Enhancing Storm Wave Data

Advancements in the quality control of heave data from wave buoys

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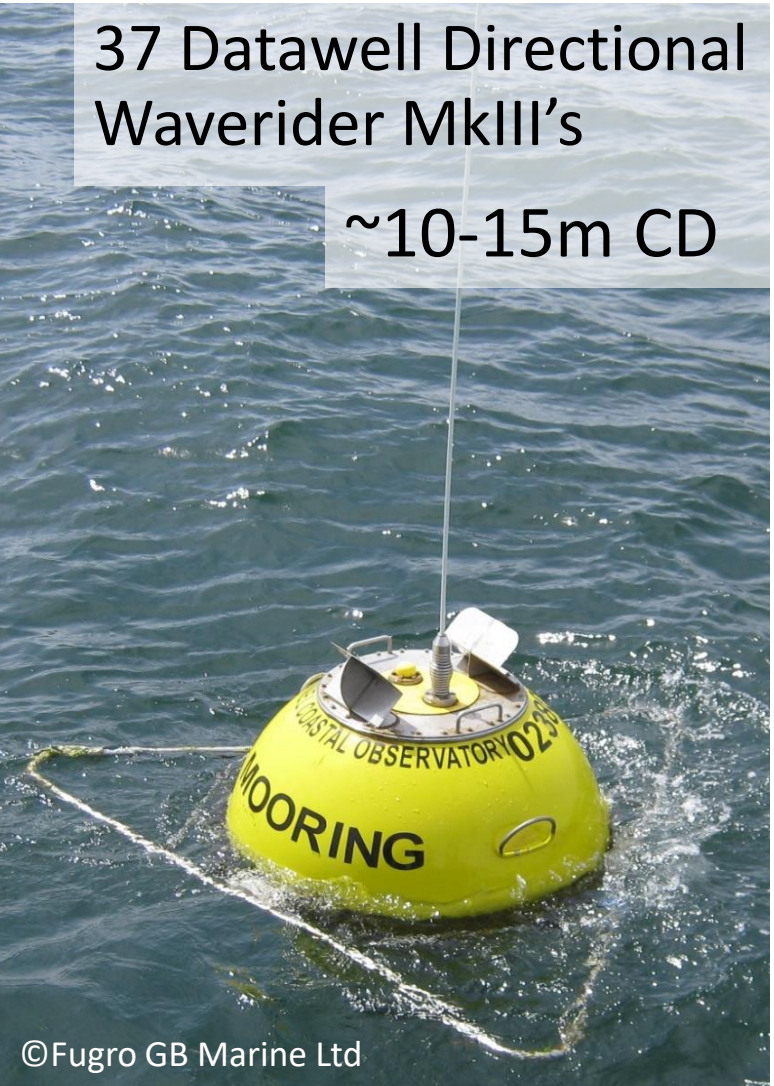
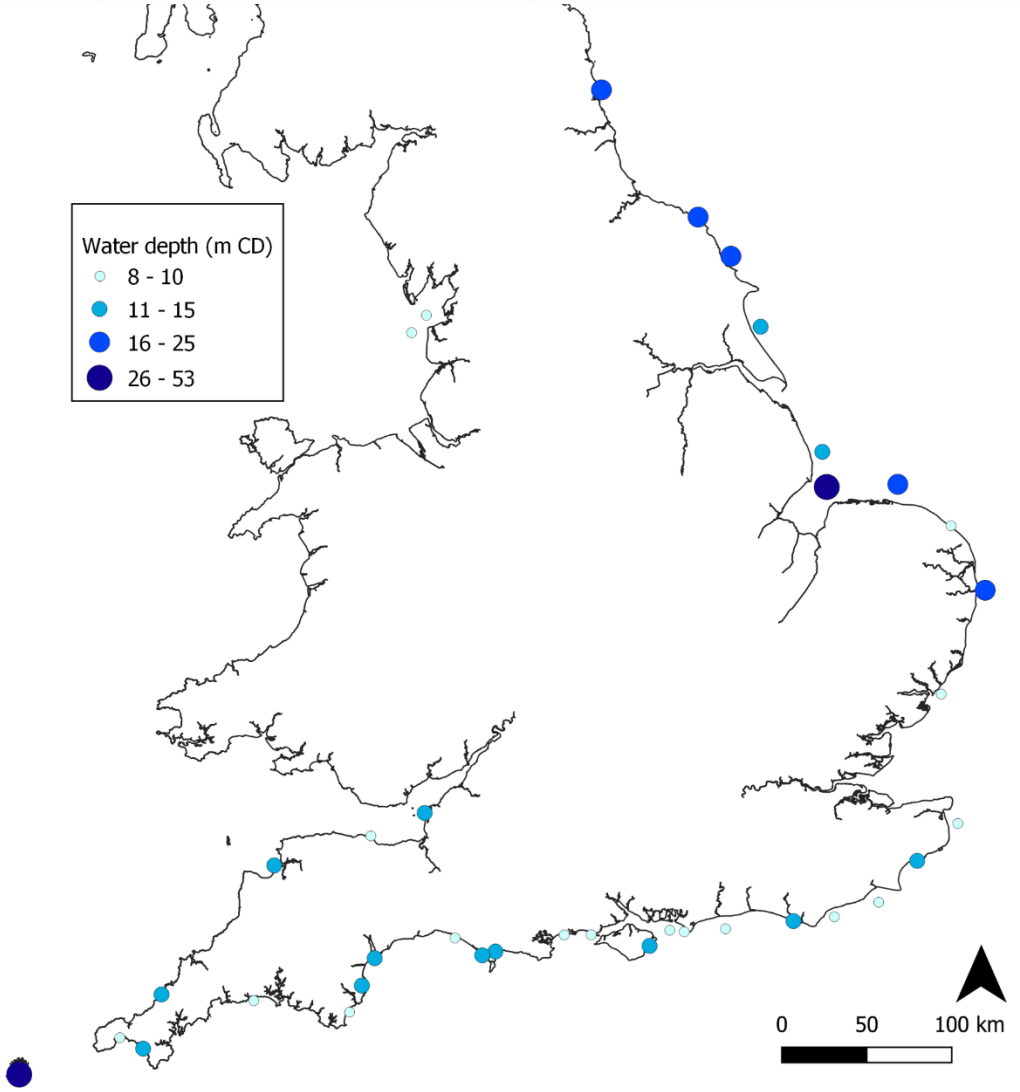
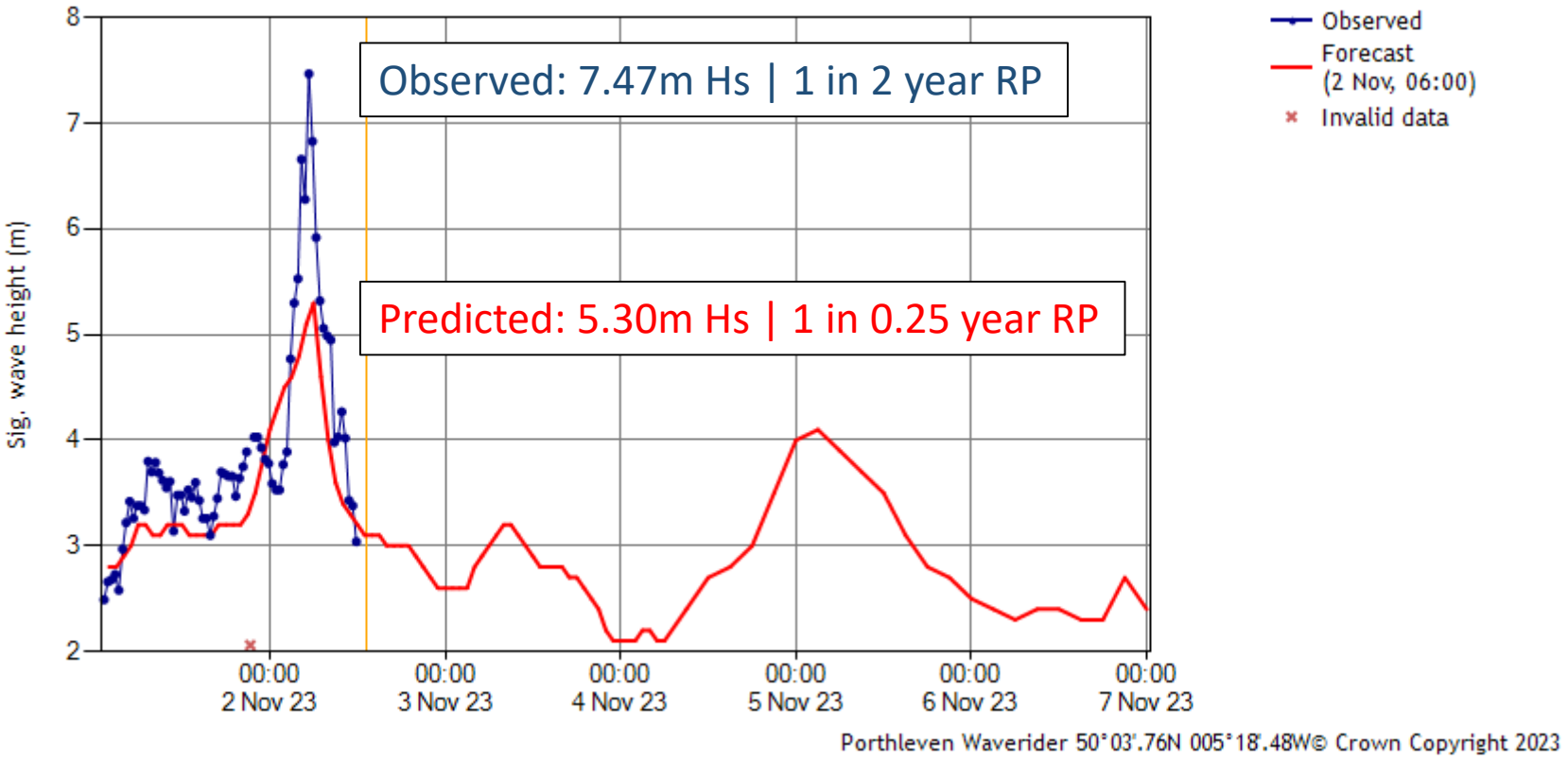
Coastal Wave Buoy Network





Coastal Wave Buoy Network

Porthleven – 02 Nov 2023 (Storm Ciarán)



Coastal Wave Buoy Network

Purposefully a coastal network:

1. Deployed in locations where, historically, high-quality long-term wave measurements were not available
2. Locations where, to this day, wave modelling efforts struggle

➔ Real value in measuring in a coastal environment

But also real challenges… one of these being buoys becoming caught in the surf zone during storm events

18 February 2022 Storm (Eunice)

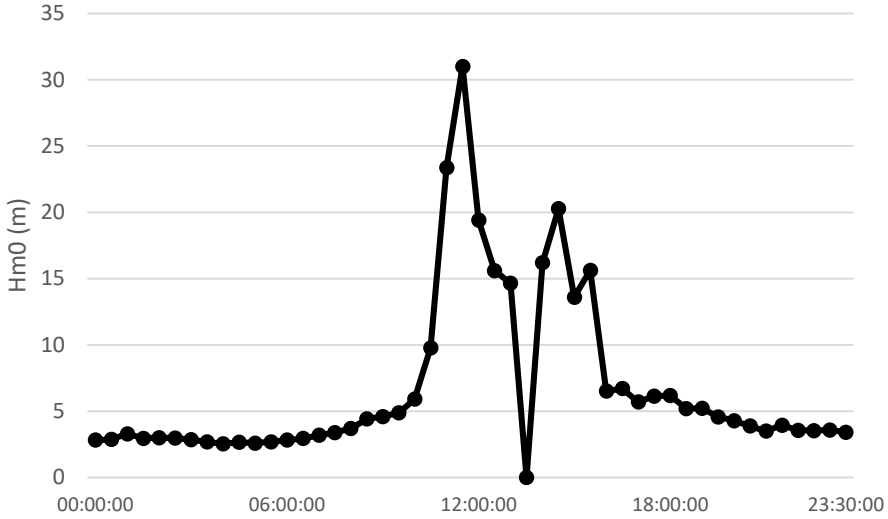
Isles of Scilly

Questions were asked about wave measurements by SW RCMP buoys during extreme events…

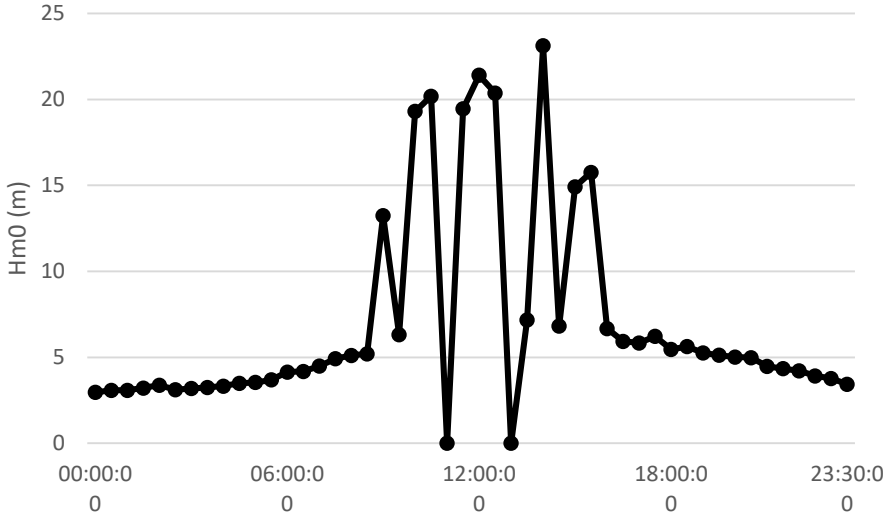
St Martins Stores and Post Office

18 February 2022 Storm (Eunice)

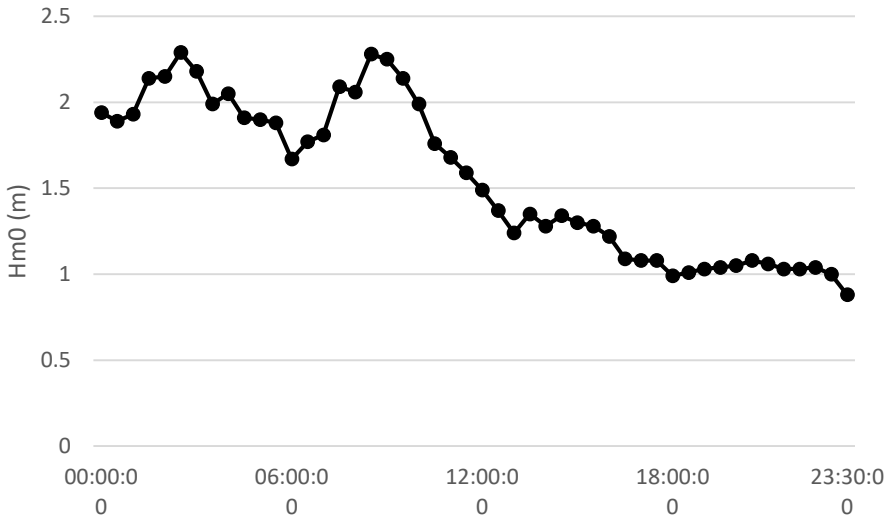
Bideford Bay - No Quality Control



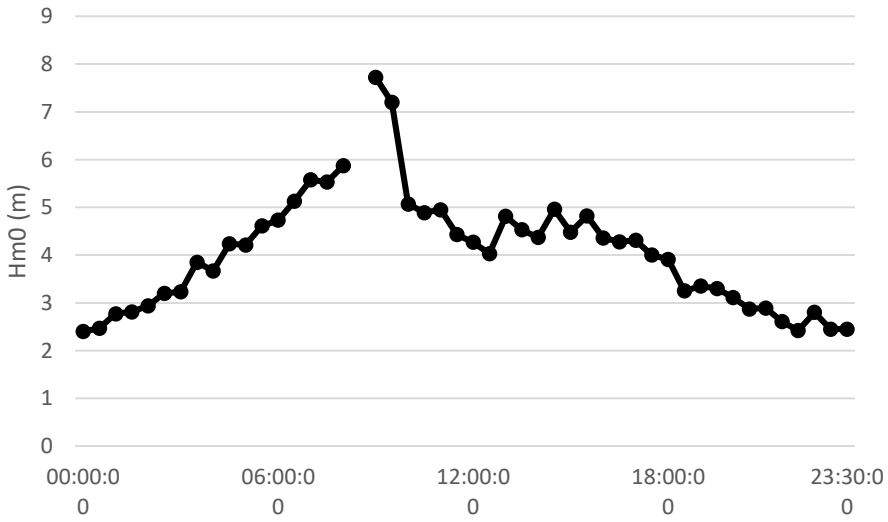
Perranporth - No Quality Control



Penzance - No Quality Control

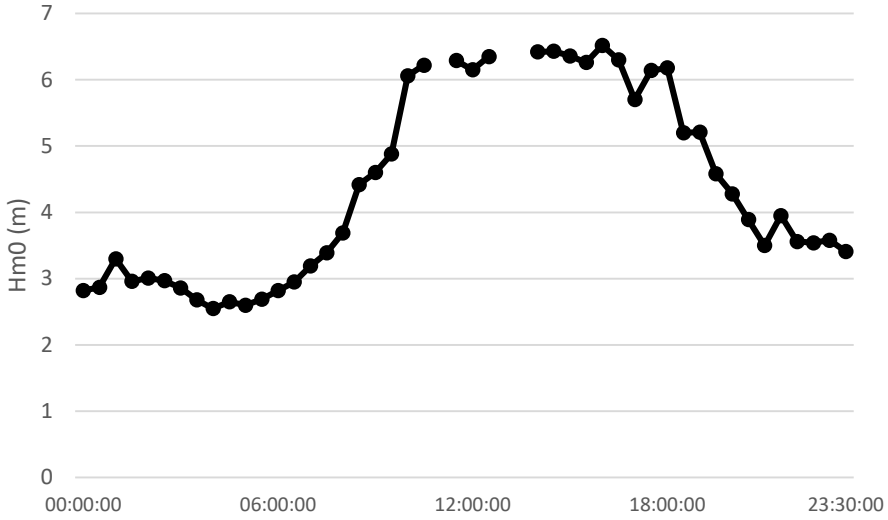


Porthleven - No Quality Control

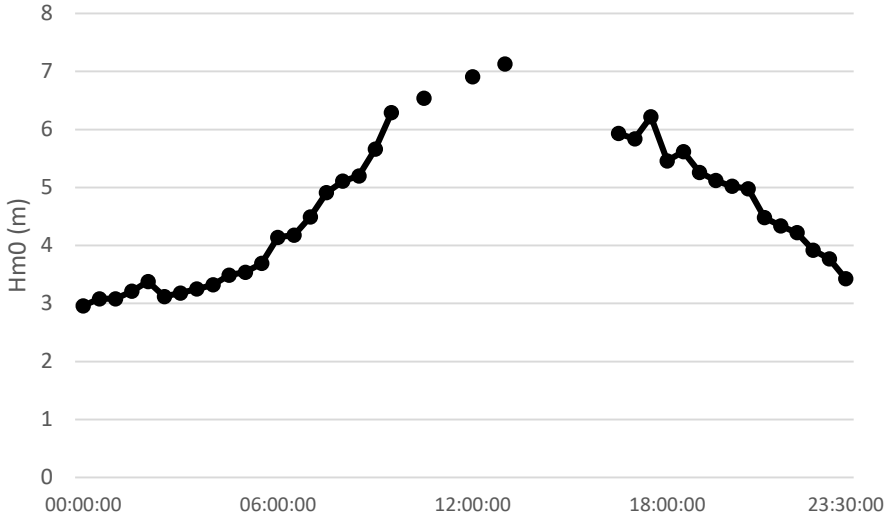


18 February 2022 Storm (Eunice)

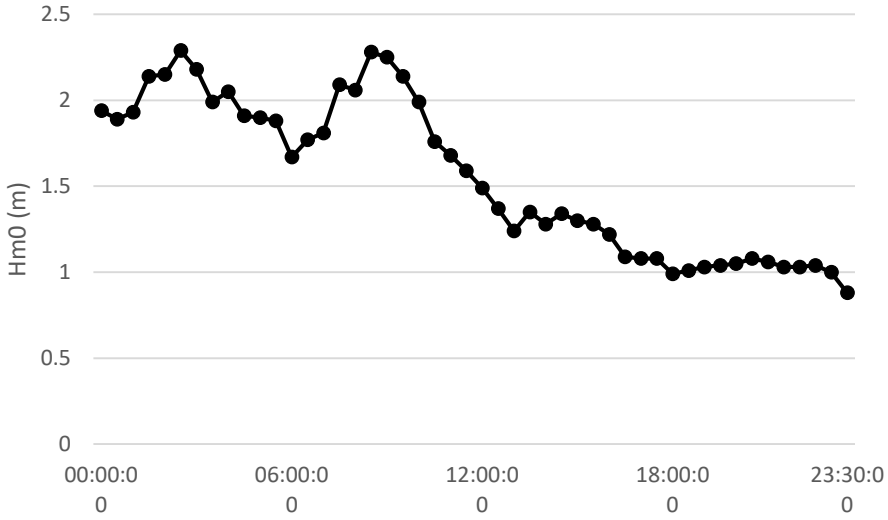
Bideford Bay - New Quality Control Approach



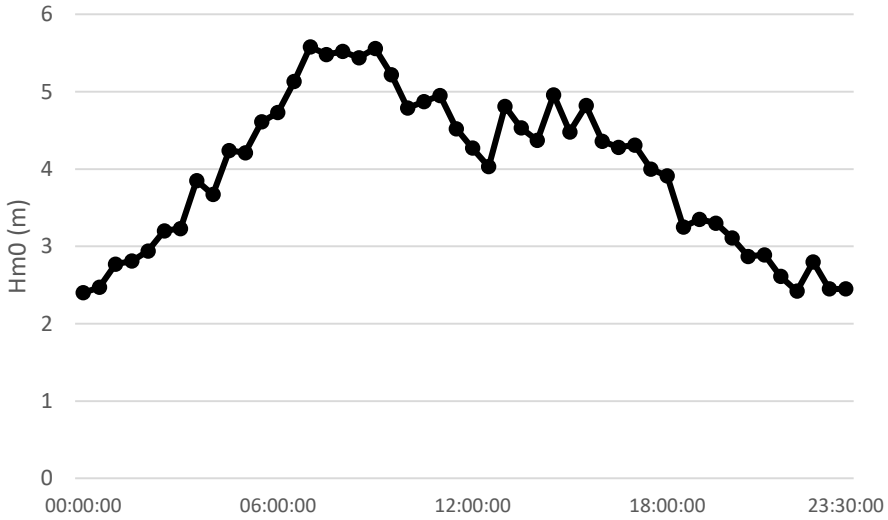
Perranporth - New Quality Control Approach



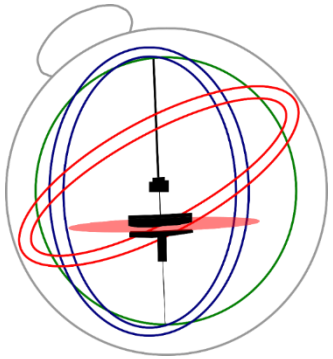
Penzance - No Quality Control



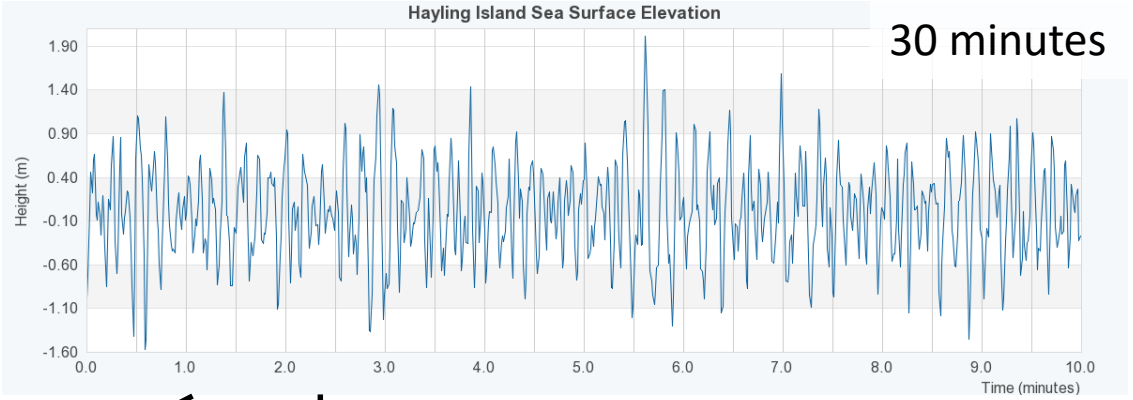
Porthleven - New Quality Control Approach



Measuring Waves

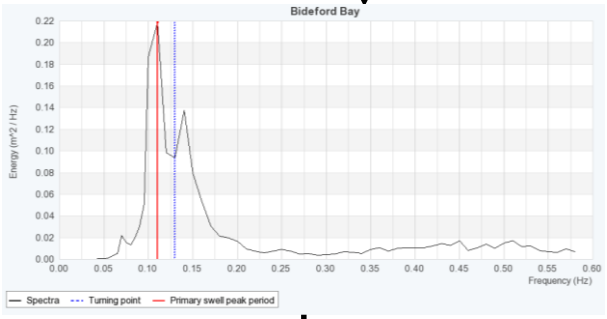


$$a(t) \rightarrow \int a(t)\,dt = v(t) \rightarrow \int v(t)\,dt = h(t)$$



Fast-Fourier Transform
Time ➔ Frequency domain

Application of simple statistics



Statistical wave parameters:

- Significant wave height $H_{1/3}$
- Maximum wave height H_{max}
- Mean wave height H_{av}
- Mean wave period T_{av}

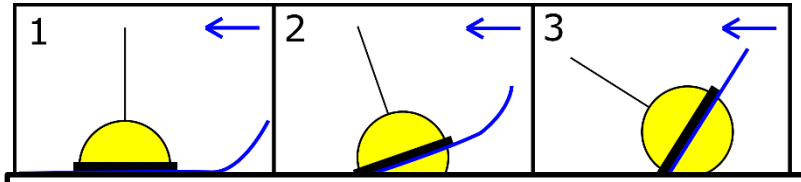
$$m_n = \int_0^\infty f^n E(f) df$$

Spectral wave parameters:

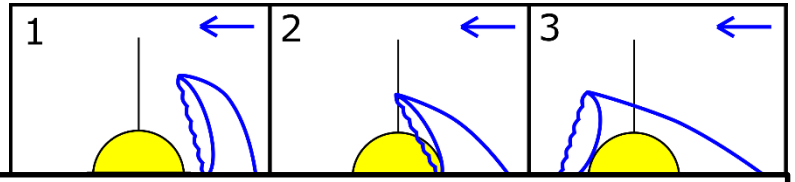
- Significant wave height H_{m0}
- Zero-upcr. period T_{m02} | T_z
- Peak period T_p
- Energy period T_{m-10} | T_e
- Peak wave direction
- Spread

Measuring Breaking Waves

Incipient breaker



Spilling breaker



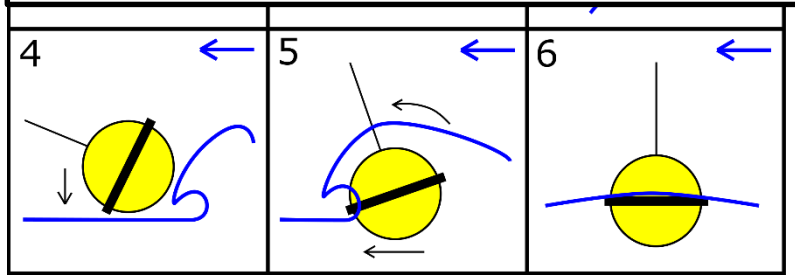
Practically….

Datawell MkIII samples the sea surface at 3.84Hz, converted to 1.28Hz

➔ All anomalous movements to which the buoy is subjected result in the same large acceleration to the instrument's sensor.

ult in

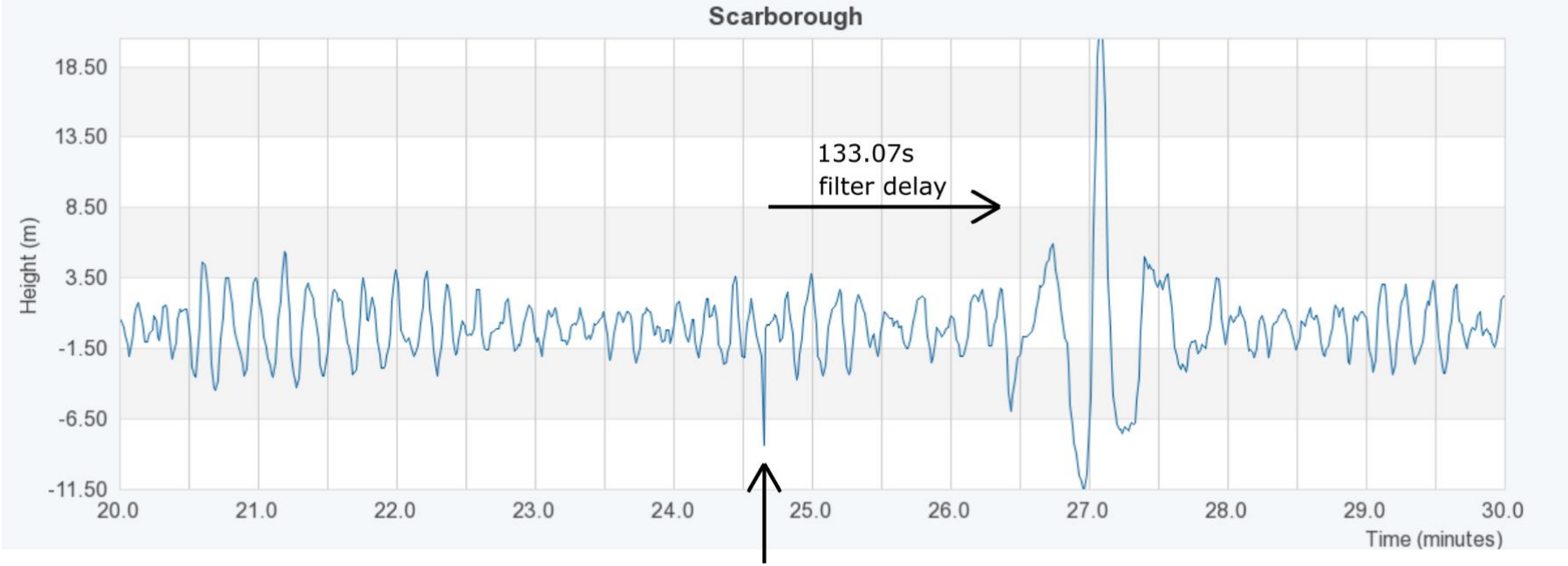
plode



upward after being submerged by a spilling breaker, or enter a moment of free-fall as it is thrown by a plunging breaker and subsequently re-enters the sea.

Measuring Breaking Waves

The result is a recognisable signature in the heave data:
One or more individual spikes followed by a very large and long wave trace approximately two minutes later



Measuring Breaking Waves

Performing spectral analysis on a 30-minute record of heave data containing one or more breaking wave ‘signatures’ results in a spectrum with a large and anomalous amount of long-period energy peaking at 22.2 seconds

Deriving any wave statistics from these heaves or this wave spectrum would clearly result in erroneous wave parameters

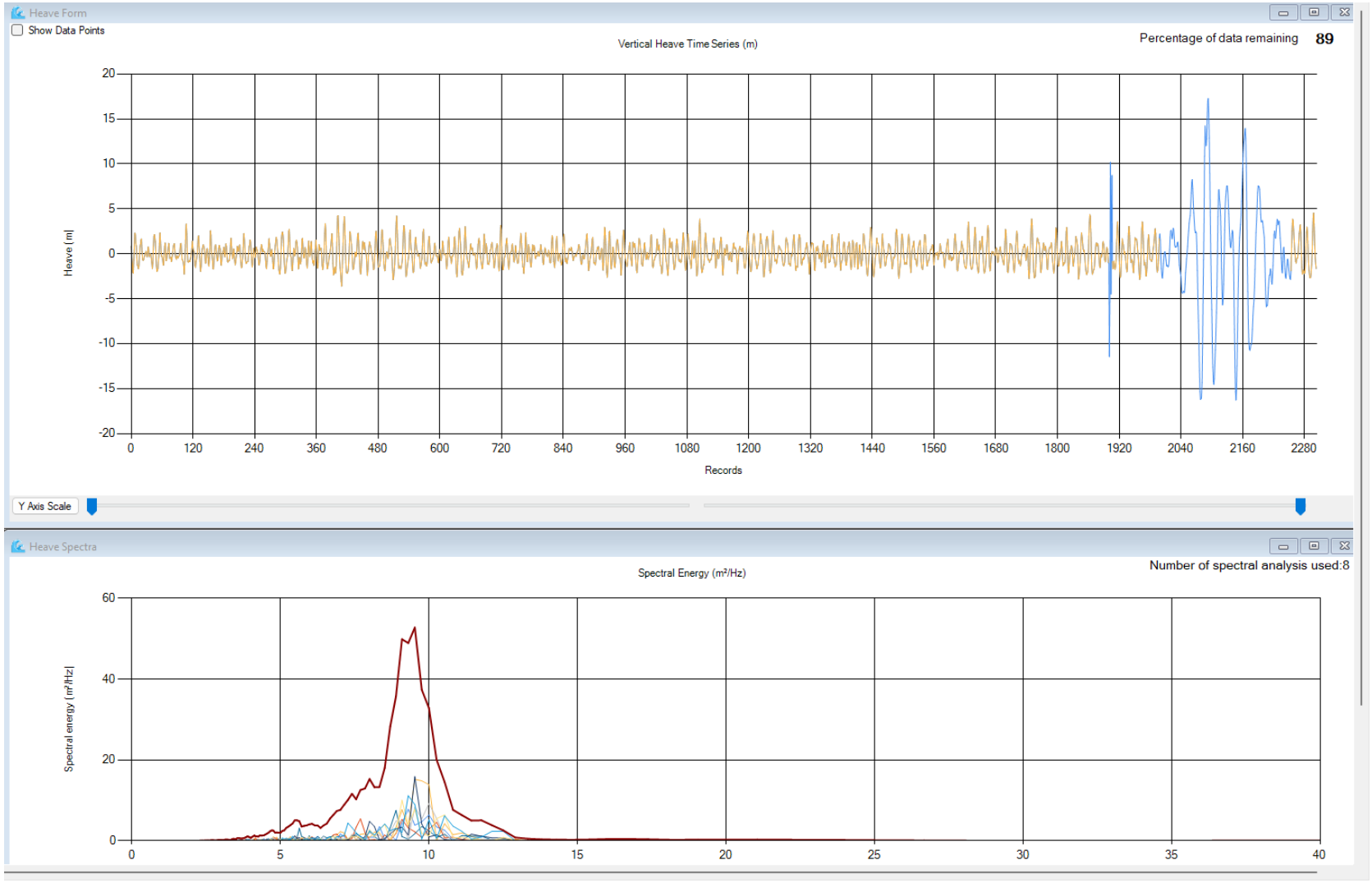
QC of Breaking Waves

➔New approach to quality control of heave data affected by breaking waves:

Remove erroneous heaves from raw data records and re-process each wave record to produce a number of statistical and spectral wave parameters from the remaining unaffected waves

Aim: Retain (and recover) as much storm data as possible

QC of Breaking Waves



QC of Breaking Waves

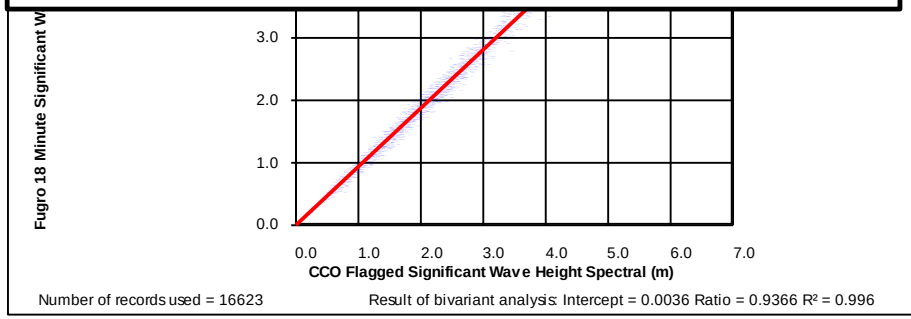
To validate the new approach, we established that…

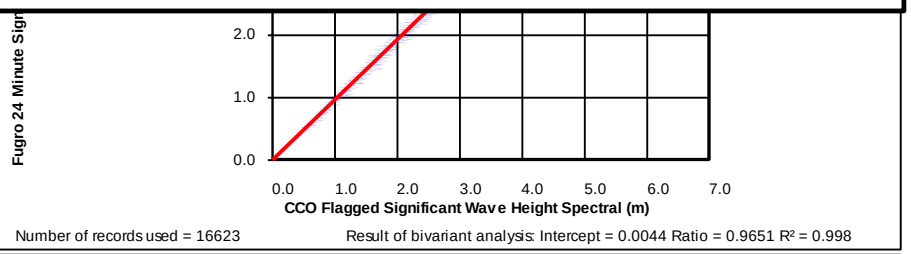
1) The wave processing applied by CCO matches the wave processing of a Datawell DWR MkIII buoy
2) Wave parameters derived from shortened wave records are very similar to those calculated from a complete 30-minute set of heaves

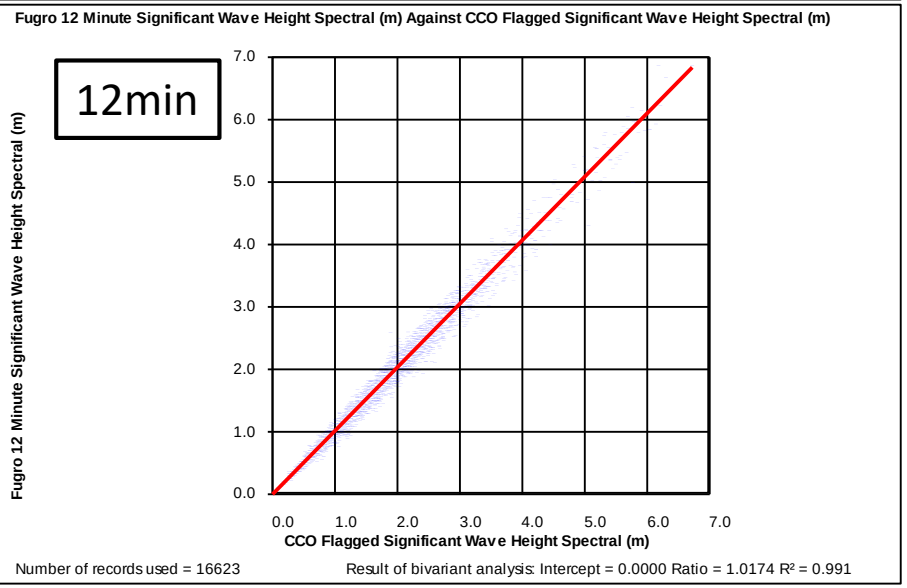
Spectral processing	**CCO**	**Datawell MkIII**
Record length	2304	2048
Method	Welch (512*9)	Bartlett (256*8)
Resolution	100 bins	64 bins

➔ By maximising the subsample length, CCO aims to provide a more robust spectrum from the available data

Approach taken is much closer to Datawell DWR4 processing





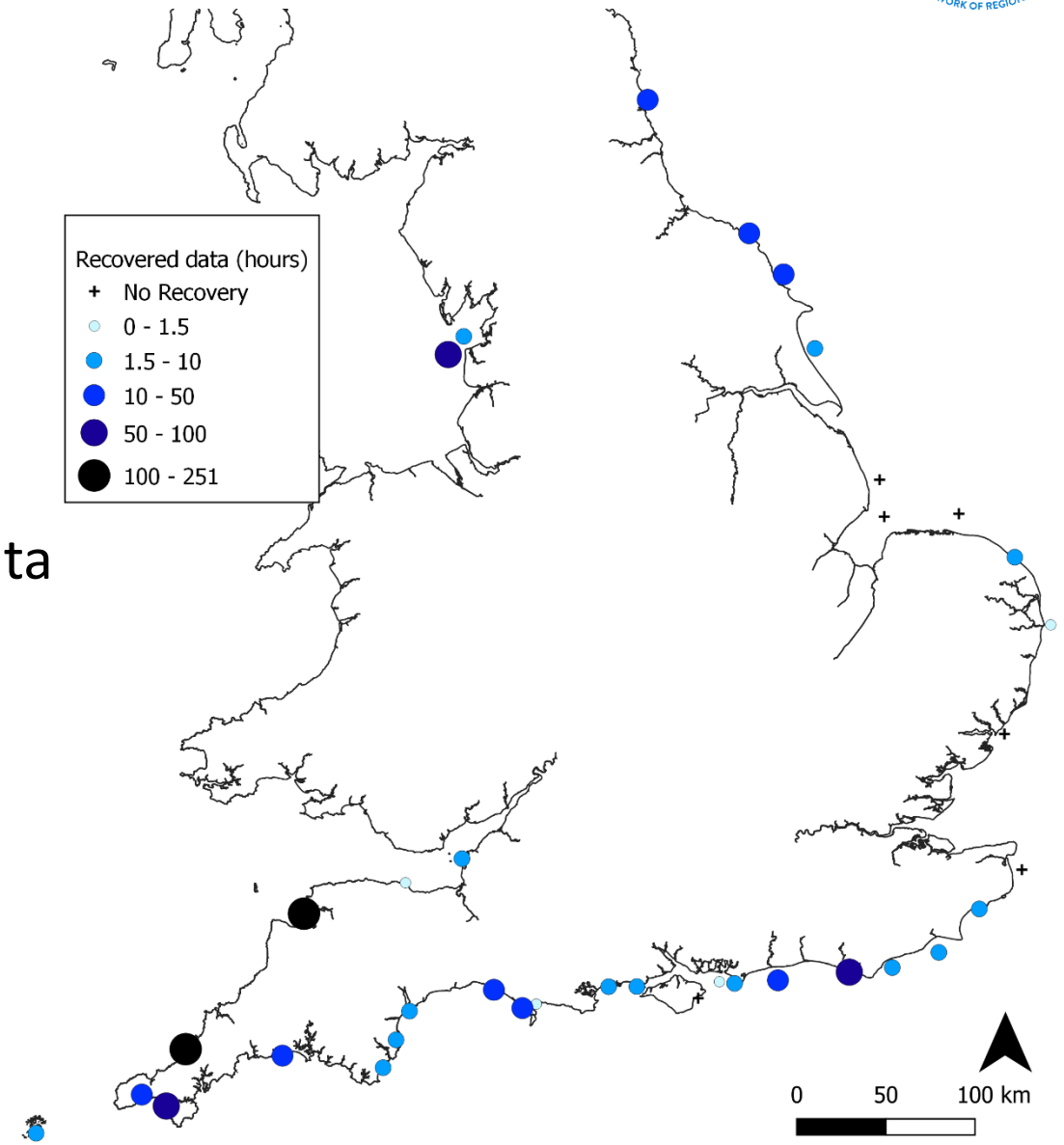


Re-Processing Storm Waves

928.5 hours of storm wave data recovered

Introduction of flag 6 to identify re-processed data

Original data in ‘allwaveparameter’ files



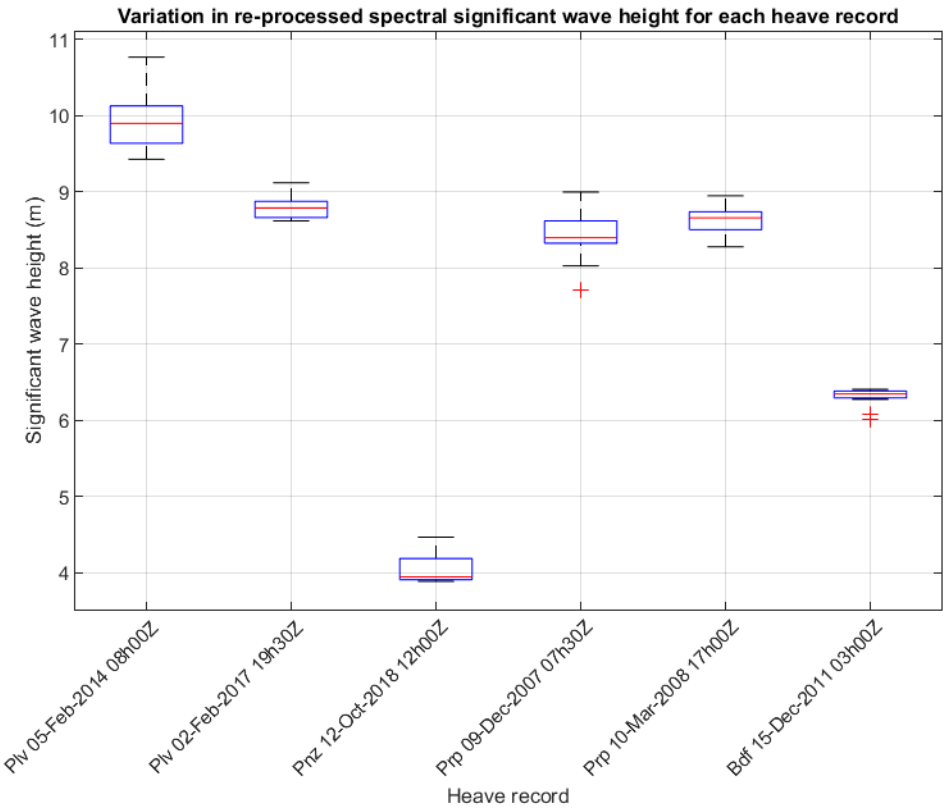
Re-Processing Storm Waves

- Current setup requires manual intervention in the heave records

➔ Sensitivity analysis to assess the variability in the wave parameters that result from the subjective interpretation of a heave record

Test setup:

- 19 coastal process scientists
  - Across two separate teams
  - Range of wave analysis expertise
- Each processed six Heave records
  - Chosen to maximise variability
- Identical methods
  - Same software
  - Same set of procedures



Re-Processing Storm Waves

- Current setup requires manual intervention in the heave records

➔ Sensitivity analysis to assess the variability in the wave parameters that result from the subjective interpretation of a heave record

- Minimum variation: 6%
- Maximum variation: 15%
  - Pnz: diff. of 0.58m Hs (diff. between 1 in 0.25 and 1 year return period)
  - Plv: diff. of 1.34m Hs (diff. between 1 in 10 and 20 year return period)

➔ Differentiator is how much data is removed at the extremities of the large anomalous heave signals

- Four coastal scientists had formal training or extensive experience in wave processing.
- Maximum variation between them was 6%.

Record:	Porthleven		Penzance	Perranporth		Bideford
	05-Feb-2014 08h00Z	02-Feb-2017 19h30Z	12-Oct-2018 12h00Z	09-Dec-2007 07h30Z	10-Mar-2008 17h00Z	15-Dec-2011 03h00Z
Hs Max	10.77	9.12	4.47	9.00	8.95	6.41
Hs Mean	9.95	8.80	4.06	8.44	8.63	6.32
Hs Median	9.90	8.79	3.95	8.40	8.66	6.35
Hs Min	9.43	8.62	3.89	7.72	8.28	6.01
Range	1.34	0.50	0.58	1.28	0.67	0.40
Std. Dev.	0.37	0.14	0.17	0.28	0.18	0.10
Range relative to median	14%	6%	15%	15%	8%	6%

High-Level Observations

- Typically only one or two anomalous 2-min heave sequences in a record
- Extent to which a buoy experiences breaking waves is a function of exposure and water depth
- Stage of the tide plays significant part in the wave heights that can be generated
- Breaking waves are typically limited to the period around low tide
- The average number of hours that waves were breaking at a buoy site ranged from 1 to 4 hours
- 60% of storms contained at least one record affected by breaking waves
- Only a quarter of reprocessed storms resulted in a new storm peak
- Significant new outlier-events were introduced in time series
    - At Porthleven, the 04 Feb 2014 storm peak 5.6m Hs ➔ 10.07m Hs

Acknowledgements

Technical Report

Dhoop, T., Newman, R., Warwick-Champion, E. 2023. Re-processing Datawell Directional Waverider MkIII heave data affected by breaking waves. Channel Coastal Observatory. TR121. www.coastalmonitoring.org/reports/

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