National Network of Regional Coastal Monitoring Programmes of England

Quality Control of Wave Data

Version 1.2 August 2023

Cover photograph: Datawell Directional Waverider MkIII in Weymouth Bay

Photo courtesy of Fugro GB Marine Limited

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Quality Assurance & Quality Control of Wave Data

Version 1.2

August 2023

Version	Date	Status	Modification
1.0	01 March 2017	Final	
1.1	17 January 2022	Final	- Jump test for T_P removed - Spike test for T_P added - Thresholds for tests of data from step gauges and wave radars added
1.2	07 August 2023	Final	- Update to quality control of breaking waves

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Channel Coastal Observatory

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1. Introduction

The National Network of Regional Coastal Monitoring Programmes (NNRCMP) of England has developed a coastal wave network which concentrates on measurements in shallow water where, traditionally, there are very few long-term wave data and where the wave transformation models are generally less reliable.

The main purposes of the coastal wave network is to provide the evidence base needed for flood and coastal erosion risk management (FCERM). In more detail, the network aims to:

- Provide real-time data for use in coastal flood forecasting, warning, and beach operations
- Provide baseline design statistics for future coastal and marine planning projects
- Enable operational assistance in coastal construction projects
- Assist the monitoring of coastal processes such as beach erosion and sediment transport
- Provide validation of coastal wave hydrodynamics and sediment dynamics modelling

Quality assurance (QA) and quality control (QC) practices are in place to provide high-quality marine observations and to ensure the value and credibility of the data to users. **Quality Assurance** concerns aspects such as the choice of equipment suitable for the environment; ensuring sufficient accuracy, precision, reliability and resolution of the data; and ensuring the operational maintenance required to ensure high quality observations in the long term. **Quality Control** refers to the subsequent steps taken to review the measured data using both automated and manual techniques.

The Channel Coastal Observatory (CCO) functions as the central hub for the quality control, analysis, and dissemination of the coastal wave data measured by NNRCMP instrumentation. At the time when data collection began in 2003, no worldwide or European standard for wave data existed. This document outlines the QA practices and QC tests implemented by the CCO.

The following quality-controlled wave parameters are collected and archived:

- Significant wave height H_S (m)
- Spectrally-derived zero-crossing wave period T_Z (s)
- Peak wave period T_P (s)
- Wave direction Dir (°)
- (Directional) Spread Spd (°)
- Maximum observed wave height H_{max} (m)
- Sea surface temperature SST (C°)

The full range of parameters available from a Datawell Directional Waverider MkIII buoy, the raw buoy displacements and wave spectra are also collected and archived.

2. Quality Assurance

2.1 Wave Buoys

The regional coastal monitoring programmes operate Directional Waverider buoys (DWR) MkIII, manufactured by Datawell (Figure 1). They are moored using Datawell's shallow water mooring, which consists of 2 x 15 m bungees buoyed at each section or, at a few sites, a single 30 m bungee. GPS positions are received by a top-mounted receiver. Buoys have radar reflectors fitted, and are lit and charted.

Figure 1: Morecambe Bay DWR prior to deployment (left); Tor Bay following a scheduled service (right). Photos courtesy of Fugro GB Marine Limited.

2.2 Step Gauges

At several sites, Etrometa step gauges have been deployed, primarily to serve as tide gauges, but non-directional wave parameters can also be obtained (Figure 2).

Figure 2: Herne Bay (left) and Port Isaac (right). Photos courtesy of Fugro GB Marine Limited.

2.3 Wave Radars

At several sites, measurements are made using a WaveRadar REX, manufactured by Rosemount (Figure 3). These are downward-looking, frequency modulated continuous wave radars which measure distance to the sea surface. As with the Etrometa step gauges, these instruments are deployed primarily to serve as tide gauges, but non-directional wave parameters are also measured.

Figure 3: WaveRadar REX at Deal Pier (left) and Sandown Pier (right). Photos courtesy of Fugro GB Marine Limited.

2.4 Data Transfer

The heave measurements of a DWR buoy are the filtered, double-integrated accelerations measured by Datawell's onboard vertical accelerometer. The sampling rate on a DWR MkIII is buoy is 3.84 Hz. Data are subsequently filtered and down-sampled to 1.28 Hz. Wave parameters are calculated over a 30 minute sampling period, every 30 minutes. Timestamping is at the start of the burst. To construct the spectrum, Fourier analysis is performed on eight consecutive blocks of 200 seconds worth of wave displacements. The resulting eight spectra are averaged on board the buoy to compute the half-hourly wave spectrum. Data is transferred from the buoy to a shore station via HF radio link. Care is taken to ensure that no other HF equipment is operating on the same frequency as the DWR receiver.

For the step gauge, burst sampling is at 2.56 Hz for 30 minutes, every 30 minutes. For the wave radars, burst sampling is at 4 Hz, also for 30 minutes, every 30 minutes, to provide measurements consistent with the wave buoys. Timestamping is again at the start of the burst.

All shore stations are equipped with a dedicated phone line and broadband with fixed IP address. Particular care is taken to ensure correct time stamping. All timestamps are recorded in Coordinated Universal time (UTC) / Greenwich Mean Time (GMT). Anti-virus software is installed on all PCs and is kept up to date with regular software upgrades. In case of failed data transfer due to external circumstances (*e.g.* power failure), the raw data can be downloaded directly from a buoy during scheduled service visits to ensure maximum data recovery.

2.5 Equipment Maintenance

Regular maintenance is required to ensure accurate data collection, including avoidance of significant bio-fouling which can gradually degrade observational accuracy. Scheduled maintenance visits are undertaken every 6 months for the DWR buoys and every 9 months for the step gauges and wave radars. In accordance with the manufacturer recommendations, the wave buoys are calibrated by the manufacturer approximately every 6 years; the radars and step gauges do not require re-calibration.

3. Quality Control

Quality control of measured data involves both automated and manual inspection. No data are removed, but poor or suspect data are flagged. As a result, users have the option of using the flags to remove data for analysis, or to undertake their own quality control. The procedures aim to apply a relatively 'light touch' in terms of QC to avoid over-flagging.

Time series are continuous and monotonic, with missing data given as "9999".

3.1 Flagging System

Each measurement is allocated a flag to indicate its quality, with a system of 9 different flags to indicate a variety of QC "failures" (Table 1).

Flag	Description
0	All data pass
1	Either H_S or T_Z fail, so all data fail (except SST)
2	T_P fail + derivatives
3	Dir fail + derivatives
4	Spread fail + derivatives
6	Re-processed due to breaking waves
7	Buoy off location
8	SST fail
9	Missing data

Table 1: Flags indicating QC test results.

3.2 QC tests

QC tests are conducted at three different stages:

- **Real-Time** Automated checks on the plausibility of incoming data
- **Monthly** Automated data flagging, plus manual review
- **Yearly** Further manual QC of annual data file

3.2.1 Real-Time

Automated checks on the incoming data are currently undertaken by the Regions' hydrodynamics contractor(s), with further automated out-of-range checks before the real-time data are viewable on the website. Measurements which fail the out-of-range checks are manually reviewed and either accepted or rejected. Rejected values are removed from the graph display, but remain in the data table.

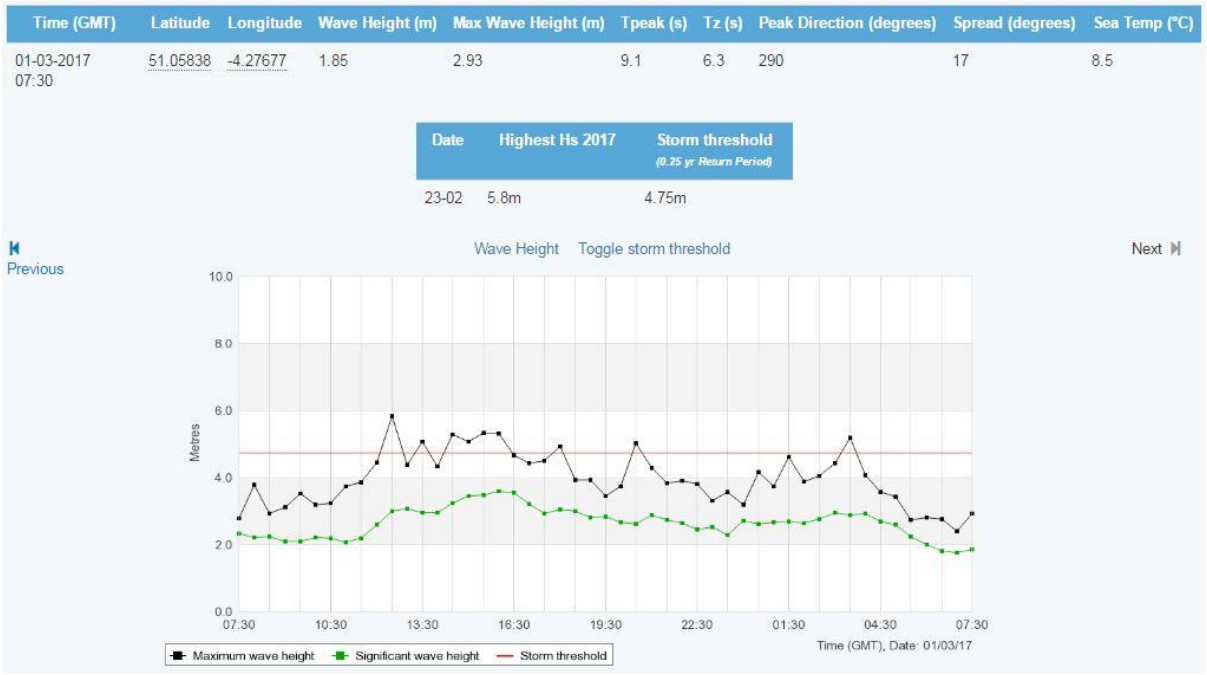

Figure 5: Real-time data display on the programme's website for Bideford Bay.

3.2.2 Monthly QC

Monthly, in arrears, the data collected from all monitoring sites undergoes the main quality control. Automated QC checks are done in reverse order of severity, so that the flag represents the most serious case of failure. Thresholds are based on historical knowledge and statistics derived from data acquired over the previous decade (Tables 2 and 3).

Note that the spike test is based on the rate of change between measurements e.g. for a 30 minute time series, the maximum change in measurement between two consecutive readings. “Spikes” are individual measurements which exceed the threshold rate of change, but where the preceding and following measurements do not exceed the threshold.

Parameter	Out of range		Spikes	Flag
	Minimum	Maximum		
Hs (m)	0	20	0.5	1
T_Z (s)	1.6	20	1	1
T_P (s)	1.6	28.6	3	2
Dir (°)	0	360		3
Spread (°)	0	90	45	4
SST (°C)	-5	35	1	8

Table 2: Parameters and tests for DWR data with thresholds and associated flags.

Parameter	Out of range		Spikes	Flag
	Minimum	Maximum		
Hs (m)	0	10	0.5	1
T_Z (s)	1.6	20	2.5	1
T_P (s)	1.6	28.6	3	2

Table 3: Parameters and tests for step gauge and wave radar data with thresholds and associated flags.

Following automated QC, measurements are viewed manually to check whether data has been justifiably flagged or whether suspect data were missed. Given that many of the wave buoys are located in shallow water (~10 m CD) and subject to swell, particular attention is paid to T_P which is sensitive to over-flagging by the automated system (Flag 2). When a buoy has come adrift, out-of-position but plausible data are flagged manually (Flag 7). H_{max} is also flagged manually if required. Measurements are also compared with data from adjacent sites to check the feasibility of exceptional measurements and as a quick check against drift in timestamping of the data.

Severe wave conditions undergo further checks, including inspection of the raw (1 Hz) displacement data in case the wave parameters have been corrupted by breaking waves (Figure 6). Where data has been corrupted, an effort is made to remove the erroneous heaves from the raw data and to re-process the record to produce wave parameters from the remaining unaffected waves (Dhoop *et al.* 2023). Re-processed parameters are assigned the quality control flag 6.

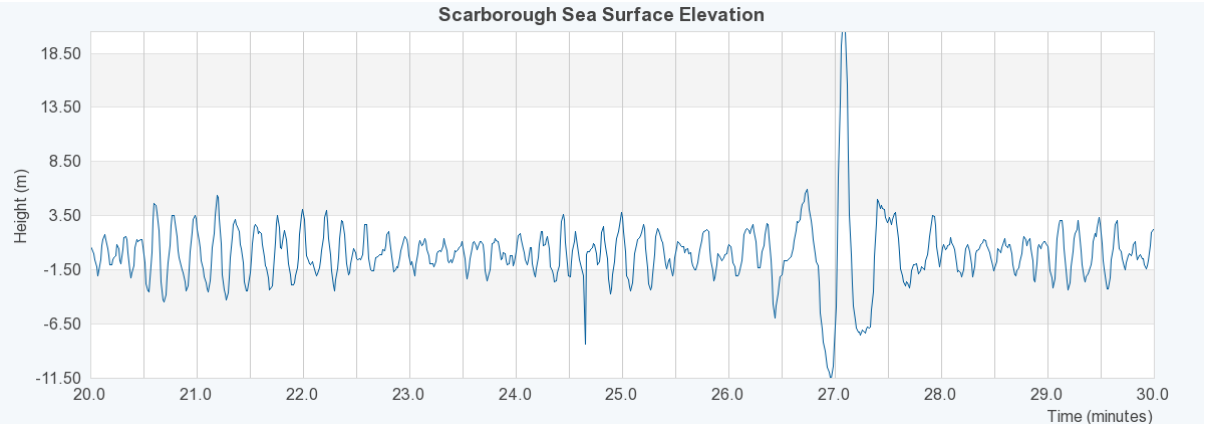

Figure 6: Ten-minute trace of 1 Hz data from the Scarborough buoy. The spike between minutes 24 and 25 is the moment of shock to the accelerometers, leading to the apparent long and high wave artefact approximately two minutes after the initial shock.

3.2.3 Annual QC

Annually, all measurements undergo a final visual check for gaps and spikes in H_S, T_P, Dir, H_{max} and SST (Figure 7). This annual QC regime allows for the boundaries between months to be checked.

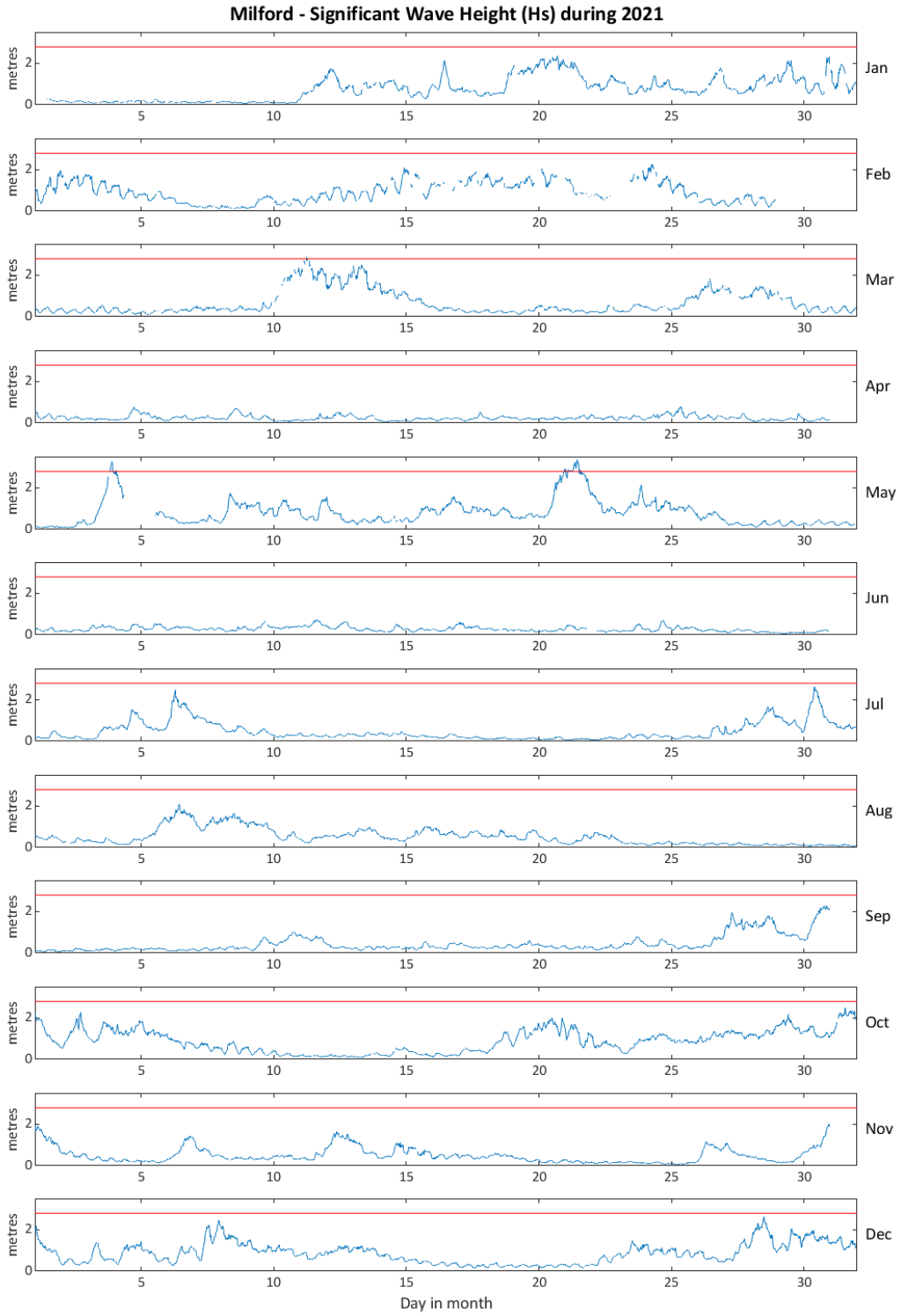

Figure 7: Quality-controlled H_S measurements at Milford during 2021. The red line indicates the storm threshold at this site at 2.79 m.

4. Data Dissemination

Wave data is made freely available via the coastal monitoring programmes' website:

- Real-time data viewer (out-of-range quality control only)
  https://coastalmonitoring.org/realtimedata/

- Real-time data provision via API
  https://coastalmonitoring.org/ccoresources/api/

- Monthly and annual files containing quality checked wave parameters and full metadata can be downloaded from the real-time data page of each individual wave buoy site.

- Monthly and annual files containing the non-quality checked full data output from a Datawell Directional Waverider MkIII buoy.

- Raw displacement data and wave spectra files can be downloaded from the real-time data page of each individual wave buoy site.

- Annual reports containing statistical analysis of quality-controlled data
  http://coastalmonitoring.org/reports/

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Acknowledgements

The procedures given in this document were originally developed from the CEFAS WaveNet QA/QC procedures (2003). Many of the procedures currently in use have been refined in partnership with Fugro GB Marine Limited.