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Far-Wind Wakes Characterization using SAR Sentinel 1A/B data

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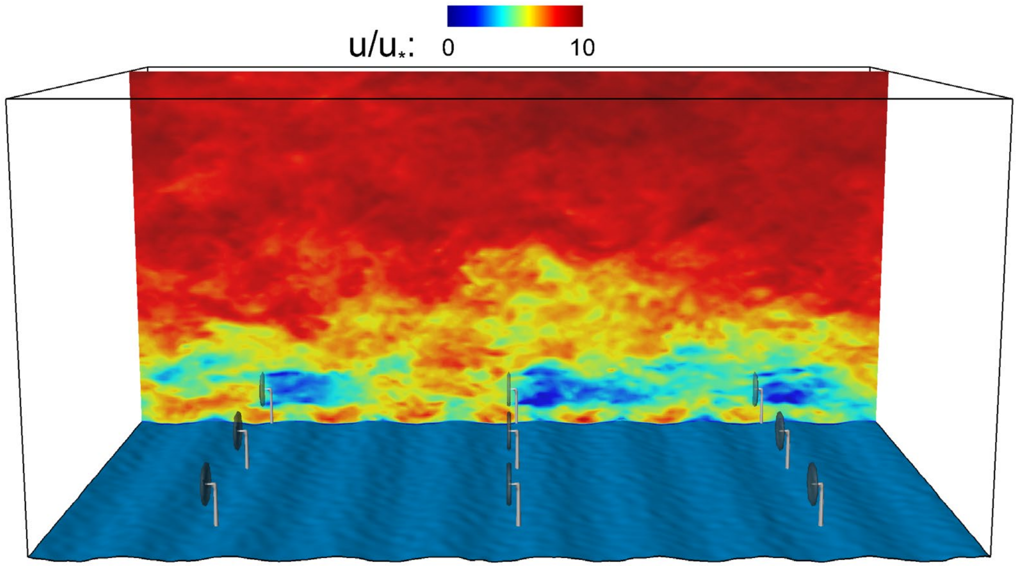
Outline

- Wind Wakes.
- SAR Wind retrieval.
- Study area and Materials.
- Research Findings.
- Conclusion &Future works.

Wind Wakes

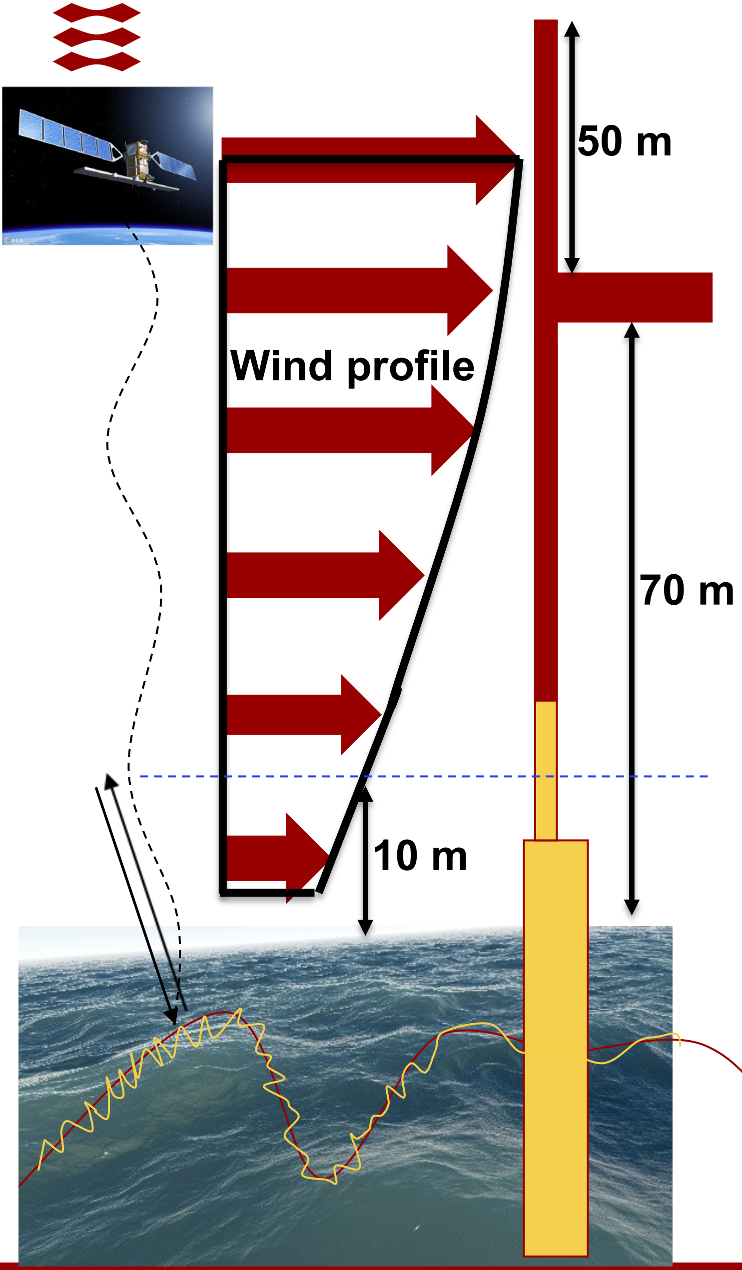
Wind wakes are:

- caused by turbines' power extraction.
- reduction in wind speed behind the turbines.
- aggregated influence.
- extended several kilometres at downstream side of the offshore wind farms (OWFs).



Large Eddy Simulation "LES" model for an offshore wind farms (***Xiao et al, 2019***)

SAR Wind Retrieval (1)



- Atmospheric flow (turbulent) can be well described by constant stress layer

$$\vec{t} = \rho u_* \vec{u}_*$$

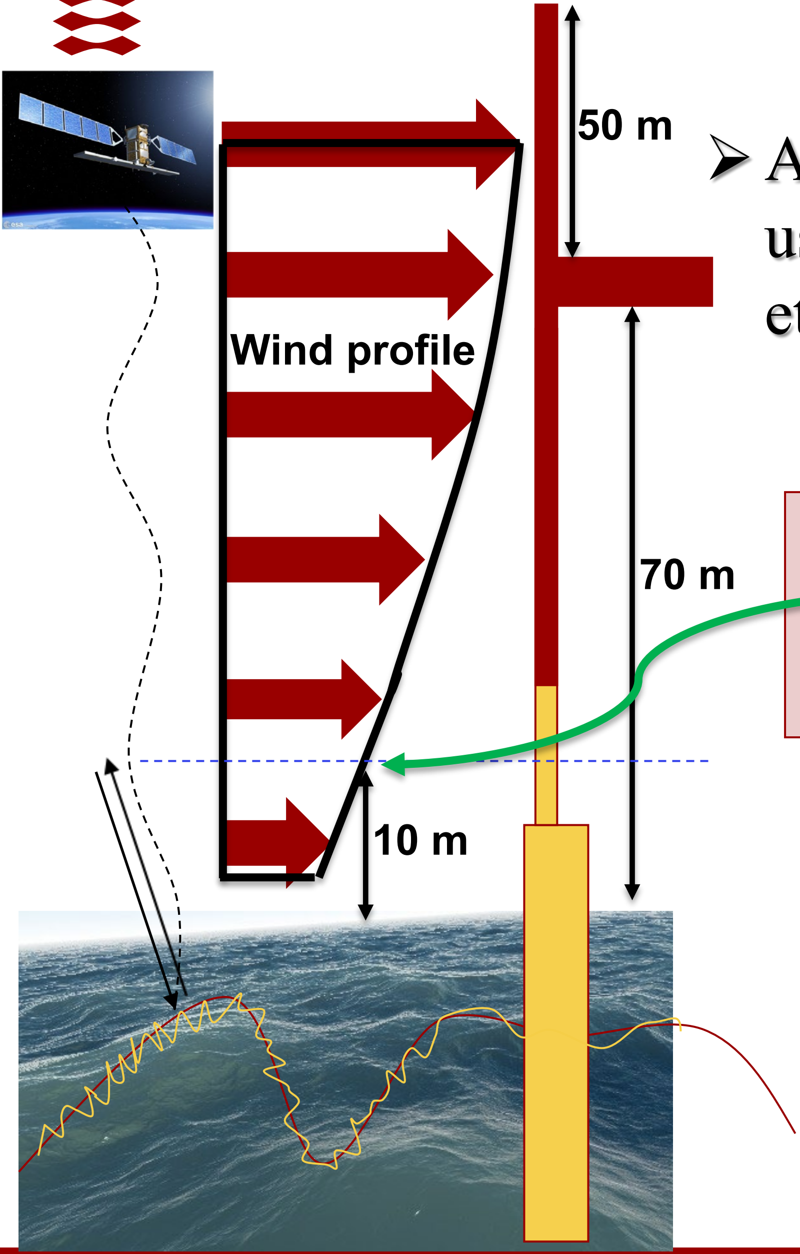
where ρ air density and u_*: the friction velocity

- Wind logarithmic profile determines the relation between near-surface wind and magnitude of stress.

$$\vec{u}(z) = \frac{\vec{y}^*}{k}\{\log\left(\frac{z+z_0}{z_0}\right) - \psi_m\left(\frac{z+z_0}{L}\right) + \psi_m\left(\frac{z_0}{L}\right)\}$$

$\vec{u}\,(z)$: wind speed at z level, z_0: sea surface roughness, ψ_m : stability-dependant gradient functions, L: Obukhov length.

SAR Wind Retrieval (2)

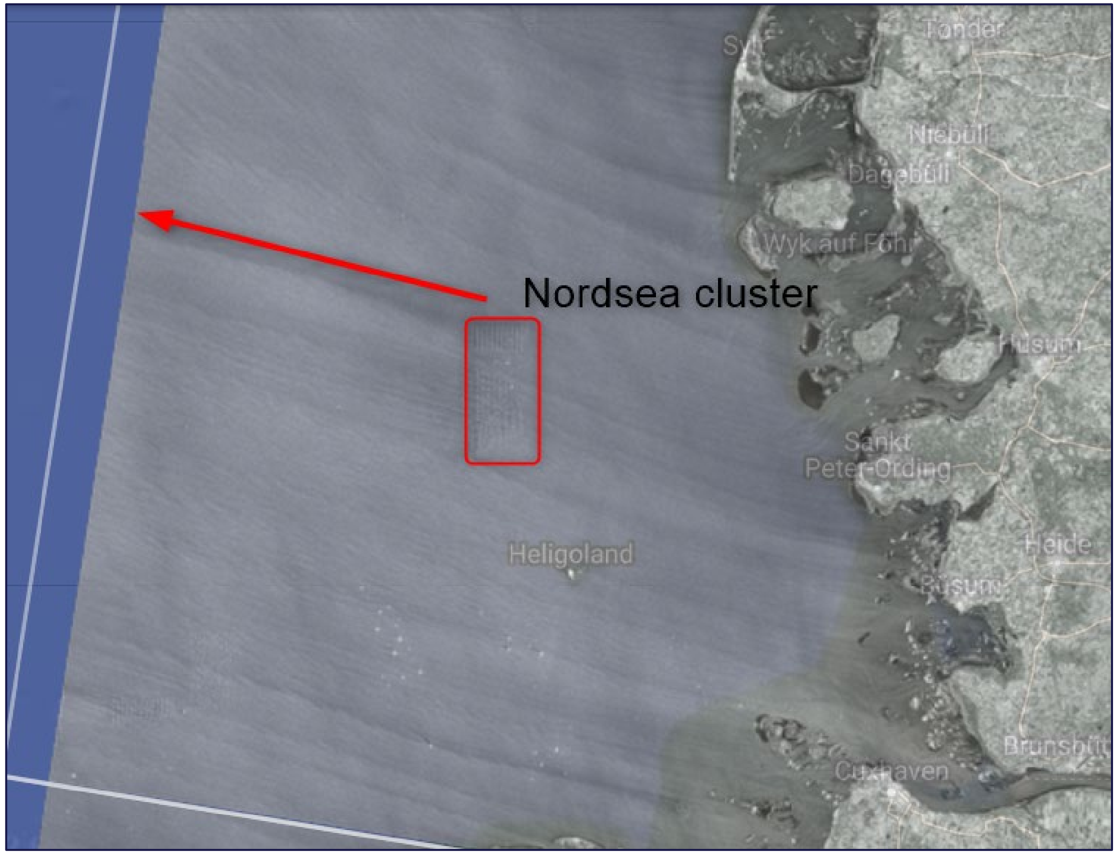


- A Geophysical model function (GMF), CMOD5.N for instance, is used to related the NRCS to the wind speed at 10 m level. (Hersbach, et al 2007)

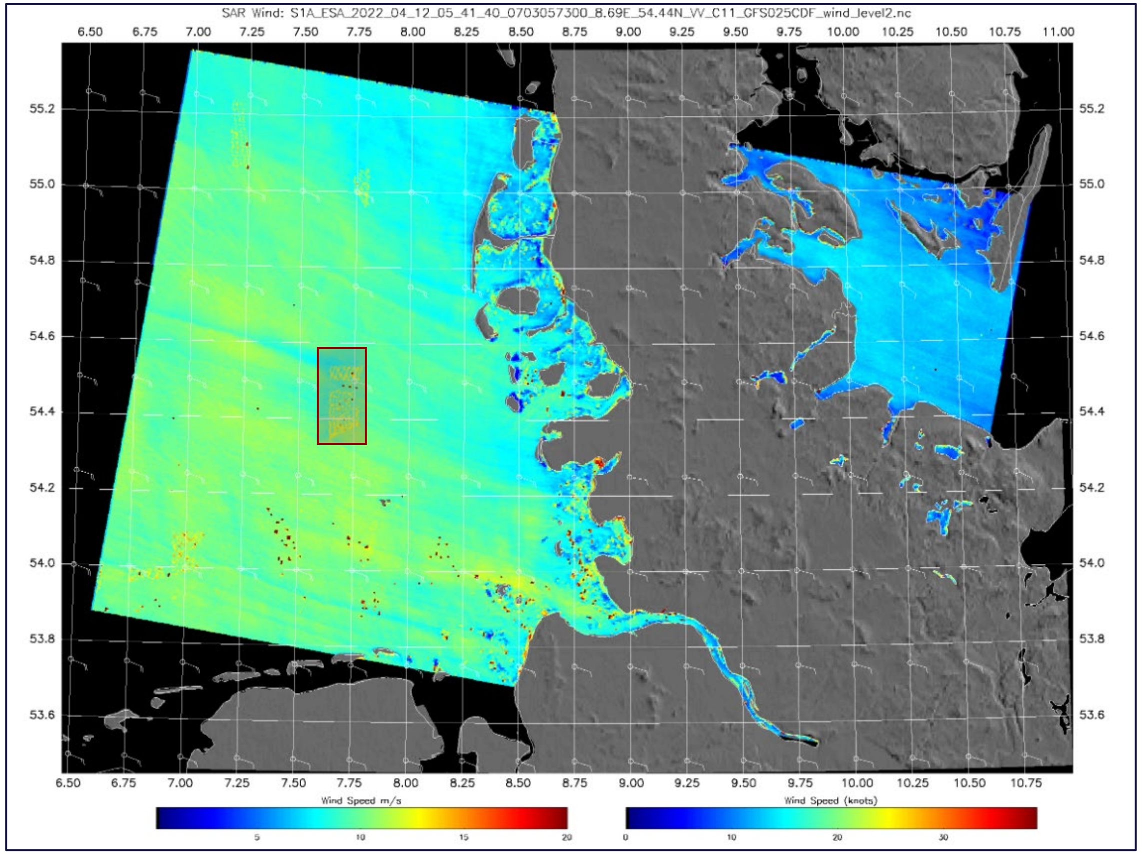
$$\sigma_0(U, \theta, \varphi) = B_0(U, \theta)\,[1 + B_1(U, \theta)\,\cos(\varphi) + B_2(U, \theta)\,\cos(2\varphi)]$$

where: σ_0: NRCS values, *U: wind speed at 10 m, θ: incidence angle, φ: radar look direction relative to wind direction, and* B_i *are tunable functions*

SAR Wind Retrieval (3)

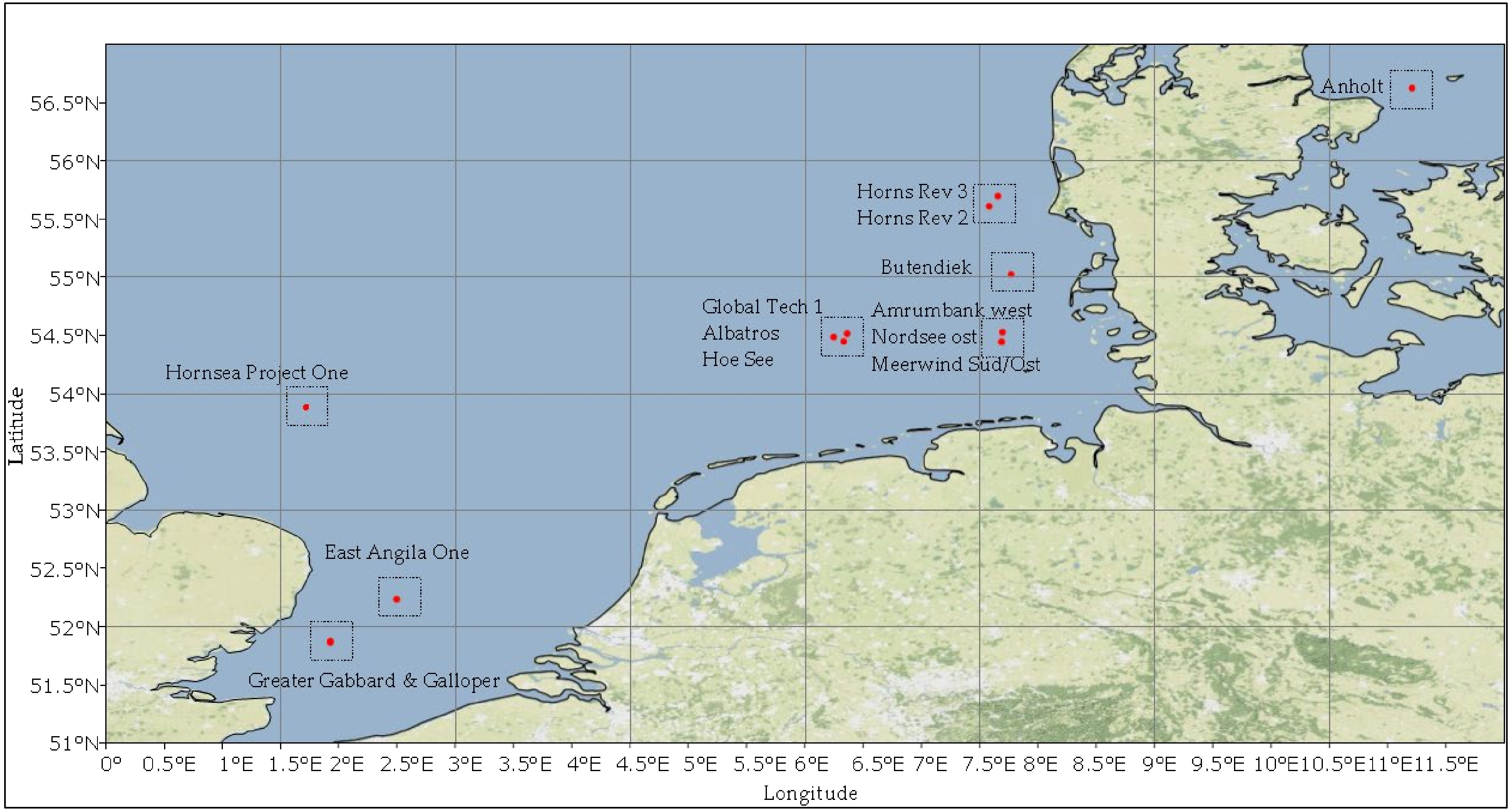


Sentinel 1A-level 1-GRDH was taken at 12th April 2022 05:41:27
https://ovl.oceandatalab.com/



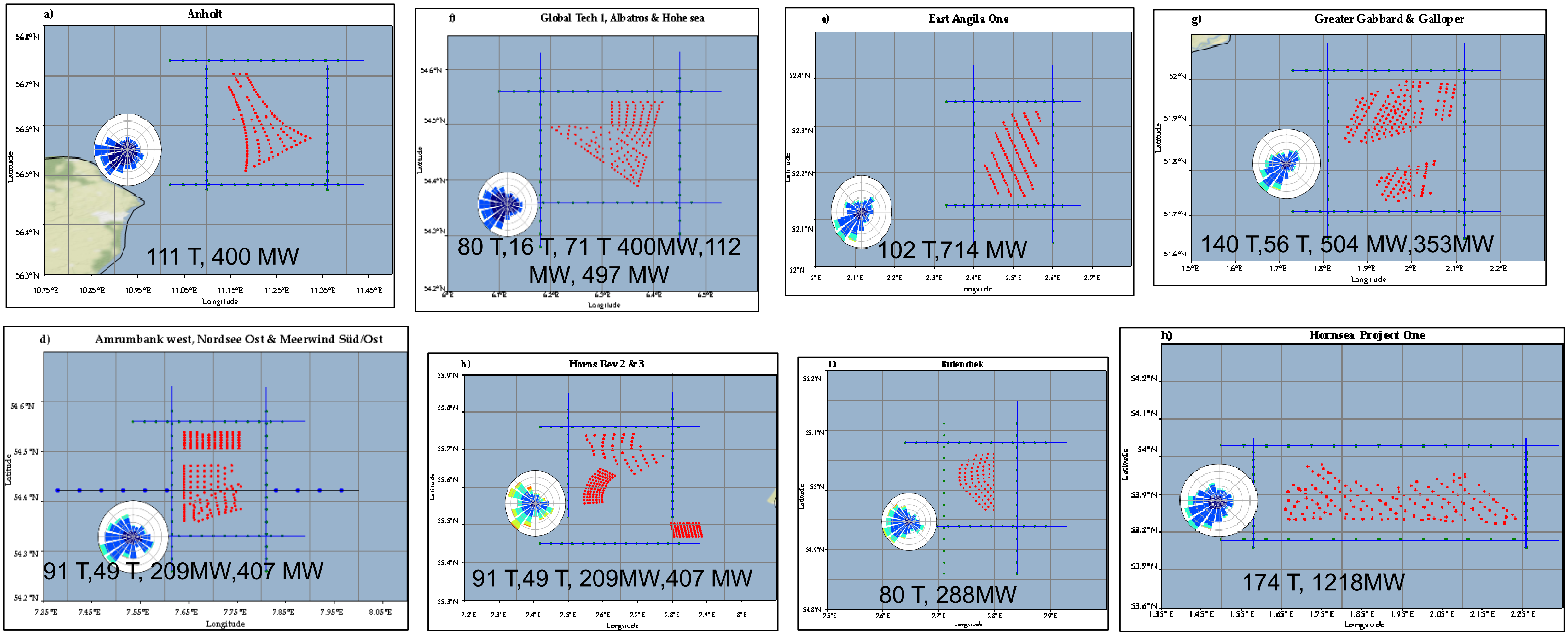
SAR wind map for the same Sentinel scene (left)
https://science.globalwindatlas.info/

Study Area and Datasets (1)



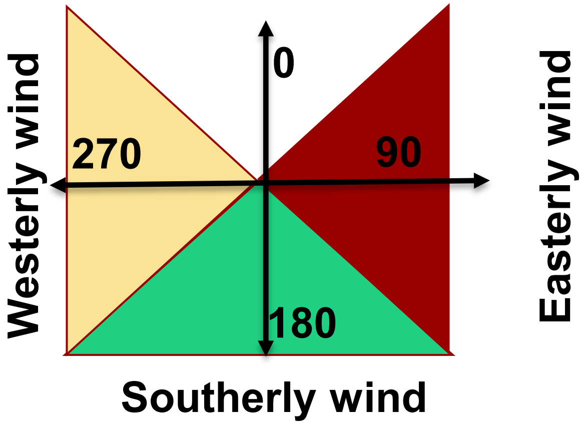
Minimum distance between OWFs is ***less 20 km***, minimum number of turbines **80** and at leass **100 SAR** scenes for each wind case of 24 cases.(***Owda et al, 2022***)

Study Area and Datasets (1)



(Owda, et al 2022)

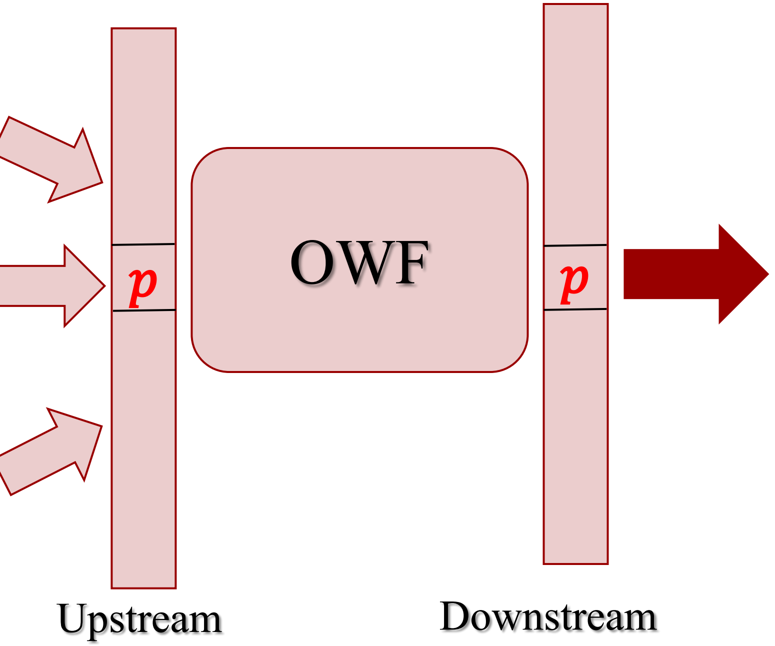
Study Area and Dataset (2)



	Westerly			Easterly			Southerly		
OWF/Cluster	**Before**	**After**	**Ratio (%)**	**Before**	**After**	**Ratio (%)**	**Before**	**After**	**Ratio (%)**
Anholt	363	343	94.4	188	178	94.7	262	178	67.9
Horns Rev cluster	82	113	137.8	68	39	57.3	68	39	57.3
Butendiek	368	430	116.8	197	180	91.4	239	233	97.5
Nordsee cluster	320	196	61.25	148	84	56.7	203	165	81.3
East Anglia One	473	32	6.76	215	18	8.3	368	47	12.8
Global Tech cluster	574	76	13.2	250	43	17.2	348	68	19.5
Greater Gabbard and Galloper	212	39	18.4	99	42	42.4	193	39	20.2
Hornsea Project One	393	44	11.20	153	14	9.15	279	25	9.0
Total	**2785**	**1273**		**1318**	**598**		**1960**	**794**	

"Classify the collected scenes from 2000-2021 based on wind direction (sector angle 90 degree) and commissioning dates of the offshore wind farms" (***Owda, et al 2022***)

Research Findings (1)

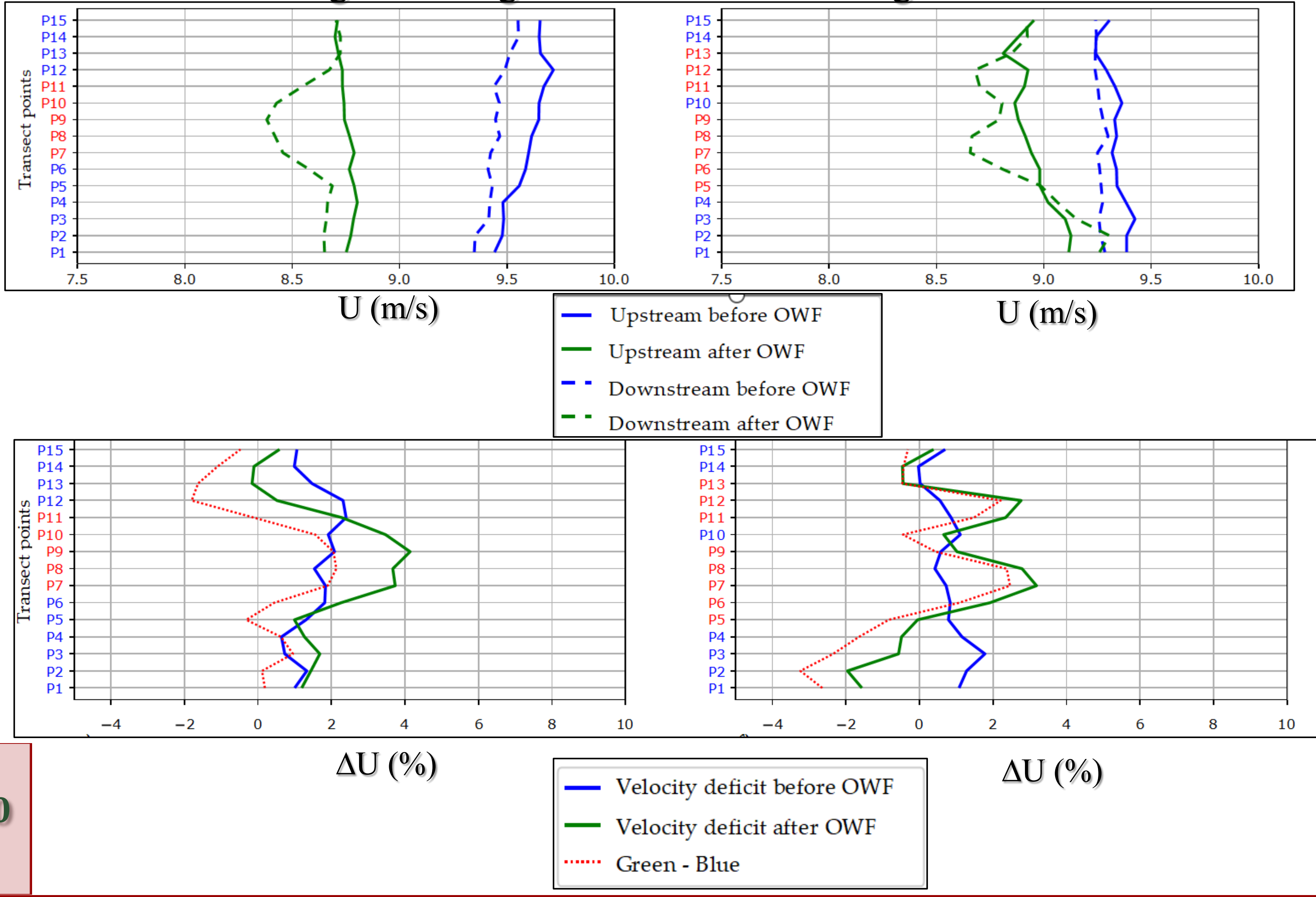


Butendiek

Commissioning date: August 2015

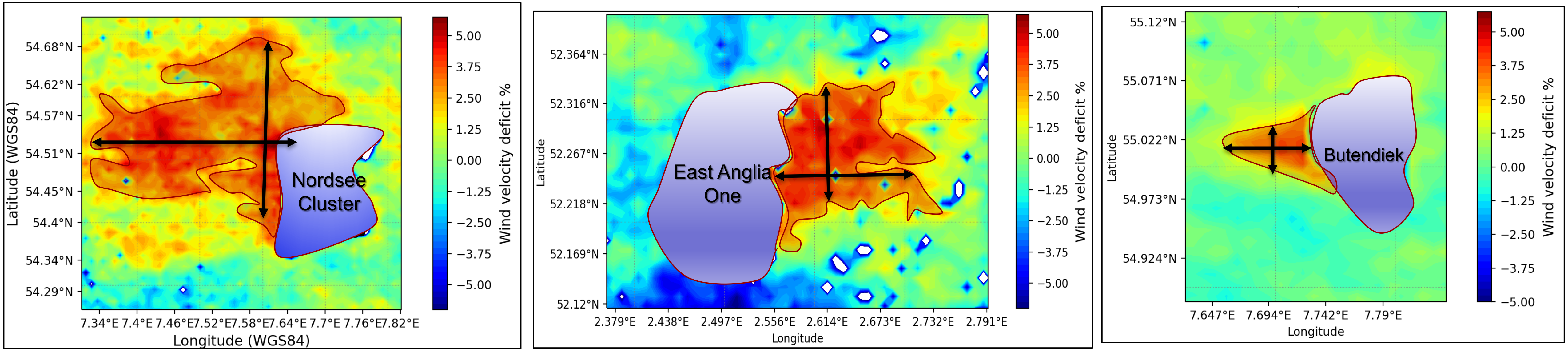
Nordsee Cluster

Commissioning date: December 2014



$$\Delta_U = \frac{U_{upstream,pi} - U_{downstream,pi}}{U_{upstream}} \times 100$$

Research Findings (2)



Nordsee cluster

3 OWFs, 3 × 80 T, 678 MW.

Wakes length > 20-22 km.

ΔU (%) > 5%

East Anglia One

1 OWF, 102 T, 714 MW

Wakes length > 18-20 km.

ΔU (%) > 5%

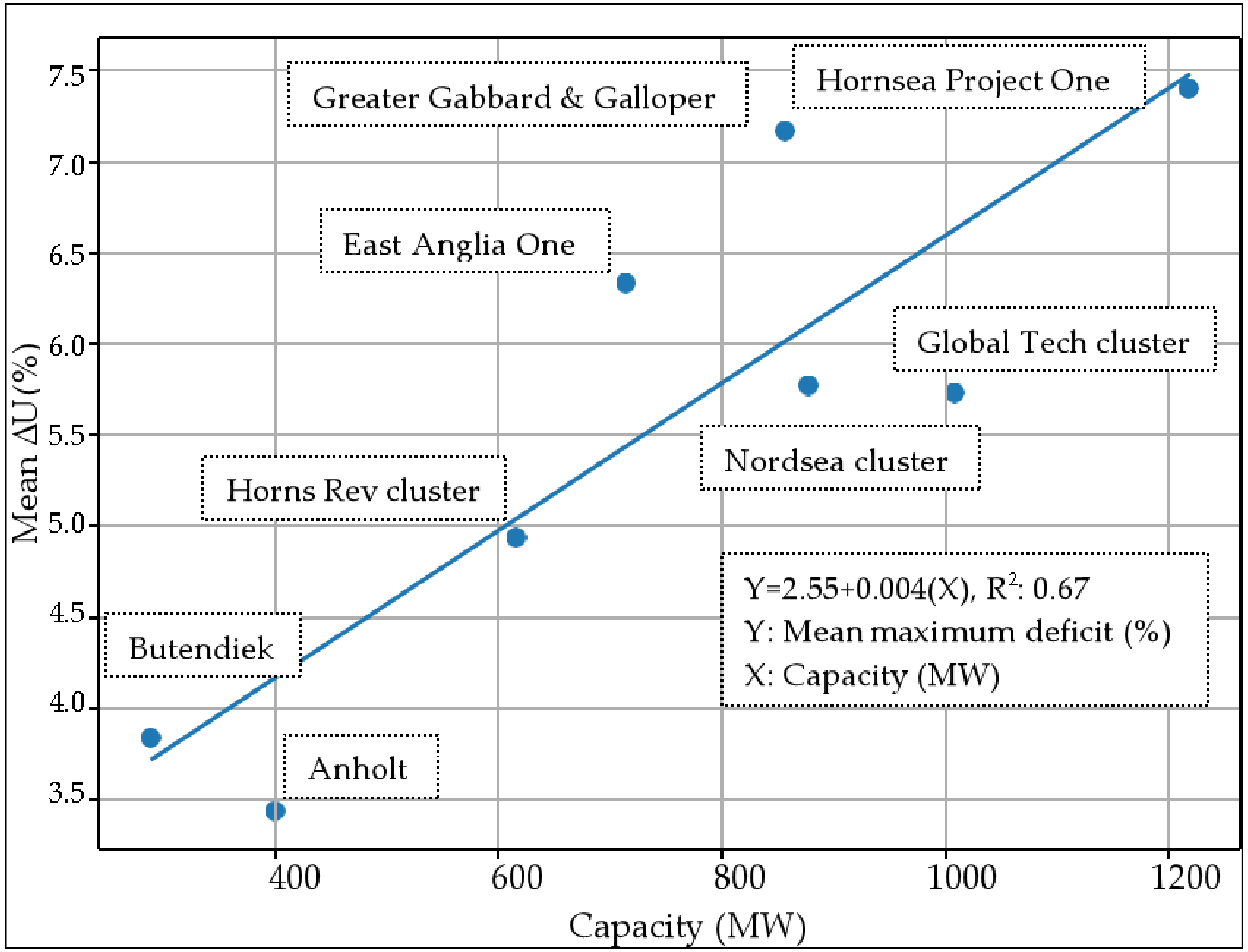
Butendiek

1 OWF, 80 T, 288 MW

Wakes length > 3-5 km.

ΔU (%) < 5%

Research Findings (3)



(*Owda et al, 2022*)

Conclusion and Future (1)

❖ Conclusion

- ➢ SAR archieve is exploited to monitor wind speed variation and shows variability in wind speed in northern European seas.
- ➢ SAR is rich with useful information for offshore wind energy development and planning.
- ➢ Wind deficits areas at downstream side of OWFs are proportional with OWFs' capacity.

Conclusion and Future (2)

❖ Future Perspective:

- ➢ More improvement for SAR wind retrieval to avoid the anomalous SAR pixels (**Poster day 4, code:64037**).
- ➢ Extrapolate the results up to hub height turbine.
- ➢ Validate the results with other simulation model like (LES).

Thanks for your attention

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Special issue remote sensing MDPI

"Wind Speed Variation Mapped Using SAR before and after Commissioning of Offshore Wind Farms"