Wave Climate Analysis in South Pembrokeshire from 20-year Time Series of the Turbot Bank Buoy

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Introduction

Data was acquired from the UK Met Office for the Turbot Bank buoy, the only buoy in the South Wales wave resource area. The buoy is located at 51.603 N 5.100 W (Figure 1). The buoy record used spans from 1/09/1994 to 30/04/2014 (Figure 2). The turbot bank buoy is non directional and only provides significant wave height and mean wave period. The follow report uses this data to characterise the wave climate in the area. Significant wave height, mean wave period and wave steepness are considered, wave power calculated and a representative year determined and extreme wave heights calculated.

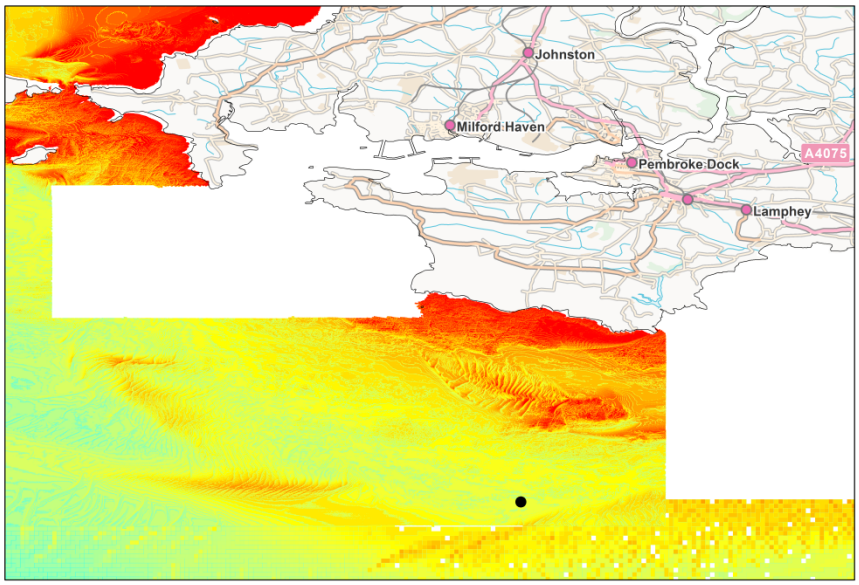

Figure 1: A map of South Pembrokeshire showing the location of the Turbot Bank Buoy (black circle)

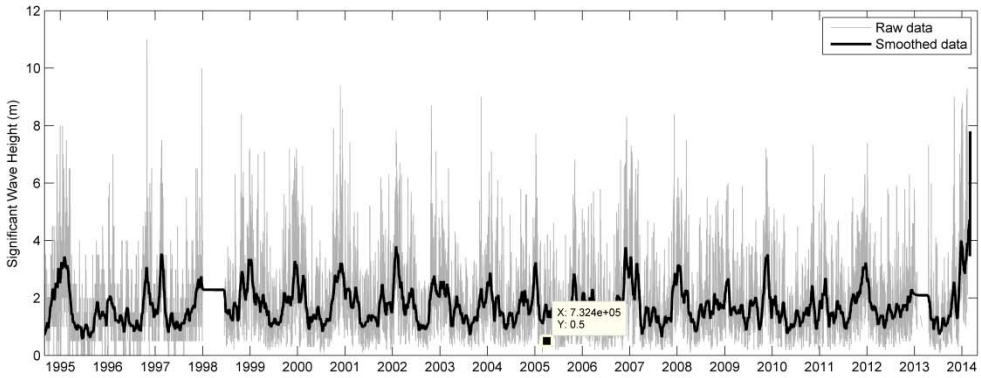

Figure 2: A plot of the raw data (grey) and smoothed data (black). Seasonality is clearly evident in the wave record.

Monthly mean conditions

The mean monthly wave heights, periods and steepness proxy (H/T) are presented in Table 1 along with the standard deviation of this parameter. Figure 3 shows that there is a greater noticeable seasonality to the maximum wave height than to the mean wave height. Standard deviation in wave height shows some seasonality but this is not evident in the standard deviation in wave period. There is also some seasonality in wave steepness with steeper waves occurring in winter.

Table 1: Monthly means and standard deviation for wave height, period and steepness

Month	Mean Hs	Std Hs	Mean T	Std Hs	Mean St.	Std st.
January	2.26	1.39	6.44	2.18	0.34	0.15
February	2.07	1.37	6.51	2.20	0.31	0.15
March	1.65	1.10	6.25	2.12	0.26	0.14
April	1.31	0.89	5.91	2.02	0.22	0.12
May	1.28	0.90	5.68	1.96	0.23	0.13
June	1.17	0.79	5.58	1.79	0.21	0.12
July	1.15	0.72	5.37	1.67	0.22	0.11
August	1.17	0.74	5.35	1.64	0.22	0.11
September	1.34	0.89	5.63	1.81	0.24	0.12
October	1.87	1.11	6.02	1.59	0.30	0.14
November	2.06	1.20	6.38	1.31	0.32	0.15
December	2.27	1.32	6.50	1.41	0.34	0.16

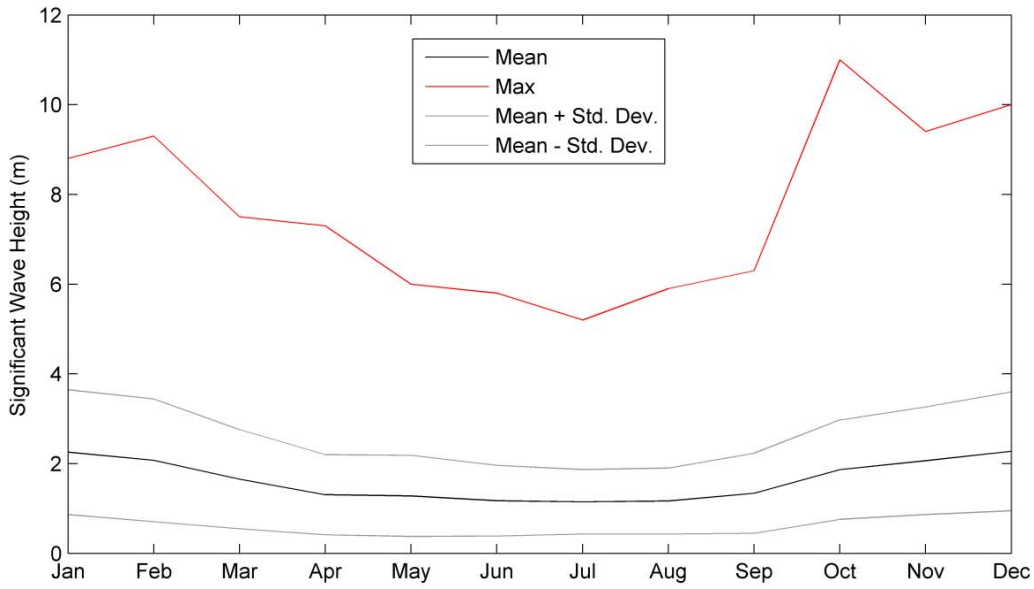

Figure 3: Monthly mean and maximum wave heights and standard deviations between 1994-2014

Annual means and variability.

Mean significant wave height over the entire record is 1.63m, mean wave period is 6s. The minimum annual mean wave height is 1.11m and the maximum mean annual wave height is 1.99. The standard deviation in annual mean is 0.2m. Maximum annual mean wave period is 7.3s and the minimum annual mean wave period is 5.6s. The standard deviation in mean wave period is 1.86

Annual and monthly means are shown in Figure 4. The mean value ± standard deviation is also plotted. The inter-annual variability can be seen but it is evident that such variability is within the standard deviation of the wave period and is close to that for the wave height.

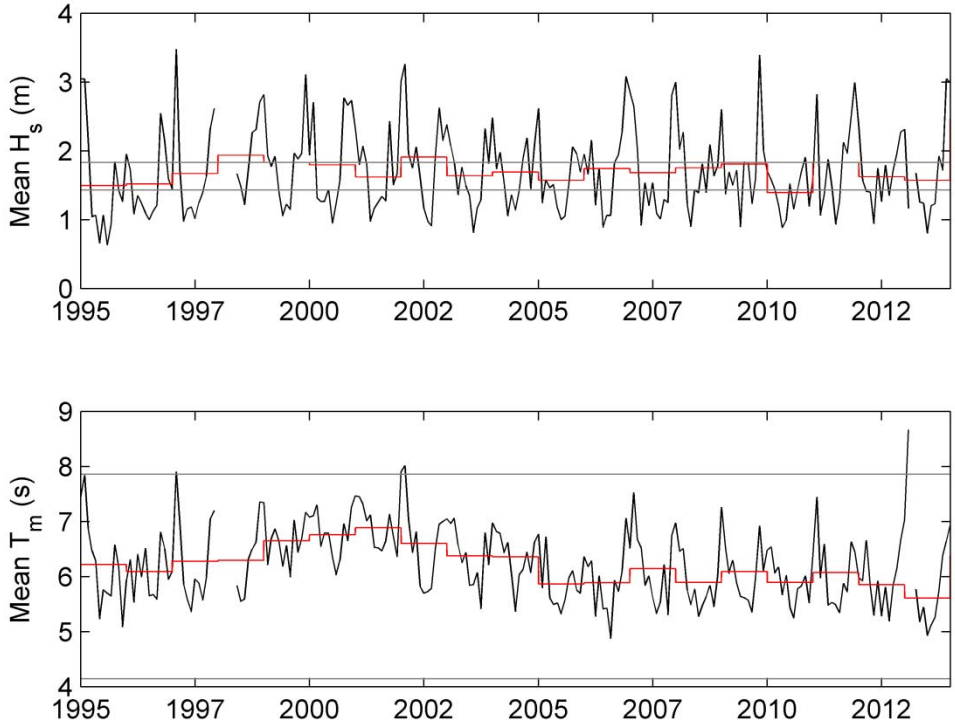

Figure 4**:** Yearly means (red) and monthly means(black) for wave height and wave period. The standard deviation in parameters is shown in grey.

Wave Power Analysis

The following section looks at the wave power at the Turbot Bank location. Wave power per meter of wave crest is calculated via:

$P=ECg$

Where the wave energy, E, is calculated via

$E=\rho g H_s^2/16$

And the wave group velocity Cg is a function of water depth and wave period.

The mean wave power at the buoy over the 20 year period is 17 kw/m. Figure 5 shows the raw wave power and a smoothed time series to better show the seasonality in resource. Figure 6 shows the mean wave power for each month over the 20 year time series (in black) and monthly means for each individual year (grey). Seasonality can be seen in the resource with variation between monthly means of 6.5 kw/m in July and 34.5 kw/m in January. Yearly mean power varies between 10 kw/m and 24 kw/m. The yearly means are displayed in Figure 7. Linear fitting to the yearly means show a slight decrease in wave power over the period between 1995-2013.

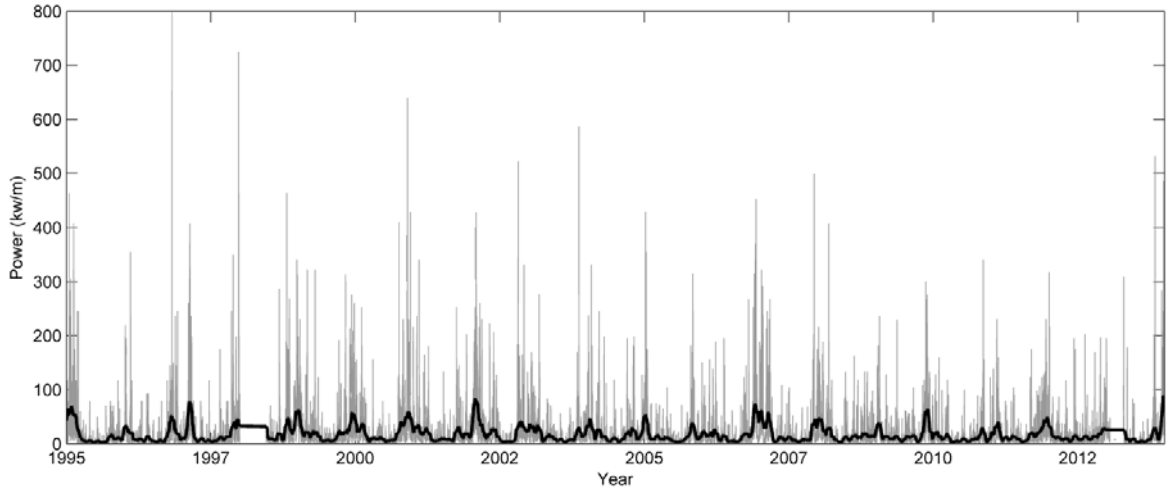

Figure5: A time series of the raw power at the turbot bank location (grey) and smoothed time series (black).

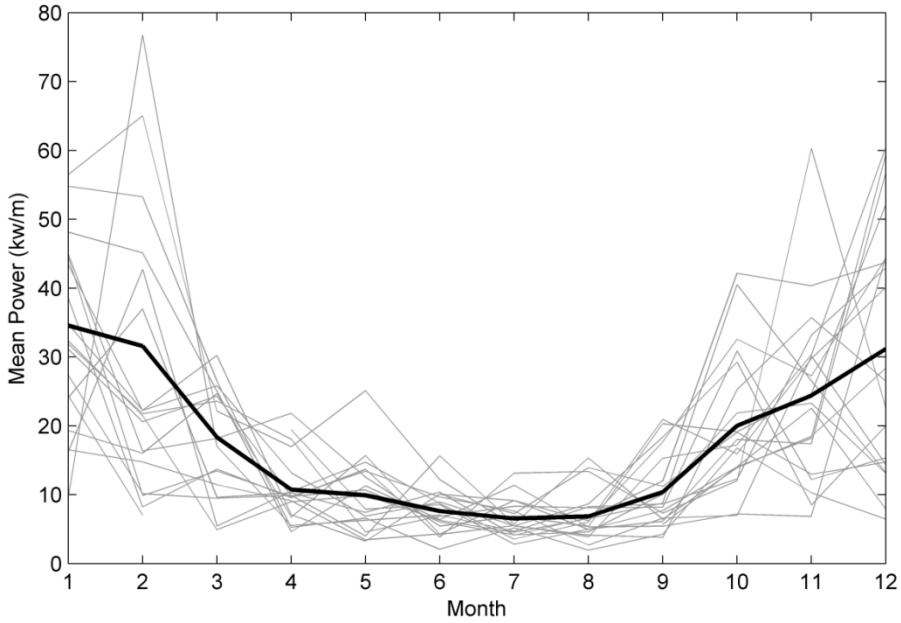

Figure 6: Monthly mean power over the 20 year period (black) and monthly means of the individual years in the record (grey).

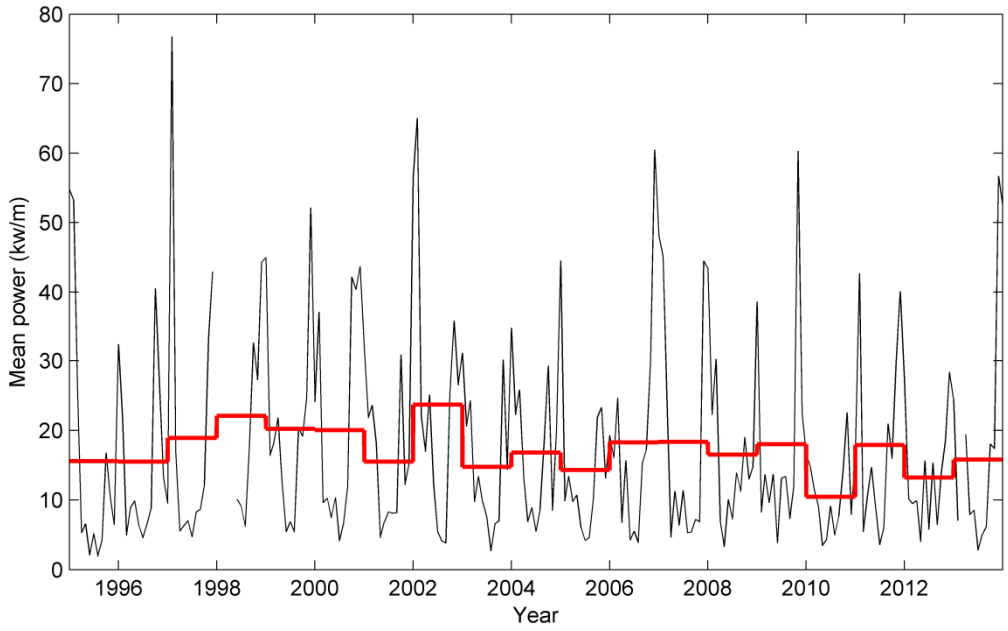

Figure 7: Yearly means (red) and monthly means (black) for power at the Turbot bank buoy.

Definition of a representative year

It is useful to define a representative year for wave conditions in a given location in case more detailed modelling studies are to be carried out. Best practise would be to model the area over a multi-year period but constraints on computational expense often prevent this. In this section the methodology described in [1] is applied. Years are ranked based on their deviation from the annual mean and based on the sum of deviations from the monthly mean and the quarterly mean. Wave power is considered - not only is this the most important metric for resource assessments, it depends upon both wave height and wave period. Table 2 shows the top 5 ranked years for the three different categories. Based on this is can be seen that 2004 is the most representative year. Time series of wave parameters for 2004 are displayed in Figure 8.

Table 2: The top five ranked years for deviation from mean, monthly means and quarterly means

Yearly mean	Monthly mean	Quarterly mean
2011	2005	2001
2009	**2004**	**2004**
2006	1998	1996
2004	2003	1997
2007	1996	2005

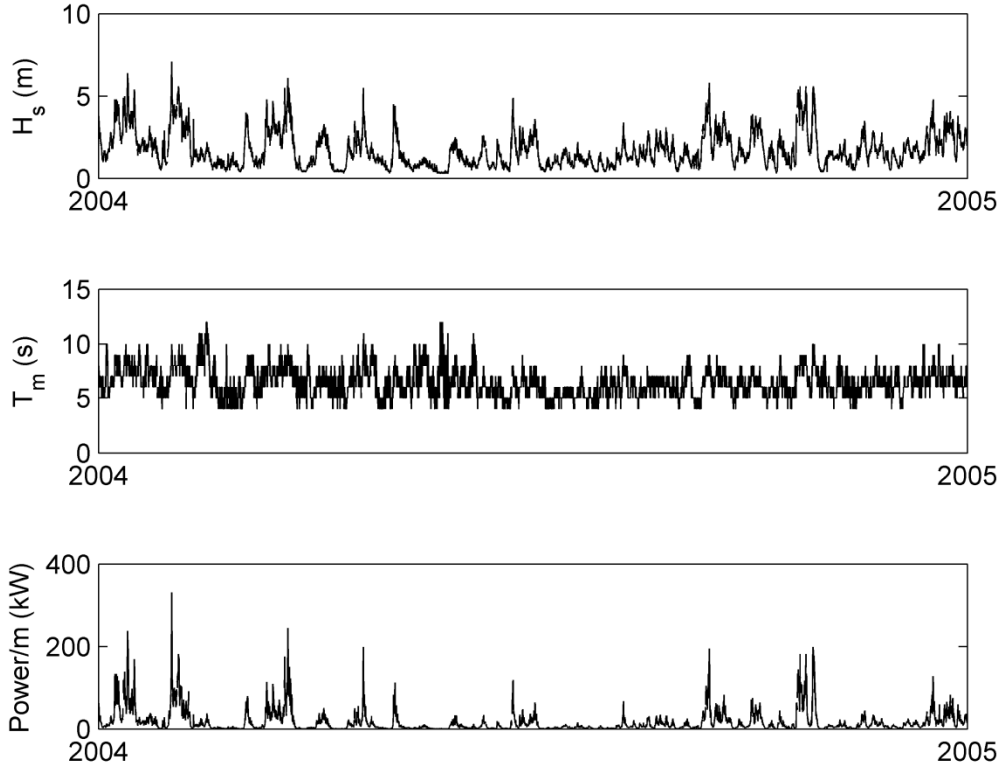

Figure 8: Wave parameters for the representative year (2004).

Estimation of extreme wave height

The wave climate is approximated using a gumbel distribution to estimate wave heights for return periods of 50, 100, 200 years(Figure 9). These are displayed in Table 3.

Table 3: Extreme significant wave heights for corresponding return periods			
Return Period (yr)	50	100	200
Wave height (m)	14.15	14.74	15.32

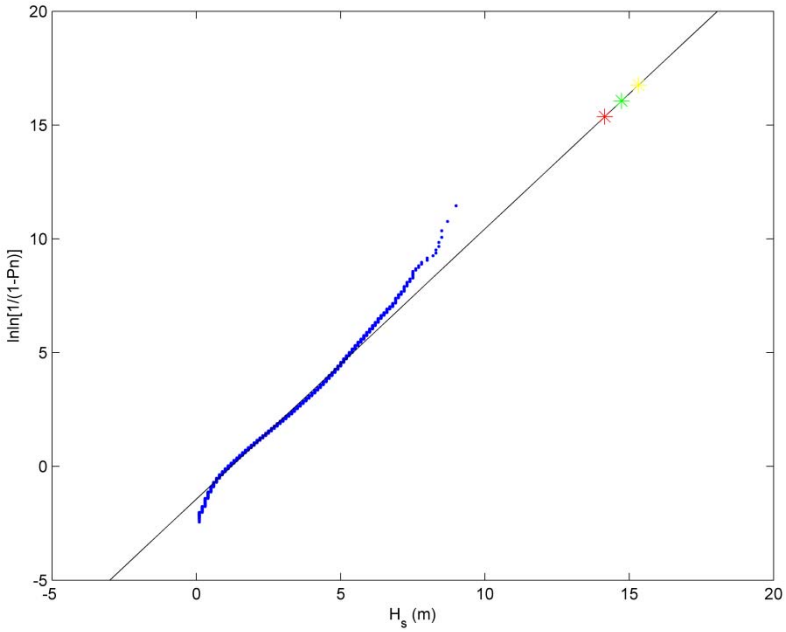

Figure 9: Extreme wave height analysis

References

[1]Halcrow, Pentland Firth and Orkney Waters Model, report to MSS, March 2013