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

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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]

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
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

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 km²

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]

Wind conditions in Sørlige Nordsjø II

At hub height = 150 m

Weibull \((a = 12.1, b = 2.25)\)

\[
\langle \bar{u} \rangle = 10.3 \text{ m s}^{-1}
\]
Wind conditions in Utisra Nord

At hub height = 150 m

Weibull ($a = 11.6, b = 1.95$)

$\langle \tilde{u} \rangle = 9.7 \text{ m s}^{-1}$
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

\[ u > 15 \text{ m s}^{-1} \]

\[ \bar{u} > 15 \text{ m s}^{-1} \]
Wave conditions in Sørlige Nordsjø II

$H_s$ (m)
- 0 to 2
- 2 to 4
- 4 to 6
- $\geq$ 6

$T_p$ (s)
- < 4
- 4 to 6
- 6 to 8
- 8 to 10
- 10 to 12
- 12 to 14
- > 14
Wind-wave misalignment in Sørlige Nordsjø II

Wave and wind are fairly well aligned

\[ \langle \Delta \theta \rangle \approx 0^\circ \]

\[ \langle \Delta \theta \rangle = -4^\circ \]

Fitted conditional PDF of \( \Delta \theta \) given \( \bar{u}_{hub} \)

\( \bar{u}_{hub} = 10.6 \text{ m s}^{-1} \)

\( \bar{u}_{hub} = 35.0 \text{ m s}^{-1} \)
Wave conditions in Utsira Nord

$H_s$ (m)
- Yellow: 0 to 2
- Light green: 2 to 4
- Medium green: 4 to 6
- Dark blue: $\geq$ 6

$T_p$ (s)
- Yellow: < 4
- Light green: 4 to 6
- Medium green: 6 to 8
- Blue: 8 to 10
- Dark blue: 10 to 12
- Dark purple: 12 to 14
- Black: $> 14$
Wind-wave misalignment in Utsira Nord

Utsira Nord

$< \Delta \theta > = -17^\circ$

Clear deviation between wind and wave direction

$< \Delta \theta > = -9^\circ$

$\bar{u}_{hub} = 10.6 \text{ m s}^{-1}$

$\bar{u}_{hub} = 35.0 \text{ m s}^{-1}$
Extreme value analysis

50-year return period at SN2:

\( \bar{u}_{\text{hub}} = 37.7 \text{ m s}^{-1} \)

\( H_s = 13.4 \text{ m} \)

50-year return period at UN:

\( \bar{u}_{\text{hub}} = 42.3 \text{ m s}^{-1} \)

\( H_s = 14.6 \text{ m} \)

50-year contour surface at Utsira Nord
Case study: offshore operation duration

**Assumption:** The operation needs $H_s < 2 \text{ m}$

**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

![Graph showing the duration of operations with $H_s < 2 \text{ m}$ for 12 hours over different months.]
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

• Approximately 0.25 millions 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
Thank you