

# Appendix C

Wind

## Appendix C. Wind

### C1. Description of Met Office NWP Model

Wind data are provided to the project ultimately from the Met Office's Numerical Weather Prediction (NWP) system, at the heart of which is the Unified Model. An understanding of the source of this data is important so that both its strengths and weaknesses can be properly understood.

This model forms the basis of all forecasts issued by the Met Office. It should though be noted that in the majority of operational forecasts this raw model output is further refined. This is achieved by the application of a more site-specific model or by a forecaster with their knowledge of the particular location and how the model is likely to perform in the present atmospheric conditions. For example, when forecasting for windfarms, a forecaster would be used to modify upwards the wind-speeds to allow for the exposed nature of that location compared to the average provided by the raw model output.

The atmospheric component of the Unified Model is grid-point based and uses a regular latitude-longitude grid in the horizontal. Operationally, the Met Office runs two configuration of its Unified Model (Figure C1.1). The Global Model has a horizontal resolution of  $0.8333^{\circ}$  longitude and  $0.5555^{\circ}$  latitude giving an approximate resolution of 60km in mid-latitudes. There are 30 vertical levels with humidity calculated on the lowest 27 levels (Table C1.1). The Global Model is used to provide boundary conditions to a mesoscale atmospheric model, which is a regional model centred on the United Kingdom. This model has a resolution of  $0.11^{\circ}$  latitude by  $0.11^{\circ}$  longitude, which equates to approximately 11km. This model has 38 levels in the vertical with additional levels in the boundary layer to provide extra detail for forecasting over the UK. It is this higher-resolution mesoscale model which is used here.

**Table C1.1** Details of the numerical schemes

Model	Horizontal Resolution	Horizontal Grid EW x NS	Vertical Levels
Global	$0.8333^{\circ} \times 0.5555^{\circ}$ (approx. 60km)	432 x 325	30
UK Waters	$0.111^{\circ} \times 0.166^{\circ}$ (approx. 11 km)	146 x 182	38

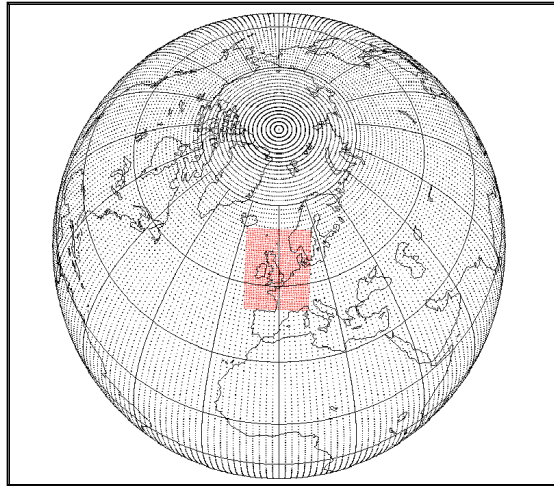


Figure C1.1 The grids used by the Global (grey) and UK (red) forecast systems

The vertical levels within the numerical models are arranged in a hybrid system. The lower levels are based upon sigma levels, i.e. the ratio of pressure to surface pressure such that they closely follow the ground terrain. The upper levels are pressure levels (Figure C1.2).

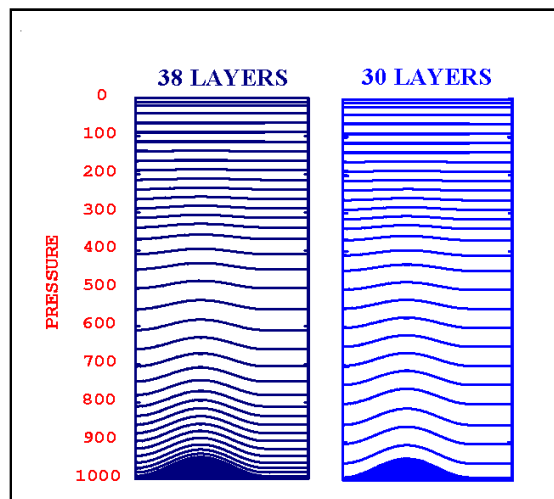
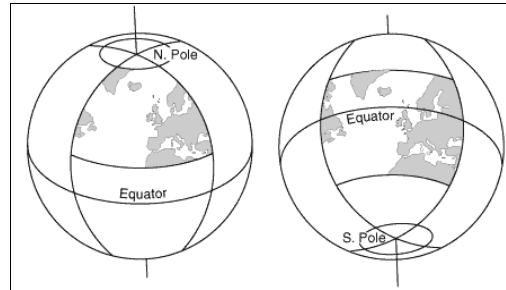


Figure C1.2 The distribution of levels used in the Global (right) and UK (left) configurations

In the UK Waters Model the grid's North Pole is not located at the geographical North Pole but is rotated to 37.5°N 177.5°E (Figure C1.3). This therefore places the UK near the equator allowing a fairly uniform horizontal resolution to be obtained over the area of interest, i.e. the UK.

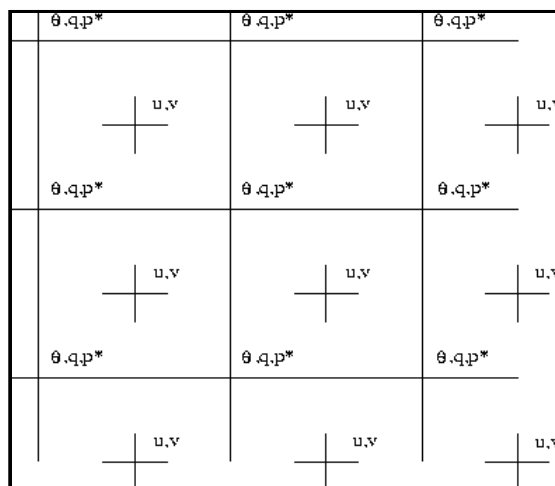


**Figure C1.3 Illustration of the location of the North Pole in the UK Waters Model**

- Left: An example of a limited area grid with boundaries defined by lines of actual latitude and longitude, with grid-points converging polewards.
- Right: The limited area grid rotated to place the area of interest near the equator. Thus the grid boxes are a more uniform dimensions.

The boundary conditions for UK Waters Model are provided by Global Model fields interpolated onto the UK Waters Model co-ordinates. These are applied to the outermost points around the UK Waters Model grid.

The primary physical parameters of potential temperature ( $q$ ), surface pressure ( $p^*$ ) and specific humidity ( $q$ ) are calculated on grid points, and the two horizontal wind components ( $u,v$ ) are calculated in the centre of the grid boxes. This arrangement of variables is known as the Arakawa 'B' grid (see Figure C1.4). Collectively these variables are called 'tracers' as they are calculated at every stage of a model run.



**Figure C1.4 The Arakawa B grid**

Potential Temperature ( $\theta$ ), surface pressures ( $p$ ) and specific humidity ( $q$ ) are calculated at a grid point and the horizontal wind components ( $u,v$ ) are calculated at the centre of the grid boxes.

The atmospheric prediction uses a set of equations that describe the time-evolution of the atmosphere. The equations are solved for the motion of a fluid on a rotating, almost-spherical planet. The main variables are the zonal (latitudinal) and meridional (longitudinal) components of the horizontal wind, potential temperature and specific humidity. To solve the system of equations, a number of approximations or assumptions have to be made.

In common with most other atmospheric models, the Unified Model's atmospheric prediction scheme is based on the hydrostatic primitive equations. This means that the model atmosphere is always in hydrostatic balance such that there are no vertical accelerations. Other atmospheric models make the shallow-atmosphere approximation which derives its name from the fact that the depth of the atmosphere is much smaller than the radius of the Earth. The Unified Model does not make this assumption. This makes the equations a little more complicated to solve by adding in extra terms which can be important when planetary-scale motions are considered.

The physical processes represented in the Unified Model include:

- atmospheric radiation which allows for the effects of clouds, water vapour, ozone, carbon dioxide and a number of trace gases;
- land surface processes including a multi-layer soil temperature and moisture prediction scheme;
- a treatment of the form drag due to the sub-grid scale variations in orography;
- vertical turbulent transport within the boundary layer;
- large-scale precipitation determined from the water or ice content of a cloud;
- the effects of convection through a scheme based on the initial buoyancy flux of a parcel of air. It includes entrainment, detrainment and the evaporation of falling precipitation. An explicit treatment of downdraughts is included; and
- The effects of the drag caused by vertically propagating gravity waves is modelled using sub-grid scale orographic variance and known absorption properties of gravity waves.

The representation of these processes within the code determine the evolution of the model-atmosphere as it runs forward in time to produce forecast data. The model requires initialisation and this is termed the 'analysis field'. It is derived from observations (from radar, satellites, ground-based observing sites etc) which are assimilated onto the regular model grid and blended with previous model output to ensure the evolving model atmosphere is not subjected to step-changes as these can introduce instabilities.

The mesoscale model is run in this way four times each day (at 0,6,12 and 18hours GMT) and out to 48 hours from the start time. Wind fields from this model are then incorporated into and used to force the UK Waters Wave Model. This brief description of the model indicates the large number of i) parameters necessary to model the evolution of the atmosphere during the forecast period (many of which are available as output); and ii) geographical points for which data is available.

## C2. WASP Numerical Modelling

### Model Details

The software WASP is a computational wind flow model designed specifically for use in the wind energy industry. There are three main inputs to the model; a summary of the known long term wind climate at point (usually derived from wind measurements), a digital topographic map and a description of the surface roughness of the surrounding terrain. The output from WASP is a series of wind speed predictions at a specified height arranged in a grid at a user-defined resolution.

In the case of the coastal correction exercise, the use of onshore topographic data was unnecessary because of the limited effect orographic features have on the offshore wind climate. Hence, land masses within the UKCS have been modelled as surface roughness elements only. Following the Davenport Classification, areas of sea and land have been assigned surface roughness lengths of 0.0002 m and 0.1 m respectively.

Wind data from the 3.3 year Met Office UK Waters Model, were used to derive summary wind speed and direction frequency tables for thirteen points spread evenly around the UKCS. These were then used to initiate the wind flow model. All these, so called, initiation points were selected to be as close to the coastal buffer zone as possible given the resolution of the UK Waters Model (between 30 km and 40 km from the coast).

The arbitrary selection of this number of points allowed the UKCS to be broken down into thirteen areas or grids which are no larger than 200km x 200km. By using data from the Met Office UK Waters Model at each of these points as the input to the wind flow model, the wind regime in the coastal zone could be determined in each of the thirteen UKCS regions.

The selection of regional wind flow model inputs was necessary for two reasons :

1. in order to determine a realistic wind regime in the coastal zone, the input to the wind flow model must represent regional conditions. Using the wind flow model to predict conditions at distances much greater than 100km might provide unrepresentative results, hence the choice of 200km x 200km grids; and
2. the results of any corrections in the coastal zone must be consistent with the UK Waters Model data for areas outside of this zone in order to avoid any discontinuity at the coastal zone boundary. Without a region by region approach, it is unlikely that this could be achieved.

It should be made clear that the use of modelled data as an input for the wind flow model is non conventional. However, this approach was necessary in this case, since the wind data in the coastal zone appear to be unrealistically low towards the coast (Appendix C4). Confidence in the UK Waters Model data is greater at locations further offshore and therefore it is valid to initiate the wind flow model from modelled data at such locations, so that a more realistic picture of the wind resource within the coastal zone can be obtained.

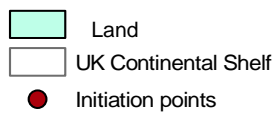
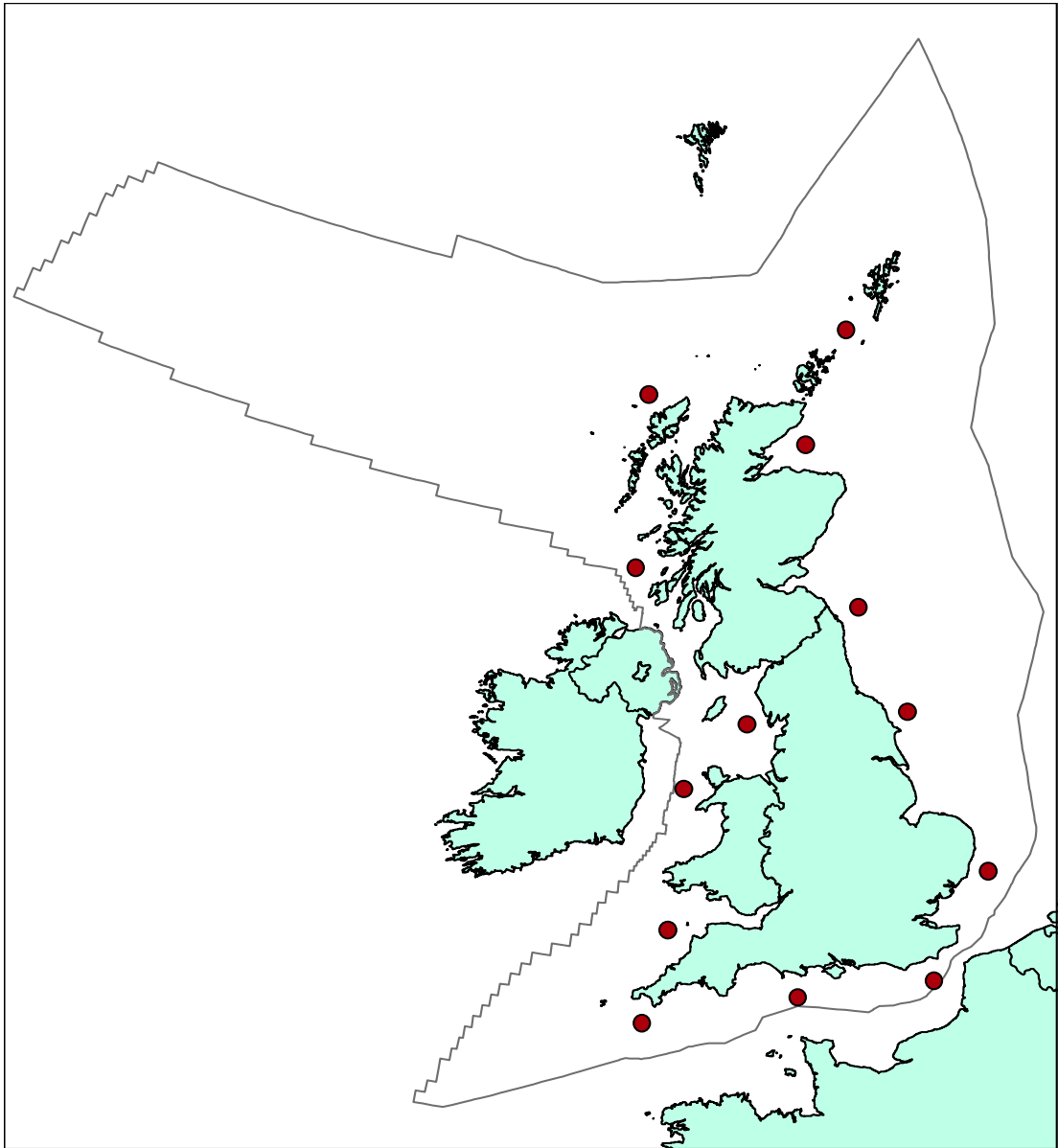
In order to ensure that the coastal corrections are consistent from region to region, an overlap of 20 km was created at the boundary of neighbouring grids. Predicted wind speeds in these overlap regions have been derived by taking a weighted average of the results of the neighbouring grids in question.

## Application to the Atlas

Wind speed and direction time histories for thirteen points from the UK Waters Model were selected for use as the wind flow model initiation input (Table C2.1; Figure C2.1). These points are distributed evenly around the UKCS at a distance of between 30 km and 40 km from the coast. The selection of this number of points allowed the UKCS to be broken down into 13 nearshore zones, which are no larger than 200km x 200km.

**Table C2.1** Position of the thirteen initiation points selected as input to the WASP modelling

Point	Location (deg WGS84)	
	Latitude	Longitude
1	49.72N	5.42W
2	51.06N	5.08W
3	53.06N	5.08W
4	54.06N	3.75W
5	56.06N	6.92W
6	58.50N	7.25W
7	59.72N	2.08W
8	58.06N	2.92W
9	55.83N	1.25W
10	54.39N	0.09E
11	52.17N	2.09E
12	50.61N	0.92E
13	50.28N	2.08W



N  
▲  
V

**Figure C2.1** WASP initiation points

The wind flow model was executed at heights of 80m and 100m in each of the thirteen individual grids to be representative of turbine hub heights. The results from the wind flow model were used to calculate wind speeds within each grid at a resolution of 5km x 5km.

## **C3. Additional Wind Resource Details**

### **Wind Roses**

Eleven of the twenty-one long-term data points (Appendix C4) were selected and a wind rose was derived for each.

A wind speed and direction frequency distribution was derived for each of these points and used to produce wind roses as presented in Figure C3.1. These have been created using 12 directions each sector representing 30°.

### **Seasonal, Monthly and Diurnal Variation**

The same eleven points were used to derive seasonal and diurnal variation in wind speeds. Plots of the mean seasonal and diurnal variation of wind speed at the eleven selected points are presented in Table C3.1, Figure C3.2, Table C3.2 and Figure C3.3.

These data have been normalised about the overall mean wind speed at each point to allow regional comparison. Normalised variations are presented in Table C3.3, Figure C3.4, Table C3.4 and Figure C3.5.

While the monthly trends for all eleven points are highly consistent, the comparison of diurnal wind speed variation shows significant differences from point to point. The latter may be due to differences in the distance to large land masses in predominant wind sectors and the associated thermally driven diurnal effects.

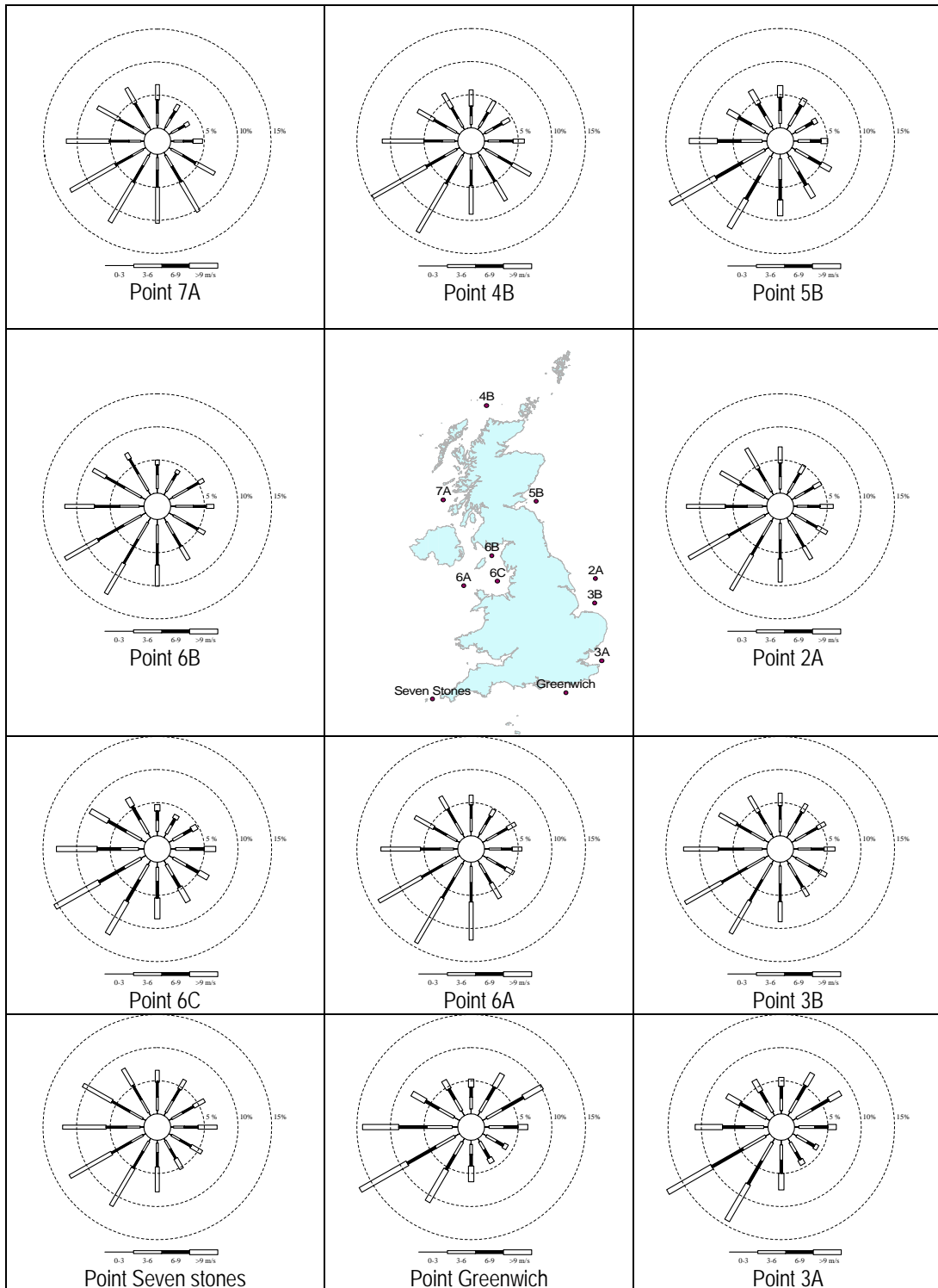


Figure C3.1 Wind roses shown at selected sites over the UKCS

Table C3.1 Mean monthly non-normalised wind speed at 19.5m ASL (m/s)

Coordinates (WGS84)	EU3B	EU4B	EU5B	EU6A	EUGREE	EUSEVE	EU2A	EU3A	EU6B	EU6C	EU7A
	53.25	59.00	56.25	53.50	50.50	50.00	54.00	51.50	54.50	53.75	56.00
	1.14	-5.26	-2.06	-5.26	-0.06	-6.06	1.14	1.54	-4.06	-3.66	-6.86
Jan	9.20	10.73	9.02	10.03	9.55	10.39	10.01	9.03	8.43	9.05	10.89
Feb	8.81	11.46	9.13	9.97	8.38	9.56	9.66	8.25	8.46	9.14	11.28
Mar	7.74	10.04	7.95	8.48	7.31	8.45	8.39	7.32	7.36	7.91	9.71
Apr	6.81	8.22	6.53	7.32	6.90	8.11	7.15	6.76	6.19	6.67	7.89
May	6.31	6.88	5.86	6.61	6.36	7.12	6.54	6.31	5.84	6.19	6.76
Jun	5.84	6.95	5.90	6.23	5.62	6.56	6.21	5.73	5.58	5.89	6.95
Jul	5.41	6.35	5.25	5.96	5.55	6.33	5.69	5.55	5.26	5.71	6.45
Aug	5.67	6.44	5.39	5.88	5.51	6.14	5.98	5.65	5.21	5.61	6.44
Sep	6.77	7.67	6.23	7.10	6.70	7.33	7.25	6.61	6.02	6.55	7.62
Oct	8.24	9.39	7.68	8.98	8.28	8.87	8.91	7.98	7.42	8.07	9.43
Nov	8.57	10.14	8.37	9.70	8.53	9.57	9.27	8.27	8.07	8.72	10.40
Dec	8.98	9.82	8.49	9.94	9.53	10.51	9.63	9.00	8.14	8.94	10.26

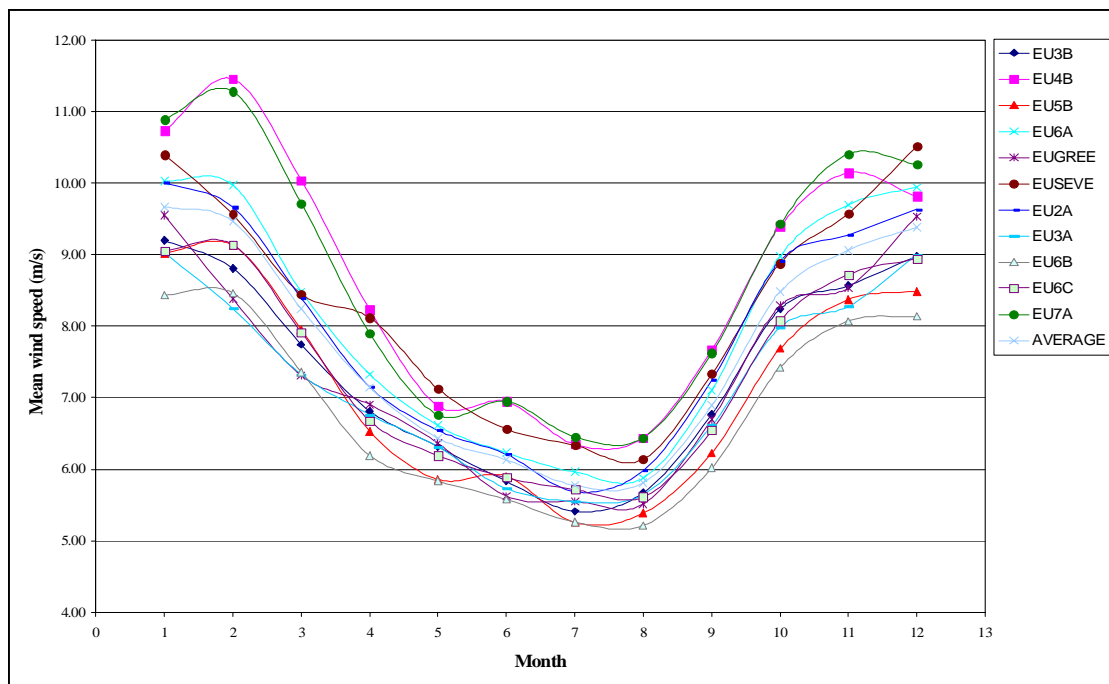


Figure C3.2 Mean monthly non-normalised wind speed at 19.5m ASL (m/s)

Table C3.2 Mean diurnal non-normalised wind speed at 19.5m ASL (m/s)

Coordinates (WGS84)	EU3B	EU4B	EU5B	EU6A	EUGREE	EUSEVE	EU2A	EU3A	EU6B	EU6C	EU7A
	53.25	59.00	56.25	53.50	50.50	50.00	54.00	51.50	54.50	53.75	56.00
	1.14	-5.26	-2.06	-5.26	-0.06	-6.06	1.14	1.54	-4.06	-3.66	-6.86
00:00	7.36	8.62	7.08	8.06	7.38	8.20	8.02	7.14	6.75	7.32	8.64
03:00	7.33	8.70	7.02	8.10	7.47	8.33	7.93	7.16	6.77	7.37	8.71
06:00	7.37	8.56	7.03	8.10	7.32	8.19	8.04	7.05	6.74	7.36	8.71
09:00	7.40	8.71	7.12	8.15	7.32	8.27	7.94	7.16	6.89	7.44	8.77
12:00	7.50	8.68	7.22	8.00	7.28	8.24	7.85	7.28	6.95	7.45	8.67
15:00	7.36	8.70	7.25	7.82	7.35	8.26	7.62	7.37	6.95	7.39	8.56
18:00	7.22	8.58	7.21	7.81	7.19	8.11	7.74	7.13	6.75	7.27	8.51
21:00	7.27	8.63	7.15	7.97	7.42	8.22	7.88	7.23	6.76	7.28	8.59

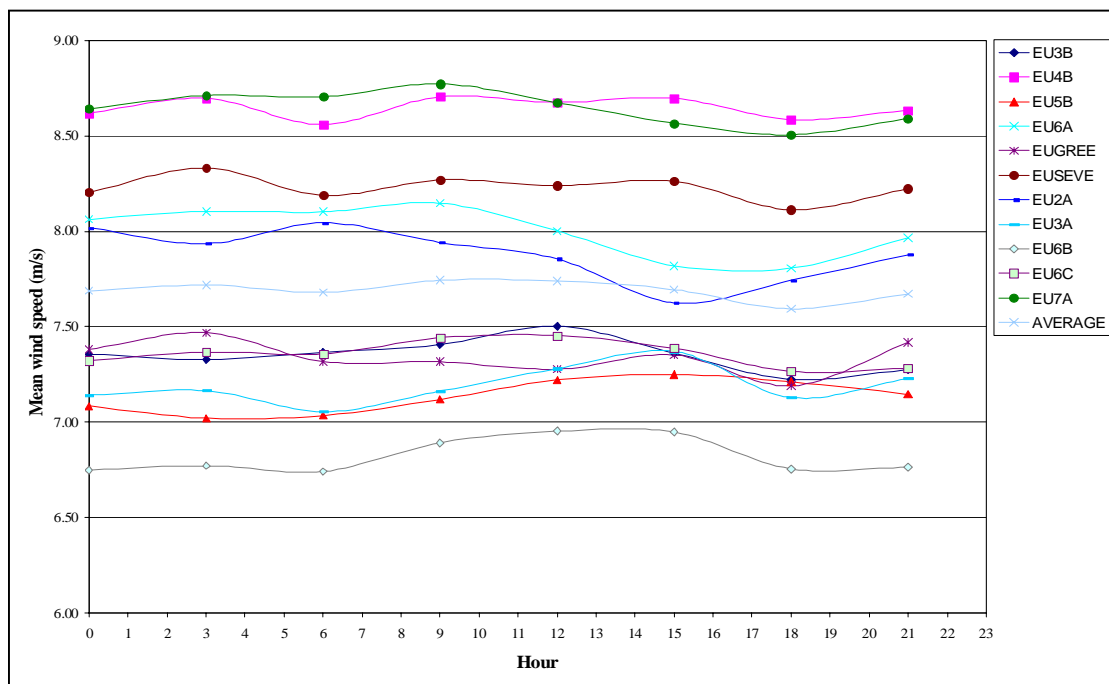


Figure C3.3 Mean diurnal non-normalised wind speed at 19.5m ASL (m/s)

Table C3.3 Mean monthly normalised wind speed

Coordinates (WGS84)	EU3B	EU4B	EU5B	EU6A	EUGREE	EUSEVE	EU2A	EU3A	EU6B	EU6C	EU7A	Average
	53.25	59.00	56.25	53.50	50.50	50.00	54.00	51.50	54.50	53.75	56.00	
	1.14	-5.26	-2.06	-5.26	-0.06	-6.06	1.14	1.54	-4.06	-3.66	-6.86	
Jan	1.25	1.24	1.26	1.25	1.30	1.26	1.27	1.25	1.23	1.23	1.26	1.254
Feb	1.20	1.32	1.28	1.24	1.14	1.16	1.22	1.14	1.24	1.24	1.30	1.226
Mar	1.05	1.16	1.11	1.06	0.99	1.02	1.06	1.02	1.08	1.07	1.12	1.068
Apr	0.93	0.95	0.91	0.91	0.94	0.98	0.91	0.94	0.91	0.91	0.91	0.926
May	0.86	0.79	0.82	0.82	0.87	0.86	0.83	0.88	0.85	0.84	0.78	0.837
Jun	0.79	0.80	0.83	0.78	0.76	0.80	0.79	0.80	0.82	0.80	0.80	0.796
Jul	0.73	0.73	0.73	0.74	0.75	0.77	0.72	0.77	0.77	0.78	0.74	0.750
Aug	0.77	0.74	0.75	0.73	0.75	0.74	0.76	0.78	0.76	0.76	0.74	0.755
Sep	0.92	0.88	0.87	0.89	0.91	0.89	0.92	0.92	0.88	0.89	0.88	0.895
Oct	1.12	1.08	1.07	1.12	1.13	1.08	1.13	1.11	1.09	1.10	1.09	1.100
Nov	1.16	1.17	1.17	1.21	1.16	1.16	1.18	1.15	1.18	1.18	1.20	1.175
Dec	1.22	1.13	1.19	1.24	1.30	1.27	1.22	1.25	1.19	1.21	1.18	1.219

Table C3.4 Mean diurnal normalised wind speed

Coordinates (WGS84)	EU3B	EU4B	EU5B	EU6A	EUGREE	EUSEVE	EU2A	EU3A	EU6B	EU6C	EU7A	Average
	53.25	59.00	56.25	53.50	50.50	50.00	54.00	51.50	54.50	53.75	56.00	
	1.14	-5.26	-2.06	-5.26	-0.06	-6.06	1.14	1.54	-4.06	-3.66	-6.86	
00:00	1.00	1.00	0.99	1.01	1.01	1.00	1.02	0.99	0.99	0.99	1.00	1.00
03:00	1.00	1.01	0.98	1.01	1.02	1.01	1.01	1.00	0.99	1.00	1.01	1.00
06:00	1.00	0.99	0.99	1.01	1.00	0.99	1.02	0.98	0.99	1.00	1.01	1.00
09:00	1.01	1.01	1.00	1.02	1.00	1.00	1.01	1.00	1.01	1.01	1.01	1.01
12:00	1.02	1.00	1.01	1.00	0.99	1.00	1.00	1.01	1.02	1.01	1.00	1.01
15:00	1.00	1.01	1.02	0.98	1.00	1.00	0.97	1.02	1.02	1.00	0.99	1.00
18:00	0.98	0.99	1.01	0.98	0.98	0.99	0.98	0.99	0.99	0.99	0.98	0.99
21:00	0.99	1.00	1.00	1.00	1.01	1.00	1.00	1.01	0.99	0.99	0.99	1.00
00:00	1.00	1.00	0.99	1.01	1.01	1.00	1.02	0.99	0.99	0.99	1.00	1.00
03:00	1.00	1.01	0.98	1.01	1.02	1.01	1.01	1.00	0.99	1.00	1.01	1.00
06:00	1.00	0.99	0.99	1.01	1.00	0.99	1.02	0.98	0.99	1.00	1.01	1.00
09:00	1.01	1.01	1.00	1.02	1.00	1.00	1.01	1.00	1.01	1.01	1.01	1.01

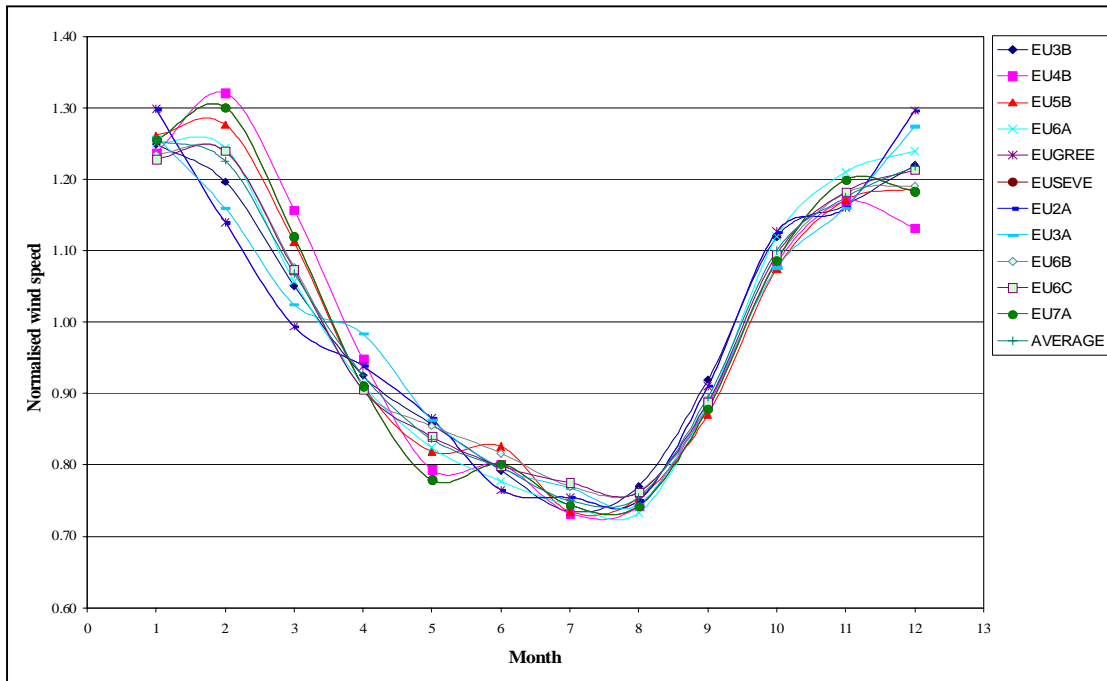


Figure C3.4 Mean monthly normalised wind speed

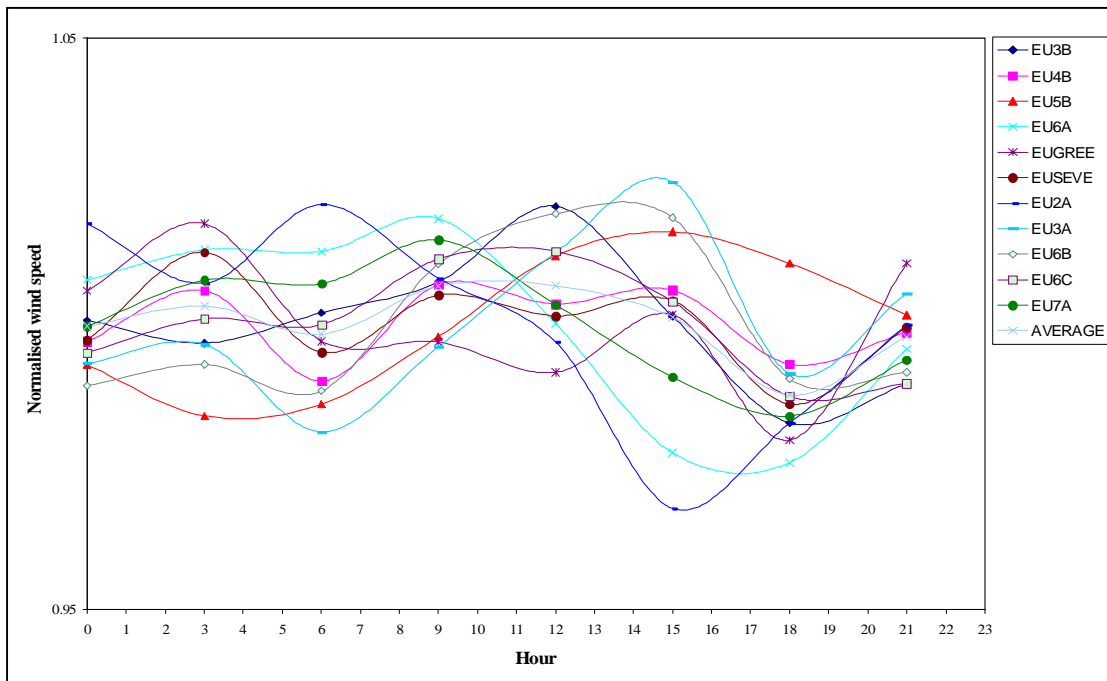


Figure C3.5 Mean diurnal normalised wind speed

The normalised monthly mean wind speeds have been averaged for all eleven points and then combined to give a seasonal normalised mean wind speed. Both sets of values are presented in Table C3.5.

**Table C3.5 Mean seasonal normalised wind speed**

Month	Monthly Normalised Mean Wind Speed	Season	Seasonal Normalised Mean Wind Speed
Dec	1.219	Winter (December, January, February)	1.233
Jan	1.254		
Feb	1.226		
Mar	1.068	Spring (March, April, May)	0.944
Apr	0.926		
May	0.837		
Jun	0.796	Summer (June, July, August)	0.767
Jul	0.750		
Aug	0.755		
Sep	0.895	Autumn (September, October, November)	1.057
Oct	1.100		
Nov	1.175		

The normalised monthly and seasonal values were then used to calculate the monthly and seasonal mean wind speeds for each point. The annual mean wind speed was factored, using the seasonal normalised values to derive the mean seasonal wind speed and the monthly normalised values to derive the monthly mean wind speed.

This analysis was performed for both sets of wind speed data : the Met Office wave models wind data and the wind data that have been corrected for coastal effects.

A different approach was adopted to estimate the monthly and seasonal variation in energy production.

- (1) for each month, the percentage variation of the monthly mean wind speed from the annual mean wind speed was established;
- (2) the sensitivity of changes in energy production to changes of wind speed was calculated;
- (3) the sensitivity value was used to calculate twelve adjusted annual energy production values based on the normalised monthly mean wind speed; and
- (4) the twelve adjusted values were converted to monthly energy values by multiplying the values with the number of days in each month divided by the annual energy yield multiplied by 365.25.

## C4. Validation of the Wind Data

### The Coastal Zone

The mean wind speed data at 80m height was compared against previous wind resource data from the Garrad Hassan/Germanischer Lloyd work (GH/GL), "Study of Offshore Wind Energy in the EC". Both datasets were transformed to the same height. Using GIS, the two datasets were analysed.

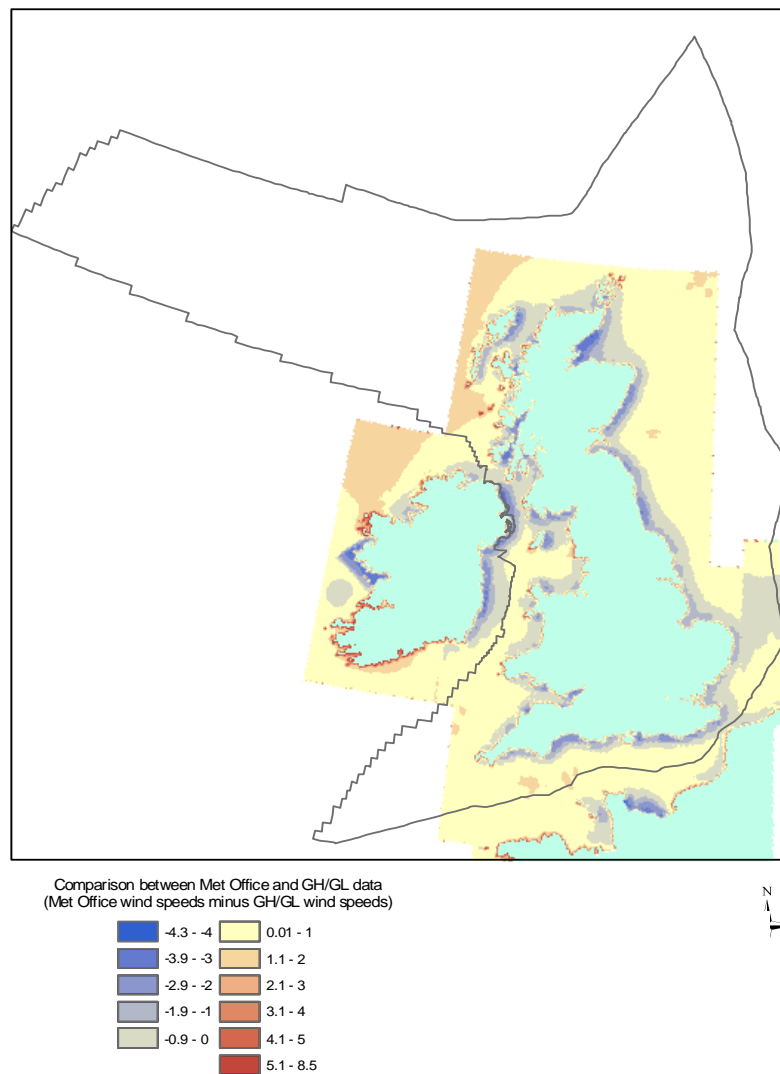
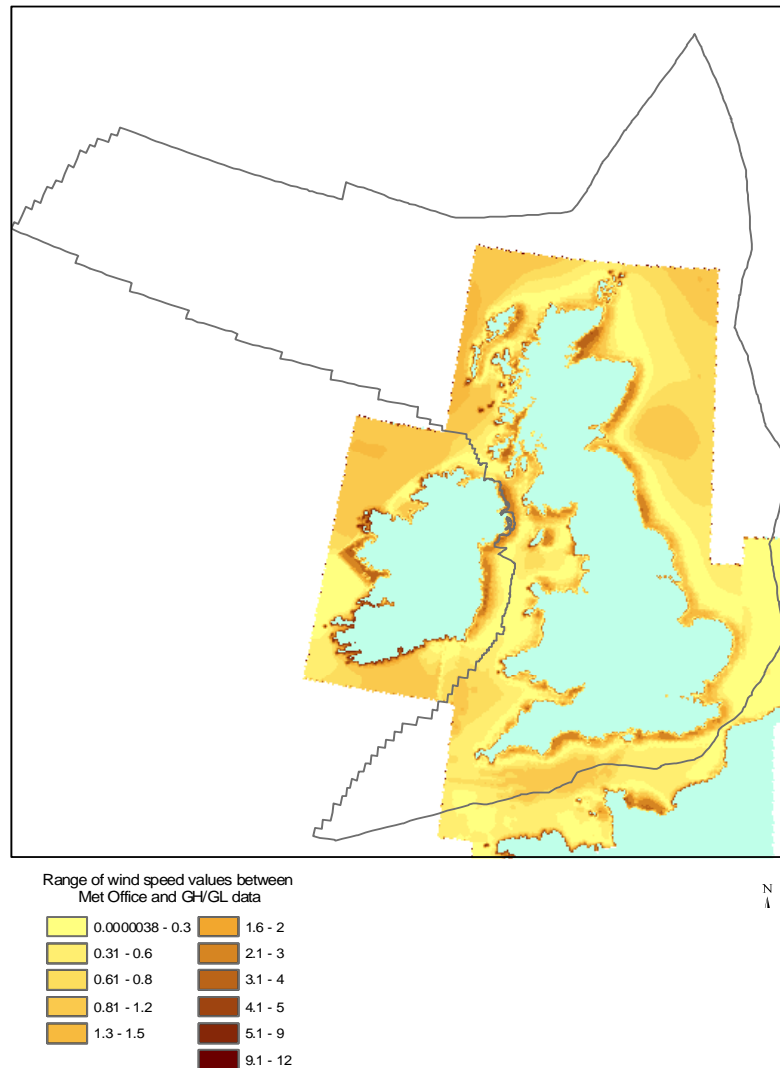


Figure C4.1 Shows the GH/GL results subtracted from the Met Office data-derived results



**Figure C4.2** Shows the size of the difference in values between the two datasets

The mean value range is 2.0 m/s, with the Met Office data generally higher. Major differences between the two datasets are observed near the coast, where the Met Office data are lower, with maximum difference of 4 m/s. When moving further offshore the range of wind speed values decreases significantly, reducing to zero.

The results from this comparison lead to the use of the use of the coastal correction modelling, or WASP. The WASP modelling is detailed in Appendix D2.

## UK Waters Met Office Model & Observations

Observation time-series data were selected from sites comprising the Met Office Marine Automatic Weather Station (MAWS) Network (Figure 17) in order to undertake the validation exercise.

These sites provide observations of both marine wind and wave parameters (see Appendix D2), specifically wind speed (at 10m above sea-level) and wind direction. Locations were chosen to provide a spread of data around the UKCS, and are summarized in Table C4.1.

**Table C4.1 Met Office Marine Automatic Weather Station (MAWS) sites used in validation study**

Station Name	WMO Number	Station Position		Station Type	Water Depth (Model* m)
		Latitude	Longitude		
K5	64045	59° 04' N	11° 25' W	Buoy	> 200.0
RARH	62106	57° 00' N	09° 54' W	Buoy	> 200.0
Aberporth	62301	52° 17' N	04° 30' W	Buoy	31.0
Turbot Bank	62303	51° 37' N	05° 09' W	Buoy	40.0
Seven Stones	62107	50° 04' N	06° 04' W	Lightship	73.0
Lyme Bay	62101	50° 37' N	02° 44' W	Buoy	33.0
Greenwich	62305	50° 25' N	00° 00' E	Lightship	54.0
K17	62026	55° 25' N	01° 10' E	Buoy	69.0
K16	62109	57° 00' N	00° 00' E	Buoy	84.0

To provide the best comparison of wind data, model wind speeds output at model pressure level 1 (approximately 19.5m) were scaled to a 10m value using the scalar relationship:

$$V_{10} = 0.94V_{19.5} \quad (1)$$

where

the subscript denotes model level in metres.

The data distribution plus mean and standard deviation values generated over the annual cycle for wind speed ( $V_{10}$ ) and wind directions ( $W_d$ ) were used. In addition, RMS errors between model and observation data values were determined to provide some assessment of the model predictive performance.

Wind values are recorded by the MAWS network in units of whole knots. In order to match the model data and Atlas database units these were converted to metres per second. This correction means that observed values will be discretized into bins at approximately every 0.51m/s which may compound errors shown by the statistics, particularly in terms of RMS error. Nevertheless, wind speed mean errors are typically less than 10% between the model and MAWS sources (Table C4.2). Geographically mean errors show a trend where wind speed values are :

- under-predicted for MAWS stations south of 52°N (Seven Stones, Lyme Bay and Greenwich); and
- over-predicted for those stations north of 52°N.

RMS errors (in relation to the mean value) tend to be highest for the stations north of 52°N. This is possibly due to the greater difficulty of modelling atmosphere around the English Channel and its approaches, where sub-grid scale changes in topography at the English and French coastlines may impact the actual wind field. The poorest performance in terms of wind data occurs at the Aberporth wave buoy, where the model over-predicts the mean wind speed by over 30% and RMS errors are at 36%. These errors may be due to the buoy's location within Cardigan Bay, where the coastline to the south provide more protection from the strong prevailing southerly to south-westerly winds than is anticipated by the model.

**Table C4.2 Annual wind statistics for validation sites**

Station Name	$V_{10}$ Mean (m/s)			$V_{10}$ Std. Dev. (m/s)			$V_{10}$ RMS Error (m/s)
	Model	MAWS	% Error	Model	MAWS	% Error	
K5	8.59	7.89	9	3.94	3.83	3	2.41
RARH	8.71	8.19	6	4.14	3.72	12	1.76
Aberporth	7.18	5.35	34	3.56	2.83	26	2.64
Turbot Bank	6.71	6.66	1	3.16	3.33	-5	1.59
Seven Stones	8.04	8.54	-6	4.25	3.66	16	2.06
Lyme Bay	5.08	5.58	-9	2.41	2.67	-10	1.55
Greenwich	7.97	8.60	-7	3.59	4.44	-19	2.06
K17	7.70	7.19	7	3.66	3.42	7	1.47
K16	7.81	7.13	10	3.81	3.50	9	1.72

## Data Distributions

Distributions of model and MAWS wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) data are shown in Figures C4.3 to C4.11. Errors in the annual statistics suggest a general geographic divide in performance between stations to the north (K5, RARH, K16 and K17) and the more southerly stations. The over-predictions of mean wind speed shown in Table C4.2 for the northerly stations are consistent with a general slight under-prediction by the model of the frequency of moderate to strong breezes observed at these stations and similar small over-prediction of the frequency of near gales and stronger. The contrast between modelled and observed wind directions at these stations also show similar patterns in that the model provides a smoother distribution for directions from southeast through to north compared to the observations, which tend to show a more 'peaky' profile corresponding to one or more prevailing wind directions.

The stations at Turbot Bank and Seven Stones show a good agreement between the model and observations for both wind speed and wind direction, suggesting that in climate terms these data are providing a good representation of wind conditions. Wind speed distributions show a good agreement for Greenwich, however the model tends to over emphasise a peak in

westerly directed winds, whereas the observations show a more even spread through southerly to west-northwest directions. At Lyme Bay the converse is true, with the direction distribution well represented, but wind speed frequencies for a moderate breeze or lower being over-predicted, whilst the frequency of winds in the moderate breeze to near gale range are under-predicted. The differences at these latter two stations may well be indicative of the difficulty of modelling winds near to the coastline in the narrow English Channel Straits.

At Aberporth, the worst performing station in terms of the annual statistics, the reason for the overestimate of mean wind speed by the model is due to an underestimate of the frequency of wind speeds in the light to moderate breeze range by the model and overestimate of the frequency of stronger winds. The model also misses an observed peak in southerly directed winds. Instrument error aside, these differences are most likely a local effect of the high relief topography surrounding Cardigan Bay.

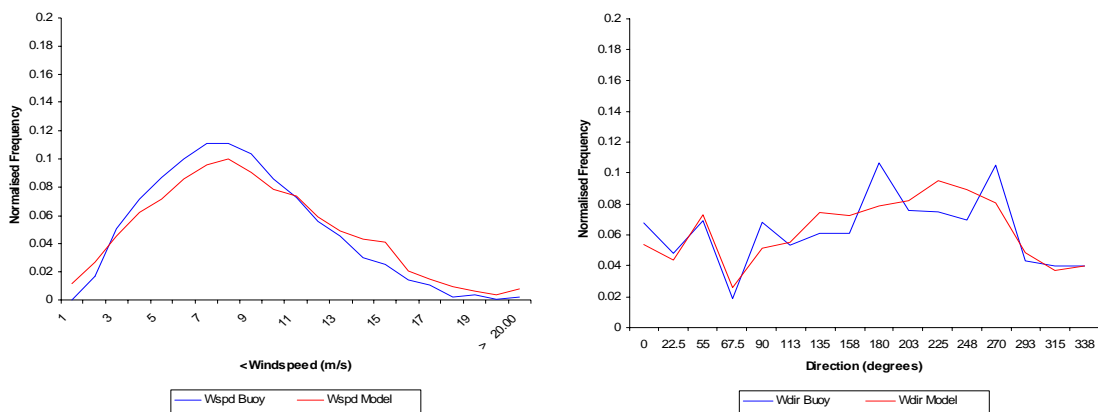


Figure C4.3 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the K5 MAWS station

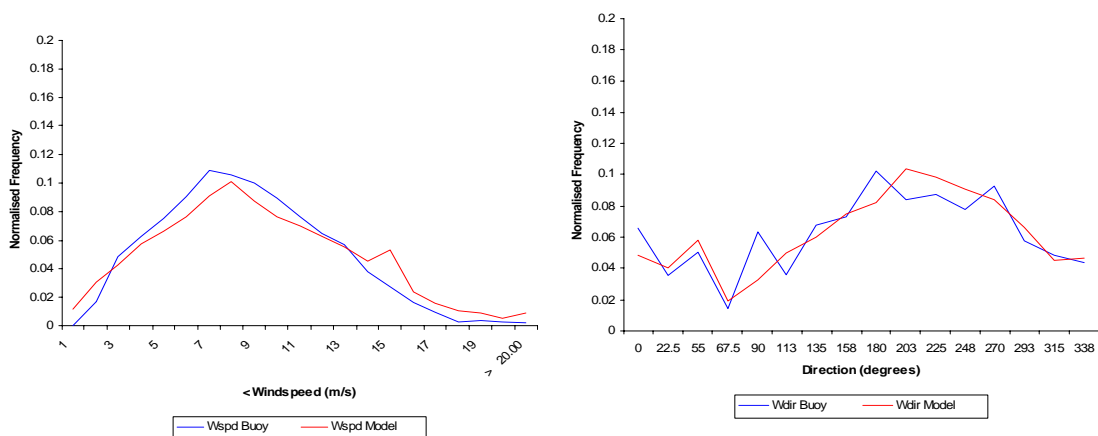


Figure C4.4 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the RARH MAWS station

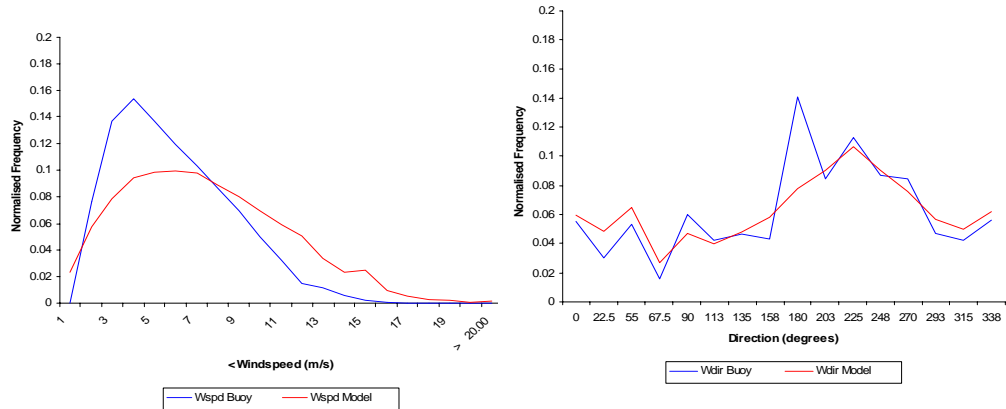


Figure C4.5 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the Aberporth MAWS station

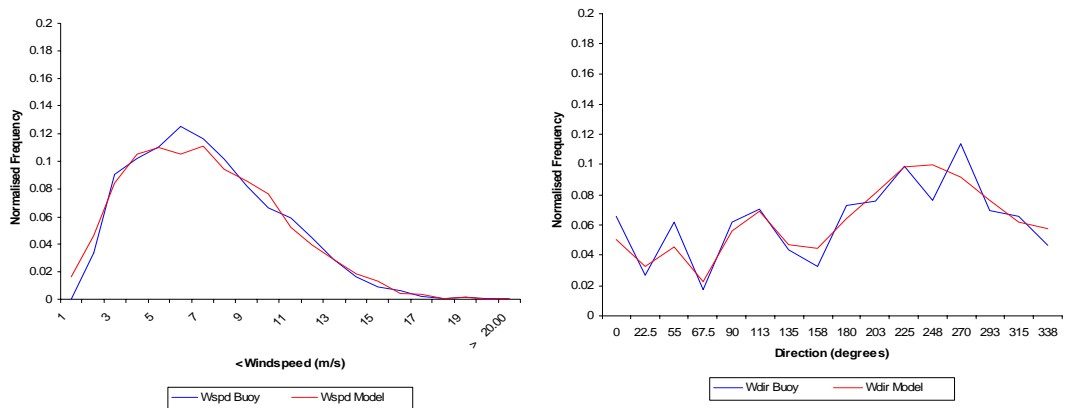


Figure C4.6 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the Turbot Bank MAWS station

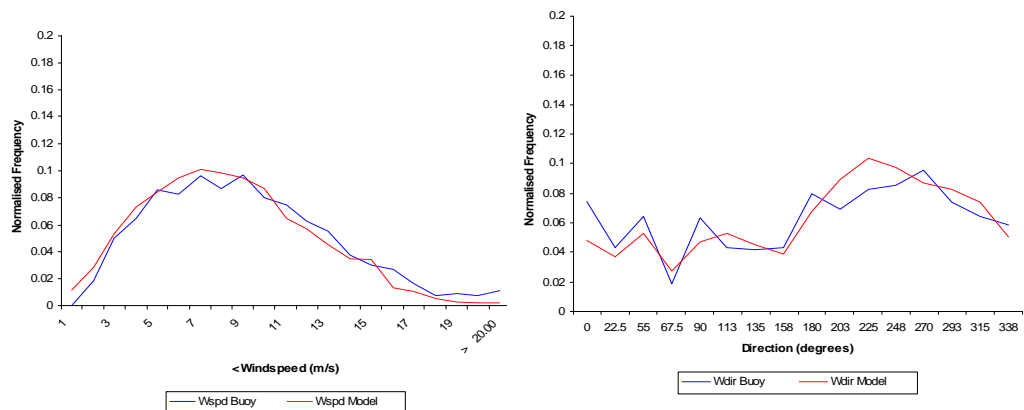


Figure C4.7 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the Seven Stones MAWS station

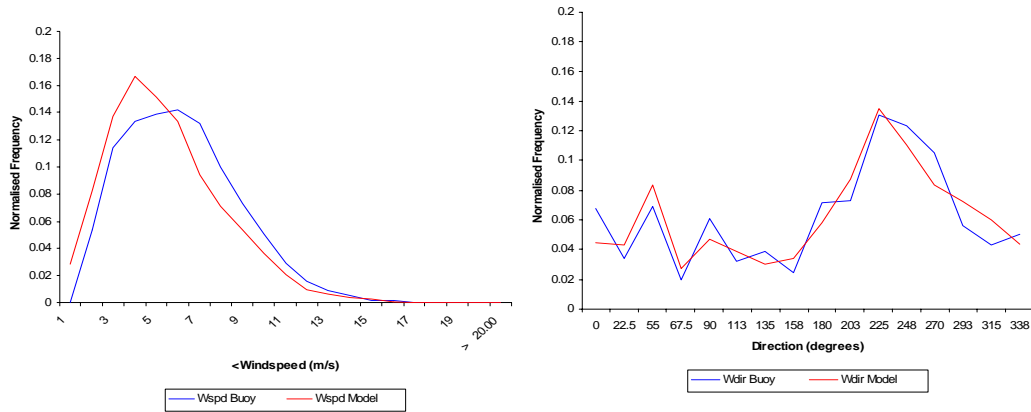


Figure C4.8 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the Lyme Bay MAWS station

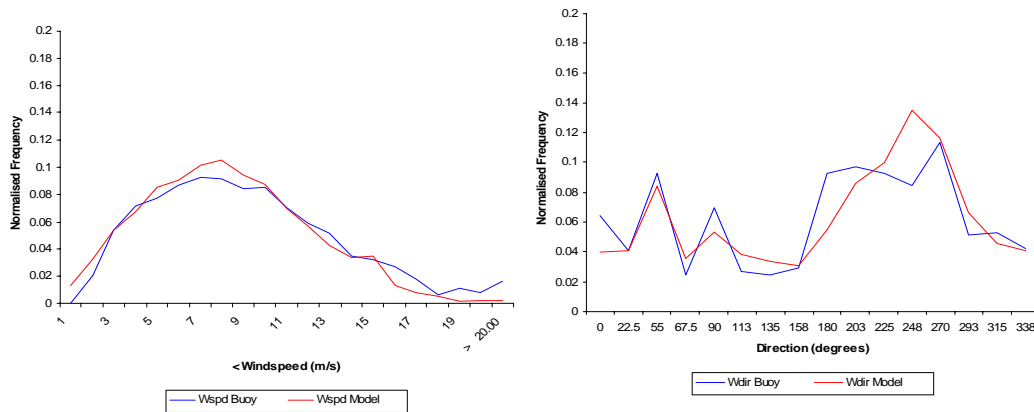


Figure C4.9 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the Greenwich MAWS station

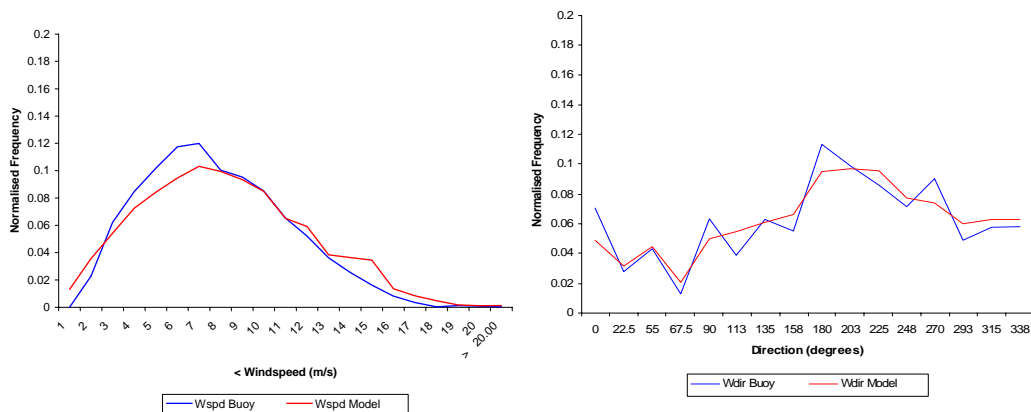
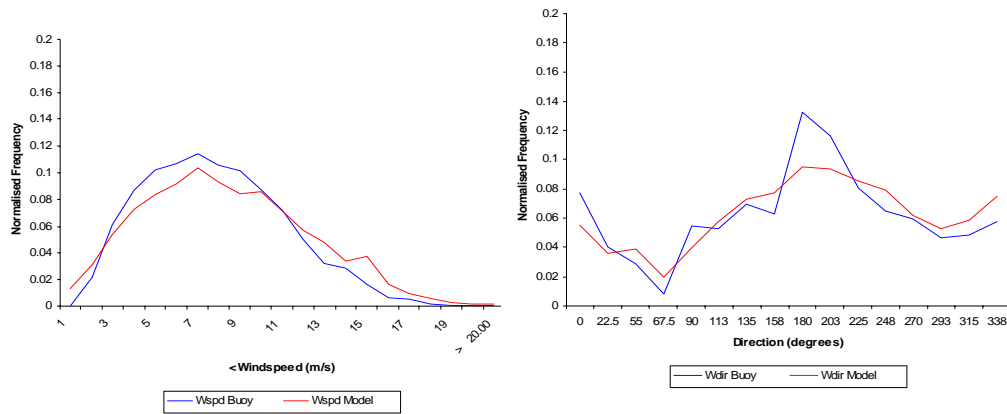


Figure C4.10 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the K17 MAWS station



**Figure C4.11 Modelled and observed wind speed ( $V_{10}$ ) and wind direction ( $W_d$ ) distributions at the K16 MAWS station**

In general, the mean offshore wind resource in terms of speed and power should be well represented since an agreement in mean wind speed values within 10% was found for most sites. However, when examining the tendency of wind speeds to occur within certain operating ranges more caution may need to be applied. This is since the model showed a tendency to overestimate wind speeds at sites in northern areas of the UKCS such that the frequency occurrence of moderate breezes or lighter was under-predicted and stronger winds over-predicted. In general the model also showed a tendency to generate a more even spread of wind directions where locally one or two prevailing directions were observed. This potential error may require further examination if considering devices that will function for a limited range of wind directions. Errors in both annual statistics and wind speed and wind direction distributions for stations at Lyme Bay, Greenwich and Aberporth in particular highlighted the difficulties in making an accurate forecast of wind conditions for a model of this resolution close to land-sea boundaries. For Aberporth locally high relief topography, and for Lyme Bay and Greenwich the proximity to not only the UK but French coastlines, are likely considerations in reducing the reliability of the model data. As a result it is suggested that in the near coastal zone local effects of topography (which are likely to be well known within region, e.g. by local weather centres/coastguard) be given due consideration and the Atlas data treated appropriately.

## UK Waters Met Office Model and European Waters Model Comparisons

Data extracted from 21 points within the European Waters Model have been used to assess the long-term validity of the data used from the UK Waters Model for the period 2000 to 2003. These sites are listed in Table C4.3.

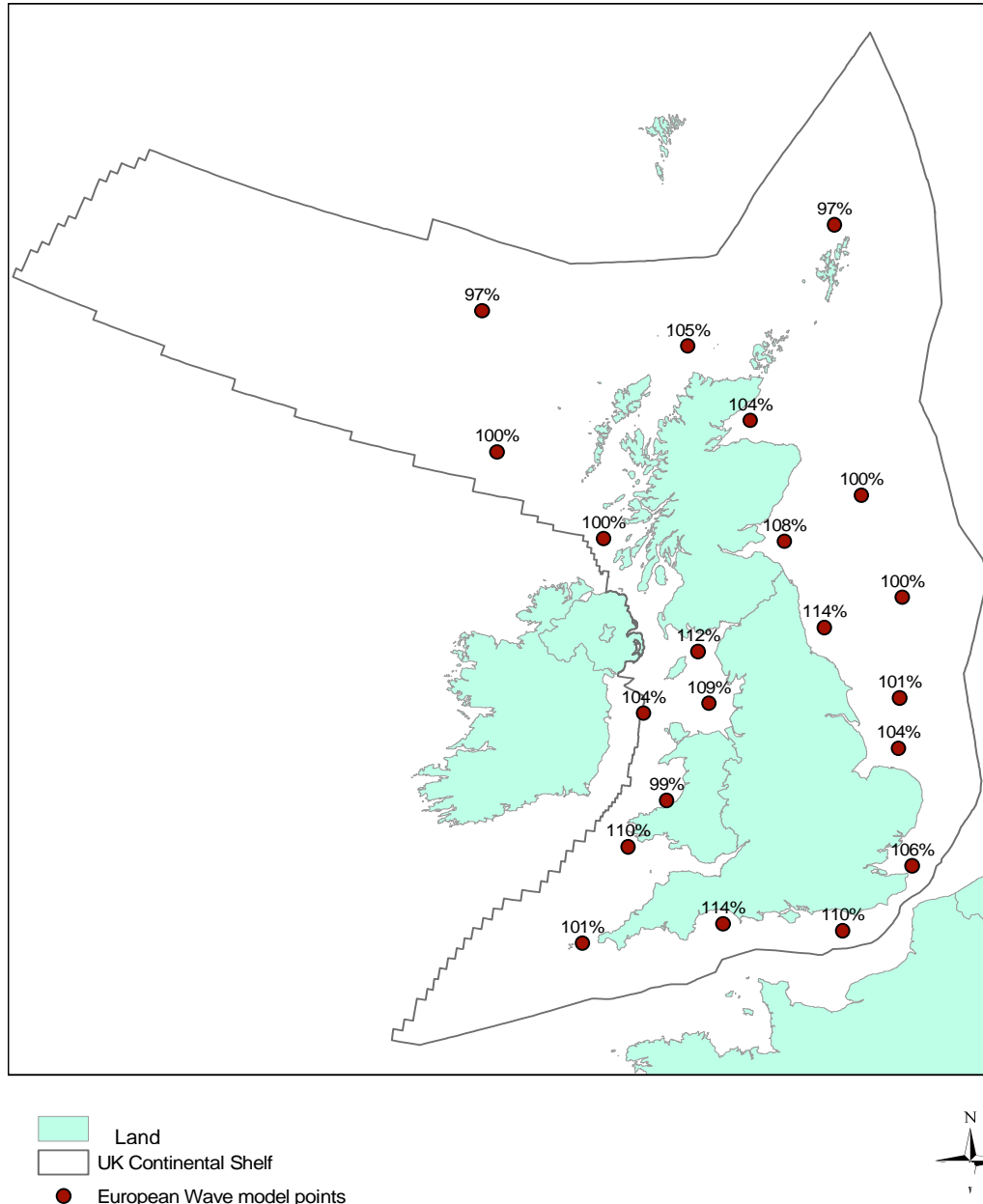
**Table C4.3 Location of sites used to compare the UK Waters Model and the European Waters Model**

Site Name	Closest UK Waters Point (deg WGS84)		Closest European Point (deg WGS84)	
	Lat	Long	Lat	Long
K5	59° 04' N	11° 25' W	59.00°N	11.26°W
RARH	57° 00' N	09° 54' W	57.00°N	10.06°W
Seven Stones	50° 04' N	06° 04' W	50.00°N	06.06°W
Turbot Bank	51° 37' N	05° 09' W	51.50°N	05.26°W
Lyme Bay	50° 37' N	02° 44' W	50.50°N	02.86°W
Greenwich	50° 25' N	00° 00' E	50.50°N	00.06°W
Aberporth	52° 17' N	04° 30' W	52.25°N	04.46°W
K17	55° 25' N	01° 10' E	55.50°N	01.14°E
K16	57° 00' N	00° 00' E	57.00°N	00.06°W

This comparison was initially made with a view to adjusting the short-term data so as to be more representative of long-term wind conditions. The ratios of short-term to long-term wind speeds (windiness) are presented in Figure C4.12 for the 21 sites selected.

It is well-known in the wind industry that the years 2000 to 2003 have seen mean wind speeds that are significantly less than the long-term historical records. To illustrate this point, Garrad Hassan investigated the windiness of the period from June 2000 to September 2003 at the Malin Head Meteorological Station in Co. Donegal, Ireland.

The meteorological station was visited by Garrad Hassan staff in July 2002 and discussions concerning the consistency of the measurement system held with the operations staff. The station currently comprises a Dines pressure tube wind speed and direction sensor, mounted on a lattice mast 22 m in height. The station appears to be well maintained with good data coverage. The system at Malin Head, in its current state, has been in continuous operation since 1966. Apart from routine maintenance, there have not been any changes to the system since its installation.



**Figure C4.12 Windiness (2000 to 2003) of selected points**

For the purposes of this study, Garrad Hassan assumed that the long-term mean wind speed at Malin Head would be adequately defined by a ten year period of measurements. Therefore the period from October 1993 to September 2003 was used to assess the long-term mean wind speed. Both the long and short-term mean wind speeds were derived from monthly mean wind speeds measured at Malin Head. The results of the windiness assessment based on this meteorological station are presented in Table C4.4.

**Table C4.4 Windiness assessment**

Parameter	Details
Period assessed	June 2000 to September 2003
Measured mean wind speed of period	7.59 m/s
Long-term mean wind speed	8.11 m/s
Windiness of period	93.6 %

It was concluded that any adjustment based on these short-term to long-term wind speed ratios would compromise the accuracy of the atlas wind speeds. Therefore, no such adjustment has been implemented.