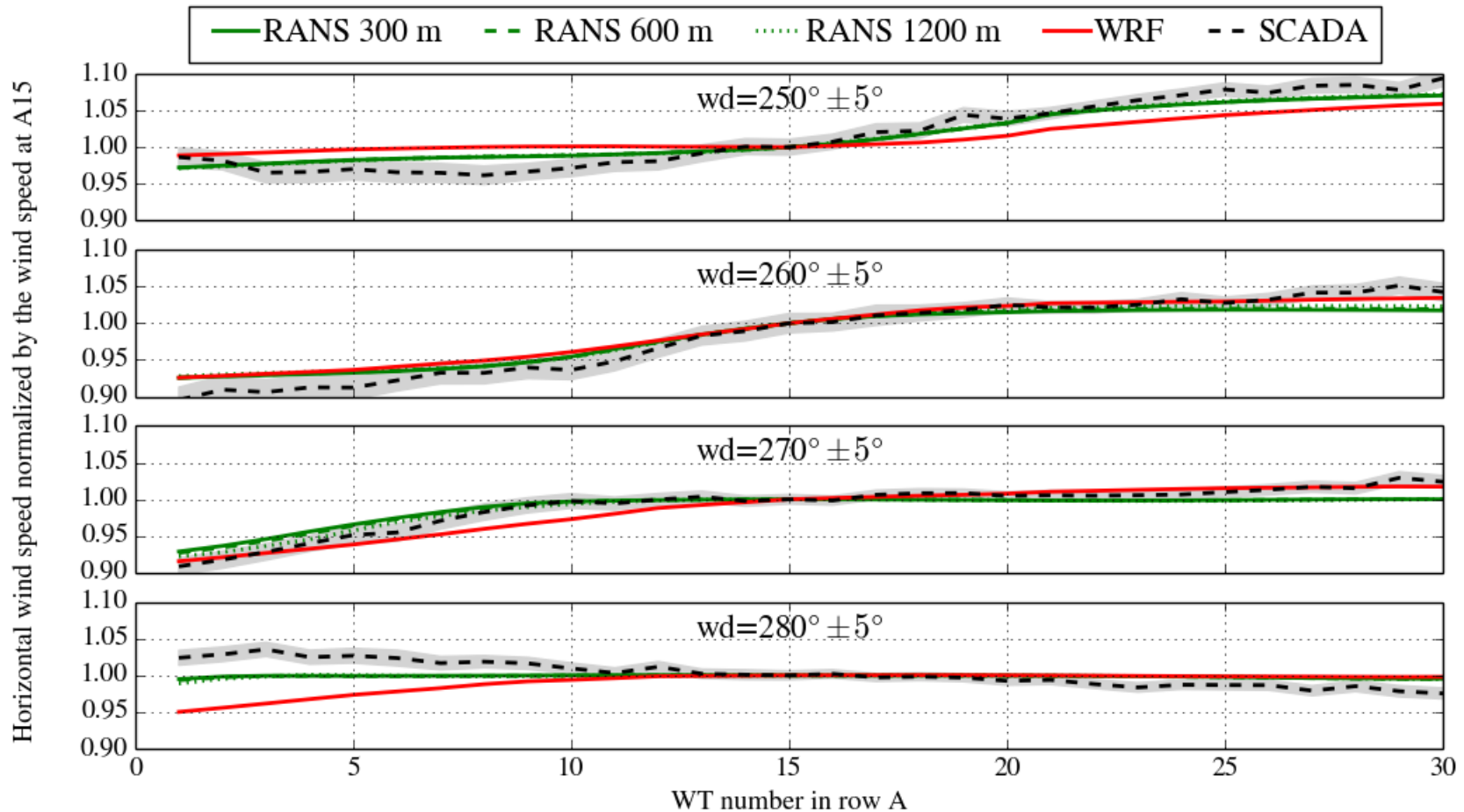
Influence of coast line on inflow conditions at hub height of Anholt WF, wd=245.0



# RANS, WRF and SCADA

## Wind speed at Row A

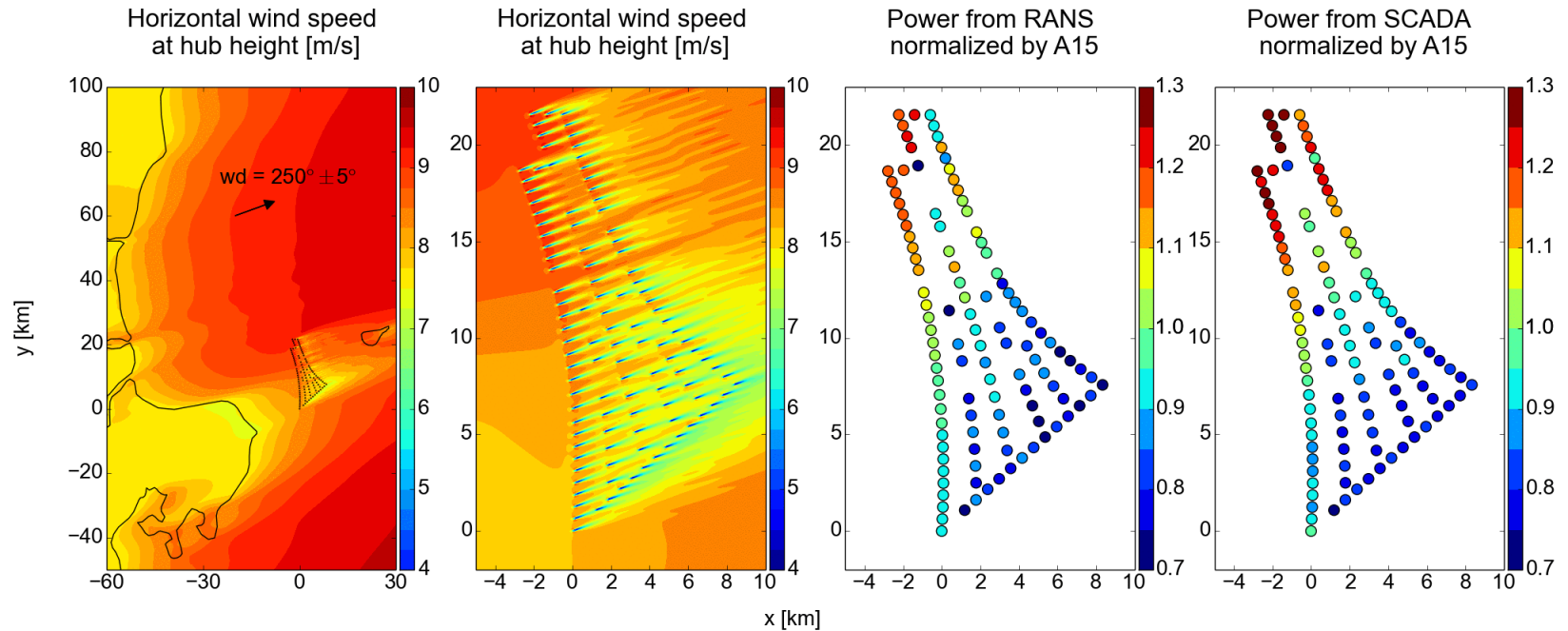
### (turbines from south to north)



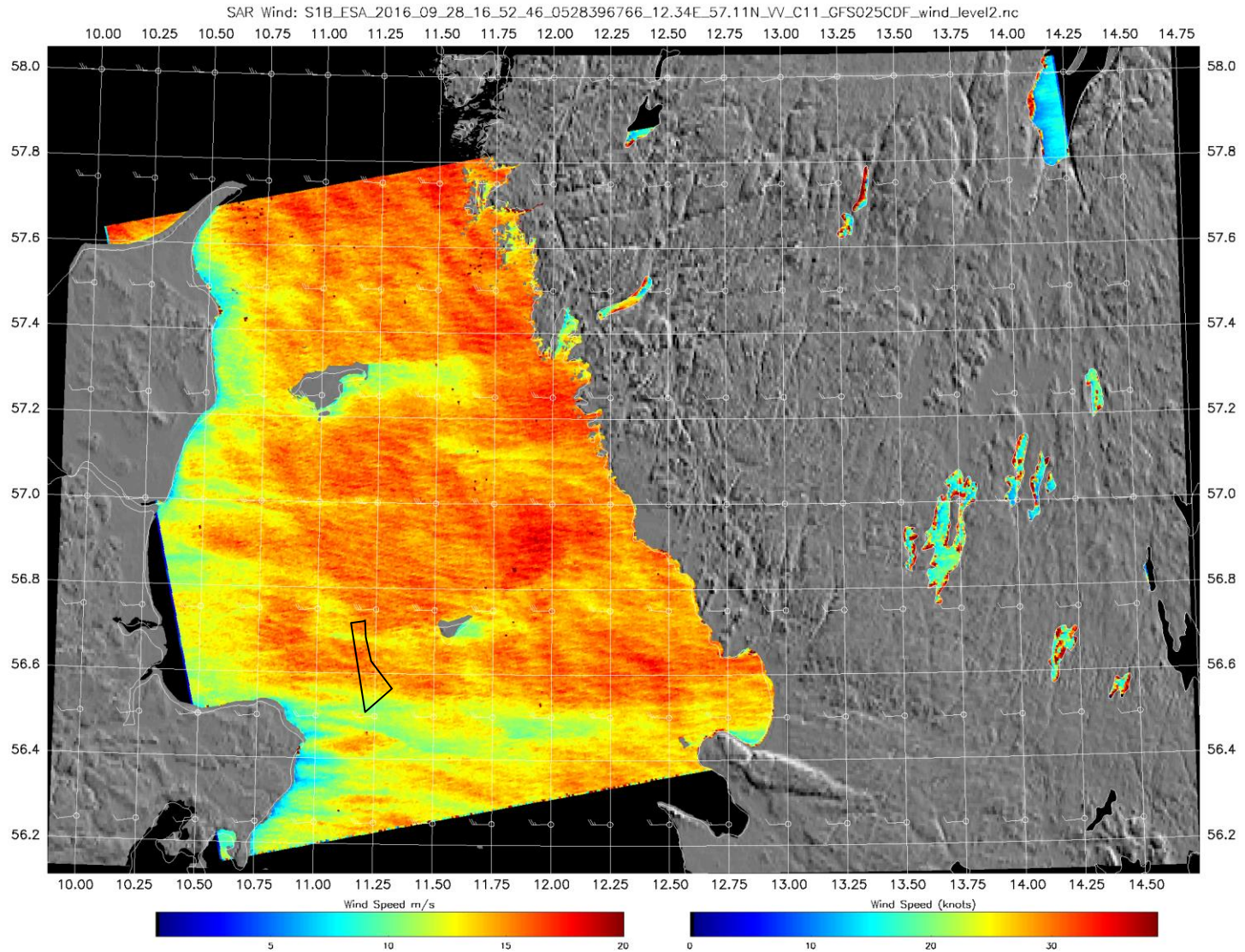


# Wake investigation

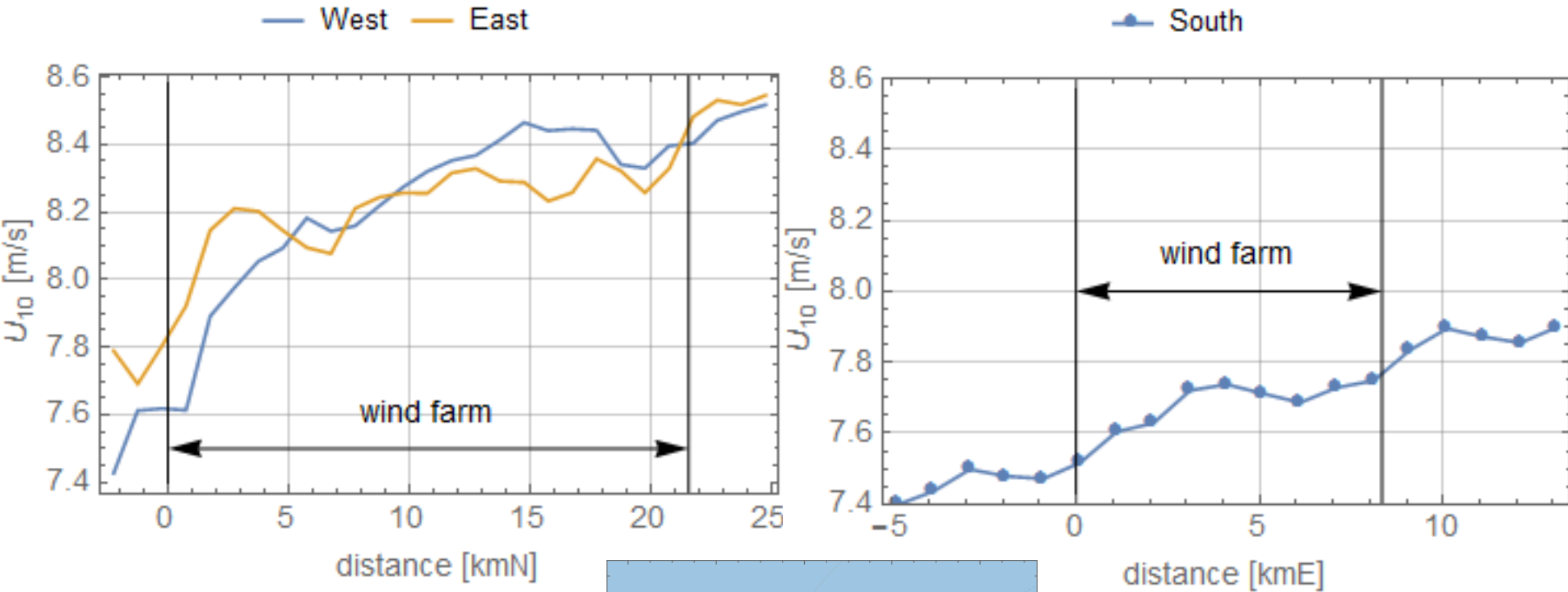
# RANS and SCADA wind turbine power (normalized)



# Wakes in SAR wind map

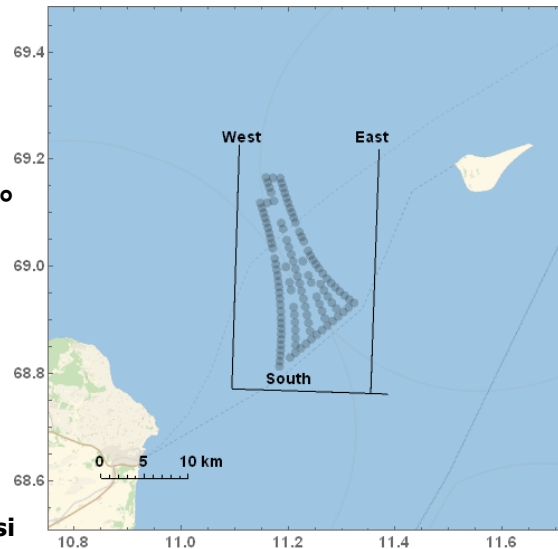


# SAR-based mean wind speed at 10 m



## 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

We thank DONG Energy and partners for the SCADA data.

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