Comparisons of winds from satellite SAR, WRF and SCADA to characterize coastal gradients and wind farm wake effects at Anholt wind farm

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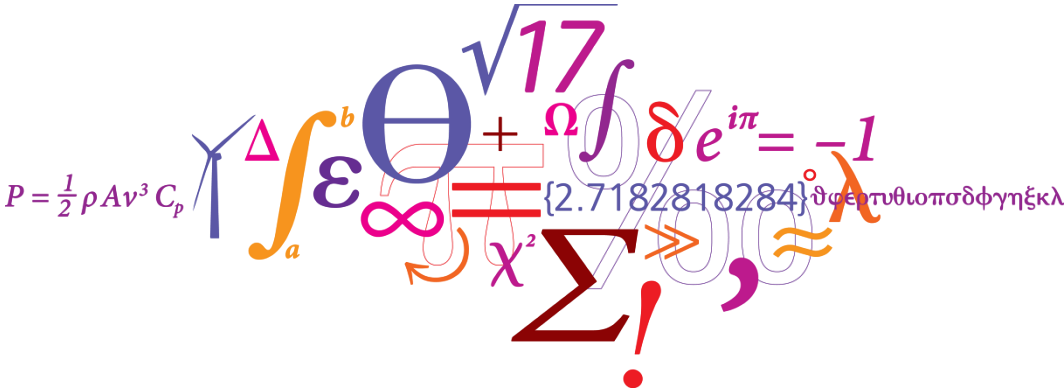
News on satellite SAR



Vindkraftnet meeting, Ørsted, 9 April 2018

DTU Wind Energy

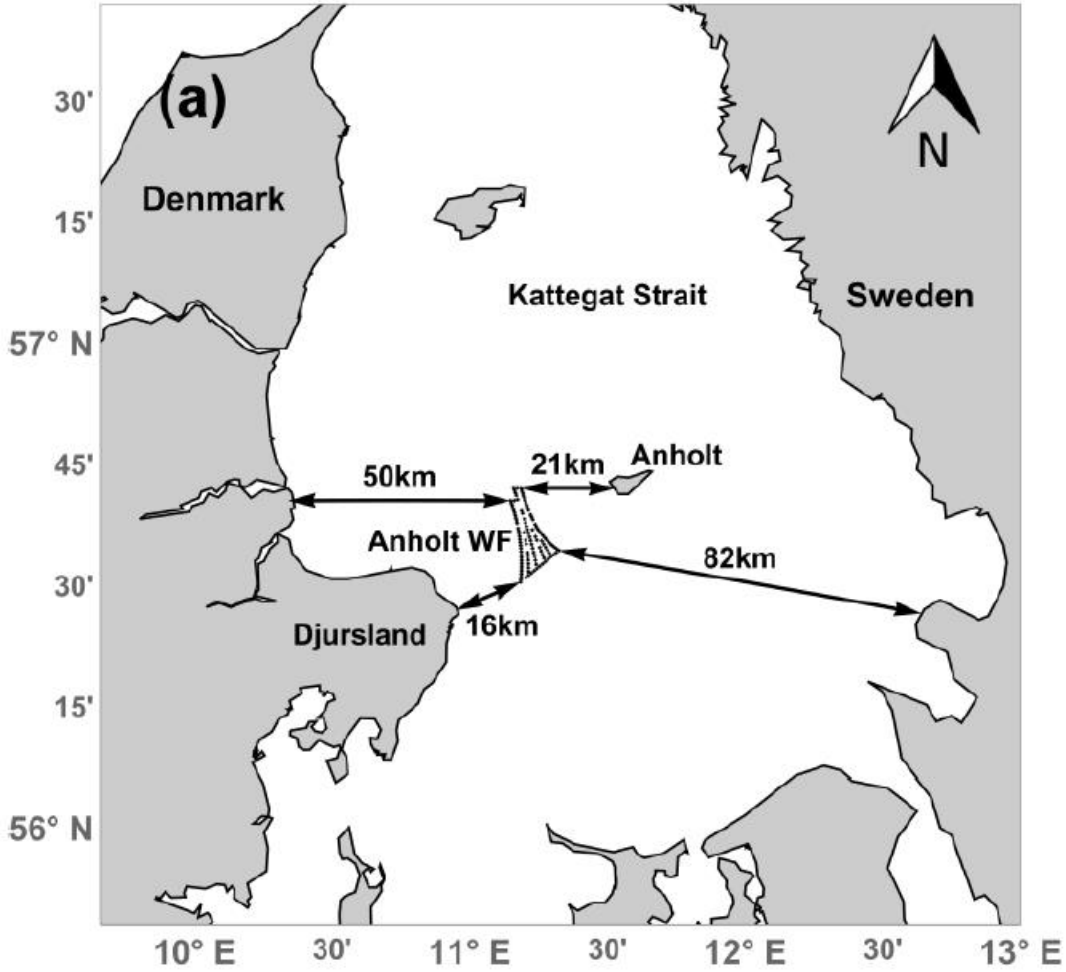
Department of Wind Energy

Content

- Anholt wind farm
- Wind speed data
- Coastal wind speed gradient
- Wind farm wake

- Satellite SAR news

Anholt wind farm in Kattegat



Anholt wind farm

2013

Wind speed data

SCADA:	01.2013 – 06.2015	(2.5 years, 10 minute)
Envisat ASAR:	08.2002 – 04.2012	(10 years)
Sentinel-1:	12.2014 – 05.2017	(3 years)
WRF:	01.2002 – 12.2017	(16 years, hourly)

SCADA

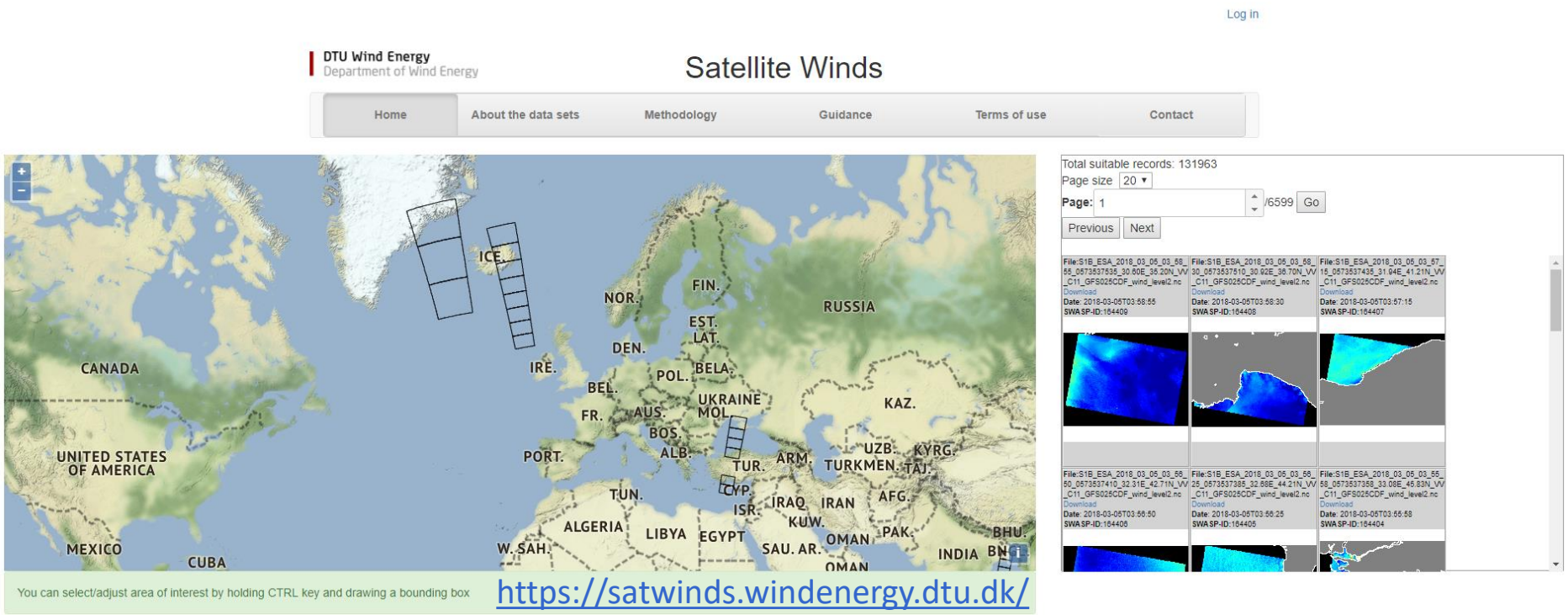
Exclude SCADA data when wind turbines are not grid connected or are not producing power during a complete 10-minute period or is curtailed.

The remaining periods are applicable for analysis after a final examination of the power curve.

Peña, A. et al., 2017. On wake modeling, wind-farm gradients and AEP predictions at the Anholt wind farm. *Wind Energy, Science Discussions*, 2017, pp.1–18.

Satellite SAR wind data archive at DTU

- 30,000+ ENVISAT ASAR scenes (2002-2012)
- 100,000+ Sentinel-1 A/B SAR scenes (2014->)

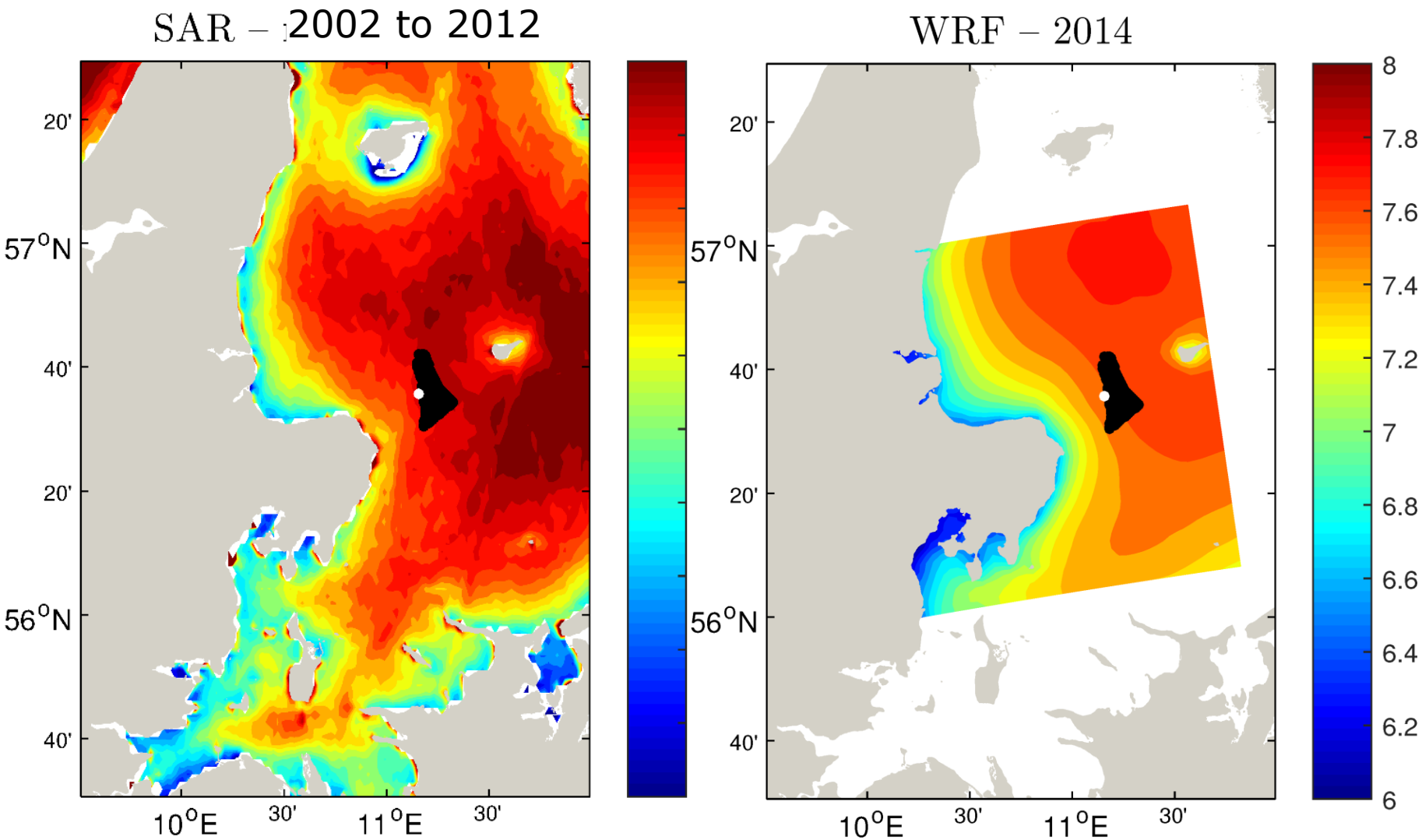


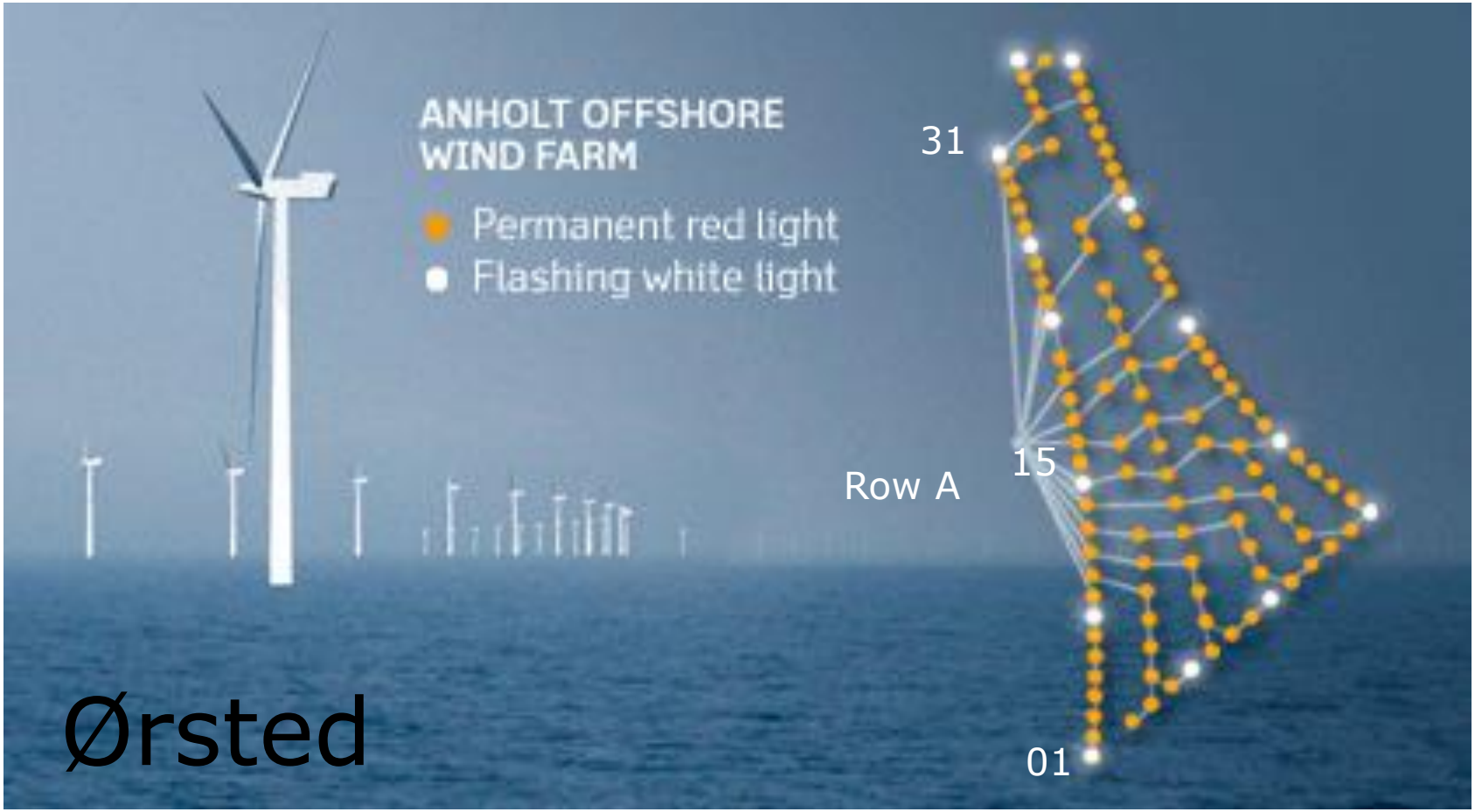
WRF

- The total simulated period covers 28 years from 1990 to 2017.
- The computational domain consists of three nests with an 18 km, 6 km and 2 km grid spacing.
- The outermost domain is forced by ERA-Interim Reanalysis. Using Yonsei University Scheme Planetary Boundary Layer scheme.

Further details in Peña, A. & Hahmann, A.N., 2017. *30-year mesoscale model simulations for the "Noise from wind turbines and risk of cardiovascular disease" project*, DTU Wind Energy E, Vol. 0055.

SAR and WRF mean wind speed at 10 m



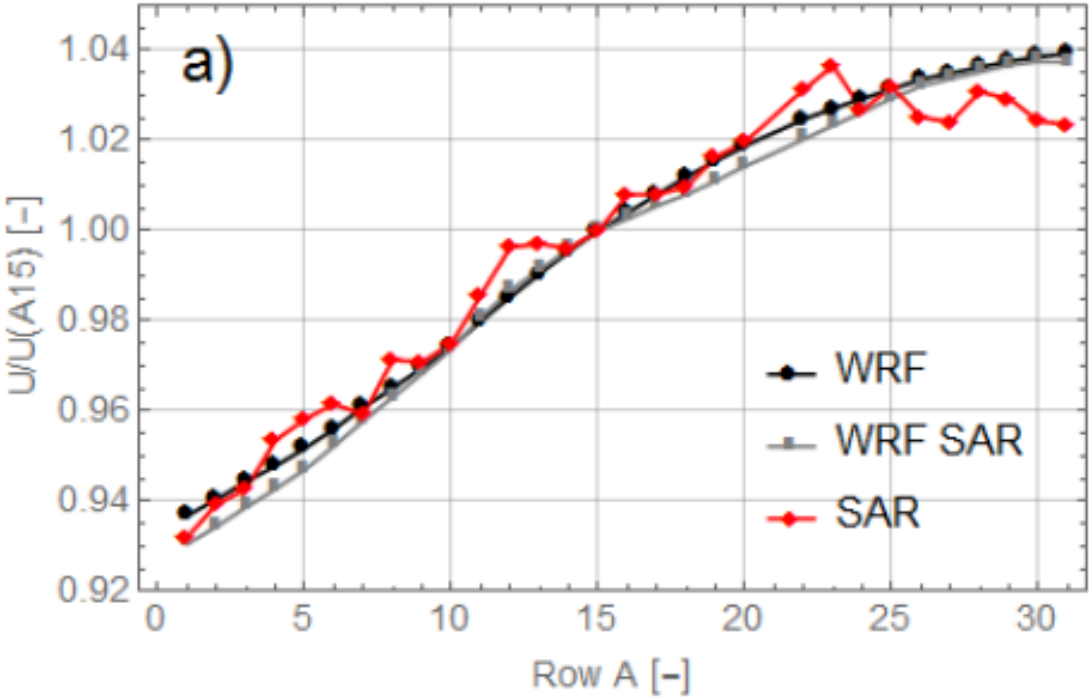

ANHOLT OFFSHORE
WIND FARM
Permanent red light
Flashing white light
31
15
Row A
01
Ørsted

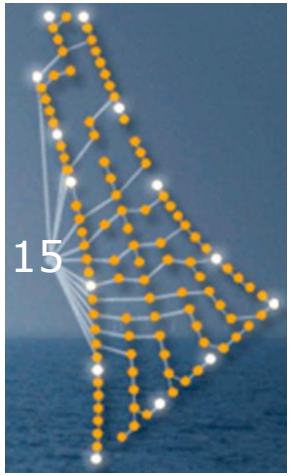
Wind conditions

Criteria

- Wind direction between 245° and 275°
- Above cut-in wind speed
- Data available for all turbines at Row A

SAR vs. WRF

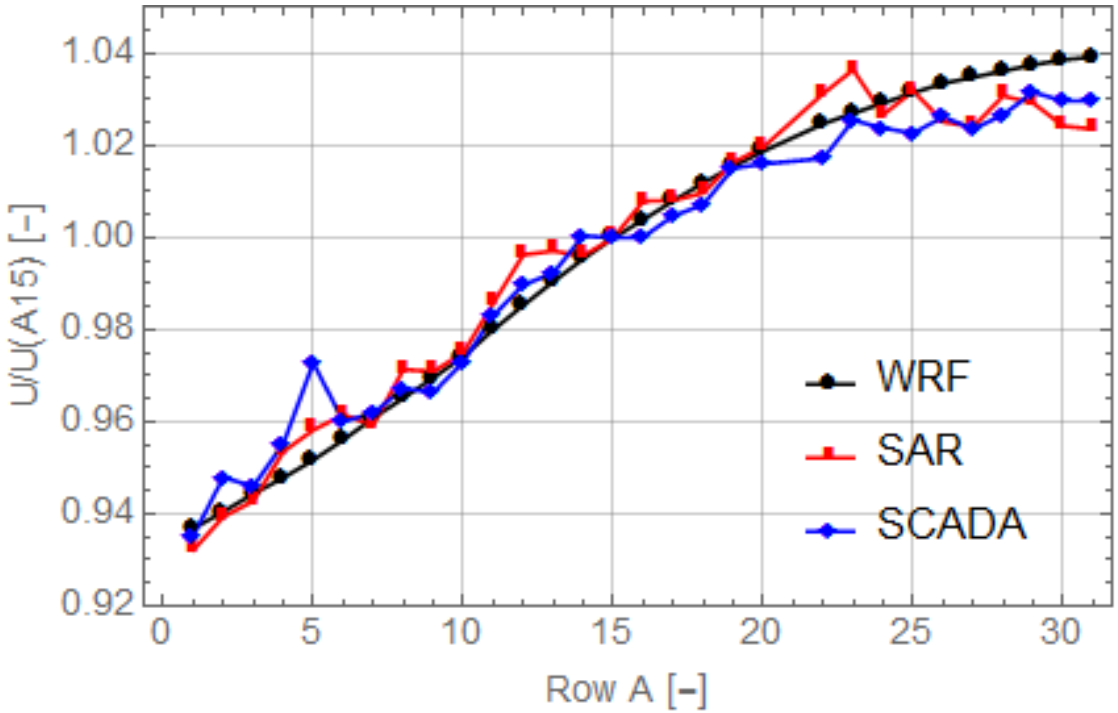


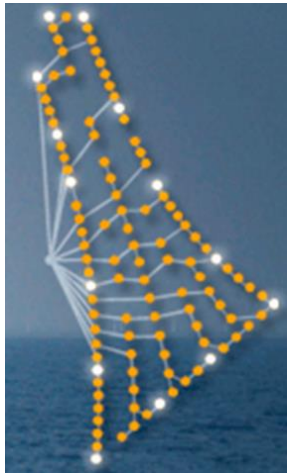


WRF (2002 to 2012) and WRF collocated with SAR.

The maximum deviation of mean wind speeds from the two WRF data sets is below 0.5%.

SAR vs. WRF vs. SCADA



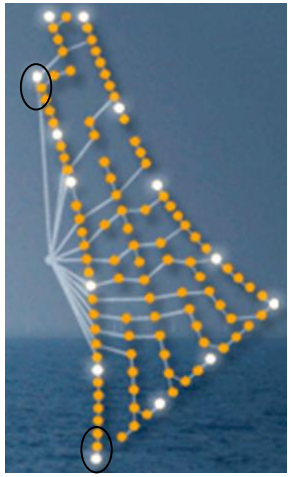


WRF (2002 to 2012), SAR (2002-2012) and SCADA (2013-2015).

Wind speed variation between North and South turbines at Row A

Table 3: Sample size and difference between most Northern and Southern turbines $\Delta U_{N,S}$ (three turbine location averaged).

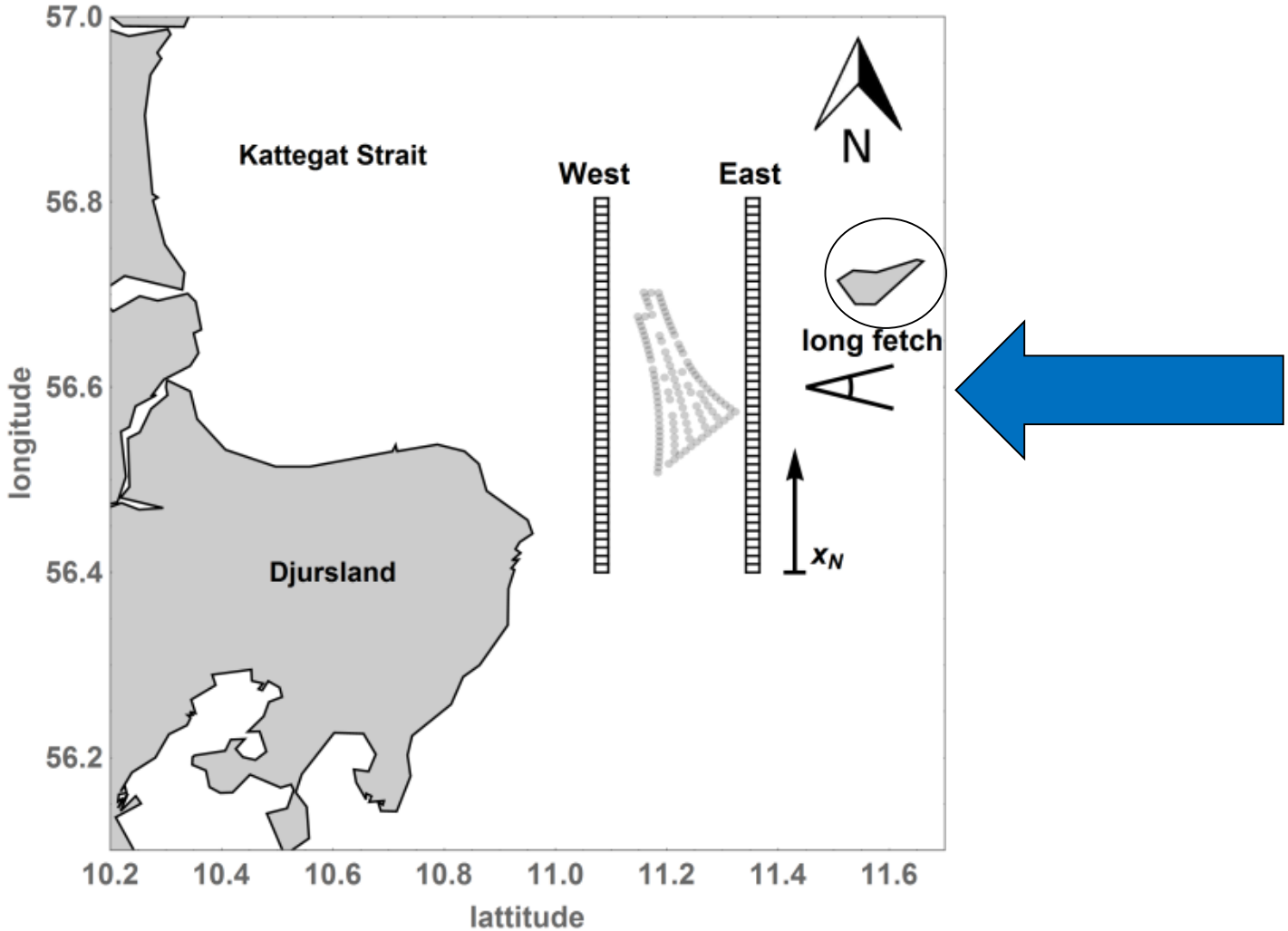
	SAR	WRF SAR	WRF	SCADA
Samples N [-]	72	72	10524	4625
$\Delta U_{N,S}$ [m/s]	0.92	1.02	0.98	0.95
$\Delta U_{N,S}/U_{15}$[%]	8.8	10.3	9.8	8.7



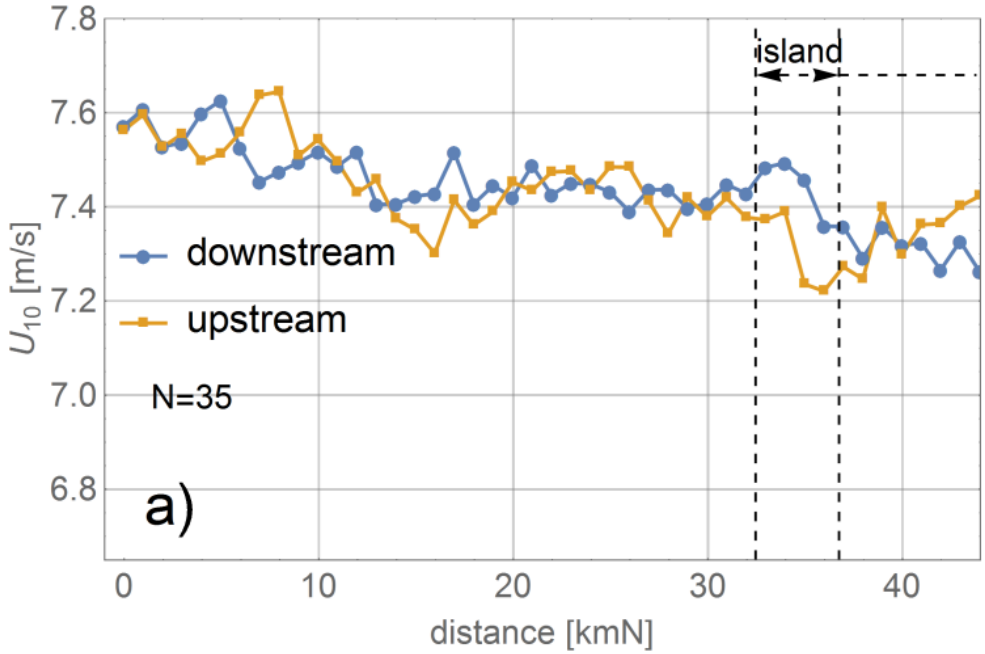
$$\Delta U_{N,S} = \sum_{i=A28}^{A31} U_i - \sum_{i=A01}^{A03} U_i$$

Wind farm wake analysis using SAR only

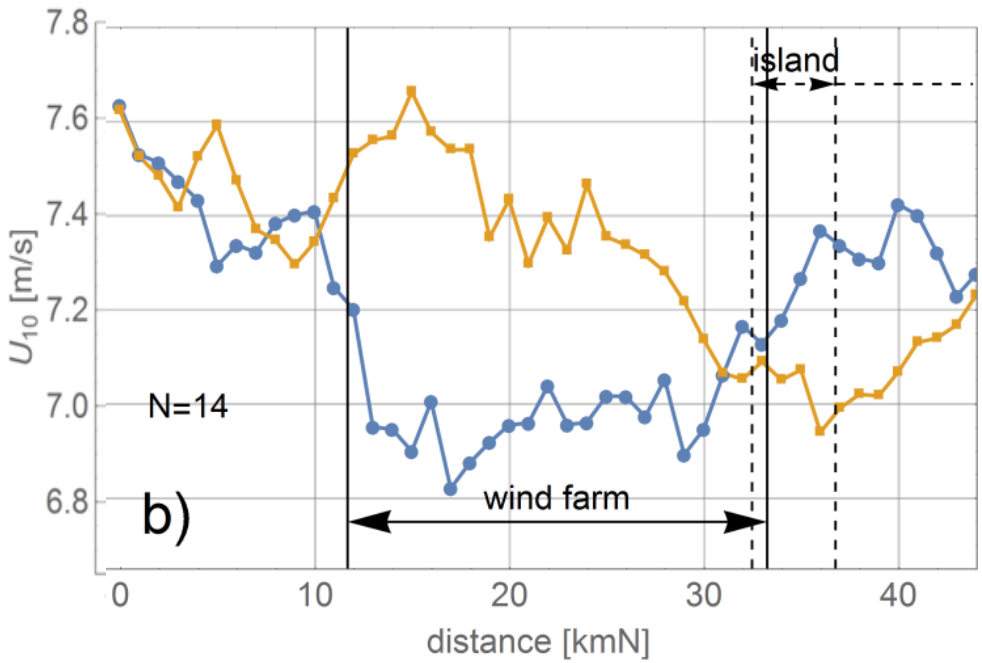
Two horizontal transects (East and West)



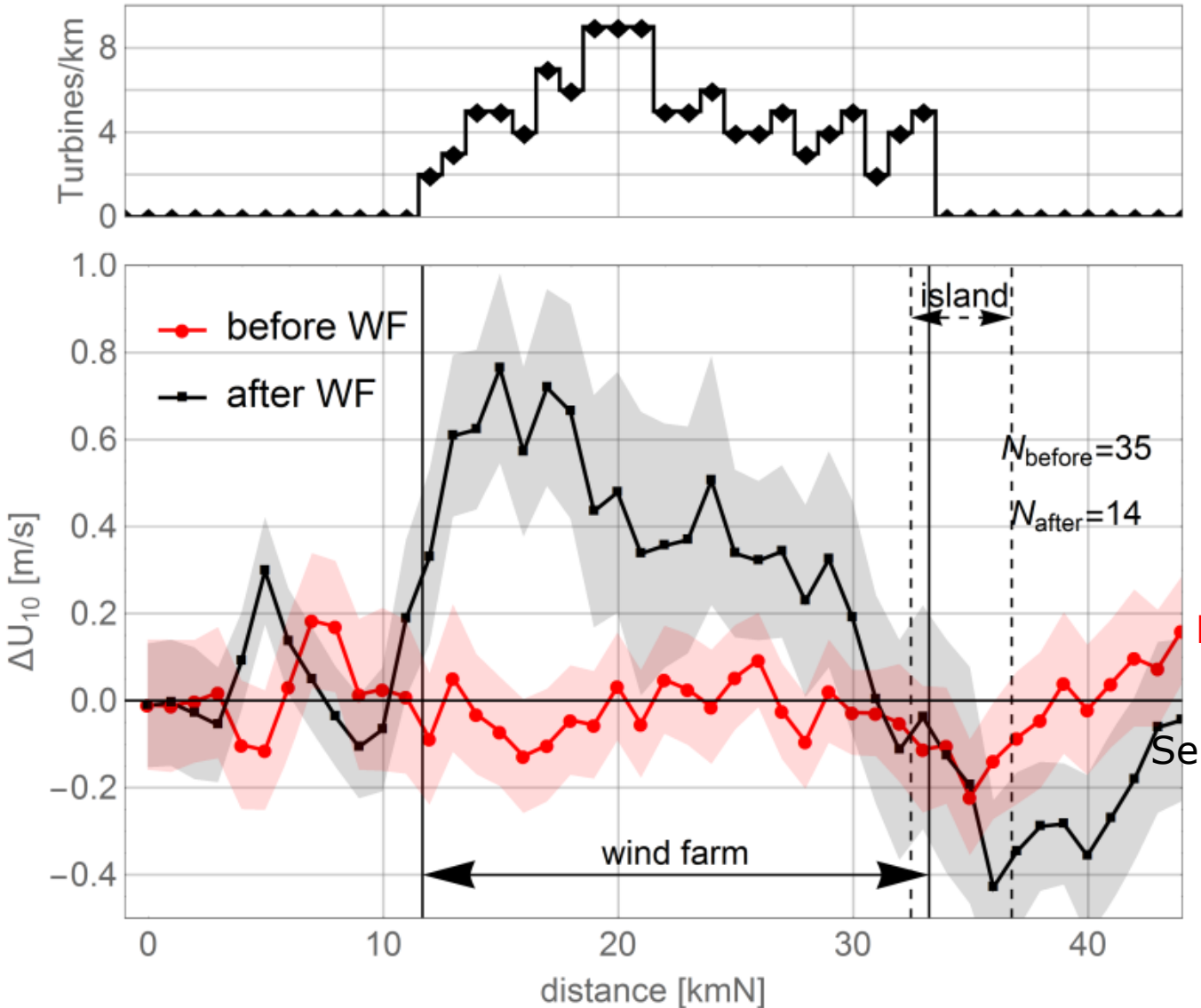
Before wind farm construction



After wind farm construction



Difference (East – West) and ± one std.dev.



Envisat 2002-2012

Sentinel-1 2014-2017

Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2018-2
Manuscript under review for journal Wind Energ. Sci.
Discussion started: 1 February 2018

Applications of satellite winds for the offshore wind farm site Anholt

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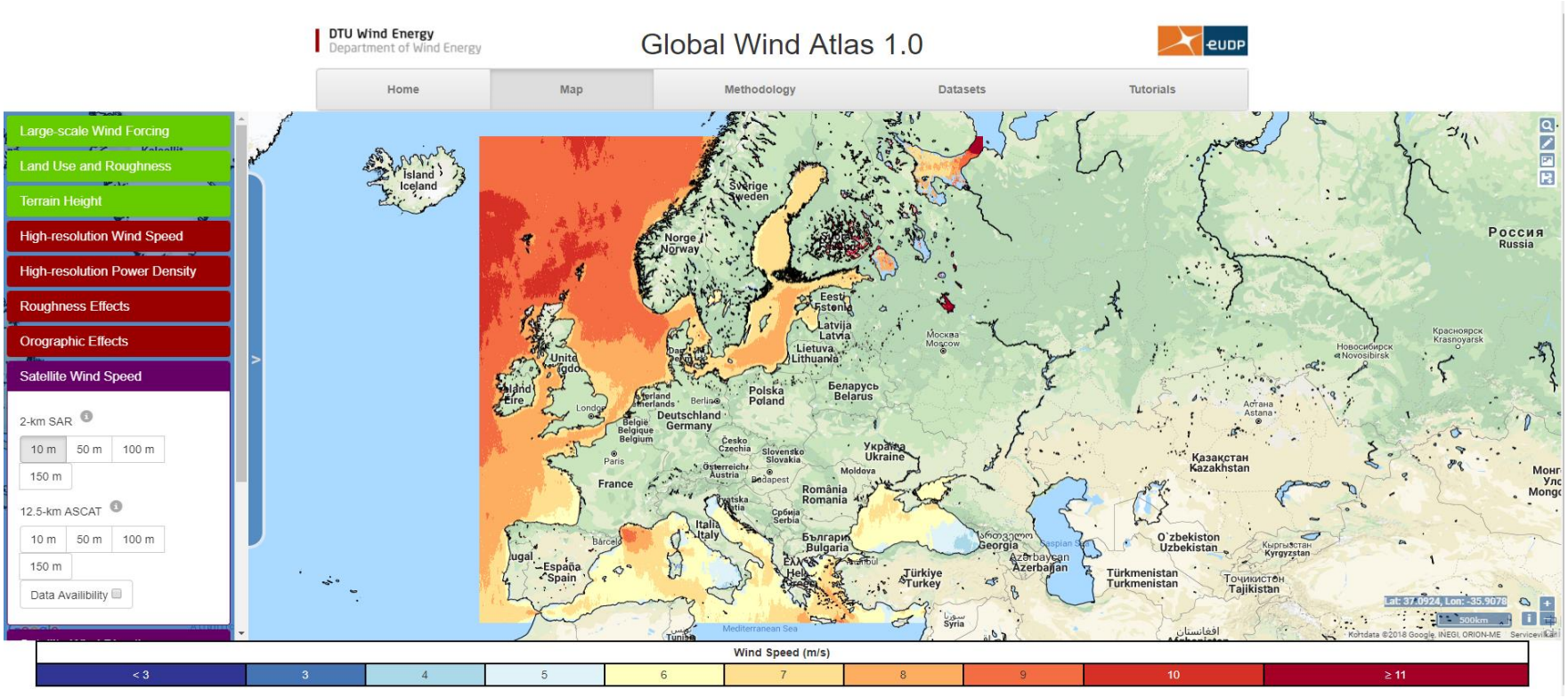
https://www.wind-energ-sci-discuss.net/wes-2018-2/

Satellite SAR wind news

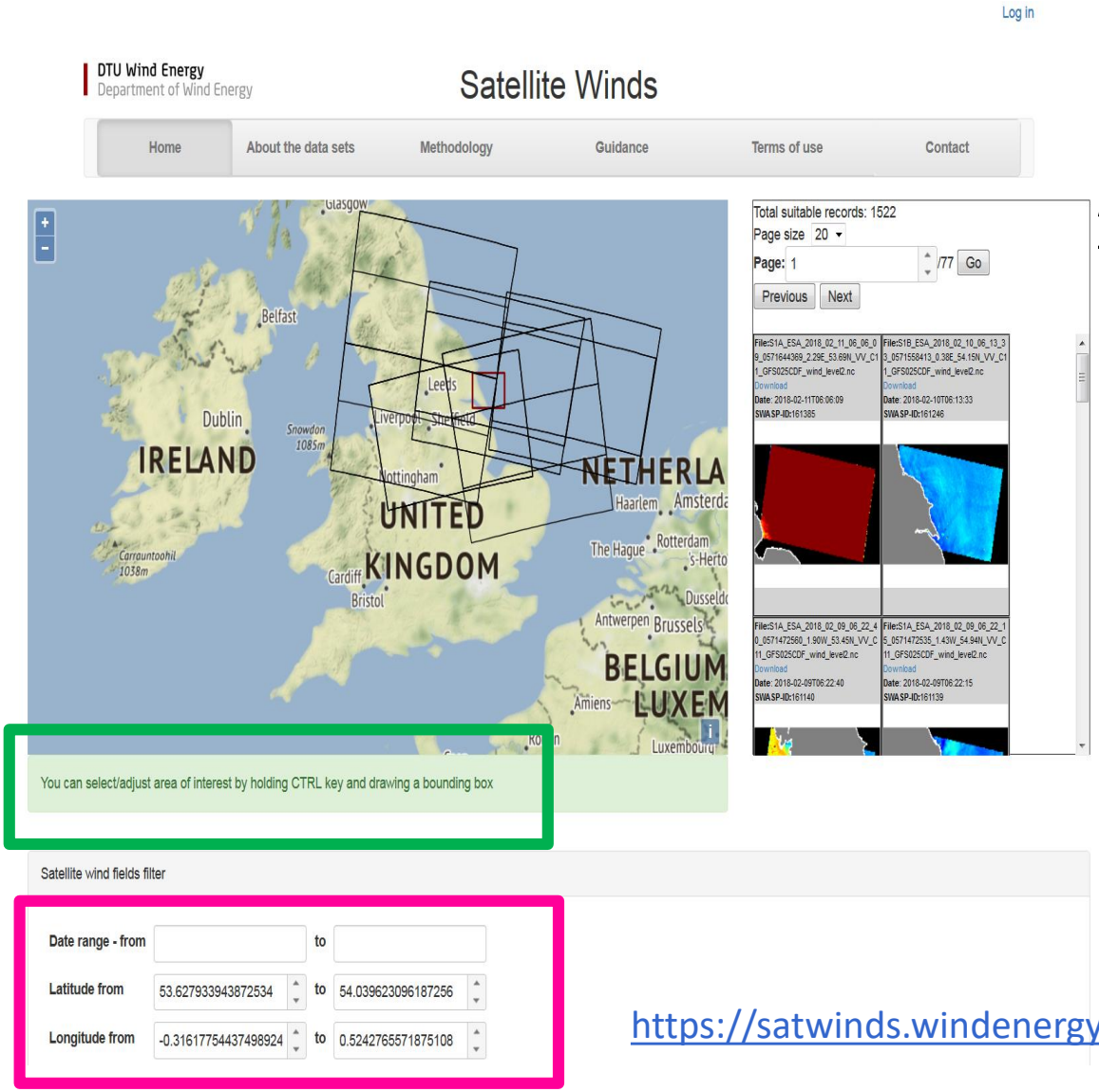
Global wind atlas

http://science.globalwindatlas.info/science.html

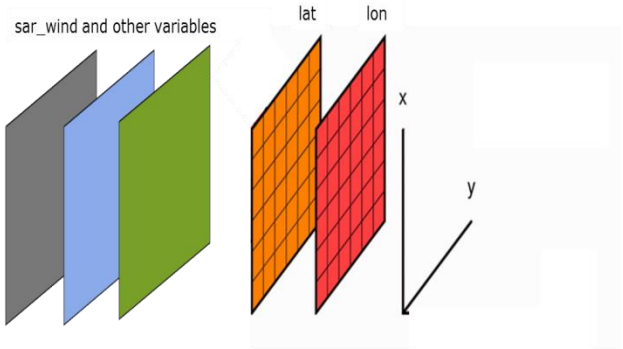


DTU Wind Energy satellite data station

Processed wind maps:
Define Area Of Interest (AOI)



AOI: Westermost Rough
Time period: Entire archive
➢ 1522 images



Format of single netCDF file

https://satwinds.windenergy.dtu.dk/

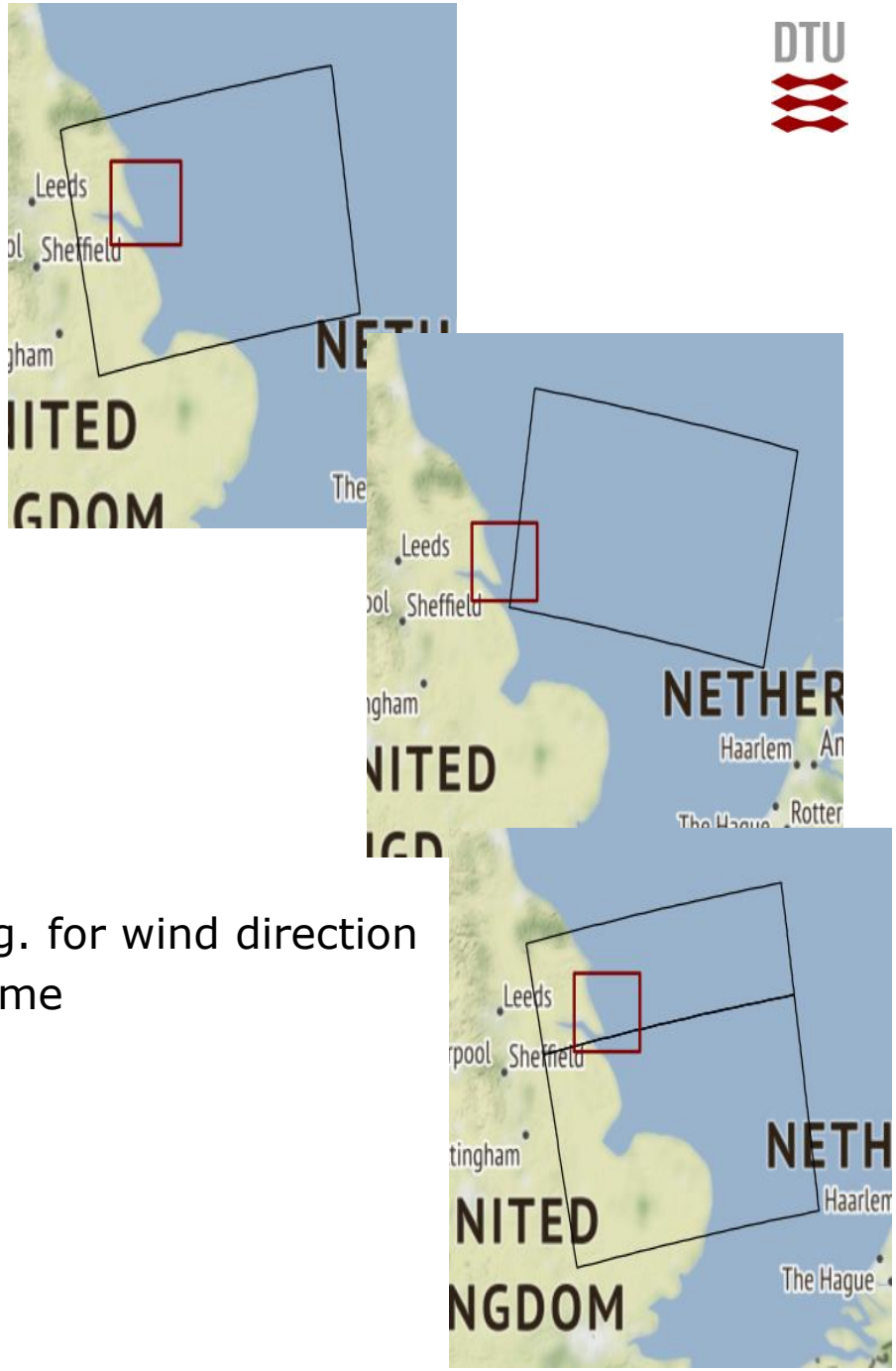
Ease of use

Westermost Rough example:

- More than 1500 single images
  - 1500 coordinate systems
  - 62GB of data

- Different image coverage
  - Full coverage
  - Partial coverage
  - Subsequent images

- Quantitative studies: Filtering data e.g. for wind direction
  - Data format makes this cumbersome



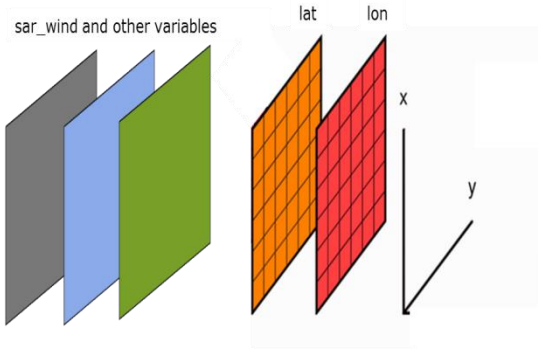
Solution

- Single netCDF with “time series” of SAR wind fields

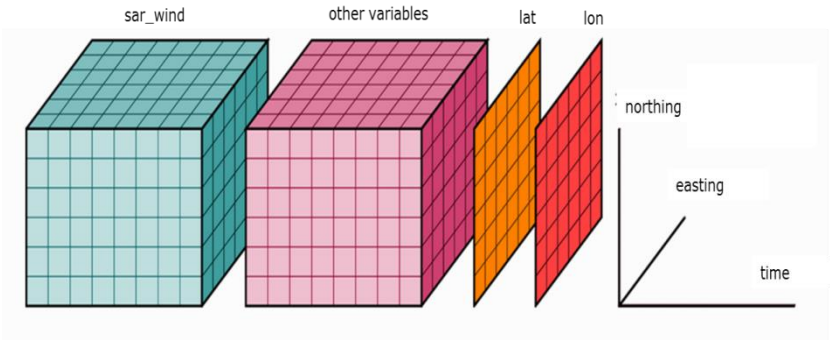
- Select AOI on the order of 25 km by 25 km
- Make a UTM coordinates (meters)
  - Nearest neighbour (accept up to 250m shift)
  - Only full coverage of AOI => constant sampling
  - Keep all information
- Implementation in python using xarray
- Output: netCDF file format

For the example:

- 1500 file to 1 file
- 1500 irregular grids to 1 UTM grid
- 62GB to 500MB (15min calculation)

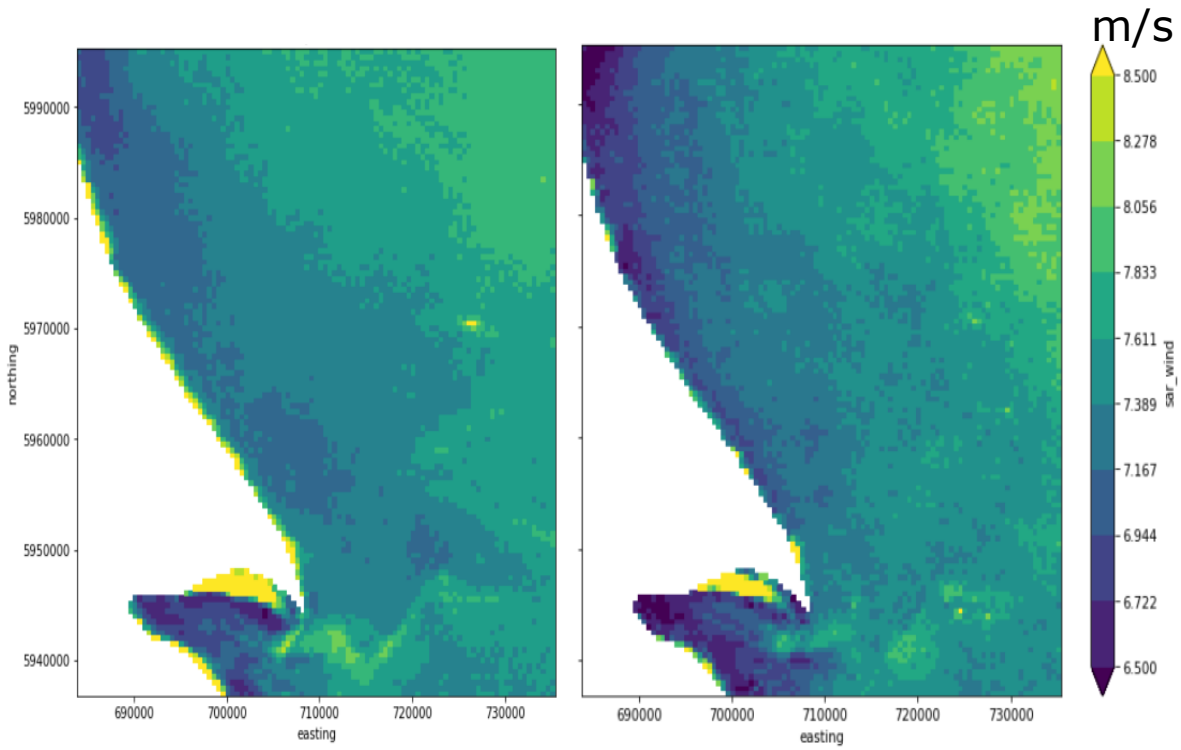


1500 single netCDF file



1 single netCDF file

Mean wind maps and coastal gradient study



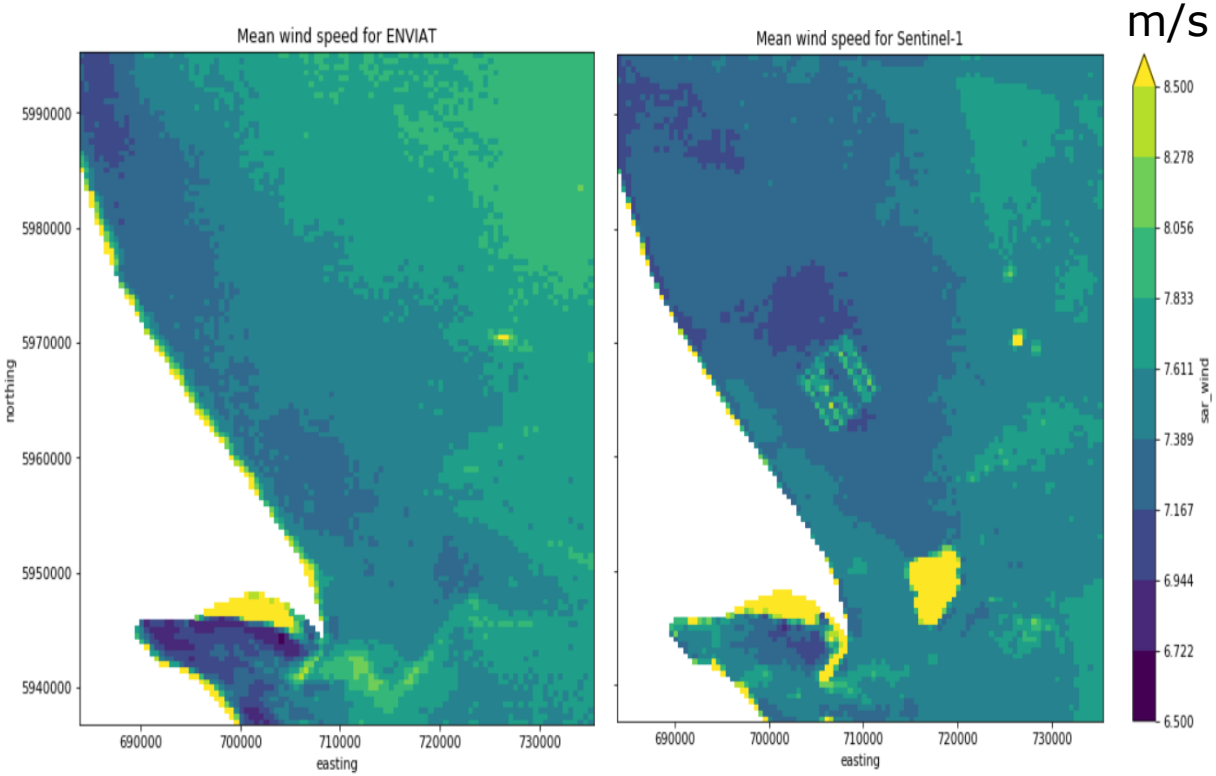
- Consistent sampling is important for wind speed gradients
- No borders between images

Mean wind speed from Envisat

Left: All wind directions (445 images)

Right: Images with wind directions between 240 and 300 degrees (77 images)

Wind speeds before and after wind farm construction



Left: All wind maps before the wind farm showing mean wind speed (Envisat ASAR)

Right: All wind maps after the wind farm showing mean wind speed (Sentinel-1)

What is this good for?

Fast and easy in:

- Local reprocessing
- Filtering and selecting
- Debugging of analysis

Easily integrate other data sources:

- Can be used for validation and verification on offshore wind speeds

Acknowledgements

We would like to acknowledge:

- Ørsted and partners for granting access to data from the Anholt wind farm,
- Johns Hopkins University Applied Physics Laboratory and the National Atmospheric and Oceanographic Administration (NOAA) for the use of the SAROPS system,
- ESA for providing public access to data from Envisat ASAR,
- Copernicus for providing public access to data from Sentinel-1.