PO450

Reducing structural loads via advanced metocean analysis: wind-sea, swell, and atmospheric stability

Jorge Garza[1], Christian Berg Mørch[1], Martin Juul Krogstrup[1], Rémi Gandoin[1]

[1]C2Wind, Denmark

When addressing metocean conditions for support structure fatigue loads and design, considering atmospheric stability and sea state decomposition into wind sea and swell reduces uncertainty and yields lower support structure costs

- Wind across the ABL, sea state, and currents are deeply interlinked. Atmospheric stability affects wind-wave correlations and turbulence, and the relative importance of wind-sea and swell waves. Every offshore site presents a unique combination of these phenomena.

- Accurate characterization of these interactions through measurements and models is essential, yet there are currently no practical guidelines for aligning wind resource and metocean studies. This disconnect can lead to inefficiencies and uncertainties in yield predictions, fatigue load effect assessments, support structure design risk and project planning.

- We address this with several methods of increasing complexity:
  - Total sea state and assuming no variation of stability conditions.
  - Separation of wind sea and swell through 2D spectral hindcast data, assuming no variation of stability conditions
  - Separation of wind sea and swell through 2D spectra combined with atmospheric stability and accounting for the coherent ambient turbulence and wind shear.

- All three are run through integrated load analysis using a 15 MW generic WTG model to assess the impact on design.

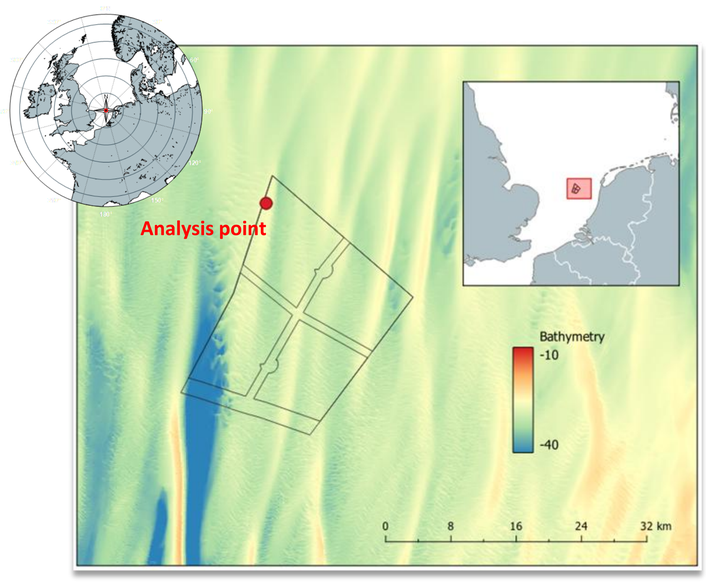

Figure 1: Location of the analysis case (IJmuiden Ver).

- Example case from IJmuiden Ver
  - Metocean and GT publicly available from RVO
  - Stability assessment based on ERA5

- For every hourly timestamp, wind-sea and swell components are constructed from directional spectra using a modified wave-age criterion.
  - Proper separation improves correlation between wind-sea waves and wind speed and reduces misalignment scatter.
  - Atmospheric stability classification increases correlation between wind-sea waves and wind speed.

- ILA considering DLC 1.2 & DLC 7.2 can be run without drastically increasing the number of simulations

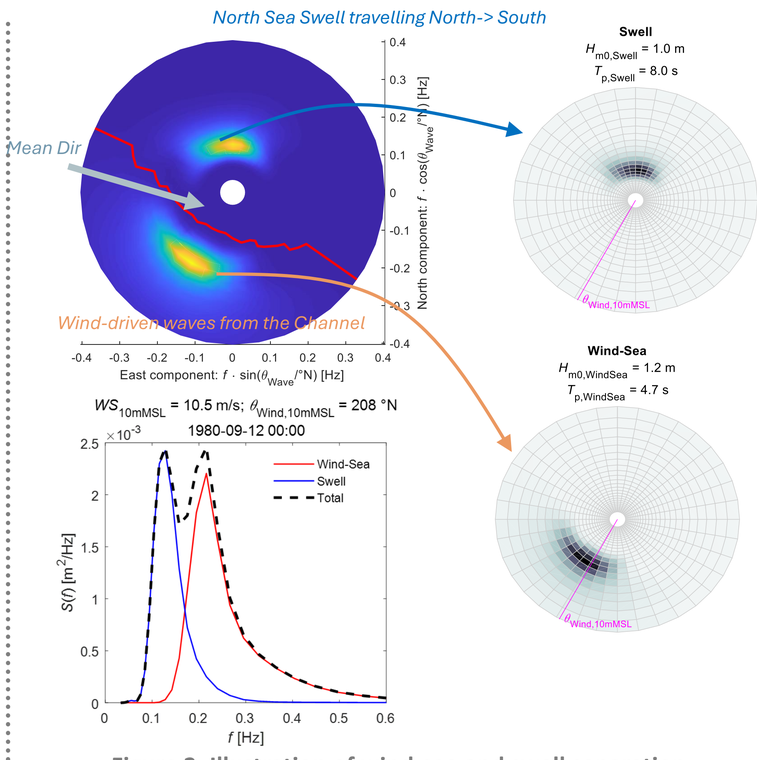

Figure 2: Illustration of wind-sea and swell separation.

- **Results**:
  - Wind-sea and swell separation reduces fatigue loads by 5% compared to total sea state, enabling a steel saving of up to 4%.
  - The directional fatigue distribution changes and fatigue-critical items are de-risked.
  - Further avoidance of plates with large thickness thus easier sourcing of plates.
  - Any FLS load effect reduction will result in a lower utilization of bolted L-flange connections.
  - Influence of atmospheric stability is limited for this site, but not for others.

Wind EUROPE ANNUAL EVENT 2026 MADRID 21-23 APRIL

windeurope.org/annual2026
#windeurope2026

Meet us at

Watch this presentation

Download the poster