

## A simple time series method for the site-specific assessment of directional turbulence intensity at offshore sites

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- Directional variations in freestream and wake-added turbulence intensity affect WTG layout design, support structure loads and thereby design lifetime estimates.
- It is often difficult to characterise turbulence directionally in Site Conditions Assessments due to the general lack of site-specific cup or sonic anemometer measurements.
- We present a method for providing accurate directional freestream TI assessments without on site measurements.
- The methodology is validated at 10 offshore met masts (Figure 1) against measured directional turbulence, as well as simpler approaches typically used in the industry.



Figure 1: Publicly available met mast datasets used in the validation. Two additional, proprietary met mast datasets were used in the analysis, located in the Baltic Sea and in East Asia, and are not shown for confidentiality.

- Even for simple sites such as the IJmuiden mast in the Dutch North Sea there can be large variations in directional mean- and 90% quantile TI, see Figure 2. TI conditioned on atmospheric stability reveals that these variations are closely tied to the directional variability in atmospheric stability.
- Characterising turbulence as a function of wind speed and atmospheric stability allows the transfer of high-quality TI measurements from IJM to other sites requiring only knowledge of the wind speed-, direction and atmospheric stability distributions from model data.
- Despite neglecting the impact of boundary layer height, the approach it proves sufficient for most offshore sites.

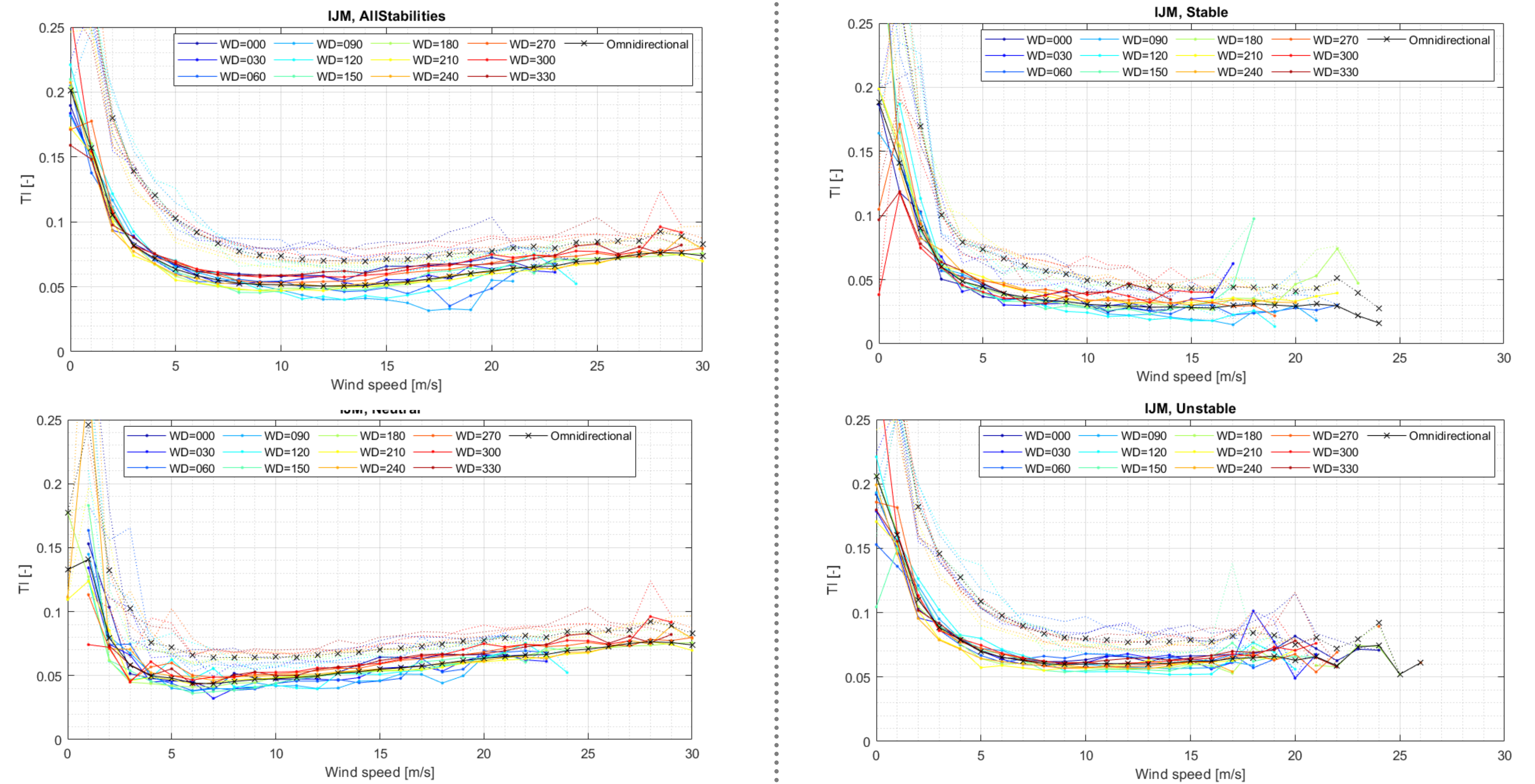


Figure 2: Mean- and 90% quantile TI (solid and dashed lines) at the IJmuiden met mast for 12 wind direction sectors and for 4 stability categories.

- Directional distributions of atmospheric stability are obtained for each met mast based on ERA5, and the stability-dependent TI measured at IJM is transferred to each target mast based on the difference between their stability distributions.
- The measured directional TI at each met mast is compared against several possible proxies:
  - The same met mast's omnidirectional TI distribution.
  - The IEC 61400-1 TI definition
  - The model results
- TI comparisons are made for the mean, 90% quantile, as well as generalized means with m-power 5 and 10 as per the recent amendment to the IEC 61400-1 standard.
- The results show that the proposed method provides a significant improvement over the conservative turbulence expressions in IEC 61400-1.
- Furthermore, the proposed method consistently achieves error metrics comparable to those of the measured omnidirectional TI. That is: the method yields results of comparable accuracy to on-site measurements.

For more on how to account for the boundary layer height see [https://c2wind.com/f/content/0-006-06-01\\_3---c2wind-and-rwe---ti-modelling-offshore.pdf](https://c2wind.com/f/content/0-006-06-01_3---c2wind-and-rwe---ti-modelling-offshore.pdf)

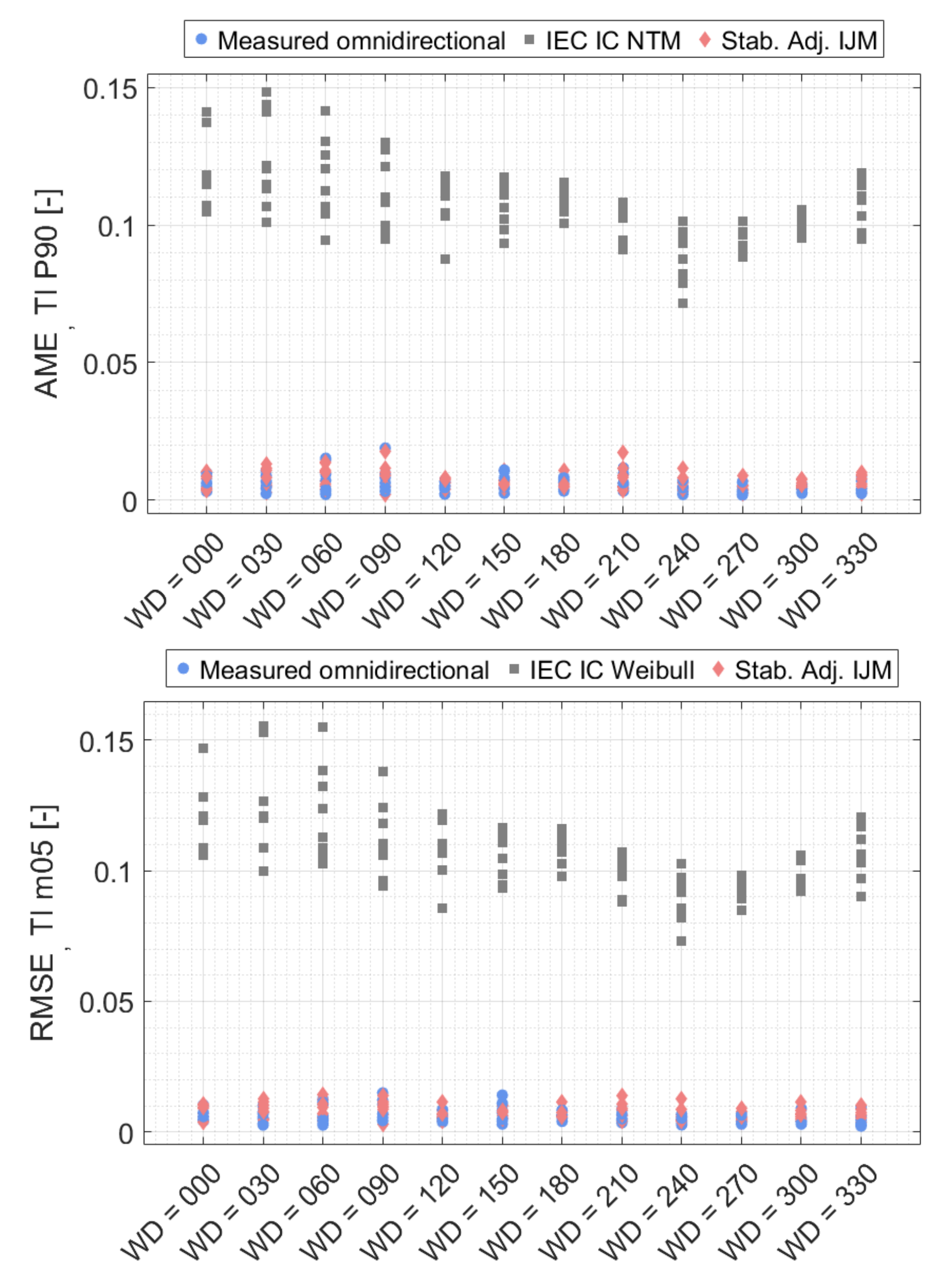


Figure 3: Absolute Mean Error of directional TI 90% quantile estimates (top) and RMSE of directional generalized mean TI with power  $m = 5$  (bottom) for the 10 met masts. The proposed method's results in red provide comparable accuracy to the measured omnidirectional quantities in blue, and much improved over the standard IEC expressions in grey.

This method provides directional estimates of ambient turbulence intensity at a target offshore site based solely on model wind speed, direction and atmospheric stability distributions, and of comparable accuracy to on-site measurements.