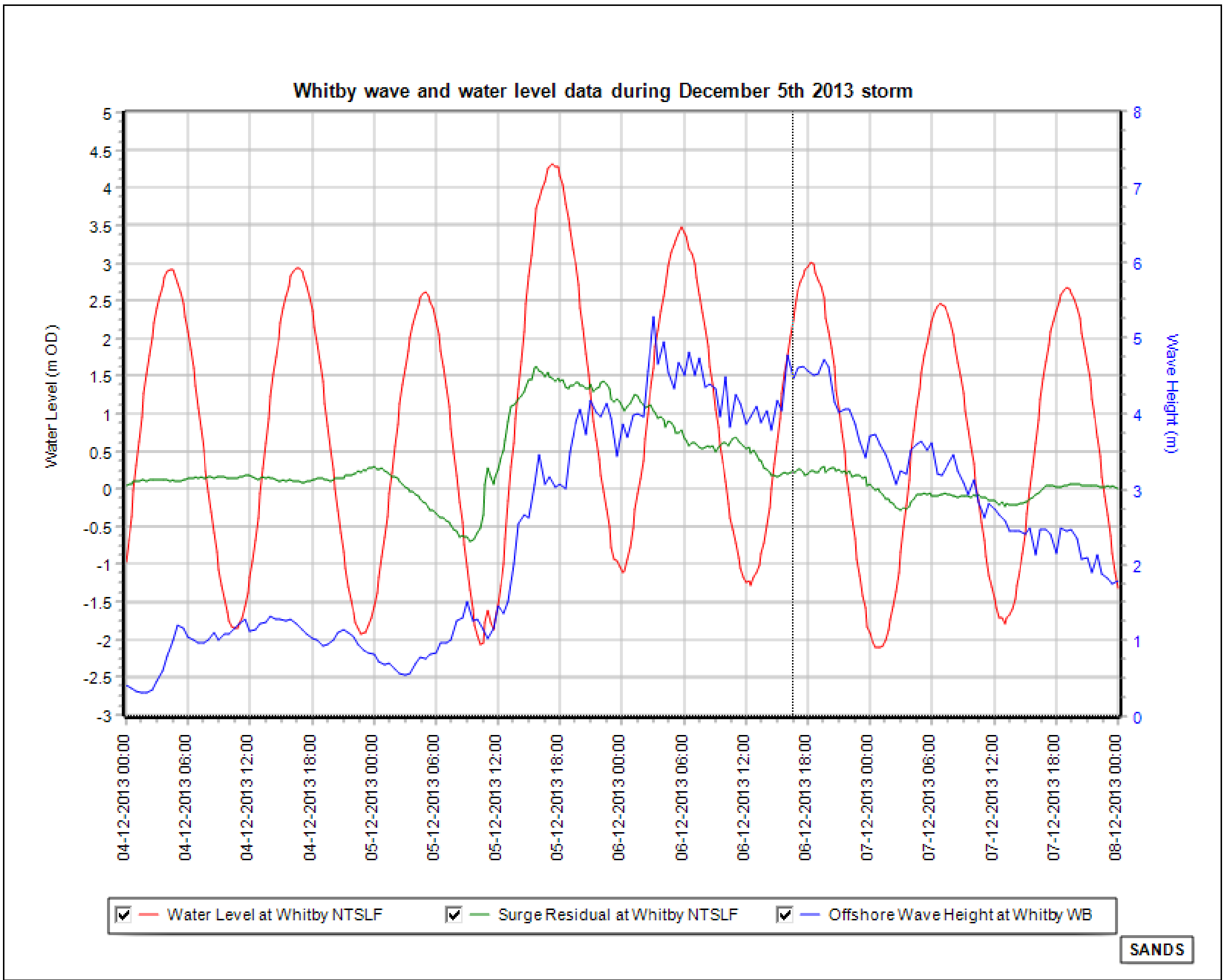

Cell 1 Regional Coastal Monitoring Programme
Wave Data Analysis Report 2: 2013 - 2014

Final Report
March 2014

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Raw data analysed in this report is available to download via the project's webpage: www.northeastcoastalobservatory.org.uk. The North East Coastal Observatory does not "license" the use of images or data or sign license agreements. The North East Coastal Observatory generally has no objection to the reproduction and use of these materials (aerial photography, wave data, beach surveys, bathymetric surveys), subject to the following conditions:

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This study uses sea level monitoring data for Whitby and North Shields from the National Tide and Sea Level Facility, provided by the British Oceanographic Data Centre and funded by the Environment Agency.

Some of the wave data presented and analysed in this report has been obtained from the Cefas WaveNet site (http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes/wavenet.aspx) and are subject to the Cefas data usage license as described on the next page.

Abbreviations and Acronyms

Acronym / Abbreviation	Definition
AONB	Area of Outstanding Natural Beauty
CD	Chart Datum
DGM	Digital Ground Model
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
NTSLF	National Tide and Sea Level Facility
m	metres
OD	Ordnance Datum

Glossary of Terms

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the intertidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.

Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial sediment to varying thicknesses, softer rock cliffs and extensive landslide complexes.

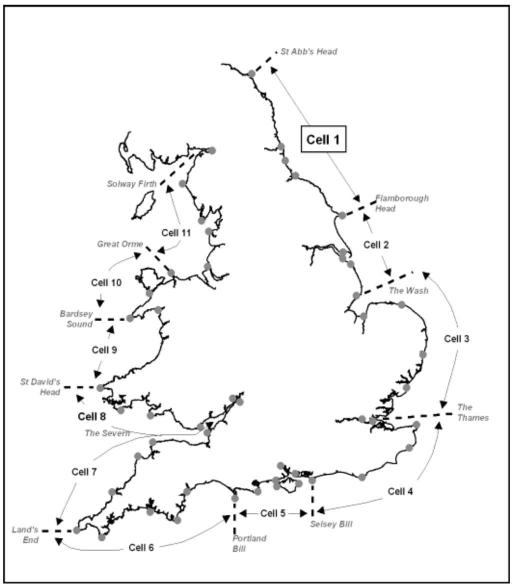

Figure 0.1 Sediment Cells in England and Wales

The work commenced with a three-year monitoring programme in September 2008 that was managed by Scarborough Borough Council on behalf of the North East Coastal Group. This initial phase has been followed by a five-year programme of work, which started in October 2011. The work is funded by the Environment Agency, working in partnership with the following organisations:

The original three year programme of work was undertaken as a partnership between Royal Haskoning, Halcrow and Academy Geomatics. For the current five year programme of work the data collection associated with beach profiles, topographic surveys and cliff top surveys is being undertaken by Academy Geomatics. The analysis and reporting for the programme is being undertaken by Halcrow.

Wave and tide data collection under the present phase of the programme started in January 2013. The data collection is being undertaken by Fugro Emu, and the new wave and tide data that will be collected will be available in near real-time on both the Channel Coast Observatory website and the www.northeastcoastalobservatory.org.uk website developed for this programme.

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The main elements of the Cell 1 Regional Coastal Monitoring Programme involve:

- beach profile surveys
- topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography
- walk-over surveys

The beach profile surveys, topographic surveys and cliff top recession surveys are undertaken as a 'Full Measures' survey in autumn/early winter every year. Some of these surveys are then repeated the following spring as part of a 'Partial Measures' survey.

Each year, an Analytical Report is produced for each individual authority, providing a detailed analysis and interpretation of the 'Full Measures' surveys. This is followed by a brief Update Report for each individual authority, providing ongoing findings from the 'Partial Measures' surveys.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as wave data collection, bathymetric and sea bed sediment data collection, aerial photography, and walk-over visual inspections.

The present report is **Wave Data Analysis Report 2.** This provides an update to the analysis presented in the baseline wave data report and compares the wave data collected between January 2013 and January 2014, to the baseline established in Wave Data Analysis Report 1.

1. Introduction

1.1. Study background and scope

Wave data collection is an integral part of the Cell 1 Regional Coastal Monitoring programme. Under the present programme data collection commenced in June 2010 when two Waverider buoys were deployed at Whitby and Newbiggin in May 2010 by Cefas. These two buoys were decommissioned in June and November 2011 respectively.

Under the current phase of the programme three new Waverider buoys have been deployed, located offshore from at Scarborough, Whitby and Newbiggin Ness. The data from these new buoys has been disseminated in near real time on the Cell 1 Regional Coastal Monitoring programme website at www.northeastcoastalobservatory.org.uk and the Channel Coast Observatory website http://www.channelcoast.org/. The data can also be downloaded from the Cefas website http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes/wavenet.aspx.

Additionally, under the programme the existing tide gauge at Scarborough has been serviced and linked up to record concurrent water level data and a new tide gauge was deployed at Whitby.

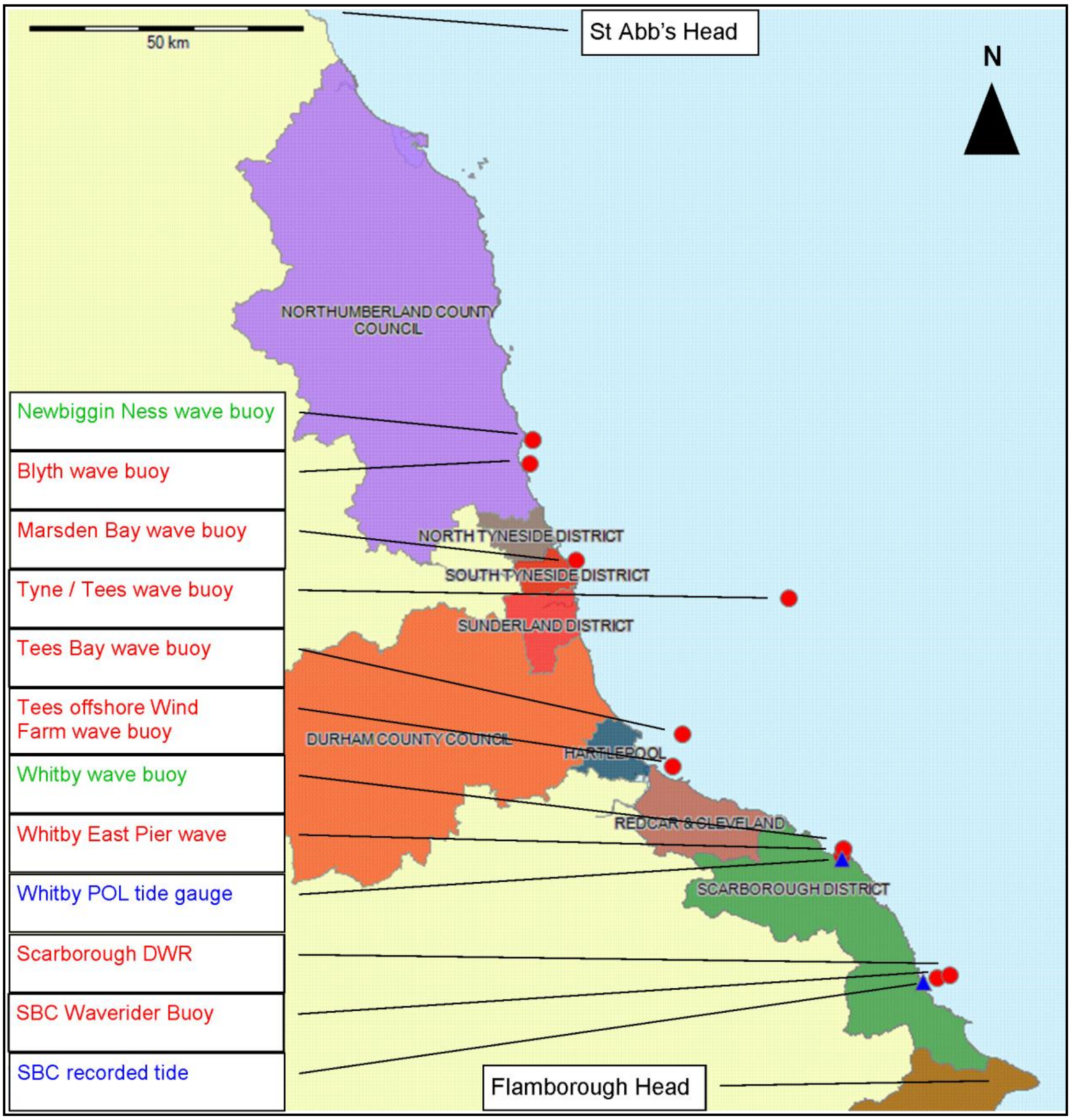
The present report is **Wave Data Analysis Report 2** and provides an analysis of the wave data collected during 2013 as part of the programme. The report forms an update to the baseline assessment in **Wave Data Analysis Report 1 (Halcrow 2013).** It also takes into consideration other freely available data collected in the region, in particular the Cefas WaveNet Tyne Tees offshore wave buoy, tide gauge data from Whitby and Scarborough and recently available Met Office modelled hindcast data from 1980 to 2012 in order to extend the analysis undertaken in the baseline report and inform the assessment and interpretation of other data collected under the programme such as the beach, cliff and coastal defence monitoring.

1.2. Study area and available wave and tide data

The Cell 1 study area extends along the northeast coast of England, from the Scottish border through to Flamborough Head. The baseline report considered the data at each location shown in Figure 1.1 below. In accordance with the recommendations in the baseline report this update report concentrates on the following locations, progressing from North to South along the coastline:

- Newbiggin wave buoy (Cell 1 programme),
- South Shields NTSLF Class A Tide gauge ((NOC, formerly POL),
- Tyne Tees wave buoy (Cefas / WaveNet),
- Whitby wave buoy (Cell 1 programme),
- Whitby NTSLF Class A Tide gauge (NOC, formerly POL),
- Scarborough wave buoy (Cell 1 programme),
- Scarborough tide gauge (Cell 1 programme),

These locations are shown in Figure 1.2 below and more detailed location maps are shown in Appendix A.



Note: green text denotes the wave buoys that were installed by Cefas within the Cell 1 programme.

Figure 1.1 Study Area and data sets reviewed in the baseline report

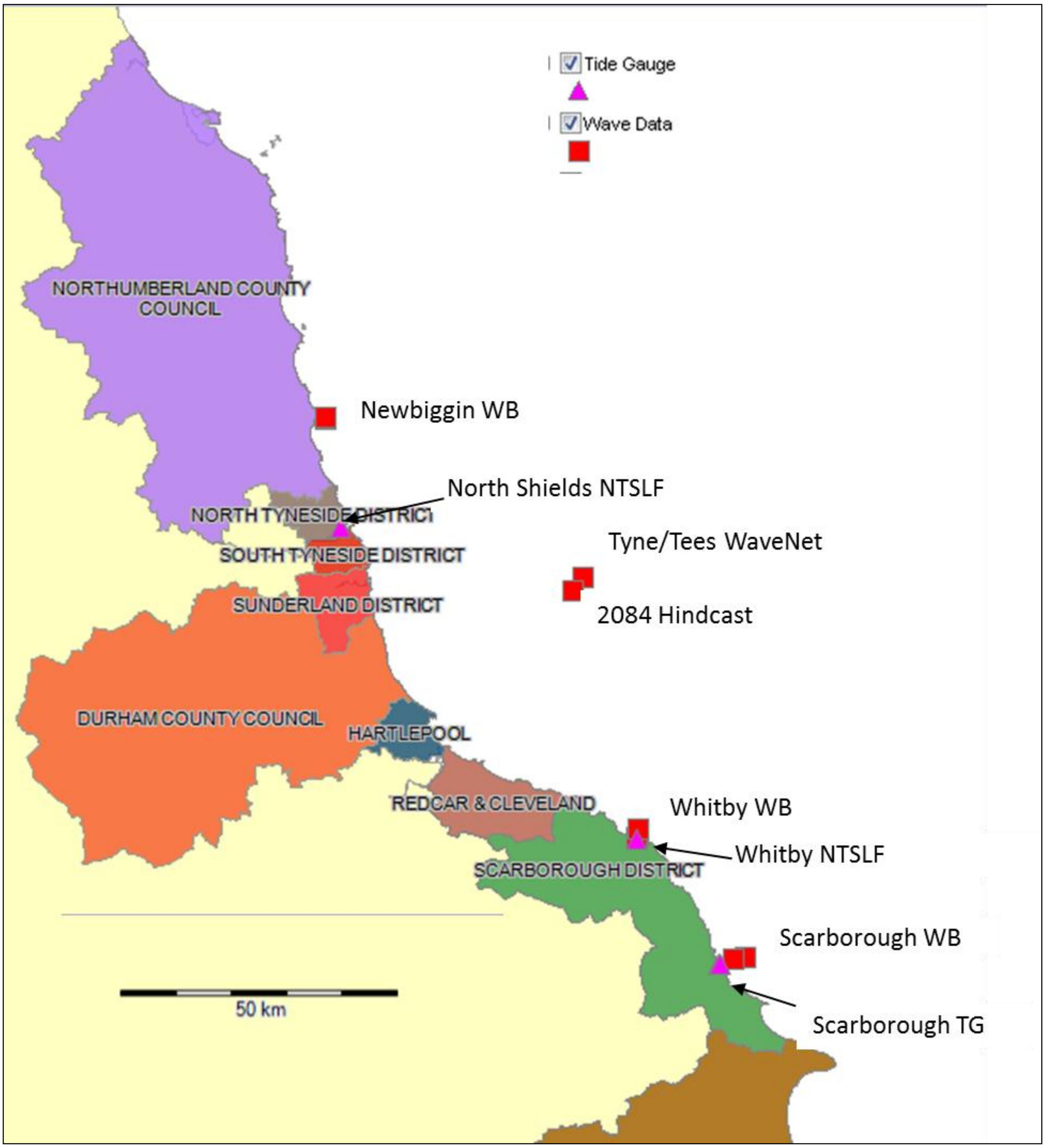


Figure 1.2 Data sets reviewed in this report

1.3. Methodology

The wave data received from the deployments at Newbiggin Ness, Whitby and Scarborough were imported into the Shoreline And Nearshore Data System (SANDS) database set up for the Cell 1 Regional Monitoring project for analysis and for comparison with other datasets from the adjacent coastline.

Detailed graphs of the significant wave height, maximum wave height, mean and peak period, peak direction and water temperature for the Newbiggin Ness, Whitby and Scarborough wave buoy locations can be found in Appendix B, C and D respectively. A report by Fugro-Emu describing the deployment of the instrumentation has been attached in Appendix F. Detailed plots of the tide gauge data and the 2013 report on analysis of the Scarborough tide gauge data by the Channel Coast observatory is provided in Appendix E.

It was identified in the baseline report that it was important to consider the Cefas WaveNet Tyne Tees offshore wave buoy as it has the longest consistent record offshore of the project area (deployed in December 2006). Data was therefore downloaded from the Cefas website http://cefasmapping.defra.gov.uk/Map and loaded into SANDS for inter-comparison.

A new Met Office hindcast of modelled waves at locations around the UK coast became available through Cefas in 2013. The data covers the period 1st January 1980 to 31st December 2012. This was not available at the time of preparation of the baseline report and so a preliminary analysis has been included in this report. The nearest point to the Tyne Tees offshore wave buoy has been downloaded and imported to SANDS for comparison to the measured data.

The following wave analyses were carried out:

- Wave roses were produced from the wave height and direction data at each location;
- Scatter tables of peak period and wave height were generated at each location; and
- Storm analyses were undertaken at each location.

The data from 2013 were compared to the previous data.

The water level monitoring data from the Scarborough tide gauge managed by Fugro-Emu for Scarborough BC was also downloaded for analysis. The tide gauge deployed at Whitby under the programme has had operational problems and not yet returned useful data. However, data from the Class A gauge maintained by NTSLF at Whitby was also downloaded. Data were also obtained from the Class A NTSLF tide gauge at North Shields for inclusion in the analysis.

1.4. Summary of new data available

The new data sets considered in this report for comparison to the baseline data are listed in Table 1-1 below.

Table 1.1 List of new datasets available for the 2013 to 2014 report

Name of Location	Type of Data	Approx. Water depth (m)	Start Time	End Time
Newbiggin Ness WB	Wave Data	23m	21/06/2013	31/01/2014 (ongoing)
North Shields NTSLF Tide Record	Tidal Levels	N/A	24/01/1946	31/01/2014 (ongoing)
Tyne Tees WaveNet Site (WMO ID 62293)	Wave Data	65m and 66m	07/12/2006	31/01/2014 (ongoing)
Met office wave model hindcast data at Tyne Tees	Wave data (modelled)	N/A	01/01/1980	31/12/2012
Whitby Waverider Buoy	Wave Data	17m	17/01/2013	31/01/2014 (ongoing)
Whitby NTSLF Tide Record	Tidal Levels	N/A	01/01/1991	31/12/2013 (ongoing)
Scarborough WB*	Wave Data	19m and 30m	17/01/2013	31/01/2014 (ongoing)
Scarborough TG	Tidal Levels	N/A	28/04/2003	31/12/2013 (ongoing)

* Note that the location of the Scarborough WB was changed in June 2013. Data from the latter, further offshore location are designated as Scarborough WB2 in this report

2. Analysis of data

This section considers the data collected under the Cell 1 monitoring programme (i.e., the three wave buoys deployed by Fugro-EMU at Newbiggin Ness, Whitby and Scarborough respectively). It also reviews the longer term record for the Tyne Tees Cefas buoy and tide gauge data available from North Shields, Whitby and Scarborough.

2.1. Newbiggin Ness Waverider Buoy

The wave data in the baseline report for Newbiggin Ness was collected by the Cefas wave buoy deployed under the Cell 1 programme and published on the Cefas website. The baseline data set was just over 1 year and runs from 20/05/2010 to 07/06/2011.

The new data for Newbiggin runs from 21/06/2013 when the new wave buoy was deployed by Fugro-Emu. Detailed monthly plots of the data collected are presented in Appendix B.

Although we do not yet have a full year's data, the new data set has been compared to the baseline data using scatter plots and tables produced in SANDS using the time series data analysis facilities.

2.1.1. Wave Height vs Peak Period

The wave height and peak period for the baseline and new wave data records have been plotted together on a scatter plot (see Figure 2.1 below). At Newbiggin the baseline data was collected by Cefas and runs from 20/05/2010 to 07/06/2011, whist the new data runs from 01/06/2013 to 31/06/2014. As both data sets are quite short no definitive conclusions can be drawn yet. Although the wave height / period relationship in Figure 2.1 appears similar there are some longer period waves observed in the new data set.

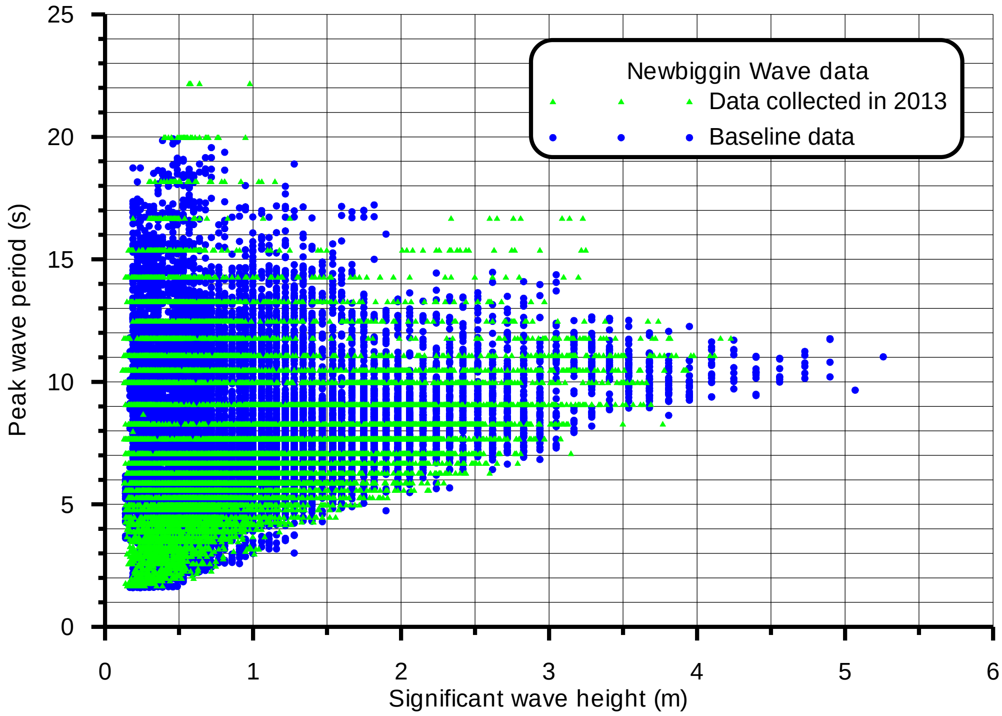


Figure 2.1 Scatter plot of Wave Height Vs Peak Period at Newbiggin wave buoy

2.1.2. Wave Rose

Wave rose showing wave height distribution by direction are shown in Figures 2.2 and 2.3 below. The baseline plot in Figure 2.2 is a full years' data from the original deployment and shows that the waves predominantly approach the Newbiggin Ness wave buoy from the Northeast (30 to 60 degrees).

Comparing the wave rose in Figure 2.2 to the other locations analysed (see later in report) indicates that the Newbiggin Ness site is relatively sheltered from waves from the north.

The new wave data available for this report covers less than a full year, but the wave rose plotted in Figure 2.3 shows a quite different directional distribution to the baseline plot, with a significant proportion of waves from the southeast.

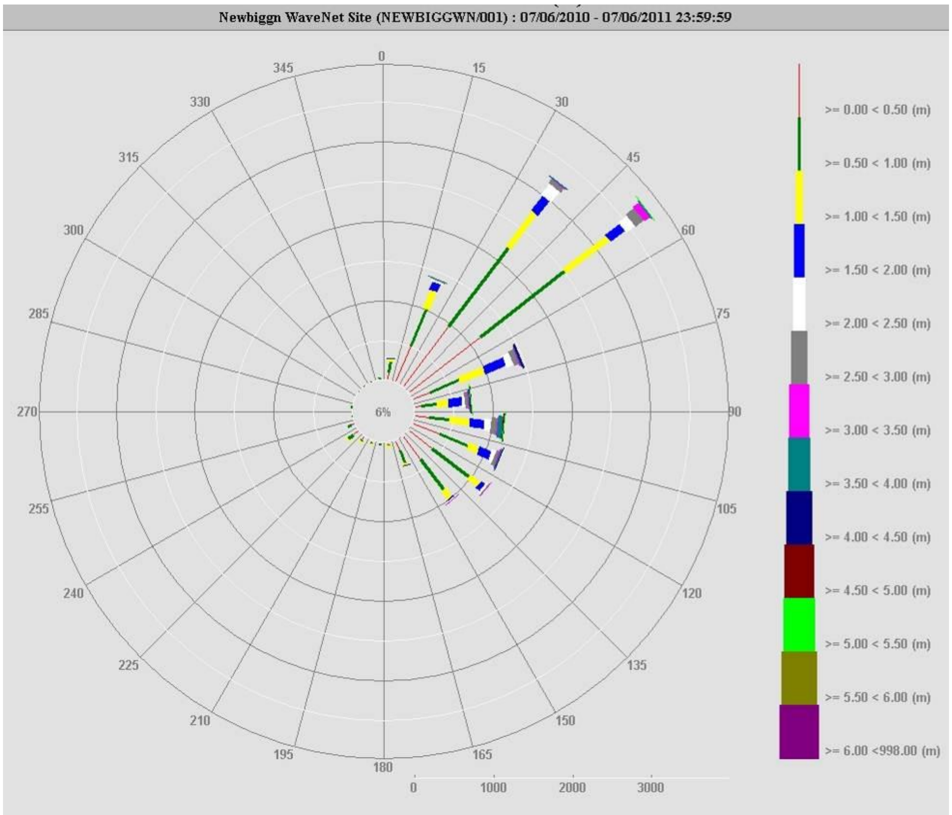


Figure 2.2 Wave Rose for Newbiggin wave buoy site (7/06/2010 to 7/06/2011)

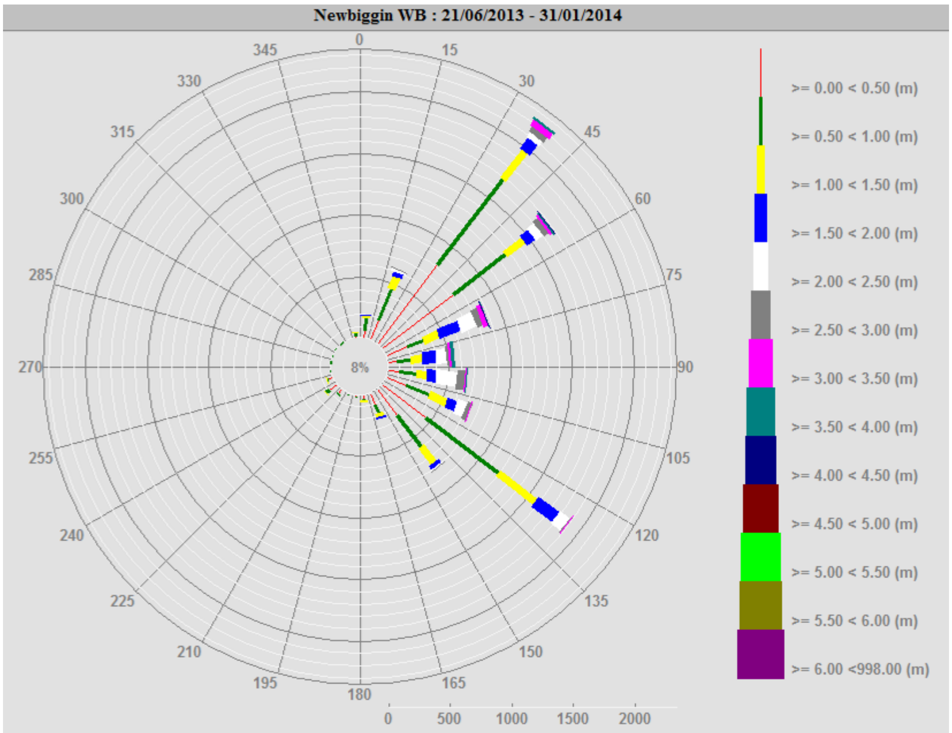


Figure 2.3 Wave Rose for Newbiggin WB site new data (21/06/2013 to 31/01/2014)

2.1.3. Storm Analysis

The baseline report storm analysis of the Newbiggin Ness wave dataset undertaken using a wave height threshold of 3m and a storm separation threshold of 120 hours is shown in Table 2.1. This analysis used the full data range available, from 20/05/2010 to 07/06/2011. The storms recorded at this wave buoy arrive from the northeast to east directions (47 to 105 degrees). The storm with the largest wave height at peak in the baseline report data set, highlighted in bold, occurred on 9th November 2010.

Table 2.1 Storm analysis for Newbiggin Ness (20/05/2010 to 07/06/2011)

General Storm Information							At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir (°)**	**No of Events (30 min dataset)**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
19/06/2010 12:30	20/06/2010 09:00	21	19/06/2010 23:00	48	39	43	3.9	10.3	51	3265
06/09/2010 18:30	07/09/2010 20:30	26	07/09/2010 15:30	99	51	352	3.8	9.3	90	2465
17/09/2010 10:00	17/09/2010 15:30	5.5	17/09/2010 14:30	53	4	42	3.0	12.1	51	2667
24/09/2010 03:00	25/09/2010 23:30	45	25/09/2010 10:00	47	79	43	3.5	10.5	56	2728
08/11/2010 06:30	**10/11/2010 00:30**	**42**	**09/11/2010 04:00**	**89**	**70**	**2**	**5.2**	**9.3**	**84**	**4688**
28/11/2010 23:30	02/12/2010 13:30	86	29/11/2010 20:00	81	78	11	4.2	9.9	62	3445
12/02/2011 01:30	12/02/2011 12:00	11	12/02/2011 12:00	100	4	0	3.2	8.1	73	1298
19/02/2011 06:00	19/02/2011 09:30	3.5	19/02/2011 08:30	105	3	357	3.3	6.9	84	1013

The results from a storms analysis for the full set of new data is shown in Table 2.2 below. The longest storm ran from 10th to 14th October and had peak wave height of 4.2m. There was one storm from the Southeast direction in the record, occurring on 1st January 2014. It is notable that the storm that occurred on 5th / 6th December 2013 causing widespread damage to beaches and coastal defences on the east coast had a peak wave height of 3.2m on the afternoon of 6th December at Newbiggin and while it had highest wave energy at peak and an unusually long wave period, it did not have the largest peak wave height.

Table 2.2 Storm analysis for Newbiggin WB (data 21/06/2013 to 30/01/2014)

General Storm Information							At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir (°)**	**No of Events (30 min dataset)**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
06/09/2013 18:30	06/09/2013 22:30	4	06/09/2013 22:30	47	8	44.9	3.1	7.6	48	1,090
10/10/2013 00:30	14/10/2013 08:00	103.5	10/10/2013 18:30	47	65	43.7	4.2	9.9	46	3,329
30/11/2013 01:00	30/11/2013 05:00	4	30/11/2013 05:00	38	5	54.9	3.1	9.3	37	1,654
06/12/2013 01:30	06/12/2013 21:30	20	06/12/2013 16:30	47	27	44.4	3.2	14.0	53	4,014
01/01/2014 16:30	01/01/2014 17:30	1	01/01/2014 17:30	142	2	329.2	3.1	7.0	118	913
19/01/2014 05:30	20/01/2014 10:30	29	19/01/2014 20:00	69	48	21.3	4.2	9.9	70	3,442

2.2. North Shields Tide gauge

There is a tide gauge at North Shields that is operated continuously by the National Tide and Sea Level Facility (NTSLF) on behalf of the Environment Agency as part of the main UK tide gauge network. Information on this tide gauge installation is available on the NTSLF website: http://www.ntslf.org/tgi/portinfo?port=North Shields including the site history reproduced below. The Chart Datum at North Shields is 2.6m below Ordnance Datum (http://www.ntslf.org/tides/datum). Due to its location in the mouth of the estuary the recorded water levels can be influenced by high freshwater flows in the river Tyne.

Site history:

- 1946 – Earliest data available
- 1974 – A Munro gauge was installed over one of the stilling wells and an Ott digital gauge over the other
- 1984 – The Ott digital gauge was removed and a Wellhead unit was installed
- 1984 – The DATARING system was installed with potentiometers attached to the Munro gauge and the Wellhead unit
- 1993 – All equipment removed while a new tide gauge building was built
- 1993 – New building completed and all equipment reinstated
- 1998 – Wind speed and direction instruments installed
- 1998 – Both stilling wells blocked - the POL diving team cleared the blockage
- 2000 – POL data logger installed.

Table 2.3 Predicted tide levels at North Shields

Tidal State	Level (m Chart Datum)	Level (m Ordnance Datum)
HAT	5.73	3.13
LAT	0.00	-2.60
MHWS	5.12	2.52
MHWN	4.08	1.48
MLWN	1.90	-0.70
MLWS	0.73	-1.87
Highest predicted 2014	5.68	3.08
Lowest predicted 2014	0.08	-2.52
Highest predicted 2015	5.73	3.13
Lowest predicted 2015	0.06	-2.54

Note: Based on data from http://www.ntslf.org/tgi/portinfo?port=North Shields

Data is available on the internet in real time (http://www.ntslf.org/data/realtime?port=North Shields) and quality controlled data can be downloaded from the British Oceanographic Data Centre (BODC) website.

The full data set was downloaded and imported into SANDS for analysis alongside the other monitoring data. An example plot of the water level data from the NTSLF tidal gauge record at North Shields is shown in Figure 2.4 below to demonstrate data availability (Data Source: BODC, https://www.bodc.ac.uk/data/online_delivery/). The data are at hourly intervals prior to 1993 and then at 15 minute intervals. The data were adjusted from Chart Datum to Ordnance Datum during import to SANDS.

Although there is occasional data available from 1946, there are many large gaps in the record up until 1964, as illustrated in Figure 2.4, but the overall record appears very consistent. The spike in the high water levels shown near the end of the plot is the storm surge level of 3.98 mOD at 16:15 on the 5th December 2013. This shows how exceptional the conditions were, with the previous maximum recorded water level of 3.56m occurring at 17:00 on 31st January 1953 (note that prior to 1990 only hourly data are available and so the actual maximum water level in the 1953 storm event may have been higher than the recorded 3.56m).

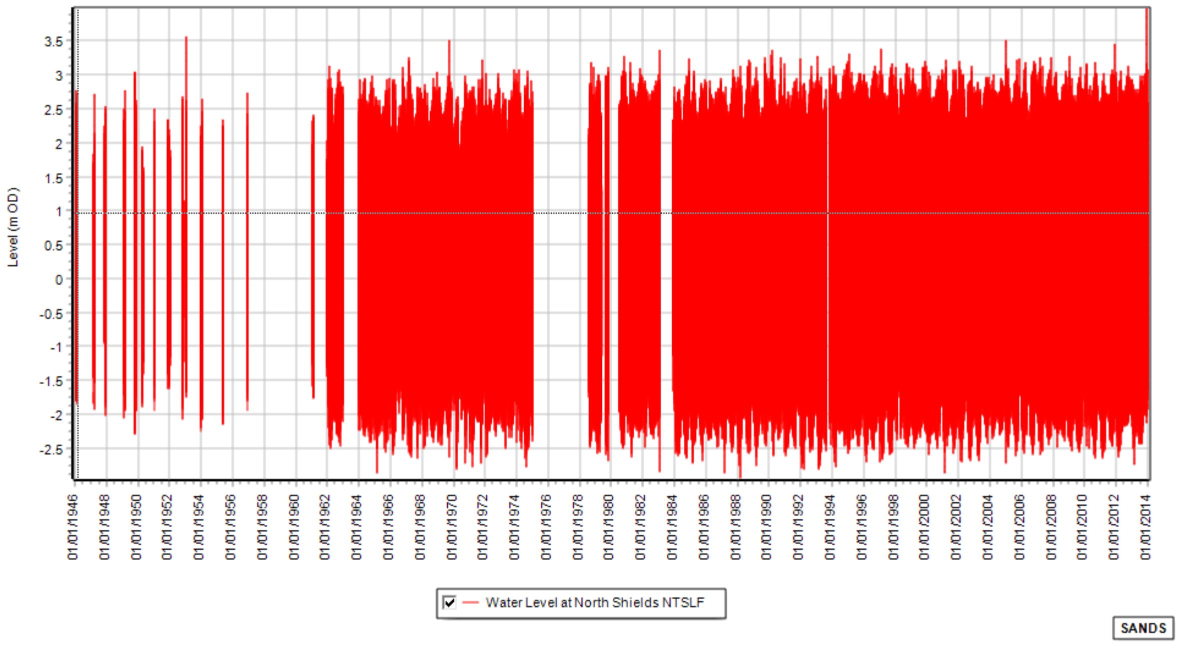


Figure 2.4 Plot of water level data available at North Shields NTSLF Tide Gauge

Extreme water level predictions from the Environment Agency's (EA) 2011 national Coastal Flood Boundary (CFB) Conditions study for a location offshore from North Shields are shown in Table 2.4 below. This indicates that the December 5th 2013 storm surge, which caused extensive damage to defences and beaches on the east coast had an annual exceedence probability (chance each year) of between 1 in 200 and 1 in 500 based on the analysis of previous data.

Table 2.4 Predicted extreme tide levels at North Shields

Annual Exceedence probability	Extreme Level (m OD) from EA CFB Study (2011)	Confidence intervals (m) from EA CFB Study (2011)	Extreme levels from SANDS analysis of North Shields NTSLF(mOD)
1 in 1	3.20	0.1	3.16
1 in 2	3.27	0.1	3.25
1 in 5	3.38	0.1	3.37
1 in 10	3.46	0.1	3.46
1 in 20	3.55	0.1	3.55
1 in 25	3.58	0.1	
1 in 50	3.67	0.1	3.67
1 in 75	3.72	0.1	
1 in 100	3.76	0.2	3.76
1 in 150	3.82	0.2	
1 in 200	3.87	0.2	3.85
1 in 250	3.90	0.2	
1 in 300	3.92	0.2	3.91
1 in 500	4.00	0.3	3.97
1 in 1,000	4.11	0.3	

Note: data from EA (2011), Chainage 3630
http://evidence.environment-agency.gov.uk/FCERM/en/Default/FCRM/Project.aspx?ProjectID=F162D56F-87C4-4F14-B77B-A8A3EFDB363F&PageId=a0fe6dfc-506a-452c-9bff-a7ec06b4e6b0

The water level data from the North Shields tide gauge were also analysed in SANDS to derive extreme levels to compare to the EA 2011 CFB data. The Peak over Threshold approach was used, with a threshold of 2.5m and data bins of 0.1m. This analysis excluded the 5th December

2013 storm as its inclusion would affect the statistical results. The results, which had a good correlation coefficient of 0.995 for the Gumbel fit, are given in the right hand column of Table 2.4 and are very similar to the results of the EA 2011 CFB study. Note that the confidence levels for the EA data should also be assumed to apply to the local data analysis undertaken with SANDS. The set of return periods derived in SANDS is different to the EA 2011 CFB study so results are not available to compare for all return periods.

2.3. Tyne Tees WaveNet Buoy

This buoy was deployed by Cefas in 2006 and continues to operate as part of the National Network managed by Cefas for the Environment Agency alongside the UK strategic tide gauge network. The wave buoy is located some 35km offshore in around 65m water depth and therefore potentially provides a suitable baseline of offshore data as the record extends from before the Cell 1 strategic programme commenced in 2008.

The baseline report included a sample comparison of the recorded waves at Newbiggin and Whitby under the Cell 1 programme to the WaveNet buoy Tyne Tees buoy. This has been updated in Figure 2.5 below to additionally show the modelled data from the nearest Met Office hindcast location 2084. As noted in the baseline report there are generally similarities between the data sets but also some significant differences. During the early part of the record around the 9th October, see blue circle, the wave heights at the three sites were very similar.

However, there are some storms, for example the one the 13th November 2010, circled in red in Figure 2.5, when storms were only picked up at the further offshore, Tyne Tees buoy and the hindcast at location 2084. Reviewing the wave direction data over this period shows that for Tyne Tees the waves were directed offshore (270 degrees) for this storm.

Due to the fetch of around 40km for the dominant southwest to westerly winds it is not surprising that there are storms in the record from the buoy for periods when the wind is directed offshore at the coast. During periods of offshore winds the record at the Tyne Tees buoy will be dominated by locally generated wind waves, whereas the conditions at the closer inshore Newbiggin, Whitby and Scarborough wave buoys would be sheltered and not affected by offshore directed winds so nearshore waves would be swell from the decaying previous storms. This serves to illustrate the need for the programme to continue with several strategic buoys fairly near to the coast rather than just relying on the Tyne Tees buoy.

It is notable that the hindcast wave data, which is available from 1980 to 2012, show a very similar temporal record to the measured data at Tyne Tees, but the peak wave height on most storms is significantly under-estimated, with peak wave heights often 0.5m or more less than measured. This indicates that the model calibration is not good for peak storms in this location and that caution should be used and consideration given to adjusting or calibrating the Met Office hindcast offshore data if it is to be used as boundary conditions in coastal modelling studies. This is further illustrated by the plot in Figure 2.6 showing a comparison of predicted and measured storms in November and December 2009.

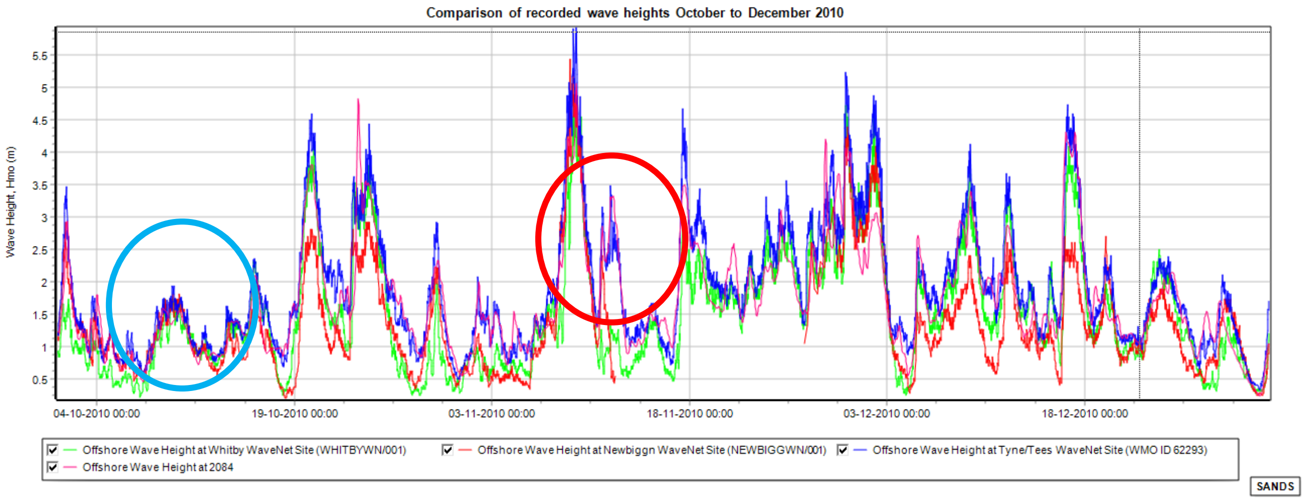


Figure 2.5 Comparison of recorded and modelled wave heights during winter 2010

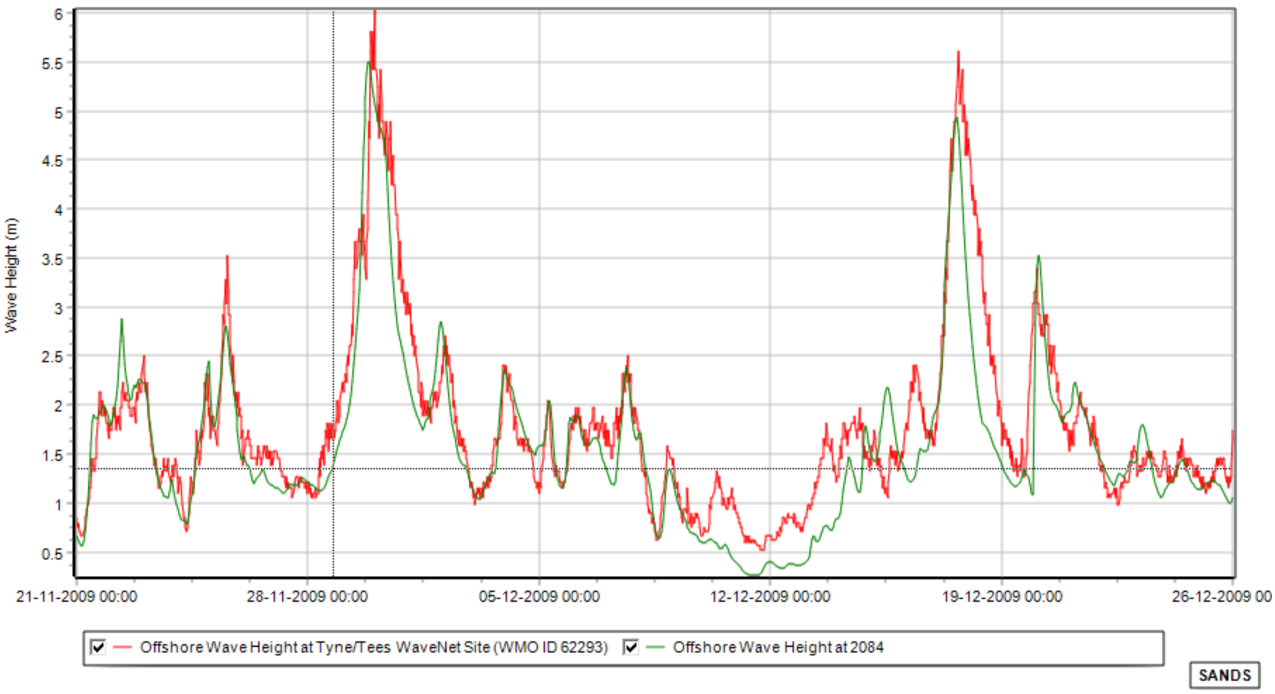


Figure 2.6 Comparison of recorded and modelled wave heights at Tyne Tees in winter 2009

The data record which was reviewed at the Tyne Tees wave buoy for the baseline report ran from December 2006 to September 2012. A scatter table and wave rose was produced for the buoy using five full years of wave data. Storm and extremes analyses were also carried out and are shown in the sub-sections below.

2.3.1. Wave height vs Wave Period

The distribution of the wave height, peak and zero crossing period for the wave data record has been plotted as a scatter plot (see Figure 2.7 below). The largest storms recorded have a peak period of 12.4 and 13.4 seconds (see Table 2.8 below).

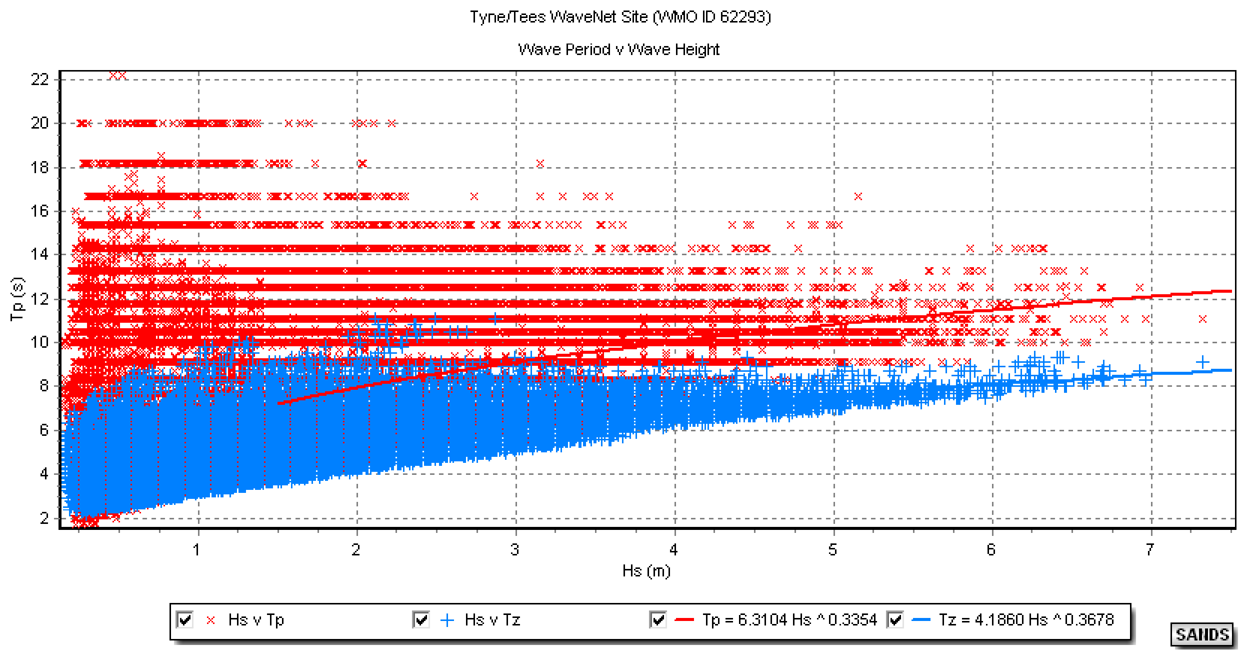


Figure 2.7 Scatter plot of Wave Height Vs Peak Period at Tyne Tees wave buoy site

2.3.2. Wave Rose and Wave Direction Scatter Tables

The wave rose for Tyne Tees in Figure 2.8 has been updated to include 7 full years of wave data. The plot shows that the majority of the waves come from the north to north-northeast (0-30 degrees). There is a small secondary peak from the south east (120-150 degrees). Due to the offshore location of this buoy there are also small peaks from the southwest and northwest, although of course these would represent calm periods at the coast.

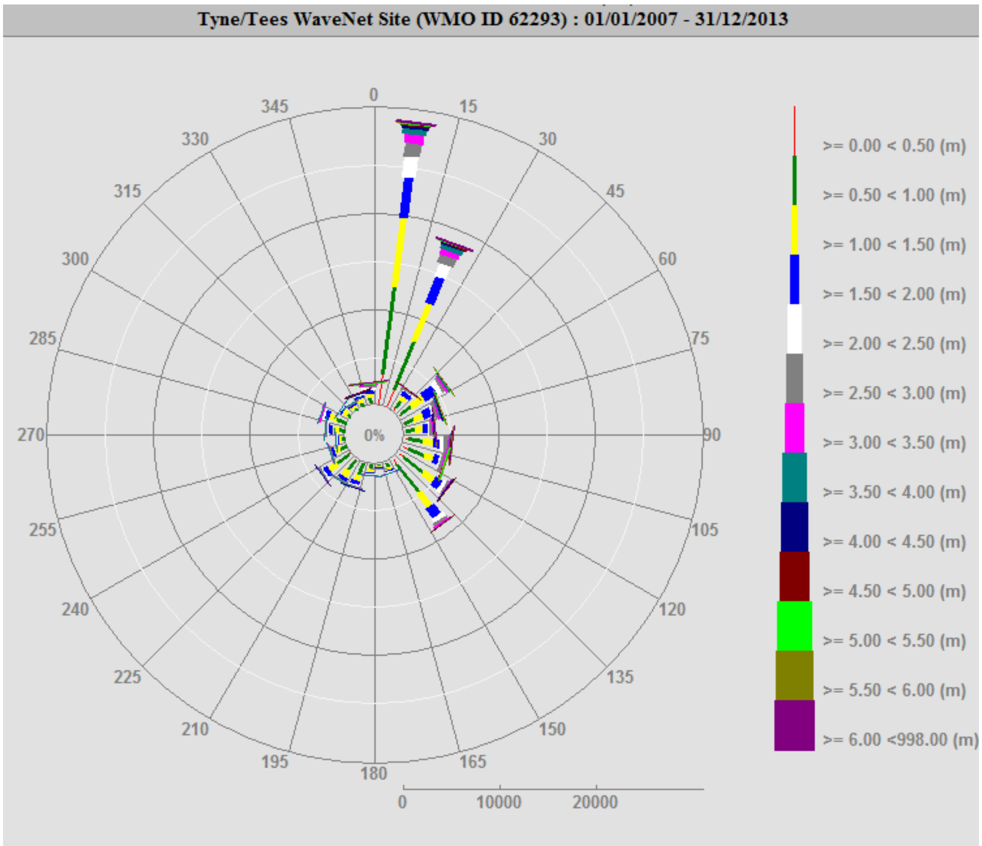


Figure 2.8 Wave Rose at Tyne Tees wave buoy site (WMO ID 62293)

The associated wave height and wave period vs wave direction data are provided below in Table 2.5 and Table 2.6 respectively.

Table 2.5 Wave Height and Direction Scatter Table for Tyne Tees WaveNet Site

Offshore Wave Height	Offshore Wave Direction												
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-0.5	5330	790	467	1189	1466	196	240	493	157	172	145	350	10995
0.5-1	14684	2179	1875	3197	6166	658	1516	2854	1191	1810	785	1120	38035
1-1.5	11452	2202	1818	2154	3296	382	1122	1761	777	1404	810	809	27987
1.5-2	7219	1878	1432	1218	2071	218	666	1033	478	892	347	657	18109
2-2.5	3635	791	600	697	908	69	274	239	127	395	134	359	8228
2.5-3	2225	446	511	556	491	37	110	143	121	239	63	269	5211
3-3.5	1558	258	305	289	211	4	23	36	39	59	13	129	2924
3.5-4	922	132	195	169	108	1	11	5	6	15	2	53	1619
4-4.5	463	54	131	126	48		3	1				31	857
4.5-5	292	29	80	74	18							27	520
5-5.5	144	7	62	71								13	297
5.5-6	70	1	25	21								8	125
6-6.5	55		5	16								4	80
6.5-7	10		2									1	13
7-7.5	2												2
7.5-8	9												9
Total	48070	8767	7508	9777	14783	1565	3965	6565	2896	4986	2299	3830	

Location: Tyne/Tees WaveNet Site (WMO ID62293);
Date range :01/01/2007 to 21/12/2013 (6.5 years of data accounting for gaps)
Offshore Wave Direction Peak (x) vs Offshore Wave Height Hm0 (y), showing numbers of 30 min observations.

Table 2.6 Wave Period and Direction Scatter Table for Tyne Tees WaveNet Site

Offshore Wave Tp	Offshore Wave Direction												
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	Total
0-2	1		3	1	2	2	1	1		1			12
2-4	213	68	84	291	1159	557	1250	2588	1189	1512	579	232	9722
4-6	2098	1344	1779	3840	7955	792	2325	3341	1392	2897	1479	1493	30735
6-8	7418	3692	3288	3977	4181	92	173	238	174	340	130	1120	24823
8-10	13694	2684	1790	1276	1037	1		1				321	20804
10-12	12993	729	463	220	29							241	14675
12-14	6454	65	7	3								115	6644
14-16	1945	15										33	1993
16-18	415	5										16	436
18-20	141	4										8	153
Total	45372	8606	7414	9608	14363	1444	3749	6169	2755	4750	2188	3579	

Location: Tyne/Tees WaveNet Site (WMO ID62293);
Date range :01/01/2007 to 31/12/2013 (.5 years of data accounting for gaps)
Offshore Wave Direction Peak (x) vs Offshore Peak Wave Period Tp (y), showing numbers of 30 minute observations.

2.3.3. Extremes Analysis

The extremes analysis undertaken for the Tyne Tees buoy location in the baseline report has been updated. As previously, a peak wave height threshold of 4.6m was used, which provided 45 peaks in 7.2 years. The Gumbel distribution used for extrapolation gives a good correlation coefficient of 0.9917 and the visual fit appeared satisfactory. Given the length of the record, the data should only be considered reliable up to a 1 in 30 year return period. The results of the extremes analysis are shown in Table 2.7 below.

Table 2.7 Extremes Analysis for Tyne Tees buoy

Return Period (1 in X years)	Gumbel Fit Extreme Wave Height (Hs, m)
0.2	4.8
0.3	5.3
0.5	5.7
1	6.2
2	6.6
3	6.9
5	7.2
10	7.6
20	8.0
30	8.3

2.3.4. Storm Analysis

A SANDS storm analysis of the Tyne Tees data set was undertaken using a wave height threshold of 4m and a storm separation threshold of 120 hours. This allows extraction of typically between 3 and 10 storms of the biggest storms each year. The period of data examined ran from 07/12/2006 to 07/01/2014. Note that the 2012 and 2013 analysis uses the telemetry data download, rather than the checked post-recovery data used for earlier years. Future updates to this report may update this analysis if more accurate data becomes available.

The storm analysis results are presented in Table 2.8 below. To aid interpretation of the results in Table 3.4 alternate years have been shaded and the storm with the largest peak wave height each year has been highlighted in bold. The annual storm with the highest wave energy at peak has also been highlighted in bold red text as this depends on wave period as well as wave height and so is not always the same as the largest wave height, e.g. in 2009 and 2010.

Plots of storm direction and storm duration are shown in Figure 2.9 and Figure 2.10 below. The storms mostly arrive from the north to northeast direction, 0 to 40 degrees, which has the longest fetch, but there are also a significant number of storms from other directions, particularly 80 to 140 degrees. The largest peak wave height (Hs = 7.9m) was associated with the longest duration storm (180 hours) in March 2008.

Comparing the annual storm records, it can be seen that 2010 had the most storms (13). 2010 was also unusual in that the largest storm had an incident direction of 73 degrees at peak, whereas in all of the other years direction at peak of the largest storm was from the north to northeast sector. From these results we might expect that the alongshore drift on the Cell 1 beaches in 2010 may have been atypical with unusual changes from the storm conditions. This was indeed noted in several of the 2010 Full Measures reports. For example the Hartlepool report noted unusual beach lowering along North Sands, and there was significant beach lowering at a number of locations at Sunderland.

The year with the fewest storms was 2011. This was reflected by accretion recorded in a number of the annual Full Measures reports. For example recovery of the beaches at North Sands and Middleton beaches in Hartlepool, and recovery of beaches was noted at Sunderland.

The winter of 2012 to 2013 appears to have suffered with larger storms than usual, with the second largest peak wave height recorded on 23rd March 2013. The longest duration storm in the record was from 5th to 15th December 2012.

The storm surge that damaged many defences and received significant media attention on 5th and 6th December 2013 does not appear to have had exceptional wave conditions at the Tyne Tees buoy, with a peak significant wave height of 4.7m and storm duration of 38 hours. However, the wave period was over 14 seconds, is unusual, and the longest storm wave period recorded.

Table 2.8 Storm Analysis at Tyne Tees WaveNet Buoy (updated to include 2013 data)

General Storm Information							At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Direction (°)**	**No of Events (30 min dataset)**	**Mean Direction Vector (°)**	**Hs (m)**	**Tp (s)**	**Direction (°)**	**Energy @ Peak (KJ/m/s)**
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	21	73	79.0	6.2	12.4	22	11759.3
25/06/2007 20:00	26/06/2007 13:30	17.5	26/06/2007 10:00	33	28	81.6	4.4	8.6	22	2832.6
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	10	36	80.4	4.6	11.6	6	5488.7
08/11/2007 20:00	**12/11/2007 15:00**	**91**	**09/11/2007 08:30**	**14**	**64**	**78.7**	**6.2**	**13.4**	**6**	**13698.9**
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	74	59	78.8	4.9	10.7	17	5353.7
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	65	11	85.1	4.1	10.8	17	3816.4
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	77	24	14.8	4.2	9.1	62	2964.9
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	37	34	80.9	6.0	13.8	17	13641.7
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	146	9	307.6	4.6	8.0	141	2631.9
17/03/2008 15:00	**25/03/2008 03:00**	**180**	**22/03/2008 05:00**	**59**	**78**	**83.8**	**7.9**	**12.4**	**6**	**19123.9**
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	44	22	83.8	4.6	11.6	6	5520.5
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	15	8	75.9	4.2	9.9	11	3492.5
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	30	32	82.4	4.7	11.4	22	5728.4
21/11/2008 04:00	25/11/2008 12:30	104.5	22/11/2008 11:30	15	112	75.8	6.0	13.1	11	12267.5
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	109	37	331.9	4.9	8.3	129	3286.2
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	84	57	7.1	5.8	9.5	84	6078.5
23/03/2009 20:30	28/03/2009 20:30	120	28/03/2009 18:30	92	26	89.7	4.9	9.3	0	4053.0
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	13	2	78.8	4.2	9.9	11	3504.3
29/11/2009 20:00	**30/11/2009 15:00**	**19**	**30/11/2009 00:30**	**17**	**38**	**73.4**	**6.0**	**9.4**	**11**	**6331.4**
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	64	36	26.4	5.4	10.6	68	**6549.5**
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	84	24	7.7	5.1	7.5	90	2866.0
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	30	10	63.7	4.2	10.7	11	4044.1
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	6	29	83.9	5.4	8.6	6	4258.2
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	18	7	72.6	4.6	8.5	17	2925.7
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	21	49	69.4	5.4	10.7	22	**6611.8**
29/08/2010 14:00	30/08/2010 06:30	16.5	29/08/2010 22:30	131	26	91.8	4.9	8.9	0	3715.5
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	101	22	353.3	4.6	8.8	90	3192.5
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	10	17	80.8	4.7	11.0	11	5323.3
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	19	86	73.1	5.3	10.1	11	5564.7
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	13	16	78.3	4.2	11.3	17	4514.5
08/11/2010 14:00	**09/11/2010 20:30**	**30.5**	**09/11/2010 10:00**	**87**	**58**	**3.1**	**5.6**	**8.8**	**73**	**4870.6**

General Storm Information							At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Direction (°)**	**No of Events (30 min dataset)**	**Mean Direction Vector (°)**	**Hs (m)**	**Tp (s)**	**Direction (°)**	**Energy @ Peak (KJ/m/s)**
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	136	9	322.2	4.7	7.8	129	2646.0
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	80	45	11.8	5.1	9.4	56	4474.2
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	10	25	80.2	4.6	10.5	17	4504.6
23/07/2011 14:00	**24/07/2011 11:00**	**21**	**24/07/2011 03:00**	**23**	**39**	**67.5**	**4.7**	**10.8**	**17**	**5082.6**
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	103	26	348.5	4.1	9.5	79	2986.1
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	6	3	84.4	4.1	11.9	6	4669.0
05/01/2012 15:30	06/01/2012 05:00	13.5	06/01/2012 00:30	29	24	81.4	4.5	9.9	14	3896.6
03/04/2012 13:30	04/04/2012 10:30	21	04/04/2012 03:00	64	43	26.5	5.7	8.4	90	4510.0
24/09/2012 07:30	25/09/2012 11:00	27.5	24/09/2012 17:30	73	54	17.2	5.3	9.3	77	4786.2
26/10/2012 12:00	27/10/2012 15:00	27	26/10/2012 23:00	11	44	78.9	4.9	12.9	11	**7839.9**
05/12/2012 15:00	**15/12/2012 01:30**	**226.5**	**14/12/2012 18:30**	**83**	**49**	**39.6**	**6.1**	**8.4**	**107**	**5080.9**
20/12/2012 06:00	21/12/2012 14:30	32.5	20/12/2012 23:30	103	63	347.3	6.0	8.8	103	5436.3
18/01/2013 17:30	22/01/2013 07:30	86	21/01/2013 09:30	83	62	7.6	6.8	9.3	83	7978.4
06/02/2013 08:00	07/02/2013 08:30	24.5	06/02/2013 12:30	56	47	82.6	5.6	9.9	11	6039.7
07/03/2013 21:00	11/03/2013 04:00	79	08/03/2013 04:00	67	53	24.3	5.1	8.4	82	3667.4
18/03/2013 07:00	**25/03/2013 02:00**	**163**	**23/03/2013 10:30**	**86**	**166**	**4.5**	**7.3**	**9.3**	**89**	**9164.3**
23/05/2013 18:00	24/05/2013 12:00	18	23/05/2013 22:30	13	32	77.5	6.7	10.5	17	**9678.4**
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	11	14	79.3	4.4	9.2	11	3237.0
29/11/2013 22:30	30/11/2013 05:30	7	30/11/2013 00:30	62	12	82.8	5.6	10.7	11	7071.5
05/12/2013 14:00	07/12/2013 04:30	38.5	06/12/2013 20:00	26	56	80.4	4.7	14.3	6	8937.4
27/12/2013 09:30	27/12/2013 12:30	3	27/12/2013 10:00	218	3	249.3	4.1	6.1	202	1237.4

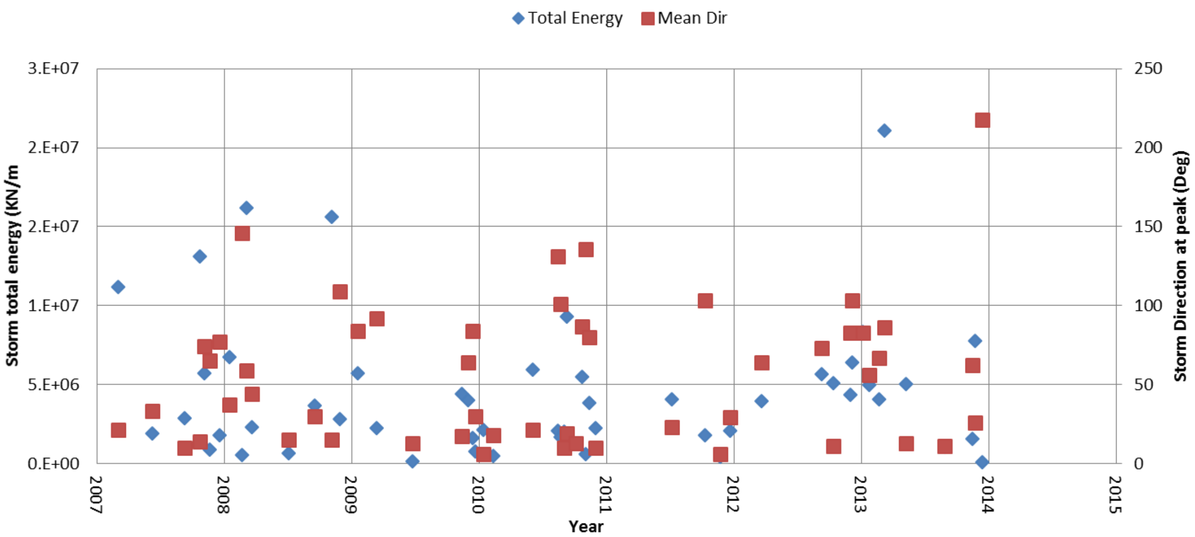


Figure 2.9 Storm energy and peak direction data for Tyne Tees Wave Buoy

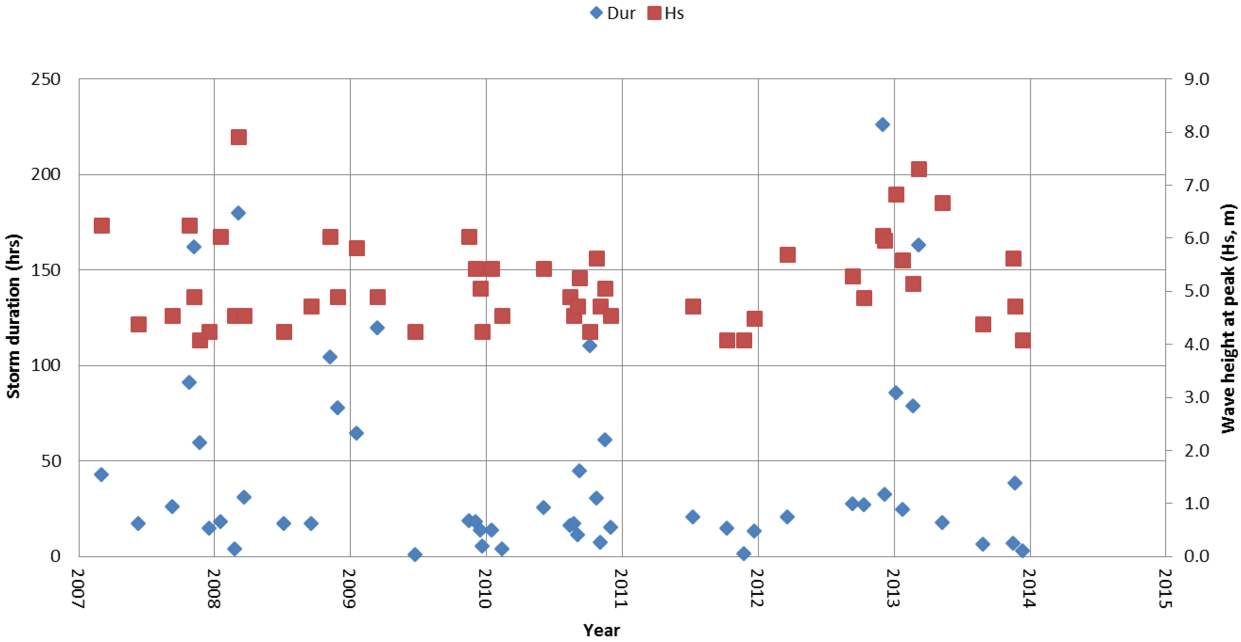


Figure 2.10 Storm duration data at Tyne Tees Wave Buoy

An analysis of the joint occurrence of waves and water levels has been undertaken using the measured NTSLF water level data from North Shields and the measured wave data from the Tyne Tees buoy. The results, presented as a scatter table of the number of occurrences of joint events, are given in Table 2.9.

Table 2.9 Scatter table for Tyne Tees WaveNet data vs North Shields water levels

	Water level (m) at North Shields										
Wave height (m) at Tyne Tees	-3.00 - -4.00	-2.00 - -3.00	-1.00 - -2.00	0.00 - -1.00	1.00 - 0.00	2.00 - 1.00	3.00 - 2.00	4.00 - 3.00	5.00 - 4.00	6.00 - 5.00	7.00 - 6.00
7.00 - 8.00	0	0	0	0	1	0	0	0	0	0	0
6.00 - 7.00	0	0	7	19	24	15	16	1	1	0	0
5.00 - 6.00	0	0	30	93	75	112	68	6	3	6	0
4.00 - 5.00	0	15	177	333	298	342	151	8	6	4	0
3.00 - 4.00	0	35	529	1067	909	1012	421	20	18	14	4
2.00 - 3.00	0	97	1783	3245	2684	3388	1296	55	47	72	15
1.00 - 2.00	0	367	6105	10306	8509	10683	4313	236	280	177	14
0.00 - 1.00	0	430	6653	10527	8524	10996	4486	145	133	62	0

Based on 5.79 years of data with records at 0.5 hour intervals

2.4. Whitby Waverider Buoy

In the baseline report, one full year's data for Whitby, from October 2010 to October 2011, was analysed in SANDS to prepare a wave rose and scatter table for the baseline. The new data collected is from a very similar location and covers the period from 17th January 2013 to 30th January 2014. The data was imported into SANDS for comparison and analysis alongside the other available monitoring data.

There is a gap in the data record from 19th to 21st June 3013 whilst the buoy was off station following possible damage by a fishing vessel in the area. Supporting data tables and monthly plots of the new data are provided in Appendix C.

2.4.1. Wave Height vs Peak Period

The distribution of the wave height and peak period for the wave data record has been plotted as a scatter plot with the new data for 17th January 2013 to 30th January 2014 overlaid on the baseline data (20/05/2010 to 25/10/2011), see Figure 2.11 below. The distribution of wave height and period appears similar, although there are several larger storm waves in the new data set and also some longer period swell.

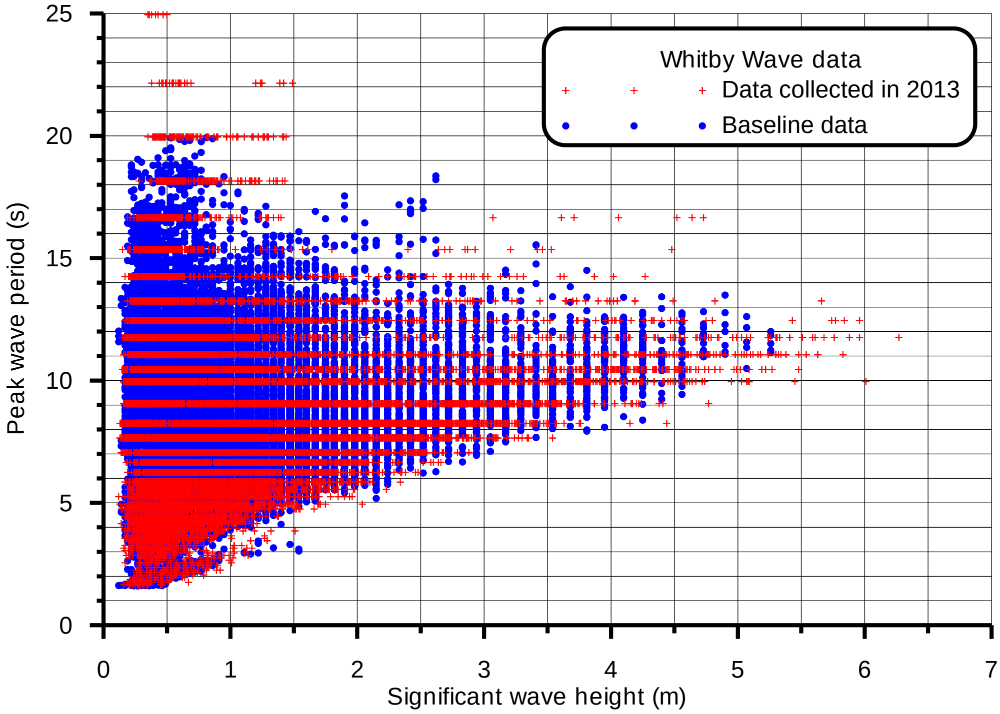


Figure 2.11 Scatter plot of Wave Height Vs Peak Period at Whitby wave buoy site

2.4.2. Wave Rose

The directional data of the wave record has also been used to plot a wave rose for the baseline and new data sets, with both showing a quite similar distribution, see Figure 2.12 and Figure 2.13 below. The wave roses are fairly similar and show that the waves predominantly approach the coastline at Whitby from the northeast by north direction (0 to 30 degrees).

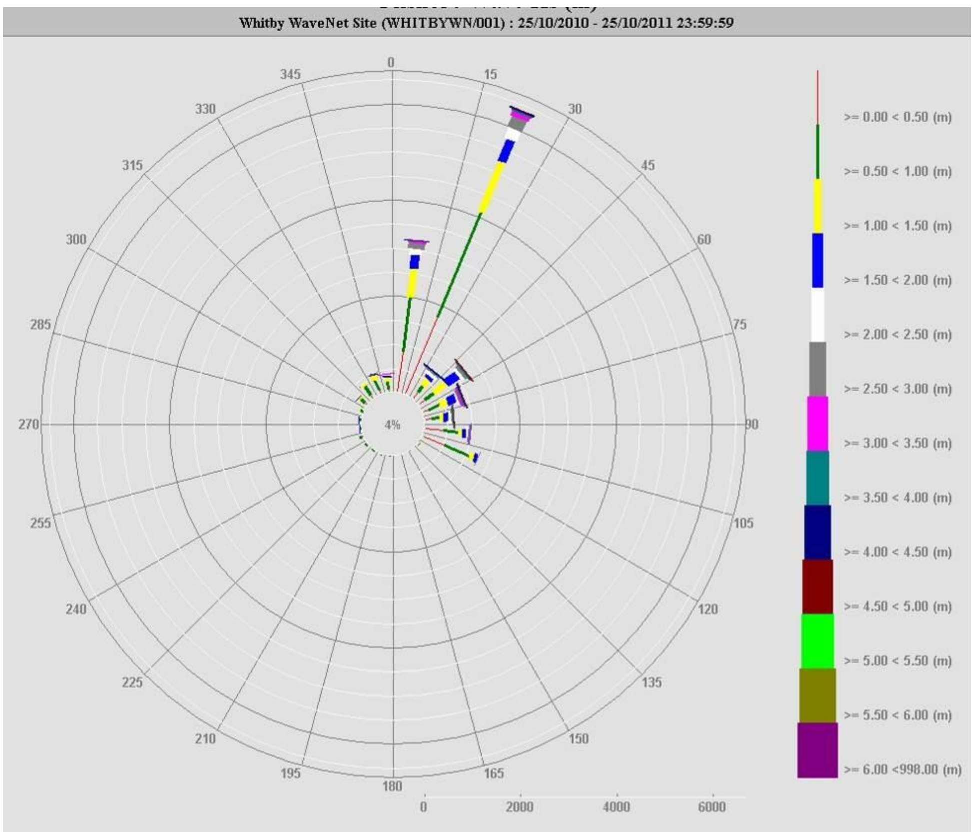


Figure 2.12 Wave Rose at Whitby wave buoy site – data for 2010 to 2011

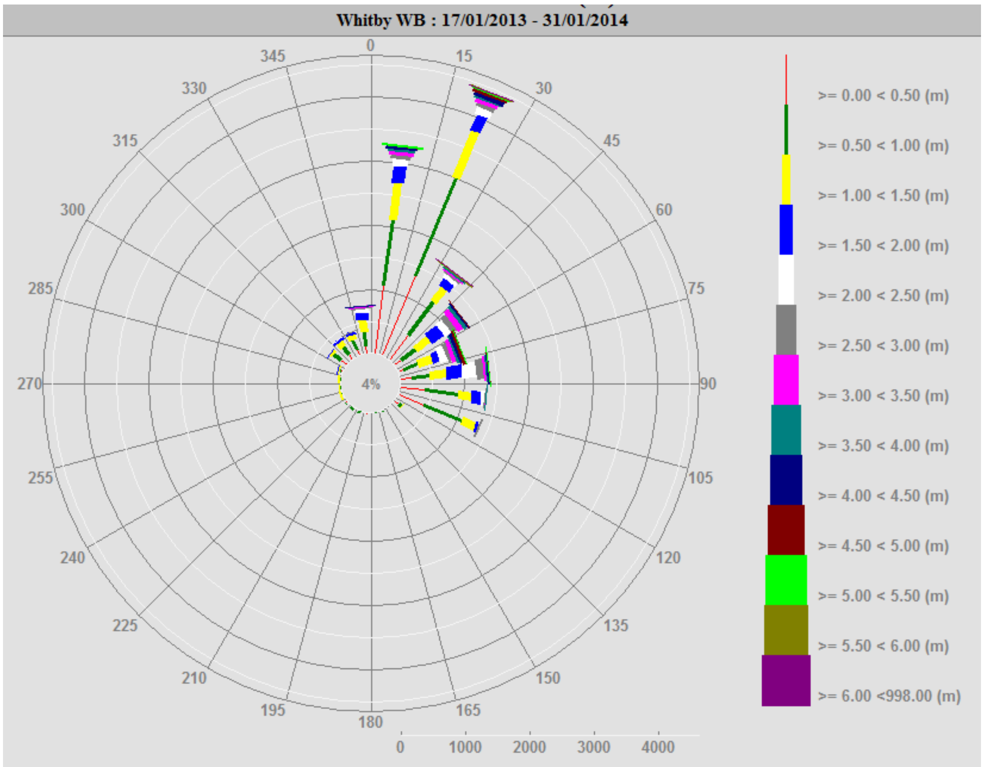


Figure 2.13 Wave Rose at Whitby wave buoy site – data for 2013

2.4.3. Storm Analysis

A storm analysis of the Whitby data set was undertaken for the baseline report using a wave height threshold of 4m and a storm separation threshold of 120 hours. The period of data examined ran from 20/05/2010 to 25/10/2011 and the results are presented in Table 2.10 below. The storms mostly arrive from the north to east-northeast (5 to 66 degrees). The storm in the baseline record with the largest wave height (5.1m H_{mo}) at peak occurred on 25th September 2010, whilst the storm with greatest wave energy at peak was on 20th June 2010. The storms analysis of the new data is shown in Table 2.11.

Table 2.10 Storm Analysis results for Whitby – Baseline data 20/05/2010 to 25/10/2011

General Storm Information							**At Peak**			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir (°)**	**No of Events (30 min dataset)**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
19/06/2010 08:30	20/06/2010 07:30	23	20/06/2010	26	38	64.5	4.9	11.4	28	**6085.3**
29/08/2010 16:30	30/08/2010 02:30	10	29/08/2010 17:30	5	7	85.1	4.4	8.0	6	2429.6
17/09/2010 09:00	17/09/2010 11:00	2	17/09/2010 11:00	28	2	67.5	4.4	11.3	22	4853.9
24/09/2010 05:30	**26/09/2010 03:30**	**46**	**25/09/2010 17:00**	**23**	**67**	**66.9**	**5.1**	**10.2**	**28**	**5298.6**
09/11/2010 03:30	09/11/2010 19:00	16	09/11/2010 05:30	66	19	24.9	4.7	9.2	68	3755.6
29/11/2010 20:00	02/12/2010 01:00	53	29/11/2010 22:00	60	19	31.3	4.7	9.9	56	4327.9
23/07/2011 15:30	24/07/2011 11:00	20	24/07/2011 03:00	29	29	61.9	4.2	10.8	22	4114.2

Comparing the storm data at Whitby in Table 2.10 and 2.11 with those in Table 2.1 and 2.2 for Newbiggin it can be seen that several of the storms were recorded at both locations, but the durations, peak wave heights and directions for the storms were quite different. Due to the differing conditions the storm analysis also identified different storms at both locations.

Table 2.11 Storm analysis for Whitby WB (data 17/01/2013 to 30/11/2013)

General Storm Information							**At Peak**			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir (°)**	**No of Events (30 min dataset)**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
21/01/2013 05:30	22/01/2013 03:00	21.5	21/01/2013 14:30	64	31	27	5.0	9.3	61	4,259
06/02/2013 11:00	07/02/2013 04:00	17	06/02/2013 18:30	17	32	73	4.8	9.9	16	4,528
08/03/2013 03:30	11/03/2013 05:00	73.5	11/03/2013 04:00	56	6	39	4.3	8.4	45	2,603
18/03/2013 18:30	24/03/2013 17:30	143	23/03/2013 13:00	71	87	20	5.2	9.3	72	4,678
23/05/2013 21:00	24/05/2013 10:30	13.5	24/05/2013 00:00	21	25	70	5.8	10.5	24	7,372
10/09/2013 14:00	10/09/2013 21:00	7	10/09/2013 16:00	19	13	71	4.4	9.3	24	3,251
10/10/2013 01:30	11/10/2013 06:30	29	11/10/2013 00:00	30	56	69	5.7	11.2	31	7,838
30/11/2013 00:00	30/11/2013 06:00	6	30/11/2013 03:30	16	12	74	4.8	10.5	20	4,976
05/12/2013 20:00	**06/12/2013 22:00**	**26**	**06/12/2013 19:30**	**21**	**38**	**70**	**4.7**	**14.0**	**32**	**8,625**

The storms analysis for the new data at Whitby show that by far the largest peak wave energy was associated with the storm that occurred from 5th to 6th December 2013. The largest peak wave height in the record was 5.7m during the storm from 10th to 11th October 2013.

As we only have two years of wave data it is not yet possible to say if the conditions in 2013 were more or less stormy than usual. Further insight into this can be gained by reference to the longer data set from the Tyne Tees wave buoy.

2.5. Whitby Tide Gauge

There is a tide gauge at Whitby that is operated continuously by the National Tide and Sea Level Facility (NTSLF) on behalf of the Environment Agency as part of the main UK tide gauge network. Information on this tide gauge installation is available on the NTSLF website: http://www.ntslf.org/tgi/portinfo?port=Whitby , including the site history reproduced below. The Chart Datum at Whitby is 3m below Ordnance Datum (http://www.ntslf.org/tides/datum). Due to its location in the mouth of the estuary the recorded water levels can be significantly influenced by high freshwater flows in the River Esk.

Whitby Tide Gauge Site history

- 1980 – Installed Aanderaa recorder attached to a pneumatic bubbler
- 1989 – DATARING system installed with full-tide pressure points; the Aanderaa recorder was removed
- 1995 – New steel work with two full-tide and mid-tide measuring systems installed
- 2002 – POL data logger installed.

Table 2.12 Predicted tide levels at Whitby

Tidal State	Level (m Chart Datum)	Level (m Ordnance Datum)
HAT	6.21	3.21
LAT	0.22	-2.78
MHWS	5.59	2.59
MHWN	4.50	1.50
MLWN	2.25	-0.75
MLWS	0.99	-2.01
Highest predicted 2013	6.03	3.03
Lowest predicted 2013	0.41	-2.59
Highest predicted 2014	6.17	3.17
Lowest predicted 2014	0.32	-2.68

Note: Based on data from http://www.ntslf.org/tgi/portinfo?port=Whitby

Data is available on the internet in real time (http://www.ntslf.org/data/realtime?port=Whitby) and quality controlled data can be downloaded from the British Oceanographic Data Centre (BODC) website.

An example plot of water level data from the POL tidal gauge record at Whitby is shown in Figure 2.14 below (Source: BODC, https://www.bodc.ac.uk/data/online_delivery/). The data available for analysis at the time of writing the baseline report was from 01/01/1991 to 30/04/2011, with data available at 15min intervals. The data availability was checked again when writing this report and additional data from 1980 to 1990, at hourly intervals has been downloaded and added to the project SANDS database. The 15min data from April 2011 to January 2014 has also been downloaded and added to the database. The data were adjusted from Chart Datum to Ordnance datum.

There are occasional gaps in the Whitby data as illustrated in the example plot below in Figure 2.14, but the overall record appears very consistent. The spike in the high water levels shown near the end of the plot is the storm surge level of 4.32mOD at 17:15 on the 5th December 2013. This shows how exceptional the conditions were, with the previous maximum observed water level of 3.6m occurring at 18:00 on 1st February 1982 (note that prior to 1990 only hourly data are available and so the maximum water level may have been higher than the recorded 3.6m).

Extreme water level predictions from the EA's 2011 national Coastal Flood Boundary (CFB) Conditions study for a location offshore from Whitby are shown in Table 2.13 below. This indicates that the December 5th 2013 storm surge, which caused extensive flooding around Whitby town centre had an annual exceedence probability (chance each year) of between 1 in 100 and 1 in 500.

Table 2.13 Predicted extreme tide levels at Whitby

Annual Exceedence probability	Extreme Level (m OD) from EA CFB Study (2011)	Confidence intervals (m) from EA CFB Study (2011)	Extreme levels from SANDS analysis of Whitby NTSLF (mOD)
1 in 1	3.37	0.1	3.3
1 in 2	3.46	0.1	3.4
1 in 5	3.58	0.1	3.6
1 in 10	3.68	0.1	3.7
1 in 20	3.78	0.1	3.8
1 in 25	3.81	0.2	
1 in 50	3.92	0.2	3.9
1 in 75	3.98	0.2	
1 in 100	4.02	0.3	4.0
1 in 150	4.09	0.3	
1 in 200	4.14	0.3	4.1
1 in 250	4.17	0.3	
1 in 300	4.20	0.4	
1 in 500	4.29	0.4	
1 in 1,000	4.41	0.5	

Note: data from EA (2011), Chainage 3718
http://evidence.environment-agency.gov.uk/FCERM/en/Default/FCRM/Project.aspx?ProjectID=F162D56F-87C4-4F14-B77B-A8A3EFDB363F&PageId=a0fe6dfc-506a-452c-9bff-a7ec06b4e6b0

The water level data from the Whitby NTSLF tide gauge were also analysed in SANDS to derive extreme levels to compare to the EA 2011 CFB data. The Peak over Threshold approach was used, with a threshold of 2.2m and data bins of 0.1m. This analysis excluded the 5th December 2013 storm as its inclusion would affect the statistical results. The results, which had a correlation coefficient of 0.979 for the Gumbel fit are given in the right hand column of Table 2.13 and are very similar to the results of the EA CFB study. Note that the confidence levels for the EA data should also be assumed to apply to the local data analysis undertaken with SANDS. The set of return periods derived in SANDS is different to the EA CFB study so results are not available to compare for all return periods.

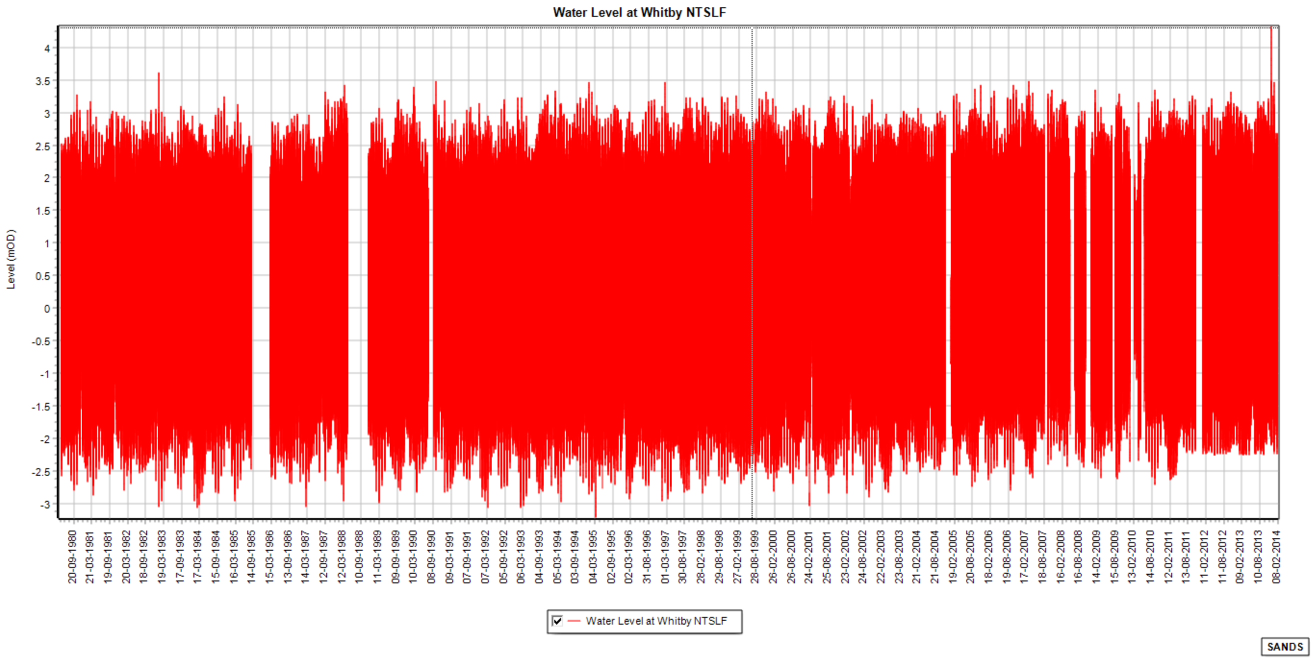


Figure 2.14 Water Level data availability at Whitby NTSLF tide gauge site

The Whitby tide gauge data has also been used to consider the joint occurrence of high waves and high water levels as these are the most damaging events for coastal defences and most likely to precipitate coastal erosion events. The baseline report gave a table with less than 1 full year of data from 20/05/2010 to 30/04/2011. For this report, the previous wave data at the Whitby Waverider buoy location has been combined with the new data collected in 2013 to produce an updated analysis, which is presented in Table 2.14 below. This appears to indicate a slight tendency for larger waves to occur at higher water levels. This may in part be due to depth limited wave breaking at the wave buoy which was located in about 16m water depth. However, it is difficult to draw conclusions as the combined record analysed is only 2.3 years of data. It is recommended that the analysis is repeated in future when a longer concurrent data set is available.

Table 2.14 Scatter table of water level and offshore wave height at Whitby

		Water level (mOD) from NTSLF gauge at Whitby									
		-2.00 - -3.00	-1.00 - -2.00	0.00 - -1.00	1.00 - 0.00	2.00 - 1.00	3.00 - 2.00	4.00 - 3.00	5.00 - 4.00	6.00 - 5.00	7.00 - 6.00
Wave height (Hs, m) from Whitby Waverider Buoy	7.00 - 8.00	0	0	0	0	0	0	0	0	0	0
	6.00 - 7.00	0	0	0	0	1	1	0	0	0	0
	5.00 - 6.00	0	1	9	8	14	16	4	4	9	0
	4.00 - 5.00	0	19	70	80	123	91	19	12	6	0
	3.00 - 4.00	4	91	233	235	327	164	25	47	6	0
	2.00 - 3.00	12	353	646	577	765	419	60	58	34	0
	1.00 - 2.00	131	1524	2546	2175	2921	1588	119	97	96	2
	0.00 - 1.00	233	3578	5851	4959	6367	3448	305	332	164	4

Water Level (x) vs Offshore Wave Height Hm0 (y) (numbers of 30 minute observations)
For date range: 20/05/2010 to 25/10/2011 and 17/01/13 to 31/01/2014 (2.3 years of data)

2.6. Scarborough Waverider Buoy

Baseline data

At Scarborough, data from the Waverider buoys deployed by Cefas and Emu (labelled as SBC and DWR wave buoys) were considered in the baseline report. These were located about 2.8 and 4.8 km offshore respectively. The data record reviewed at the Emu DWR wave buoy runs from April 2004 to March 2006 and the record for the Cefas SBC buoy runs from April 2003 to July 2004. Scatter tables and wave roses were produced for both datasets using full years of data and these were for two and one year respectively. Storm and extremes analyses were carried out for the full record of the DWR wave data; the resulting figures and tables are shown in the sub-sections below.

New data

Under the latest phase of the programme, a Waverider buoy was deployed by Fugro-Emu offshore from Scarborough on 17th January 2013 at 54˚17.460'N, 000˚21.000'W. This is similar to the original SBC location. On 10th June 2013 the buoy was serviced and, following requests from fishermen, the buoy was moved to a further offshore location at 54˚17.605'N, 000˚19.082'W, which is similar to the previous DWR location. Details of the deployment are given in Appendix F and monthly plots of the data are included in Appendix D. There is a gap in the data set when buoy came adrift on 21st November 2013 until it was redeployed on 17th December 2013.

2.6.1. Wave height vs Wave Period

The distribution of the wave height and peak period for the baseline wave data record at Scarborough DWR and Scarborough SBC wave buoys has been plotted as a scatter plot (see Figure 2.15 and Figure 2.16 below, respectively). The largest waves at the Scarborough SBC buoy appear to have a peak period of 9.5 seconds. The new data for the further offshore site has been overlaid on Figure 2.15 to compare to the baseline, and has also been plotted in Figure 2.17 to show fits for both peak and zero crossing period.

Within the baseline data in Figure 2.15 there appears to be two peaks for the higher wave heights. Likewise, it was also observed that there appeared to be two datasets plotted for the baseline data. On closer examination the earlier readings were processed in a different way to the later datasets which accounts for the two peaks. The new data plotted in red only covers the period from June 2013 to January 2014, but it is notable that the wave periods for the larger wave heights show a higher peak period than the baseline data.

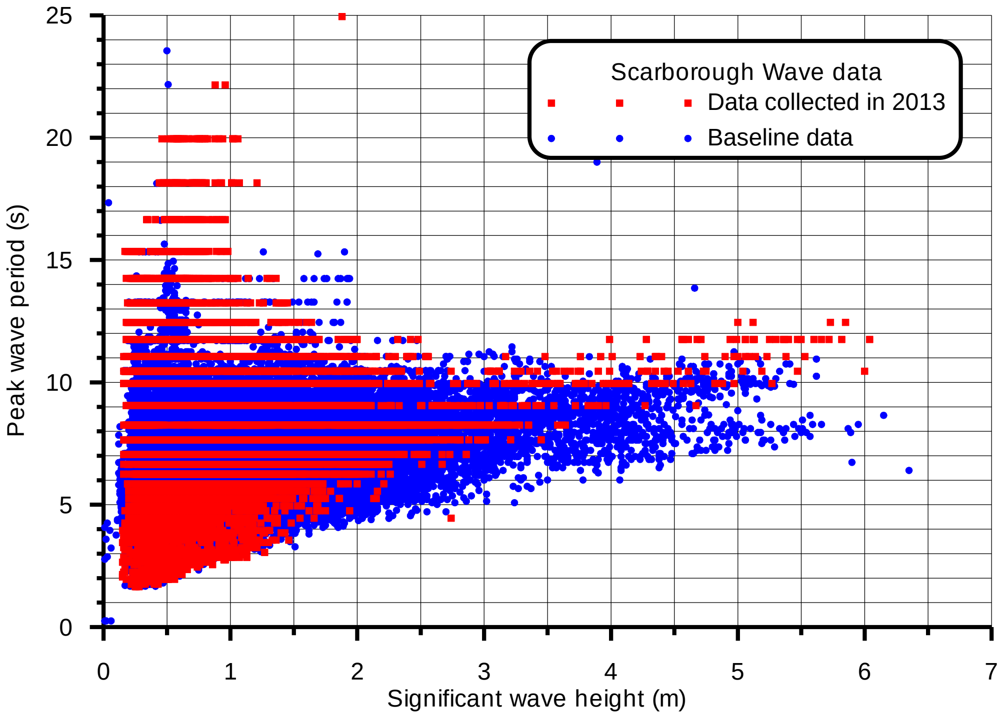


Figure 2.15 Scatter plot of Wave Height Vs Peak Period at Scarborough DWR site, 4.8km offshore

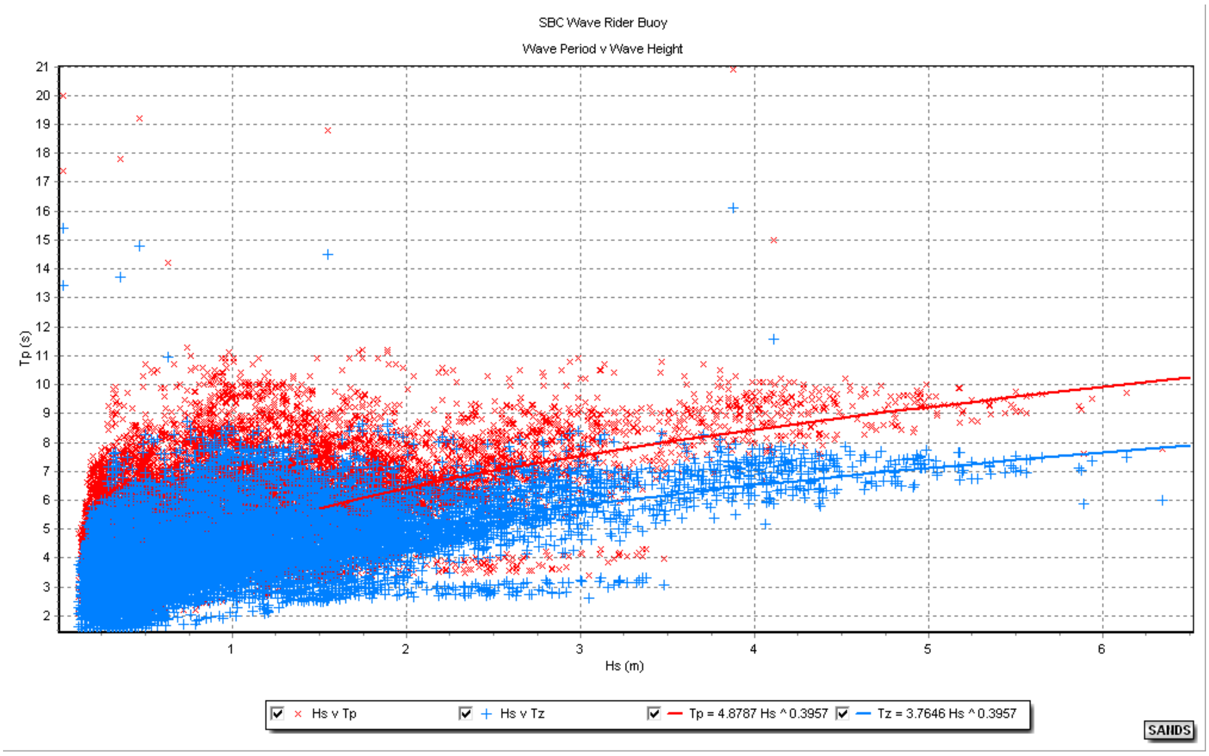


Figure 2.16 Scatter plot Wave Height Vs Period at Scarborough SBC site (April 2003 to April 2004)

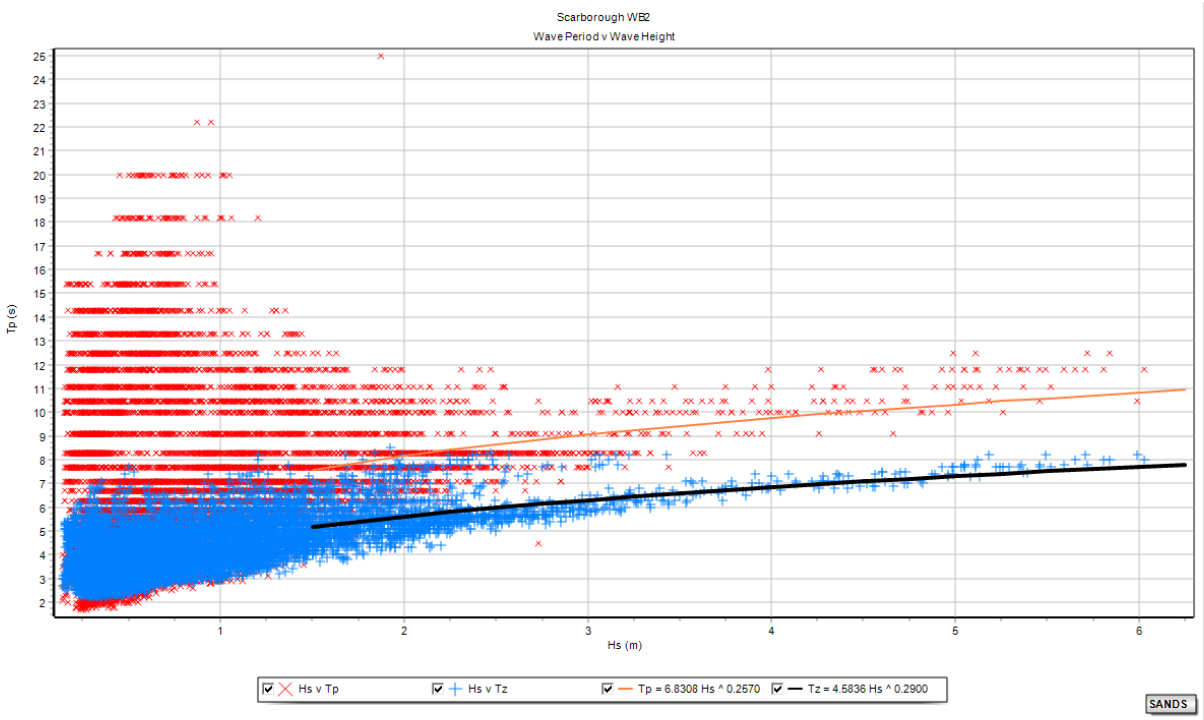


Figure 2.17 Scatter plot Wave Height Vs Period at Scarborough WB2 site (June 2013 to January 2014)

2.6.2. Wave Rose

The wave rose analysis of the Scarborough DWR and SBC Waverider datasets (Figures 2.18 and 2.19 respectively) show that the majority of the waves come from the north to northeast (0-30 degrees). The SBC dataset also shows a secondary wave direction from 105 to 120 degrees. This is interesting as the DWR buoy is further offshore and so might have been expected to have a wider spread of directions. It may be that the wider direction spread is made more apparent at the closer inshore location as it is slightly more sheltered from waves from the north, but alternatively the difference is more likely to reflect the different conditions between the two time periods analysed.

Wave roses for the new data collected from the current, further offshore, location of the Scarborough Waverider, which is very close to the location of the previous DWR data set, is given in Figure 2.20, whilst the full set of new data from the two locations is given in Figure 2.21. All four wave roses show fairly similar distributions, with most storms from 0 to 30 degrees and a secondary direction of 105 to 135 degrees.

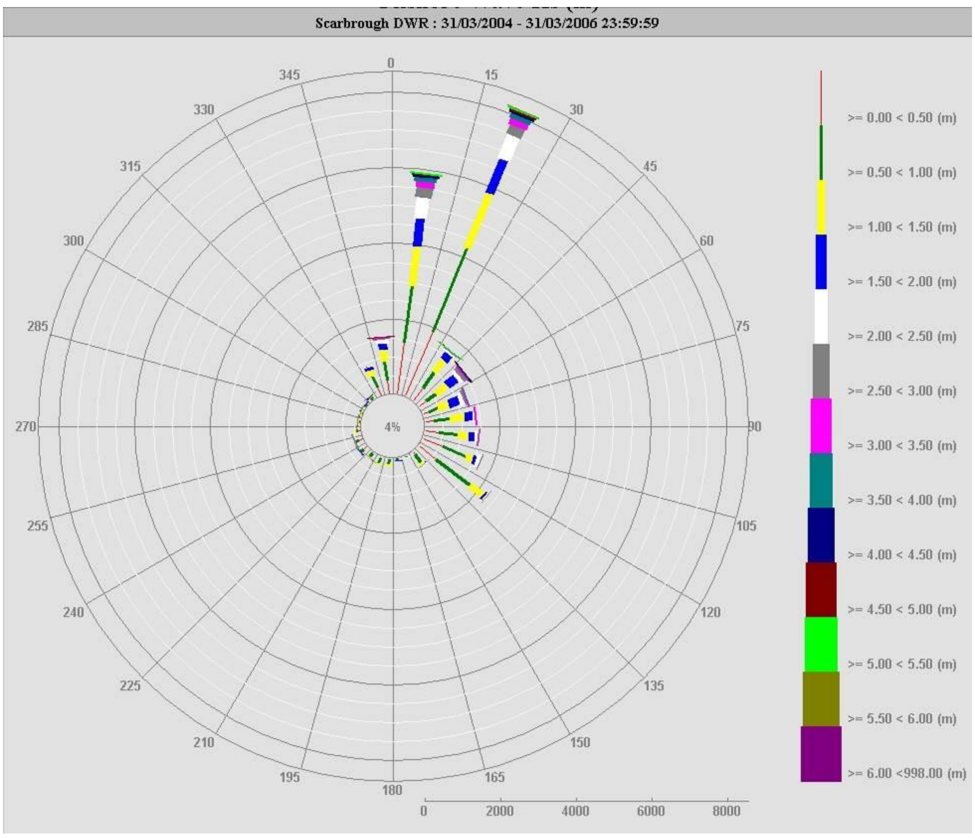


Figure 2.18 Wave Rose at Scarborough DWR site

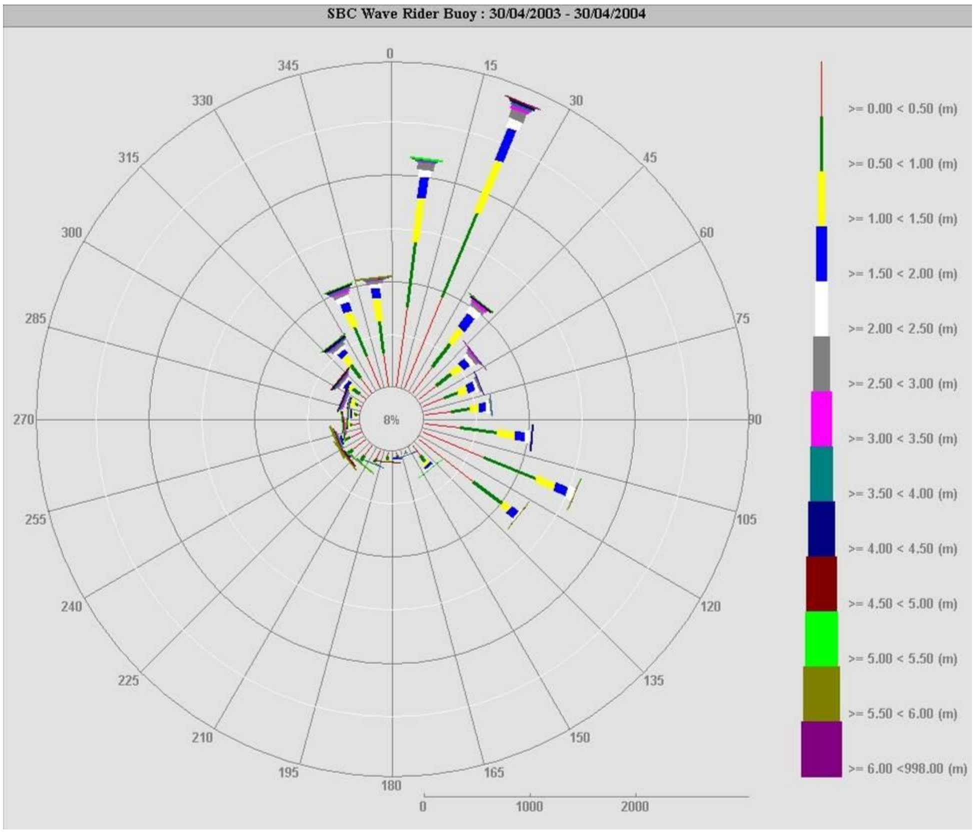


Figure 2.19 Wave Rose at Scarborough SBC site

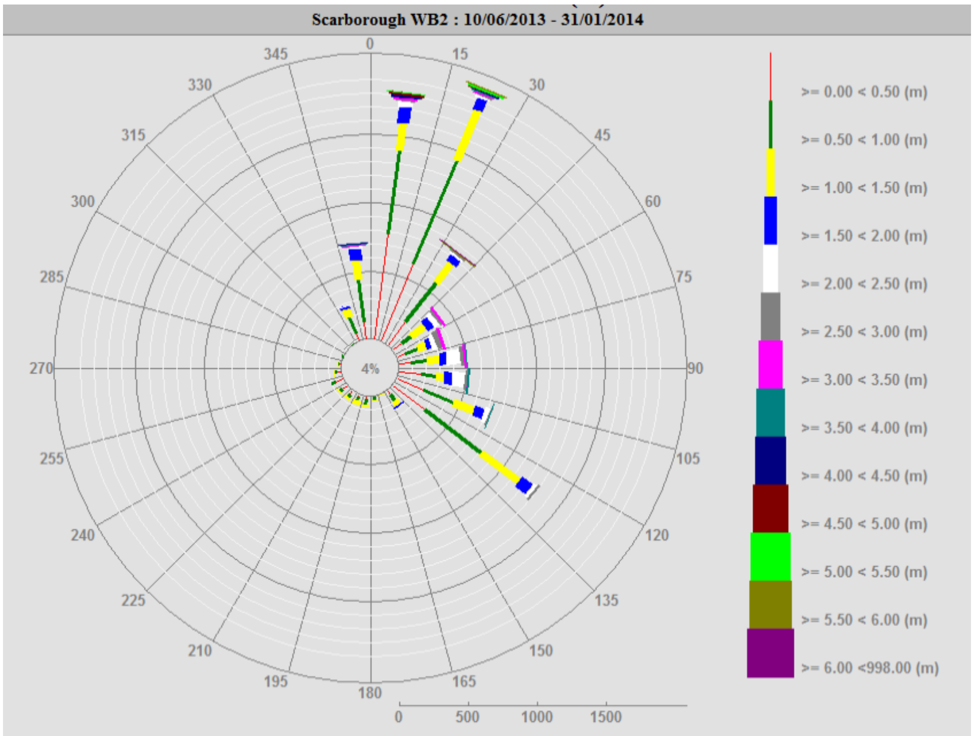


Figure 2.20 Wave Rose at Scarborough WB2 site (June 2013 to Jan 2014)

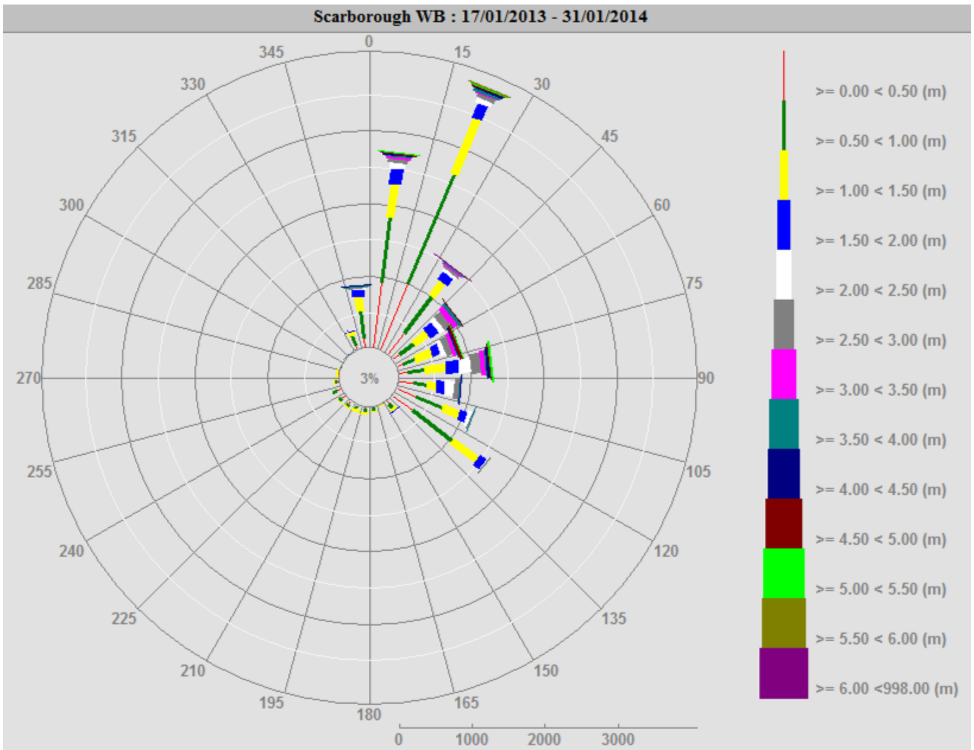


Figure 2.21 Wave Rose for all new data at Scarborough (Jan 2013 to Jan 2014)

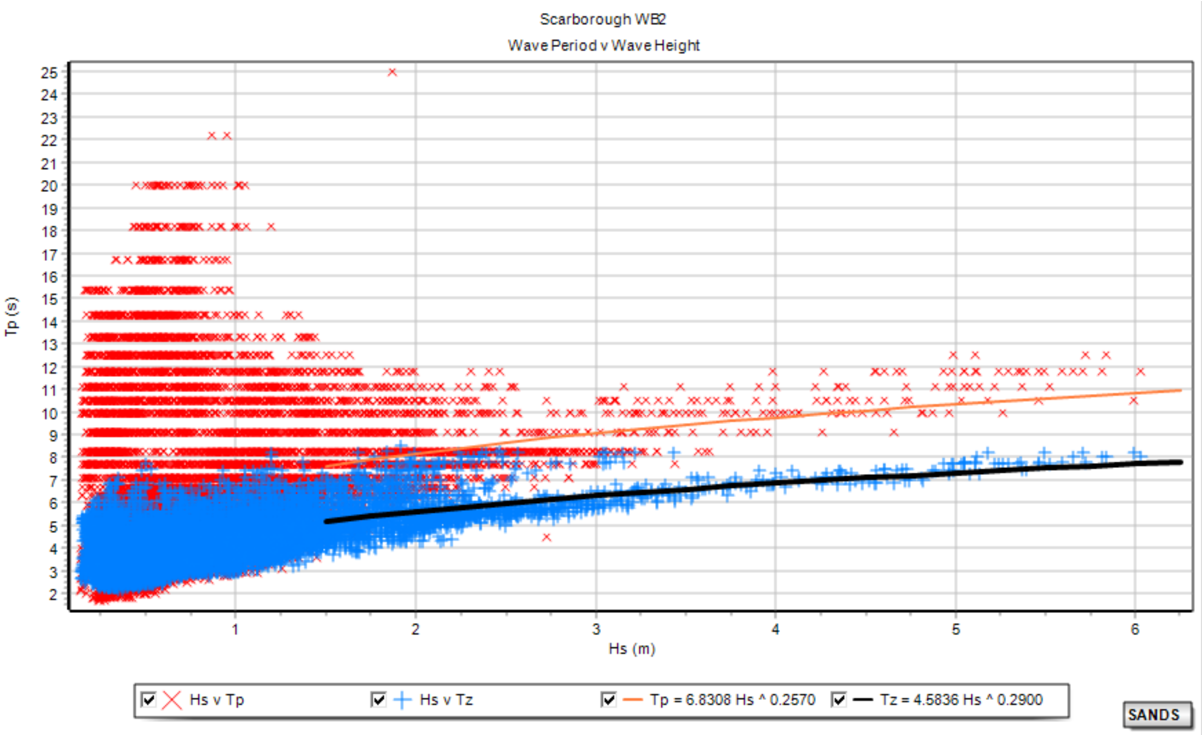


Figure 2.22 Scatter plot of Wave Height Vs Period for new data at Scarborough WB2 site

2.6.3. Extremes Analysis

In the baseline report the longest set of data at the Scarborough DWR buoy location was analysed to estimate extreme values. A peak wave height threshold of 4m was used, providing 18 peaks in 2.92 years. The Gumbel distribution gave a reasonable correlation coefficient of 0.986 and satisfactory visual fit. Given the length of the record, the data should only be read up to a 1 in 10 year return period. The new data sets collected from the two locations off Scarborough SBC are not long enough to complete such an analysis. The results of the extremes analysis from the baseline report are shown in Table 2.15 below.

Table 2.15 Extremes Analysis for Scarborough DWR

Return Period (1 in x years)	Gumbel Fit Extreme Wave Height (Hs, m)
0.2	4.5
0.3	4.9
0.5	5.4
1	5.8
2	6.3
3	6.5
5	6.8
10	7.3

The maximum recorded wave height (Hs) in the full new data set from Scarborough WB was 6.0m, on 10th October 2013. Comparing this to the baseline extremes analysis indicates that this was approximately equal to the expected worst annual storm.

2.6.4. Storm Analysis

A storm analysis was carried out on the Scarborough DWR wave data (between 30/04/2003 and 31/03/2006), using a storm separation threshold of 120 hours and a wave height threshold of 4m. The results are shown in Table 2.16 below.

As with the Tyne Tees analysis (Section 2.3.4), alternate years have been shaded, the largest storm each year is highlighted in bold and the largest wave energy at storm peak highlighted in bold red. Note that only 2004 and 2005 are complete years so the conclusions that can be drawn from this analysis are limited. The largest recorded wave height at the storm peak was 6.3m on 28th January 2004. The largest wave energy at peak occurred on 25th November 2005.

Table 2.16 Storm analysis for Scarborough DWR wave buoy – baseline info

General Storm Information							At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Dir (°)	No of Events (30 min dataset)	Mean Dir Vector (°)	Hs (m)	Tp (s)	Dir (°)	Energy @ Peak (KJ/m/s)
14/12/2003 20:05	**15/12/2003 20:35**	**25**	**15/12/2003 01:05**	**197**	**44**	**100.2**	**5.2**	**7.3**	**13**	**2808.3**
21/12/2003 06:05	22/12/2003 08:05	26	21/12/2003 10:05	205	52	198.0	6.1	7.3	18	**3961.0**
28/01/2004 14:05	**29/01/2004 08:05**	**18**	**28/01/2004 14:05**	**281**	**19**	**121.2**	**6.3**	**5.4**	**56**	**2321.3**
08/02/2004 11:35	08/02/2004 23:35	12	08/02/2004 14:35	227	22	190.1	5.8	6.3	242	2123.2
22/02/2004 13:05	27/02/2004 06:35	114	22/02/2004 14:05	177	64	99.0	4.1	8.2	25	2233.6
12/11/2004 21:05	13/11/2004 01:35	4.5	12/11/2004 23:35	7	8	82.9	4.4	8.1	4	2467.5
23/01/2005 19:05	24/01/2005 09:35	15	24/01/2005 00:05	23	30	67.4	5.4	8.4	20	4047.8
19/02/2005 08:35	24/02/2005 14:05	126	24/02/2005 02:35	36	33	54.7	4.6	7.5	46	2363.1
08/04/2005 05:05	**09/04/2005 01:05**	**20**	**08/04/2005 11:05**	**15**	**40**	**74.9**	**5.6**	**9.2**	**16**	**5286.2**
24/11/2005 18:35	26/11/2005 10:05	40	25/11/2005 03:05	22	40	76.2	4.5	16.9	22	**11368.1**
16/12/2005 10:36	17/12/2005 18:35	32	16/12/2005 11:36	18	56	72.5	4.7	11.7	11	5799.2
08/02/2006 21:35	**10/02/2006 00:35**	**27**	**09/02/2006 16:35**	**21**	**54**	**68.9**	**5.2**	**8.56**	**16**	**3920.2**
28/02/2006 11:35	01/03/2006 00:05	13	28/02/2006 22:05	11	11	79.4	4.0	8.30	8	2183.3

Storms analysis from the new Waverider buoy deployed offshore from Scarborough as part of the current programme in January 2013 is provided in Table 2.17 below. This uses the full data set, ignoring the change of location in June. The storm with the highest energy at peak was the

October storm. It should be noted that the buoy was off station during the early December storm and to clarify a note has been added in the table below.

Table 2.17 Storm analysis for Scarborough WB (data 17/01/2013 to 31/12/2013)

General Storm Information							At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir (°)**	**No of Events (30 min dataset)**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
21/01/2013 02:00	21/01/2013 20:00	18	21/01/2013 13:00	68	35	22	5.1	9.3	65	4483
06/02/2013 13:30	07/02/2013 02:00	12.5	06/02/2013 17:00	14	15	77	4.3	9.3	17	3177
22/03/2013 20:00	24/03/2013 23:00	51	23/03/2013 15:30	74	99	16	5.1	9.9	65	4988
23/05/2013 21:30	24/05/2013 10:30	13	24/05/2013 00:30	19	27	71	5.7	9.9	18	6302
10/09/2013 13:00	10/09/2013 22:30	9.5	10/09/2013 19:30	13	19	77	5.0	8.4	13	3415
10/10/2013 02:00	**11/10/2013 06:30**	**28.5**	**10/10/13 23:00**	**28**	**56**	**72**	**5.8**	**10.5**	**21**	**7397**
December 5th to 6th storm – data missing as buoy off station										

2.7. Scarborough Tide Gauge

The Scarborough tide gauge was deployed by Emu on behalf of Scarborough BC in April 2003 as part of a local monitoring initiative prior to the start of the regional programme. The data available from the Scarborough tide gauge record is shown in Figure 2.23 below. The data runs from 28/04/2003 to 31/12/2013, with a number of gaps in the record.

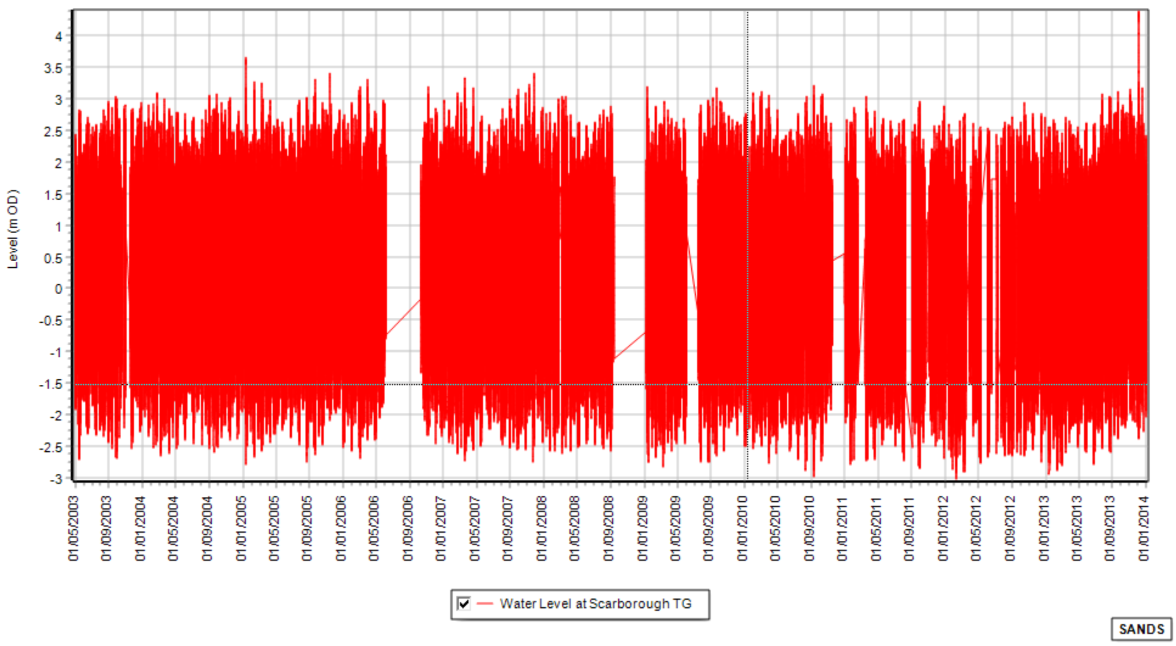


Figure 2.23 Water Levels at Scarborough SBC Recorded Tide Site

The Scarborough tide gauge data has been analysed and quality controlled by Fugro-EMU and Channel Coast Observatory, and standard tidal heights are presented in Table 2.18 below. However, it should be noted that when the site was checked and re-surveyed by Fugro-EMU in June 2013 a discrepancy was found with the original datum established in 2003, with the tide gauge zero now 0.195m higher than previously assumed. It is not known when the offset applies from, but Fugro-EMU (2013)[1] note that *"This offset brings the data back in line with predictions created through the harmonic analysis of the data from 2003 and also predictions created from the Admiralty harmonic constants for Scarborough."*

Table 2.18 Predicted tide levels at Scarborough

Tidal State	Level (m Ordnance Datum)
HAT	3.10
MHWS	2.46
MHWN	1.31
MSL	0.175
MLWN	-0.96
MLWS	-2.11
LAT	-3.04

Notes: Based on analysis of 2007 data collected at Scarborough by Fugro EMU;
See note above re-potential issue with datum.

Annual maxima water levels extracted from the Scarborough tide gauge are shown in Table 2.19 below. The highest recorded water level in 2013 was 4.39m on 5th December 2013 at 17:20, and had an associated surge of 1.66m. This is significantly higher than any of the previous 10 years, the maximum of which was 3.66m in January 2005. Comparing the measured water level of the 5th December 2013 surge to the predicted extremes from the EA's 2011 Coastal Flood Boundary (CFB) conditions data in Table 2.20 shows that the event had an annual exceedence probability of between 1 in 150 and 1 in 500.

The 10 years of water level data from the Scarborough tide gauge have also been analysed in SANDS to derive extreme levels to compare to the EA 2011 CFB data. The Peak over Threshold approach was used, with a threshold of 2.2m and data bins of 0.1m. This analysis excluded the 5th December 2013 storm as its inclusion would affect the statistical results. The results, which had a good correlation coefficient of 0.996 for the Gumbel fit, are given in the right hand column of in Table 2.20 and are very similar to the results of the EA CFB study. Note that the confidence levels for the EA CFB data should also be assumed to apply to the local data analysis with SANDS. The set of return periods derived in SANDS is different to the EA CFB study so results are not available to compare for all return periods.

Table 2.19 Annual maxima data from Scarborough Tide gauge analysis (source CCO, 2013)2

[1] Fugro EMU, August 2013, Northeast regional coastal monitoring framework; hydrodynamic services; December 2012 to June 2013 Reports.
[2] CCO February 2014, Scarborough tide gauge annual report (Draft).

Year	Annual extreme maxima		Annual surge maxima		Z_0 (OD)	Annual recovery rate
	Elevation (OD) *(Surge)*	Date/Time	Value (m)	Date/Time		
2003	3.05 *(-0.03)*	28-Sep-2003 05:10	1.13	21-Dec-2003 09:40	-	76%
2004	3.09 *(0.34)*	22-Feb-2004 17:10	0.96	18-Nov-2004 04:00	0.292	99%
2005	3.66 *(0.86)*	12-Jan-2005 17:20	1.18	20-Jan-2005 08:20	0.287	99%
2006*	3.30 *(0.17)*	30-Mar-2006 16:30	1.29	31-Oct-2006 15:40	-	77%
2007*	3.40 *(0.71)*	25-Nov-2007 04:00	1.60	08-Nov-2007 21:30	0.221	97%
2008*	3.05 *(0.16)*	09-Mar-2008 17:20	0.90	22-Feb-2008 02:10	-	65%
2009*	3.19 *(0.44)*	12-Jan-2009 16:50	1.15	18-Jan-2009 16:30	-	84%
2010*	3.21 *(0.05)*	11-Sep-2010 05:30	0.81	12-Nov-2010 04:20	-	82%
2011*	3.03 *(-0.14)*	21-Mar-2011 17:10	1.33	04-Feb-2011 11:00	-	80%
2012	2.94 *(0.06)*	17-Oct-2012 04:40	0.92	05-Jan-2012 16:40	-	70%
2013	4.39 *(1.66)*	05-Dec-2013 17:20	1.75	05-Dec-2013 15:50	0.186	98%

* Possible datum shift by up to -0.195m

Table 2.20 Predicted extreme tide levels at Scarborough

Annual Exceedence probability	Extreme Level (m OD) from EA CFB Study (2011)	Confidence intervals (m) from EA CFB Study (2011)	Extreme levels from SANDS analysis of Scarborough TG (mOD)
1 in 1	3.39	0.1	3.3
1 in 2	3.48	0.1	3.4
1 in 5	3.60	0.1	3.6
1 in 10	3.70	0.1	3.7
1 in 20	3.80	0.1	3.8
1 in 25	3.84	0.2	
1 in 50	3.95	0.2	4.0
1 in 75	4.00	0.2	
1 in 100	4.04	0.3	4.1
1 in 150	4.12	0.3	
1 in 200	4.17	0.3	4.2
1 in 250	4.20	0.3	
1 in 300	4.23	0.4	4.3
1 in 500	4.33	0.4	
1 in 1,000	4.45	0.5	

Note: data from EA (2011), Chainage 3750
http://evidence.environment-agency.gov.uk/FCERM/en/Default/FCRM/Project.aspx?ProjectID=F162D56F-87C4-4F14-B77B-A8A3EFDB363F&PageId=a0fe6dfc-506a-452c-9bff-a7ec06b4e6b0

The water level data has also been used to analyse joint occurrence of waves and water levels data, by tabulating the frequencies of coincident wave and water level measurements, see Table 2.21 below.

In the baseline report the water level and wave height analysis required post-processed interpolation to derive water level at the same times as the wave height data. The data has now been reprocessed and quality controlled by CCO (see report in Appendix E), which made the analysis straightforward in SANDS. The analysis uses the data only from the further offshore location as this is the location where there is most data available, and this is the current location of the Scarborough wave buoy. Note that the data excludes the 5th December 2013 storm surge because as noted earlier there is a gap in the data set whilst wave buoy was off station between 21st November 2013 and 17th December 2013.

Table 2.21 Scatter table of water level and wave height at Scarborough

		Water level (mOD)									
		-2.00 - -3.00	-1.00 - -2.00	0.00 - -1.00	1.00 - 0.00	2.00 - 1.00	3.00 - 2.00	4.00 - 3.00	5.00 - 4.00	6.00 - 5.00	7.00 - 6.00
Wave height (Hs,m)	7.00 - 8.00	0	0	0	0	0	0	0	0	0	0
	6.00 - 7.00	0	0	0	0	0	3	0	0	0	0
	5.00 - 6.00	0	4	7	8	21	22	14	12	15	0
	4.00 - 5.00	0	6	10	11	66	103	91	112	49	3
	3.00 - 4.00	0	15	19	27	114	224	185	266	141	16
	2.00 - 3.00	0	55	109	116	585	868	789	1013	600	21
	1.00 - 2.00	65	344	377	486	2232	3266	2664	3329	2037	73
	0.00 - 1.00	183	1111	1366	1434	5407	7198	5591	6762	4049	78

Water Level (x) vs Offshore Wave Height Hm0 (y) (numbers of 30 minute observations)
For date range :31/04/2004 to 31/03/2006 and 10/06/2013 to 31/01/2014 (3.07 years accounting for gaps)

3. December 5th Storm Surge

The most unusual event in the data records for 2013 is the storm surge on 5th/6th December 2013 which caused significant damage to both built and natural coastal defences along the north east coast of England. The previous sections of this report have commented on this event where appropriate and this section has been added to this report to compare conditions at the monitoring sites during the event.

3.1. Recorded sea levels during the surge

A comparison of the recorded water level data for the December 2013 storm surge at North Shields, Whitby and Scarborough was made with SANDS and recorded water levels are shown below in Figure 3.1 and surge residuals in Figure 3.2. This shows a similar signature at the three sites with the maximum surge height occurring before high water and that the surge increased in height as it progressed down the coast.

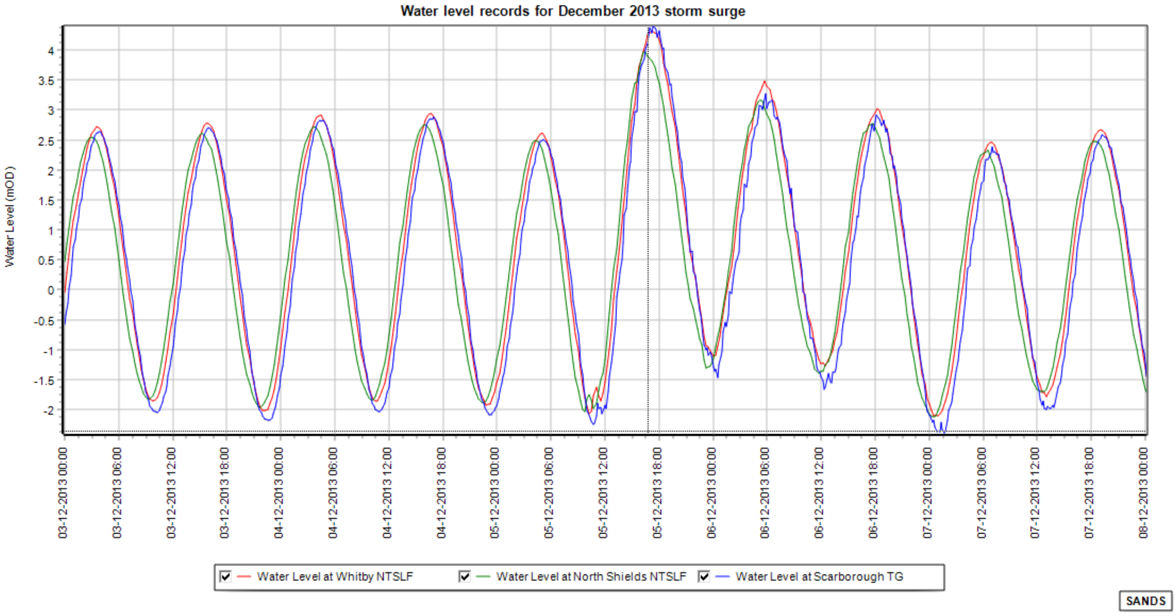


Figure 3.1 Comparison of recorded water levels at North Shields, Whitby and Scarborough during December 2013 storm surge

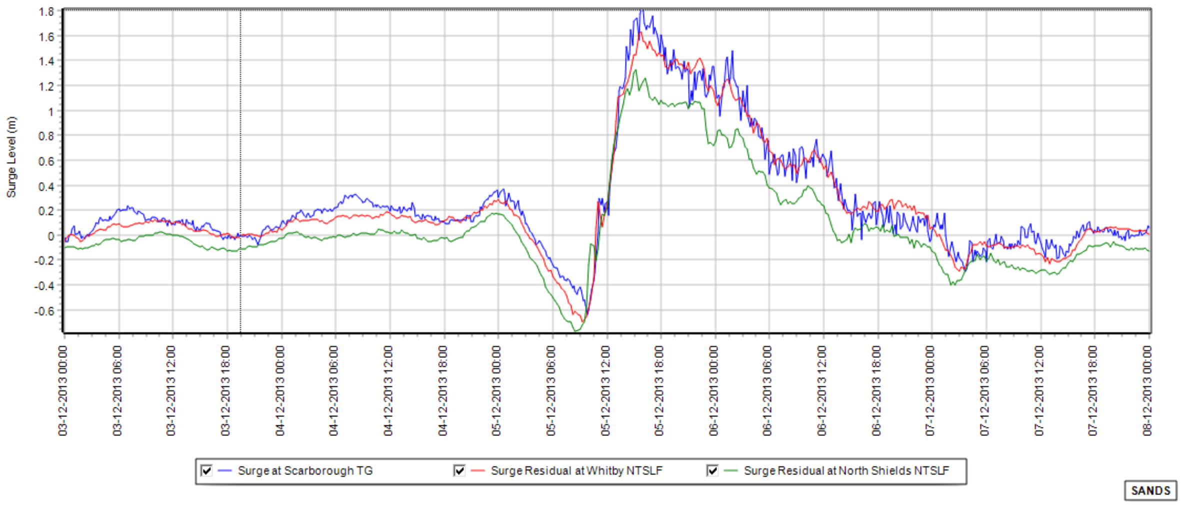


Figure 3.2 Comparison of surge residual at North Shields, Whitby and Scarborough during December 2013 storm surge

As noted earlier in this report, based on the EA (2011) Coastal Flood Boundary Condition extreme water level data the surge had the follow chance of occurrence each year:

- North Shields: between 1 in 200 and 1 in 500
- Whitby: between 1 in 100 and 1 in 500
- Scarborough between 1 in 150 and 1 in 500

To assess the impact of the December 2013 surge on the extreme level statistics, which are necessarily based on previous data, the SANDS PoT extremes analysis was repeated for the Scarborough tide gauge data set, including the 5th December 2013 surge. The Gumbel fit correlation at 0.963 was not as good as for the previous analysis reported in Table 2.20. The results showed that the 1 in 10 and 1 in 100 AEP levels would increase by about 0.3m to 4.0mOD and 4.4mOD respectively, i.e. an increase of about 0.3m. This probably indicates that the storm surge event was an outlier and could not be predicted from the previous data. This also suggests that the statistical estimates of future extreme water levels should be reassessed to take the December 2013 event into account.

3.2. Recorded wave data during the storm surge

The available data from the wave buoys in the region have been plotted together with the recorded water level data in Figure 3.3 below. Unfortunately the Scarborough buoy was off station during the storm due to an earlier incident so did not record data. It is interesting to note that the peak wave heights were not exceptionally large at the time of the maximum surge and that larger waves occurred on the following two high waters. The storm is evident in the wave record from Tyne Tees between 5th and 8th December 2013.

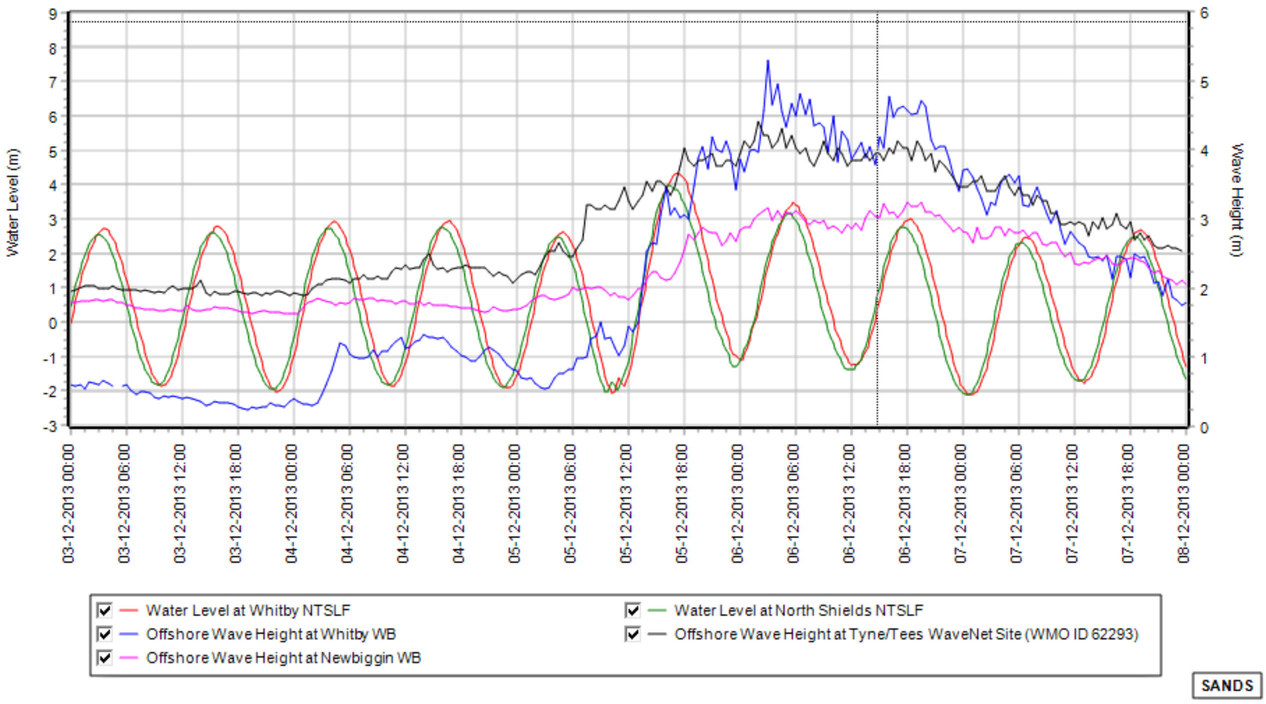


Figure 3.3 Recorded wave data at Newbiggin, Tyne Tees and Whitby plotted together with water level data from North Shields and Whitby during the December 2013 storm surge

The data from the wave buoys shows that at the time of the maximum water level the wave heights were still building and larger waves were experienced on the two subsequent high waters. The storm waves at the peak of the surge damaged many defences and received significant media attention on 5th and 6th December 2013, but do not appear to have had exceptional wave conditions. The larger waves experienced over the subsequent two days although at lower tide levels will have rapidly redistributed the storm beach profiles created during the highest water levels of the surge event on the 5th December 2013.

4. Problems encountered and uncertainty in analysis

Wave data

As noted in the report, the Scarborough Waverider buoy was moved to a new location after the initial deployment. Although the locations used are the same as two previous wave buoys the different water depths and coastal sheltering means that the new data from the two sites are not directly comparable

The Scarborough Waverider was off station due to an incident during early December and so did not record data during the storm of 5th to 6th December 2013.

The Tyne Tees wave data is available in both telemetry and post recovery format from the Cefas WaveNet site. However, the latest data for 2013 is only available as telemetry, i.e. non quality controlled data. Also, some of the data for earlier years, e.g. 2008, is missing from the post recovery data set. The data set analysed is therefore a combination of telemetry and post recovery, to give greatest coverage.

The only location where a full year of new wave data was available was at Whitby. At Scarborough the wave buoy was moved to a new location in June, and the Newbiggin wave buoy was not deployed until June.

Water level data

As noted in the baseline report there is uncertainty over datum changes for the Scarborough tide gauge between the original deployment in 2003 and the site checks in 2013, with a discrepancy of 0.195m. The data has been quality checked by CCO since the baseline report, but this uncertainty still remains.

5. Conclusions and Recommendations for future annual reports

This report has analysed new wave and water level data available relevant to Sediment Cell 1 as an update to the previous baseline reports. Future reports in this series should compare the data recorded in subsequent years with the results presented here. The key points are summarised below:

- Wave direction along the Cell 1 coast is predominantly between 0 and 30 degrees (north to northeast);
- A secondary wave approach direction from the east to southeast was also observed (cf Figure 3.13 - Scarborough SBC wave rose);
- The waves at the Newbiggin Ness site are partially sheltered from waves from the north.
- The longest consistent wave record in the region is for the Wavenet Tyne Tees buoy, which has been operating since late 2006.
- The Met Office offshore wave hindcast modelled data for 1980 to 2012 has been shown to under-predict wave heights during storm events by up to 0.5m and so should be treated with caution if used for boundary conditions in modelling studies.
- Analysis of the 2006 to 2012 data from Tyne Tees indicates that the stormiest year was 2010 whilst the year with the least number of storms was 2011. Due to the limited period of data available from Newbiggin, Whitby and Scarborough it is not yet possible to make reliable comparisons to Tyne Tees.
- Surge analysis has been undertaken for the three operational tide gauges in the region and data from these tide gauges has been used to assess the conditions that occurred during the exception storm surge event in early December 2013.

The wave roses for Newbiggin Ness, Tyne Tees, Whitby, Scarborough DWR and Scarborough SBC are collated in Figure 5.1 to supplement the points made above.

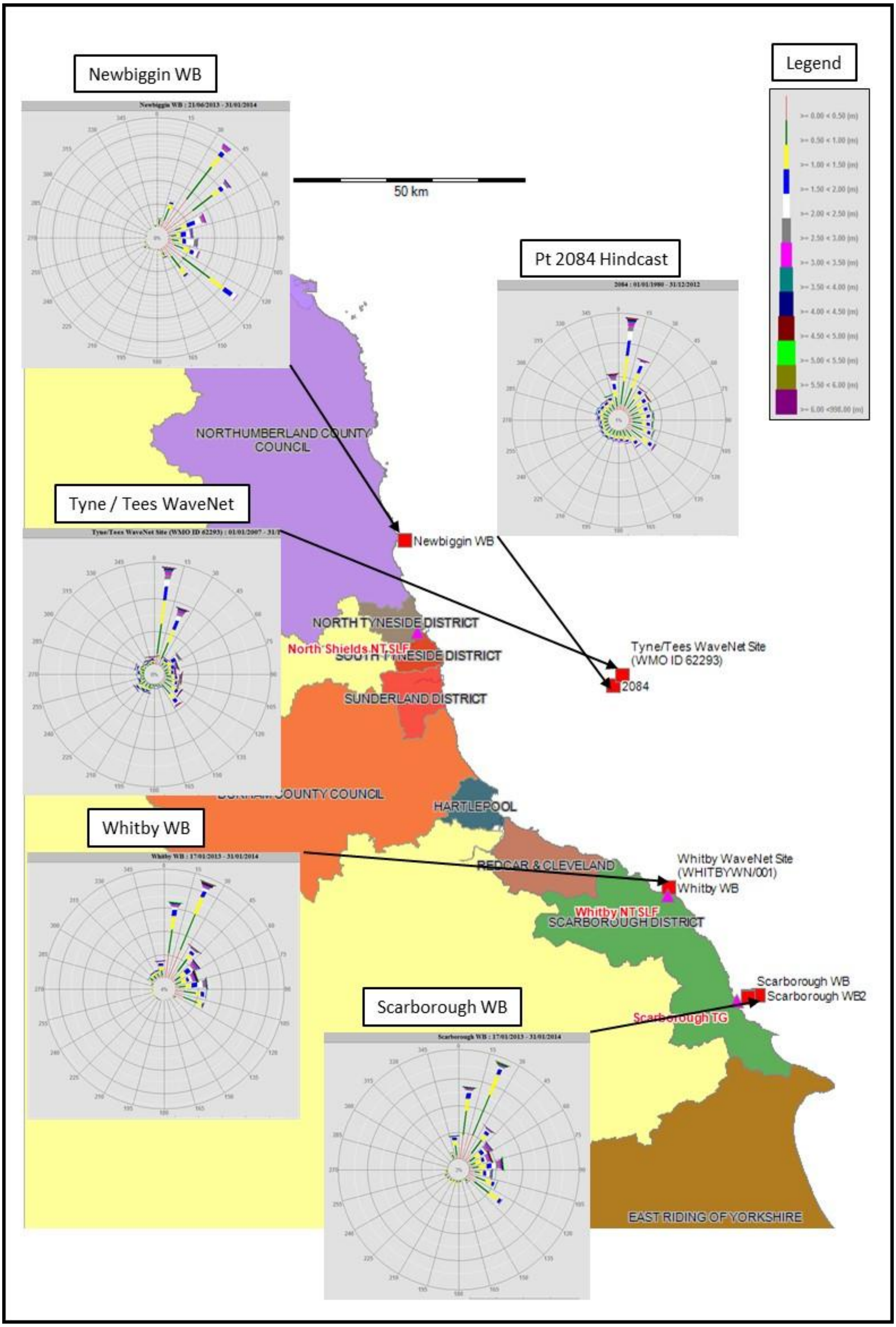


Figure 5.1 Wave Rose Locations from Newbiggin Ness to Scarborough

6. Conclusions

This report has documented the annual review and analysis of wave and tide data across Cell 1, presenting analysis of the data sets collected at the three wave buoys that were deployed under the strategic monitoring programme at Newbiggin Ness, Whitby and Scarborough, alongside data from the Cefas buoy located at Tyne Tees that is operated as part of the national programme. Tide gauge data collected under the programme has also been analysed and compared to the data from the tide gauges at Whitby and North Shields that are operated as part of the national monitoring programme.

Modelled hindcast wave data was obtained from a national modelling hindcast undertaken by the Met Office and distributed by Cefas. This data was for a location near to the Tyne Tees wave buoy to allow comparison between modelled and measured data. The comparison showed that the wave heights at the peak of the larger storms are frequently underestimated in the model data, indicating that caution should be exercised if it is used for further modelling studies.

Data from the storm surge that occurred on 5th December 2013 was compared to predictions of extreme water levels from the EA (2011) national Coastal Flood Boundary Conditions. This found that on the basis of the analysis and modelling of previous extreme events, the December surge had between a 1 in 150 and 1 in 500 an annual chance of being exceeded. However, it is recommended that the extreme water level statistics are now revised to take the event into account for future predictions.

Appendices

Appendix A

Detailed Location of Wave Buoys

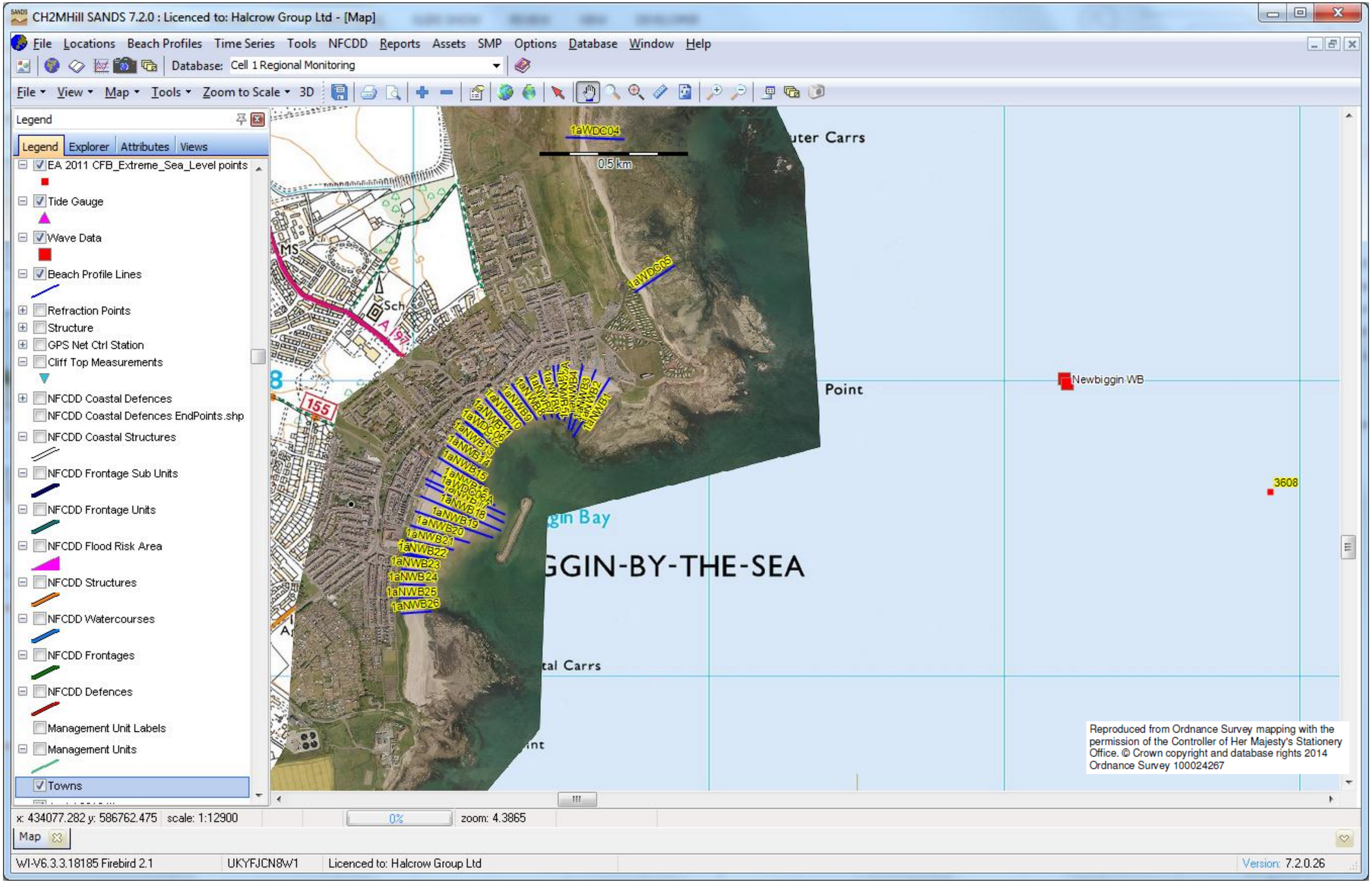


Figure A1 Location of Newbiggin Ness wave buoy

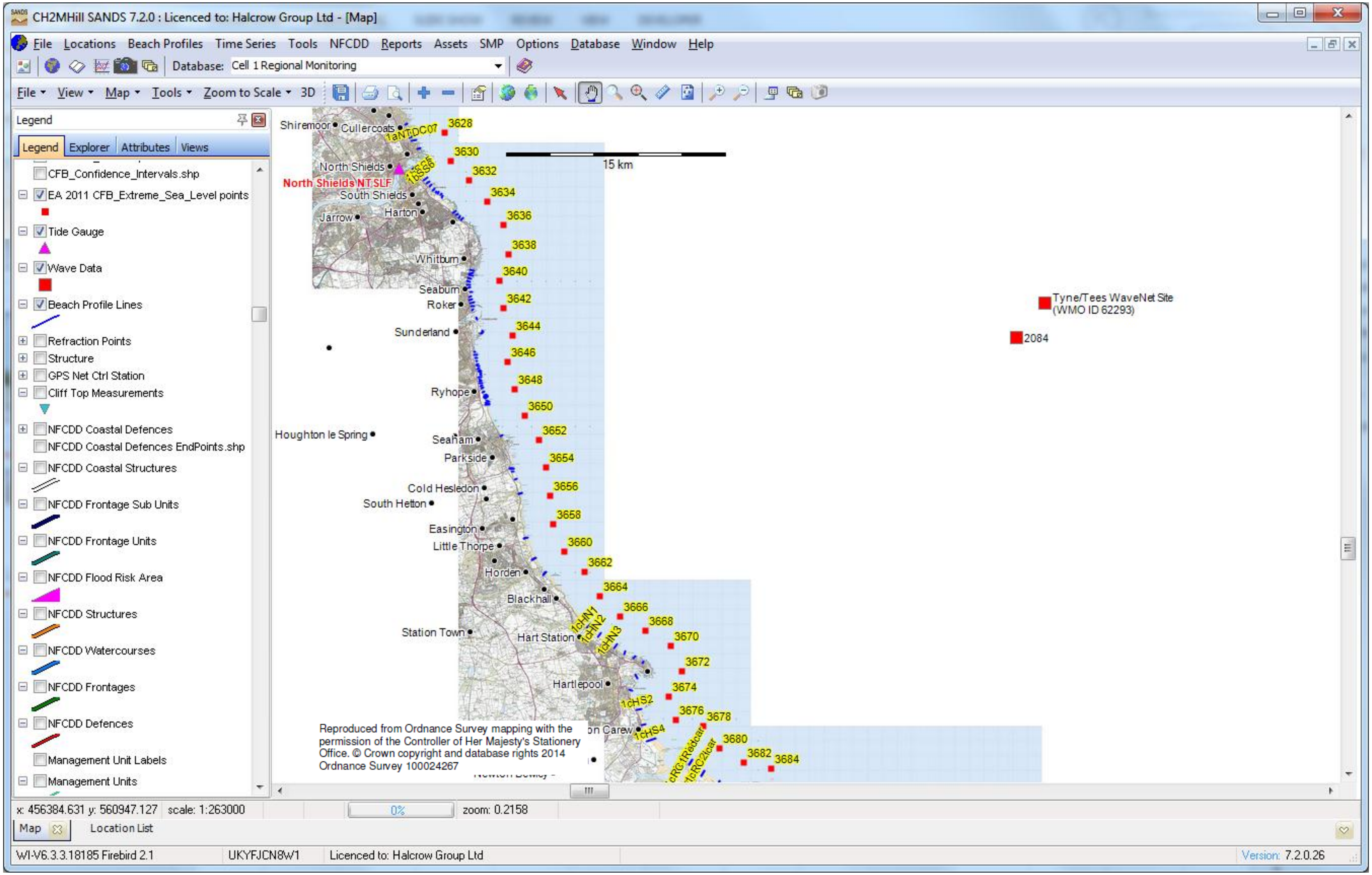


Figure A2 Location of Tyne Tees wave buoy, Met Office hindcast point 2084 and North Shields tide gauge

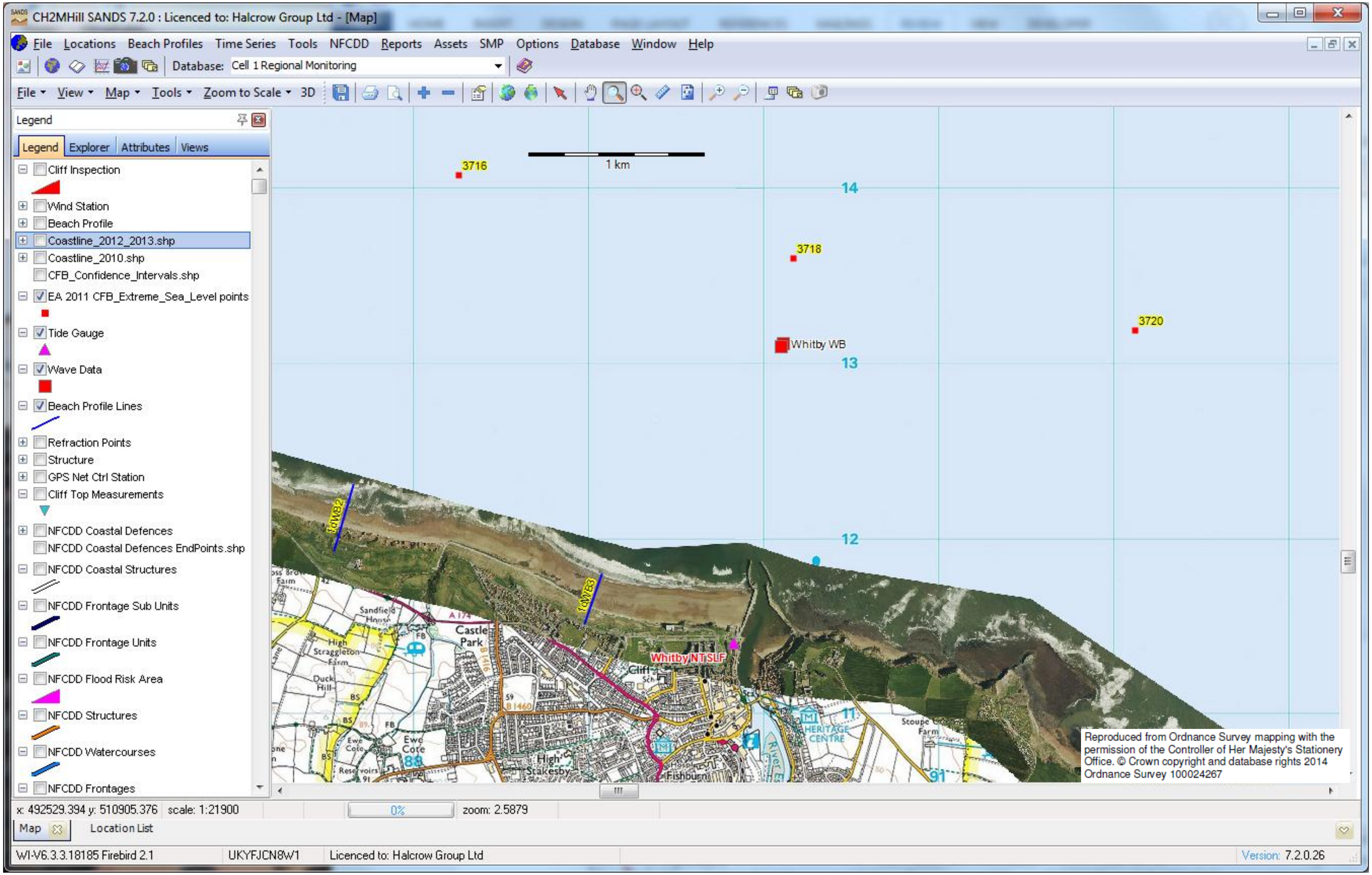


Figure A3 Location of Whitby wave buoy and tide gauge

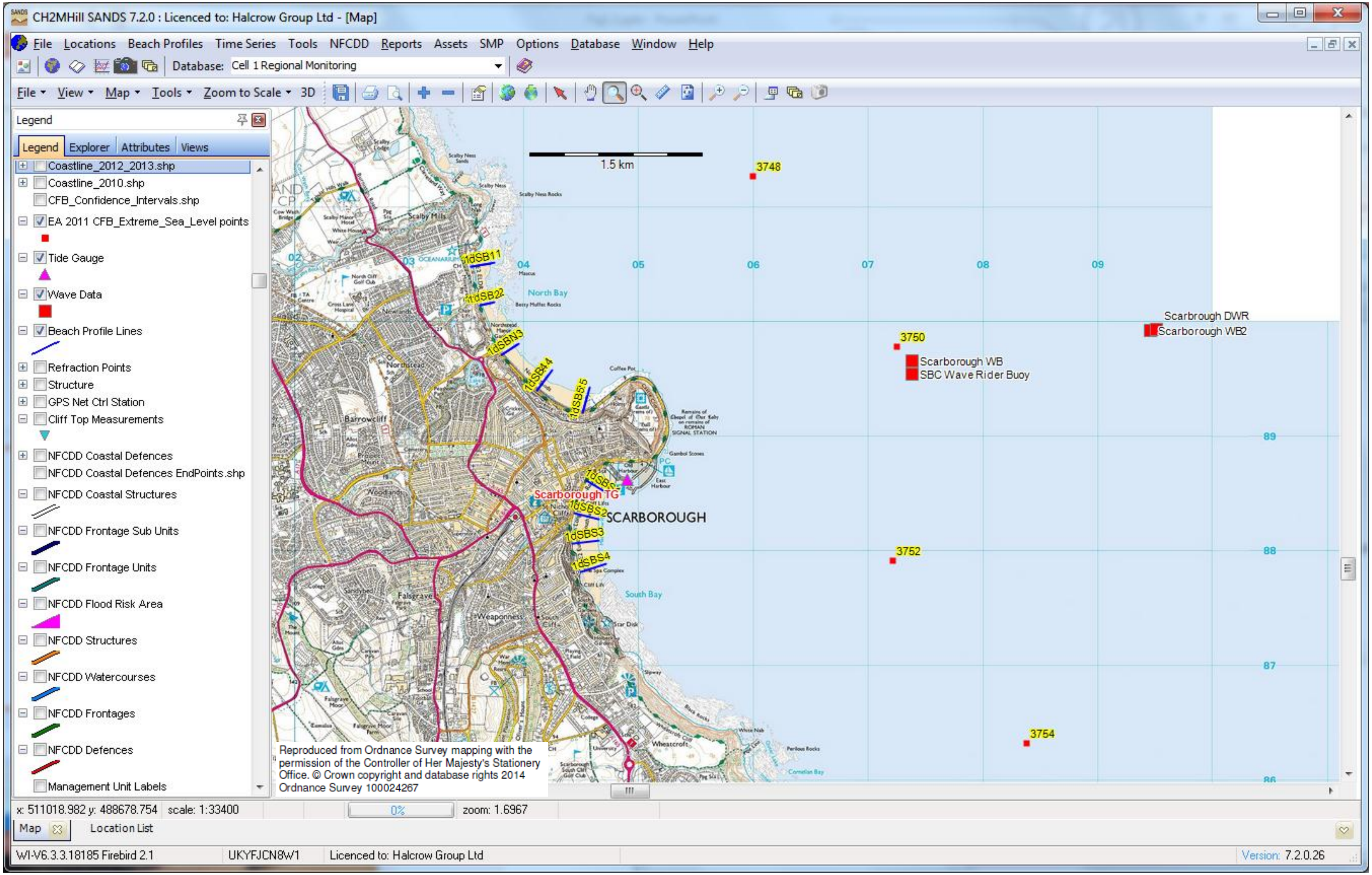
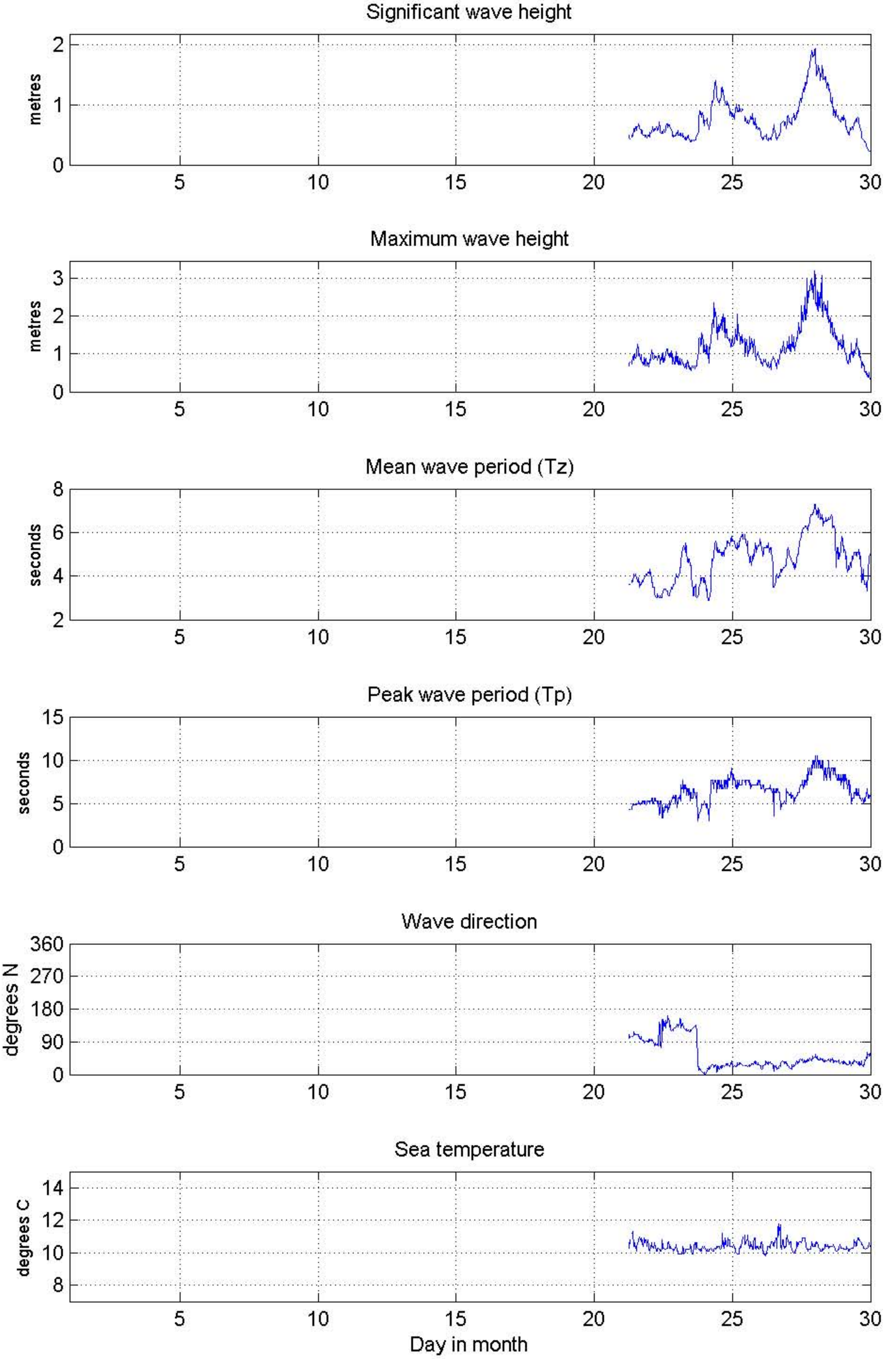


Figure A4 Locations of Scarborough wave buoys and tide gauge

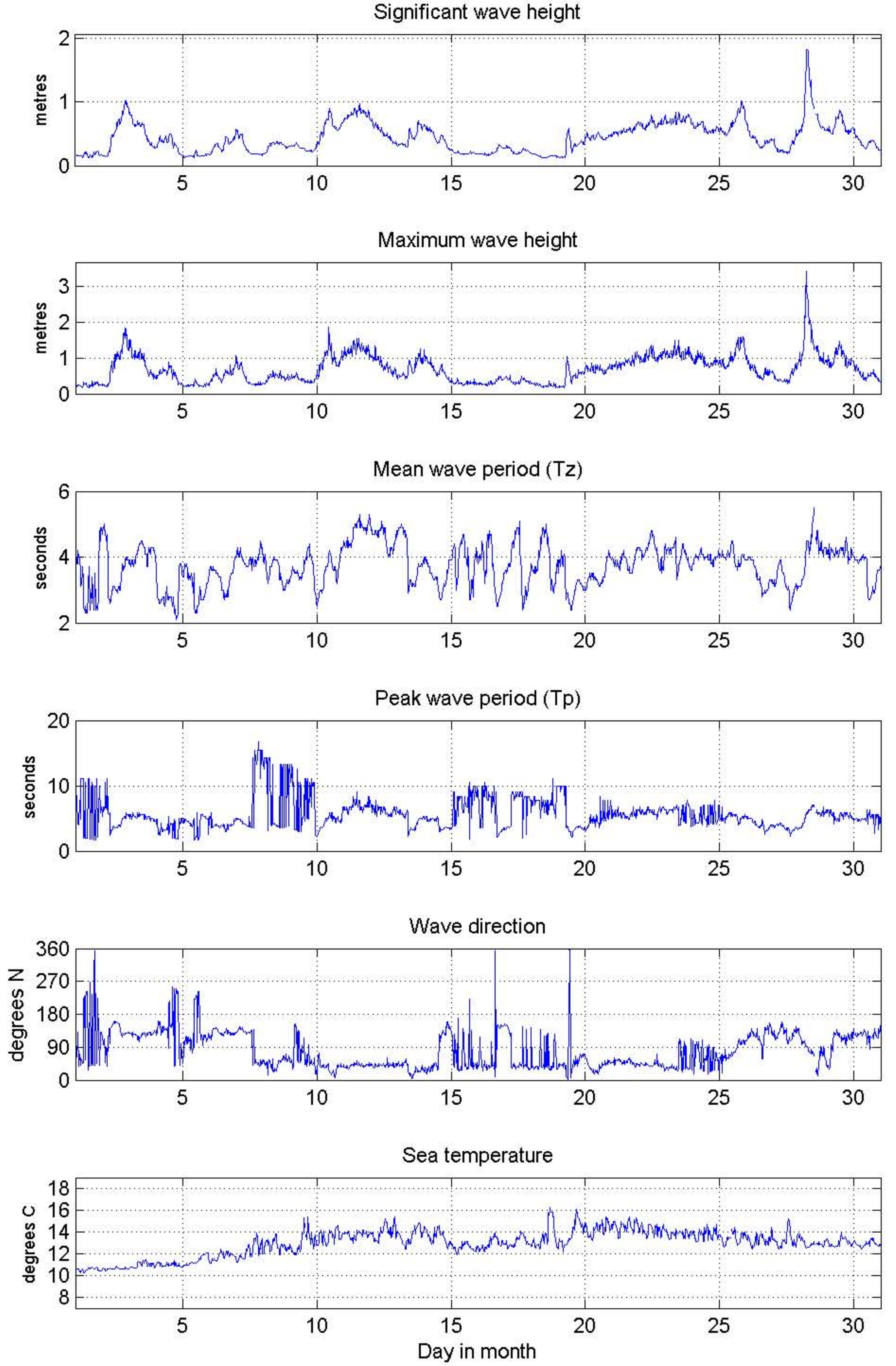
Appendix B

Supporting Graphs: Newbiggin Wave Buoy

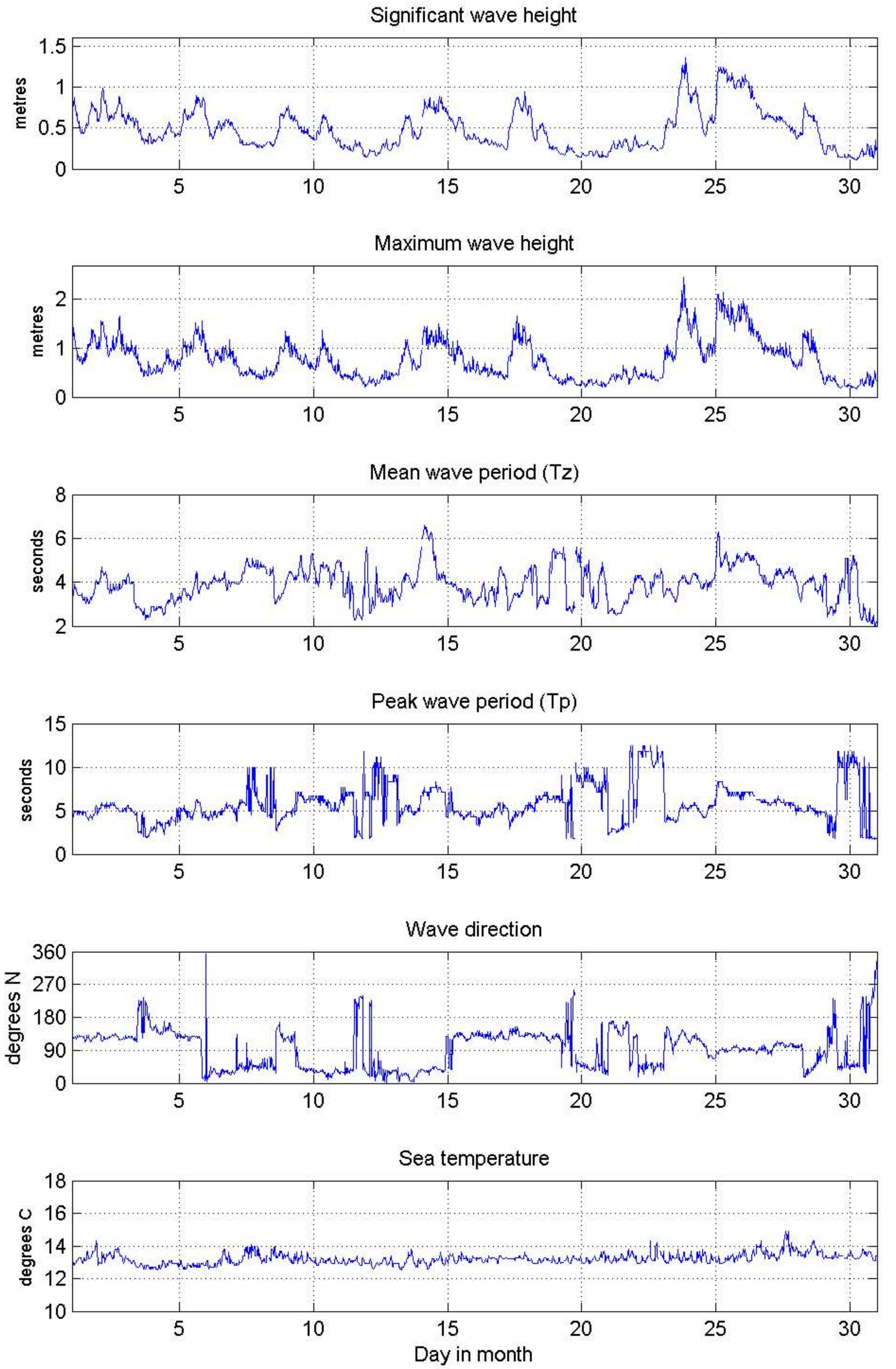
Newbiggin - June 2013



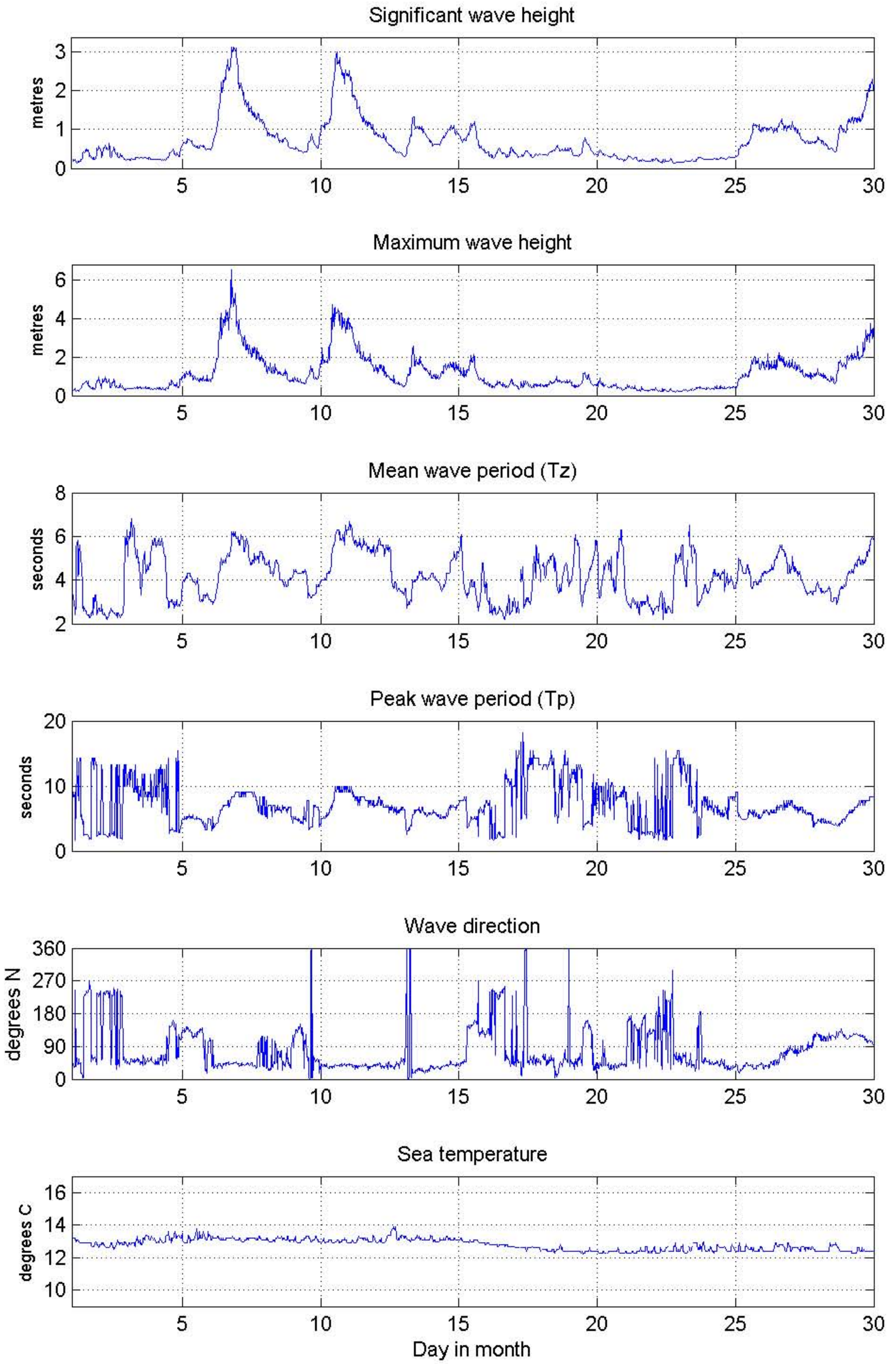
Newbiggin - July 2013



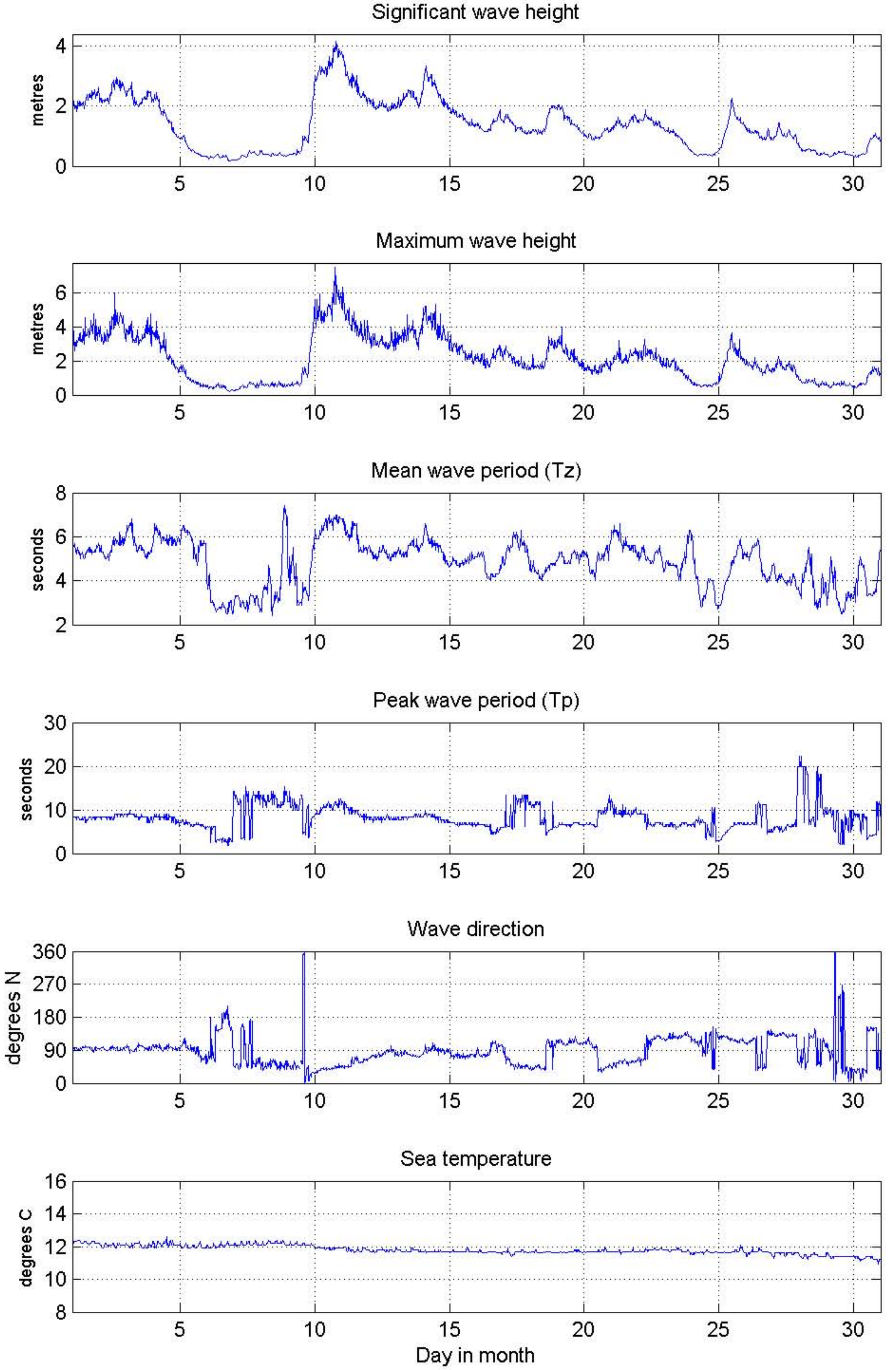
Newbiggin - August 2013



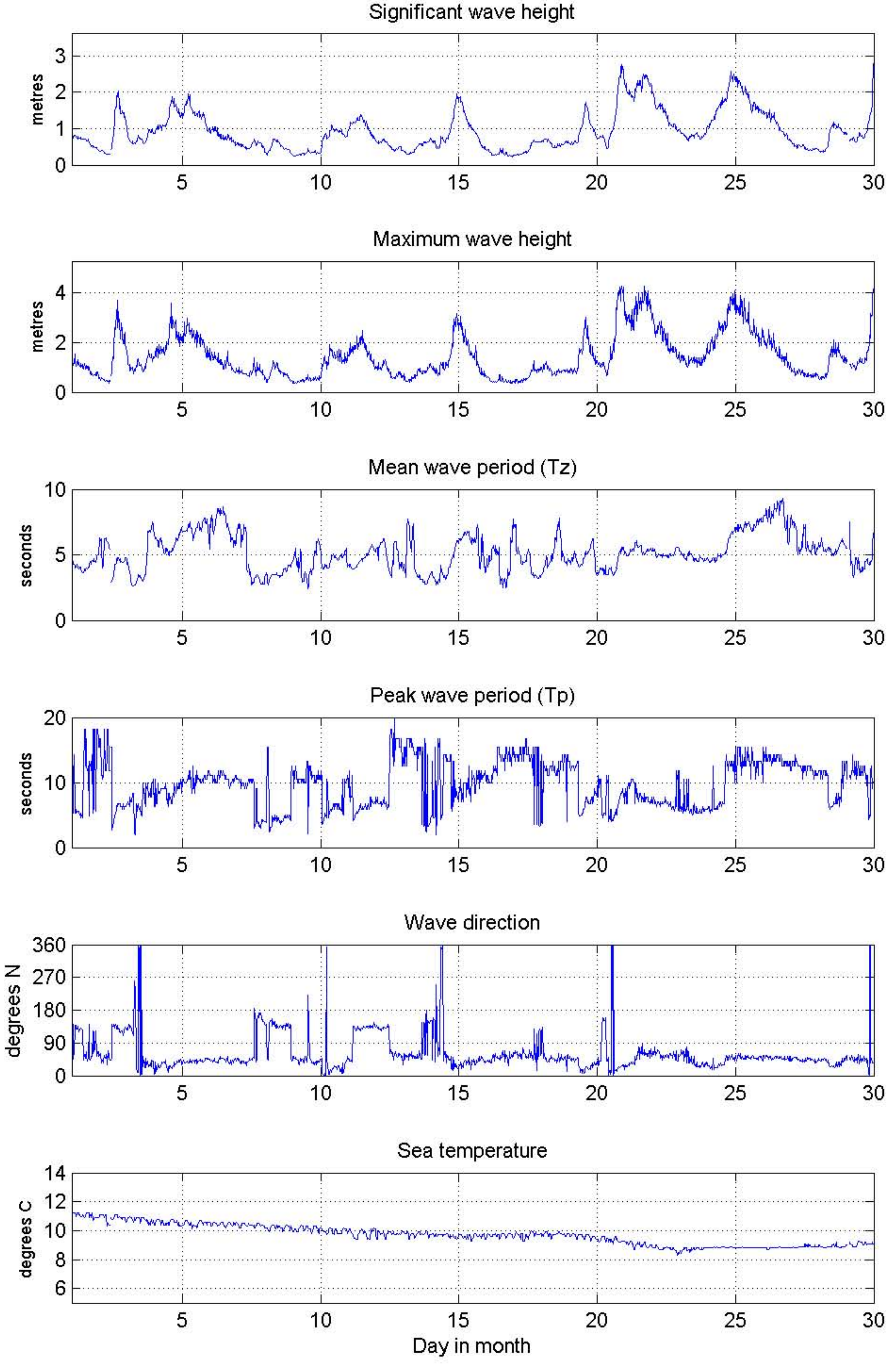
Newbiggin - September 2013



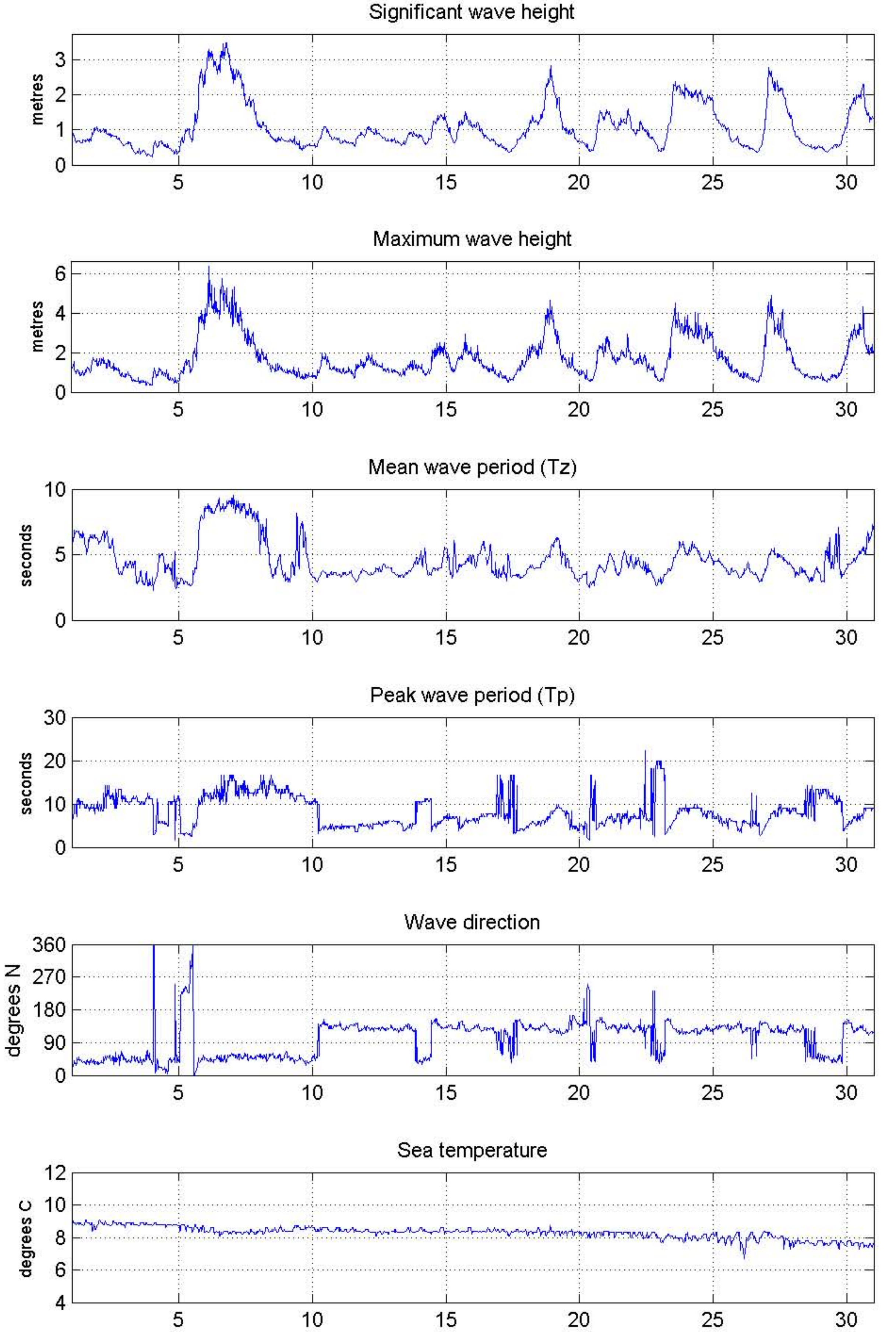
Newbiggin - October 2013



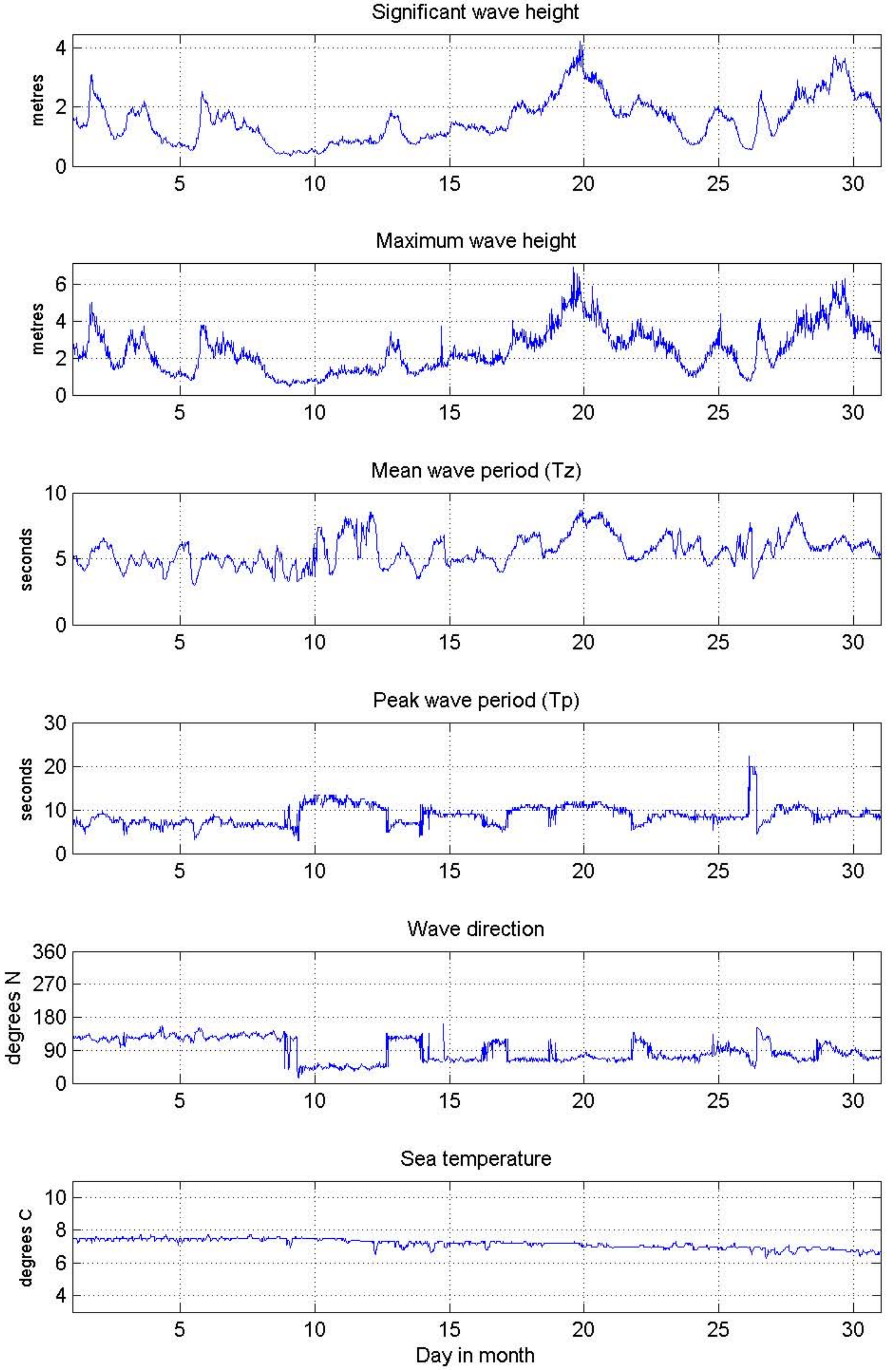
Newbiggin - November 2013



Newbiggin - December 2013



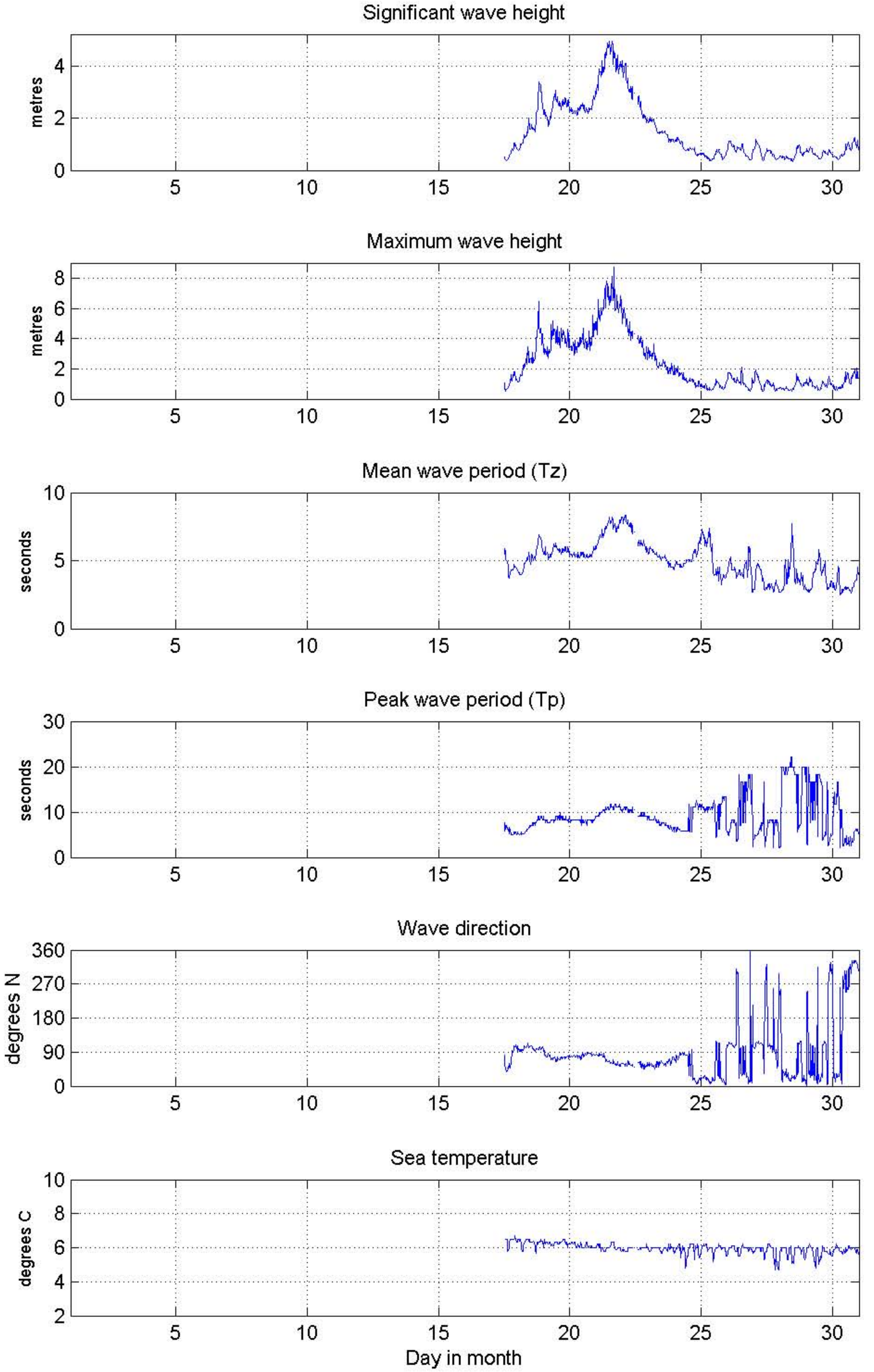
Newbiggin - January 2014



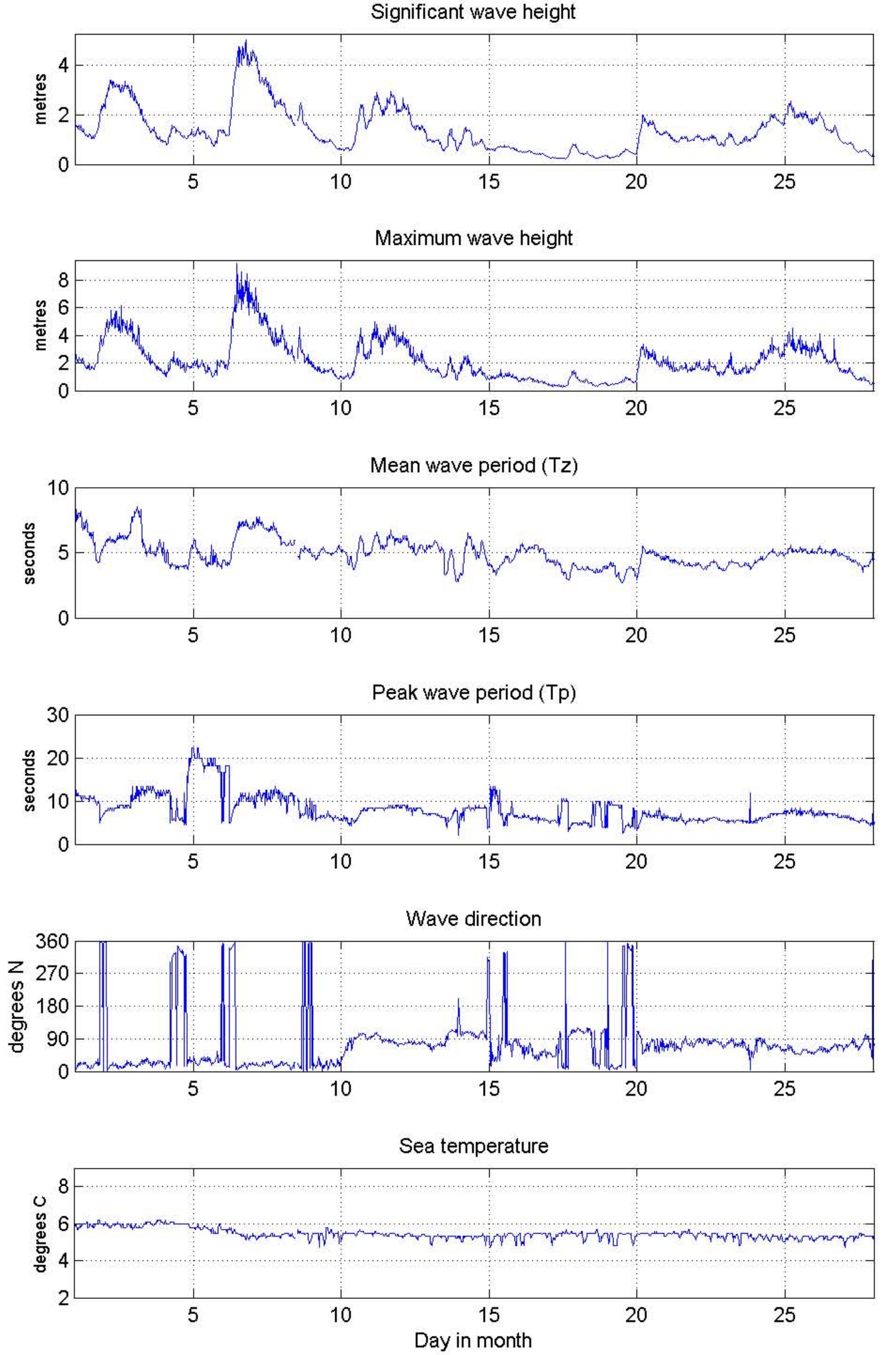
Appendix C

Supporting Graphs: Whitby Wave Buoy

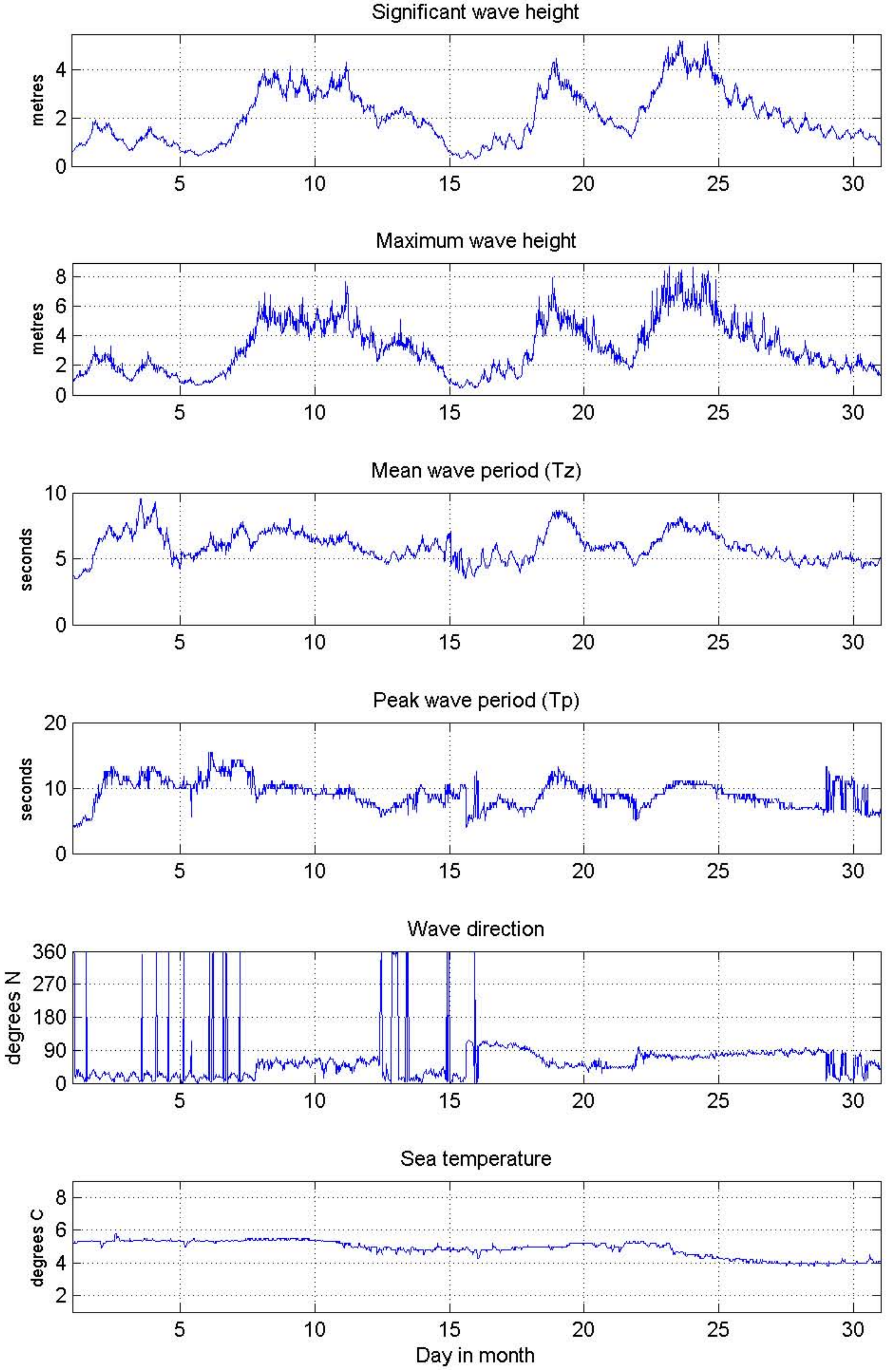
Whitby - January 2013



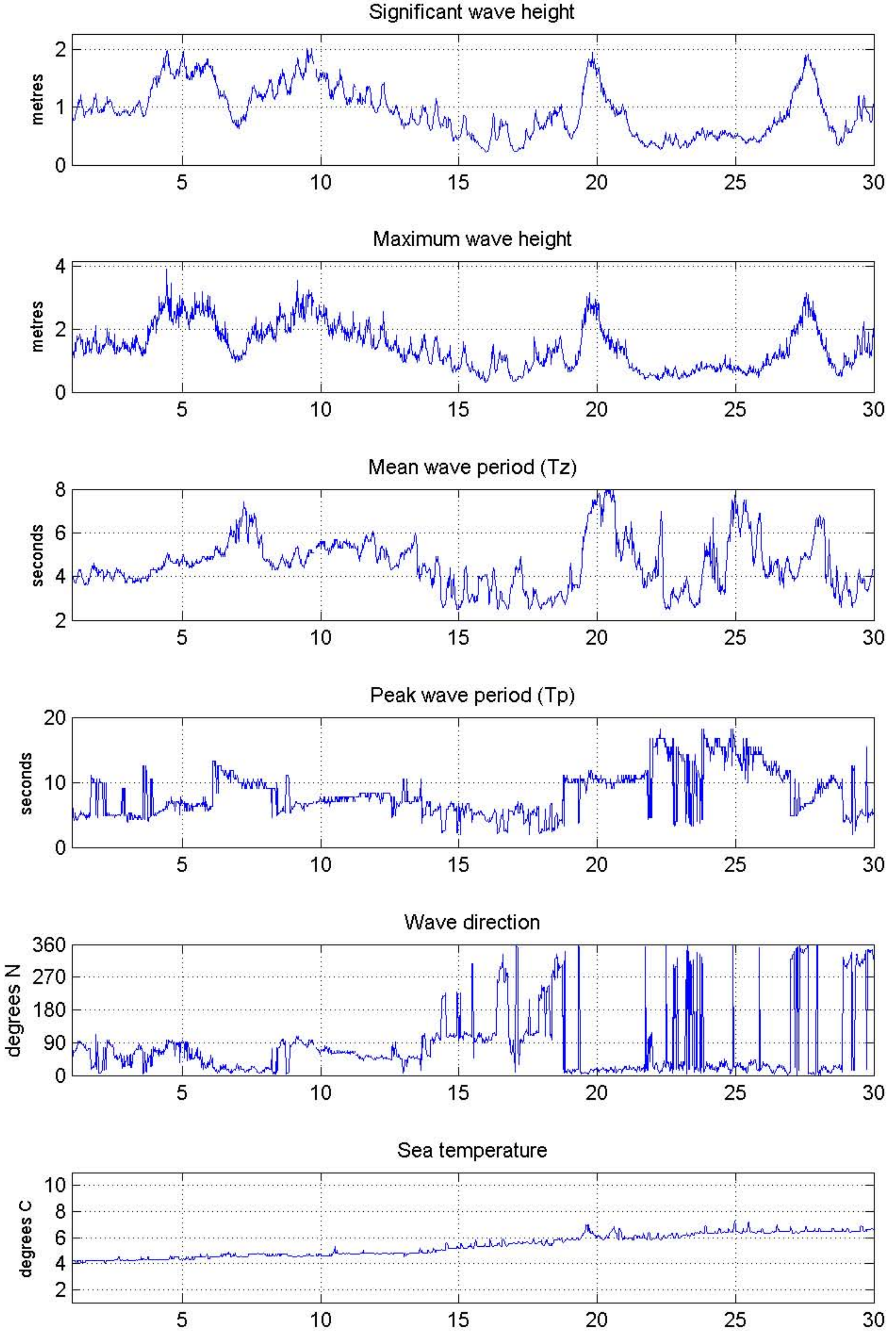
Whitby - February 2013



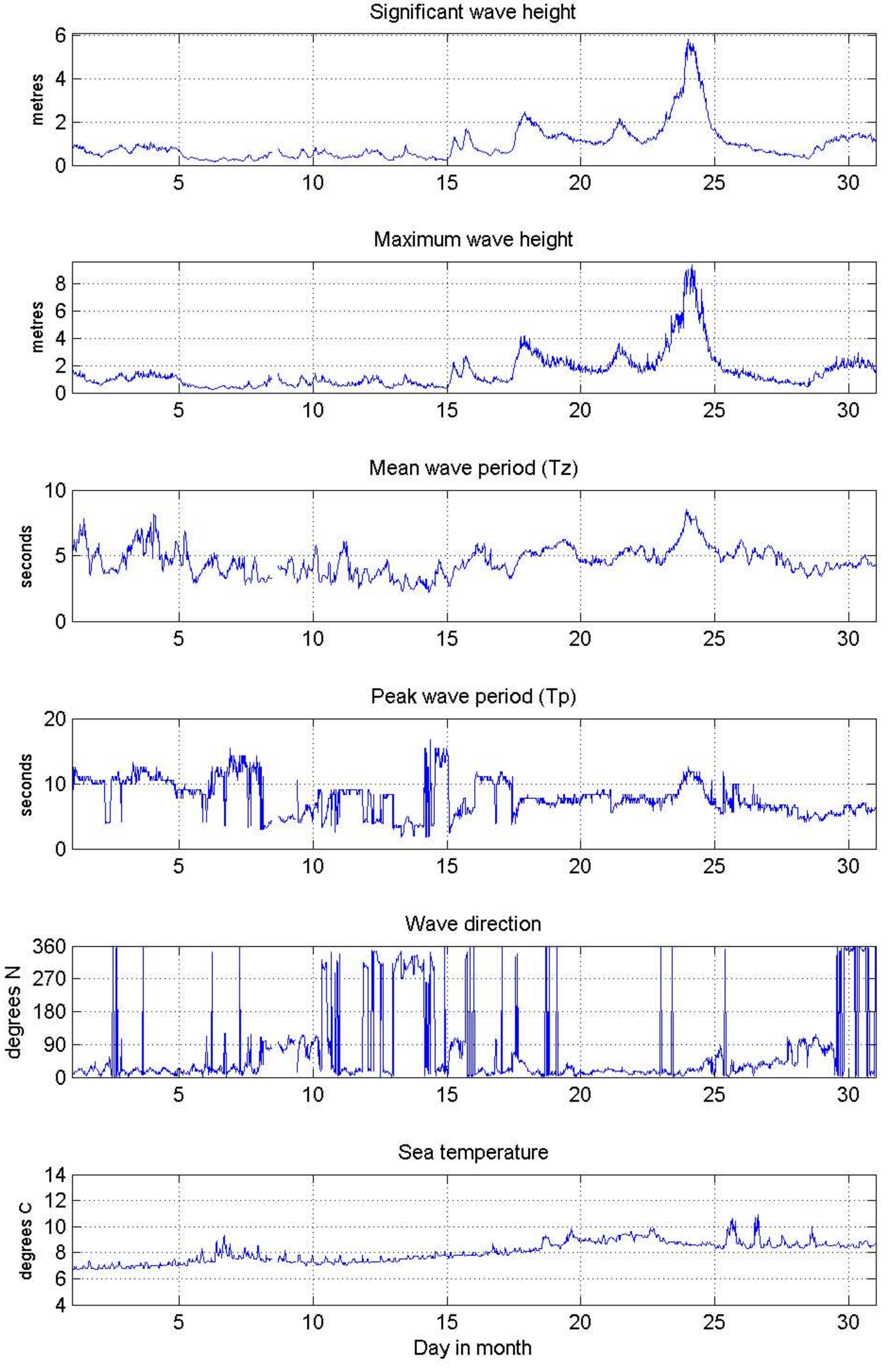
Whitby - March 2013



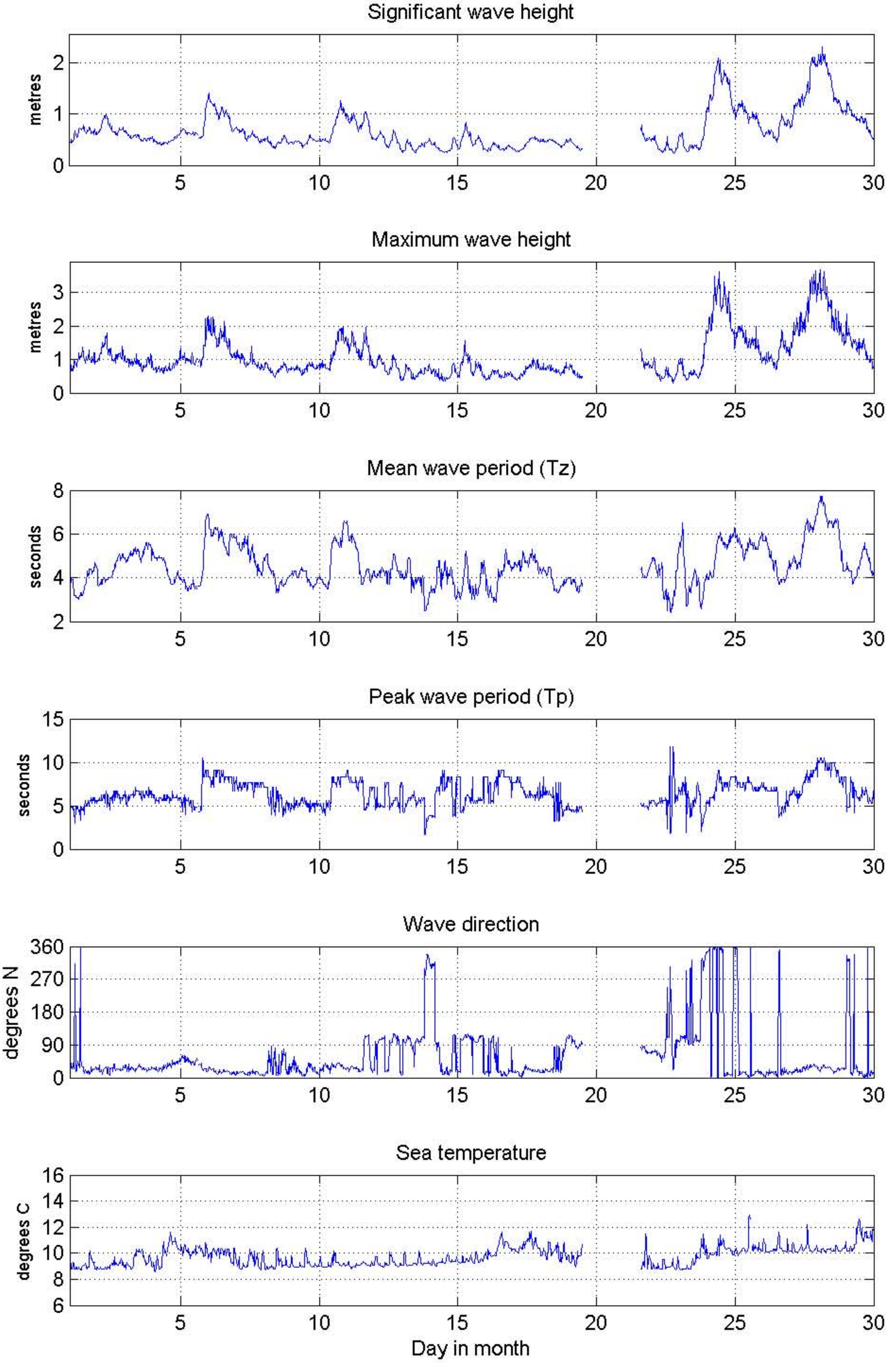
Whitby - April 2013



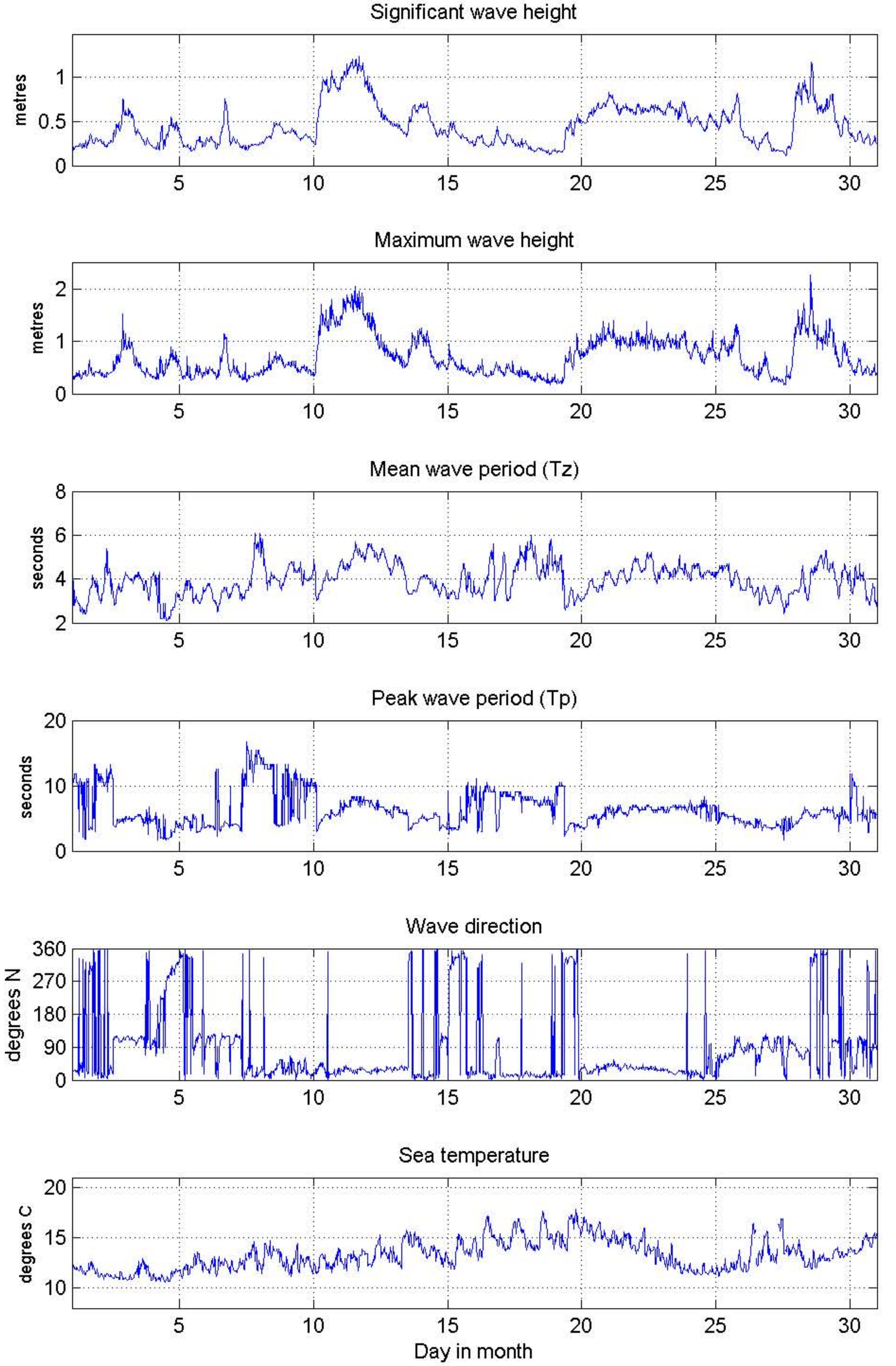
Whitby - May 2013



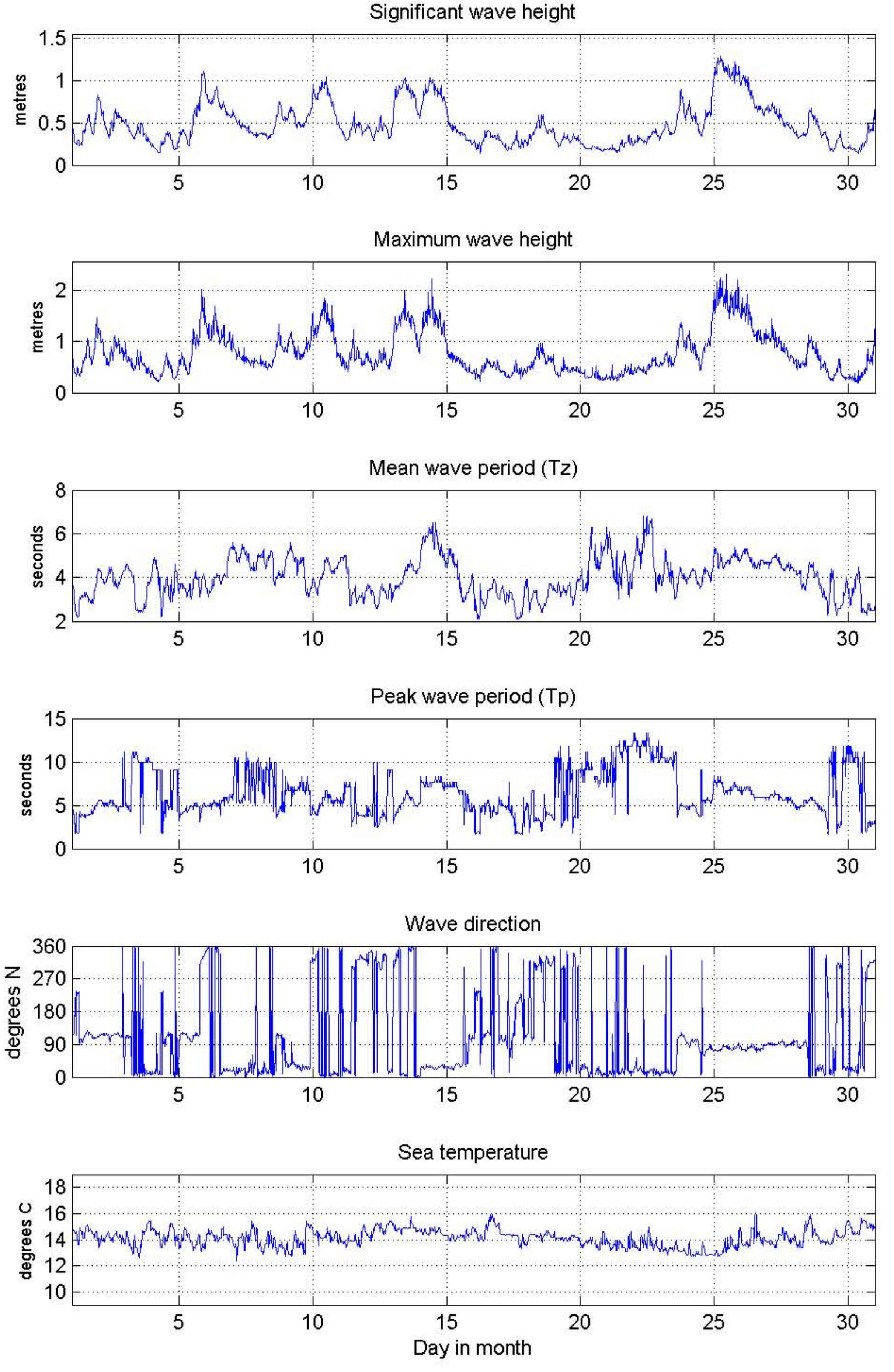
Whitby - June 2013



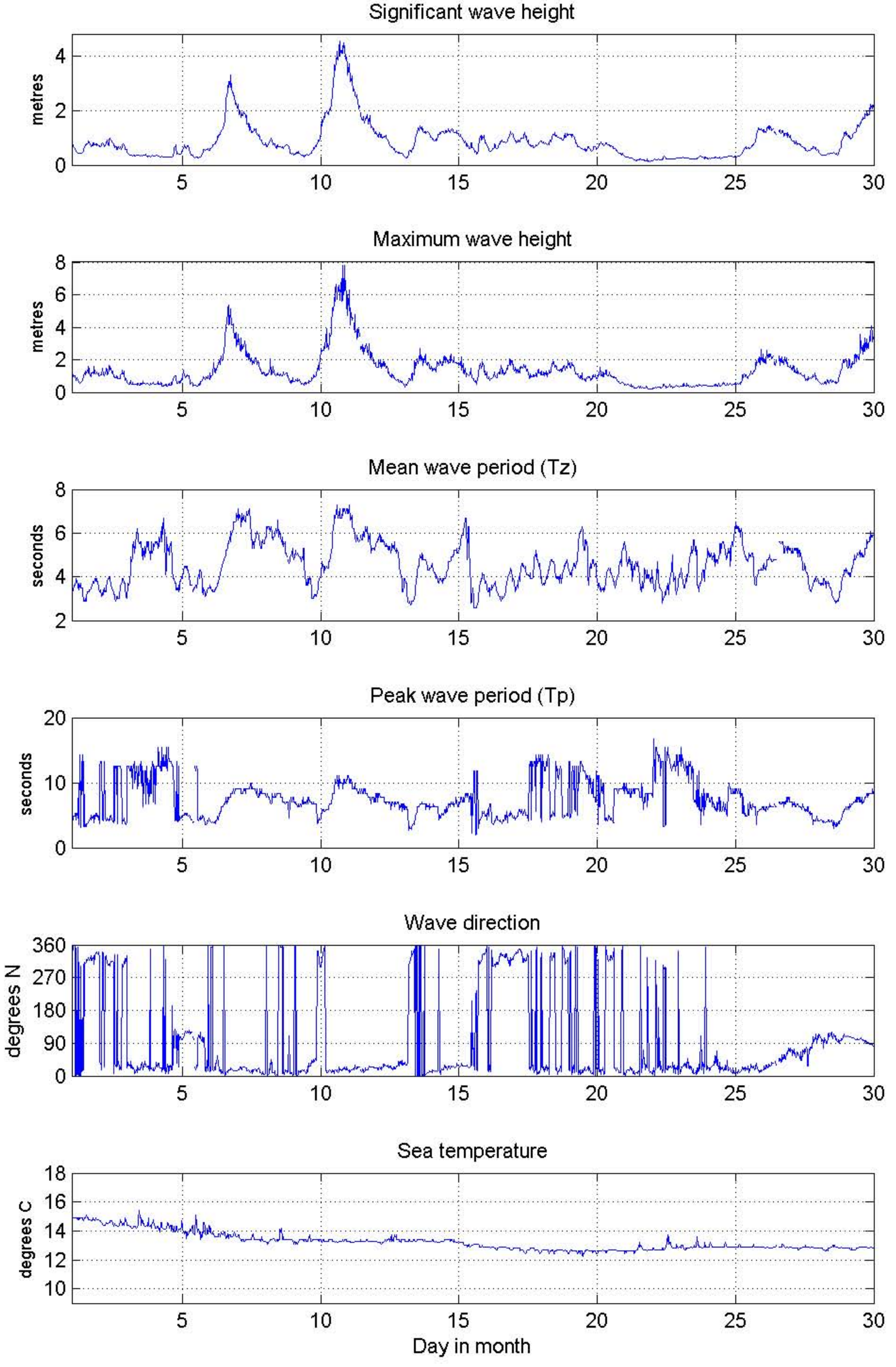
Whitby - July 2013



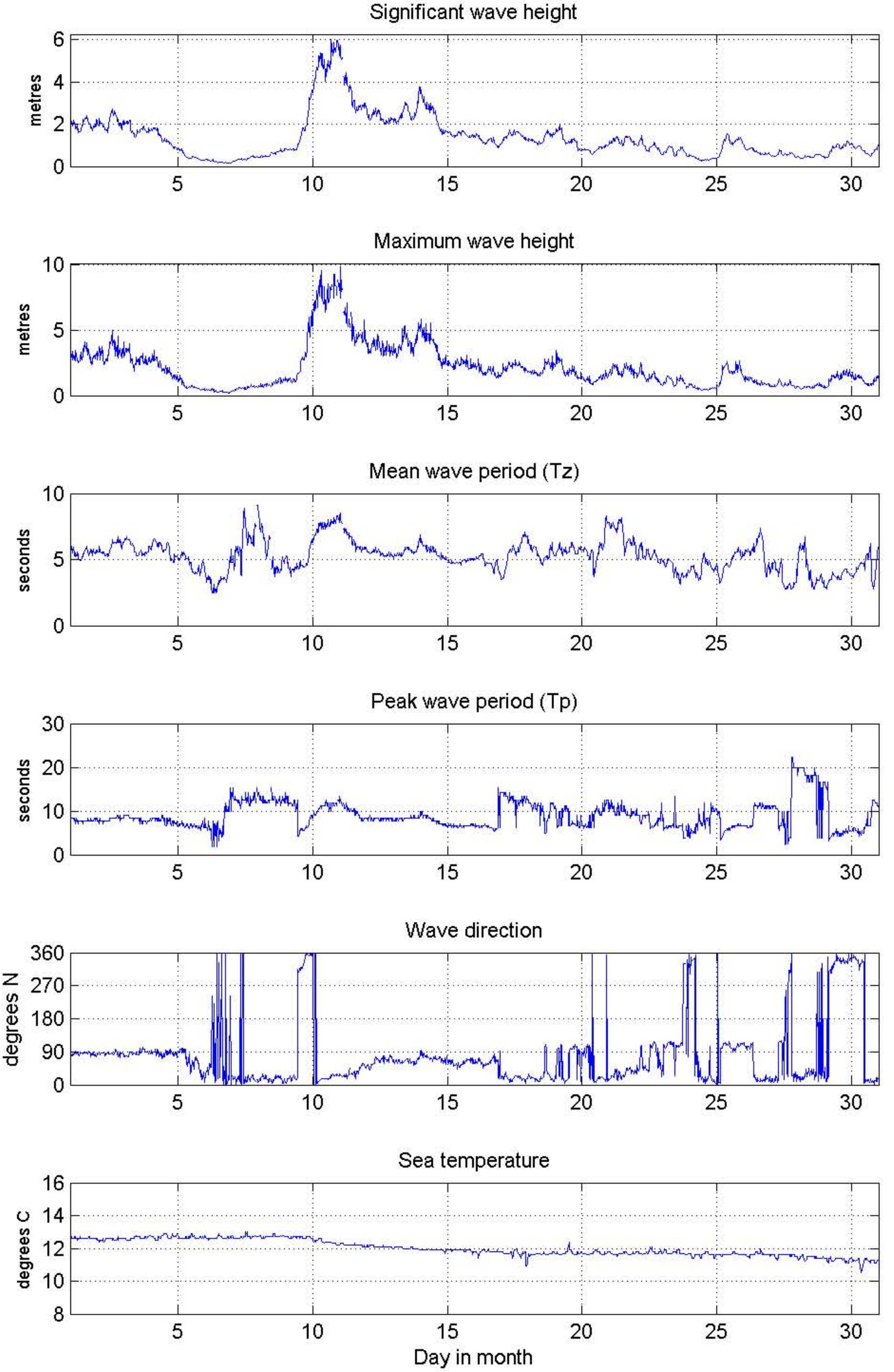
Whitby - August 2013



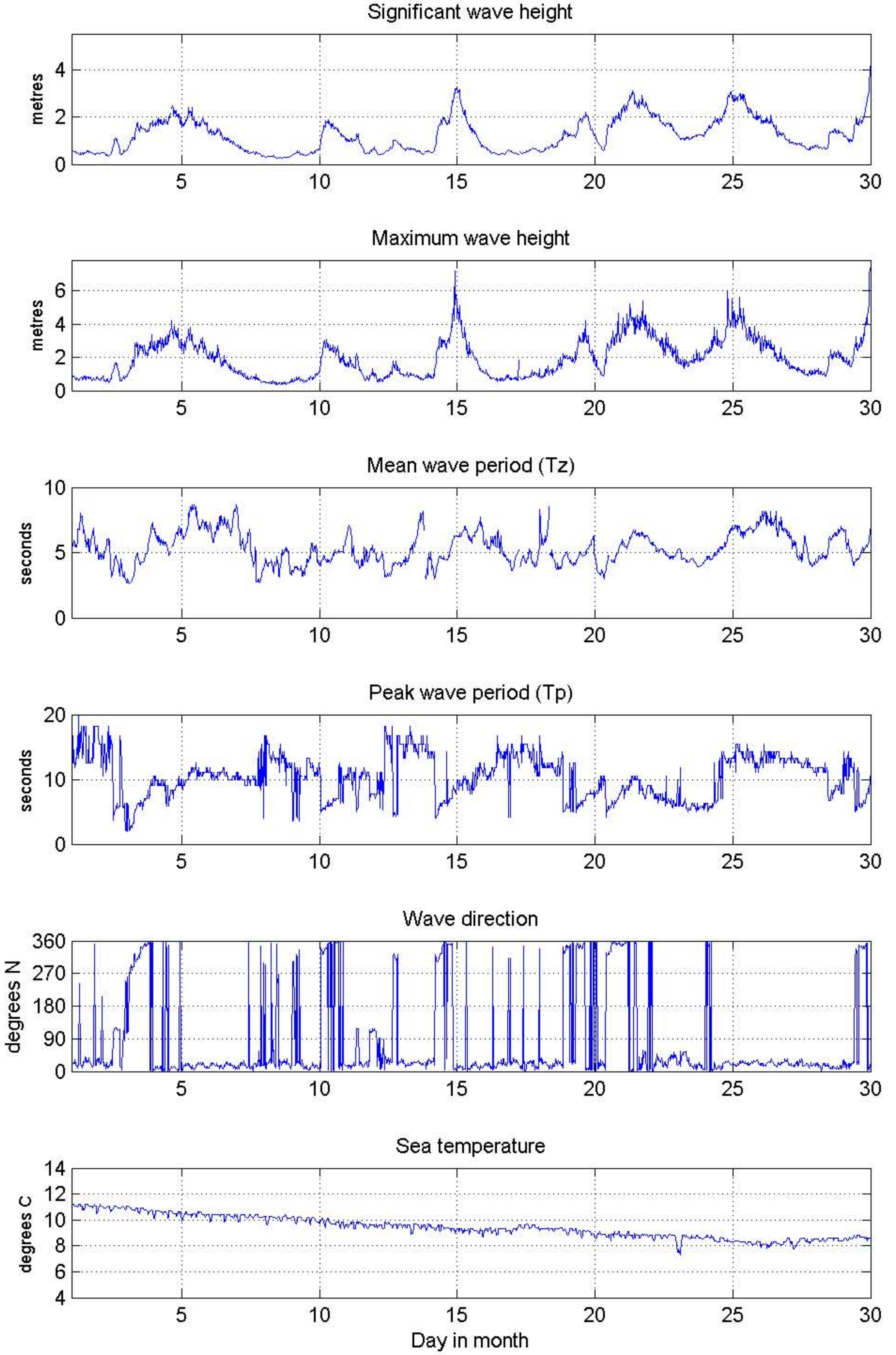
Whitby - September 2013



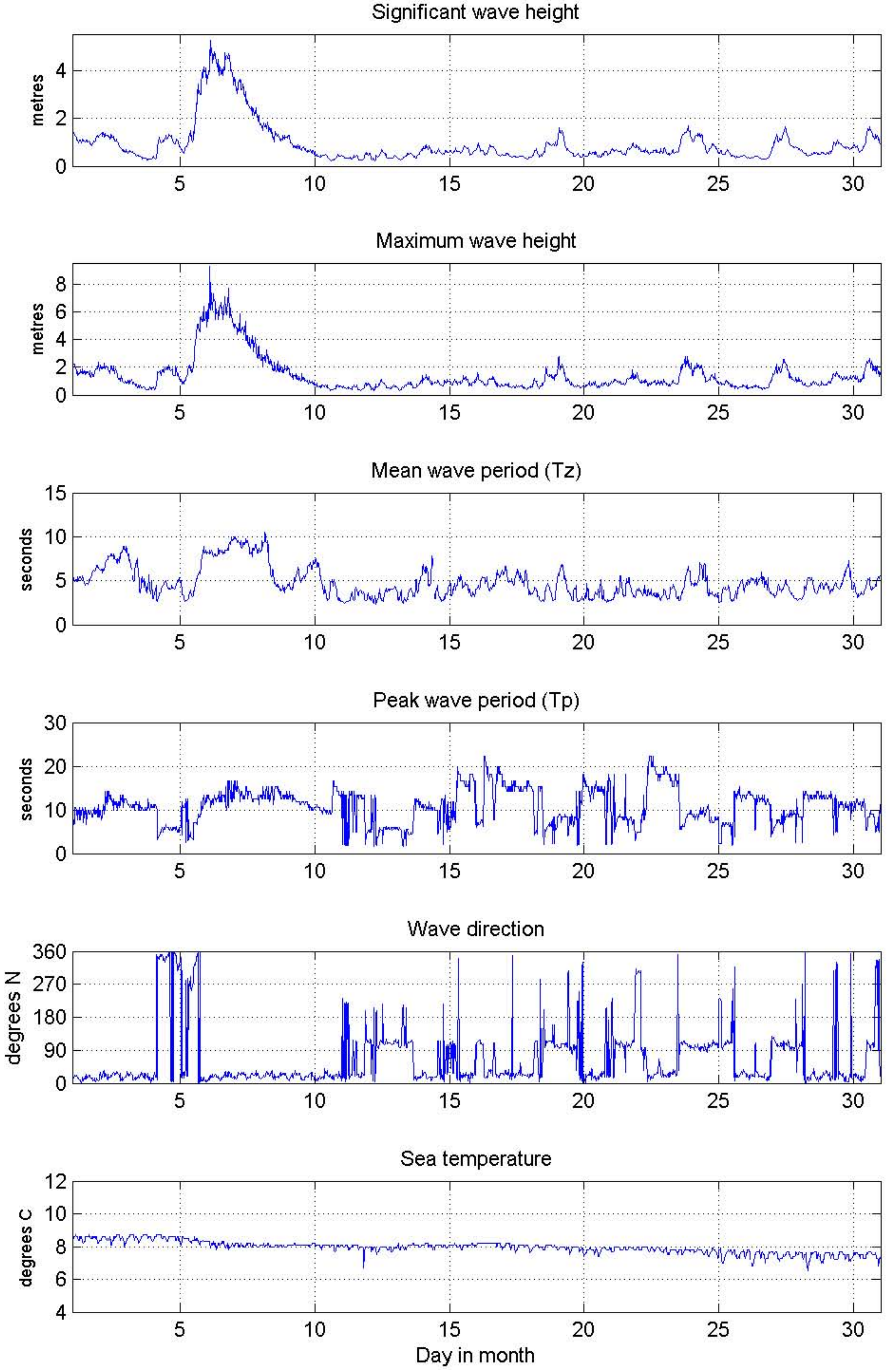
Whitby - October 2013



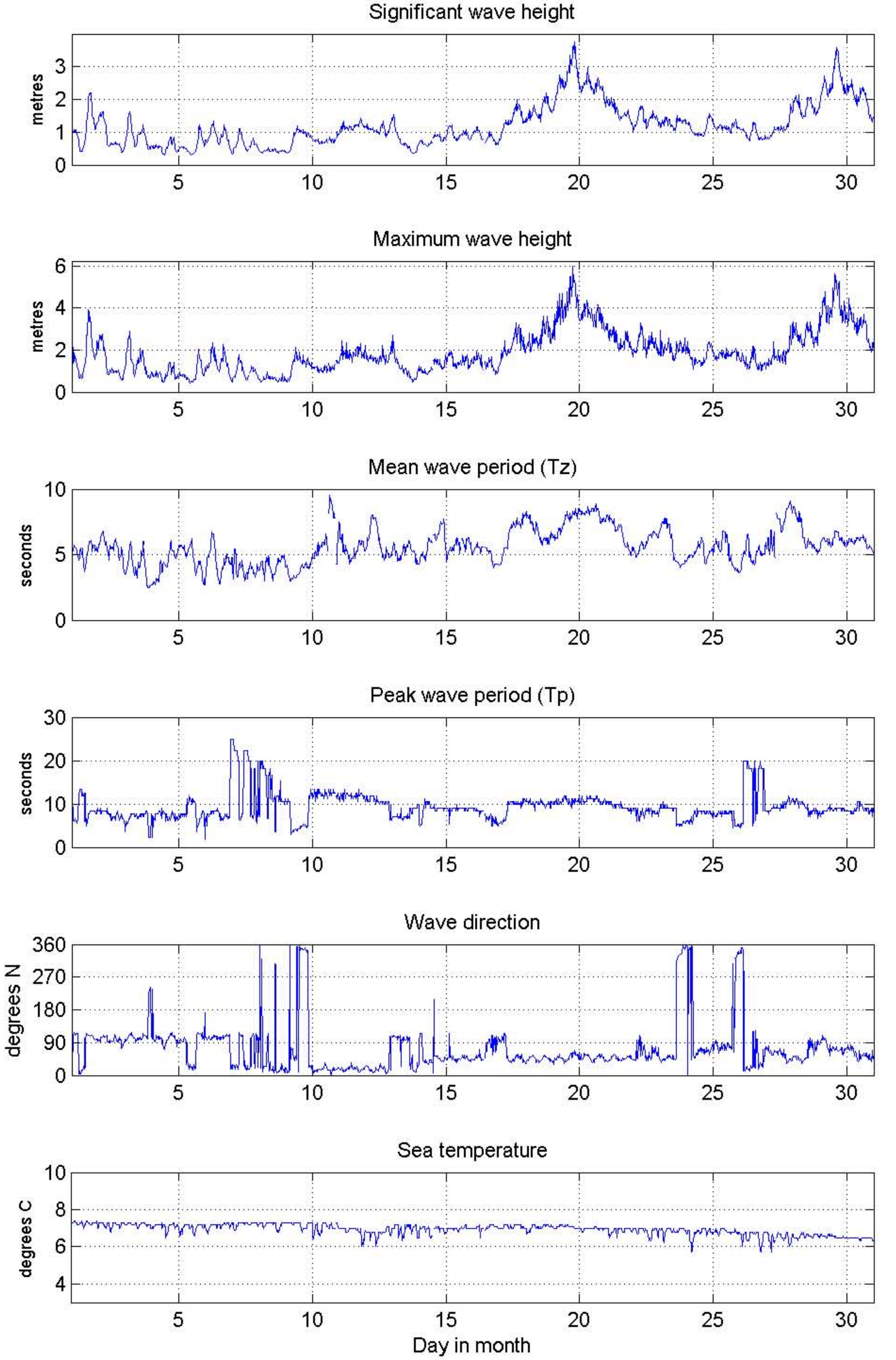
Whitby - November 2013



Whitby - December 2013



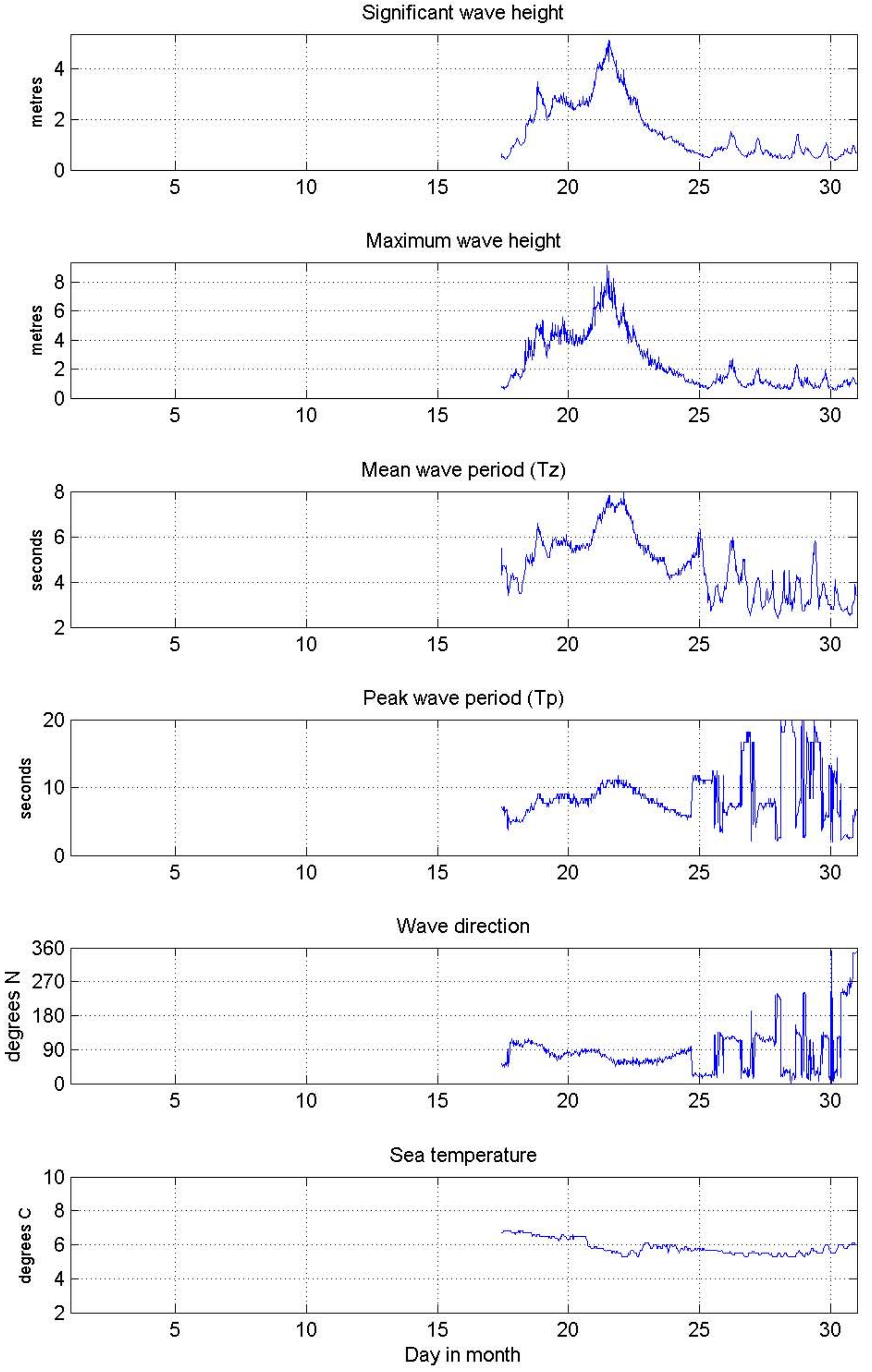
Whitby - January 2014



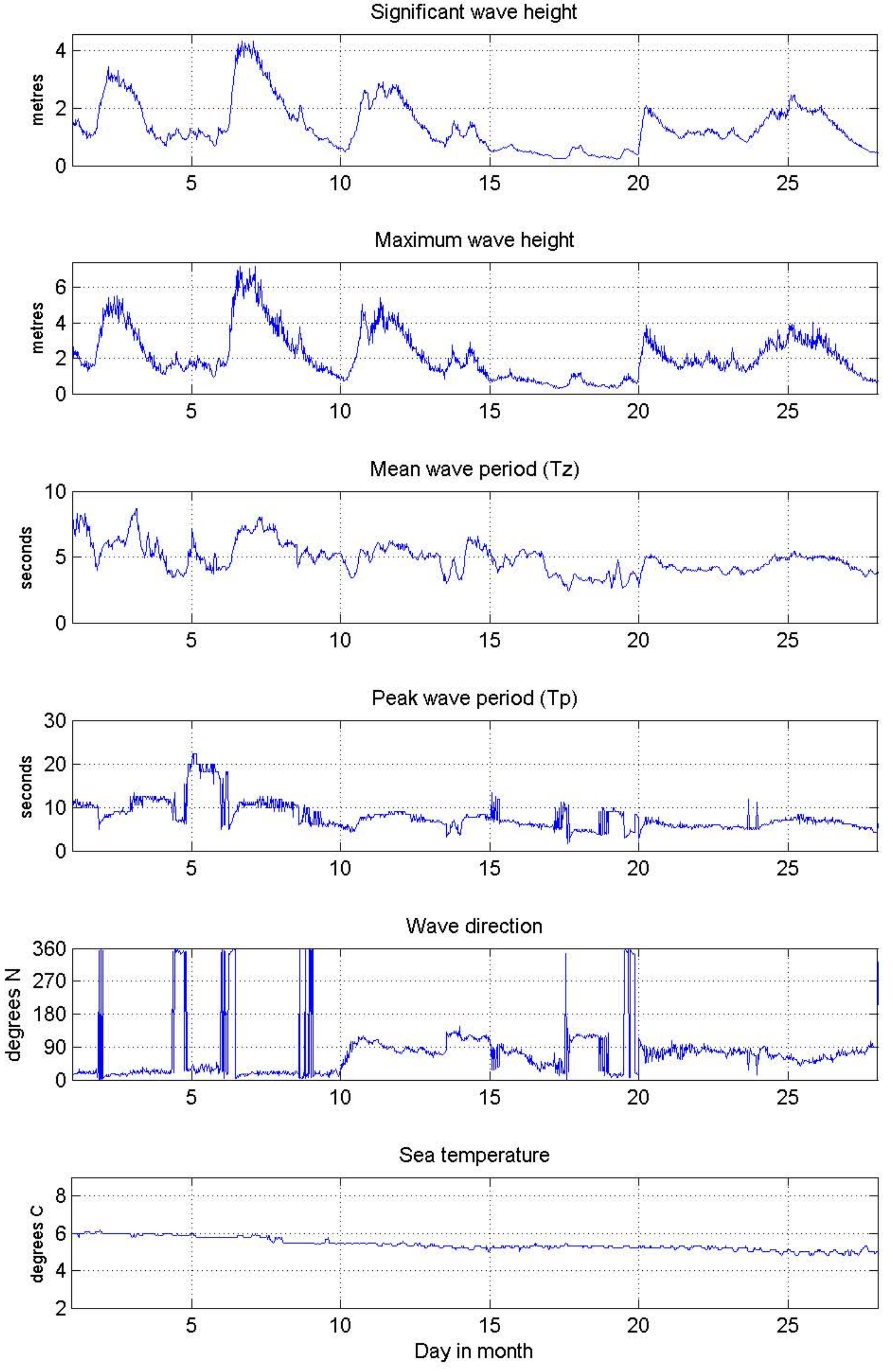
Appendix D

Supporting Graphs: Scarborough Wave Buoy

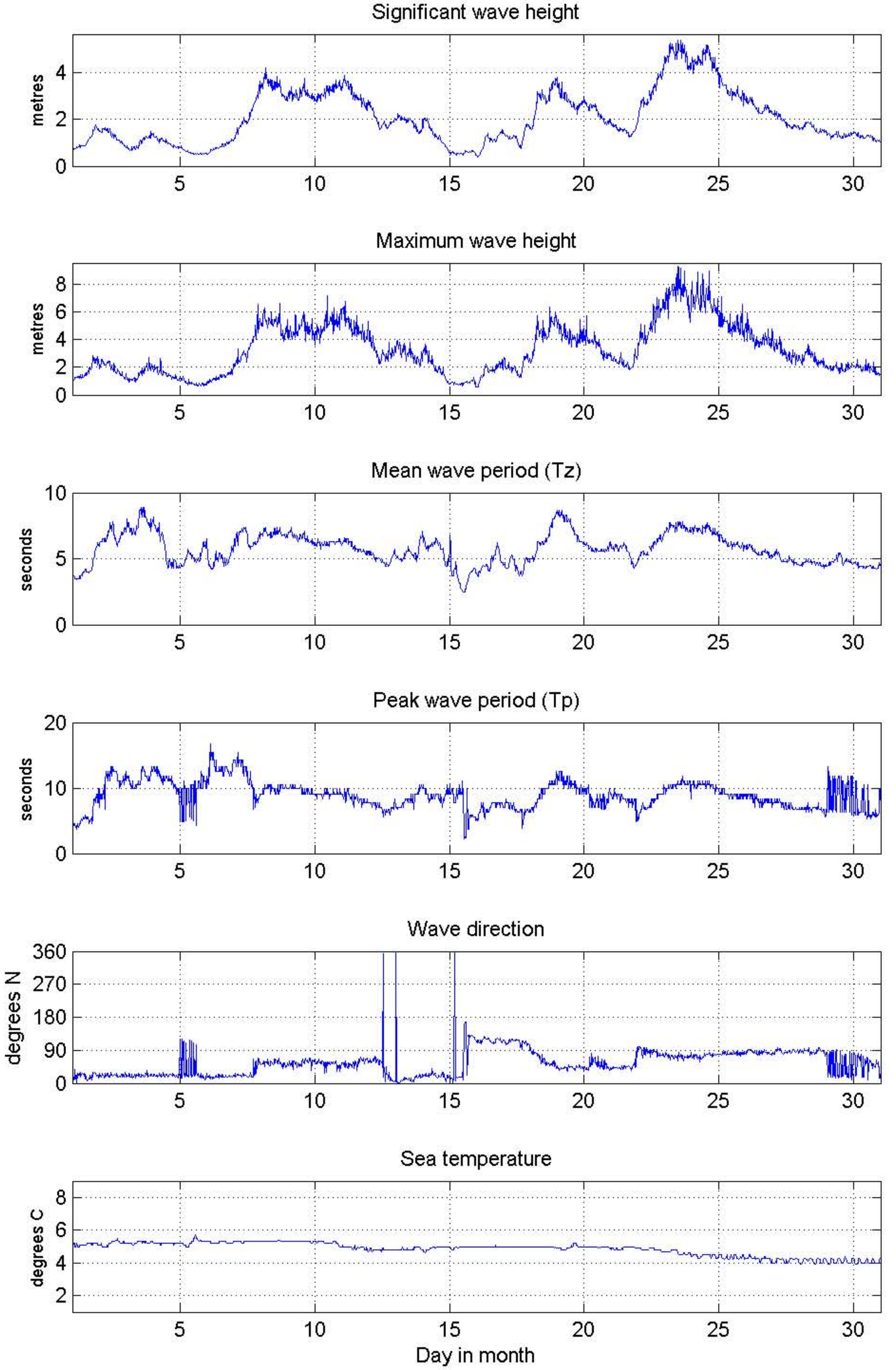
Scarborough - January 2013



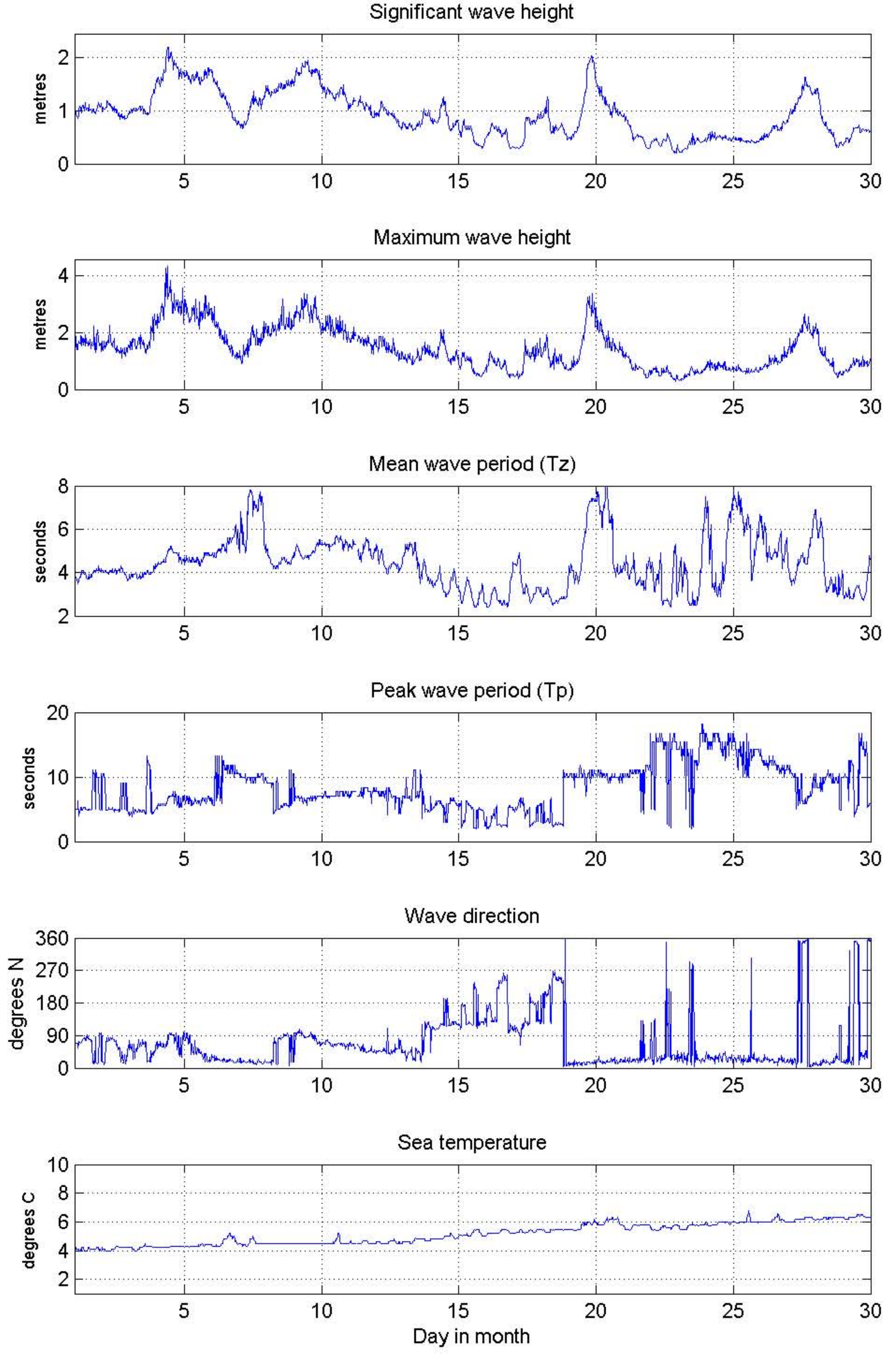
Scarborough - February 2013



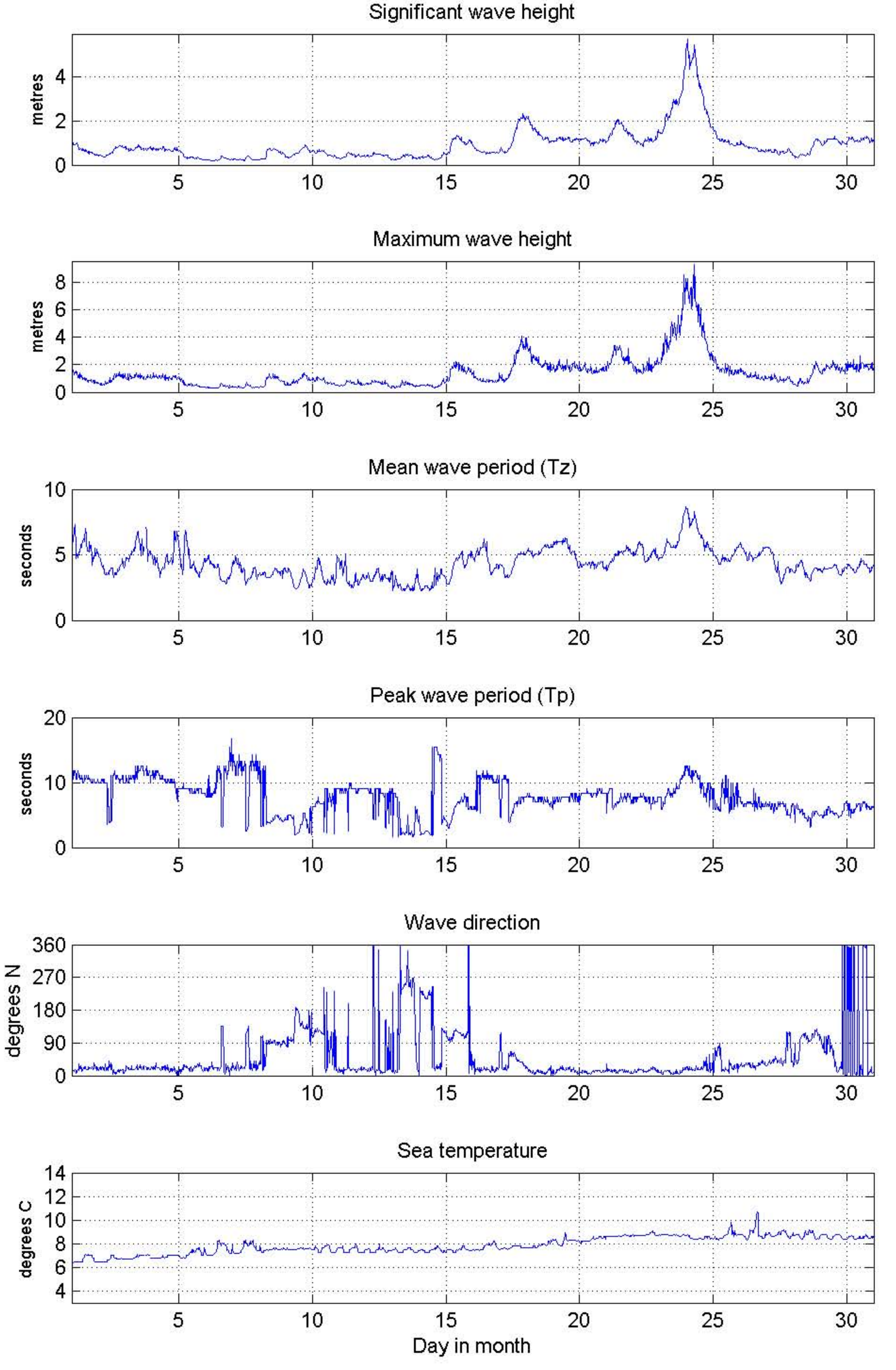
Scarborough - March 2013



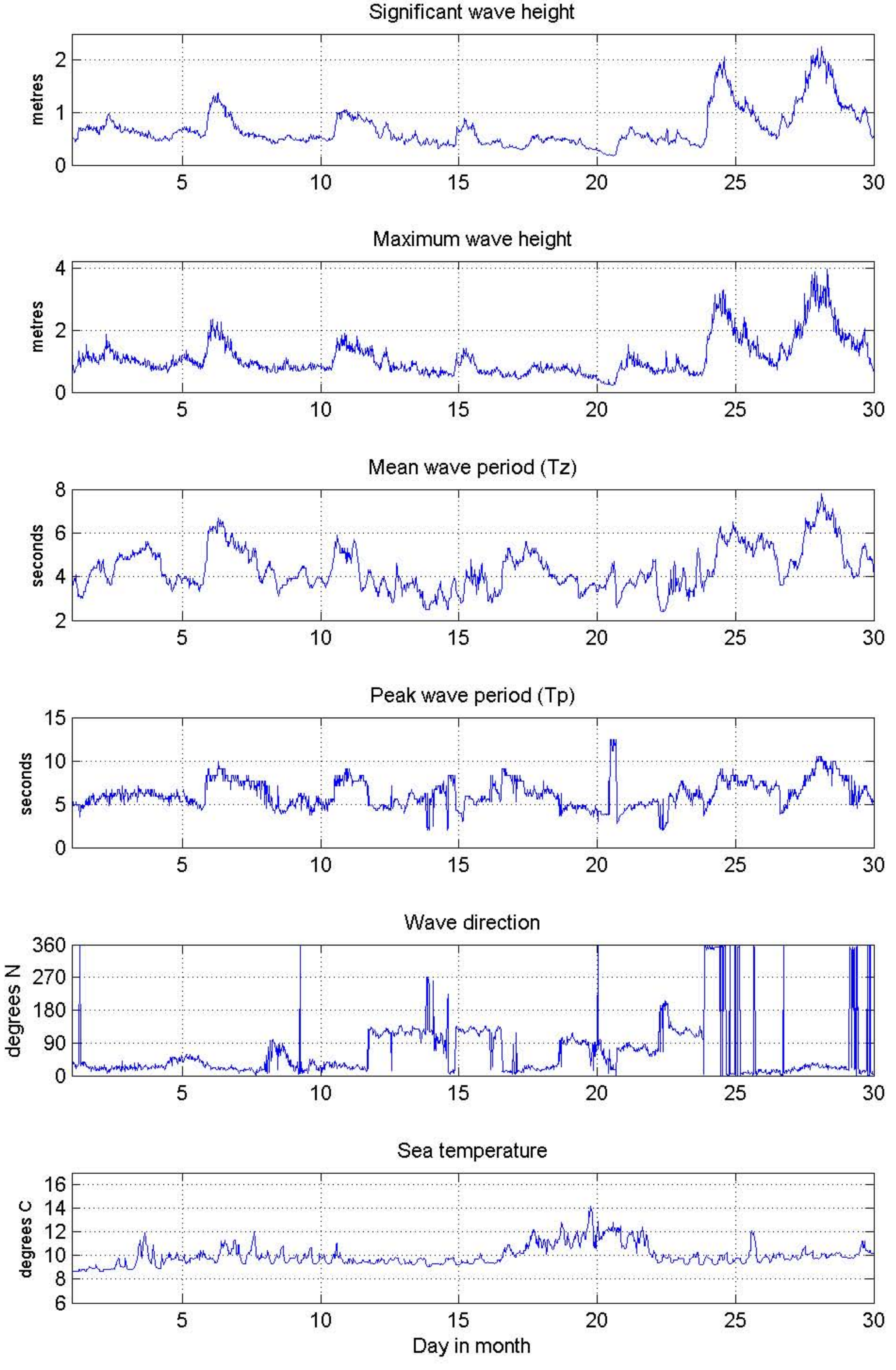
Scarborough - April 2013



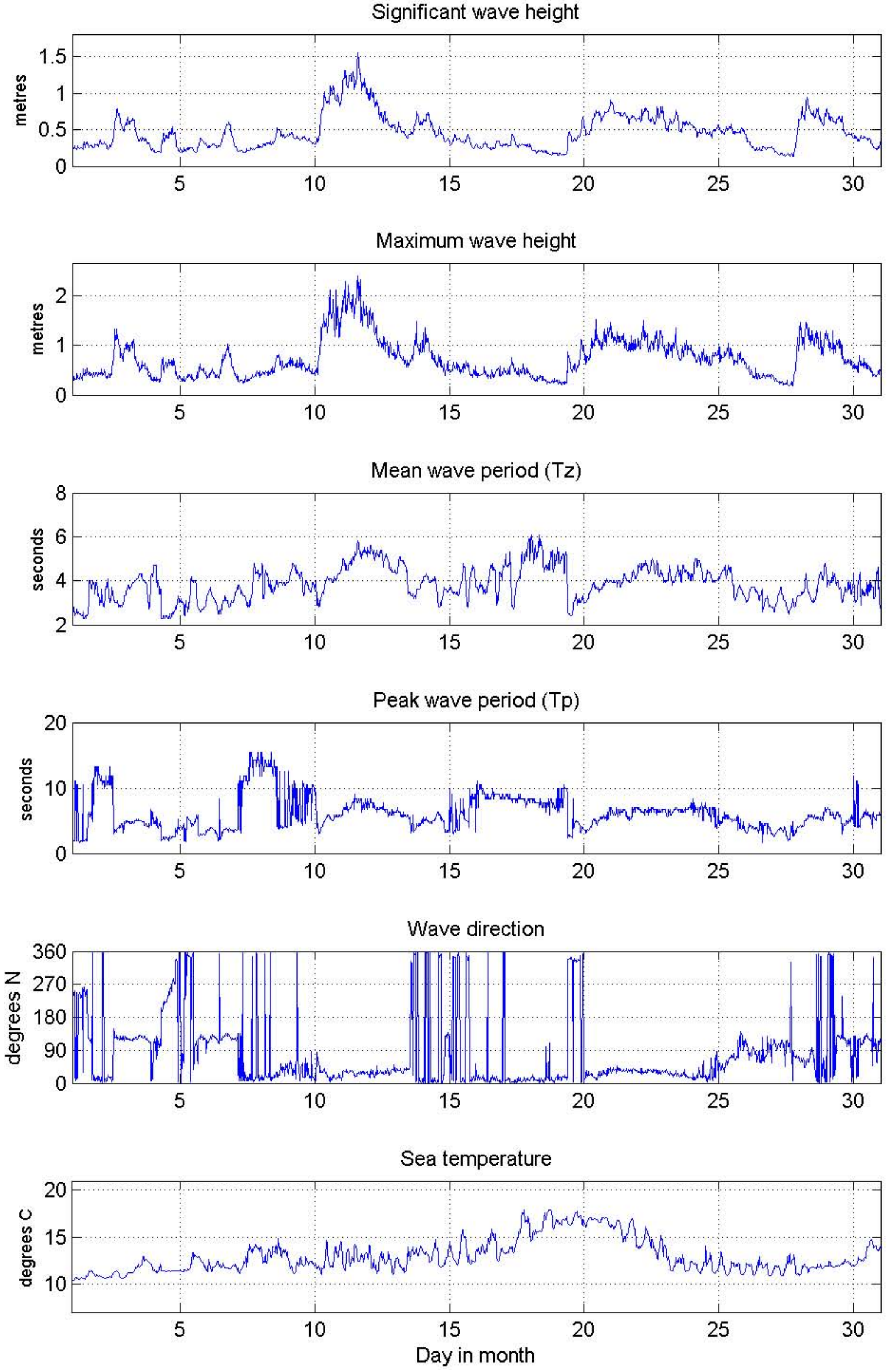
Scarborough - May 2013



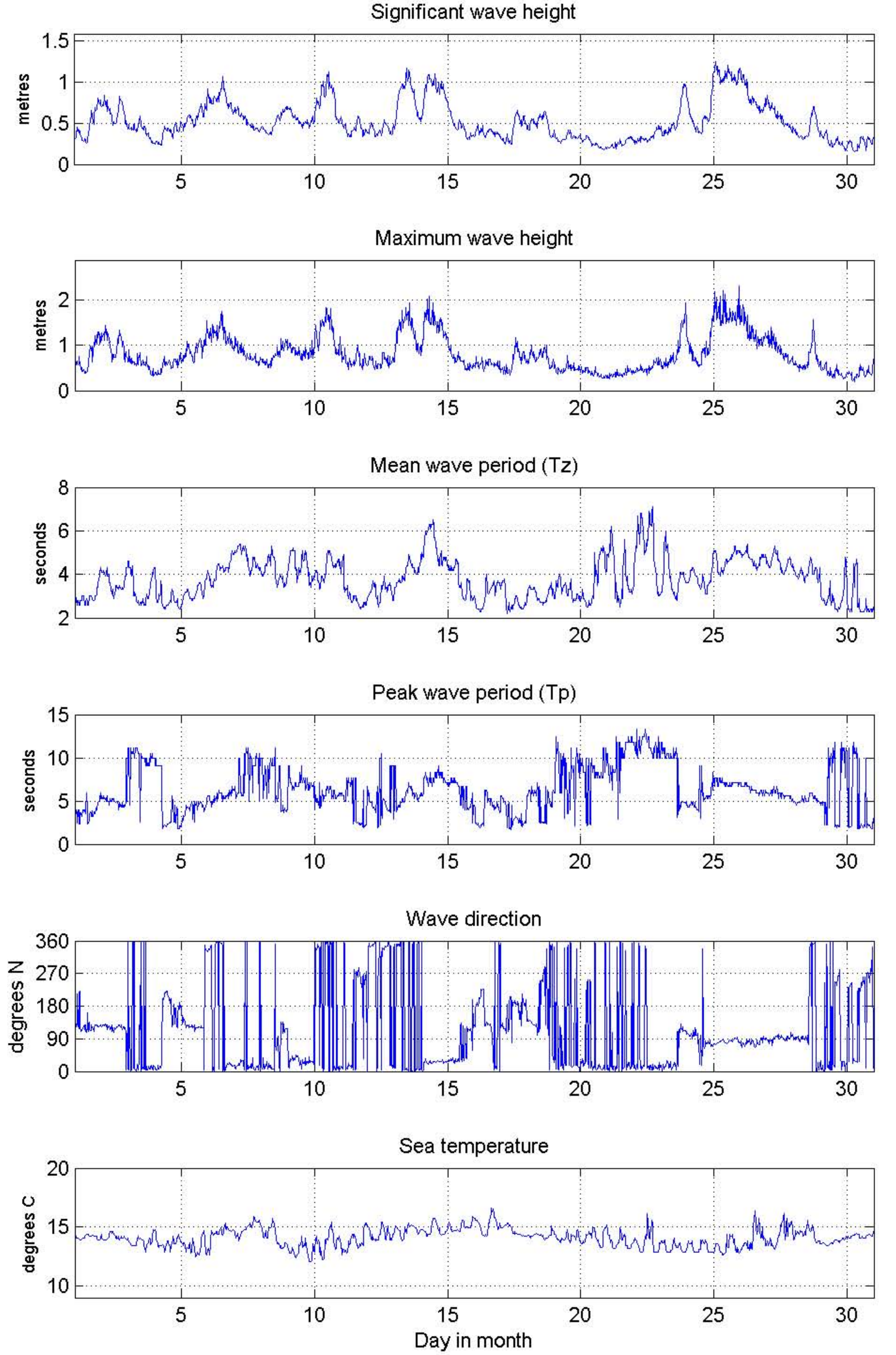
Scarborough - June 2013



Scarborough - July 2013



Scarborough - August 2013



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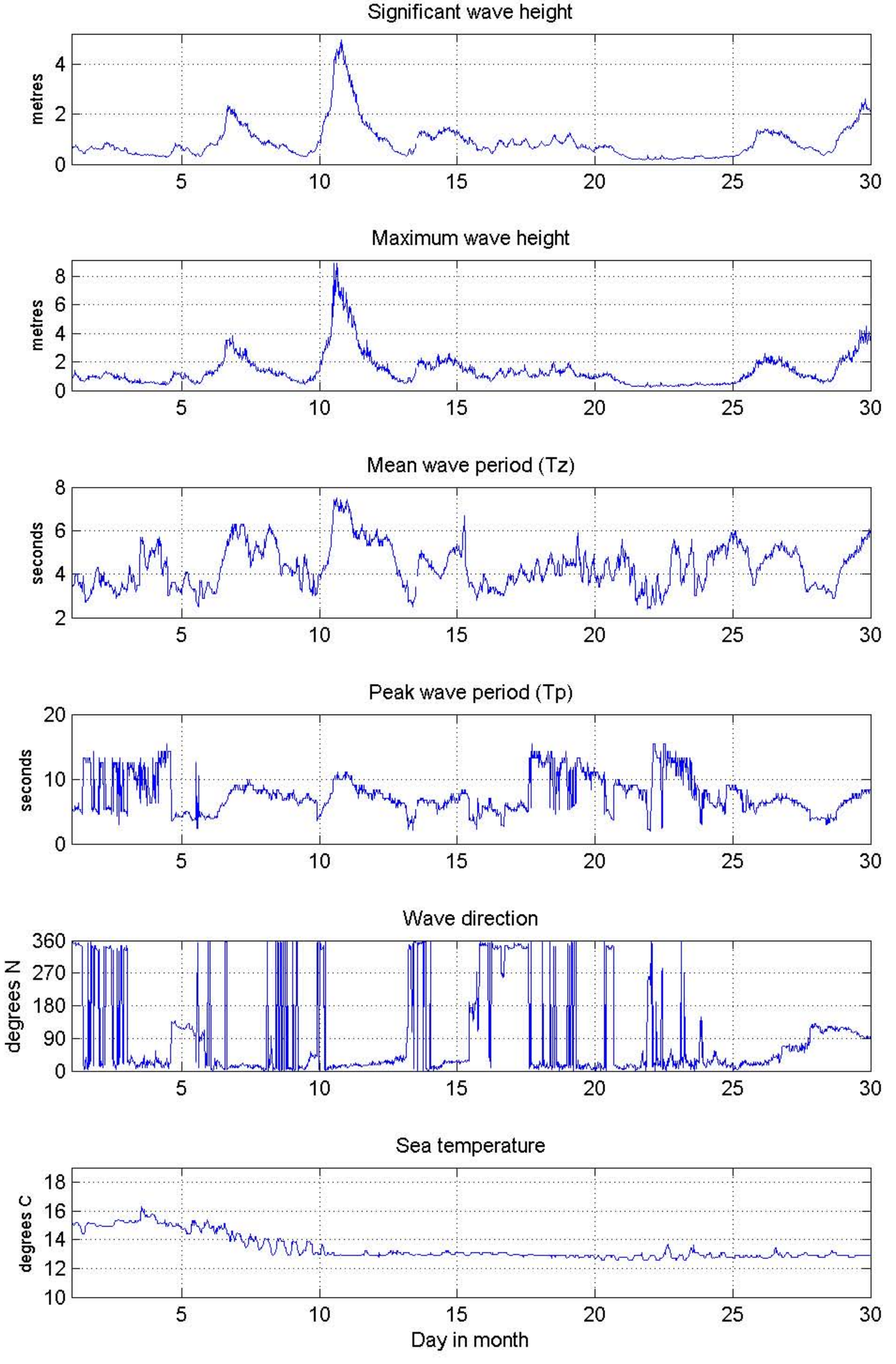
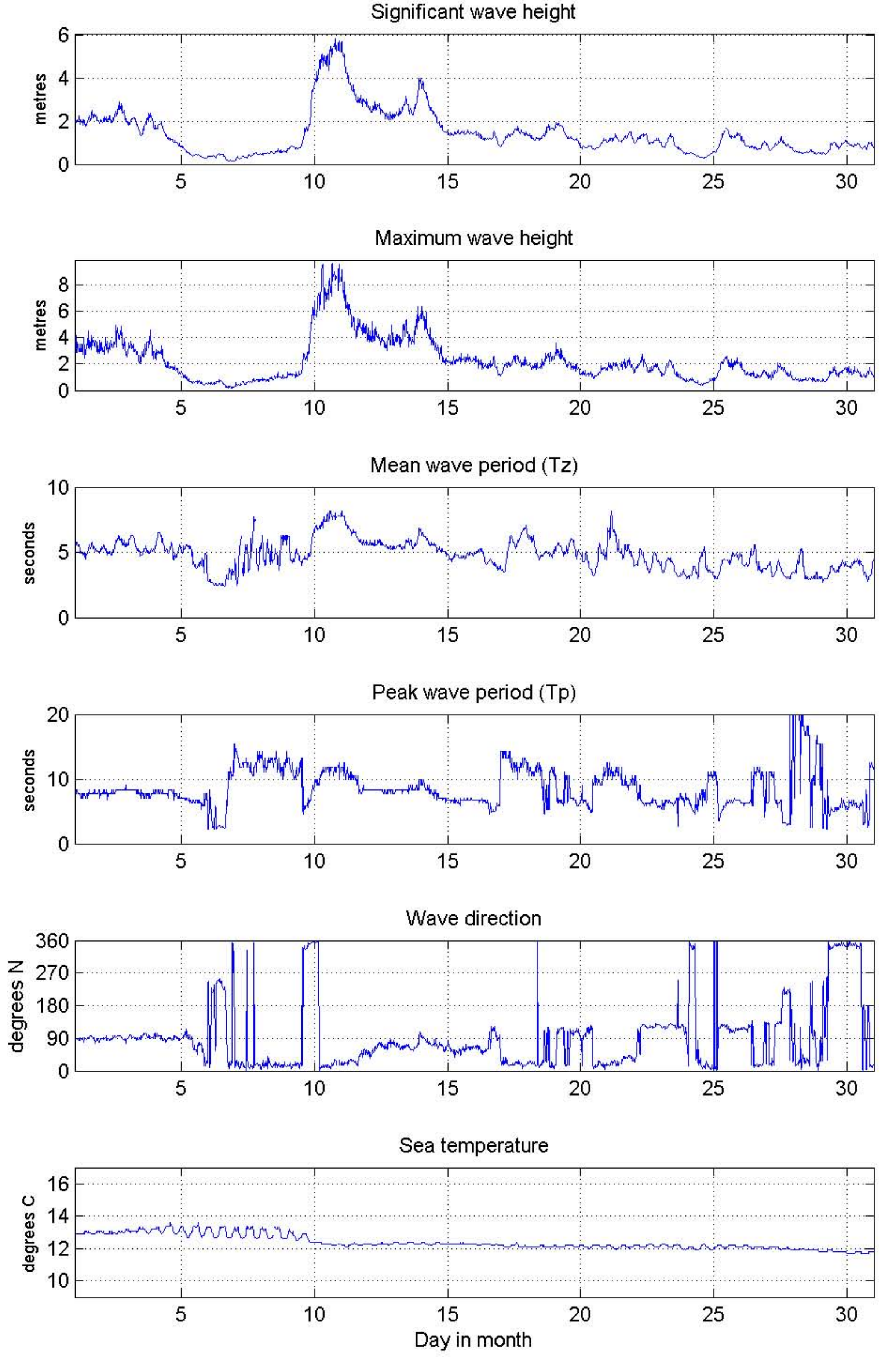
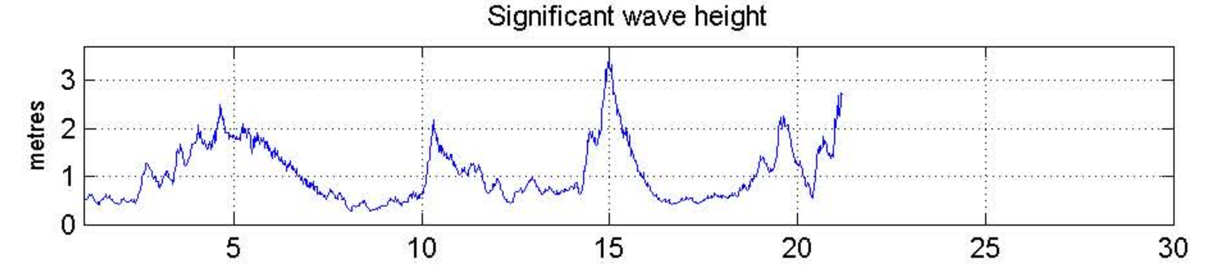
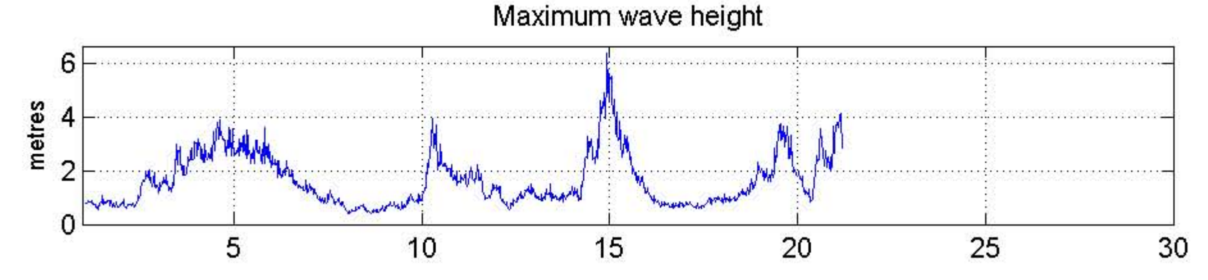


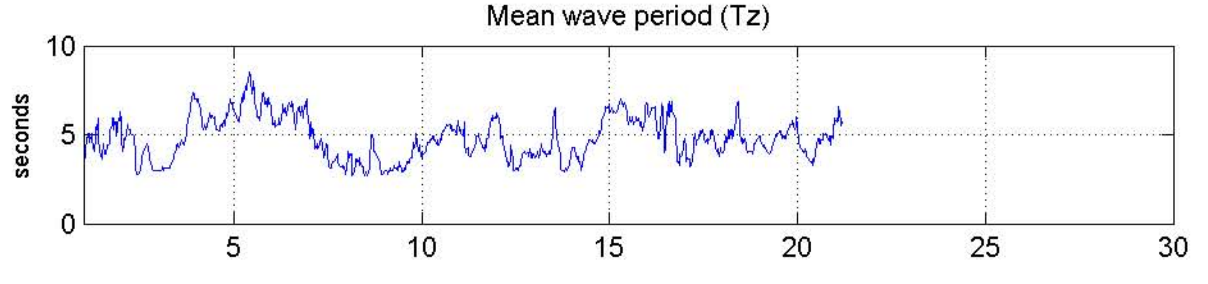
Scarborough - October 2013

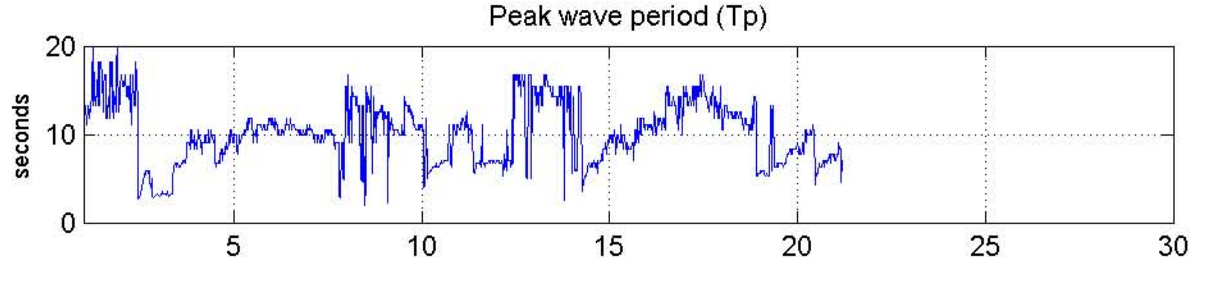


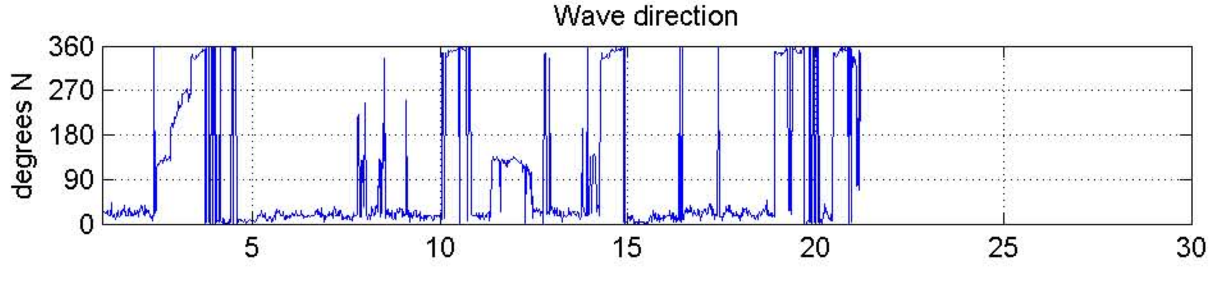
Scarborough - November 2013

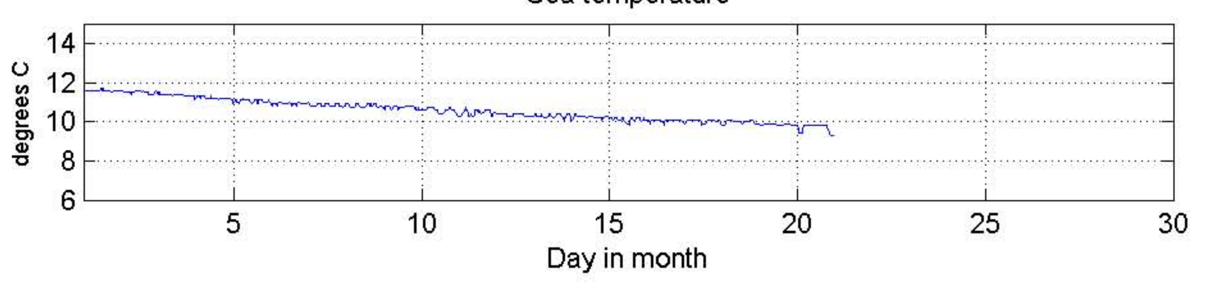




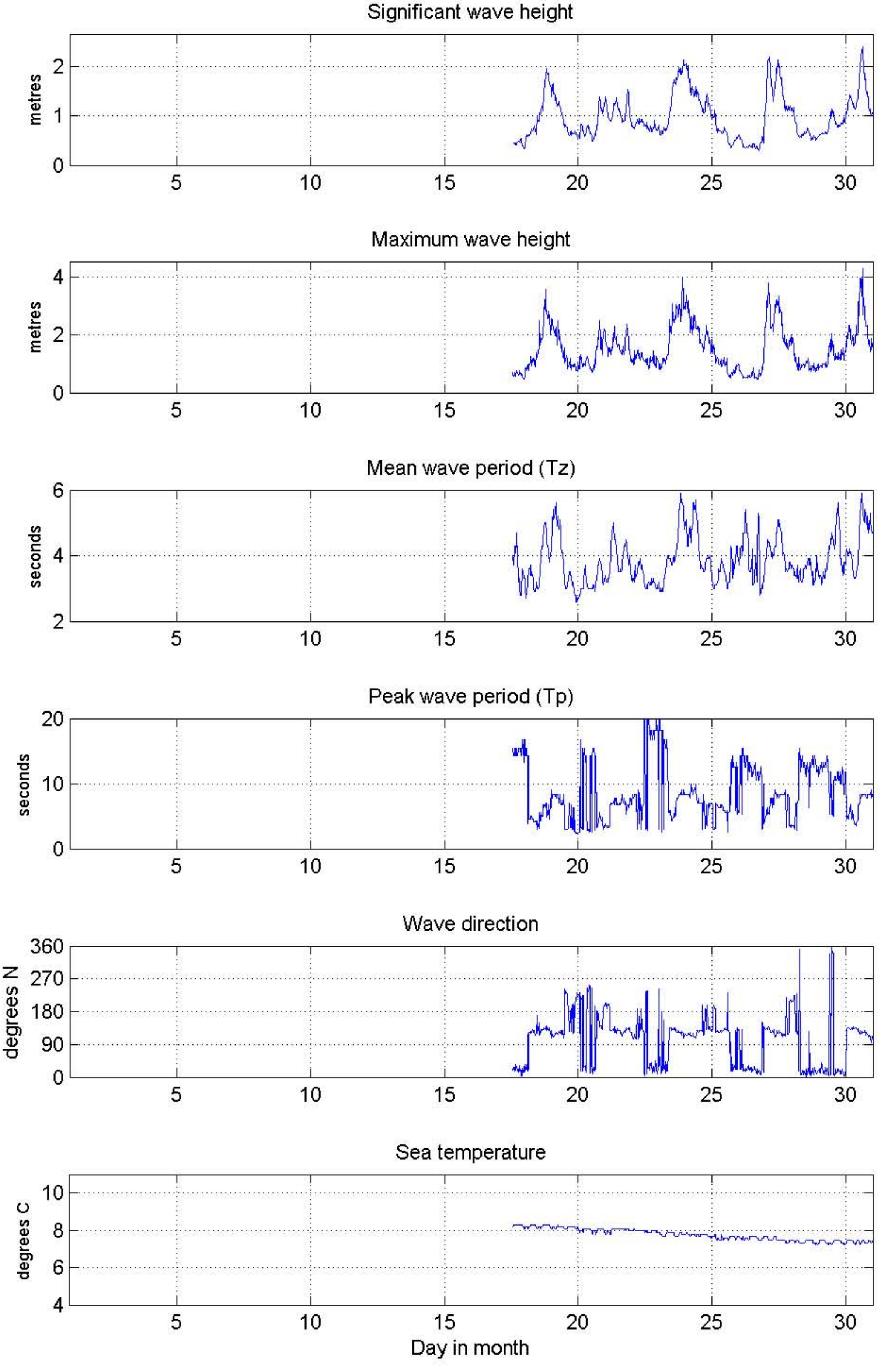




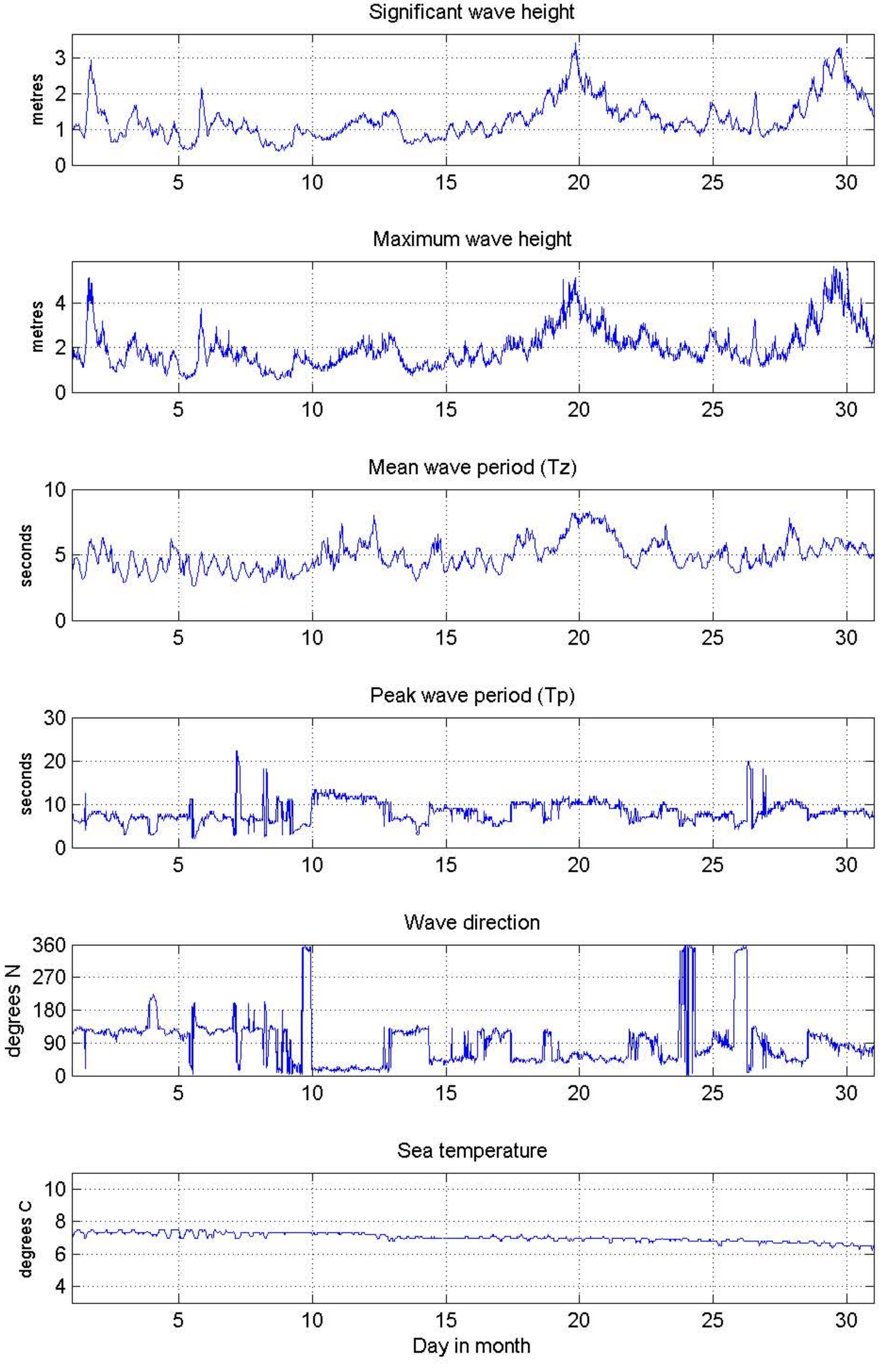




Scarborough - December 2013



Scarborough - January 2014



Appendix E

Scarborough Tide Gauge Report

(Prepared by Channel Coast Observatory)

Scarborough Tide Gauge

Location

OS: 504898E 488622N
WGS84: *Latitude:* 54° 16' 56.990"N *Longitude:* 00° 23' 25.0279"W

Instrument Type

Valeport 740 (Druck Pressure Transducer)

Benchmarks

Benchmark	*Description*
TGBM = 4.18m above Ordnance Datum Newlyn	Port BM on western slipway of inner harbour 504750.75E 488754.385N

TGZ = -2.52m above Ordnance Datum Newlyn

TGZ = 0.73m above Chart Datum

TGZ = 6.70m below TGBM

Datum

All data are to Ordnance Datum Newlyn. The height of Chart Datum relative to Ordnance Datum at Scarborough is -3.25m (Admiralty Tide Tables, Supplementary Table III).

Survey information

The site was surveyed on 13 June 2013, where the tide gauge offset was found to be 0.195m higher than on the previous survey in 2003. The datum appeared to have changed during the period 2006-2011.

Site characteristics

The pressure transducer is mounted in a stilling well in Scarborough harbour.

Data Quality

Recovery rate (%)	Sample interval
98	10 minutes

Service history

The gauge was first deployed on 28 April 2003 and maintained until December 2005. Measurements continued, and full maintenance was resumed in 2011.

Measurements

The pressure transducer samples at 4Hz. Tidal elevations are derived, every 10 minutes, as the 40 second average of the 4Hz readings. The time stamp is the start of the measuring burst. Although the time stamp is accurate, the instrument has to be started manually after servicing and it is not always possible to start exactly on a 10 minute integer. Measurements are interpolated to the hour and 10 minute intervals, if the original time series is not on the hour. Missing data exceeding 2 hours are not interpolated. All data measured prior to the gauge being fully surveyed were adjusted to the correct elevations, but it has proven difficult to establish where the datum changed occurred between 2006 and 2011. The highest values during these years are included in the Amax tables, since the date/times are valid, but the elevations should be used with caution.

Residuals and Elevations (OD and CD) for the whole year are shown in Figures 1 to 3 respectively.

Statistics

All times GMT

Month	Extreme maxima		Extreme minima	
	Elevation (OD)	Date/Time	Elevation (OD)	Date/Time
January	2.67	30-Jan-2013 18:00	-2.95	13-Jan-2013 23:50
February	2.61	01-Feb-2013 19:30	-2.89	11-Feb-2013 23:30
March	2.72	12-Mar-2013 16:40	-2.78	02-Mar-2013 00:50
April	2.56	28-Apr-2013 17:50	-2.53	28-Apr-2013 00:10
May	2.62	27-May-2013 17:40	-2.60	27-May-2013 11:40
June	2.61	27-Jun-2013 06:30	-2.80	25-Jun-2013 11:50
July	3.09	25-Jul-2013 05:30	-2.55	24-Jul-2013 11:40
August	3.05	22-Aug-2013 04:20	-2.60	23-Aug-2013 12:00
September	3.11	20-Sep-2013 04:10	-2.39	20-Sep-2013 11:00
October	2.90	07-Oct-2013 04:50	-2.22	18-Oct-2013 09:40
November	3.16	04-Nov-2013 16:10	-2.12	19-Nov-2013 23:10
December	4.39	05-Dec-2013 17:20	-2.39	07-Dec-2013 01:40

Month	Surge maxima		Surge minima	
	Value (m)	Date/Time	Value (m)	Date/Time
January	0.59	30-Jan-2013 13:00	-0.56	27-Jan-2013 06:00
February	0.48	03-Feb-2013 18:00	-1.10	13-Feb-2013 23:10
March	0.06	24-Mar-2013 18:20	-0.55	01-Mar-2013 17:40
April	0.47	15-Apr-2013 15:40	-0.59	14-Apr-2013 07:40
May	0.40	23-May-2013 21:50	-0.60	03-May-2013 04:20
June	0.08	23-Jun-2013 00:20	-0.43	04-Jun-2013 08:00
July	0.33	25-Jul-2013 11:40	-0.43	08-Jul-2013 11:30
August	0.66	18-Aug-2013 09:50	-0.10	17-Aug-2013 19:30
September	0.68	15-Sep-2013 21:50	-0.22	15-Sep-2013 13:00
October	0.89	10-Oct-2013 01:20	-0.18	30-Oct-2013 21:00
November	1.13	29-Nov-2013 21:40	-0.49	11-Nov-2013 08:30
December	1.75	05-Dec-2013 15:50	-0.65	27-Dec-2013 12:20

Month	Mean Level	
	No. of days	Elevation (OD)
January	31	0.017
February	28	-0.049
March	29	-0.010
April	30	0.053
May	31	0.040
June	30	-0.003
July	31	0.179
August	31	0.329
September	30	0.346
October	31	0.412
November	30	0.427
December	31	0.431

Highest values in 2013			
Extreme		Surge	
Elevation (OD) *(Surge component)*	Date/Time	Value (m)	Date/Time
4.39 *(1.66)*	05-Dec-2013 17:20	1.75	05-Dec-2013 15:50
3.27 *(0.85)*	06-Dec-2013 05:50	1.23	06-Dec-2013 03:30
3.17 *(0.88)*	19-Dec-2013 17:20	1.16	05-Dec-2013 13:30
3.16 *(0.61)*	04-Nov-2013 16:10	1.13	29-Nov-2013 21:40
3.11 *(0.30)*	20-Sep-2013 04:10	1.08	29-Nov-2013 20:30
3.09 *(0.15)*	25-Jul-2013 05:30	1.06	15-Dec-2013 08:30
3.06 *(0.52)*	06-Nov-2013 05:30	1.05	19-Dec-2013 14:20
3.06 *(0.47)*	05-Nov-2013 04:40	0.95	15-Dec-2013 10:50
3.06 *(0.45)*	05-Nov-2013 17:00	0.89	10-Oct-2013 01:20
3.05 *(0.14)*	22-Aug-2013 04:20	0.86	19-Dec-2013 13:10

Year	Annual extreme maxima		Annual surge maxima		Z_0 (OD)	Annual recovery rate
	Elevation (OD) *(Surge)*	Date/Time	Value (m)	Date/Time		
2003	3.05 *(-0.03)*	28-Sep-2003 05:10	1.13	21-Dec-2003 09:40	-	76%
2004	3.09 *(0.34)*	22-Feb-2004 17:10	0.96	18-Nov-2004 04:00	0.292	99%
2005	3.66 *(0.86)*	12-Jan-2005 17:20	1.18	20-Jan-2005 08:20	0.287	99%
2006*	3.30 *(0.17)*	30-Mar-2006 16:30	1.29	31-Oct-2006 15:40	-	77%
2007*	3.40 *(0.71)*	25-Nov-2007 04:00	1.60	08-Nov-2007 21:30	0.221	97%
2008*	3.05 *(0.16)*	09-Mar-2008 17:20	0.90	22-Feb-2008 02:10	-	65%
2009*	3.19 *(0.44)*	12-Jan-2009 16:50	1.15	18-Jan-2009 16:30	-	84%
2010*	3.21 *(0.05)*	11-Sep-2010 05:30	0.81	12-Nov-2010 04:20	-	82%
2011*	3.03 *(-0.14)*	21-Mar-2011 17:10	1.33	04-Feb-2011 11:00	-	80%
2012	2.94 *(0.06)*	17-Oct-2012 04:40	0.92	05-Jan-2012 16:40	-	70%
2013	4.39 *(1.66)*	05-Dec-2013 17:20	1.75	05-Dec-2013 15:50	0.186	98%

* Possible datum shift by up to -0.195m

Tidal levels		
Observation period	October 2006 to December 2012	
Tide Level	Elevation (OD)	Elevation (CD)
HAT	3.10	6.35
MHWS	2.46	5.71
MHWN	1.31	4.56
MSL	0.18	3.43
MLWN	-0.96	2.29
MLWS	-2.11	1.14
LAT	-3.04	0.21

General

The time series of 10 minute tidal elevations for one year is quality-checked in accordance with ESEAS guidelines, flagged and archived. The archived time series is continuous and monotonic, with missing data given as 9999. The missing data shown are days where the entire 24 hours of data are missing.

Monthly extreme maxima/minima are the maximum and minimum water levels from all measured data for that month. Monthly surge maxima/minima (residuals) are calculated in a similar manner from the time series of residuals. Residuals are derived as the measured tidal elevation minus the predicted tidal elevation.

The monthly Mean Level is calculated as the average of all readings for the given month. The annual Z_0 is the value of Mean Sea Level derived by the harmonic analysis of the year's data. These values should not be used for any purpose without consideration of the recovery rate.

Acknowledgement

Tidal predictions were produced using the TASK2000 software, kindly provided by the Permanent Service for Mean Sea Level (PSMSL), Proudman Oceanographic Laboratory. Tide levels were produced by Fugro EMU Limited.

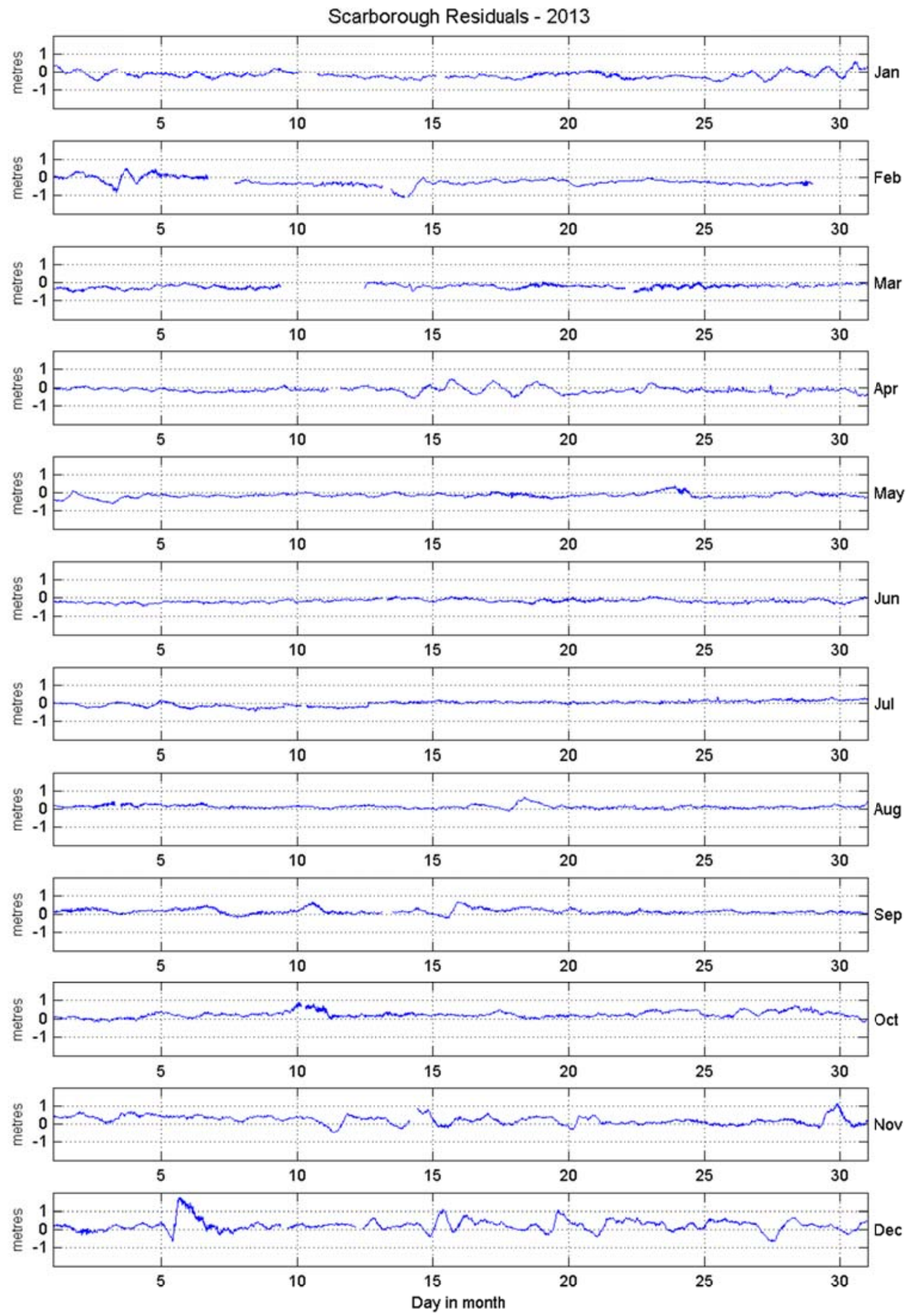


Figure 1: Scarborough residuals for 2013

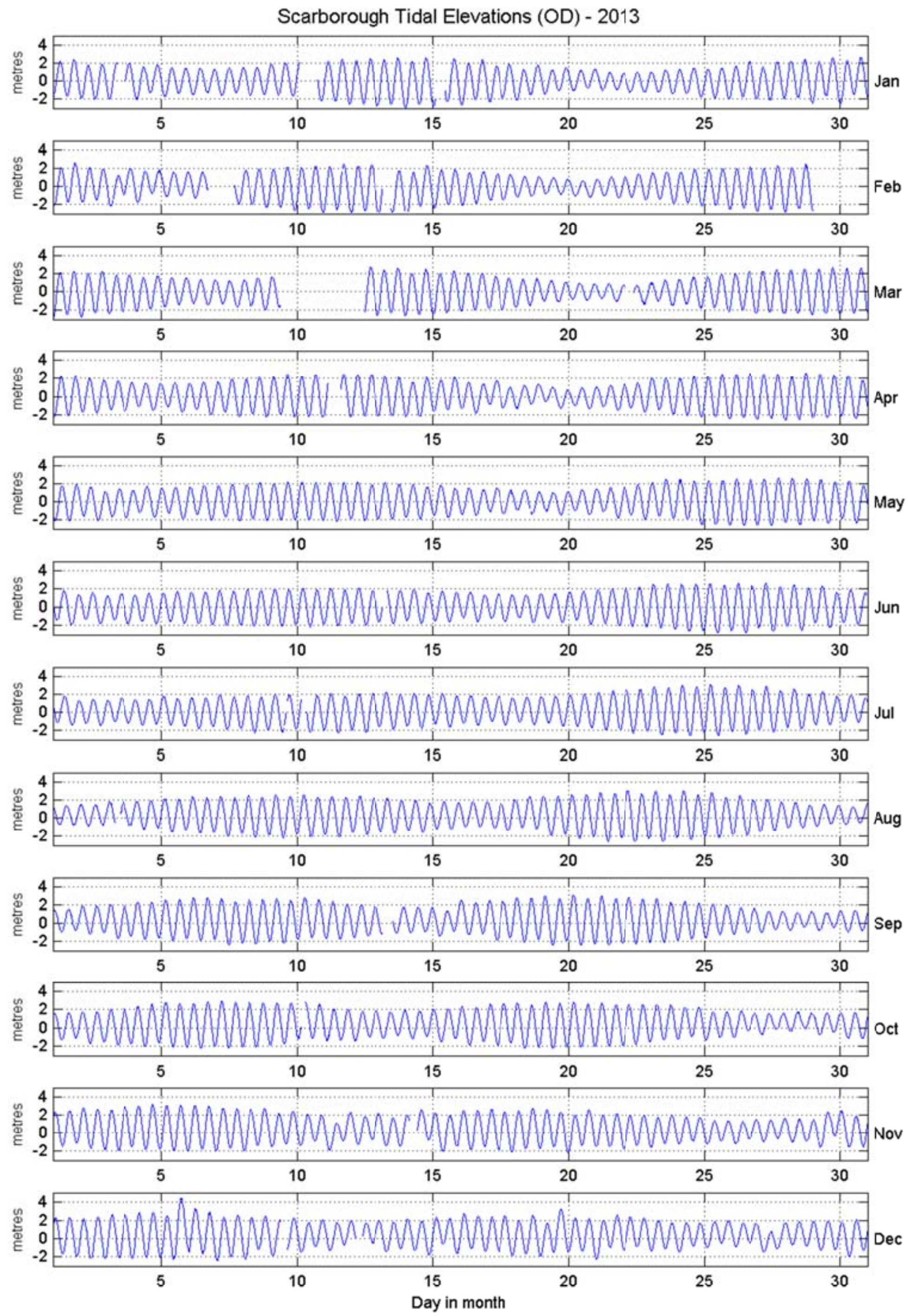


Figure 2: Scarborough tidal elevations for 2013 relative to Ordnance Datum

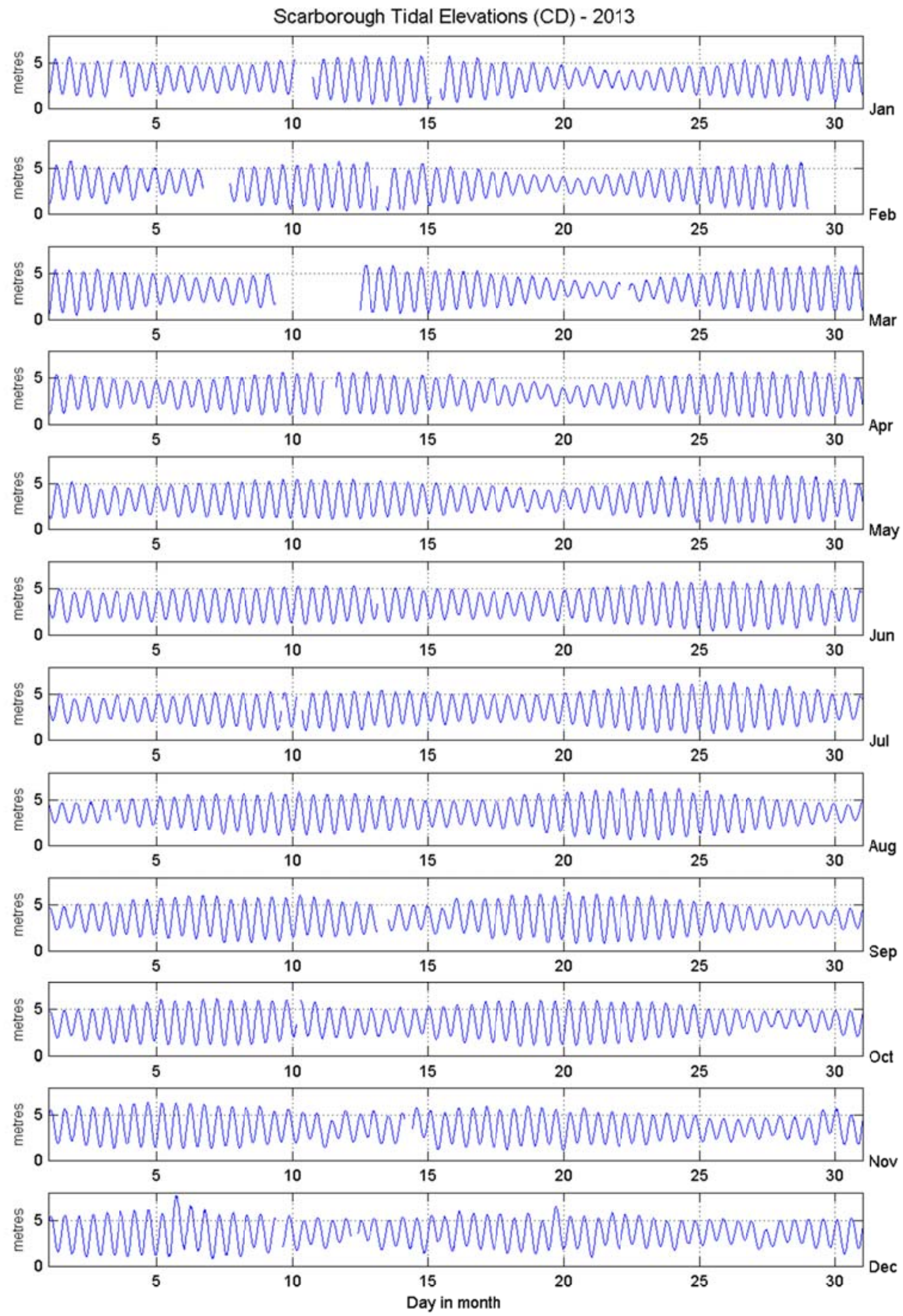


Figure 3: Scarborough tidal elevations for 2013 relative to Chart Datum

Appendix F

Fugro Emu Report on Instrument Deployment

THE NATIONAL NETWORK OF COASTAL MONITORING PROGRAMMES

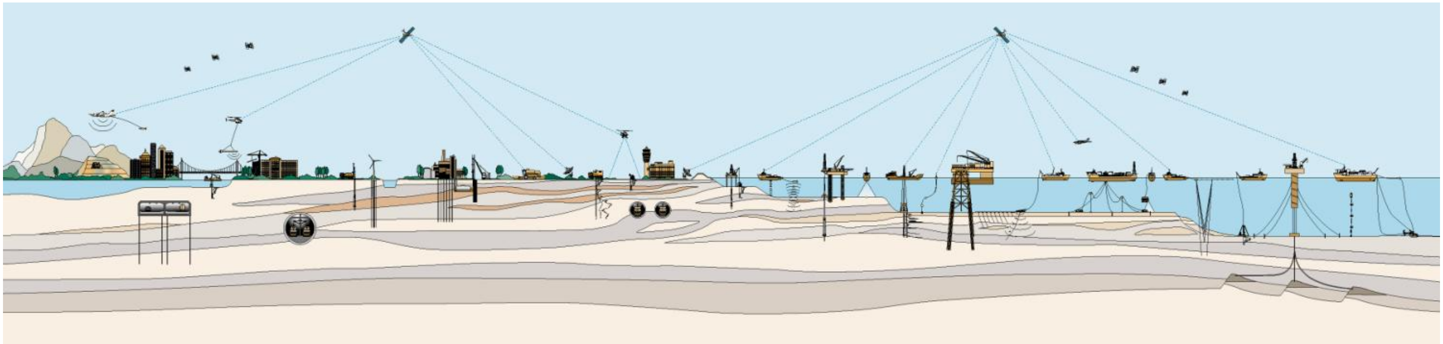
CELL 1 NORTHEAST REGIONAL COASTAL MONITORING FRAMEWORK

HYDRODYNAMIC SERVICES

December 2012 to June 2013 Reports

Date	27 August 2013
Document Reference	13/J/1/01/2131/1510
Job Number	J/1/01/2131
Issue Number	1
Fugro EMU Contact	Andrew Gowland
Client Contact	Robin Siddle
Authorised By	Robin Newman

Report Issue Page



This table contains a record of reports submitted for J/1/01/2131.

Report Issue Number	Period covered	Date	Authoriser's Signature
1	December 2012 to June 2013	30/08/2013	

Authorisation Page

North East Reports: December 2012 to June 2013

Document Release and Authorisation Record			
Fugro EMU Document Ref.	13/J/1/01/2131/1510		
Job Number	J/1/01/2131		
Issue Number	1		
Hard Copy	n/a		
Issued to	Robin Siddle		
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Technical Checker	Andrew Gowland	29/08/2013	[illegible]
Department Manager	Robin Newman	30/08/2013	[illegible]

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List of Contents

1. INTRODUCTION

The National Network of Strategic Regional Coastal Monitoring Programmes (NNSRCMP) owns and maintains a network of real time metocean data acquisition instruments around the coast of the England. The project is funded by local and national government agencies with the purpose that the data is used for coastal engineering, defence, planning and flood forecasting. The data is provided in real time to aid decision makers and input into warning systems, it is also stored and maintained for long term trend analysis.

Fugro EMU's involvement in the project is to ensure reliable data is collected for and provided to the NNSRCMP. A fundamental part of this is to regularly service the equipment, and respond to faults. Following each maintenance visit, or other works, a report is written by the field personnel. These have been collated for the months December 2012 to June 2013 and form section 2 of this report. *Reports from future works will be issued as an amendment to this report.*

Each report is site specific and usually relates to either the shore station or the metocean instrumentation. The objective of these reports is to provide fieldwork feedback to the client on the work undertaken, the condition of the equipment, any spare equipment used and recommendations for the future.

Each report typically includes information regarding:

- Date of works
- Whether the work was scheduled or unscheduled
- Surveyor(s) who completed the works
- The purpose of the visit
- Equipment details i.e. serial numbers, radio frequencies
- Condition of the equipment i.e. biofouling levels, paintwork, mooring, antennas
- List of spare equipment used during the work
- Recommendations for the next service visit, or for the site overall
- Battery voltage(s) and estimated remaining battery life (where available and applicable)
- Position of the equipment
- Any other comments

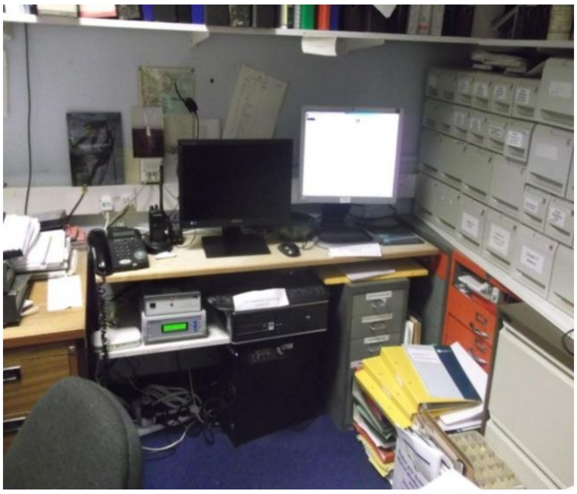
These reports are sent to Scarborough Borough Council (SBC) who act as lead authority for the Northeast regional area known as Coastal Cell 1. The reports contain a list of client owned stock which were used on deployment in the field. SBC have an agreement with the Channel Coastal Observatory (CCO) for spares and stock replenishment where SBC will replace items used during field work. This report includes both scheduled and unscheduled operations; scheduled work is included in the original contract price whereas unscheduled work is charged separately according to the unscheduled costs set out in the contract. The unscheduled work is typically a response to unforeseen issues which arise throughout the course of the project.

2. REPORTS

2.1. Scarborough shore station installation

Scarborough shore station	
Shore station location	Scarborough Town Hall
Date of site visit and staff	06/12/2012 Andrew Gowland and Catherine Boorer
Contact information of shore station site	Address: Scarborough Borough Council Town Hall, St Nicholas Street Scarborough, North Yorkshire YO11 2HG Tel: 01723 232459 Mob: 07887 708452 Email: Andy.Crossley@scarborough.gov.uk
Existing Infrastructure	A previous antenna and cable route was in situ at the Scarborough site, this was utilised where possible but the majority was replaced.
Antenna location	Roof of Town Hall, above coastal engineer's office, attached to a scaffolding pole. A new co-axial cable was fitted to the existing antenna. The new antenna is being kept as a spare at Scarborough town hall by Andy Crossley.
Computer location	Coastal Engineers Office, next to Andy Crossley's desk
Entry of cable into building	Coastal Engineers Office, through the skylight
FTP/phone lines/ADSL	Existing BT line managed by Scarborough. Static IP: 81.137.207.226 Phone number: 01723 506755 Netgear router
Working at height issues	Fall arrest points used whilst working on the roof of the building. Attachment points and PPE were compatible, enabling safe working.
Additional notes	New PC and RXC-E was set up and all software installed. A remote connection was set up between EMU and the pre-existing tide/camera computer. The tide and camera software needs to be integrated into the new computer software. A visual display will be created.

Antenna location and coaxial cable run through skylight



Computer location with new monitor on left and pre-existing monitor on right

2.2. Whitby shore station installation

Whitby shore station	
Shore station location	NYCC Area 3 depot
Date of site visit and staff	05-07/12/2012 Andrew Gowland and Catherine Boorer 08-09/05/2013 Andrew Gowland and Chloe Bodemeaid
Contact information of shore station site	Address: NYCC Area 3 depot Cholmley Way, Whitby North Yorkshire YO22 2NQ Tel: 01723 232459 Mob: 07887 708452 Email: Andy.Crossley@scarborough.gov.uk
Antenna location	East facing end of building, above the fire escape. The antenna was attached to bespoke mount installed by Fugro EMU personnel.
Computer location	Initially located in the office of John Woodhead, Northern area engineer. As of 08/05/2013 it has been relocated to main office.
Entry of cable into building	Coaxial cable runs down the exterior of the building, before entering through the wall into the office roof space. It is then routed to the computer through ducting.
FTP/phone lines/ADSL	Static IP: 81.138.8.61 Phone number: 01947 821225 Netgear router
Working at height issues	The antenna was installed using a MEWP. Much of the cable route can be inspected without working at height apparatus; however inspection of the antenna and hub will require a MEWP.
Additional notes	A new PC and RXC-E were set up and all software installed. The initial location of the computer in the office was subject to change. During the second site visit (08/05/2013) the PC was relocated and the coaxial cable was re-routed into the main office. For the installation of new Whitby tide gauge equipment at NYCC Area Depot please see report 2.6.

Antenna location and coaxial cable run

Computer location after 08/05/2013

2.3. Scarborough DWR deployment

Scarborough Directional WaveRider Buoy (DWR)		
Date of visit	17/01/2013	Scheduled
Surveyor(s)	Matthew Linham and Catherine Boorer	
Purpose of visit	DWR initial deployment	
Serial numbers	Hull: 30892 Top Plate: 70283-01 Electronics: 70283-01	
Frequency	34.6125 MHz	
Biofouling	Deployment: 0 % cover	
Paintwork	Deployment: 100 % cover	
Mooring	The DWR was successfully deployed on the licenced position with a full new mooring.	
GPS antenna	Good condition	
HF antenna	Good condition; light working, response to daylight sensor	
Triangle	Good condition	
New deployment equipment list	1 x set radar reflectors, 1 x GPS, 1 x GPS cable, 1 x HF antenna, 1 x HF cable, 1 x buoy triangle, 3 x triangle anodes, 1 x buoy chain, 1 x set chain anodes, 4 x Datawell SS shackle, 4 x large split pins, 1 x 30m mooring bungee, 1 x 29m riser line, 1 x 10Kg pellet float, 1 x 3Kg pellet float, 2 x PP terminals, 4 x small split pins, 1 x clump weight, 1 x SS clump weight chain, 45 x batteries	
Length of riser line	29 m	
Site recommendations	Mooring excursion will be monitored, and if required the riser line length will be lengthened on next service visit (The observed depth on echo sounder was 25m, deeper than charted)	
Battery voltage	24 V	
Remaining battery life	120 Weeks (Datawell estimate)	
Position	54˚17.460'N, 000˚21.000'W	
Comments	Initial deployment	

DWR being towed to deployment position


DWR within licenced position with pellet float visible

2.4. Whitby DWR deployment

Whitby Directional WaveRider Buoy (DWR)		
Date of visit	17/01/2013	Scheduled
Surveyor(s)	Matthew Linham and Catherine Boorer	
Purpose of visit	DWR initial deployment	
Serial numbers	Hull: 30891 Top Plate: 70282-01 Electronics: 70282-01	
Frequency	34.5875MHz	
Biofouling	Deployment: 0 % cover	
Paintwork	Deployment: 100 % cover	
Mooring	The DWR was successfully deployed within the licenced position with a full new mooring.	
GPS antenna	Good condition	
HF antenna	Good condition; light working, response to daylight sensor	
Triangle	Good condition	
New deployment equipment list	1 x set radar reflectors, 1 x GPS, 1 x GPS cable, 1 x HF antenna, 1 x HF cable, 1 x buoy triangle, 3 x triangle anodes, 1 x buoy chain, 1 x set chain anodes, 5 x Datawell SS shackle, 5 x large split pins, 2 x 15m mooring bungees, 1 x 26m riser line, 2 x 10Kg pellet floats, 1 x 3Kg pellet float, 2 x PP terminals, 4 x small split pins, 1 x clump weight, 1 x SS clump weight chain, 45 x batteries	
Length of riser line	26 m	
Site recommendations	None	
Battery voltage	24 V	
Remaining battery life	120 Weeks (Datawell estimate)	
Position	54°30.301’N, 000°36.451’W	
Comments	A navigational buoy is positioned on the edge of the licenced square	

DWR deployed on site

Proximity of DWR to navigational buoy

2.5. Newbiggin shore station installation

Newbiggin shore station	
Shore station location	Newbiggin Maritime Centre
Date of site visit and staff	07-10/05/2013 Andrew Gowland and Chloe Bodemeaid 20/06/2013 Andrew Gowland and Catherine Boorer
Contact information of shore station site	Address: Newbiggin Maritime Centre Church Point Newbiggin by the Sea Northumberland NE64 6DB Tel: 01670 811 951 / 01670 819 251 Contact: Trevor Bell
Antenna location	Eastern end of building, attached to the roof access ladder cage. It can easily be accessed using the roof latter.
Computer location	In plant room of centre, on upper level
Entry of cable into building	Through southeast facing roof wall into plant room
FTP/phone lines/ADSL	Static IP: 81.134.11.68 Phone number: 01670 853 072 Netgear router
Working at height issues	None
Additional notes	New PC and RXC-E were set up and all software installed. During site visit on 20/06/2013 a display screen was installed in the centre. Five Cat 5e cables were run from plant room to main office downstairs (approx. 35 m). 1. Internet connection 2. Display screen 3. RXCE data cable 4. For Newbiggin Maritime Centre 5. For Newbiggin Maritime Centre

Antenna location

Plant room - Computer location

2.6. Whitby tide gauge installation

Whitby tide gauge	
Tide gauge location	Whitby Fish Market – unit 5/7, Pier Road, Whitby, North Yorkshire, YO21 3PU
Date of site visit and staff	08-09/05/2013 Andrew Gowland and Chloe Bodemeaid
Works completed	Prior to Fugro EMU staff arrival, the Valeport TideMaster transducer, stilling well and fish market antenna were installed by SBC personnel. 08/05/2013 – Tide gauge installation: Survey staff drilled a coaxial cable entry hole into the upper floor of Whitby Fish Market building. A new PC, Valeport telemetry and tide gauge unit were set up and initial tide readings were observed. Shore station: A UHF receiving antenna was installed on NYCC Area 3 depot building and two coaxial cables routed through first floor wall. The shore station computer was relocated from corner office to main office upon request from SBC. Cavity filler was applied to all exposed drilled areas. 09/05/2013 – The tide gauge computer software was showing the expected tidal curve at the Fish Market shore station on the local display however a telemetry problem was suspected as the full data set not sending to the NYCC depot. Valeport assistance was received on site and a change of set up improved data telemetry temporarily.
Antenna location	Attached to outer wall of second floor
Computer location	Second floor, Harbour Watch office, separate room on the right.
Entry of cable into building	The cable was routed through the wall into the upper floor of the Harbour Watch office.
Additional notes	There is approximately 30 m of excess coaxial cable on the tide gauge site which could be cut back on next visit but the transducer will need re-levelling. There are on-going problems with the TideMaster. Valeport troubleshooting led to a final decision in August 2013 for a full site reinstall with Valeport providing replacement parts (temporarily). Proposed install in September 2013.

UHF Antenna location

Stilling well showing cable for transducer

Computer location

2.7. Scarborough DWR service

Scarborough Directional WaveRider Buoy (DWR)				
Date of visit	10/06/2013		Scheduled	
Surveyor(s)	Matthew Linham and Ralph Bostock			
Purpose of visit	Scheduled service and relocation to new position			
Serial numbers	Hull: 30892 Top Plate: 70283-01 Electronics: 70283-01			
Frequency	34.6125 MHz			
Biofouling	Recovery: 80% cover		Redeployment: 5% cover	
Paintwork	Recovery: 100% cover		Redeployment: 100% cover	
Mooring	The full mooring inclusive of riser rope and clump weight was recovered aboard in order to allow relocation of the buoy at an amended location. All components appeared to be in good condition and were cleaned before redeployment.			
GPS antenna	Good condition; new style			
HF antenna	Good condition; light working, response to daylight sensor			
Triangle	Good condition; no signs of water ingress			
List of spares used/components replaced	Scarborough owned: 1 x 48 m riser rope CCO owned: 2 x triangle anodes, 4 x small split pins, 3 x large split pins			
Length of riser line	48 m			
Site recommendations	Fugro EMU have notified MMO that buoy has now been relocated to the new site.			
Battery voltage	Total: 19.8 V	A: 20.0 V	B: 24.0 V	C: 24.1 V
Remaining battery life	110 Weeks (Datawell estimate)			
Position	54˚17.605’N, 000˚19.082’W			
Comments	None			

DWR on board prior to cleaning and service

DWR and full mooring on board prior to redeployment

2.8. Whitby DWR service

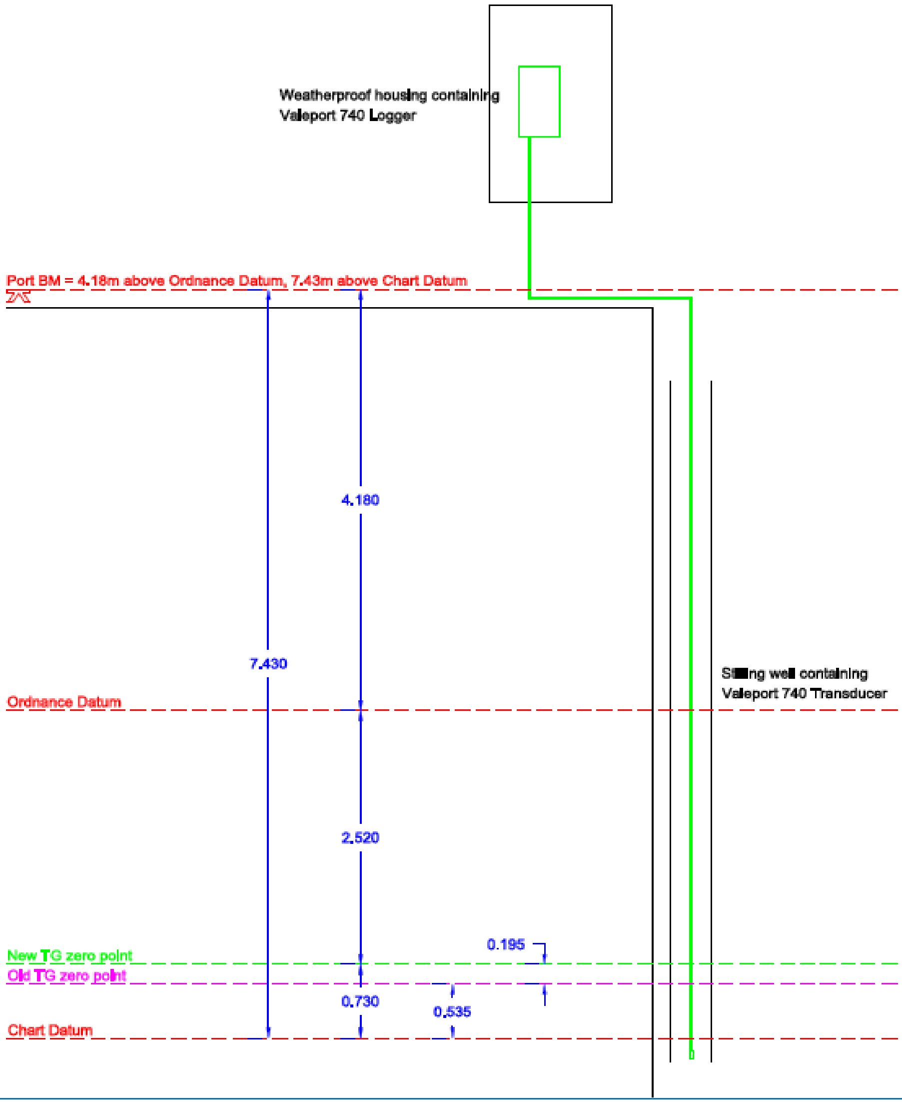
Whitby Directional WaveRider Buoy (DWR)				
Date of visit	10/06/2013		Scheduled	
Surveyor(s)	Matthew Linham and Ralph Bostock			
Purpose of visit	Scheduled service			
Serial numbers	Hull: 30891 Top Plate: 70282-01 Electronics: 70282-01			
Frequency	34.5875 MHz			
Biofouling	Recovery: 80% cover		Redeployment: 2% cover	
Paintwork	Recovery: 100% cover		Redeployment: 100% cover	
Mooring	Both 10 kg pellet floats visible upon arrival on site, indicating an untangled mooring. Both 15 m bungees and 10 kg pellet floats recovered on board and cleaned. All components appear to be in good condition.			
GPS antenna	Good condition; new style			
HF antenna	Unresponsive to daylight sensor so antenna replaced			
Triangle	Good condition; no signs of water ingress			
List of spares used/components replaced	CCO owned: 2 x large split pins, 1 x HF antenna			
Length of riser line	26 m			
Site recommendations	None			
Battery voltage	Total: 20.0 V	A: 20.2 V	B: 24.0 V	C: 24.0 V
Remaining battery life	110 Weeks (Datawell estimate)			
Position	54˚30.301'N, 000˚36.451'W			
Comments	HF antenna was sent to Datawell and found to have a crack in the light housing which needed to be replaced/repaired. Possible cause: Adrift incident impact.			

DWR on board prior to cleaning and service

DWR redeployed on position with both pellet floats visible

2.9. Scarborough tide gauge

Scarborough tide gauge	
Tide gauge location	OS: 504898E 488622N WGS84: Latitude: 54° 16.950'N Longitude: 00° 23.417'W Tide gauge logger unit and transducer located beneath Scarborough Port Control Office
Date of site visit and staff	12/06/2013 – 13/06/2013 Ralph Bostock and Matthew Linham
Works completed	The site was surveyed on 13th June 2013 to level the transducer to existing benchmarks. The weight attached to the transducer was immobile, preventing the transducer from being recovered and fully surveyed. Due to the stationary transducer and offsets applied directly to the tide gauge, it was not possible to determine the exact location of the transducer at the time of survey. As a result, the tide gauge was calibrated by undertaking tidal dips over consecutive high and low waters, comparing the results to local benchmarks. The results of the survey proved that the previously applied offset of 0.535m is no longer valid, likely due to movement of the transducer during the past 10 years. An increase of 0.195m has been applied to the offset as a result of the on-site tidal dip calibration. The new offset applied to the data is 0.730m. This offset brings the data back in line with predictions created through the harmonic analysis of the data from 2003 and also predictions created from the Admiralty harmonic constants for Scarborough.



Antenna location	Roof of Scarborough Port Control Office
Computer location	The local PC is located in the Port Control Office. Data is then telemetered to the shore station located at Scarborough Borough Council, in the office of Andy Crossley, from where it is uploaded to the internet.
Additional notes	The tide gauge bench mark used is = 4.18m above Ordnance Datum Newlyn. This is located on the flush bracket 25cm above ground on the Eastern face of the NE corner of the building. This is on the SW side of the Western slipway of the inner harbour (54° 17.023'N, 00° 23.550'W).

Port benchmark used to level in tide gauge

Stilling well for transducer

2.10. Whitby DWR AWOL

Whitby Directional WaveRider Buoy (DWR)	
Date of works	19/06/2013
Surveyors	Ralph Bostock and Philip Bishop
Purpose of works	Response to drifting DWR warnings – aim to locate and recover
Work done/completed	19/06/2013: Out of range warnings were received from the Whitby DWR starting at 08:30 GMT. A local vessel was mobilised to depart at 13:00 to recover the buoy. While mobilising, another local vessel that had previously been contacted by Fugro EMU sighted the AWOL DWR approximately 4 nm SW of its deployed position, and were subsequently contracted to bring the buoy in to Whitby Harbour. The buoy was lifted out onto the fish dock and secured until redeployment.
Comments	Further investigation using AIS revealed that a fishing vessel had been in the location of the DWR at the same time of the AWOL (see AIS track for 09:28 BST).

2.11. Newbiggin DWR deployment

Newbiggin Directional WaveRider Buoy (DWR)		
Date of visit	20/06/2013	Scheduled
Surveyor(s)	Andrew Gowland and Catherine Boorer	
Purpose of visit	DWR initial deployment	
Serial numbers	Hull in: 30893 Top Plate in: 70284-01 Electronics in: E70284-01	
Frequency	35.2875 MHz	
Biofouling	Deployment: 0 % cover	
Paintwork	Deployment: 100 % cover	
Mooring	A full mooring was deployed on site.	
GPS antenna	Good condition	
HF antenna	Good condition; light working, response to daylight sensor	
Triangle	Good condition	
New deployment equipment list	Scarborough owned: 1 x set radar reflectors, 1 x GPS, 1 x GPS cable, 1 x HF antenna, 1 x HF cable, 1 x buoy triangle, 3 x triangle anodes, 1 x buoy chain, 1 x set chain anodes, 6 x Datawell SS shackles, 6 x large split pins, 1 x 30m mooring bungee, 1 x 26.5m riser line, 1 x 10Kg pellet float, 1 x 3Kg pellet float, 2 x PP terminals, 4 x small split pins, 1 x clump weight, 1 x SS clump weight chain, 45 x batteries	
Length of riser line	26.5 m	
Site recommendations	None	
Battery voltage	24.0 V	
Remaining battery life	156 Weeks (Datawell estimate)	
Position	55˚11.115'N, 001˚28.709'W	
Comments	Initial deployment.	

DWR prior to deployment; mooring components visible.

DWR deployed at licenced position.

2.12. Whitby DWR redeployment

Whitby Directional WaveRider Buoy (DWR)		
Date of visit	21/06/2013	Scheduled
Surveyor(s)	Andrew Gowland and Catherine Boorer	
Purpose of visit	DWR redeployment after AWOL	
Serial numbers	Hull in: 30891 Top Plate in: 70282-01 Electronics in: E70282-01	
Frequency	34.5878 MHz	
Biofouling	Deployment: 0 % cover	
Paintwork	Deployment: 100 % cover	
Mooring	The mooring appears to have been cut at the lower bungee. A full new mooring was deployed on site.	
GPS antenna	Good condition	
HF antenna	Good condition; light working, response to daylight sensor	
Triangle	Good condition	
List of spares used/components replaced	Scarborough owned: 1 x 26m riser line CCO owned: 3 x triangle anodes, 3 x Datawell SS shackles, 4 x large split pins, 1 x 15m mooring bungee, 1 x 10Kg pellet float, 1 x 3Kg pellet float, 2 x PP terminals, 4 x small split pins, 1 x clump weight, 1 x SS clump weight chain	
Length of riser line	26 m	
Site recommendations	None	
Battery voltage	20.0 V	
Remaining battery life	106 Weeks (Datawell estimate)	
Position	54˚30.301'N, 000˚36.399'W	
Comments	DWR was re-sited within the licenced square due to fishing gear present on site.	

DWR redeployed on site within licenced area