A study of the variation in offshore turbulence intensity around the British Isles
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Abstract
Offshore met mast installation is expensive and time-consuming, so remote sensing devices are increasingly employed as a cheaper and quicker alternative. However, turbulence intensity measurements from remote sensing cannot be directly related to measurements provided by cup anemometers. Turbulence intensity is a key input to wake models and a significant driver of turbine loading, and therefore impacts wind farm energy yield, turbine selection, and capital expenditure.

This study investigates the variation and drivers of turbulence intensity around the British Isles, to determine whether on-site turbulence intensity measurements are required for proposed offshore wind farms.

The work has been carried out by Prevailing for the Carbon Trust’s Offshore Wind Accelerator and Mainstream Renewable Power.

Methods
8 publicly available datasets have been analysed from offshore met masts in the Irish Sea and North Sea (Figure 1). Data was sourced from The Crown Estate’s Marine Data Exchange and Energieonderzoek Centrum Nederland’s Wind Op Zee website.

Figure 1. Locations of masts used in the analysis

The measured wind data was processed and cleaned using industry standard methods. Wind speed data at all masts was extrapolated to a height of 87 m using measured shear and seasonally-balanced datasets. Various turbulence intensity metrics were derived. Combined air and sea temperature data were only available at the IJmuiden mast.

The variation of these metrics were analysed as functions of wind speed, wind direction, distance to the coast, presence of significant terrain upwind, season and temperature.

There were a number of issues with the datasets used due to a lack of installation and maintenance information, poor data coverage and equipment malfunctions at some masts. Consequently the data processing undertaken does not meet financial-grade analysis standards. Nevertheless, the resultant datasets are deemed of acceptable quality to provide robust turbulence intensity metrics for the purposes of this study.

Results
Mean turbulence intensity metrics were observed to be very consistent across all datasets (Figure 2). Similarly, distributions of mean turbulence intensity as a function of wind speed (Figure 3) and turbulence intensity probability distributions (Figure 4) are in good agreement. Sensitivity tests using an Eddy Viscosity wake model show that the use of the highest or lowest turbulence intensity distributions results in relatively small wake loss differences of approximately 0.3 % for a typical offshore wind farm, significantly lower than the uncertainty in the wake modelling itself.

A clear seasonal variation was observed (Figure 6), with lowest turbulence intensity during spring at most masts. This suggests that the slower warming of the sea, compared to land, creates a stable boundary layer resulting in lower turbulence. This effect was investigated further using the IJmuiden mast, where both air and sea temperature data are available (Figure 7). For this dataset, a clear correlation was observed between turbulence intensity and the sea-air temperature difference, supporting the stable springtime boundary layer hypothesis.

Conclusions
For the region and datasets considered in this study, the variation of turbulence intensity is observed to be more strongly connected to season than distance from the coast.

For sites more than 10 km from the coast, mean turbulence intensity and turbulence intensity distributions are very similar. Consequently, where a remote sensing device is employed on such sites, it is considered appropriate to use suitable off-site turbulence intensity measurements for wake modelling, energy yield analysis and representative turbulence intensity calculations.

Due to the observed seasonal variation in turbulence intensity, it is recommended that all turbulence intensity metrics for offshore wind farm energy yield assessment and turbine loading calculations are derived using seasonally balanced datasets.

References