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Offshore wind farm wake modelling with focus on cluster scales

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Charlotte Hasager, Merete Badger, Alfredo Peña, Jake Badger, Alessandro di Bella, Patrick Volker

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DTU Wind Energy
Department of Wind Energy

Wakes: where are we now?

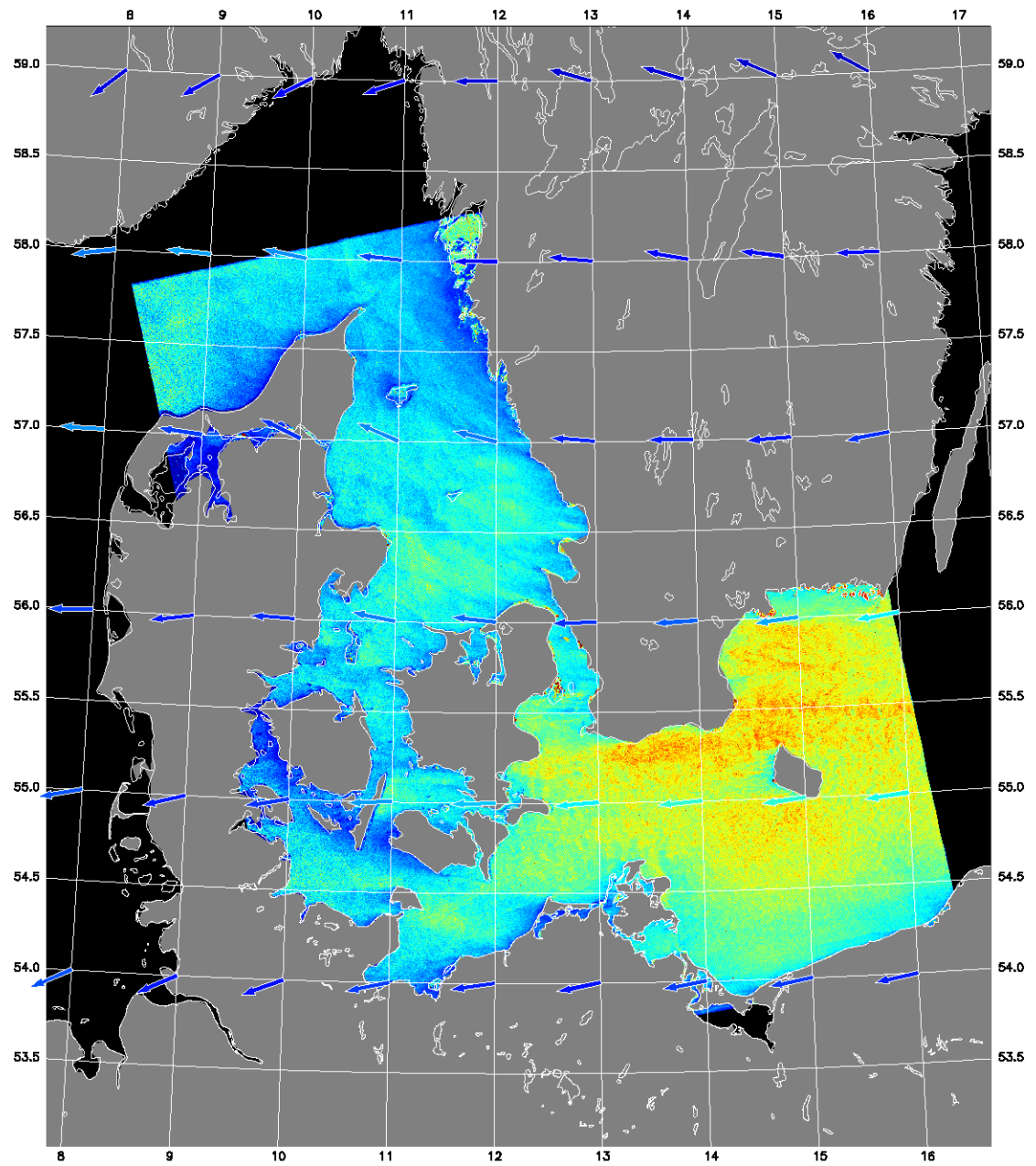For this topic, we will be looking for abstracts addressing the following points:

- External wakes, especially offshore
- Validation/comparison of model results

Motivation

- The planned development of many large new offshore wind farms has increased the need for further understanding of the expected influence of wind farm wake between wind farms.

Data source

- In order to investigate external wake effects we have chosen to use observations from satellite remote sensing radar images.
- The study is based on images from Envisat Advanced Synthetic Aperture Radar (ASAR) observed during the years 2002-2012.
- These images cover 400-km swaths and the spatial resolution of derived wind fields is 1 km.

ASA_WSM_1PNPDK20091108_204510_000000912084_00086_40220_1156.N1 with NOGAPS Wind Directions
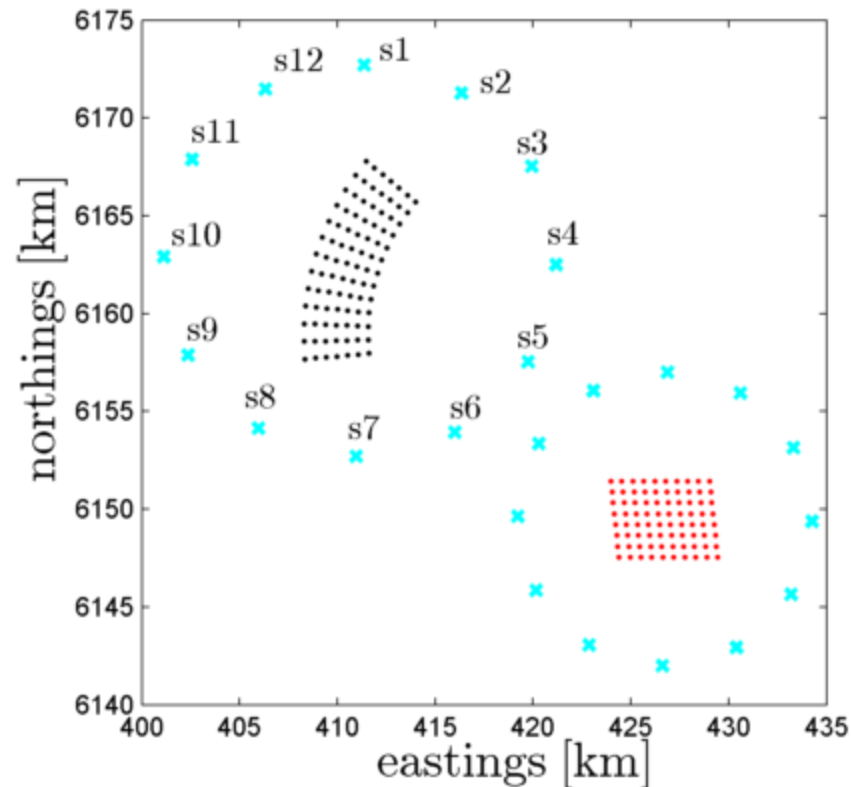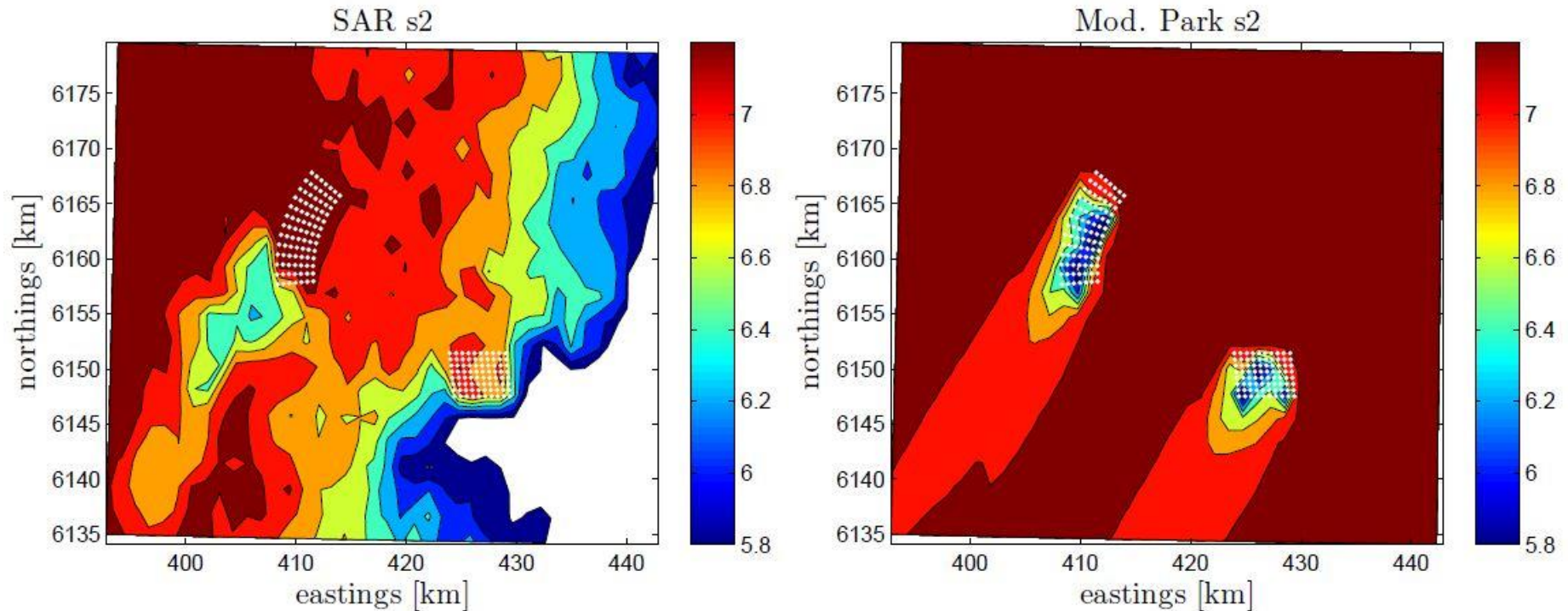
Wind Speed (m/s)

Wind Speed (knots)

5   DT

Geo-located averaging

- The wind farm wake is quantified within 12 directional sectors at Horns Rev 1 and 2 wind farms in the North Sea.
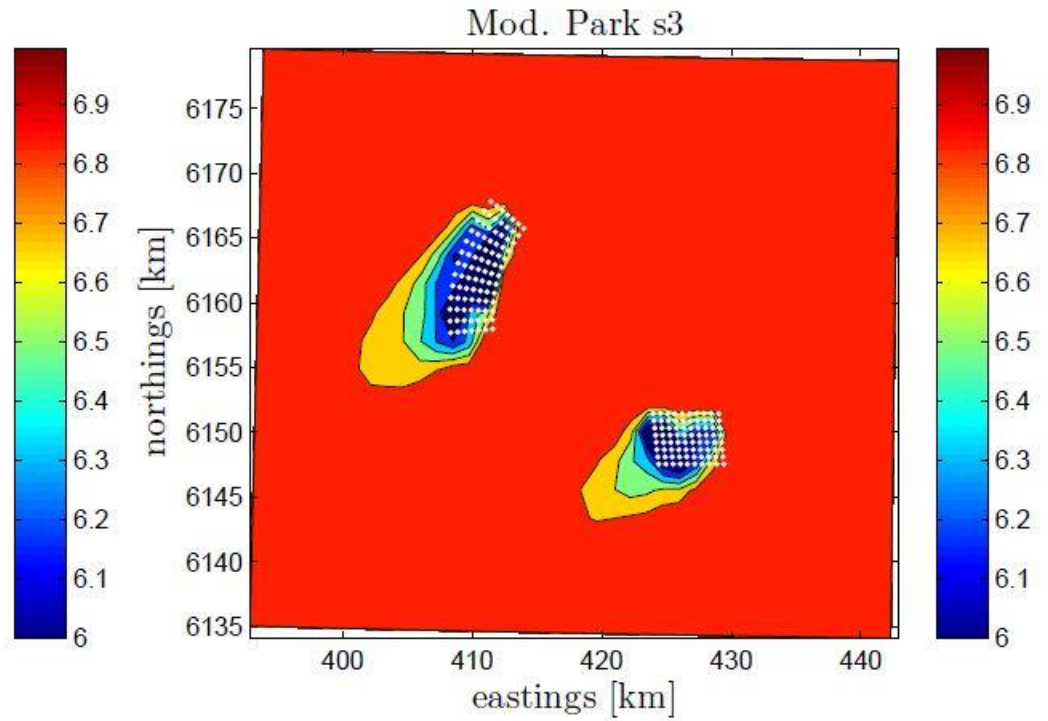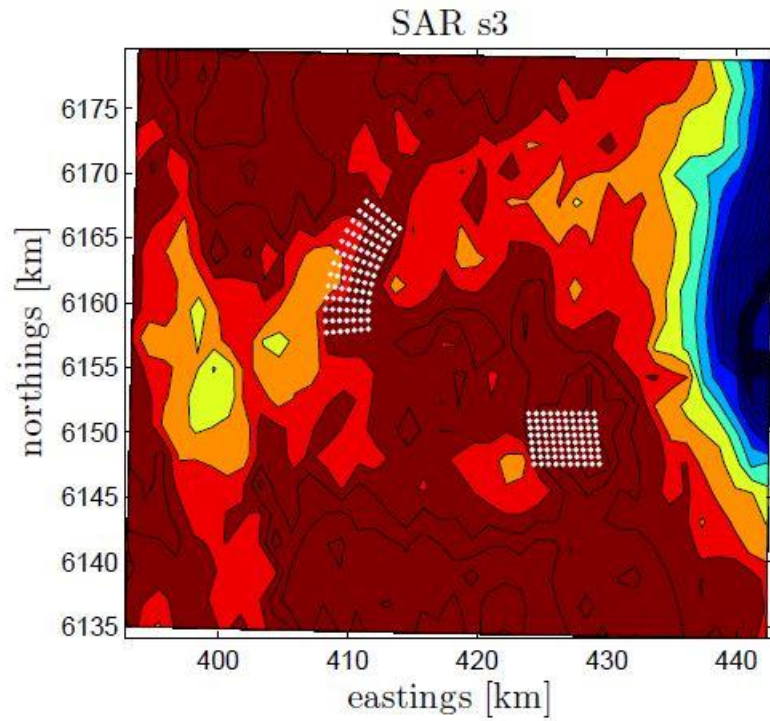
Geo-located averaging Sector 2: SAR data and PARK model results

Average wind field
based on 7 SAR wind maps

Geo-located averaging Sector 3: SAR data and PARK model results

Average wind field
based on 12 SAR wind maps

**Geo-located averaging: Interpretation of results**

SAR data

- The study reveals clear gradients in the coastal mean wind field at all sites and a wind speed deficit from the free-stream conditions.
- The number of samples is small.
- The bins represent a 30-degree range of wind directions.
- Both conditions were making it difficult to clearly identify the wind farm wake for some of the sectors.
- In addition bathymetry effects appear in the SAR wind fields.

PARK model

- The PARK model results compare to SAR data in regard to the direction and size of wake even though the coastal gradient is not modelled by PARK.

Rotation of satellite data before aggregation

- To overcome these problems a newly developed method is applied which 'rotates' or 'aligns' as first step in one degree bins the direction of the wind farm wake. In this new reference frame, the wind farm wake regions downwind of the wind farm is thus superimposed very accurately.
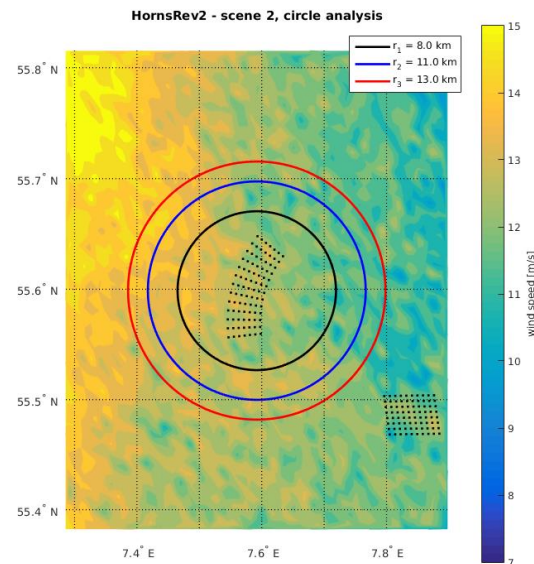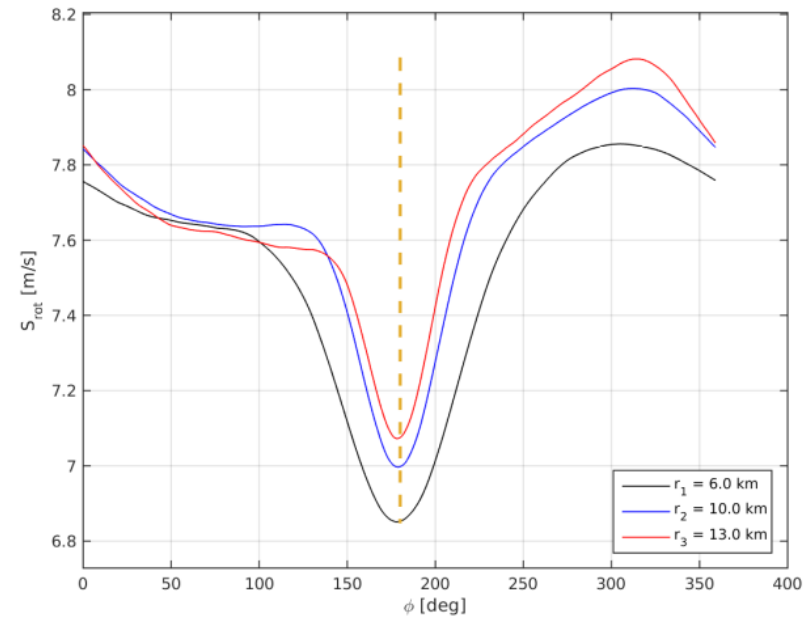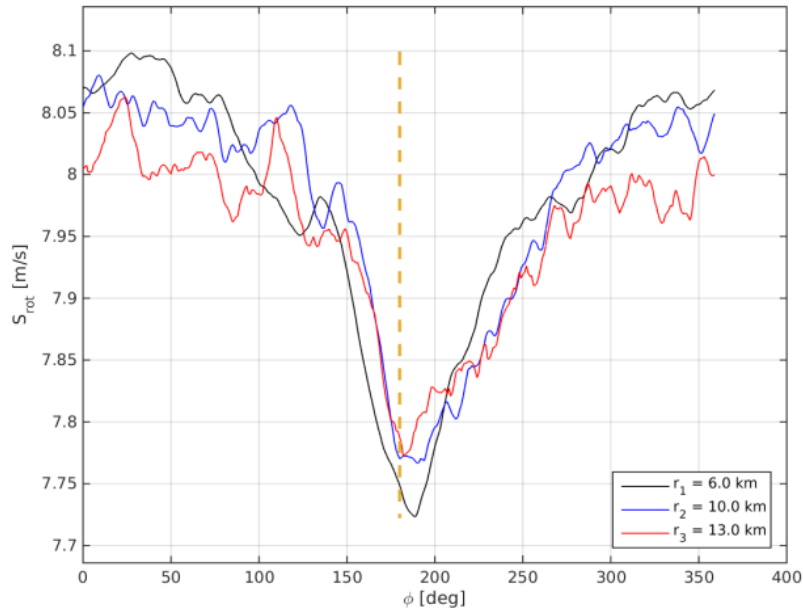
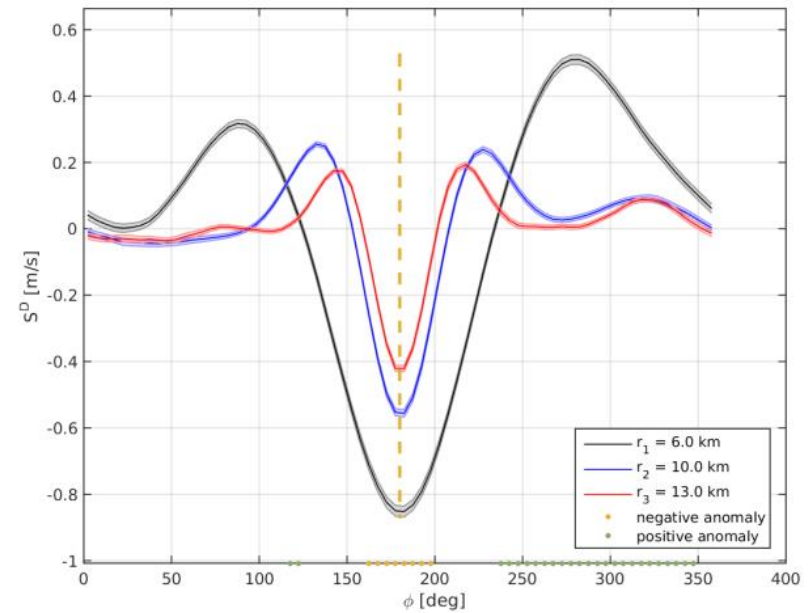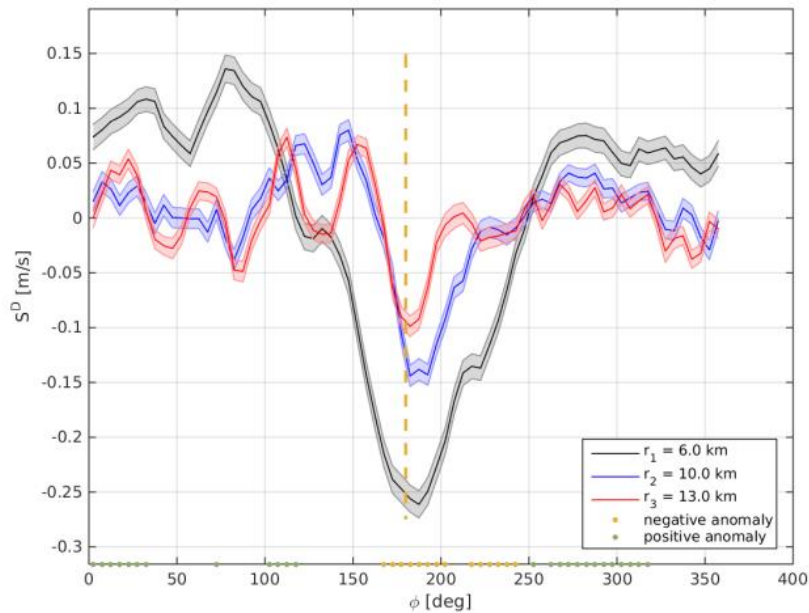# Coastal wind speed gradient: SAR data and WRF model at Horns Rev 1 (with and without wind farm)
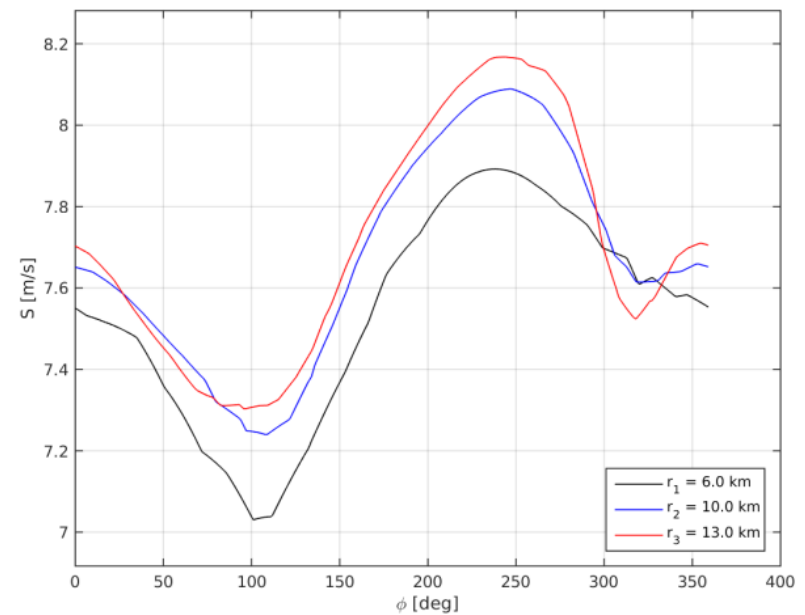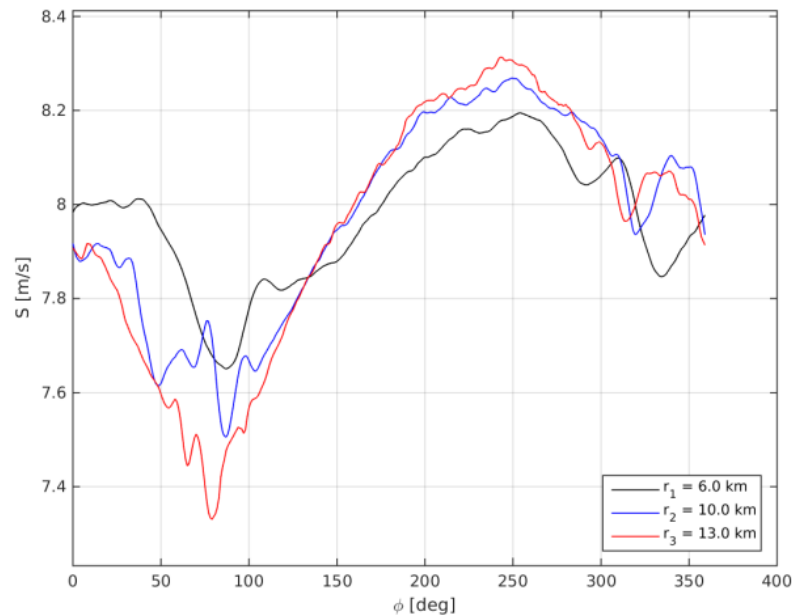
Coastal wind speed gradient: SAR data and WRF model at Horns Rev 1 (with and without wind farm)
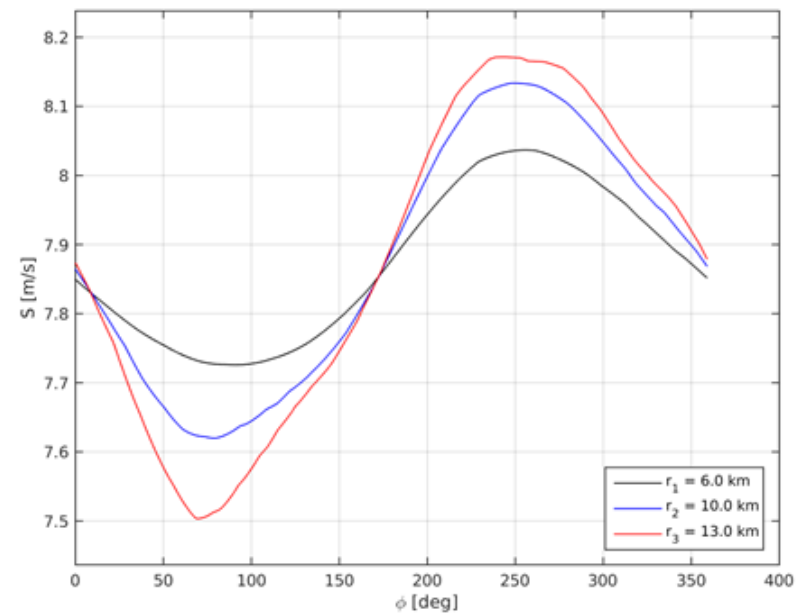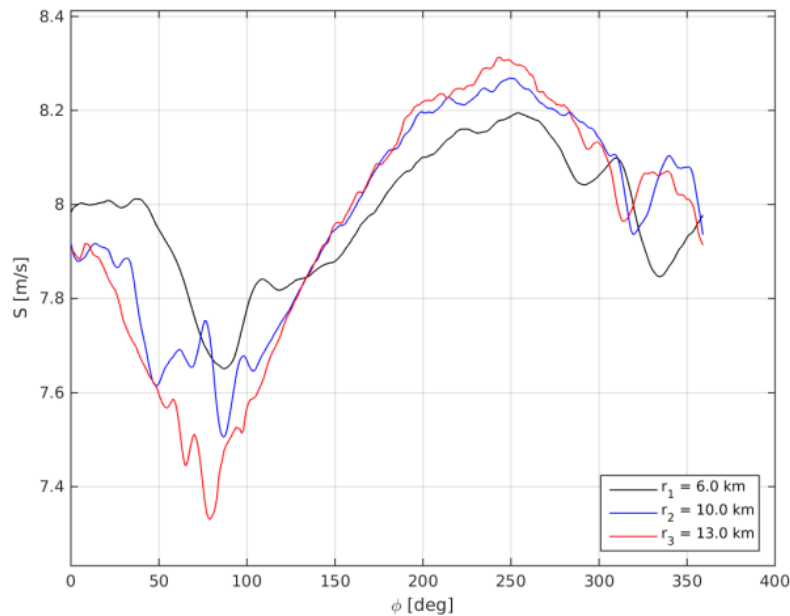
Rotated: aggregated wind farm wake from SAR data and WRF model

Rotated: aggregated wind farm wake velocity deficit normalized with side lobe winds SAR data and WRF model results

Rotation: Interpretation of results

- By applying the new methodology using rotation of the SAR-based wind fields and WRF model results comparable aggregated wind farm wake results are obtained.

- The SAR-based findings strongly support the model results at Horns Rev 1.

- The new methodology increases the number of samples, aligns the wind direction of inflow much more accurately (1° bins) and in most cases but not always overcome the coastal wind gradient.

- The most convincing results are obtained for the wind wake deficit results in which the side lobe winds are used for normalization.

- It could be possible to compare to WAsP and Fuga model results to assess in particular the far-field wake effects.

Further reading (in review):

Using satellite SAR to characterize the wind flow around offshore wind farms

9 **Charlotte Bay Hasager[1,*], Pauline Vincent[2,†], Jake Badger[1,†], Merete Badger[1,†], Alessandro Di**
10 **Bella[1,†], Alfredo Peña[1,†], Romain Husson[2,†] and Patrick Volker[1,†]**

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