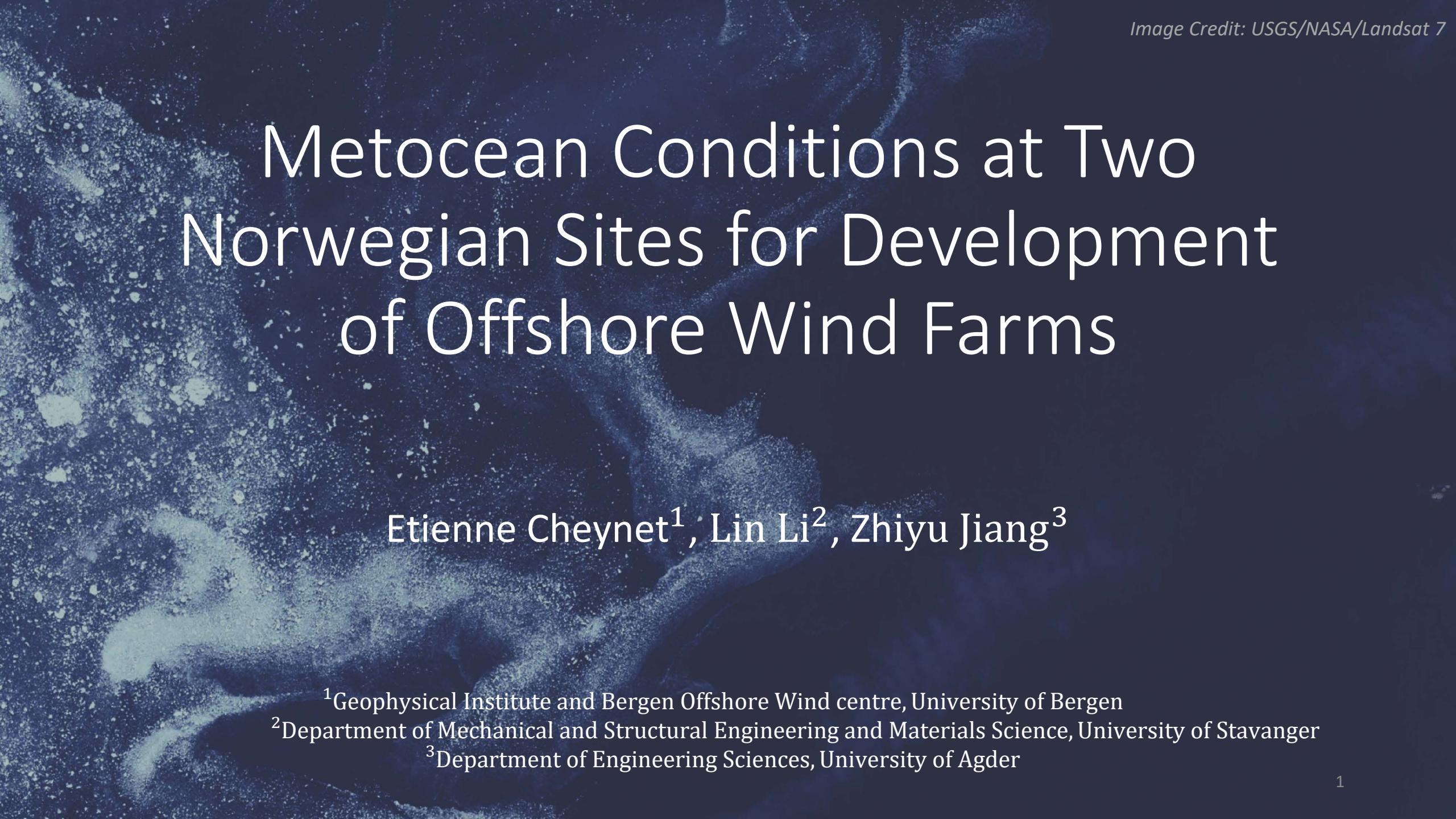

Metocean Conditions at Two Norwegian Sites for Development of Offshore Wind Farms

Etienne Cheynet[1], Lin Li[2], Zhiyu Jiang[3]

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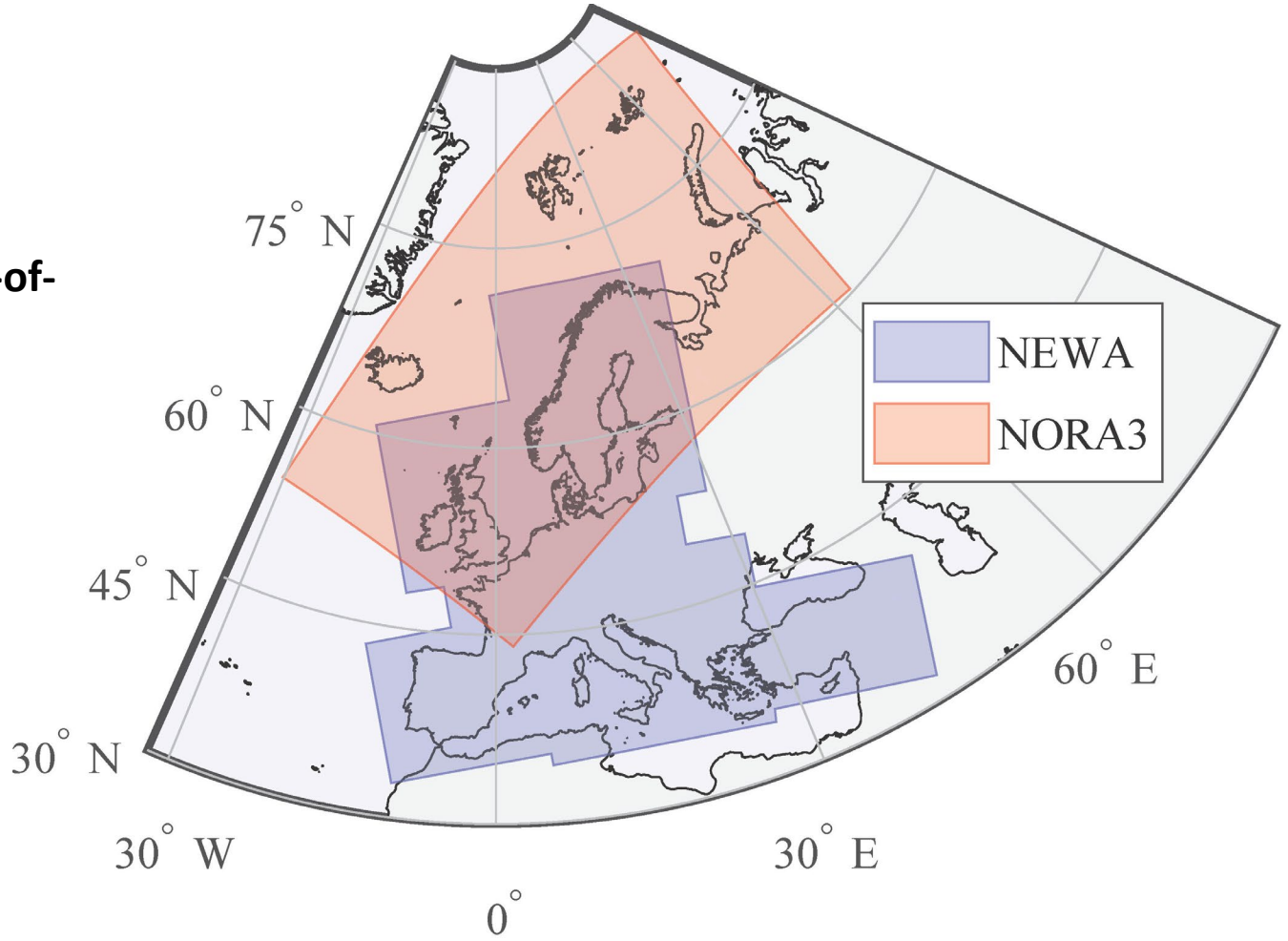
[3]Department of Engineering Sciences, University of Agder

The NORA3 database

The NORwegian hindcast Archive (NORA3) [1] is a **state-of-the-art wind atlas** (I oversimplify a little here)

Other wind atlases: The New European Wind atlas (NEWA) [2]

NORA3 may outperform NEWA in the North Sea [3]



[1] Haakenstad, et al. (2021). NORA3: A Nonhydrostatic High-Resolution Hindcast of the North Sea, the Norwegian Sea, and the Barents Sea. *Journal of Applied Meteorology and Climatology*, *60*(10), 1443-1464.
[2] Hahmann, et al.. (2020). The making of the new european wind atlas–part 1: Model sensitivity. *Geoscientific model development*, *13*(10), 5053-5078.
[3] E Cheynet, I M Solbrekke, J M Diezel, J Reuder, A one-year comparison of new wind atlases over the North Sea. Accepted for publication in the Journal of Physics: conference series

The NORA3 database

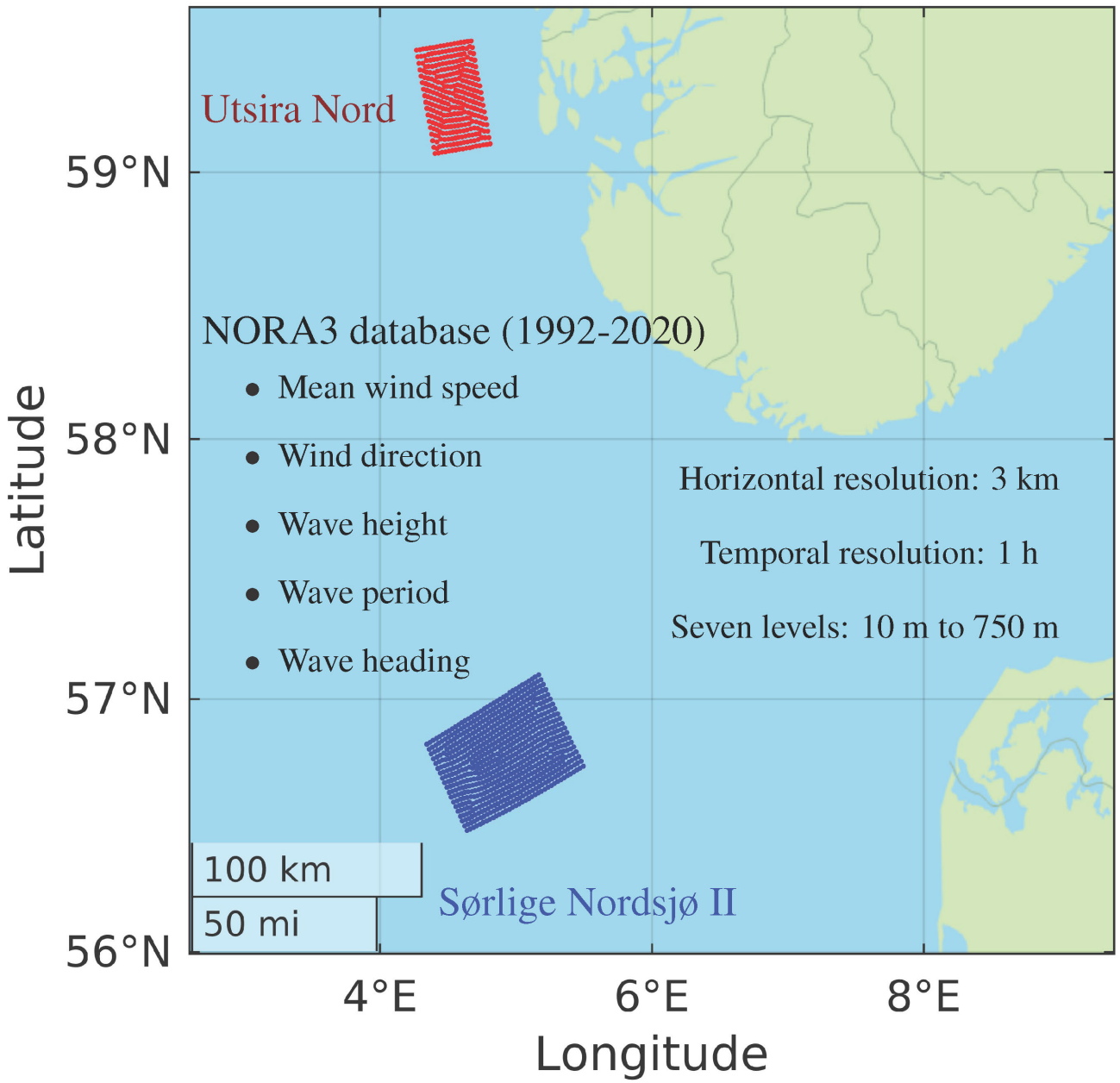
WINDSURFER News and Events

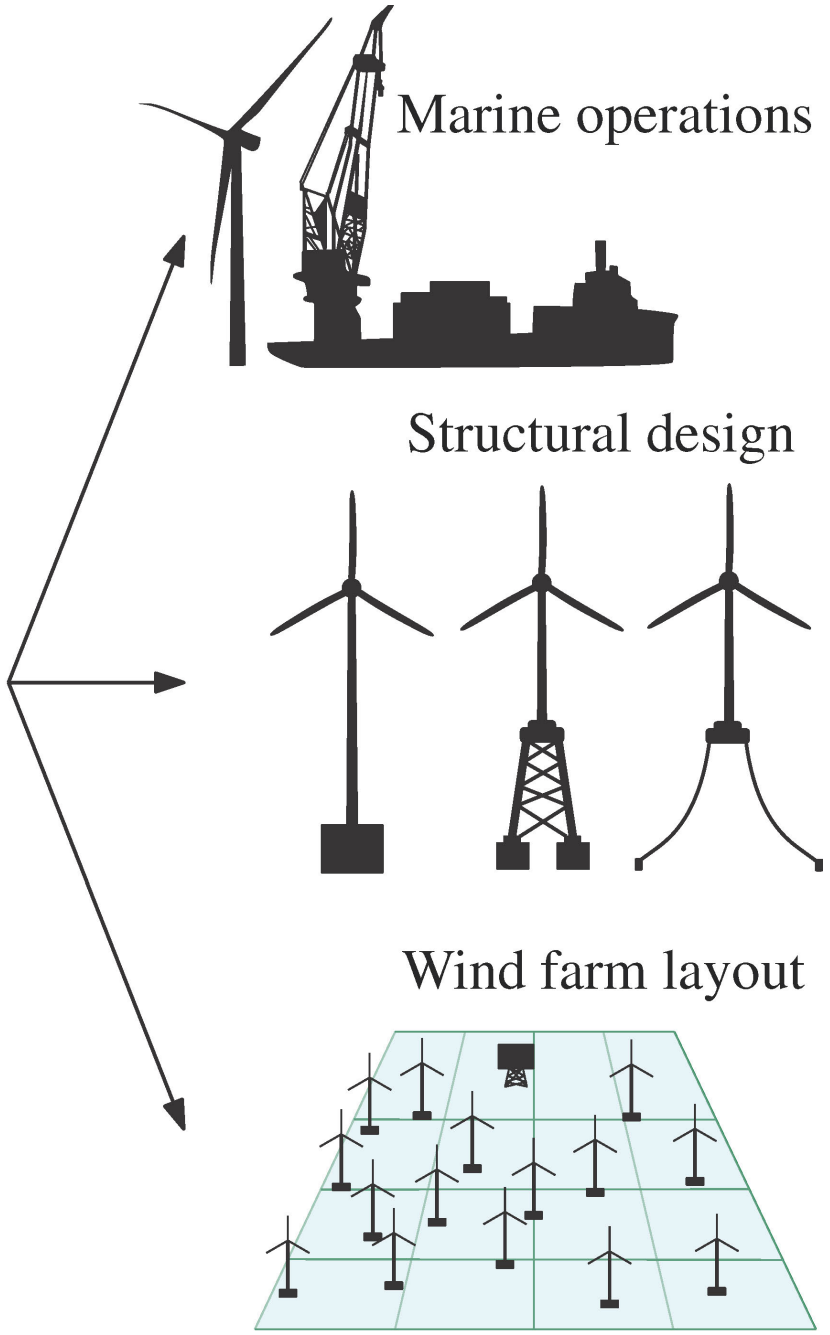
NORA3 Wave Reanalysis now available

The new NORA3 wave reanalysis from Met Norway is now available at:

https://thredds.met.no/thredds/projects/windsurfer.html

Windsurfer project:
https://sites.google.com/view/windsurfer/home


Utsira Nord
NORA3 database (1992-2020)
• Mean wind speed
• Wind direction
• Wave height
• Wave period
• Wave heading
Horizontal resolution: 3 km
Temporal resolution: 1 h
Seven levels: 10 m to 750 m
Sørlige Nordsjø II
100 km
50 mi
59°N
58°N
57°N
56°N
4°E
6°E
8°E
Latitude
Longitude


Marine operations
Structural design
Wind farm layout

Sørlige Nordsjø II(SN2)

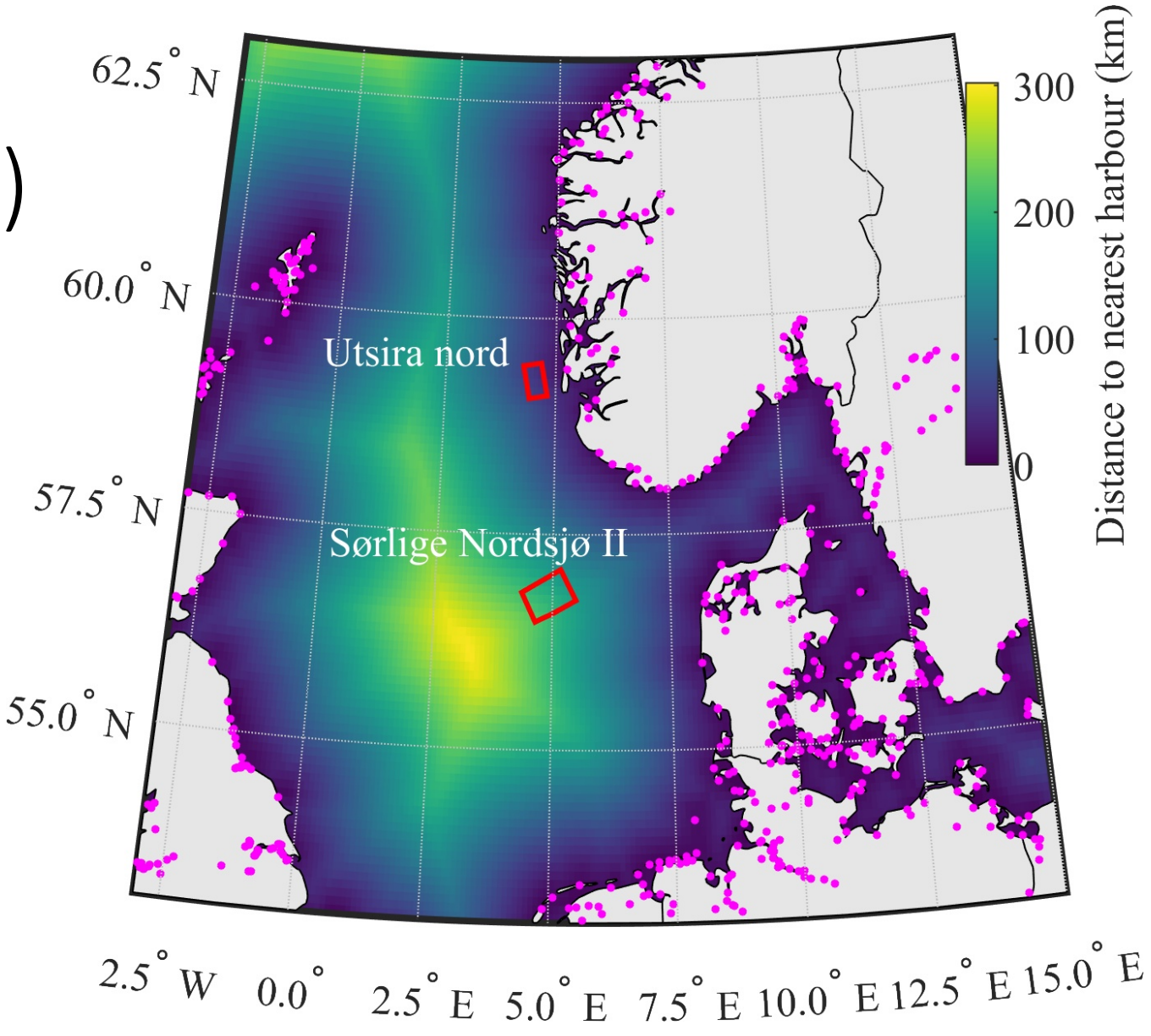
Area: 2591 km^2

Water depth: intermediate (60 m)

Planned capacity: 3x 1.5 GW

Foundation types: Floating and bottom-fixed

Distance to nearest harbour: 180 km



Utsira Nord (UN)

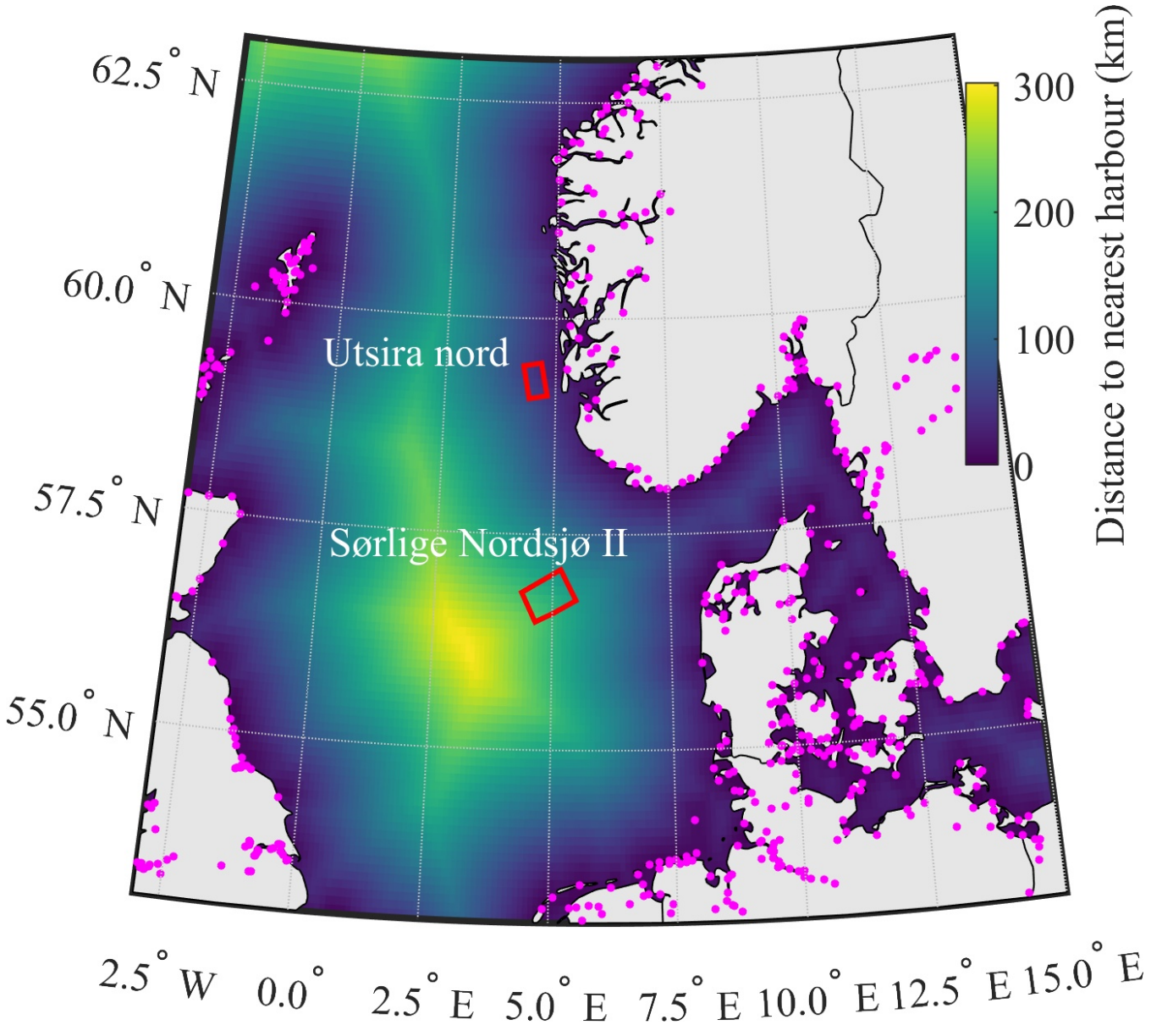
Area: 1010 km^2

Water depth: Deep water (200-280 m)

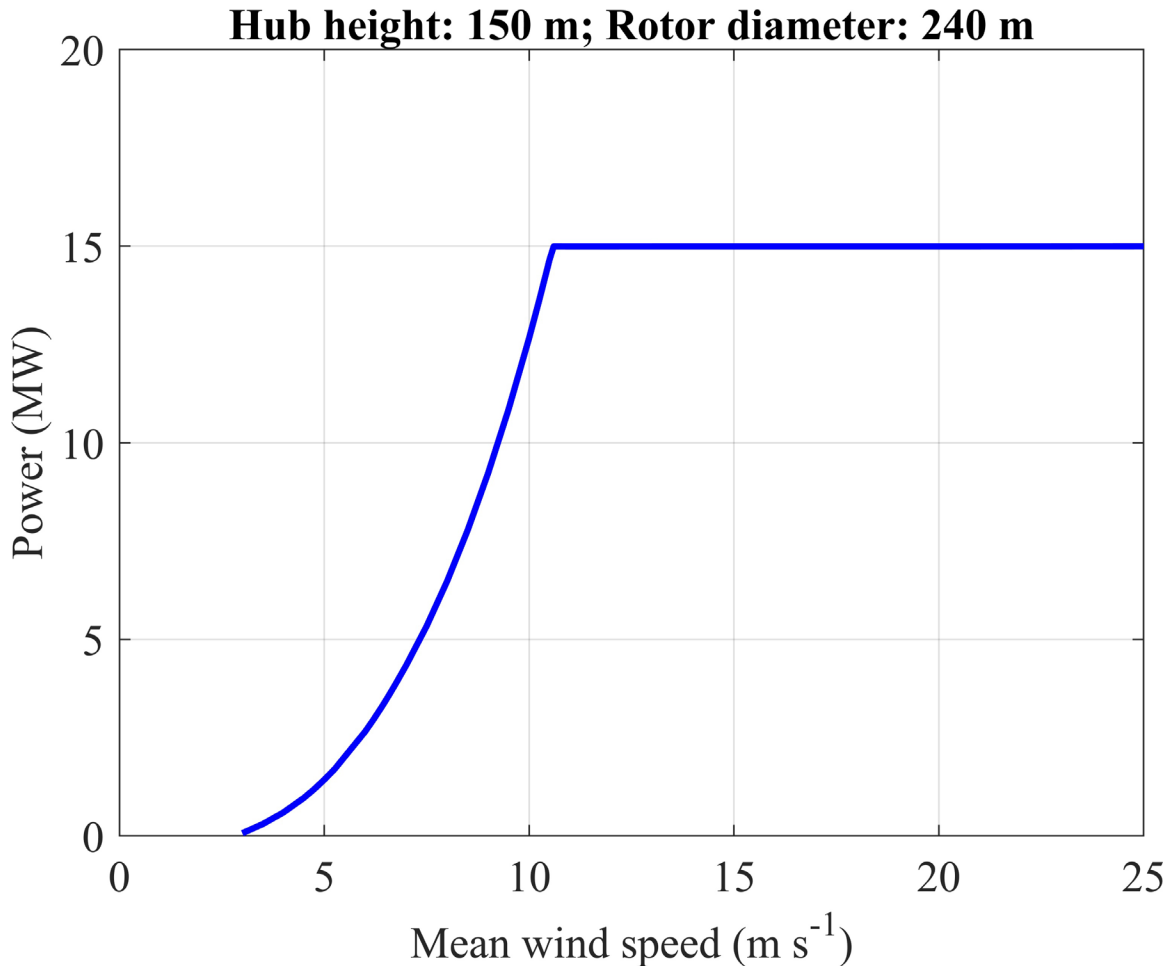
Planned capacity: 1.5 GW

Foundation types: Floating

Distance to nearest harbour: 22 km



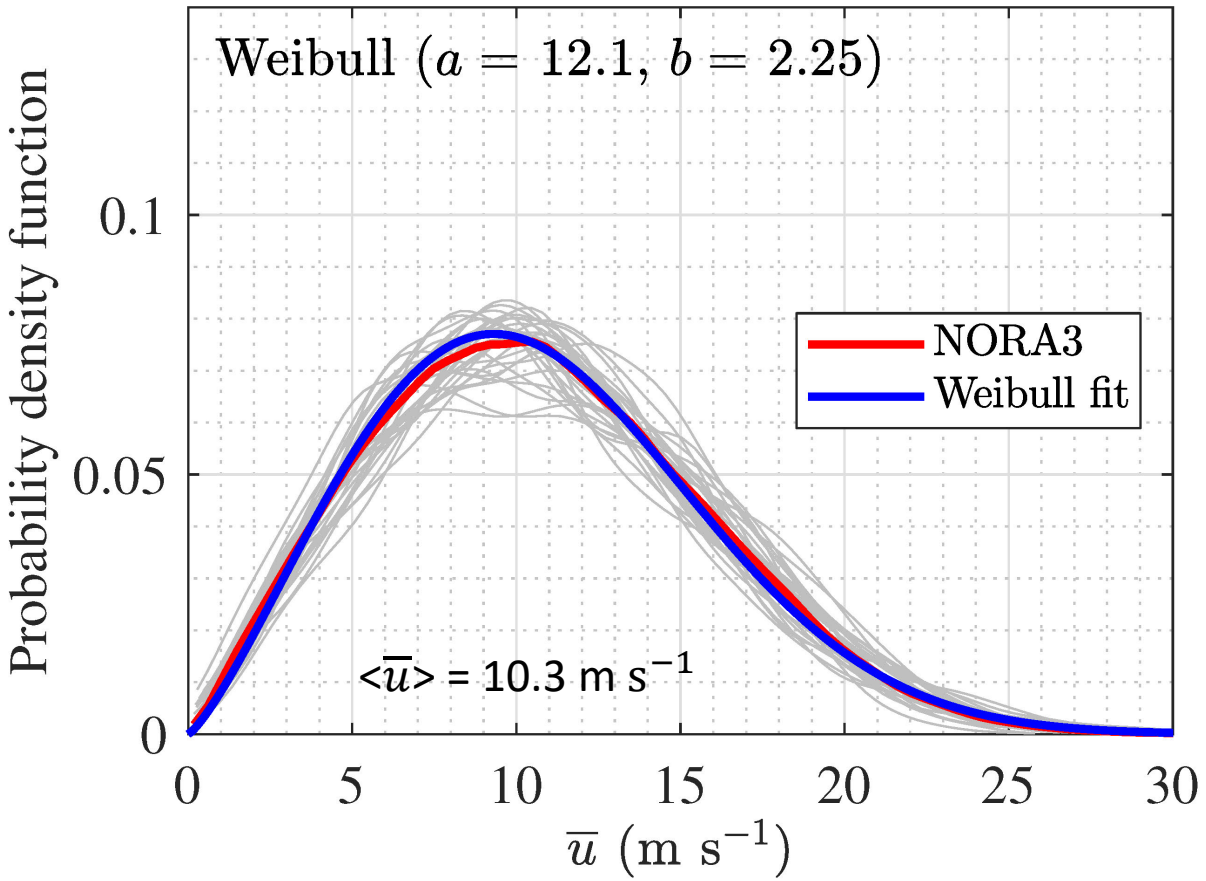
Case study: The IEA 15 MW wind turbine [1]

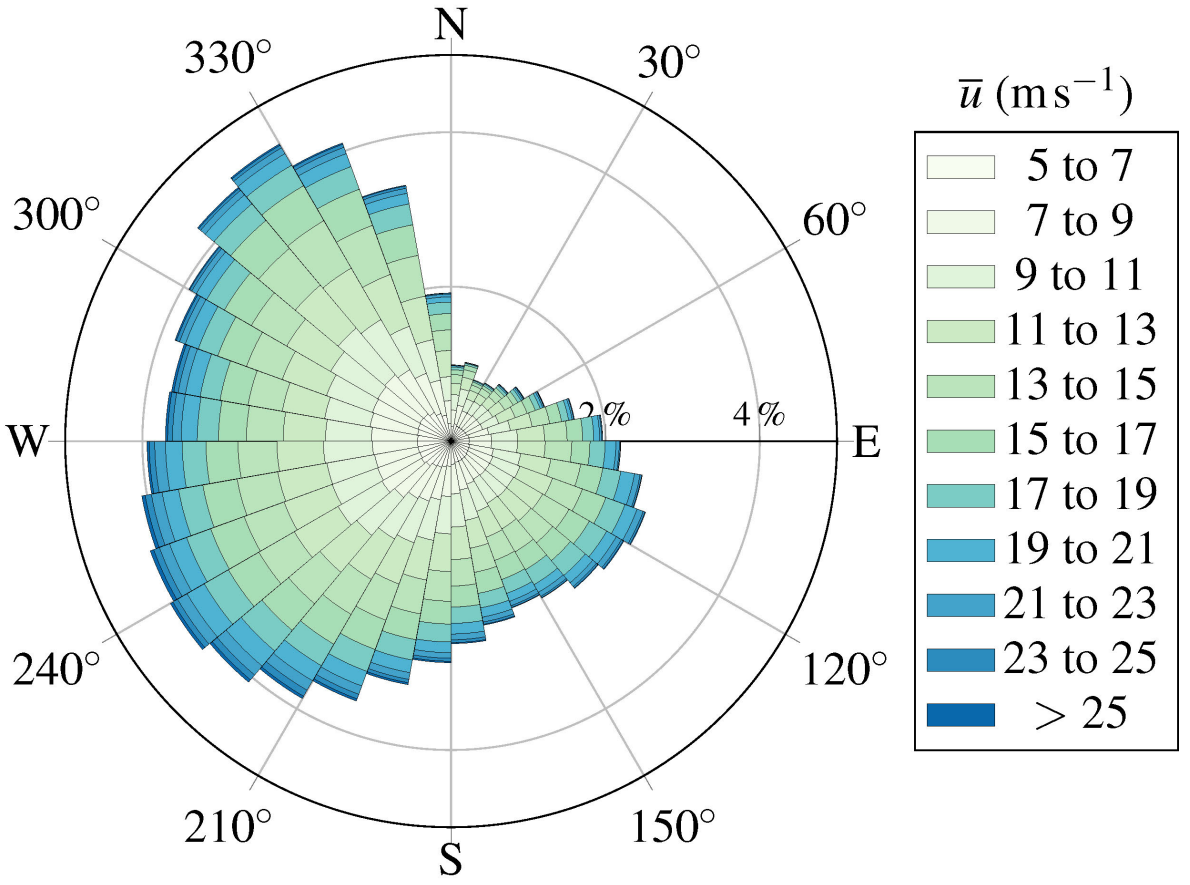


[1] Gaertner, E., Rinker, J., Sethuraman, L., Zahle, F., Anderson, B., Barter, G., ... & Viselli, A. (2020). Definition of the IEA 15-megawatt offshore reference wind turbine.

Wind conditions in Sørlige Nordsjø II

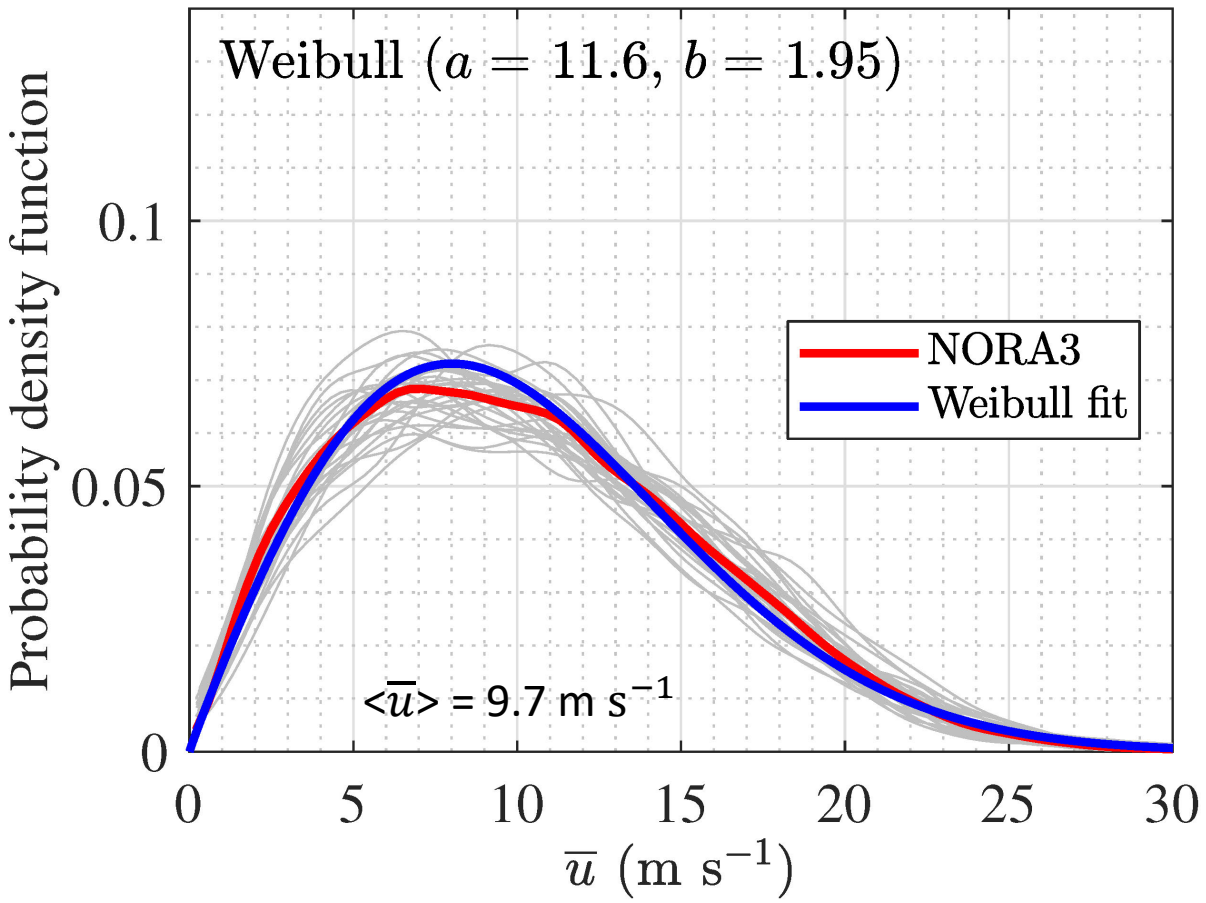
At hub height = 150 m

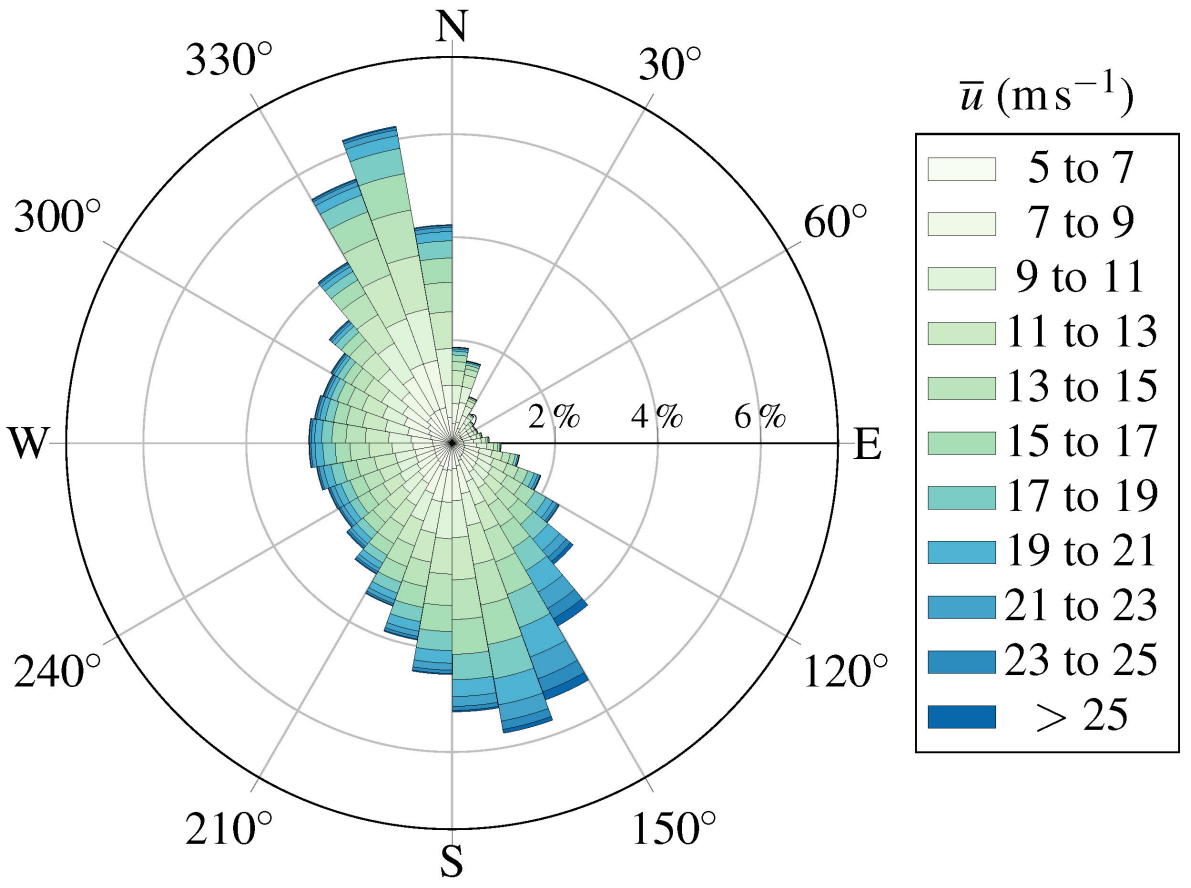


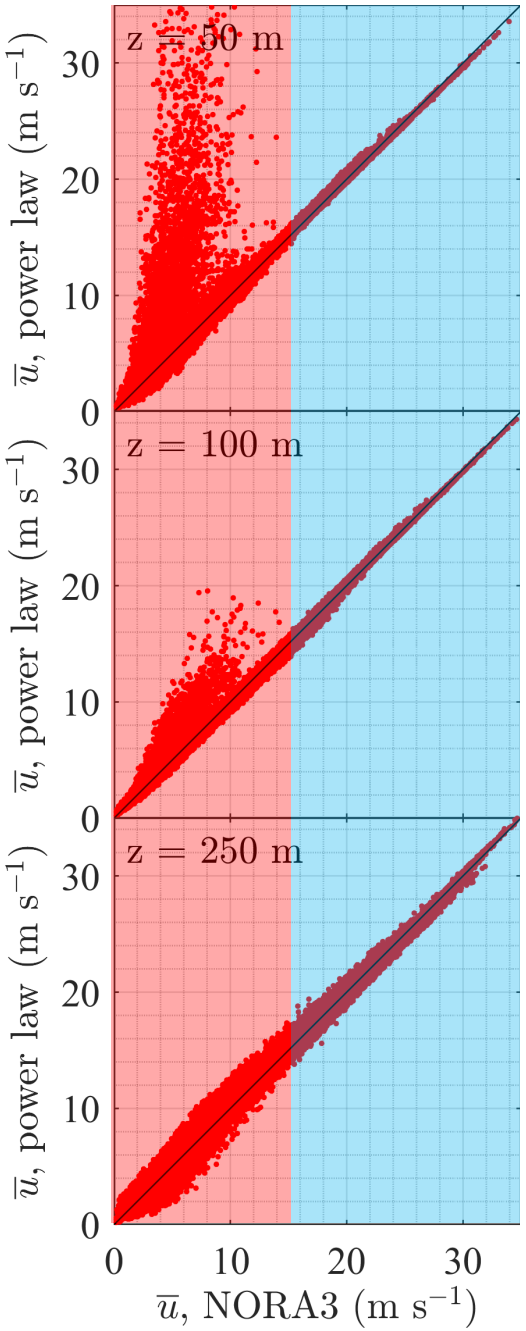


Wind conditions in Utisra Nord

At hub height = 150 m







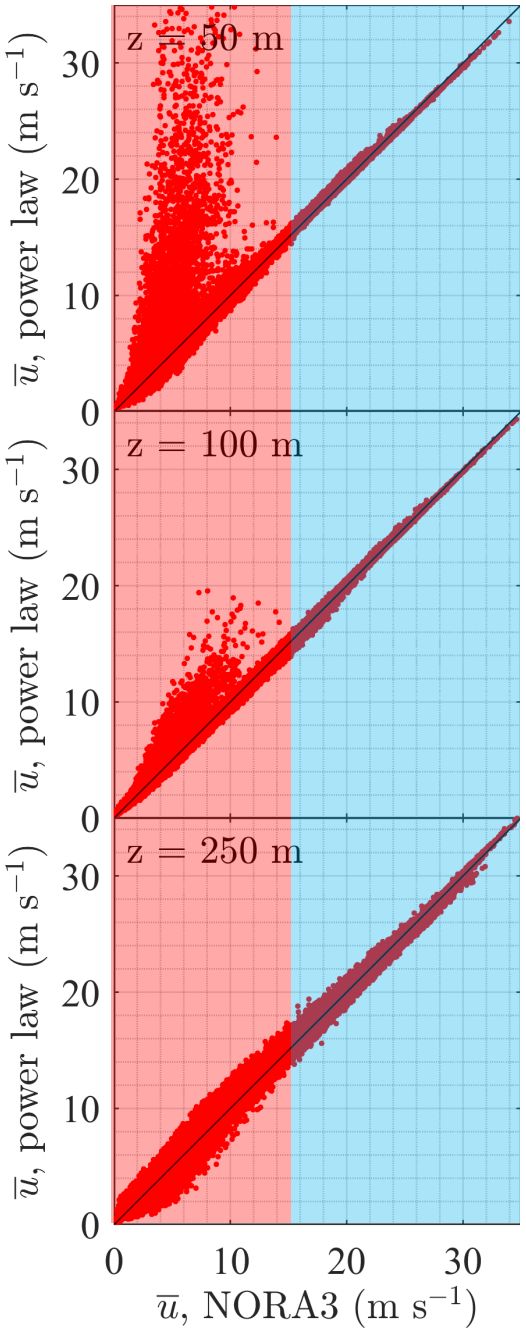
Wind speed profiles: limits of the power law

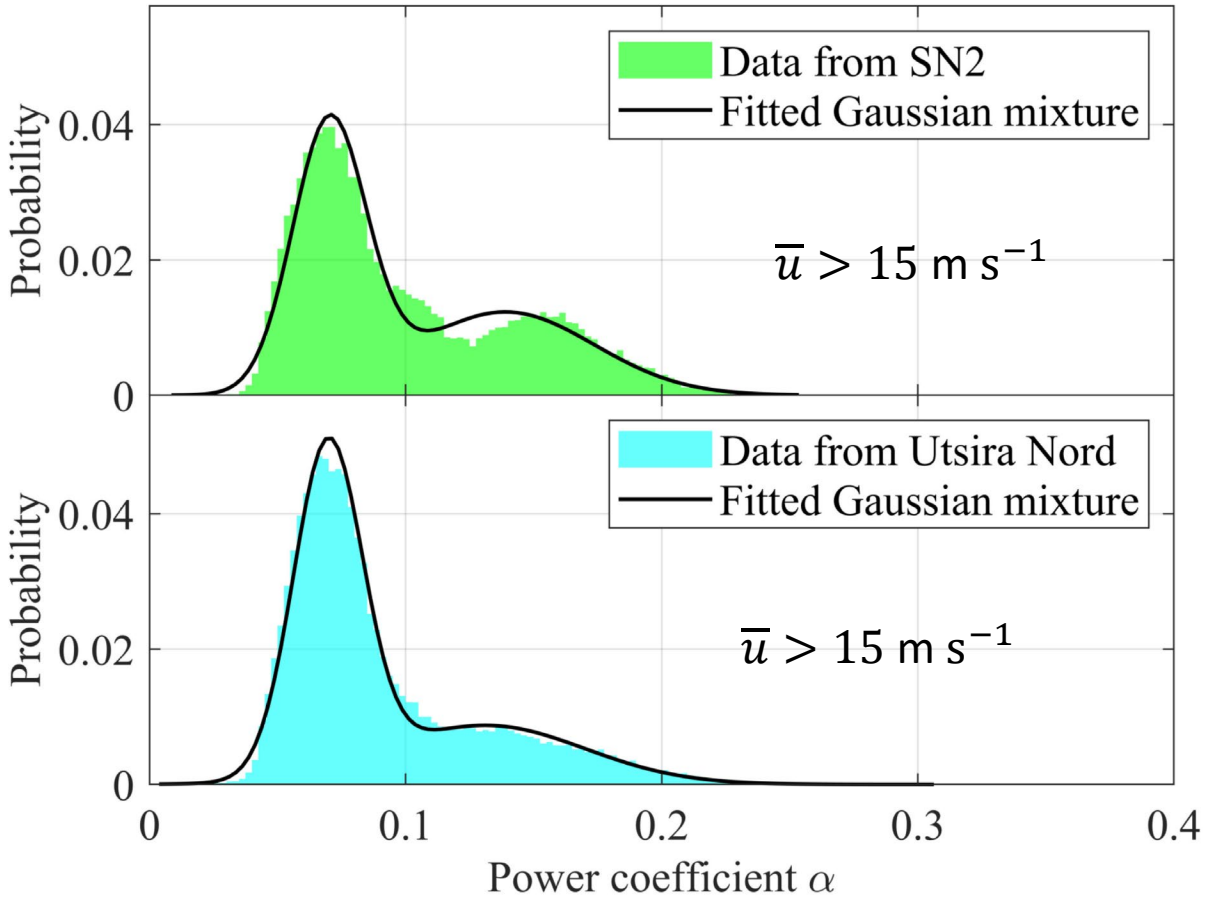
The power law is widely used in standards and codes

The power law **may be applicable** for the **ultimate limite state** design

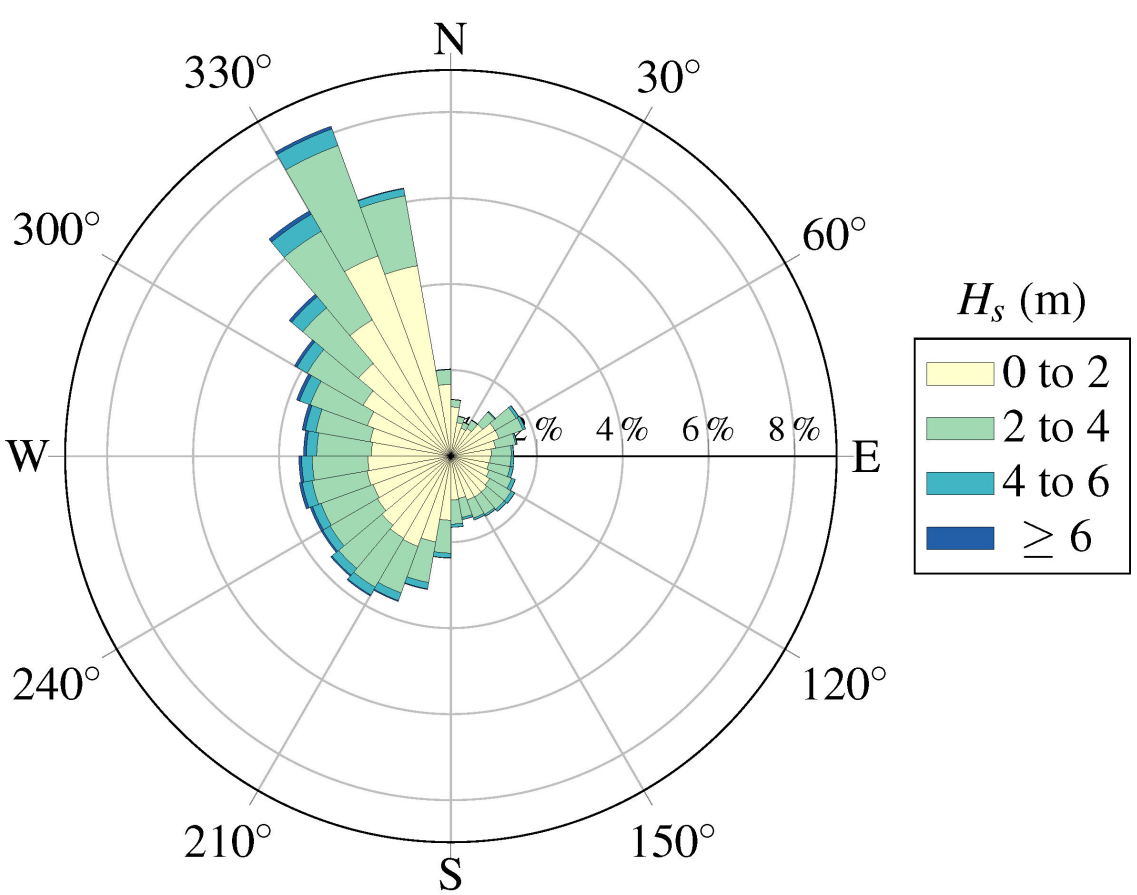
The power law **may not be applicable** for the **fatigue limite state** designs

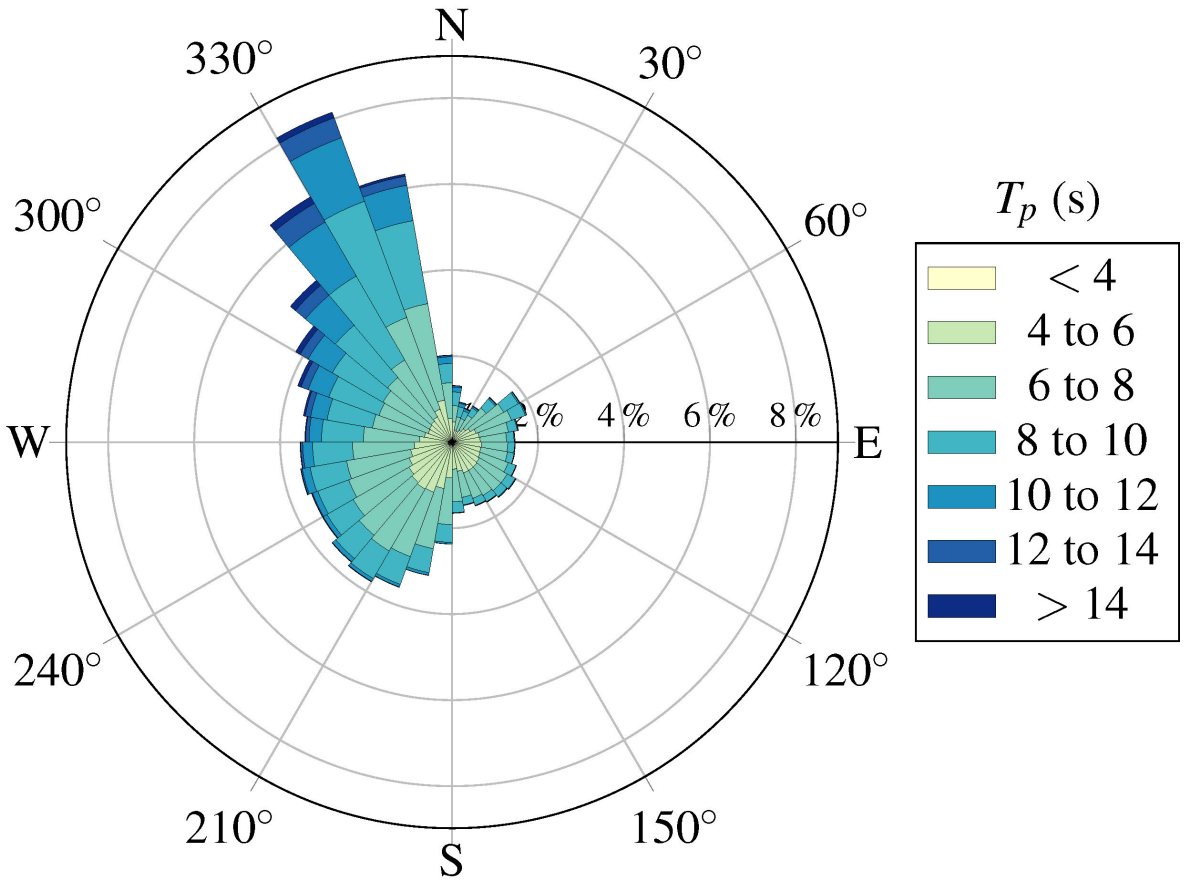
Wind speed profiles: limits of the power law



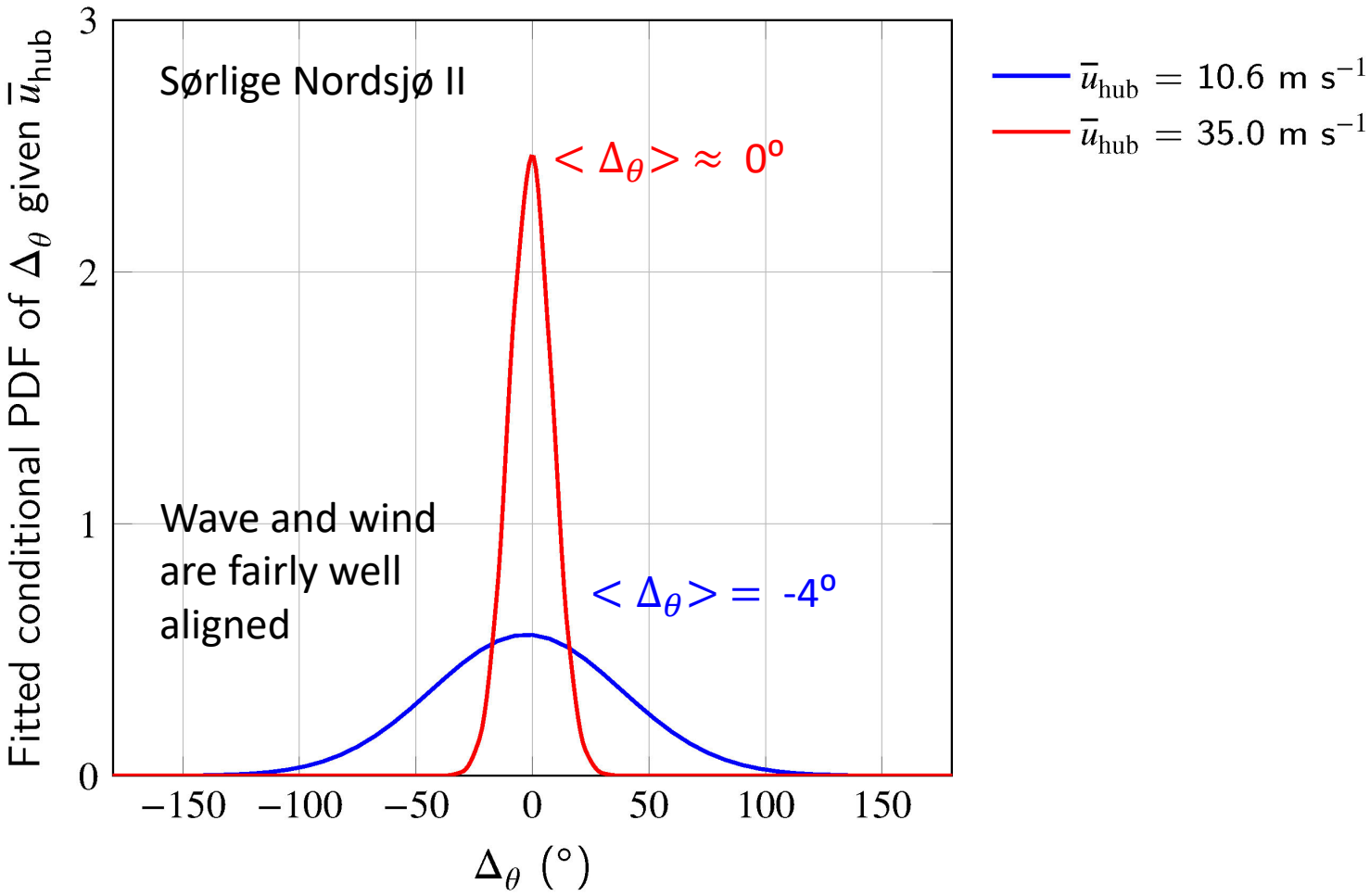


Wave conditions in Sørlige Nordsjø II

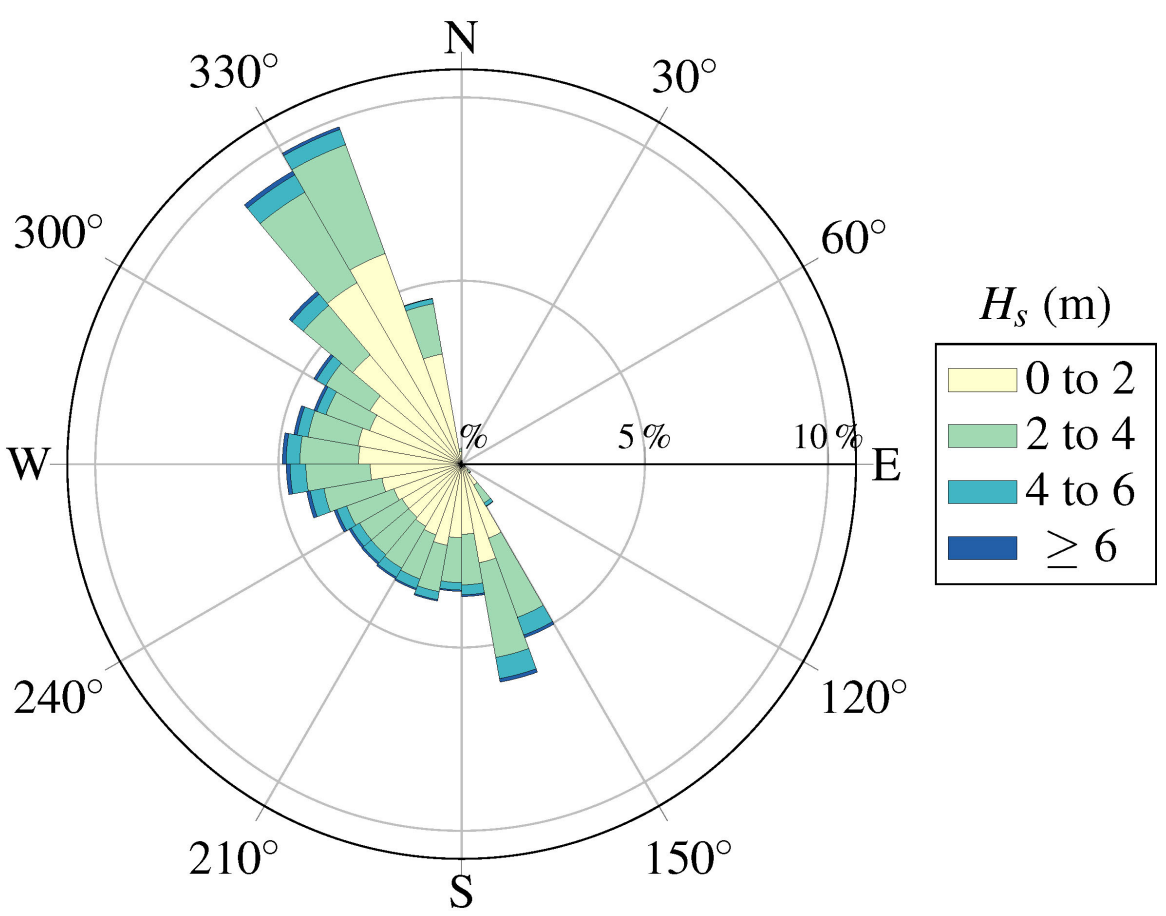


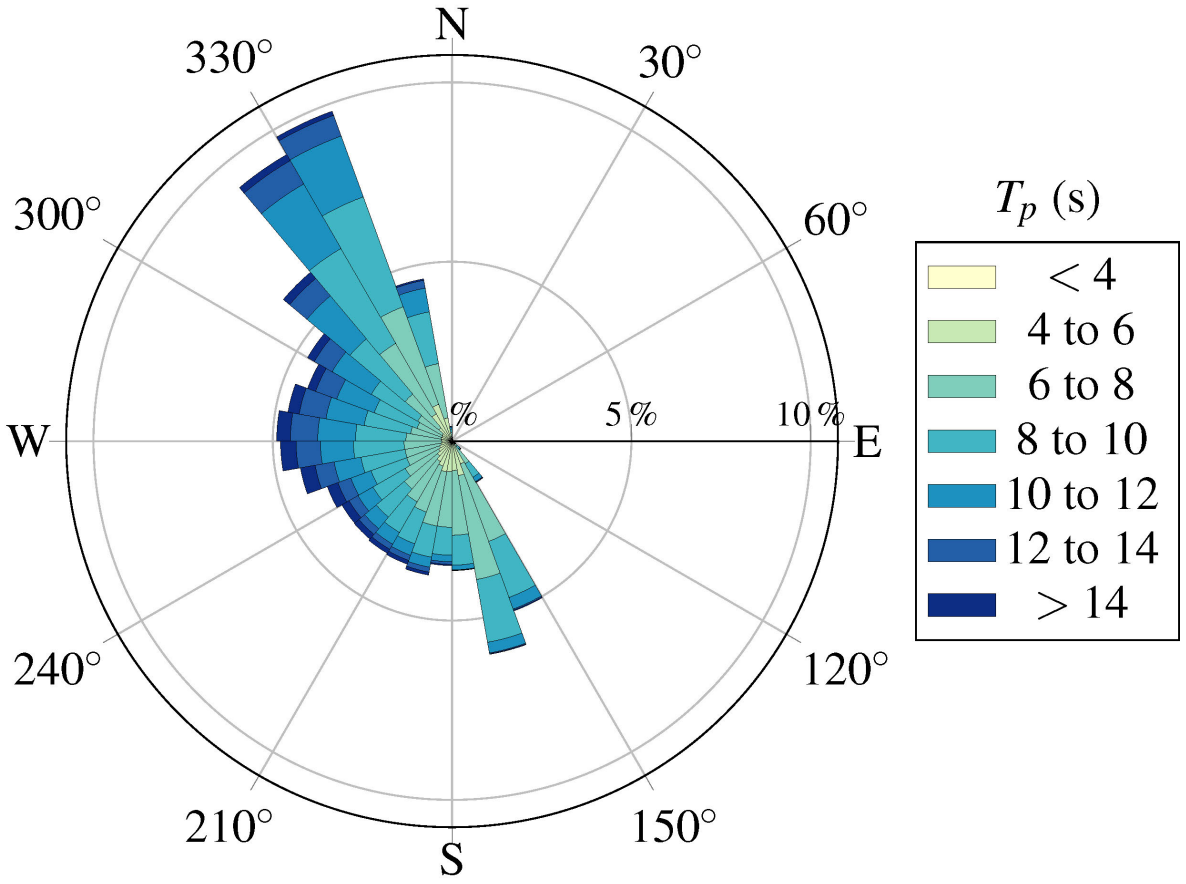


Wind-wave misalignment in Sørlige Nordsjø II

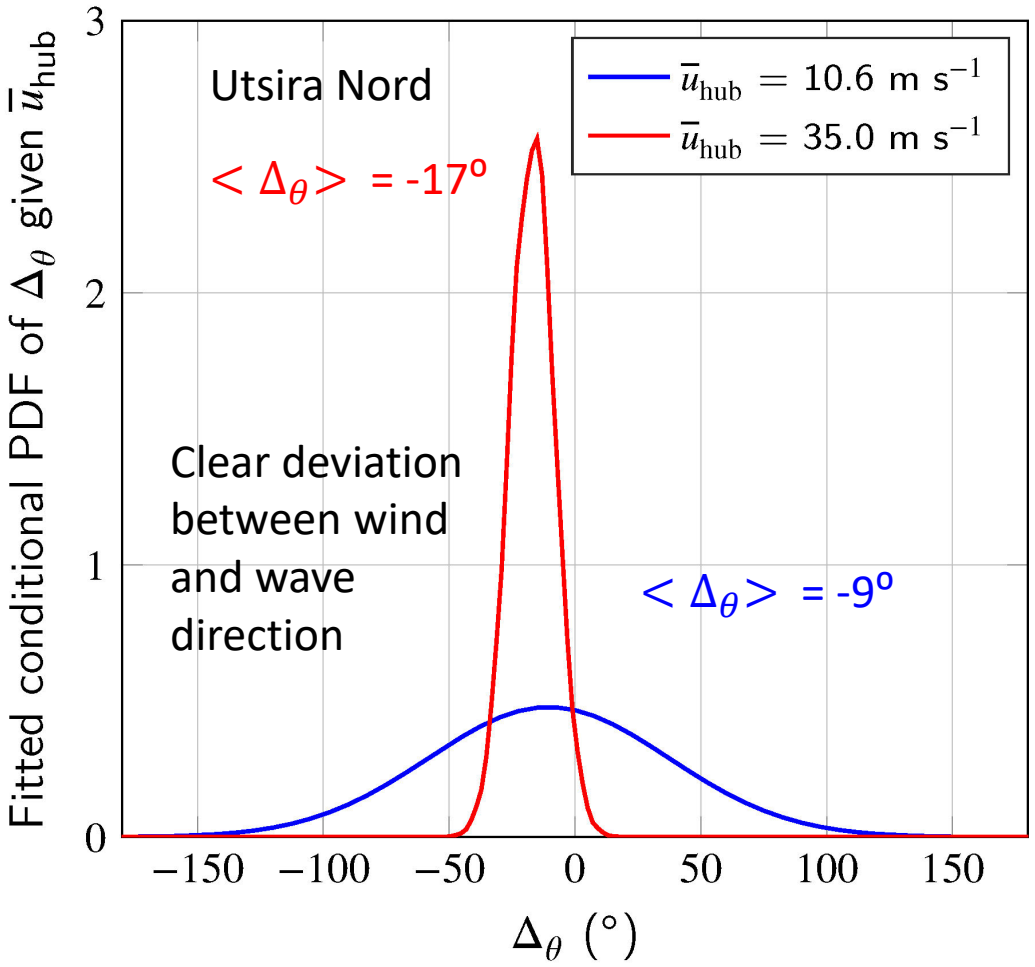


Wave conditions in Utsira Nord





Wind-wave misalignment in Utsira Nord



Extreme value analysis

50-year return period at SN2:

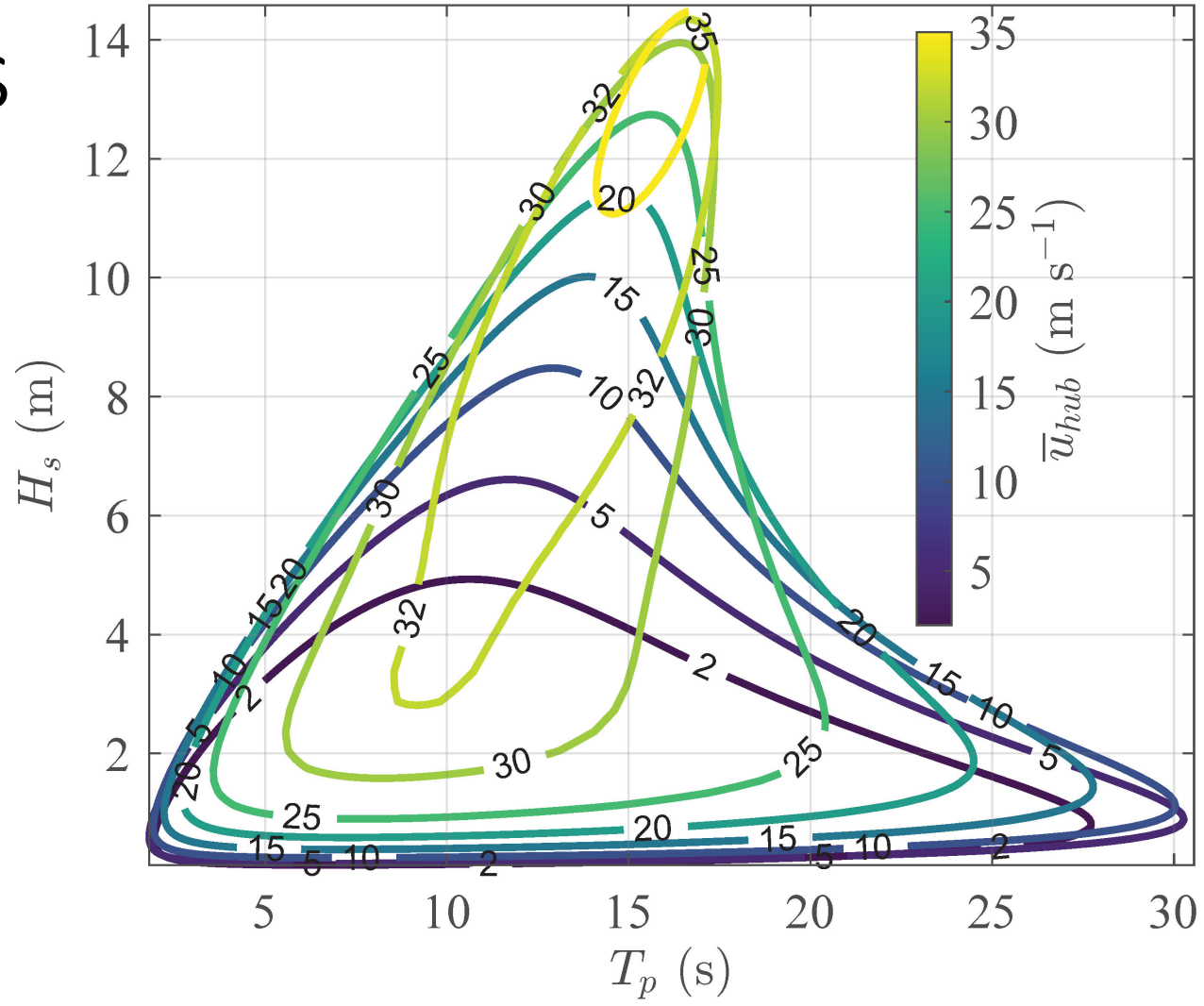
$\overline{u}_{\mathrm{hub}} = 37.7\ \mathrm{m\ s^{-1}}$

$H_{\mathrm{s}} = 13.4\ \mathrm{m}$

50-year return period at UN:

$\overline{u}_{\mathrm{hub}} = 42.3\ \mathrm{m\ s^{-1}}$

$H_{\mathrm{s}} = 14.6\ \mathrm{m}$



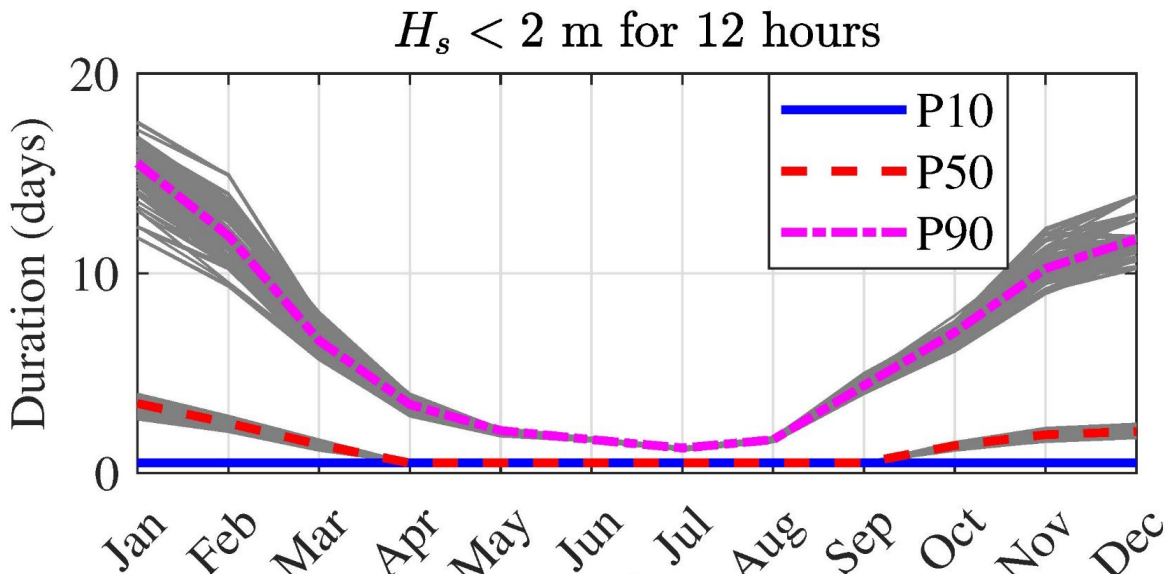
50-year contour surface at Utsira Nord

Case study: offshore operation duration

Assumption: The operation needs $H_s < 2$ m

Question: What is the characteristic duration of completing critical operations with operation duration 12 h?

Comments: The waiting time is significant. Using NORA3, we can have an estimate of the characteristic duration



Case study: Farm layout assessment in UN

FLORIS python toolbox + NORA3 dataset (1992-2020)

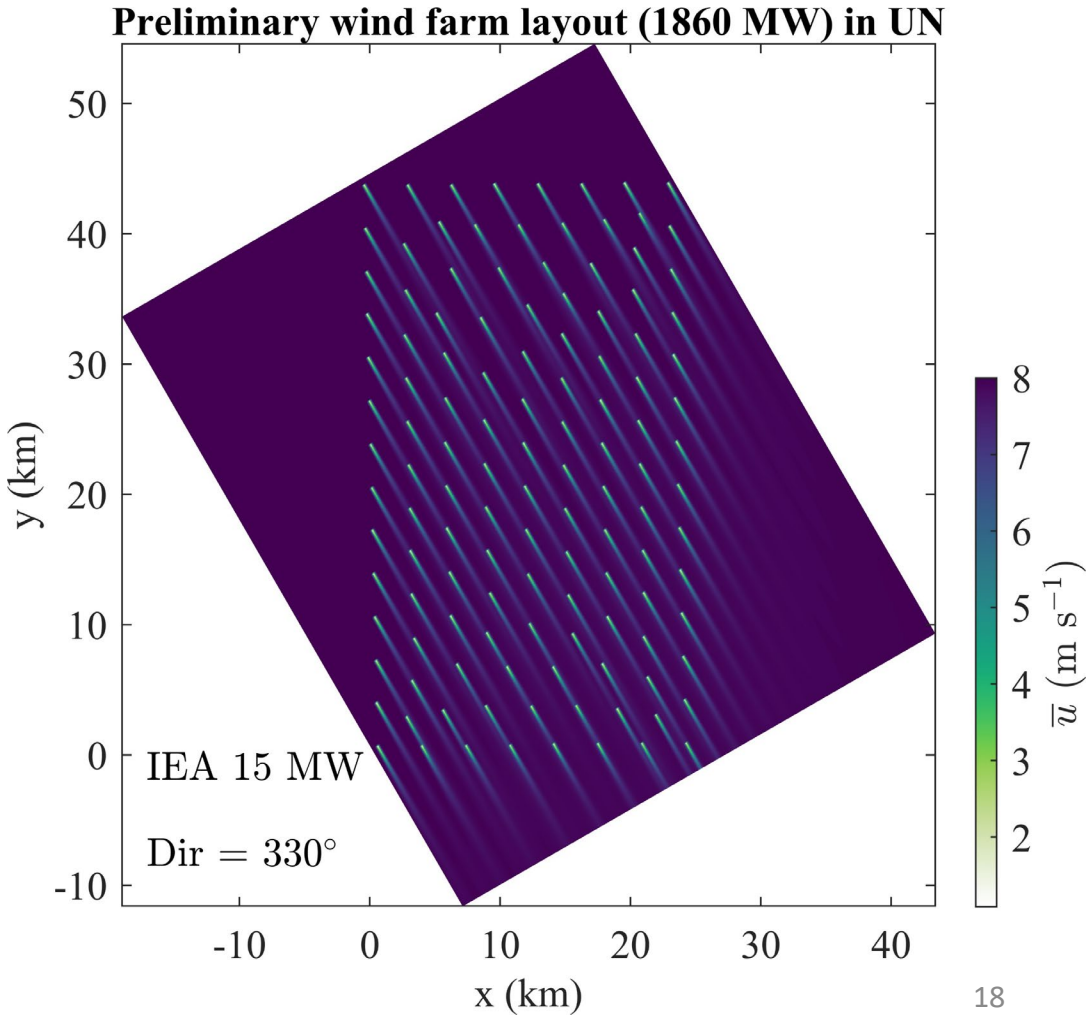
Turbine layout set by inter-turbine distances > 9 D

wind turbines : 124 x IEA 15 MW

Nominal capacity: 1.9 GW

Capacity factor: 59 %

Annual energy production: 9.8 TWh



Conclusions

- 29 years of metocean conditions extracted at Utsira Nord and Sørlige Nordsjø II
- Approximatively 0.25 milions of hourly wind speed profiles computed up to 750 m above sea level.
- Applications range from wind turbine design, to marine operation and wind farm layout analysis

Image Credit: USGS/NASA/Landsat 7

Thank you