A Comparison of the UK Offshore Wind Resource from the Marine Data Exchange

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Introduction

Offshore wind measurements are scarce and expensive, as part of the MAXFARM project (REF), an evaluation is presented of the wind-flow parameters that most affect wind turbine performance and lifetime in the context of large offshore wind farms with specific emphasis is placed on the mean and distribution of wind speed and turbulence. Unlike most offshore resource assessment campaigns which use measurements from one point location to represent the conditions across a large farm, this work uses multiple data sources around the UK to provide insight into the variability of conditions around the UK.

Approach

Multiple datasets were made available by The Crown Estate via the Marine Data Exchange (REF) from 12 meteorological masts and 3 lidar located offshore in UK waters. Atmospheric stability is calculated at 11 locations where temperature measurements are available at multiple heights, though due to the variations in instrumentation layouts between sites, multiple calculation methods are required and displaying some inherent discrepancies. The locations of masts and lidar are shown as blue dots in Figure 1.

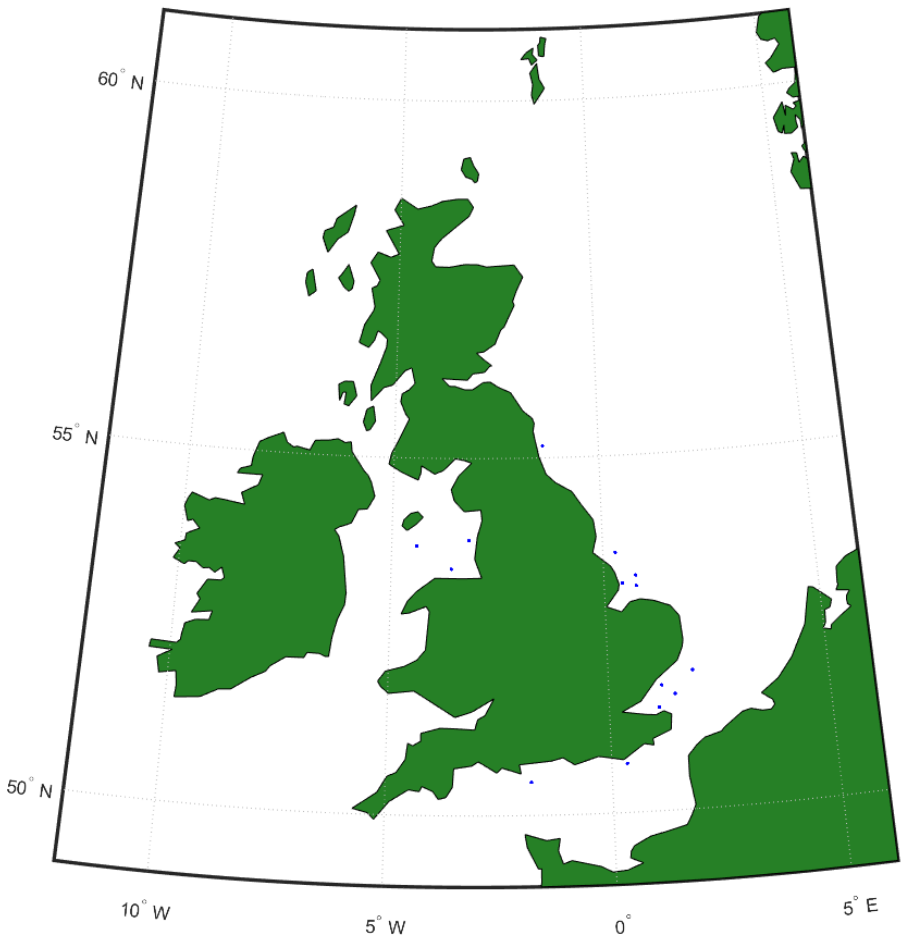

Figure 1 Location of offshore met masts and Lidar used in this work

As the data comes from many different wind farm projects they cover a wide range of dates from 1999 to 2015, varying in length and availability as shown by Figure 2. Some datasets such as from Humber Gateway do not encompass an entire year and so caution needs to be applied to any time-based statistic as the wind resource varies with the seasons. Since there is no common time frame from which all locations report data, it is assumed that inter-annual variation is minimal for the purposes of comparison between sites. In addition, not all the same parameters are available for each dataset due to varying mast instrumentation or various amounts of filtering performed by the data owners before submitting it to The Marine Exchange. An example of this is the Navitus Bay Lidar dataset which for a short period contains values of 10 minute mean wind speed and direction up to 190m above sea level but supplies no data about the 10 minute standard deviation values, making the calculation of turbulence intensity impossible.

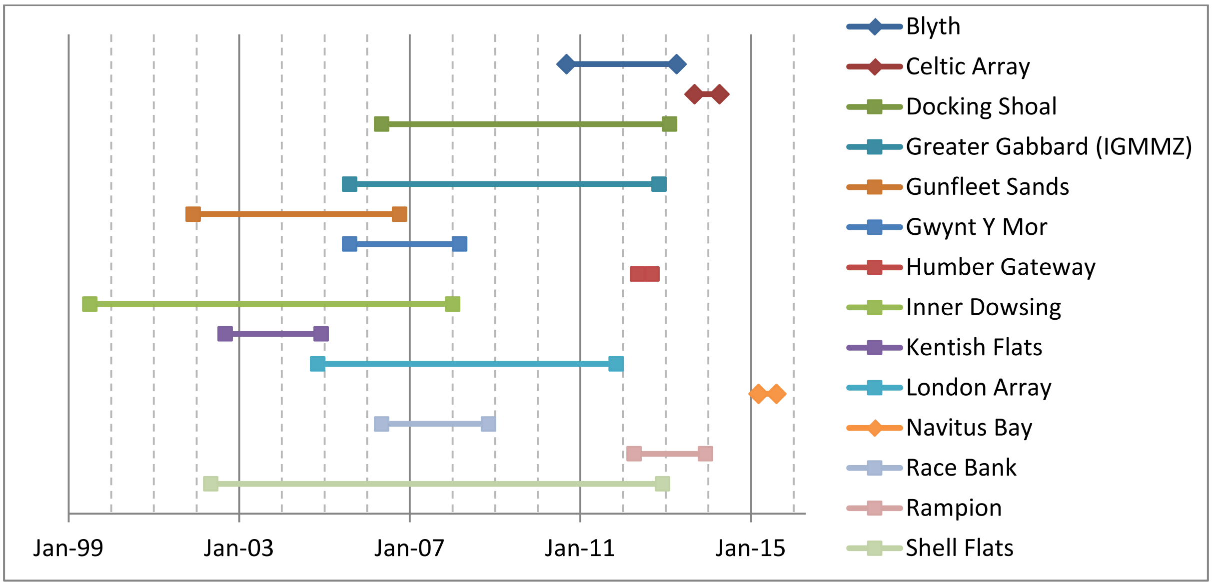

Figure 2 Availability of datasets, mast data is shown as squares, lidars as diamonds. Note there are two met masts at the Shell Flats site with similar data availability.

Main Body of Abstract

The UK offshore wind resource is heavily affected by its global location both in terms of latitude due to the polar jet stream resulting in a south-westerly prevailing wind, and by the North Atlantic Ocean Gulf Stream which maintains warmer waters than usual for that latitude. The prevailing wind is clearly seen across the collection of wind roses in Figure 3 with variation due site location around the UK being minimal. The rose for the Blyth data appears offset by about 30 degrees, as this is occurs throughout the dataset at all heights (not shown here) it is likely that either the lidar compass is misaligned of the proximity to shore (less than 2km) is affecting the flow.

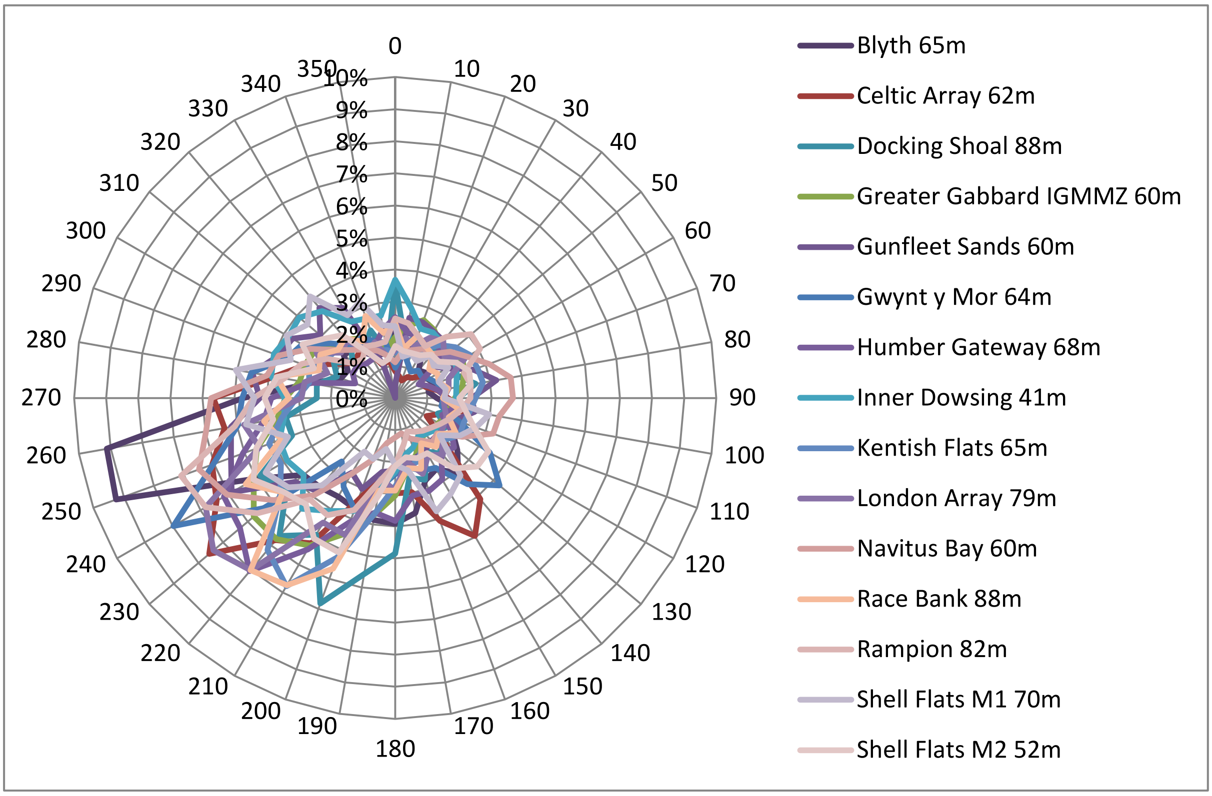

Figure 3 Wind Roses for each site at closest available measurement height to 70m above sea level

Comparison of the wind speed profiles time averaged across each dataset shown in Figure 4. Although there is variation in absolute speed values between datasets, the majority are consistent to within 1.5m/s across the mast heights and mostly conform to similar vertical wind shear values. The two exceptions are the Blyth lidar and the Inner Dowsing mast dataset, also located close to shore. The proximity to shore is revealed in the Blyth data by the rapid increase in wind shear at lower levels whilst the cause of lower speeds at Inner Dowsing is unclear though may be related to the age and design of the mast. The Navitus Bay floating lidar reveals a sharp drop in wind speed at heights approaching the sea surface, suggesting the height of the logarithmic surface layer may be lower than expected.

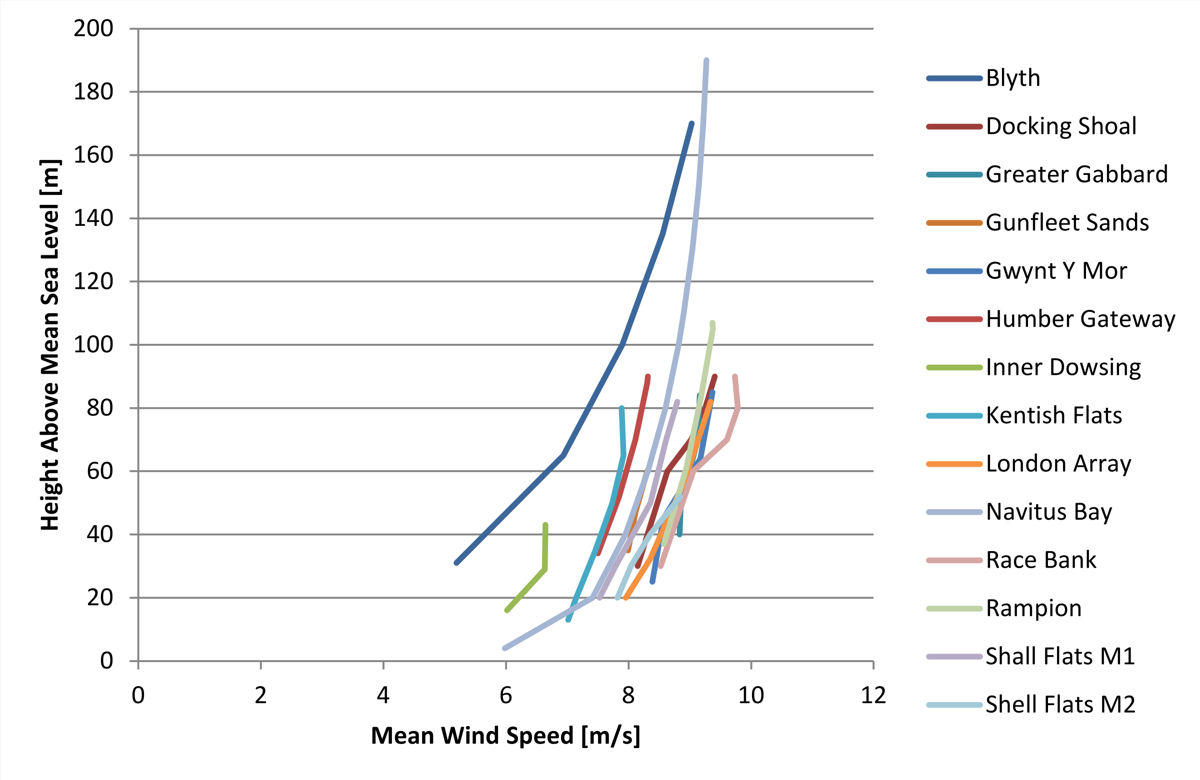

Figure 4 Time averaged wind speed profiles at each location

Comparisons of turbulence intensity (TI) by wind direction at each site again emphasise proximity to shore for the Blyth dataset. Figure 5 shows that for more than half of all directions, TI is roughly double that at locations further from shore at similar heights. This increase in TI near to shore is also shown in Figure 6 where values for TI at Blyth increase rapidly with proximity to the sea surface whilst the others indicate less variation with height. Whilst some sites report higher than expected values of TI around 70 above sea level, it is unclear if these are due to measurements issues or possible interference from the mast structure.

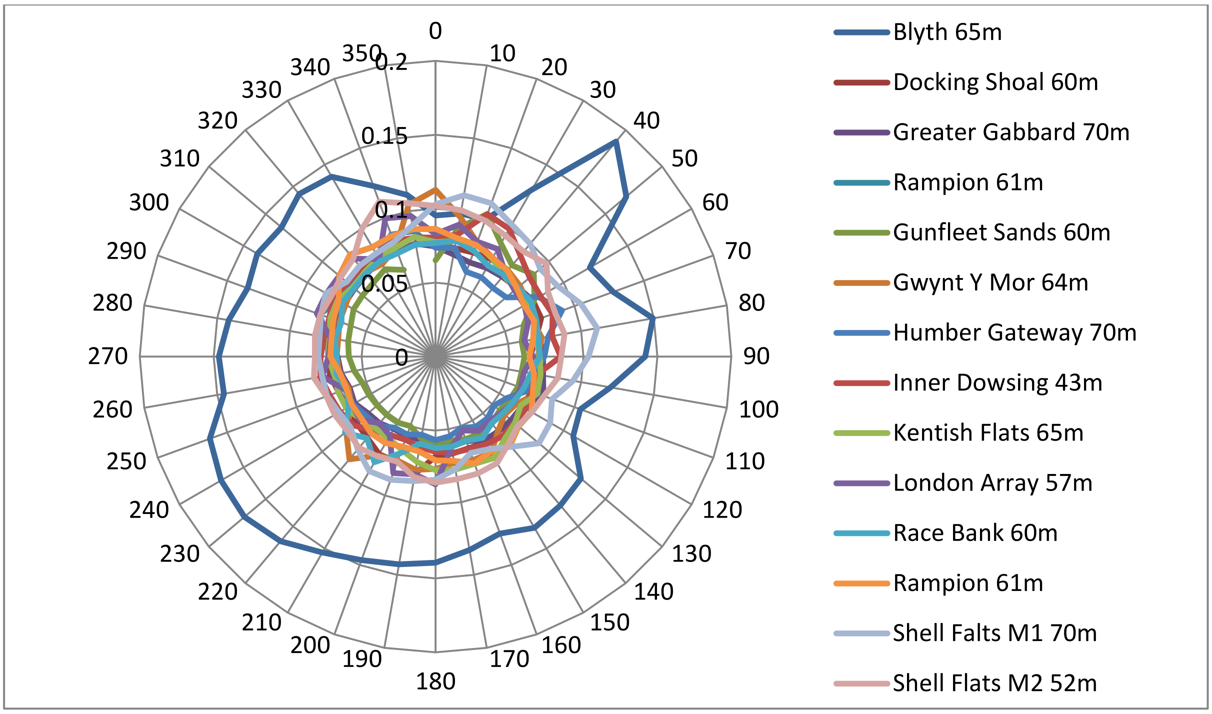

Figure 5 TI Rose for multiple sites at similar heights.

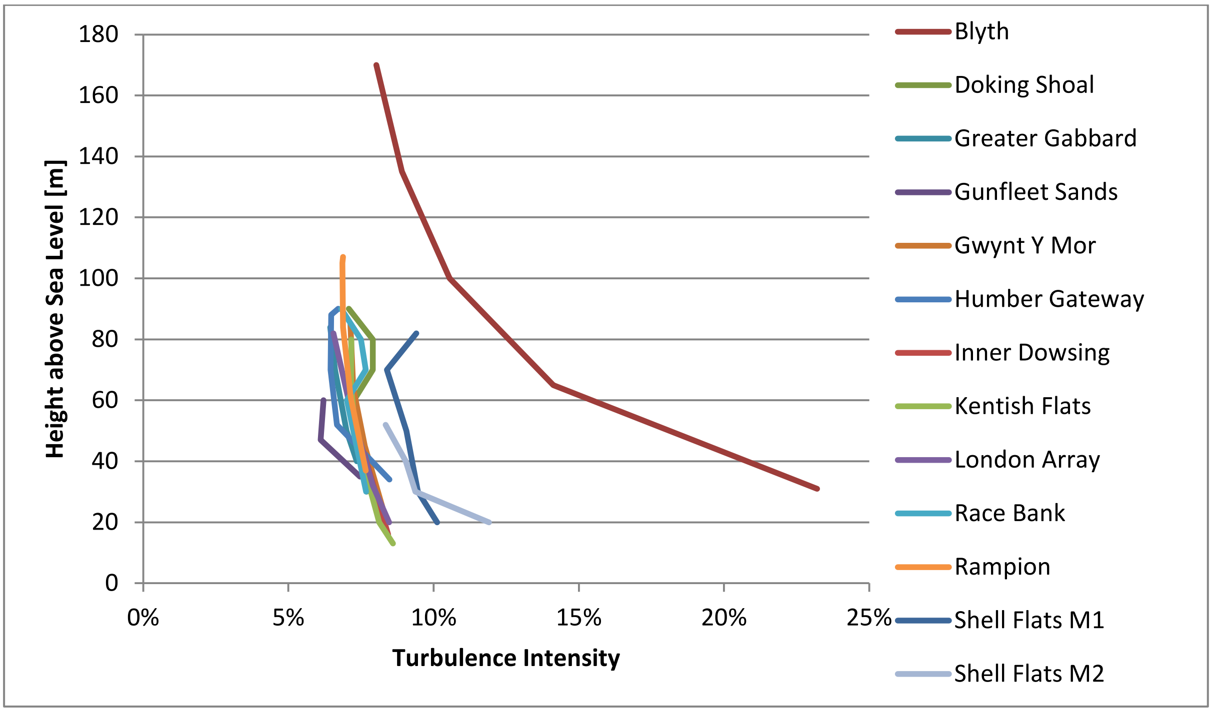

Figure 6 TI profile with height

After focusing on the mean wind speed and TI values at multiple heights and directions, it is also important to consider the distribution of values across the relevant spectrums. To this end Figure 7 and Figure 8 show the spectrum of mean speed and TI at the heights consistent with the earlier figures. Primarily they show a strong consistency between sites with no obvious difference or dependence on location around the UK coastline. Notably both the Blyth and Inner Dowsing datasets show a higher frequency of slower wind speeds as previously shown in Figure 4. The spread of TI values is also similar between sites, with the exception of the Blyth dataset which when combined with the results from Figure 6 suggest there may be either unresolved discrepancies within the data or again the site resource is more reflective of an onshore location.

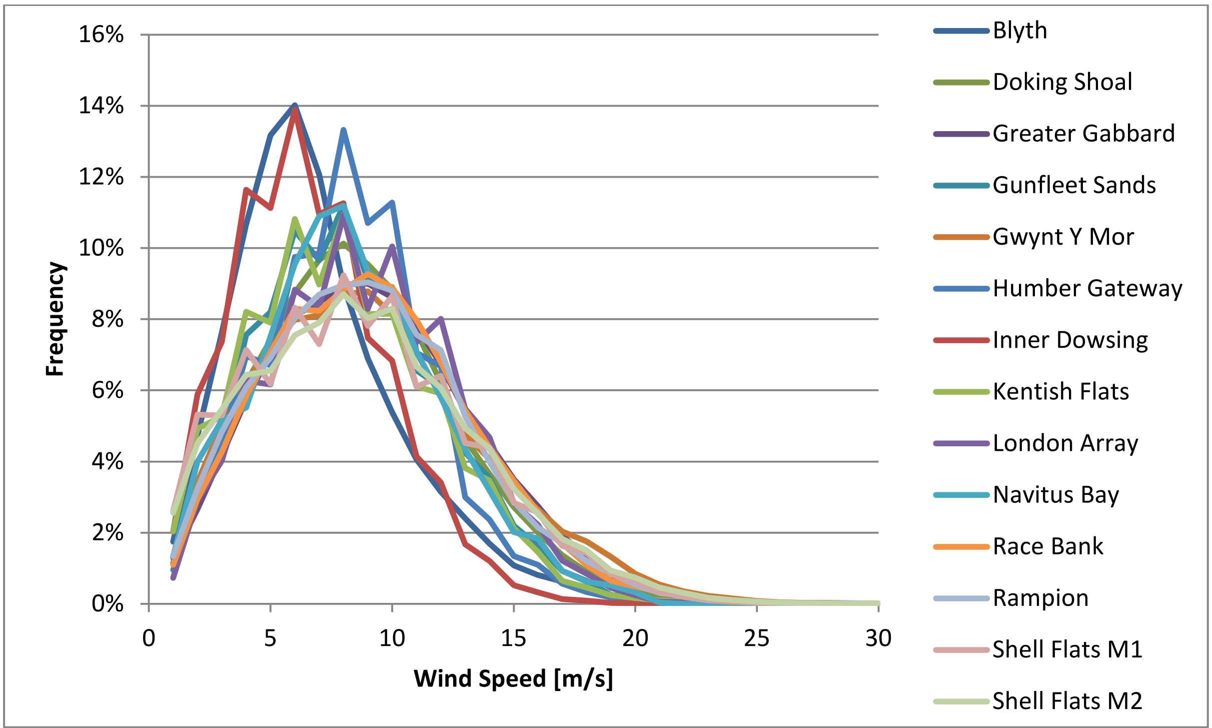

Figure 7 Spectrum of mean wind speed frequencies between each site at similar heights above the sea

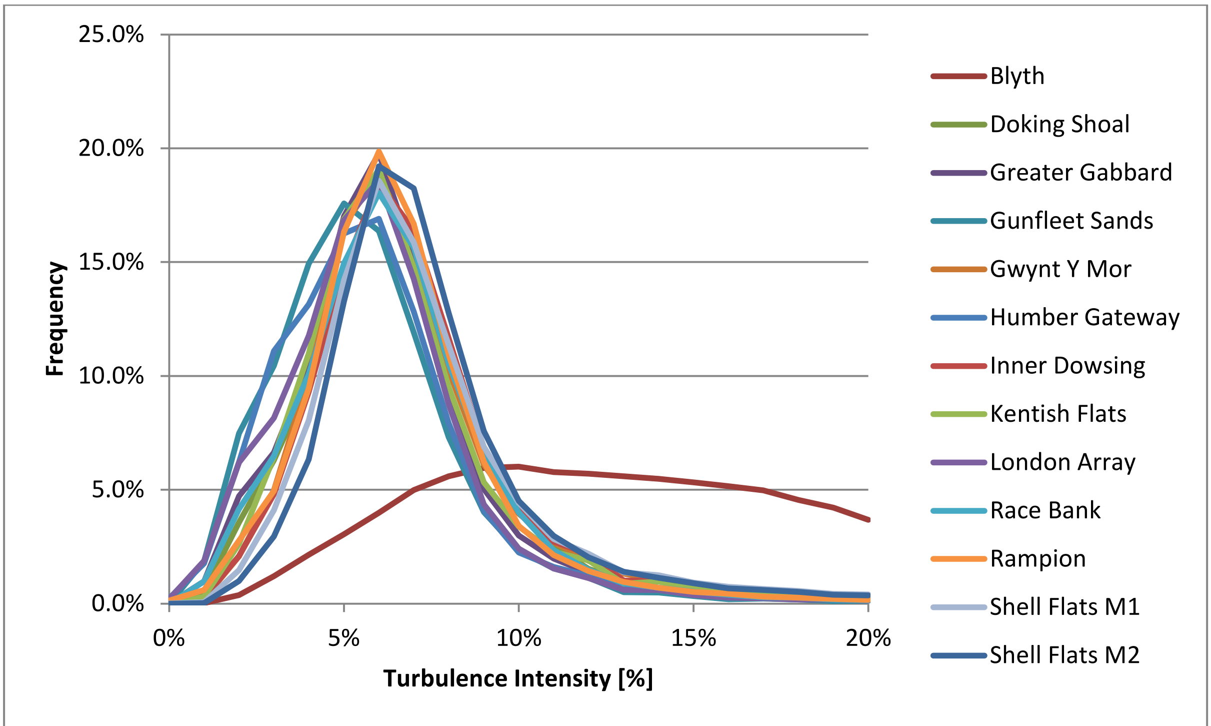

Figure 8 Spectrum of TI frequencies between each site at similar heights above the sea

Conclusion

As the meteorological data used in this project from The Marine Data Exchange was freely available without charge it is unsurprising that the quality of raw data available and the number of parameters varied significantly between individual datasets. However, once the cleaned, the data shows surprisingly little variation exists between locations in UK waters. Most of the variation seen can in part be attributed to temporal variation and length in the datasets rather than location. More effort should be made to compare temporal/seasonal variation within the longer datasets than possibly between individual shorter datasets. With enough datasets from around the UK/North Sea region, it may be possible to build up an “expected” wind profile to test against current atmospheric boundary layer theory and provide a measure of confidence to developers about their future offshore wind resource before measurement campaigns begin.

Learning Objectives

Meteorological data from around the UK is freely available for analysis though caution is highly recommended when processing the data. Variation in geographical location throughout the UK territorial waters leads to some variance in some parameters (such as turbulence intensity) although distance to shore may be more important.