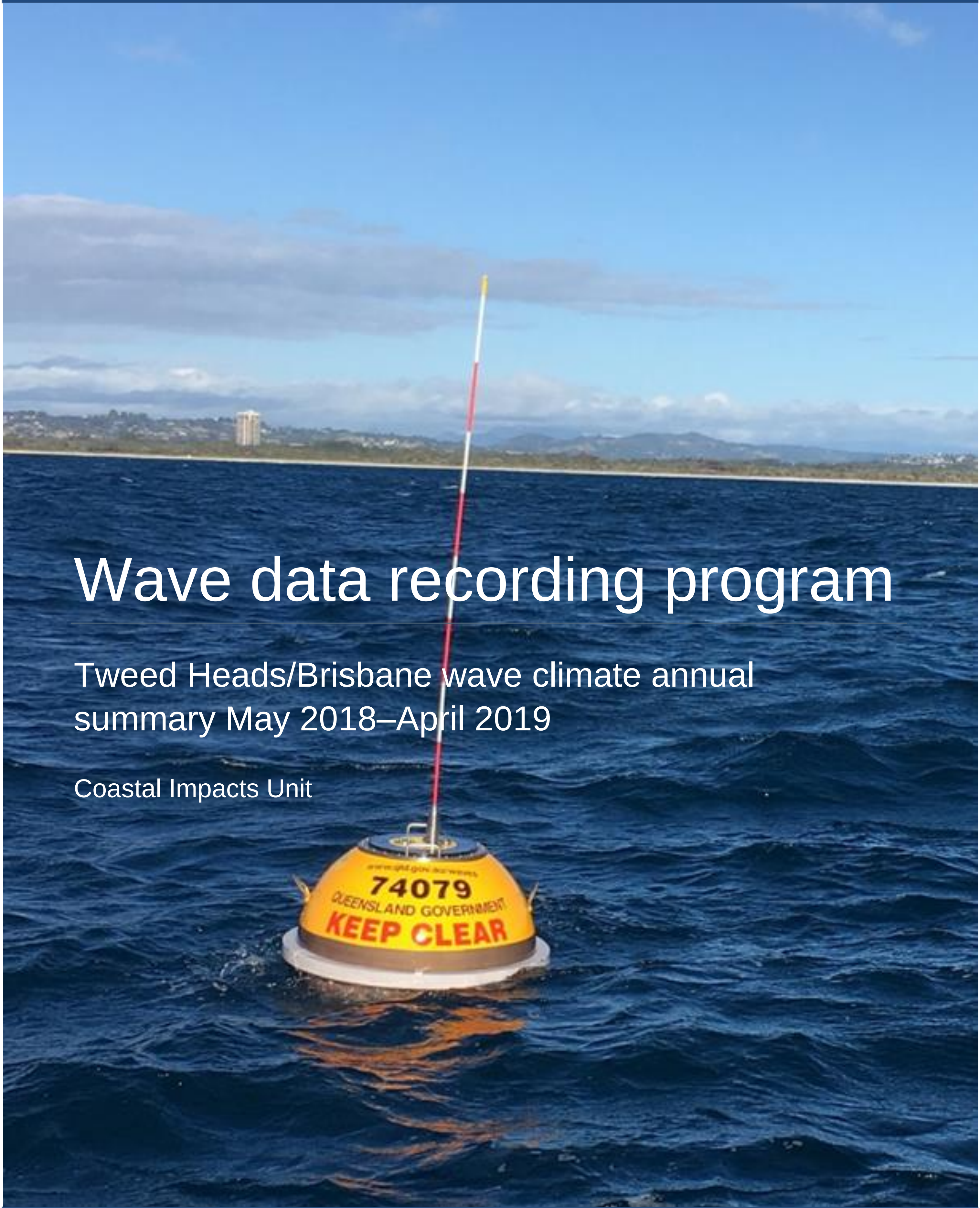

Wave data recording program

Tweed Heads/Brisbane wave climate annual summary May 2018–April 2019

Coastal Impacts Unit

Queensland Government

Prepared by

Coastal Impacts Unit
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Coastal data report No. 2019.1

July 2019

Disclaimer

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Cover photo: Tweed Heads Waverider buoy June 2017

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1 Introduction

This summary of wave climate from the Tweed Heads and Brisbane wave sites is one of a series of technical wave reports prepared annually by the Coastal Impacts Unit of the Department of Environment and Science (DES).

This report has been prepared for the Tweed River Entrance Sand Bypassing Project, in which the primary analyses of wave data recorded using Datawell directional Waverider buoys positioned off Tweed Heads and Brisbane for the period from 01 May 2018 to 30 April 2019 is presented. The data recorded covers all of the seasonal variations for one year, and includes the 2018–19 cyclone season.

Data is presented in a variety of graphical and tabulated forms, exploring the relationship between the measured wave parameters that define the sea state.

The wave data collected for the analysis period is statistically compared to the long-term average conditions at the sites. Brief details of the recording equipment, the methods of handling raw data and the type of analyses employed are provided within this report.

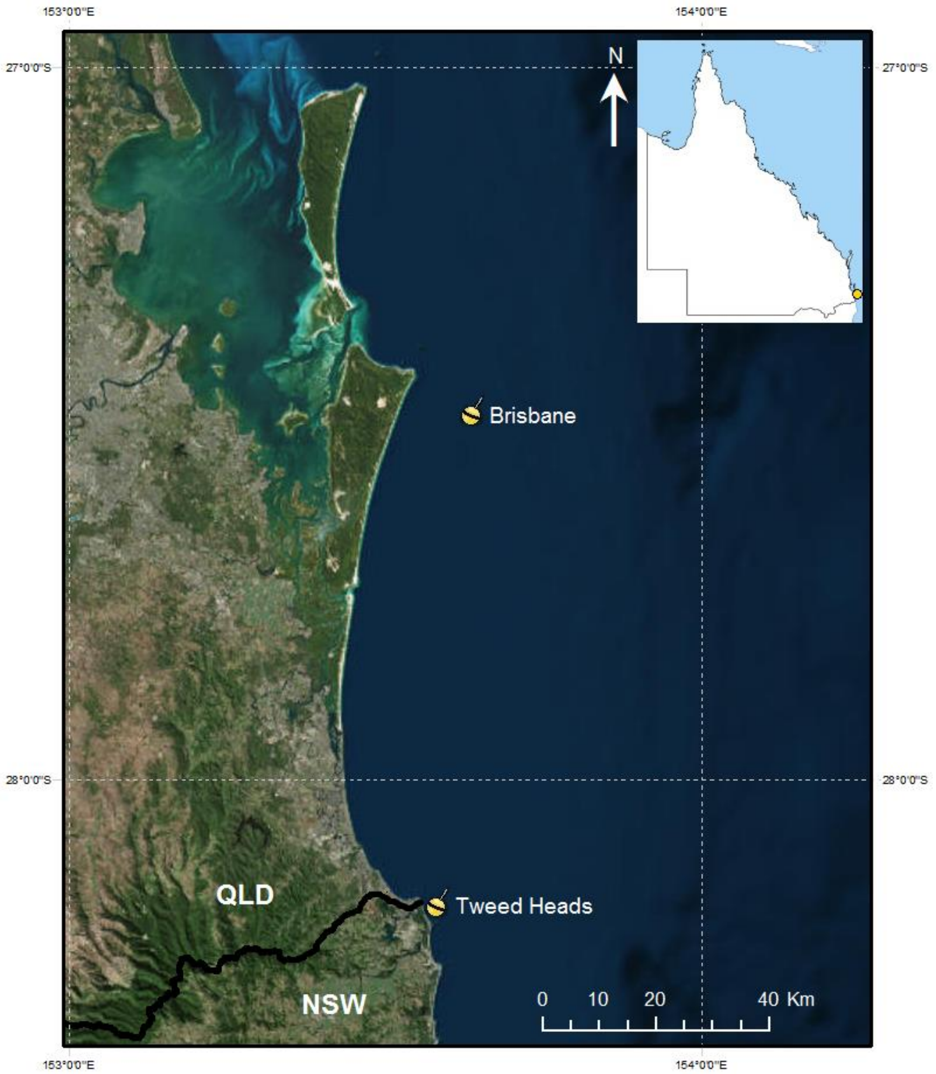

Figure 1.1: Tweed regional wave recording sites – Locality plan

1.1 Recording

DES's Coastal Impacts Unit wave recording program uses the Waverider system manufactured by Datawell of the Netherlands to measure sea surface fluctuations. Directional Waverider buoys were in operation at Tweed Heads and Brisbane during the period of this report.

1.1.1 Brisbane

The Brisbane buoy is a Waverider DWR4. The DWR4 uses the same measuring sensor as the DWR-MkIII, which measures vertical accelerations by means of an accelerometer placed on a gravity-stabilised platform. This platform is formed by a disk which is suspended in fluid within a plastic sphere placed at the bottom of the buoy. Two vertical coils are wound around the plastic sphere and one small horizontal coil is placed on the platform. The pitch and roll angles are defined by the amount of magnetic coupling between the fixed coils and the coil on the platform. Measuring this coupling gives the sine of the angles between the coils (x and y axes) and the horizontal plane (= platform plane). An additional accelerometer unit measures the forces on the buoy with respect to its x and y axes.

A fluxgate compass provides a global directional reference with which to orient the buoy. The acceleration values that are relative to the buoy are then transformed into values that are relative to the fixed compass. The measured acceleration values are filtered and double integrated with respect to time to establish displacement values for recording.

With the DWR-MkIII system only waves with frequencies within the range of 0.033–0.64 Hz could be captured by the buoy, due to physical limitations of the system. However the DWR4 can capture waves within the frequency range of 0.033-1 Hz. Wave motion with higher frequencies can't be followed/ridden properly due to the dimensions of the buoy, while lower frequency waves apply very small acceleration forces that become undetectable (Datawell, 2010). For more information regarding the DWR4 see Datawell (2018). A report investigating the differences between the DWR-MkIII system and the DWR4 system has been undertaken by DES (DISTI, 2017). A comparison between the DWR-G and DWR4 at Tweed heads has started and initial data is included at section 6 (DES, 2019).

1.1.2 Tweed Heads

The directional Waverider DWR-G buoy at the Tweed Heads site used the GPS satellite system to calculate the velocity of the buoy (as it moves with the passing waves) from changes in the frequency of GPS signals according to the Doppler principle. For example, if the buoy is moving towards the satellite the frequency of the signal is increased, and vice-versa. The velocities are integrated through time to determine buoy displacement. The measurement principle is illustrated in Figure 1.2, which shows a satellite directly overhead and a satellite at the horizon. In practice the GPS system uses signals from multiple satellites to determine three-dimensional buoy motion.

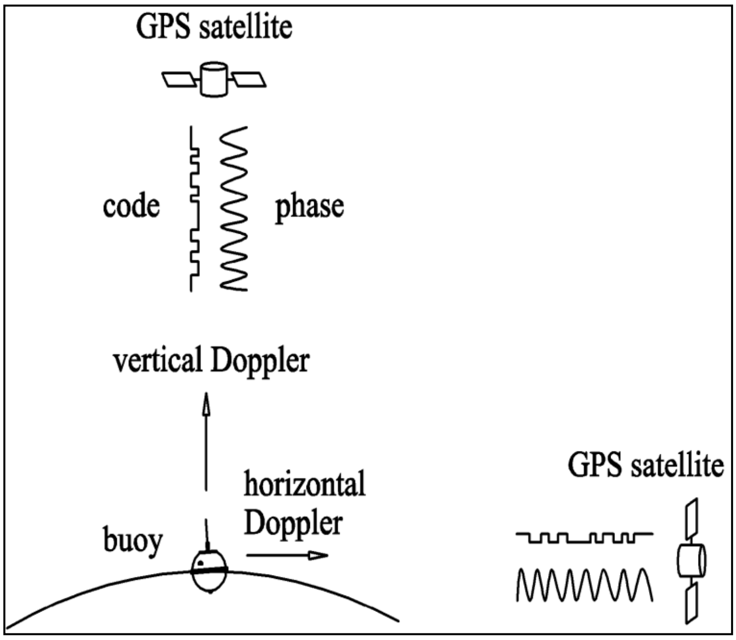

Figure 1.2: The GPS wave measurement principle (Source: Datawell, 2000)

At both Tweed Heads and Brisbane, the vertical buoy displacement representing the instantaneous water level and calculated directional data are transmitted to a receiver station as a modulated high-frequency radio signal. The DWR-MkIII and DWR-G directional Waverider receiver stations on shore are each comprised of a desktop computer system connected to a Datawell receiver/digitiser. The water level data at each site is digitised at 0.78 seconds intervals (1.28 Hz) and stored in bursts of 2,048 points (approximately 26 minutes) on the hard disk of the computer. The DWR4 has a few subtle differences regarding data transmission, namely due to a higher sample frequency. As such the water level data for the DWR4 is digitised at 0.39 second intervals (2.56 Hz) and stored in daily files rather than 26.6 minute bursts like the DWR-MkIII.

The proprietary software running on the computer controls the timing of data recording, and processes the data in near real time to provide a set of standard sea-state parameters and spectra that may be accessed remotely via a Telstra NEXTG® link. Recorded data and analysis results are downloaded every two hours to a central computer system in Brisbane for checking, further processing, and archiving.

Further information on the operation of the Waverider buoy and the recording systems can be obtained from the reference sources listed in Section 7 of this report.

1.2 Laboratory calibration checks

Waverider buoys used by the CIU undergo equipment verification checks before and after deployment, which is approximately every 12 months. Accelerometer buoys (including DWR4) are verified at the CIU's Brisbane site using a sinusoidal wave simulator with vertical displacements of 2.7 metres. It is usual to check three frequencies between 0.005–0.64 Hz during a verification. Numerous mechanism responses of the buoy are also checked throughout the procedure, including: the compass; phase and amplitude response; accelerometer platform stability and tilt; battery capacity; and power output.

While Datawell (2017b) states that calibration of a GPS buoy is not necessary, the CIU runs a verification process to ensure the system is operating correctly. This process involves placing the buoy in a fixed, unobstructed location – to ensure satellite line of sight – on land for several days while it records data. If the resulting north, west and vertical displacements remain within a few centimetres then the GPS sensor is deemed functional and accurate. There are no adjustments to the recorded wave data, based on the laboratory calibration results, this process is simply to ensure that devices deployed are functioning correctly.

1.3 Wave recording and analysis procedures

The computer-based, wave-recording systems at Tweed Heads and Brisbane record data at half-hourly intervals received from the DWR-MkIII and DWR-G. Alternatively data received from the DWR4 is recorded in daily files.

Raw wave data transmitted from the DWR-MkIII and DWR-G is analysed in the time domain by the zero up-crossing method (see Appendix A – Zero up-crossing analysis) and in the frequency domain by spectral analysis using Fast Fourier Transform (FFT) techniques to give 64 spectral estimates in bands of 0.01 hertz (0.1 to 0.58Hz). The directional information is obtained from initial processing on the buoy, where datasets are divided into data sub-sets and each sub-set is analysed using FFT techniques. The output from this processing is then transmitted to the shore station, along with the raw data, where it undergoes further analysis using FFT techniques to produce 64 spectral estimates in bands of 0.025 to 0.1 hertz.

Whilst simular, there are a number of differences in how the DWR4 calculates wave records compared to the DWR-MkIII. Primarily the zero up-crossing analysis is processed on-board (as opposed to in post processing) before being transmitted. Additionally Hs on the DWR4 is calculated using Hrms√2 as an alternative for $H_{1/3}$.

The zero up-crossing analysis is equivalent in both the Brisbane (accelerometer) and Tweed (GPS) systems. Wave parameters resulting from the time and frequency domain analysis included the following:

Table 1: Wave parameters analysed

S(f)	energy density spectrum (frequency domain)
H_{sig} (or Hs)	Significant wave height (time domain), the average of the highest third of the waves in the record.
H_{max}	The highest individual wave in the record (time domain).
H_{rms}	The root mean square of the wave heights in the record (time domain).
T_{sig}	Significant wave period (time domain), the average period of the highest third of waves in the record.
T_z	The average period of all zero up-crossing waves in the record (time domain).
T_p	The wave period corresponding to the peak of the energy density spectrum (frequency domain).
T_c	The average period of all the waves in the record based on successive crests (time domain).
Direction (Dir; Dir_{Tp})	The direction that peak period (Tp) waves are coming (in ° True North). In other words, where the waves with the most wave energy in a wave record are coming from.
SST	The sea surface temperature (in º Celsius) obtained by a sensor mounted in the bottom of the buoy.

These parameters form the basis for the summary plots and tables included in this report.

1.4 Data losses

Data losses can be divided into two categories: losses due to equipment failure; and losses during data processing due to signal corruption. Common causes of data corruption include radio interference and a spurious, low-frequency component in the water-level signal caused by a tilting platform in the accelerometer-based Waverider buoy. Obstructions in the data path between the GPS buoy and the orbiting satellites can also cause data corruption and loss of signal.

Analysis of recorded data by the computer systems includes some data rejection checks which may result in a small number of spurious and rejected data points being replaced using an interpolation procedure. Otherwise the entire series is rejected, as per research conducted by Bacon & Carter (1991) and Allan & Kormer (2001) who suggested rejecting entire records where less than a certain threshold has been recorded.

As discussed above, the various sources of data losses can cause occasional gaps in the data record. Gaps may be relatively short, caused by rejection of data records or much longer if caused by malfunction of the Waverider buoy or the recording equipment.

Whilst no significant gap in data (larger than 2 days) for Brisbane and DWR-G waverider buoy at Tweed Heads was found, there was a major gap in data for Tweed-DWR4 as outlined in Table 2.

Table 2. Significant gap in data for Tweed Heads.

Buoy	Gap start	Gap end	Cause
Tweed DWR4	2019-01-19	2019-04-27	Buoy breakage – It took 3 months to deliver a new buoy from Netherlands.

1.5 Overview

No attempt has been made to interpret the recorded data for design purposes or to apply corrections for refraction, diffraction and shoaling to obtain equivalent deep-water waves. Before any use is made of this data, the exact location of the buoy, and the water depth in which the buoy was moored, should be noted (refer to Table 3, Table 4, Figure 5.1 and Figure 6.1). Data capture rates for each wave site over the reporting period are presented in Table 5.

Table 3: Deployment details for the Tweed Heads Waverider buoy

Buoy	Latitude	Longitude	Estimated depth (m)	Calibration date	Deployed date	Removal date
46026 DWR-G	28° 10.715' S	153° 34.635' E	25	19/06/2018	29/06/2018	current
46016 DWR-G	28° 10.700'S	153° 34.519'E	24	16/01/2018	26/03/2018	29/06/2018
74106 DWR4	28° 10.638'S	153° 34.595'E	25	01/04/2019	27/04/2019	current
74079 DWR4	28° 10.575'S	153° 34.590'E	25	06/05/2017	06/06/2017	20/01/2019

Table 4: Deployment details for the Brisbane Waverider buoy

Buoy	Latitude	Longitude	Estimated depth (m)	Calibration date	Deployed date	Removal date
74083	27° 29.420'S	153° 38.044'E	80	27/11/2017	22/12/2017	current

Table 5: Wave recording program percentage data capture May 2018–April 2019

Station	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Avg.
Tweed Heads	100	70.2	100	99.8	99.86	99.53	96.60	99.93	99.73	99.10	99.87	99.79	97.03
Brisbane	96.9	99.93	100	99.87	100	99.93	98.8	99.93	99.8	99.63	98.91	100	99.47

A summary of major meteorological events, where the recorded Hsig value reached the 3-hour storm threshold wave height of two metres for Tweed Heads and four metres for Brisbane, for the period from 01 May 2018 to 30 April 2019 is shown in Table 6 and Table 7. Lists wave parameters Hsig, Hmax, Tp, and other relevant information for each event. Weather systems that contributed to the Hsig reaching the storm threshold value are listed and may be direct reproductions of synoptic descriptions provided by the Australian Bureau of Meteorology (BoM, 2019).

Table 6: Significant meteorological events May 2018–April 2019, Tweed Heads Waverider buoy

Tweed Heads Storm threshold value: 2.0 metres (H_{sig})				
Date	H_{sig} (m)	H_{max} (m)	T_p (s)	Event
7/06/2018 9:00	2.7 (3.0)	4.2 (5.3)	9.6	A high pressure centre developed on the 6th over the southern coast of NSW before shifting northeast.
3/07/2018 20:30	2.1 (2.4)	3.6 (4.3)	10.4	At the start of the month, an inland surface trough and a broad upper level trough over far western Queensland triggered thunderstorms and showers in southern Queensland and northeastern New South Wales.
31/08/2018 20:00	2.0 (2.2)	3.3 (3.8)	7	A vigorous pre-frontal trough moved across eastern Australia on the 31st and strong winds developed over southeast Queensland and northern New South Wales.
4/09/2018 14:00	2.1 (2.2)	3.4 (3.7)	7.6	By the 4th, a surface trough developed along the southeast coast of Queensland, with a second trough extending through inland Queensland and New South Wales.
15/10/2018 22:30	4.1 (4.5)	6.6 (7.8)	10.9	Showers and storms developed in southern and eastern Australia from the 14th, as a low pressure system embedded in a surface trough deepened off the southeast Queensland coast and produced isolated heavy falls around southeast Queensland and northeastern New South Wales.
18/12/2018 2:30	2.0 (2.1)	3.4 (4.0)	8.4	Ex-tropical cyclone *Owen* lingered in the Coral Sea at the start of December before it tracked slowly west southwest towards Queensland east coast from the 8th.
14/02/2019 23:30	2.0 (2.2)	3.7 (4.8)	9.6	The coastal low moved east into the Coral Sea and later developed into tropical cyclone Oma near Vanuatu late on the 12th. Oma tracked slowly southwest towards the southeast coast of Queensland over the next 11 days and weakened to a tropical low on the 23rd.
24/02/2019 9:00	4.0 (4.5)	5.6 (7.1)	13	Tropical cyclone Oma tracked towards the southeast Queensland coast in late February. Moreover, the last week of February saw a high pressure system in the Tasman Sea that directed an onshore flow onto the New South Wales and Queensland coasts.
5/03/2019 16:00	2.1 (2.3)	3.4 (4.2)	10.9	A high pressure system in the Tasman Sea moved slowly eastwards and maintained a strong ridge along the east coast of Queensland during the first week of the month.
3/04/2019 20:30	2.0 (2.1)	3.3 (3.8)	8.2	At the start of the month, onshore south-easterly flow together with a low pressure trough developed along the southeast coast of Queensland.
20/04/2019 11:00	2.4 (2.6)	4.0 (4.8)	10.4	A high pressure ridge along the east coast of Australia produced onshore showers and moderate falls in Queensland's north tropical and southeast coasts, and northeastern New South Wales.

H_{sig} and H_{max} values shown in brackets are unsmoothed values as recorded at the site.

Denotes peak Hsig event

Table 7: Significant meteorological events May 2018–April 2019, Brisbane Waverider buoy

Brisbane Storm threshold value: 4.0 metres (H_{sig})				
Date	**H_{sig}(m)**	**H_{max} (m)**	**T_p (s)**	**Event**
2018-10-15 22:00	5.3	8.6	11.1	A low pressure system embedded in a surface trough deepened off the southeast Queensland coast and produced isolated heavy falls around southeast Queensland and northeastern New South Wales.
2018-11-30 00:00	4.6	8.2	13.0	On the 27th and 28th, a band of showers and thunderstorms developed along the east-moving troughs, with one over the northern interior, and another extending through central Queensland and connected to a complex low pressure system in New South Wales. Strong winds were recorded along much of the eastern coastline.
2019-02-14 19:00	4.0	6.7	10.0	Tropical cyclone Oma formed near Vanuatu on the 12th and tracked southwest towards southern Coral Sea late in February.
2019-02-22 17:00	6.5	10.1	11.7	Although Oma remained well offshore, the system caused gale force winds, king tides, coastal erosion and inundation of low-lying areas in coastal southeast Queensland. TC Oma weakened to below cyclone intensity on the 23rd.

Denotes peak H_{sig} event

Note:

1. Barometric pressure measured in hectopascals (hPa). The H_{sig} and H_{max} values are the maximums recorded for each event and are not necessarily coincident in time. The T_p and H_{sig} values are coincident as a single event on the date shown. Due to possible statistical errors arising from finite length records used in calculating wave climate, the above storm peak H_{sig} and H_{max} values are derived from the time series smoothed by a simple three hourly moving average following the recommendation of the literature (Forristall, Heideman, Leggett, Roskam, & Vanderschuren, 1996).

Details of the wave recorder installations for the Tweed Heads and Brisbane sites are shown on the first page of each site section, including information on buoy location, recording station location, recording intervals and data collection.

The wave climate data presented in this report are based on statistical analyses of the parameters obtained from the recorded wave data. Software programs developed by DES provide statistical information on percentage of time occurrence and exceedance for wave heights and periods. The results of these analyses are presented in Figure 3.3 to Figure 3.5 and Figure 6.2 to 6.4. In each of these three figures for each site, the term ‘All data’ refers to the combined number of years of operation for each site being 24.29 years for Tweed Heads (since 13 January 1995) and 42.5 years for Brisbane (since 31 October 1977). In addition, similar statistical analysis provides monthly averages of wave heights for the seasonal year and all data. At the request of the TRESBP, morphological energy weighted average H_{sig} are also provided for the Tweed buoy, being a proxy for sediment transport capacity (WBM, 1997).

Daily wave recordings, average water temperature and peak direction (Dir_{Tp}) recordings are shown for the period from 01 May 2018 to 30 April 2019. Directional wave roses for the same period are also presented. These wave roses summarise wave occurrence at Tweed Heads and Brisbane by indicating their height, direction and frequency. Each branch of a wave rose represents waves coming from that direction with branches divided into H_{sig} segments of varying range. The length of each branch represents the total percentage of waves from that direction with the length of each segment within a branch representing the percentage of waves, in that size range, arriving from that direction for all wave periods. Note that the wave rose is only intended as a visual guide to the wave climate at the site.

This report covers the period from 01 May 2018 to 30 April 2019 to align with the Tweed River Entrance Sand Bypassing Project environmental monitoring periods. For the purposes of analysis, summer has been taken as the period from 01 November to 30 April of the following year and winter covers the period 01 May to 31 October in any one year.

3. Tweed Heads

Tweed Heads

Wave recording station

Details of data collected

2018-2019 season

Maximum possible analysis days (last record - first record)	= 364.98
Total number of days used in analysis	= 355.33
Gaps in data used in analysis (days)	= 9.65
Number of records used in analysis	= 17056

All data since-1995

Maximum possible analysis years (last record - first record)	= 24.29
Total number of years used in analysis	= 23.95
Gaps in data used in analysis (years)	= 0.34
Number of records used in analysis	= 368915

Table of highest ranked un-smoothed waves at Tweed Heads

Rank	Date(Hs)	Hs (m)	Date(Hmax)	Hmax (m)
1	03/05/1996 01:00	7.5	02/05/1996 14:30	13.1
2	28/01/2013 08:30	6.7	28/01/2013 09:00	11.8
3	06/03/2004 01:00	6.1	05/03/2004 23:30	11.1
4	21/05/2009 19:30	5.6	30/06/2005 06:30	9.9
5	04/06/2016 19:30	5.6	05/06/2016 00:30	9.8
6	01/05/2015 22:30	5.5	22/05/2009 07:00	9.7
7	24/05/1999 05:00	5.2	04/03/2006 12:00	9.6
8	04/03/2006 20:30	5.2	25/03/1998 22:30	9.5
9	12/06/2012 10:00	5.2	15/02/1995 15:30	9.3
10	15/02/1995 11:30	5.2	12/06/2012 11:30	9.3

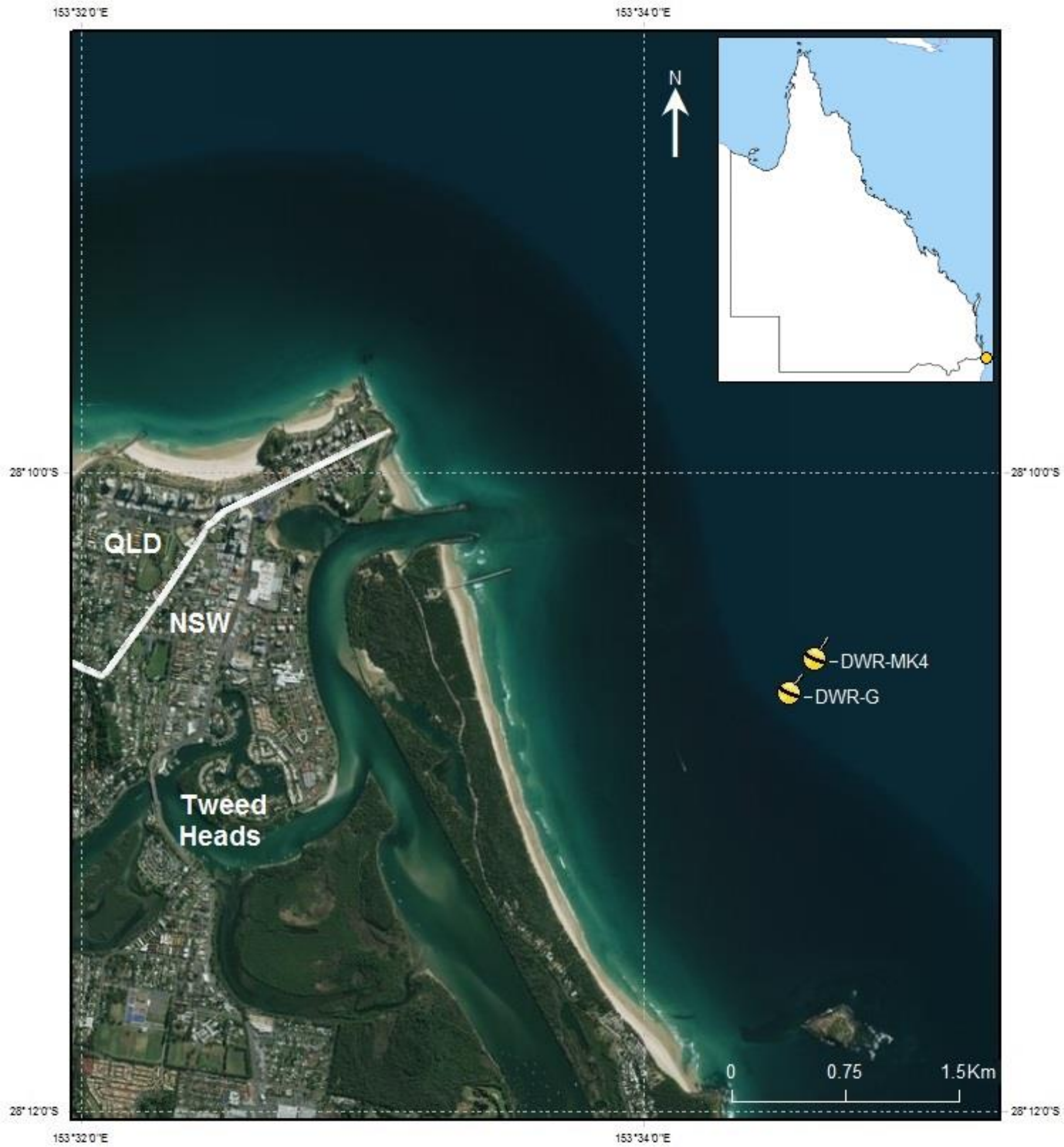

Figure 3.1: Tweed Heads DWR-G and DWR4 buoy – Locality plan

Table 8: Wave conditions 2018–19, Tweed Heads Waverider buoy

Month	Average H_{sig} (m)	Min H_{sig} (m)	Max H_{sig} (m)	Average Directions for Peak Period Dir_{Tp} (°True North)	90% of waves within the range of (m)	No. of Days When $H_{sig} \geq$ 2 m	No. of Days When $H_{sig} \leq$ 0.75 m	Events where H_{sig} > 3 m and date of storm
May-18	1.18	0.44	1.99	112	0.7 - 1.7	0	8	
Jun-18	1.26	0.43	2.98	110	0.5 - 2.1	3	5	
Jul-18	0.92	0.38	2.36	104	0.5 - 1.8	4	21	
Aug-18	0.84	0.33	2.04	103	0.5 - 1.3	1	20	
Sep-18	1.12	0.54	2.21	100	0.7 - 1.8	1	8	
Oct-18	1.41	0.56	4.51	101	0.8 - 3.5	7	5	14 15 16
Nov-18	1.06	0.39	2.16	92	0.6 - 1.6	1	10	
Dec-18	1.3	0.62	2.21	89	0.8 - 1.9	6	5	
Jan-19	1.15	0.6	1.79	81	0.7 - 1.6	0	8	
Feb-19	1.73	0.81	4.51	90	1.1 - 3.3	10	0	22 23 24 25
Mar-19	1.13	0.58	2.27	91	0.7 - 1.9	4	16	
Apr-19	1.35	0.7	2.63	92	0.9 - 2.1	8	3	
May to April	1.2	0.33	4.51	97	0.6 - 1.9	45	109	7

Table 9: Mean Values, Tweed Heads Waverider buoy

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May–Apr
Mean H_{sig} (m) 2018–19	1.18	1.26	0.92	0.84	1.12	1.41	1.06	1.3	1.15	1.73	1.13	1.35	1.2
Mean H_{sig} (m) Average from 1995–2019	1.3	1.24	1.13	1.08	1.08	1.13	1.14	1.16	1.3	1.48	1.44	1.37	1.24
Average direction for peak period Dir_{Tp} (ø True North) 2018–19	112	110	104	103	100	101	92	89	81	90	91	92	97
Average direction for peak period Dir_{Tp} (ø True North) 1995–2019	100	101	103	100	94	92	92	91	91	95	93	97	96

$$Mean\ H_{sig} = \sum H_{sig} / N$$

$$Average\ of\ Peak\ Period\ Direction: Dir_{Tp} = \sum D / N$$

Where:

H_{sig}= Significant wave height

D = Direction at Peak Period (Dir_{Tp})

N = number of records

Table 10: Weighted Mean Values, Tweed Heads Waverider buoy

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May–Apr
Weighted Mean H_{sig} (m) 2018–19	1.24	1.38	1.04	0.9	1.17	1.71	1.12	1.37	1.21	1.92	1.23	1.44	1.31
Weighted Mean H_{sig} (m) 1995–2019	1.57	1.42	1.27	1.24	1.17	1.26	1.23	1.26	1.45	1.64	1.6	1.49	1.38
Weighted direction for peak period Dir_{Tp} ($^{\varnothing}$ True North) 2018–19	111	113	101	99	103	96	88	84	79	90	89	90	95
Weighted direction for peak period Dir_{Tp} ($^{\varnothing}$ True North) 1995–2019	88	96	100	95	92	91	94	90	89	93	88	95	93

$$Weighted\ Mean\ H_{sig} = \left(\sum (H_{sig}{}^{2.5})/N\right)^{0.4}$$

$$Weighted\ Mean\ Direction = \sum (H_{sig}{}^{2.5} * D) \,/ \sum H_{sig}{}^{2.5}$$

Where:

H_{sig}= Significant wave height

D = Direction at Peak Period (Dir_{Tp})

Table 11: H_{sig} percentage (%) occurrence, Tweed Heads Waverider buoy

H_{sig} (m)	0–0.5	0.5–1	1–1.5	1.5–2	2–2.5	2.5–3	3–3.5	3.5–4	4–4.5	4.5–5	5–5.5	5.5–6	6–6.5	6.5–7
May 95–Apr 19	1.15	34.97	40.98	15.58	4.93	1.41	0.55	0.23	0.11	0.05	0.02	0.01	0.01	0.00
May 18–Apr 19	1.68	37.75	39.58	16.84	2.29	0.60	0.58	0.56	0.12	0.01	0.00	0.00	0.00	0.00

* The highlighted cell colour in Table 10 corresponds to the data presented in Figure 3.2 red for 2018–2019 and black/grey for all data (1995–2019).

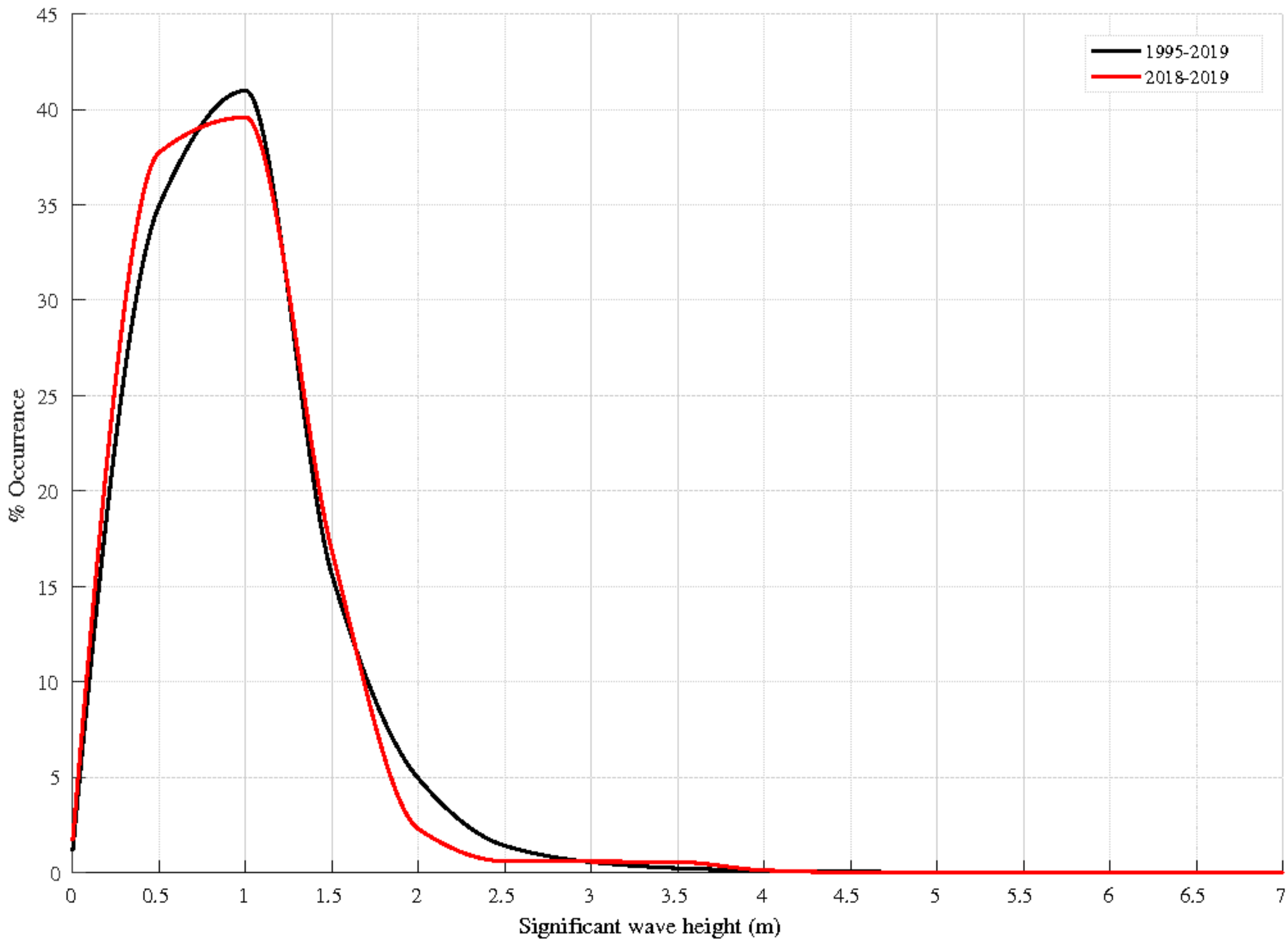

Figure 3.2: Tweed Heads Waverider buoy – Hsig percentage (%) occurrence

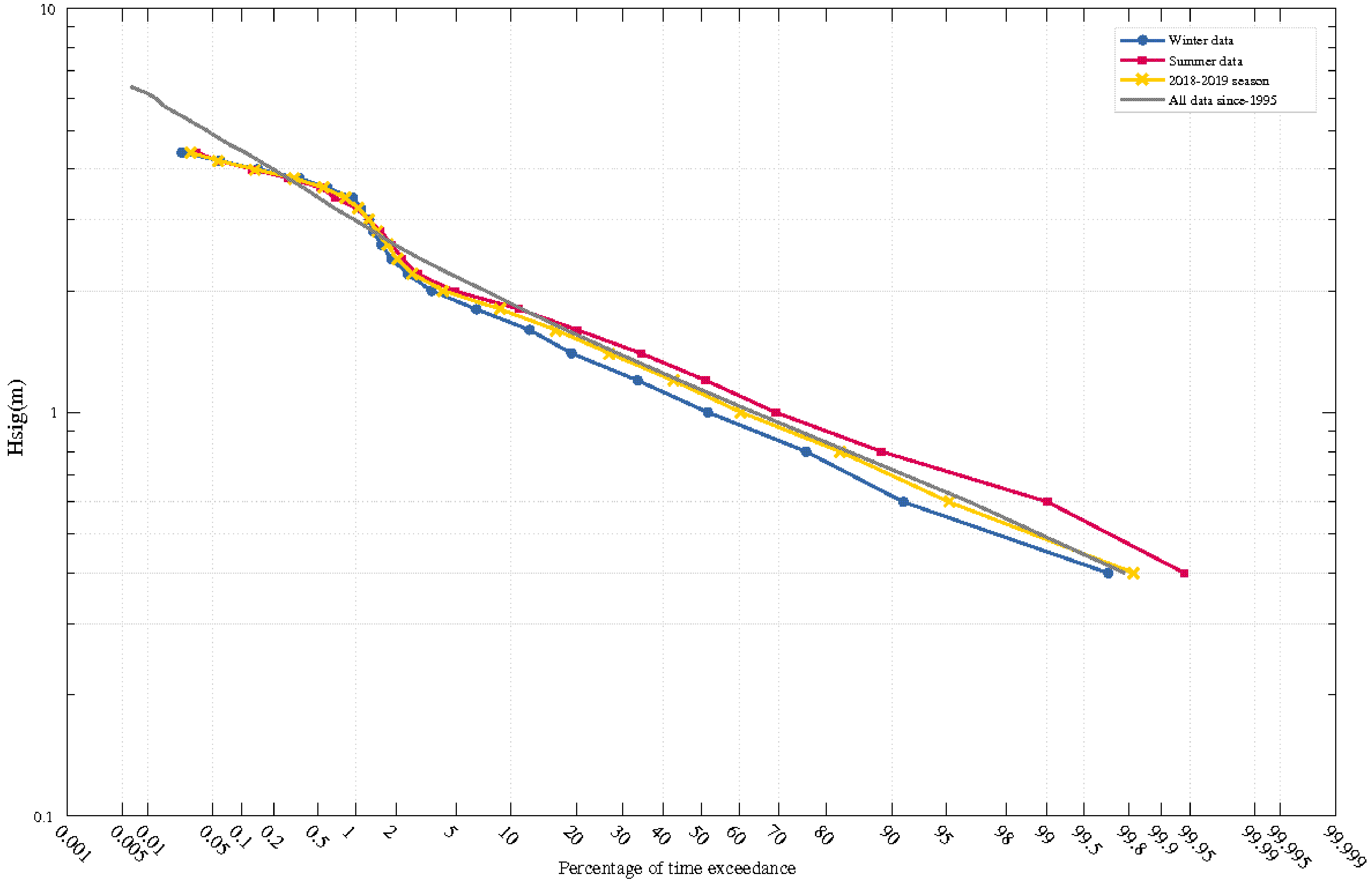

Figure 3.3: Tweed Heads Waverider buoy – Percentage (of time) exceedance of wave heights (Hsig) for all wave periods (Tp)

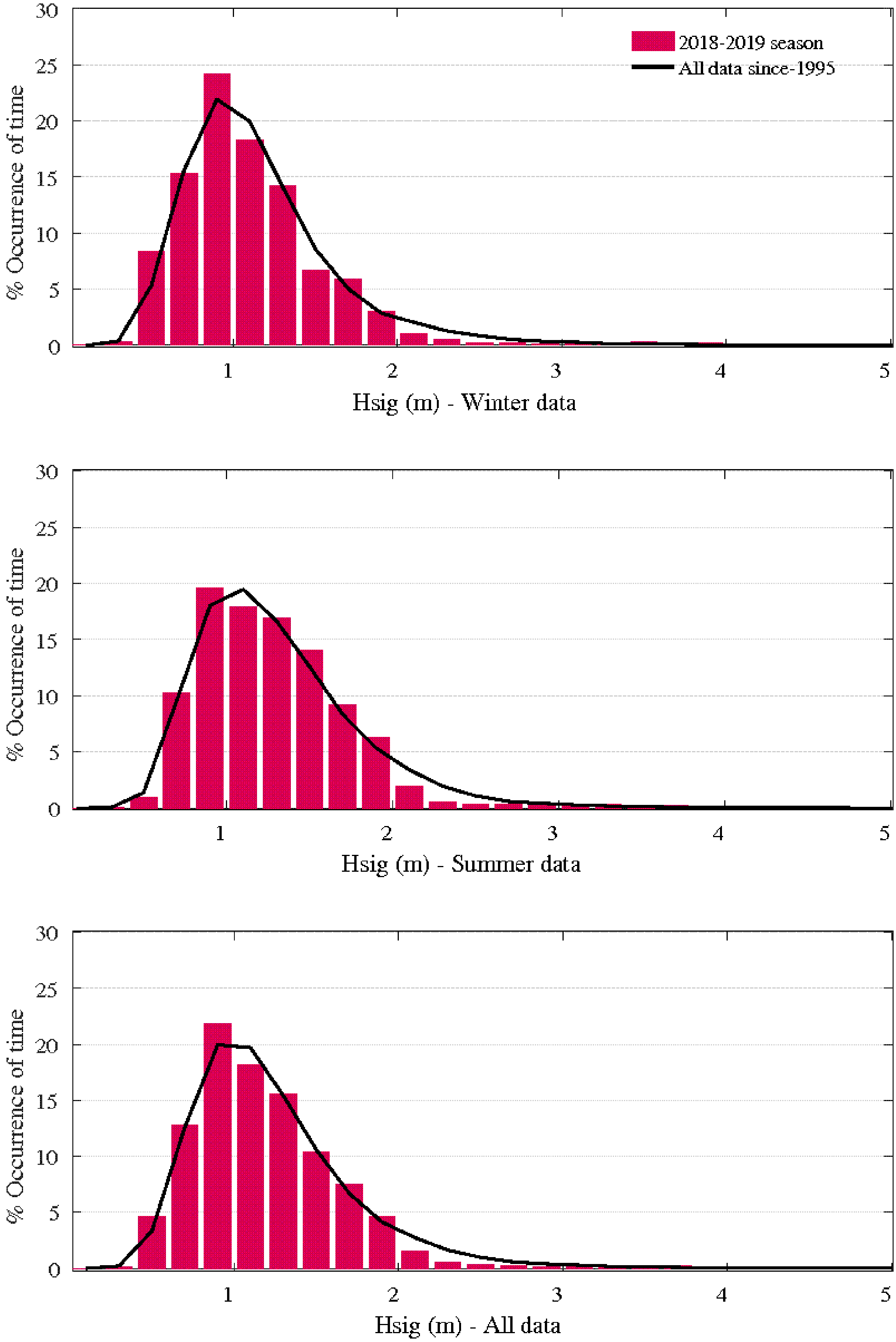

Figure 3.4: Tweed Heads Waverider buoy – Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

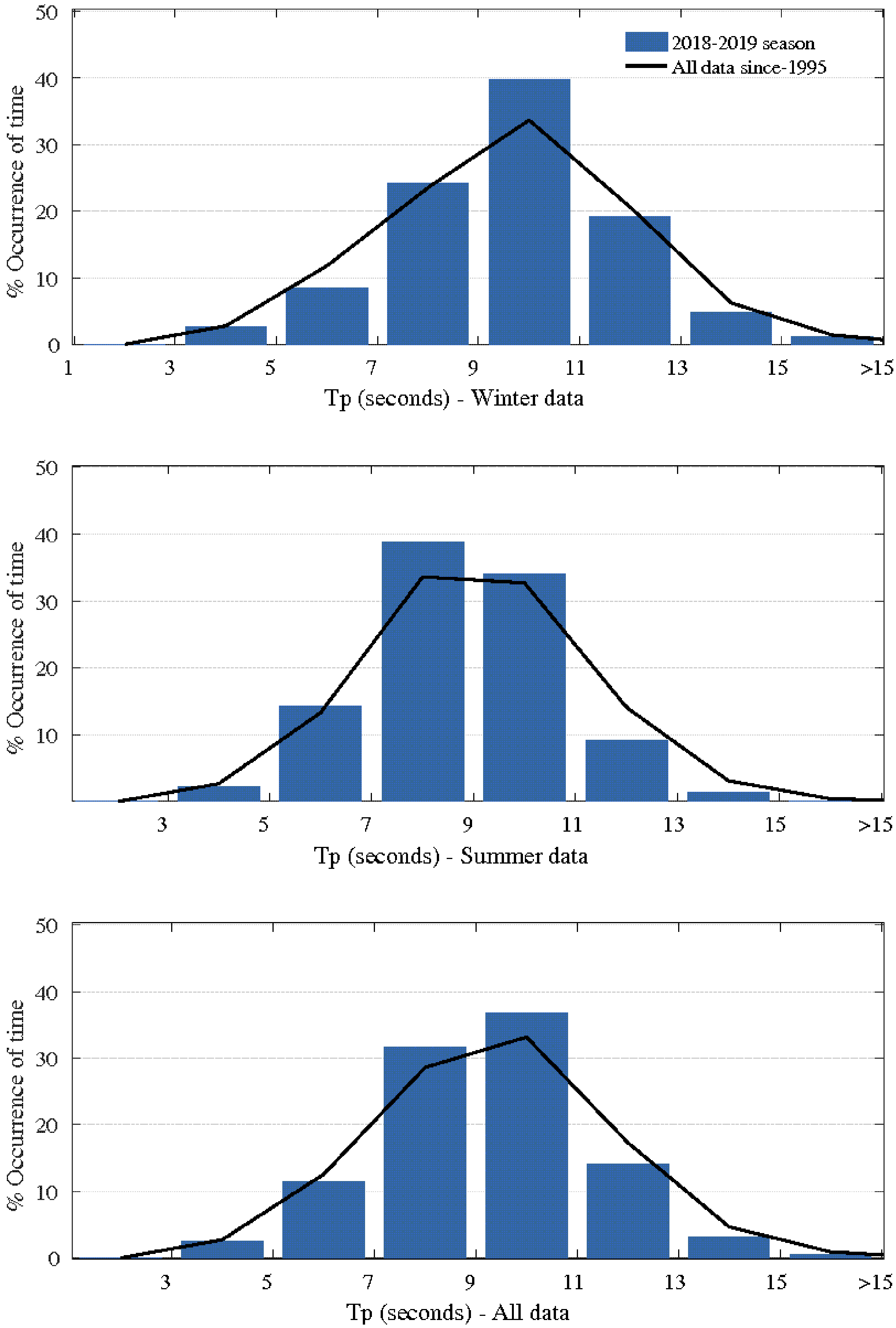

Figure 3.5: Tweed Heads Waverider buoy – Histogram percentage (of time) occurrence of wave periods (Tp) for all wave heights (Hsig)

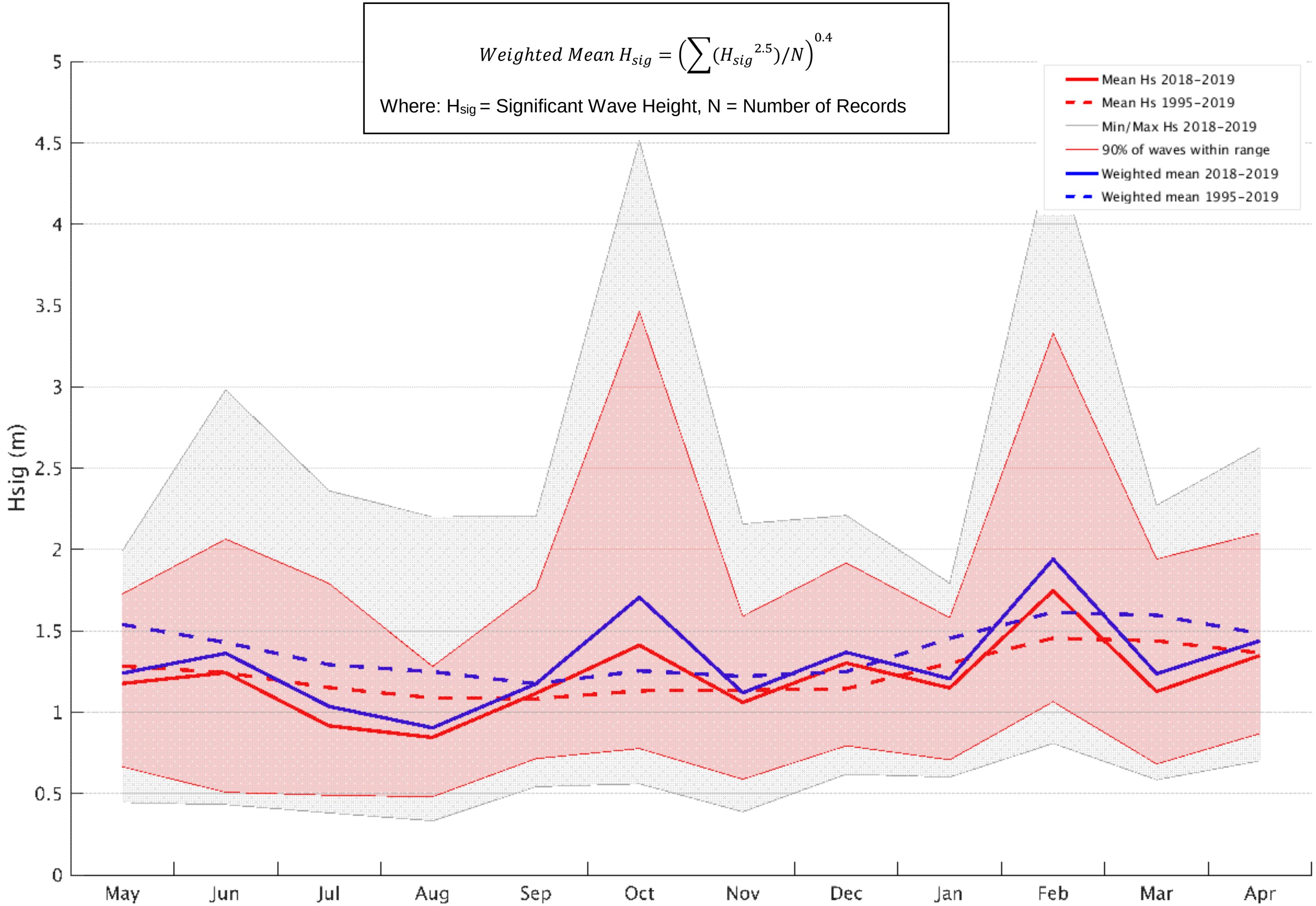

Figure 3.6: Tweed Heads Waverider buoy – Plot of monthly average Hsig for seasonal year and for all data. The weighted mean Hsig provides an indicative potential for sediment transport.

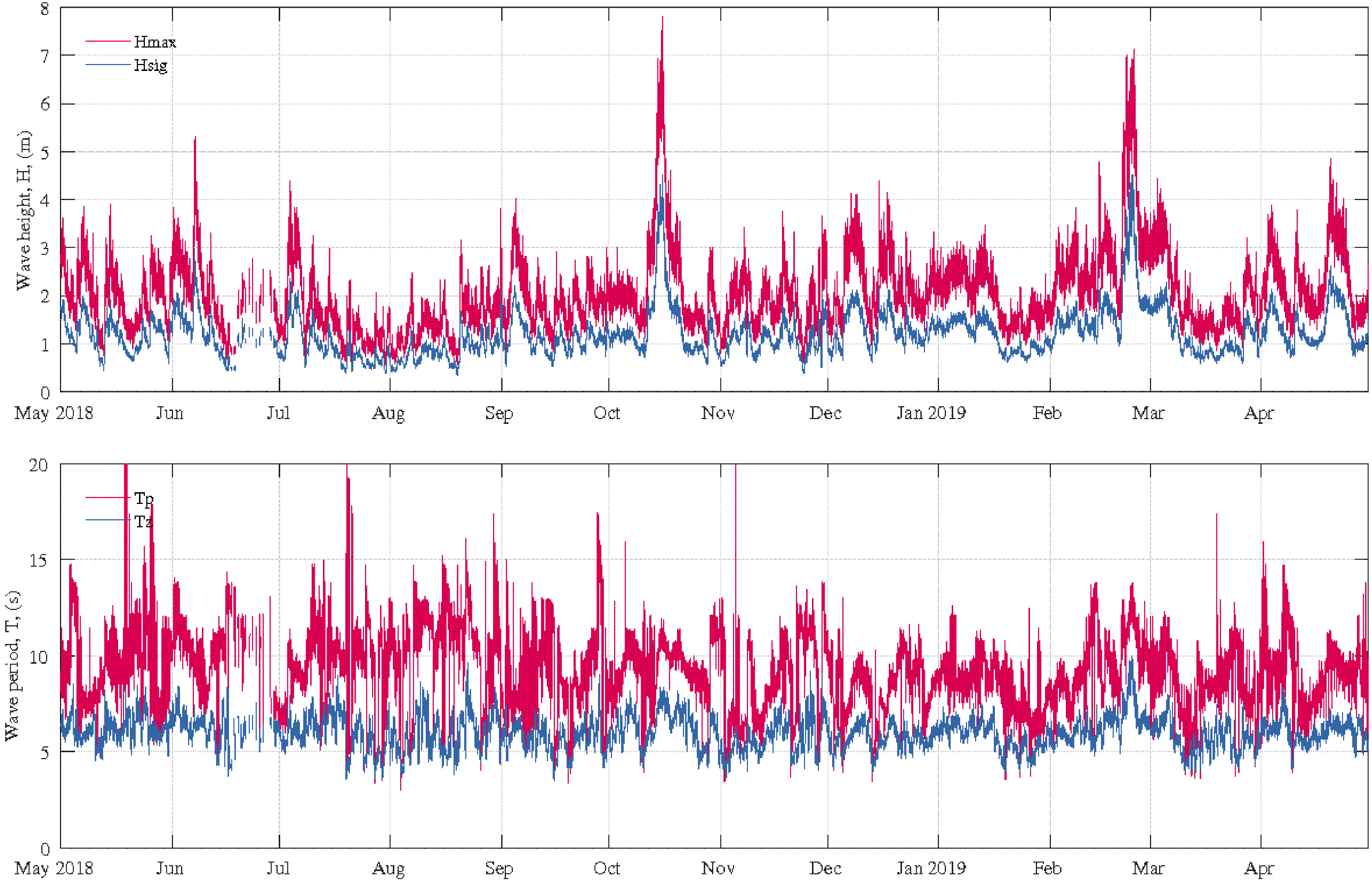

Figure 3.7: Tweed Heads Waverider buoy – Daily wave recordings

Figure 3.8: Tweed Heads Waverider buoy – Sea surface temperature and peak wave directions

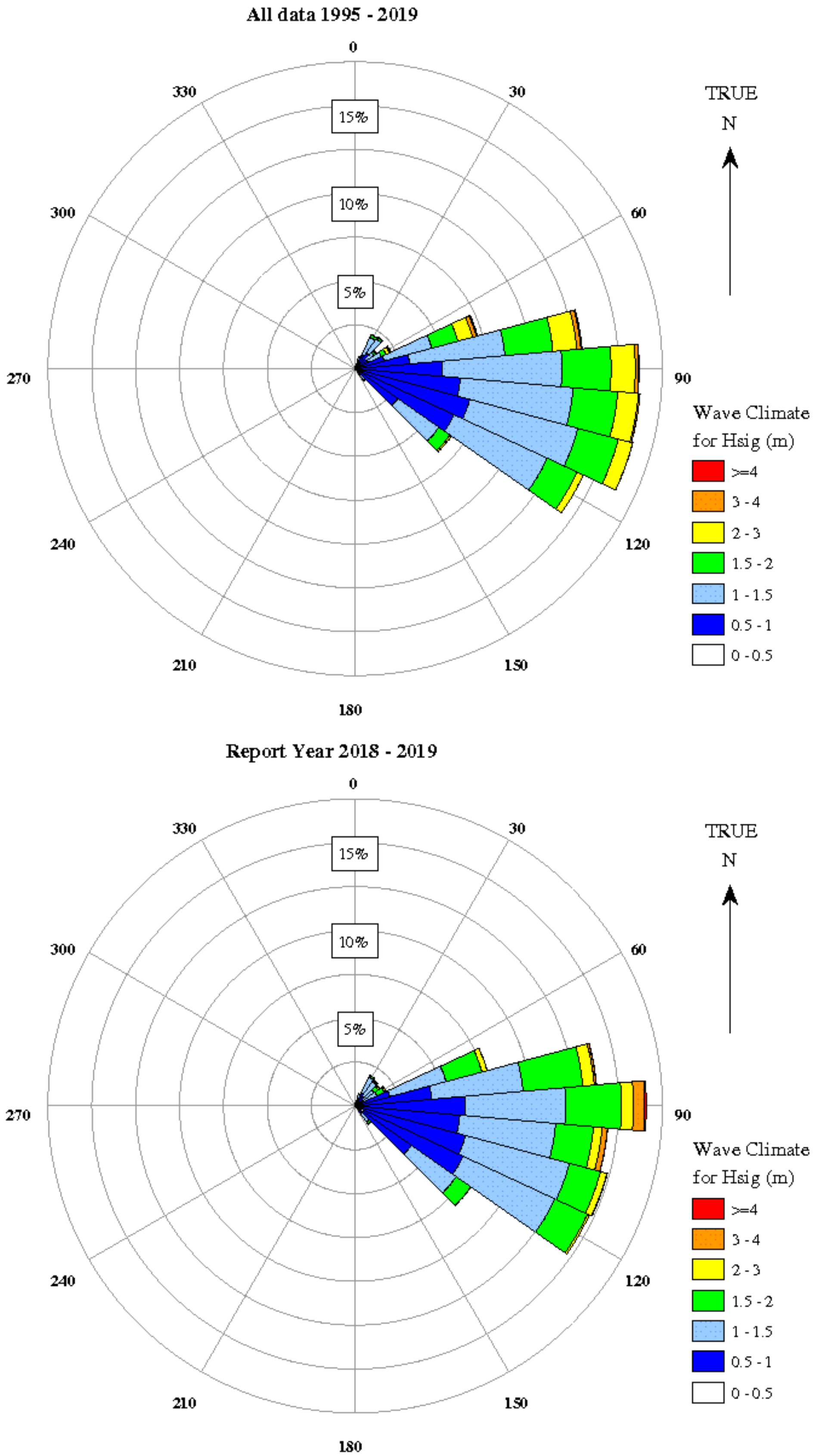

Figure 3.9: Tweed Heads Waverider buoy – Directional wave rose

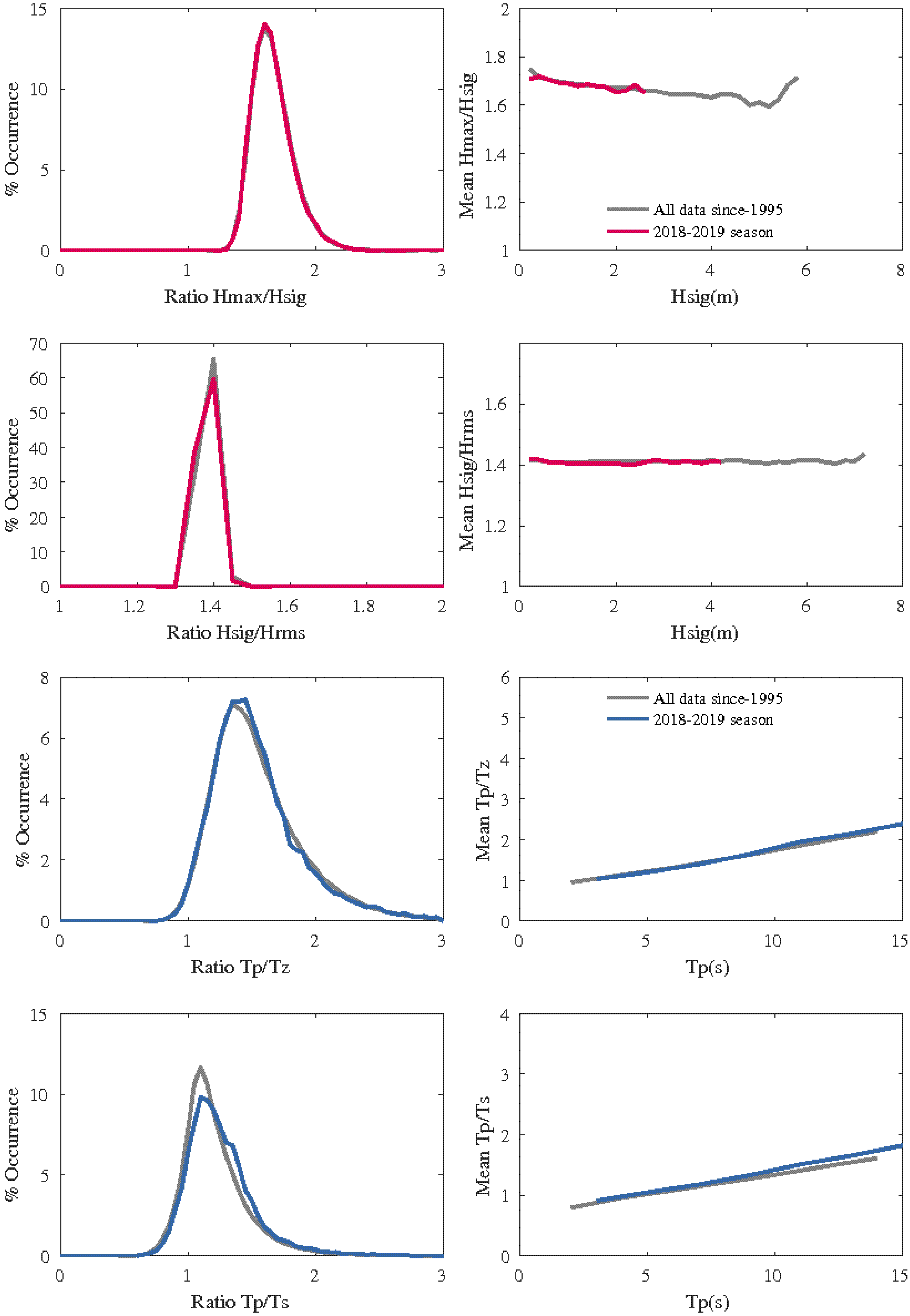

Figure 3.10: Tweed Heads Waverider buoy – Wave parameter relationships

4. Tweed Heads DWR4

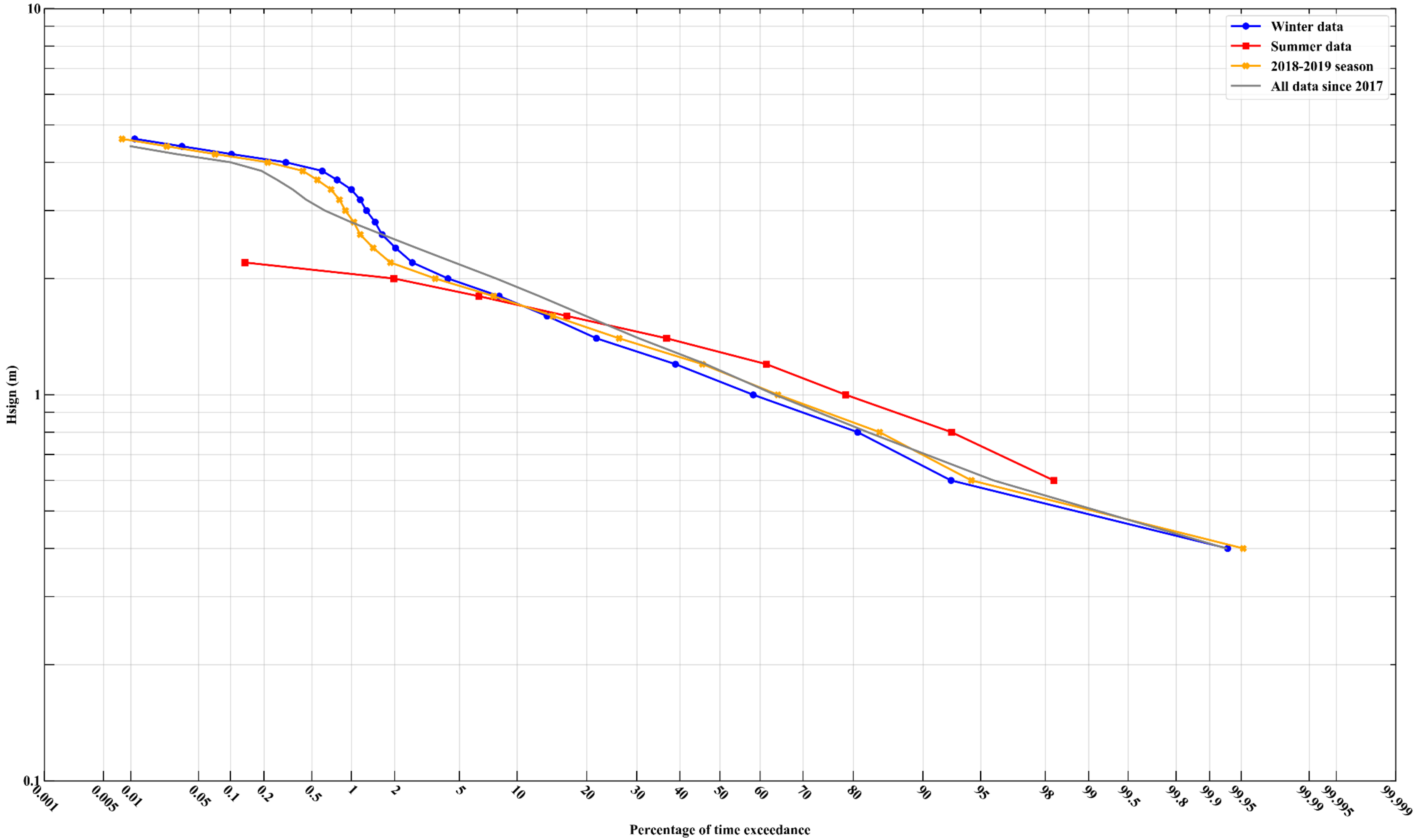

Figure 4.1: Tweed Heads DWR4 Waverider buoy – Percentage (of time) exceedance of wave heights (Hsig) for all wave periods (Tp)

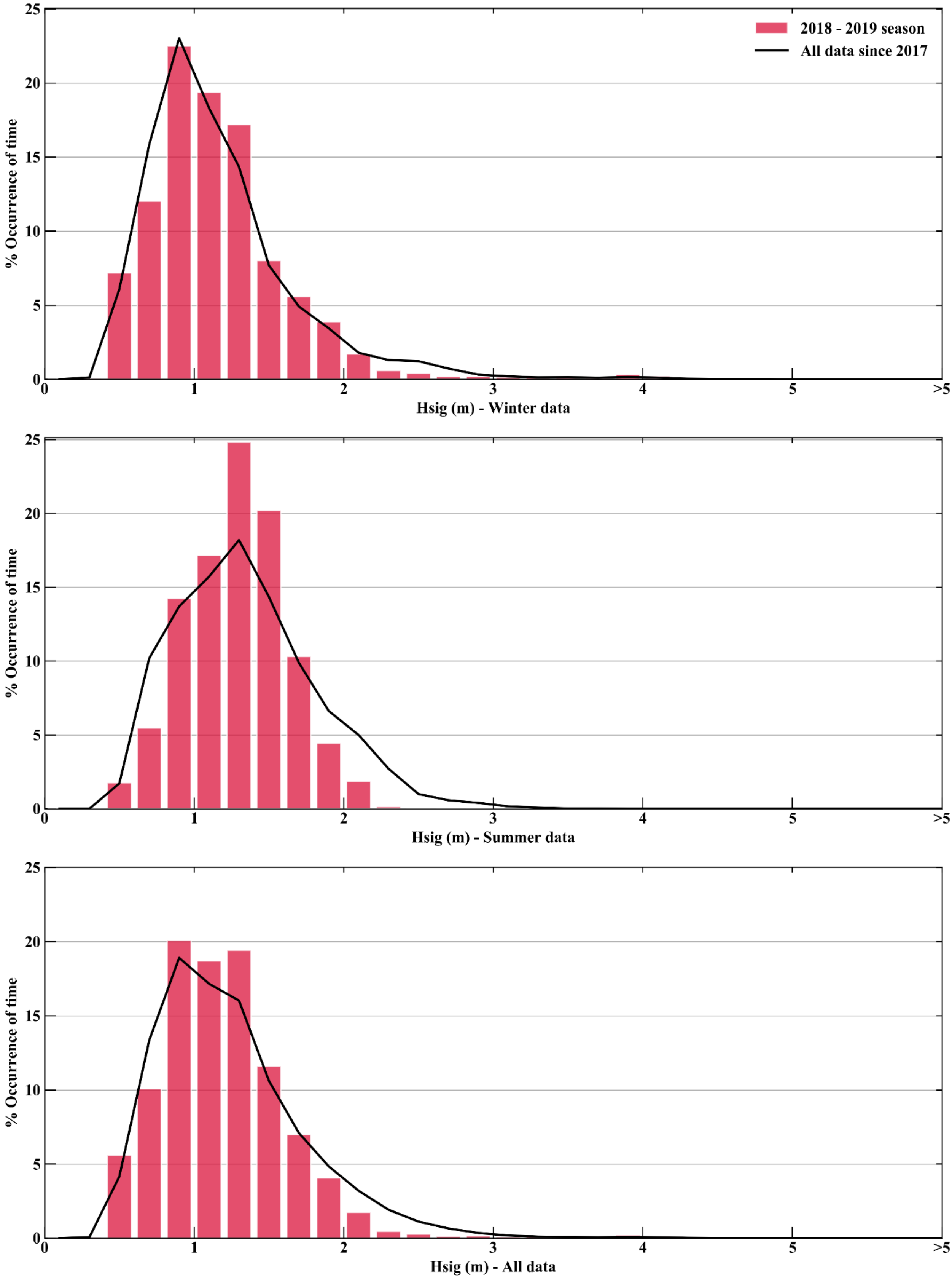

Figure 4.2: Tweed Heads DWR4 Waverider buoy – Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

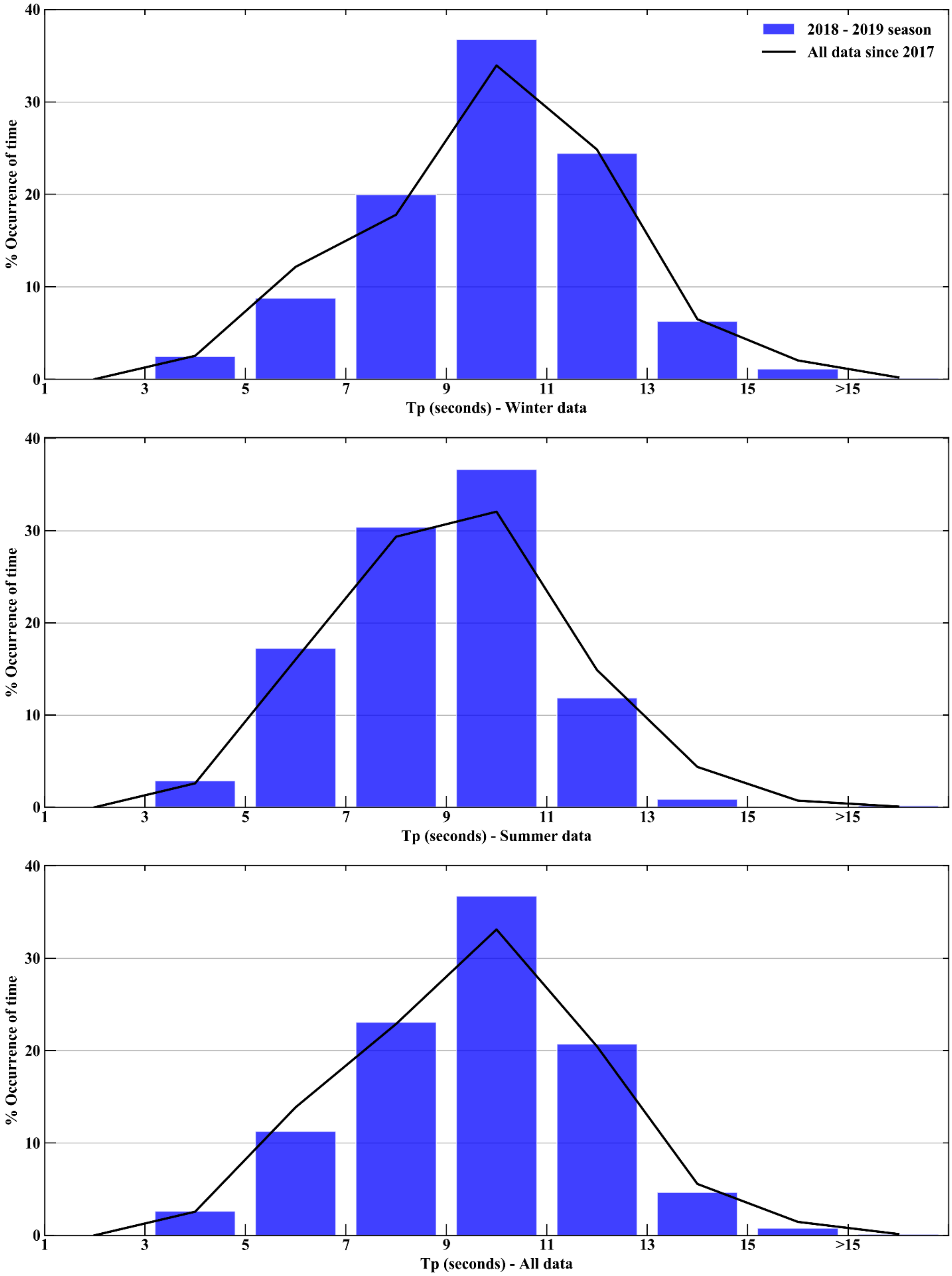

Figure 4.3: Tweed Heads DWR4 Waverider buoy – Histogram percentage (of time) occurrence of wave periods (Tp) for all wave heights (Hsig)

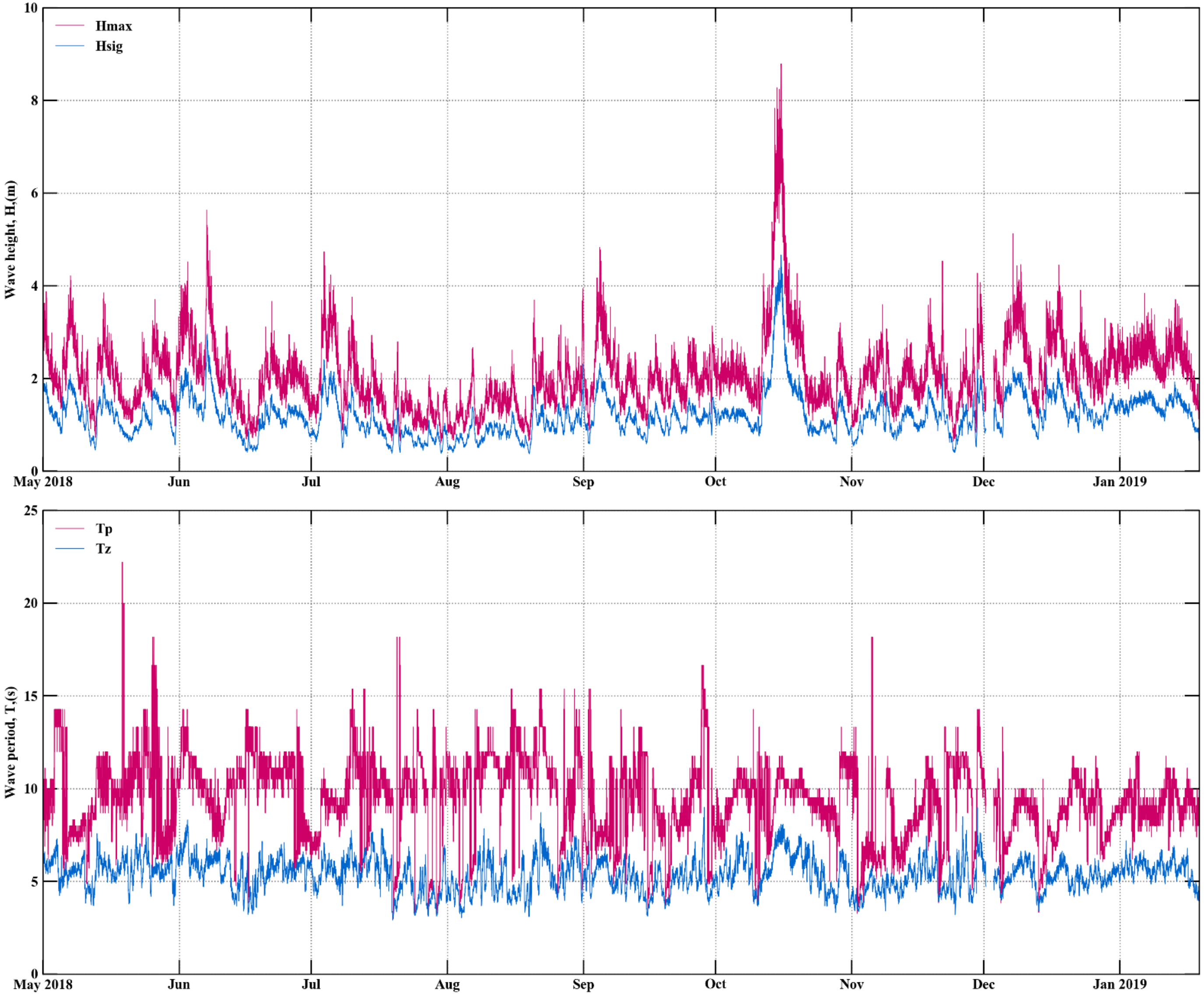

Figure 4.4: Tweed Heads DWR4 Waverider buoy – Daily wave recordings

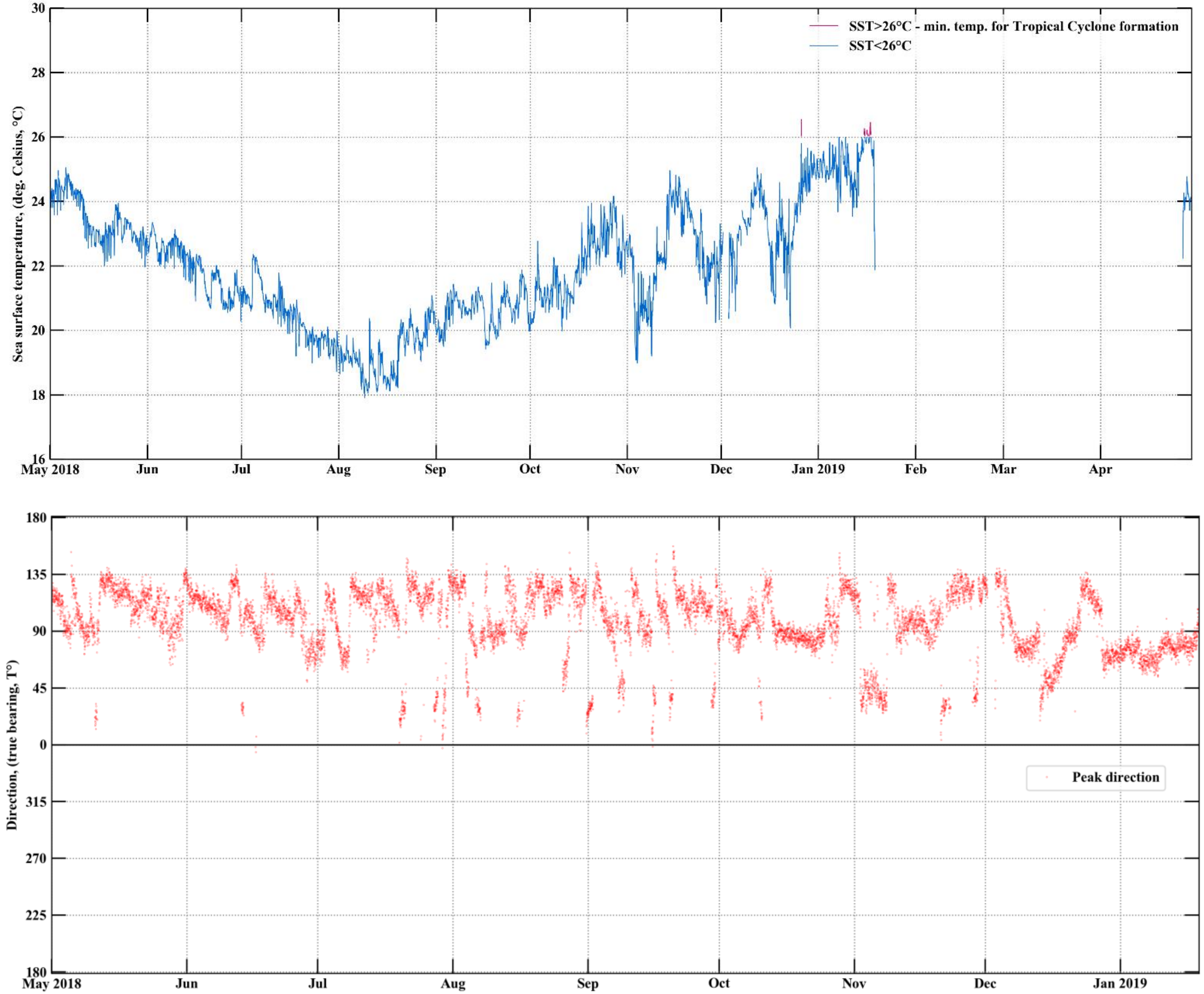

Figure 4.5: Tweed Heads MK4 Waverider buoy – Sea surface temperature and peak wave directions

*Gap in data is due to the buoy breakage as outlined in table2.

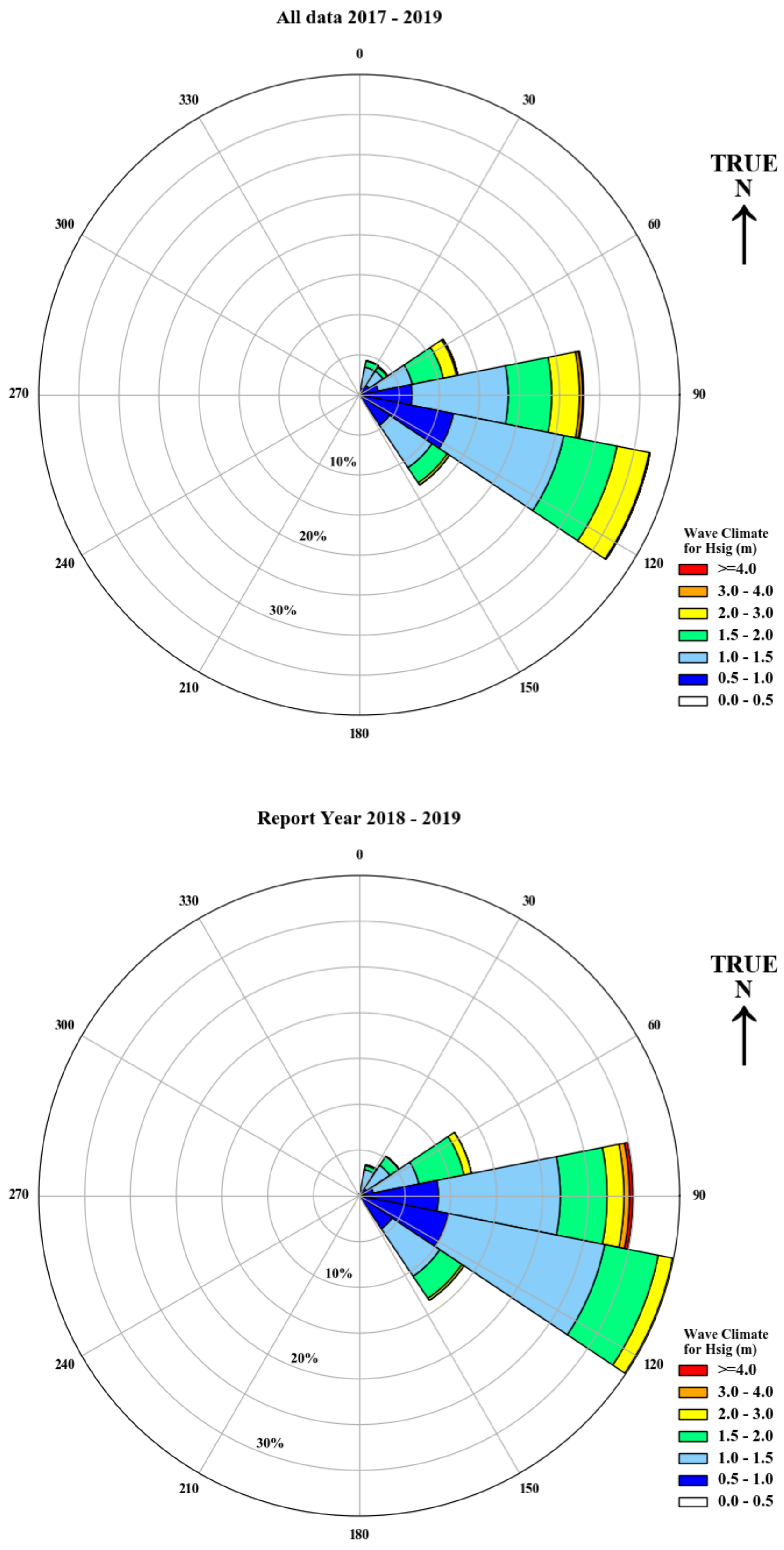

Figure 4.6: Tweed Heads DWR4 Waverider buoy – Directional wave rose

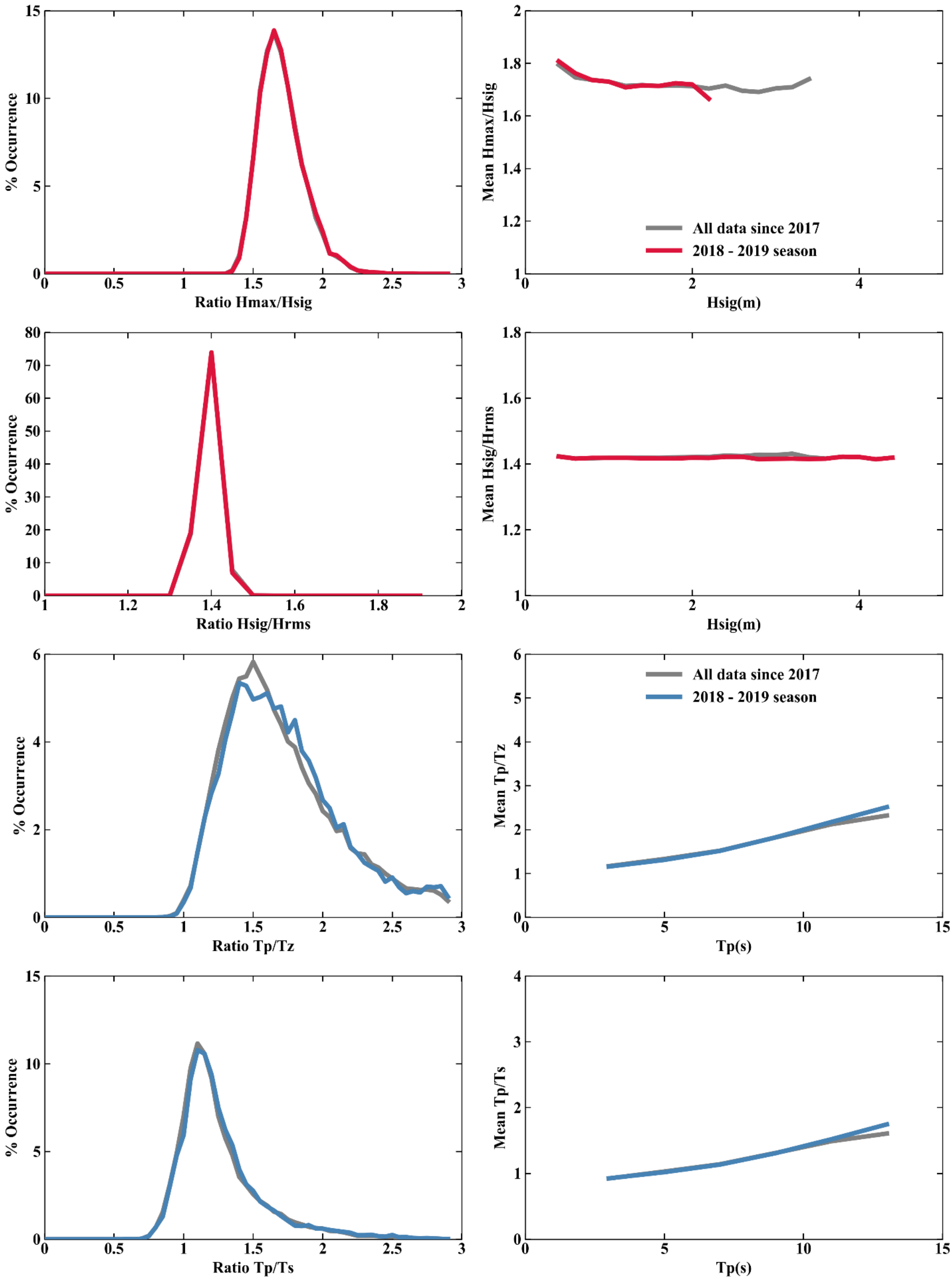

Figure 4.7: Tweed Heads DWR4 Waverider buoy – Wave parameter relationships

5. Brisbane

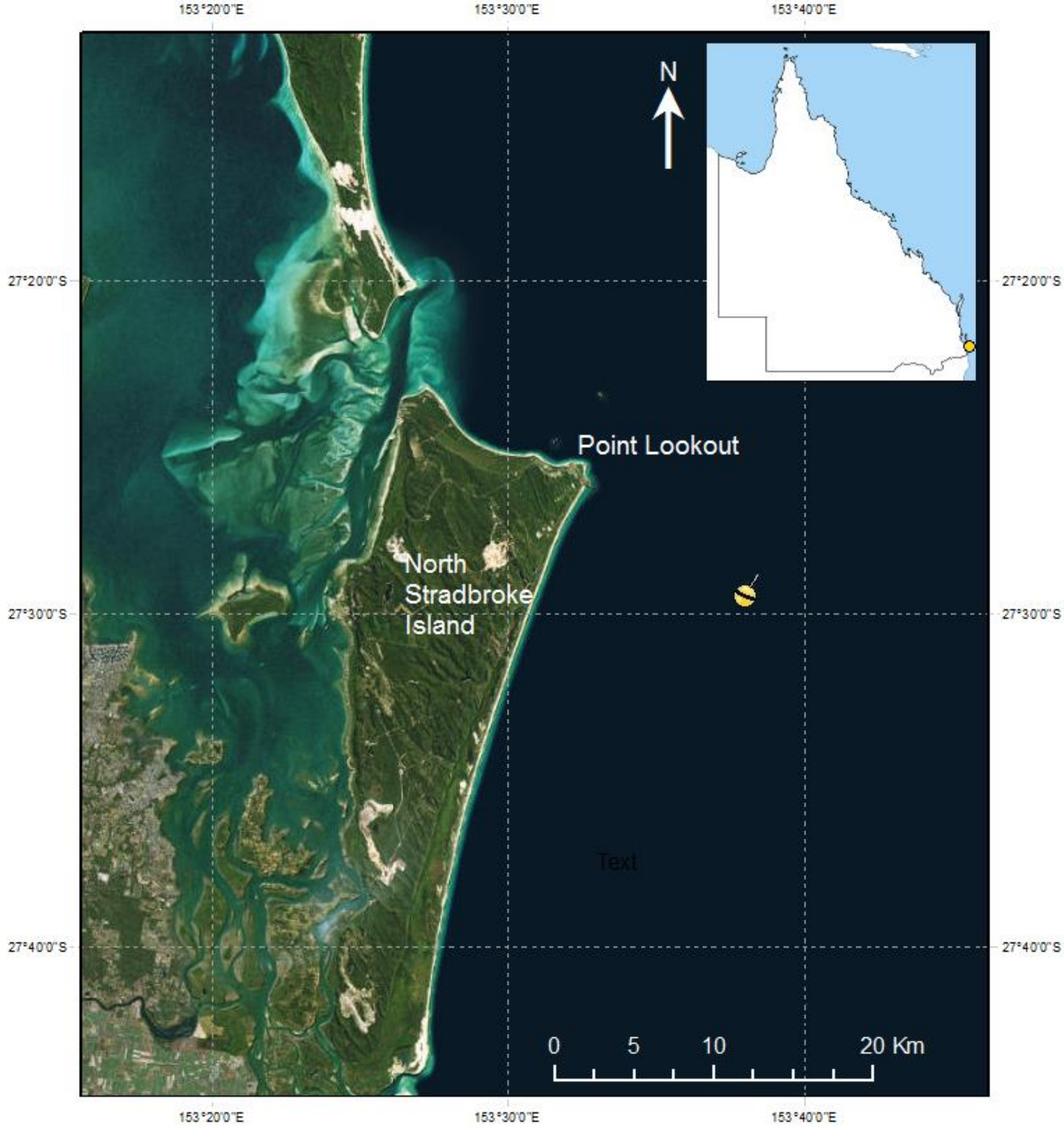

Figure 5.1: Brisbane Waverider buoy – Locality plan

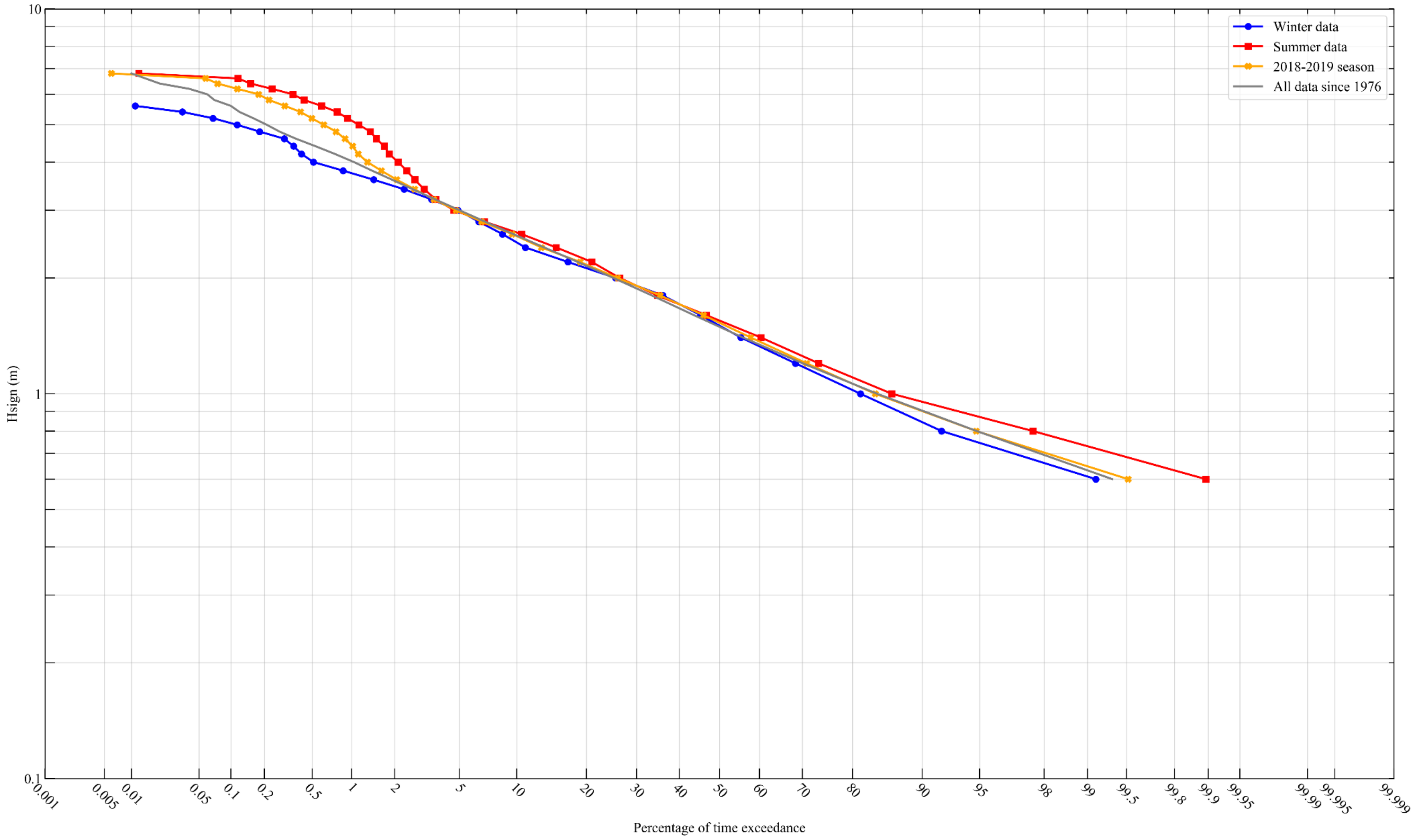

Figure 5.2: Brisbane Waverider buoy – Percentage (of time) exceedance of wave heights (Hsig) for all wave periods (Tp)

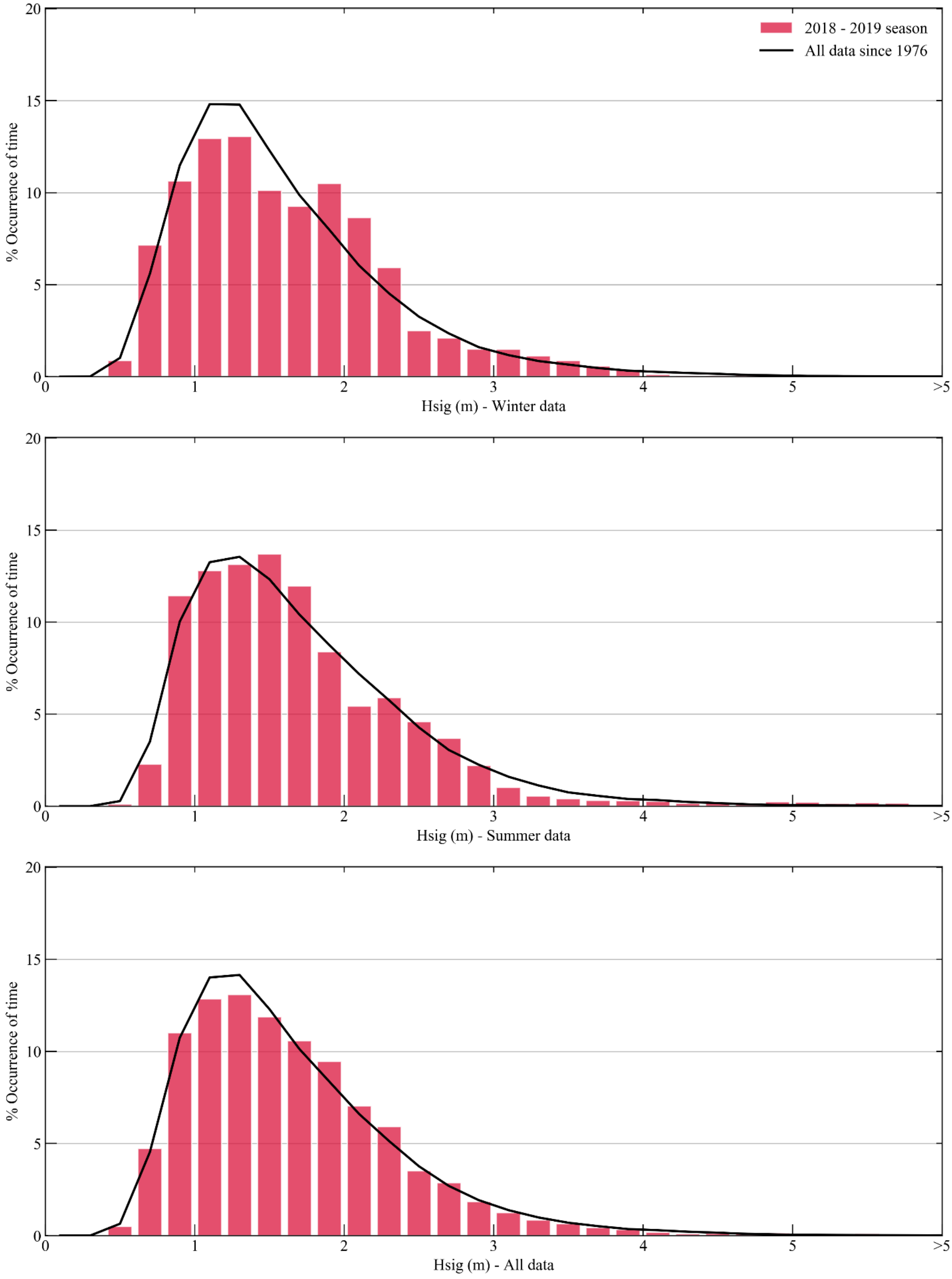

Figure 5.3: Brisbane Waverider buoy – Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

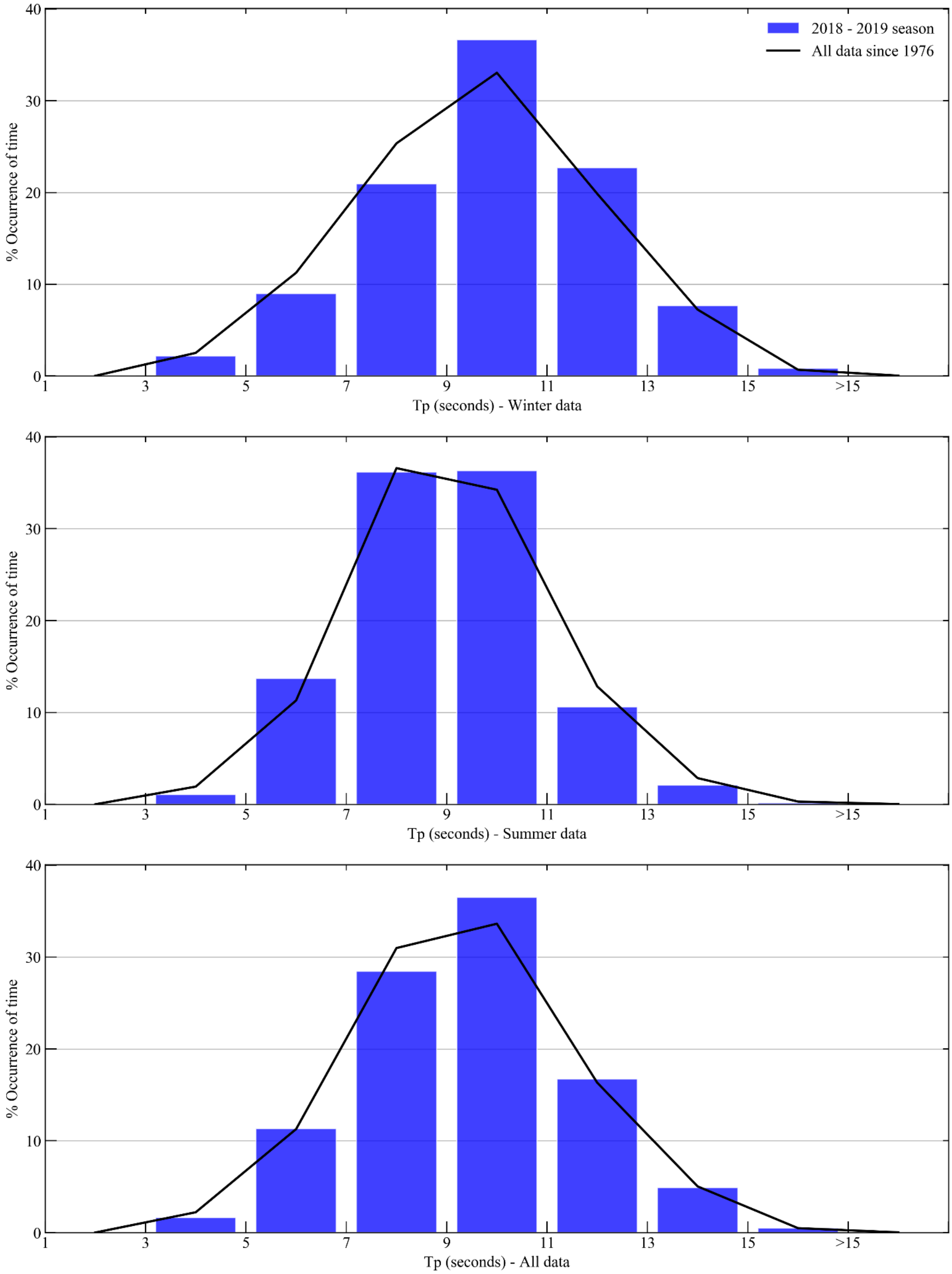

Figure 5.4: Brisbane Waverider buoy – Histogram percentage (of time) occurrence of wave periods (Tp) for all wave heights (Hsig)

Figure 5.5: Brisbane Waverider buoy – Daily wave recordings

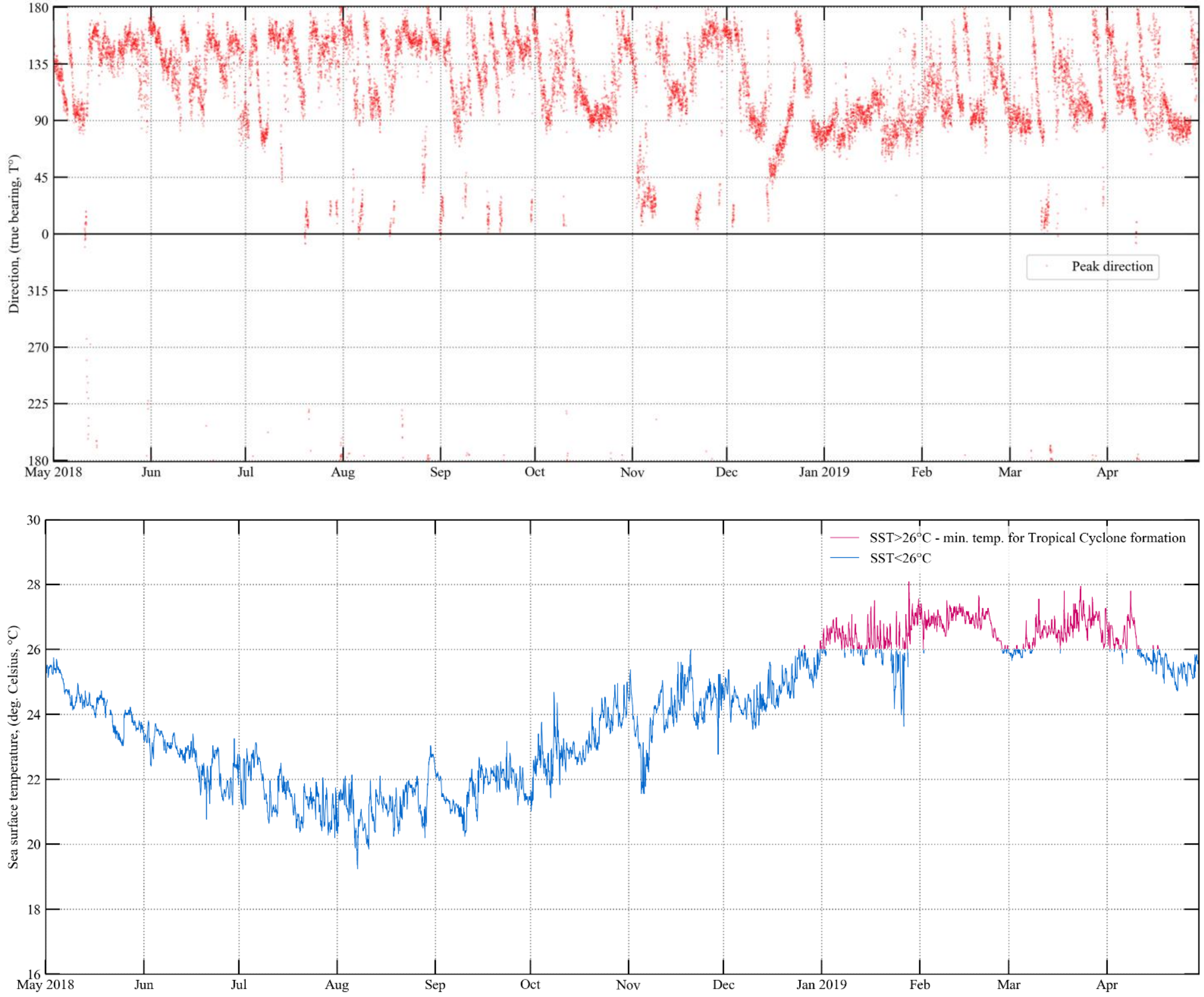

Figure 5.6: Brisbane Waverider buoy – Sea surface temperature and peak wave directions

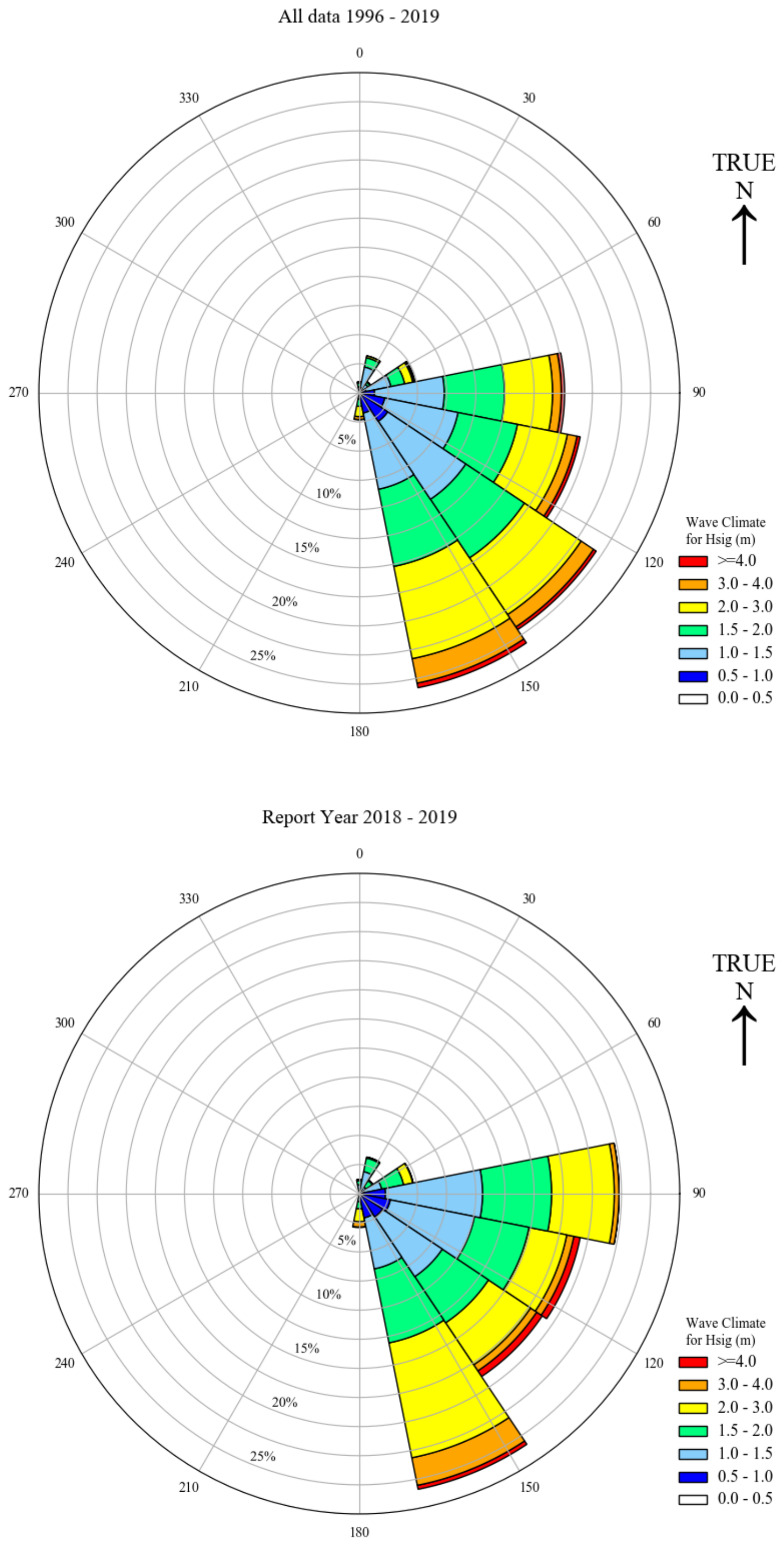

Figure 5.7: Brisbane Waverider buoy – Directional wave rose

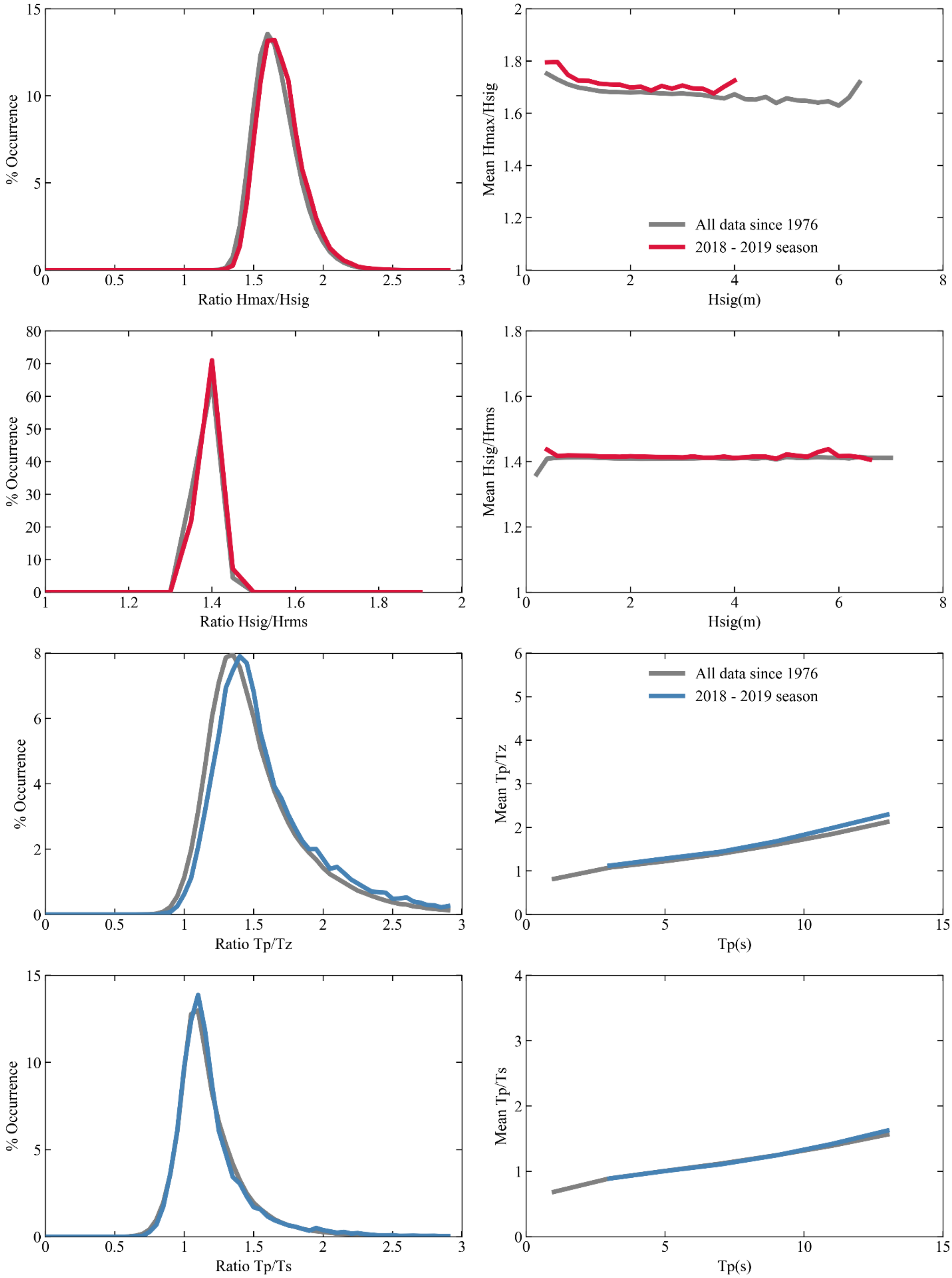

Figure 5.8: Brisbane Waverider buoy – Wave parameter relationships

6. Tweed Heads DWR-G and DWR4 Comparison

DES strives for continual improvement regarding the scientific instrumentation utilised as part of Queensland's wave monitoring network. The next generation of waverider buoy is the DWR4, which are poised to replace older buoy models that are currently used throughout the wave monitoring network. As such a dual deployment of a DWR-G and DWR4 waverider buoy has been arranged at Tweed Heads. The buoys are moored approximately 250m apart as seen in Figure 6.1. There are two major differences between the two units; 1) an increase in sampling frequency for the DWR4 and 2) a change in the calculating method utilised for spectral data. An in-depth report outlining the differences between the two buoy models has been undertaken by DES (DSITI, 2017), (DES, 2019). A comparison of the data collected from both the DWR-G and DWR4 is provided below (Figure 6.2 and 6.3). It is important to note that due to the nature of the comparison simultaneous records for both devices were necessary, as such corresponding data points to any data outages from one buoy were removed from the record for the other. Comparison is for the period 01/05/2018 – 30/04/2019.

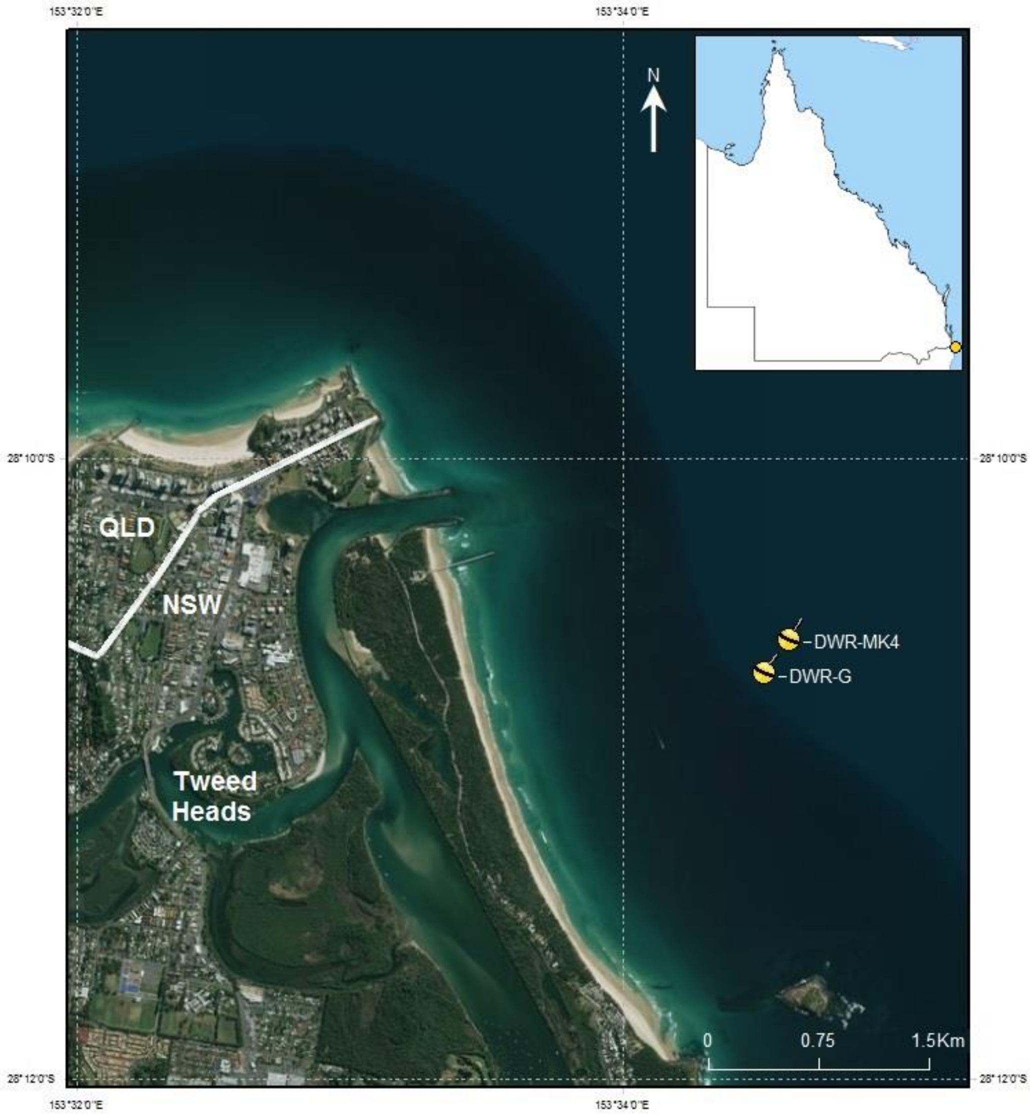

Figure 6.1: Locality plan for the Tweed Heads DWR-G and MK4 buoys

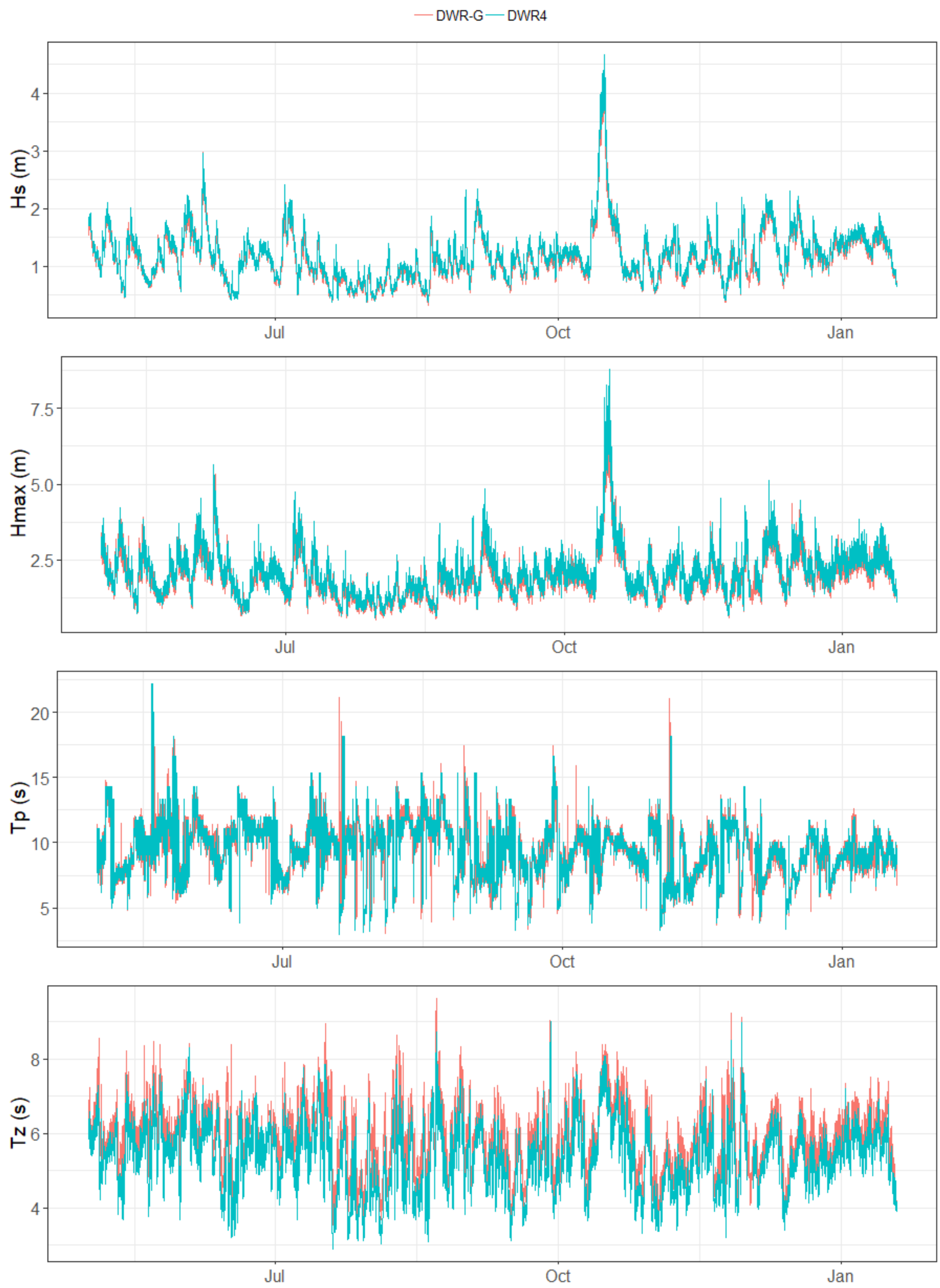

Figure 6.2: Comparison between the Tweed Heads DWR-G and DWR4 parameters; Hsig, Hmax, Tp, Tz

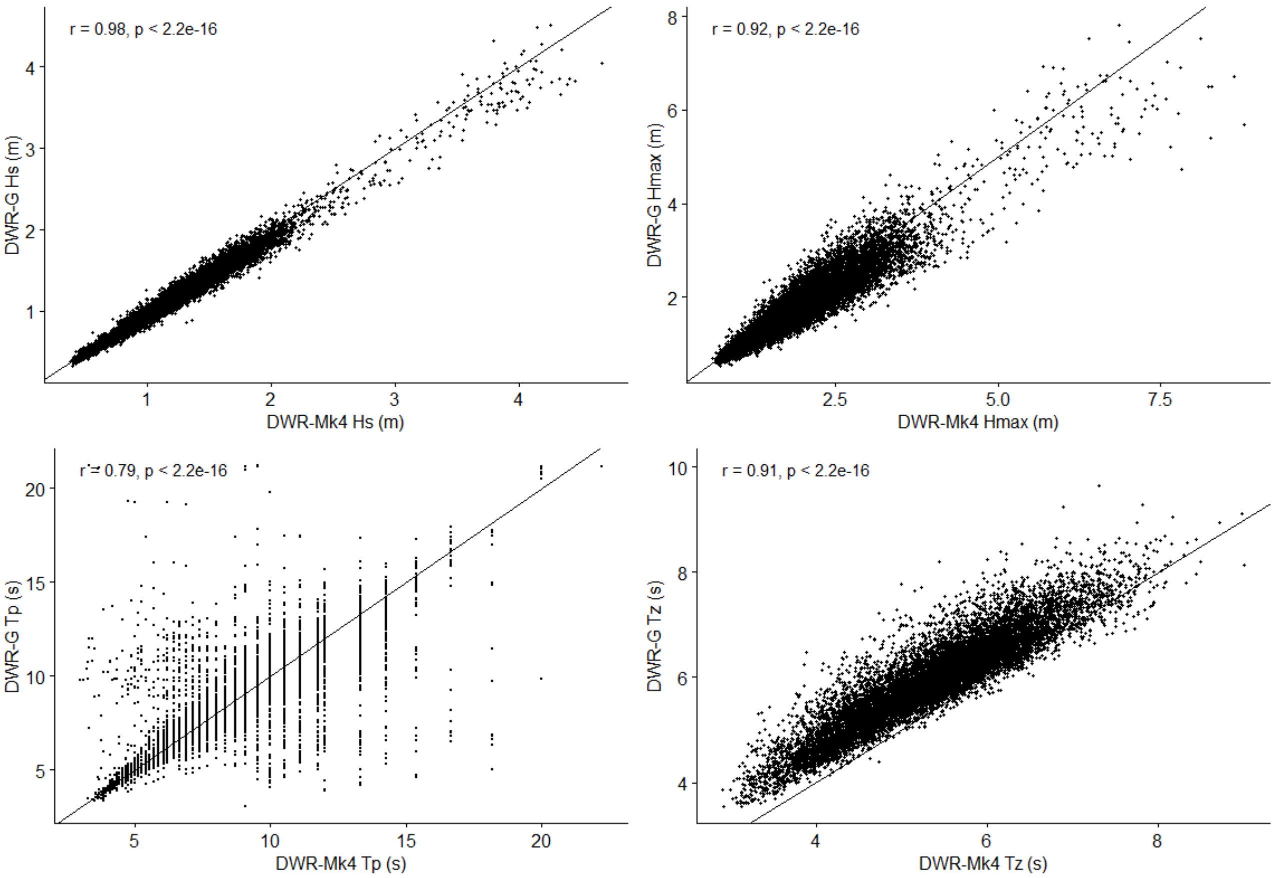

Figure 6.3: Spearmans correlation coefficient between the DWR-G and DWR4 parameters; Hsig, Hmax, Tp, and Tz

As seen in Figure 6.3 Hs, Hmax and Tz between the DWR4 and DWR-G have a high correlation (r 0.98, 0.92, 0.91 respectively), Tp on the other hand has a weaker correlation (r 0.79). Whilst both devices calculate Tp in a similar manner, there are differences in both sampling frequency and the amount of spectral bins utilised. As such differences in Tp between the two devices are to be expected. Bimodal sea states also have the potential to effect Tp, due to the potential for each device to pick up alternate peak periods from differing wave fields. For a more in depth comparison of the DWR4 to the DWR-MkIII refer to DSITI (2017).

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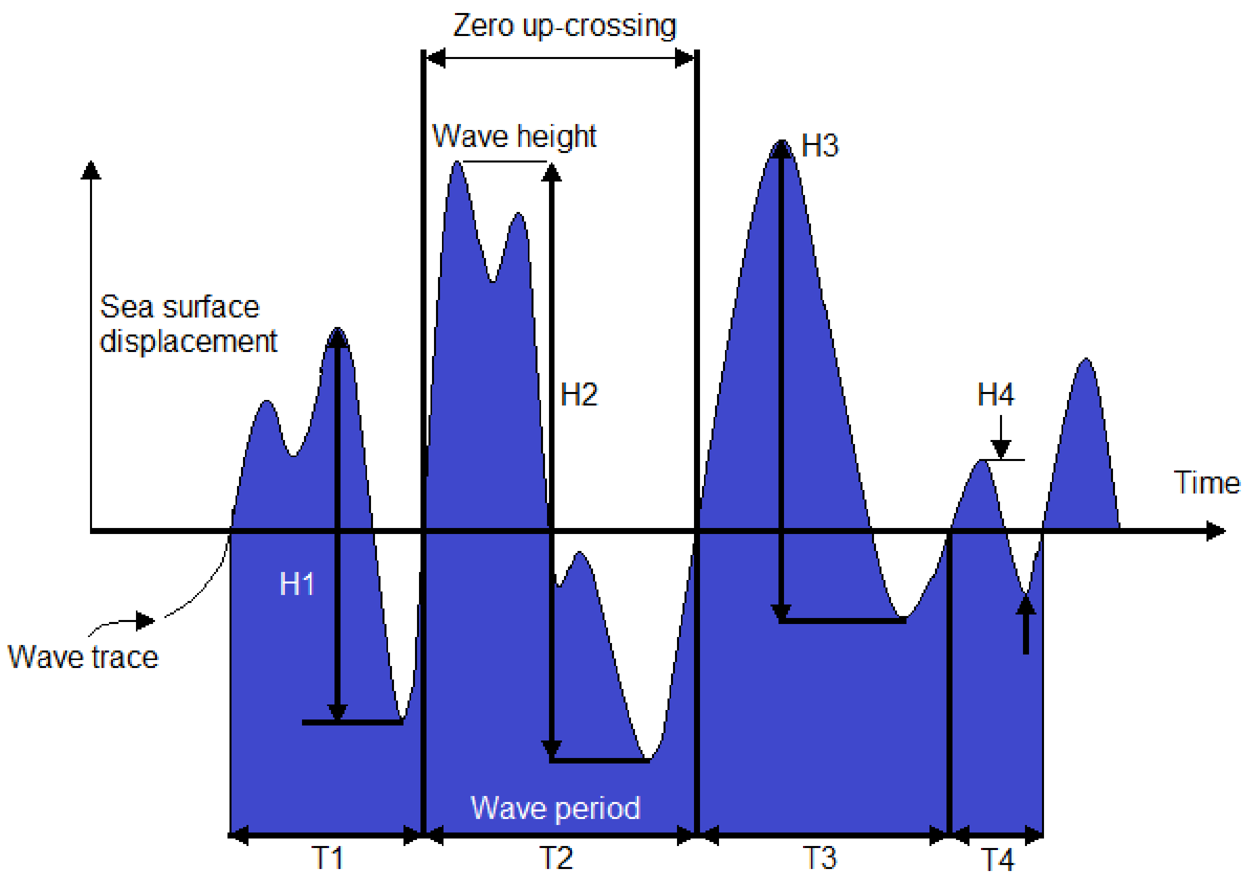
Appendix A – Zero up-crossing analysis

Zero crossing analysis

A direct, repeatable, and widely accepted method to extract representative statistics form wave data recorded by a wave measuring buoy. For zero up-crossing (used by DSITI), a wave is defined as the portion of the record between two successive zero up-crossings of the mean water line.

Waves are ranked (within their corresponding periods), and statistical wave parameters are computed in the time domain.

An explanation of wave parameters is presented in the Glossary.



Appendix B – Glossary of Terms

Parameter	Description
Hsig (Hs, significant wave height)	The significant wave height (in metres), defined as the average of the highest one-third of the zero up-crossing wave heights in a 26.6-minute wave record. This wave height closely approximates the value a person would observe by eye. Significant wave heights are the values reported by the Bureau of Meteorology in their forecasts.
THsig	The average period of the highest one-third of zero up-crossing wave heights.
Hrms	Root mean square wave height from the time domain.
Hmax	The maximum zero up-crossing wave height (in metres) in a 26.6-minute record.
Tc	The average crest period (in seconds) in a 26.6-minute record.
Tz	The average of the zero up-crossing wave periods (in seconds) in a 26.6-minute record.
H10	Average of the highest 10 per cent of all waves in a record.
TH10	The period of the H10 waves.
THmax	Period of maximum height, zero up-crossing.
Tzmax	The maximum zero crossing in a record.
Hm0	Estimate of the significant wave height from frequency domain $4\sqrt{m_0}$.
T02	Average period from spectral moments zero and two, defined by $\sqrt{m_0/m_2}$.
Tp	Wave period at the peak spectral energy (in seconds). This is an indication of the wave period of those waves that are producing the most energy in a wave record. Depending on the value of Tp, waves could either be caused by local wind fields (sea) or have come from distant storms and have moved away from their source of generation (swell).
Direction (Dir; Dir_p)	The direction that peak period (Tp) waves are coming (in º True North). In other words, where the waves with the most wave energy in a wave record are coming from.
HAT	HIGHEST ASTRONOMICAL TIDE is the highest water level which can be predicted to occur at a particular site under average weather conditions. This level may not be reached every year.
AHD	AUSTRALIAN HEIGHT DATUM is the reference level used by the Bureau of Meteorology in Storm Tide Warnings. AHD is very close to the average level of the sea over a long period (preferably 18.6 years), or the level of the sea in the absence of tides.
Wave setup	The increase in mean water level above the SWL towards the shoreline caused by wave action in the surf zone. The amount of rise of the mean water level depends on wave height and beach slope such that setup increases with increasing wave height and increasing beach steepness. It can be very important during storm events as it results in a further increase in water level above the tide and surge levels.
Astronomical tide	Or more simply, the tide is the periodic rise and fall of water along the coast because of gravitational attraction on the water by the moon and sun. When the moon, sun and earth are in line their combined attraction is strongest and the tide range is greater (spring tides). When the moon and sun are at right angles to each other (in relation to the earth) the effect of the attraction is somewhat reduced and the tide range is smaller (neap tides).
Predicted tide	The tide expected to occur under average meteorological conditions. Tide predictions are typically based on previous actual tide readings gathered over a long period (usually one year or more). The sun, moon and earth are not in the same relative position from year to year. Accordingly, the gravitational forces that generate the tides, and the tides themselves, are not the same each year.

Other published wave data reports in this series

Tweed Heads Wave Climate Summary 2006-2007	Report No. 2007.1	01 May 2006 – 30 April 2007
Tweed Heads Wave Climate Summary 2007-2008	Report No. 2008.1	01 May 2007 – 30 April 2008
Tweed Heads Wave Climate Summary 2008-2009	Report No. 2009.1	01 May 2008 – 30 April 2009
Tweed Heads Wave Climate Summary 2009-2010	Report No. 2010.1	01 May 2009 – 30 April 2010
Tweed Heads Wave Climate Summary 2010-2011	Report No. 2011.1	01 May 2010 – 30 April 2011
Tweed Heads Wave Climate Summary 2011-2012	Report No. 2012.1	01 May 2011 – 30 April 2012
Tweed Heads Wave Climate Summary 2012-2013	Report No. 2013.1	01 May 2012 – 30 April 2013
Tweed Heads Wave Climate Summary 2013-2014	Report No. 2014.1	01 May 2013 – 30 April 2014
Tweed Heads Wave Climate Summary 2014-2015	Report No. 2015.1	01 May 2014 – 30 April 2015
Tweed Heads Wave Climate Summary 2015-2016	Report No. 2016.1	01 May 2015 – 30 April 2016
Tweed Heads Wave Climate Summary 2016-2017	Report No. 2017.1	01 May 2016 – 30 April 2017
Tweed Heads Wave Climate Summary 2017-2018	Report No. 2018.1	01 May 2017 – 30 April 2018