Wave data recording program

Tweed Heads/Brisbane wave climate annual summary
May 2021–April 2022

Queensland Government

Prepared by: Queensland Government Hydraulics Laboratory, Department of Environment and Science

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August 2022

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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 Queensland Government Hydraulics Laboratory (QGHL) 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 01 May 2021 to 30 April 2022 is presented. The data recorded covers all the seasonal variations for one year and includes the 2021–22 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.

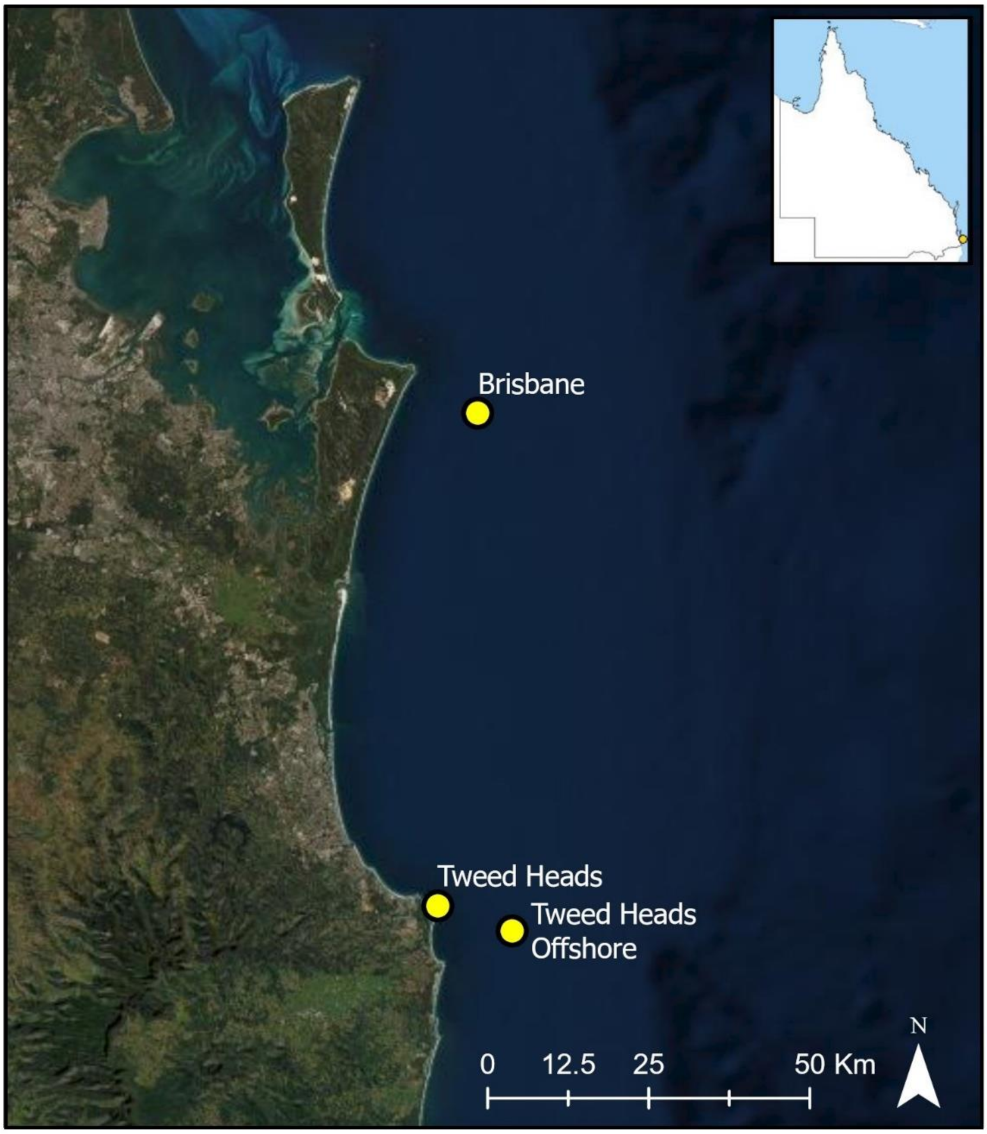


Figure 1.1 Tweed regional wave recording sites – locality plan

Recording

The QGHL 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.

Datawell DWR4 (MK4) waverider buoy

The Brisbane, Tweed Heads and the Tweed Heads offshore buoys are Waverider DWR4 (MK4) buoys. 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 hertz. Wave motion with higher frequencies cannot 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 DES (2019). A report investigating the differences between the DWR-MkIII system and the DWR4 system has been undertaken by DES (DSITI, 2017).

Datawell DWRG (GPS) waverider buoy

The directional Waverider DWR-G buoy at the Tweed Heads (removed from service in July 2019) 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 effect. 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.

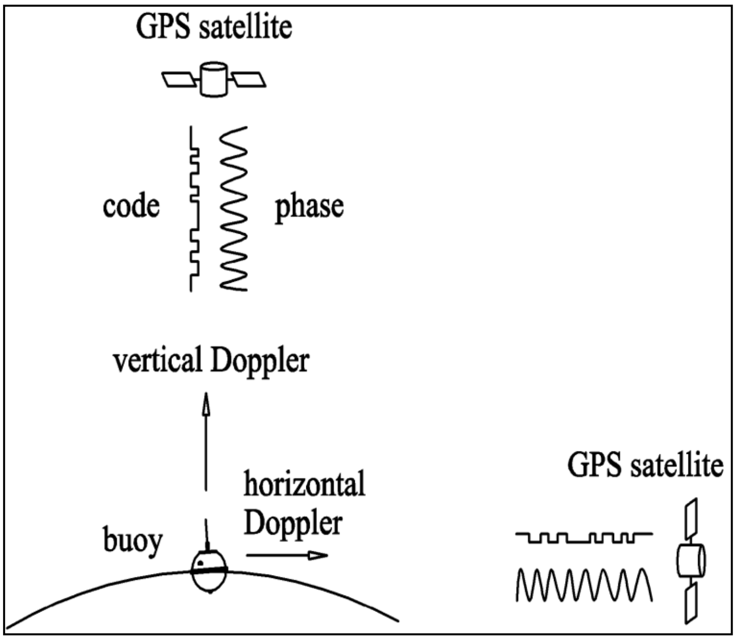


Figure 1.2 The GPS wave measurement principle (Source: Datawell, 2000)

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 are 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 buoys and the recording systems can be obtained from the Datawell references listed in Chapter 6 of this report.

Laboratory calibration checks

Waverider buoys used by QGHL undergo equipment verification checks, before and after deployment, which is approximately every 12 months. Accelerometer buoys (including DWR4) are verified at the QGHL'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 (2017) states that calibration of a GPS buoy is not necessary, the QGHL 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.

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) 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 0.58 Hz). 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 similar, there are several 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 post processing) before being transmitted. Additionally, Hs on the DWR4 is calculated using Hrms√2 as an alternative for $H_{⅓}$.

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 H_s)	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 (T_p) 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 ° 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.

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.

No significant gap (larger than two days) in the Tweed data record was found for the period from 01 May 2021 to 30 April 2022.

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 2 and Table 3). Data percentage capture rates for each wave site over the reporting period are presented in Table 4.

Table 2: Deployment details for the Tweed Heads buoy

Buoy	Latitude	Longitude	Estimated depth (m)	Calibration date	Deployed date	Removal date
DWR4	28° 10.594' S	153° 34.905' E	28	31/03/2022	02/04/2022	current
DWR4	28° 10.689' S	153° 34.527' E	25	19/10/2019	03/11/2020	02/04/2022
DWR4 Offshore	28° 13.711' S	153° 41.871' E	60	15/03/2021	28/09/2021	current
DWR4 Offshore	28° 12.822' S	153° 40.871' E	60	08/03/2021	19/03/2021	28/09/2021

Table 3: Deployment details for the Brisbane buoy

Buoy	Latitude	Longitude	Estimated depth (m)	Calibration date	Deployed date	Removal date
DWR4	27° 29.430' S	153° 38.079' E	80	25/10/2021	28/10/2021	current
DWR4	27° 29.405' S	153° 38.025' E	81	17/03/2020	04/11/2020	28/10/2021

Table 4: Wave recording program percentage data capture May 2021–April 2022

Station	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Avg.
Tweed Heads	97.85	97.84	97.92	97.85	97.99	97.92	97.91	95.9	97.85	97.89	98.4	99.64	97.91
Tweed Offshore	97.85	97.63	97.92	97.85	97.98	97.96	97.77	96.11	97.85	90.89	89.36	99.93	96.59
Brisbane	100.0	98.06	99.03	99.86	100.0	81.81	100.0	100.0	99.10	91.51	100.0	95.83	97.17

A summary of major meteorological events, where the recorded H_s 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 2021 to 30 April 2022 is shown in Table 5 and Table 6. Weather systems that contributed to the H_s reaching the storm threshold value are listed and may be direct reproductions of synoptic descriptions provided by the Australian Bureau of Meteorology (BoM, 2021).

Table 5: Significant meteorological events May 2021–April 2022, Tweed Heads buoy

Tweed Heads Storm threshold value: 2.0 metres (H_s)				
Date	**H_s (m)**	**H_{max}(m)**	**T_p (s)**	**Event**
2/05/2021 1:00	2.3	5	7.7	A high-pressure system in the Tasman Sea directed a ridge along Qld's east coast with a coastal trough developing in SEQld
25/05/2021 2:30	2.7	4.9	14.9	Cold front moved into south-west and southern inland Qld from WA and SA
31/05/2021 22:30	3	4.9	15.1	A cold front tracked across WA with a low-pressure system developing over southern coastal regions of the state
9/06/2021 6:30	2.5	4.8	7.1	A complex low-pressure system moved slowly over southern and eastern Victoria, with the associated cold front moving over eastern New South Wales and southern Queensland
4/07/2021 20:00	3.1	5.4	10.7	A strong cold front tracked through the south and south-eastern parts of the country with a complex low-pressure area over Victoria and Tasmania
11/07/2021 4:30	2.5	4.9	11.9	Low pressure system off the east coast of NSW and another south-west off WA coast
7/09/2021 5:00	2.4	4.5	11.7	Most of the country was under the influence of a high pressure from the 4th to 11th
16/09/2021 1:30	2.1	3.6	10.5	A surface trough and cold front moved across the south-western part of the country on the 15th, then tracked eastwards with a surface trough extending north-west.
31/10/2021 12:30	2.1	3.5	9.8	A low-pressure system extended across northern Australia and a high-pressure system moved west to east in the southern parts of the country
28/12/2021 6:30	2.3	4.5	10.6	Low moving eastwards through the top end, through the Gulf of Carpentaria and Cape York Peninsula and later strengthened to become TC Seth on 31st
3/01/2022 3:30	5.3	8.6	13.9	Passage of ex-TC Seth developed dangerous surf conditions causing the closure of Gold Coast beaches
13/01/2022 4:30	2.6	5.8	13.4	Tropical Low small storm circulation off Northeast-Queensland and tracking towards land
20/01/2022 22:30	2.7	4.8	11	Periods of very heavy rainfall associated with a monsoon trough with widespread shower and thunderstorms
5/02/2022 20:00	2.9	5.5	10	The passage of Tropical Cyclone Dovi which was nearest the Queensland coast on the 5th
12/02/2022 7:30	2.8	5.1	9.5	The passage of Tropical Cyclone Dovi which was a category 3 from 10th to 11th

Tweed Heads Storm threshold value: 2.0 metres (H_s)				
Date	H_s (m)	H_{max}(m)	T_p (s)	Event
28/02/2022 3:30	4.2	7.6	10.3	The final week of February due to a humidity and a slow-moving trough with upper atmospheric support, experienced multi-day very heavy rainfall and storms resulting in flooding in SE-Q and NE-NSW
15/03/2022 5:30	2.2	3.9	8.7	Low-pressure trough brought storms and heavy rainfall
29/03/2022 0:30	3.5	7.1	8.4	Heavy rainfall at the end of the month due to a low-pressure trough developing into a coastal low on 29th. This resulted in more flooding to some regions of SE-Q and NE-NSW
8/04/2022 22:30	3.1	5.6	9.7	Constant stream of moist onshore flow in combination with upper atmospheric support developed heavy rain and storms
16/04/2022 22:30	2.3	4.5	10.6	Fast moving Squall line moving east to west
25/04/2022 4:30	2.7	5.4	7.7	Low-pressure trough fed by tropical moisture

Denotes peak Hsig event

Table 6: Significant meteorological events May 2021–April 2022, Brisbane buoy

Brisbane Storm threshold value: 4.0 metres (H_{sig})				
Date	H_s(m)	H_{max} (m)	T_p (s)	Event
11/07/2021 6:00	5.7	11.4	12.3	Low pressure system off the east coast of NSW and another south-west off WA coast
31/10/2021 6:00	4.4	8.9	9.5	A low-pressure system extended across northern Australia and a high-pressure system moved west to east in the southern parts of the country
28/12/2021 6:00	4.7	9.8	9.4	Low moving eastwards through the top end, through the Gulf of Carpentaria and Cape York Peninsula and later strengthened to become TC Seth on 31st
3/01/2022 19:30	4.7	8.8	9.8	Passage of ex-TC Seth developed dangerous surf conditions causing the closure of Gold Coast beaches
20/01/2022 23:30	5.2	9.1	11.2	A monsoon trough and moist onshore flow brought widespread showers and thunderstorms
4/02/2022 16:30	4	7.2	9.1	Tropical low that would form Tropical Cyclone Dovi

Denotes peak H_{sig} event

Note: Barometric pressure measured in hectopascals (hPa). The H_s and H_{max} values are the maximums recorded for each event and are not necessarily coincident in time. The T_p and H_s 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_s 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 2.2 to Figure 2.4, Figure 3.3 to Figure 3.5 and Figure 4.2 to Figure 4.4. In each of these figures for each site, the term ‘All data’ refers to the combined number of years of operation for each site. 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_s 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 2021 to 30 April 2022. 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 2021 to 30 April 2022 to align with TRESBP 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.

Tweed Heads

Near real time data feed: Tweed Heads wave monitoring page

Details of data collection	
2021 – 2022 season	
Maximum possible analysis days (last record - first record)	365
Total number of days used in analysis	356.12
Gaps in data used in analysis(days)	8.87
Number of records used in analysis	17,094
All data since 1995 – 2022	
Maximum possible analysis years (last record – first record)	27.29
Total number of years used in analysis	26.93
Gaps in data used in analysis (years)	0.37
Number of records used in analysis	419988

Table 7: Table of highest ranked un-smoothed waves at Tweed Heads

Rank	Date (H_s)	H_s (m)	Date (H_{max})	H_{max} (m)
1	3/05/1996 1:00	7.5	2/05/1996 14:30	13.1
2	28/01/2013 8:30	6.7	28/01/2013 9:00	11.8
3	14/12/2020 8:30	6.4	14/12/2020 4:00	11.8
4	6/03/2004 1:00	6.1	5/03/2004 23:30	11.1
5	21/05/2009 19:30	5.6	30/06/2005 6:30	9.9
6	4/06/2016 19:30	5.6	5/06/2016 0:30	9.8
7	1/05/2015 22:30	5.5	22/05/2009 7:00	9.7
8	3/01/2022 3:30	5.3	4/03/2006 12:00	9.6
9	24/05/1999 5:00	5.2	25/03/1998 22:30	9.5
10	4/03/2006 20:30	5.2	15/02/1995 15:30	9.3

Table 8: Wave conditions 2021-22, Tweed Heads Waverider buoy

Month	Average H_s (m)	Min H_s (m)	Max H_s (m)	Average Direction for Peak Period Dir_{Tp} (° True North)	90% of waves within the range of (m)	No. of Days when $H_s \geq 2$ m	No. of Days when $H_s \leq 0.75$ m	Date of events where $H_s > 3$ m
May-21	1.46	0.77	3	81	1.0 - 2.1	8	0	31
Jun-21	1	0.35	2.49	92	0.5 - 1.6	2	15	
Jul-21	1.25	0.34	3.07	87	0.5 - 2.3	9	15	4
Aug-21	1.02	0.54	1.74	85	0.7 - 1.4	0	14	
Sep-21	1.31	0.5	2.38	80	0.7 - 1.9	4	7	
Oct-21	1.09	0.54	2.09	81	0.7 - 1.7	2	12	
Nov-21	1.09	0.44	1.83	79	0.6 - 1.6	0	8	
Dec-21	1.14	0.61	2.67	88	0.8 - 1.7	2	3	
Jan-22	1.83	0.98	5.33	82	1.1 - 2.6	16	0	2 3
Feb-22	1.78	0.71	4.17	87	0.9 - 2.8	16	1	27 28
Mar-22	1.58	0.52	3.45	86	0.7 - 2.8	11	3	1 5 6 28 29 30
Apr-22	1.65	0.69	3.05	88	0.9 - 2.5	11	3	8 9
May to Apr	1.35	0.34	5.33	85	0.8 - 2.1	81	81	14

Table 9: Mean Values, Tweed Heads buoy

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May–Apr
Mean H_s (m) 2021–22	1.46	1	1.25	1.02	1.31	1.09	1.09	1.14	1.83	1.78	1.58	1.65	1.35
Mean H_s (m) Average from 1995–2022	1.3	1.22	1.15	1.07	1.1	1.13	1.13	1.17	1.31	1.49	1.44	1.35	1.24
Average direction for peak period Dir_{Tp} (° True North) 2021–22	81	92	87	85	80	80	79	87	81	86	86	88	84
Average direction for peak period Dir_{Tp} (° True North) 1995–2022	98	101	102	100	93	92	91	91	90	94	93	97	95

$$Mean\ H_s = \sum H_s / N$$

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

Where:

H_s= Significant wave height

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

N = number of records

Table 10: Weighted Mean Values, Tweed Heads buoy

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May–Apr
Weighted Mean H_s (m) 2021–22	1.53	1.09	1.46	1.06	1.39	1.15	1.14	1.2	1.96	1.96	1.76	1.75	1.45
Weighted Mean H_s (m) 1995–2022	1.54	1.4	1.29	1.22	1.19	1.25	1.22	1.29	1.46	1.65	1.6	1.48	1.38
Weighted direction for peak period Dir_{Tp} (° True North) 2021–22	80	88	81	88	81	81	79	90	76	85	76	86	82
Weighted direction for peak period Dir_{Tp} (° True North) 1995–2022	88	95	98	95	91	90	93	89	87	91	88	93	91

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

$$Weighted\ Mean\ Direction = \sum \left(H_s{}^{2.5} * D\right) / \sum H_s{}^{2.5}$$

Where:

H_s= Significant wave height

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

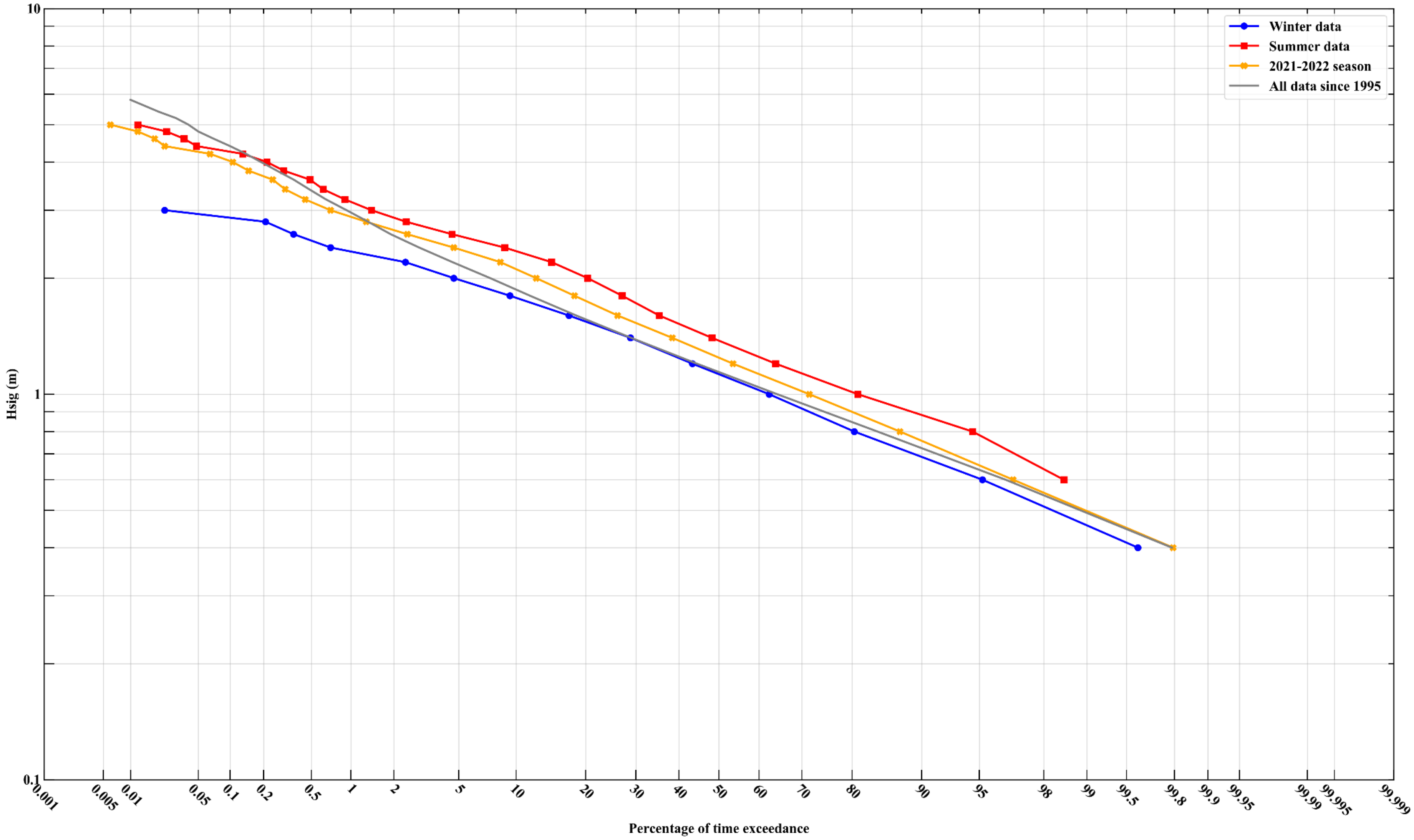


Figure 2.1 Tweed Heads buoy – percentage (of time) exceedance of wave heights (H_s) for all wave periods (T_p)

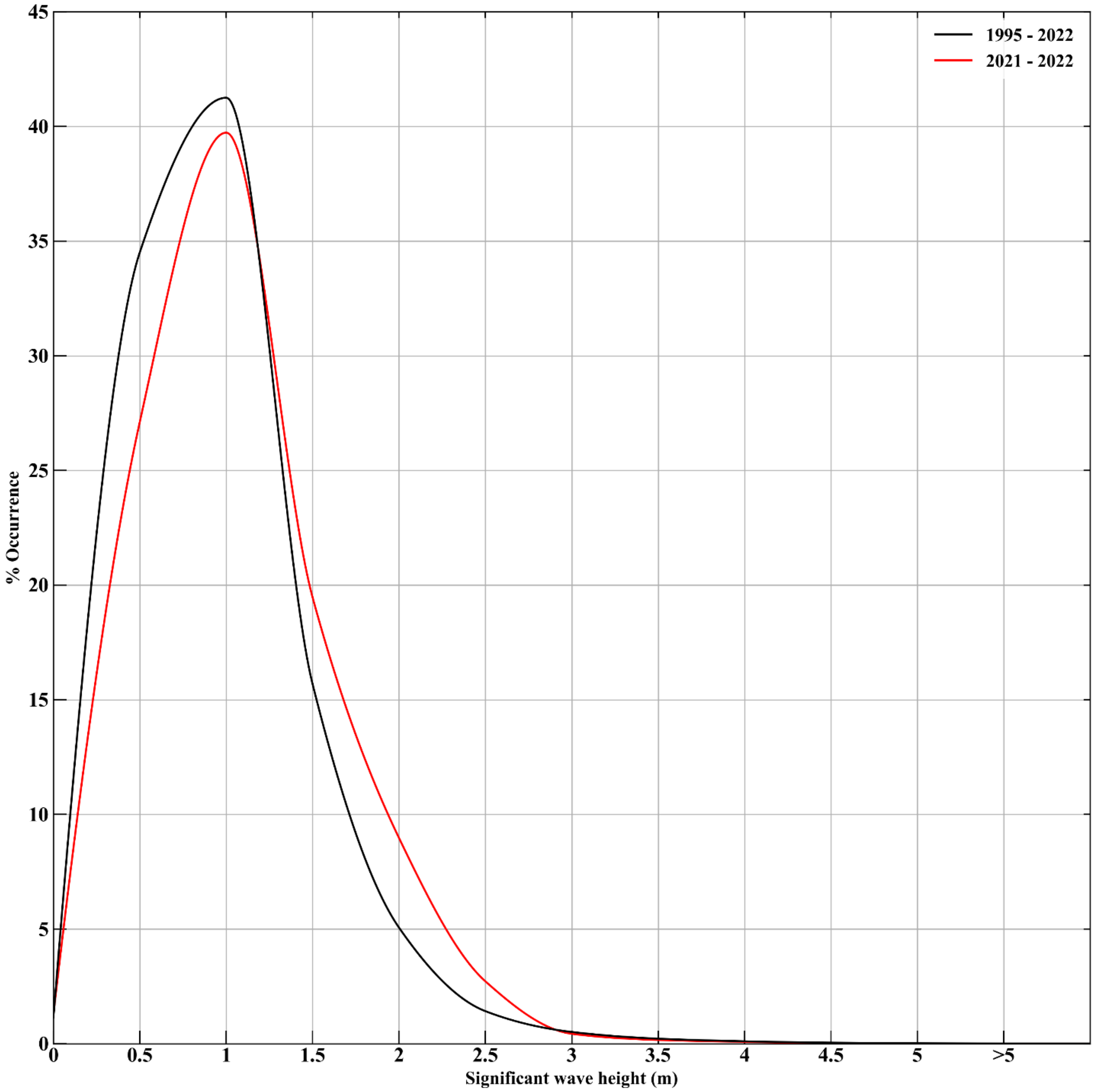


Figure 2.2 Tweed Heads buoy – H_s percentage (%) occurrence

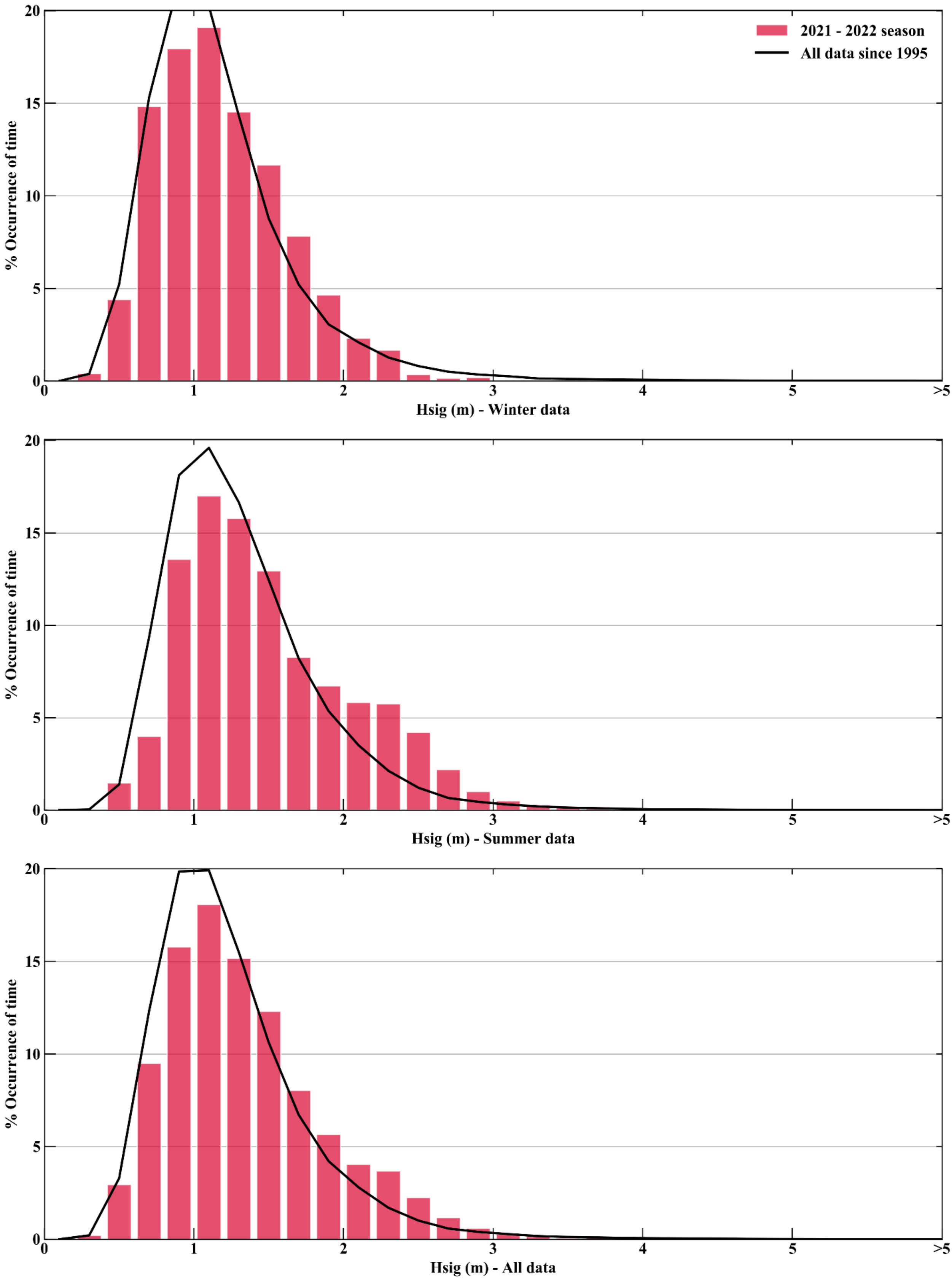


Figure 2.3 Tweed Heads buoy – histogram percentage (of time) occurrence of wave heights (H_s) for all wave periods (T_p)

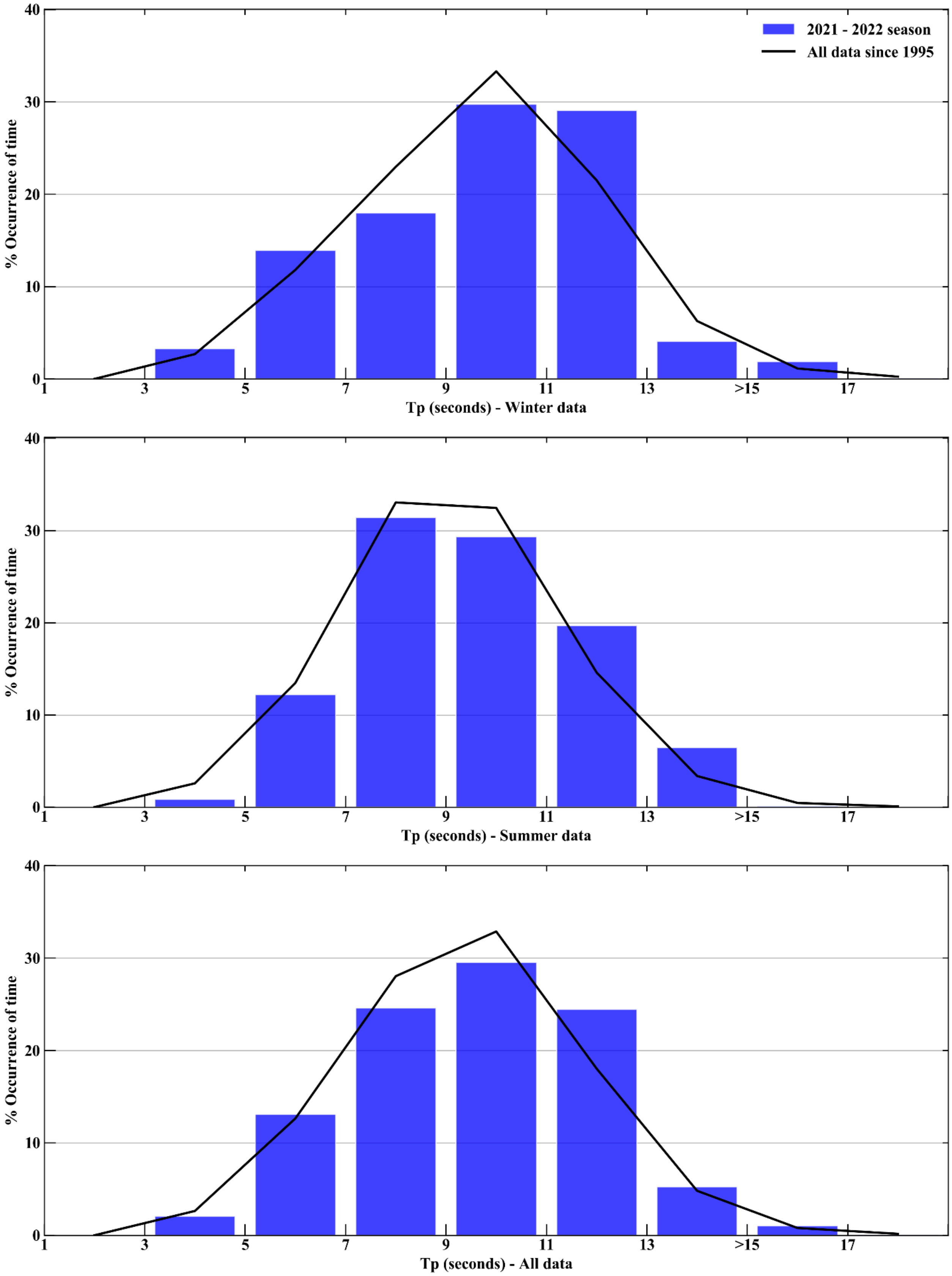


Figure 2.4 Tweed Heads buoy – histogram percentage (of time) occurrence of wave periods (T_p) for all wave heights (H_s)

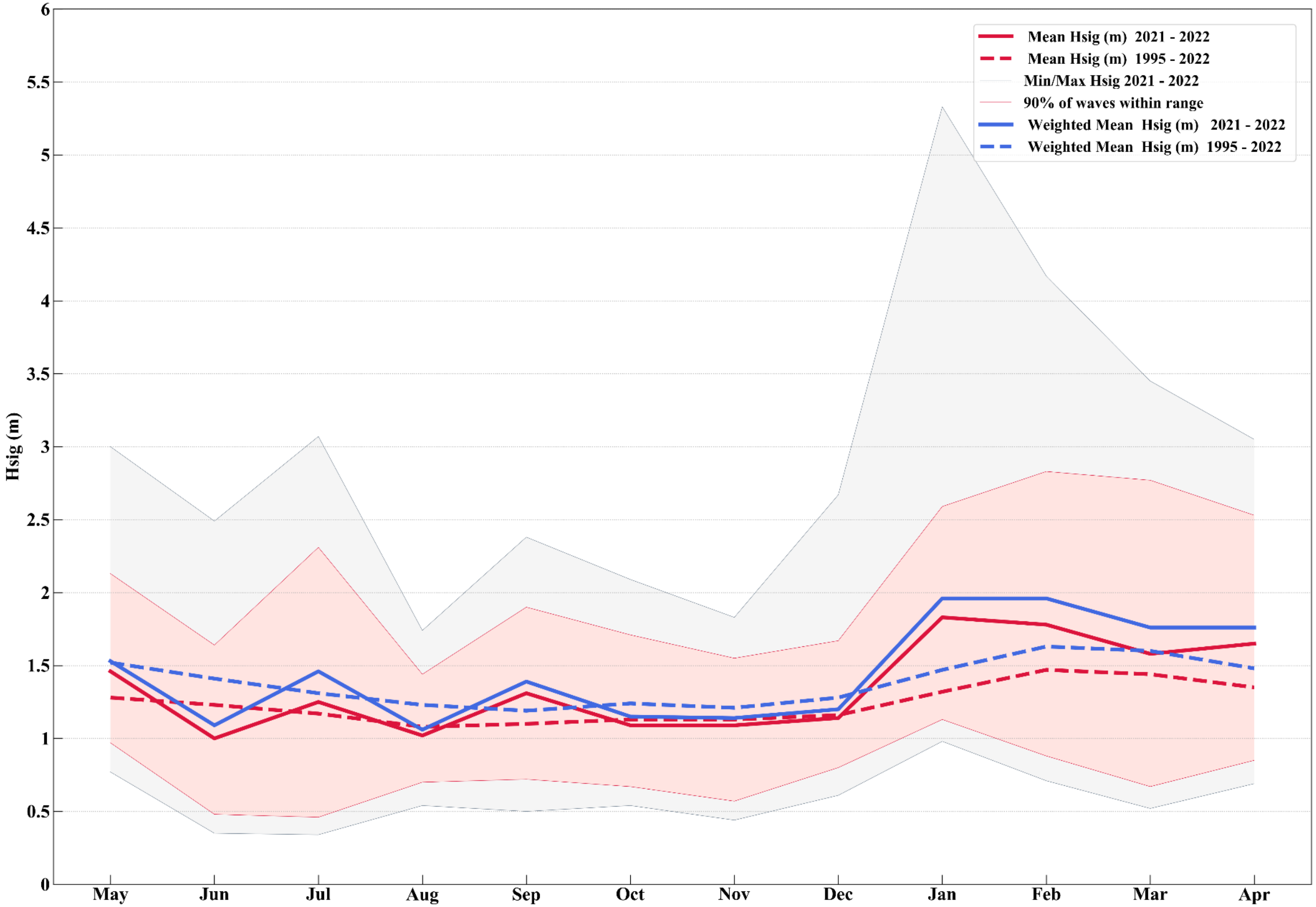


Figure 2.5 Tweed Heads buoy – monthly average H_s for seasonal year and for all data. The weighted mean H_s provides an indicative potential for sediment transport.

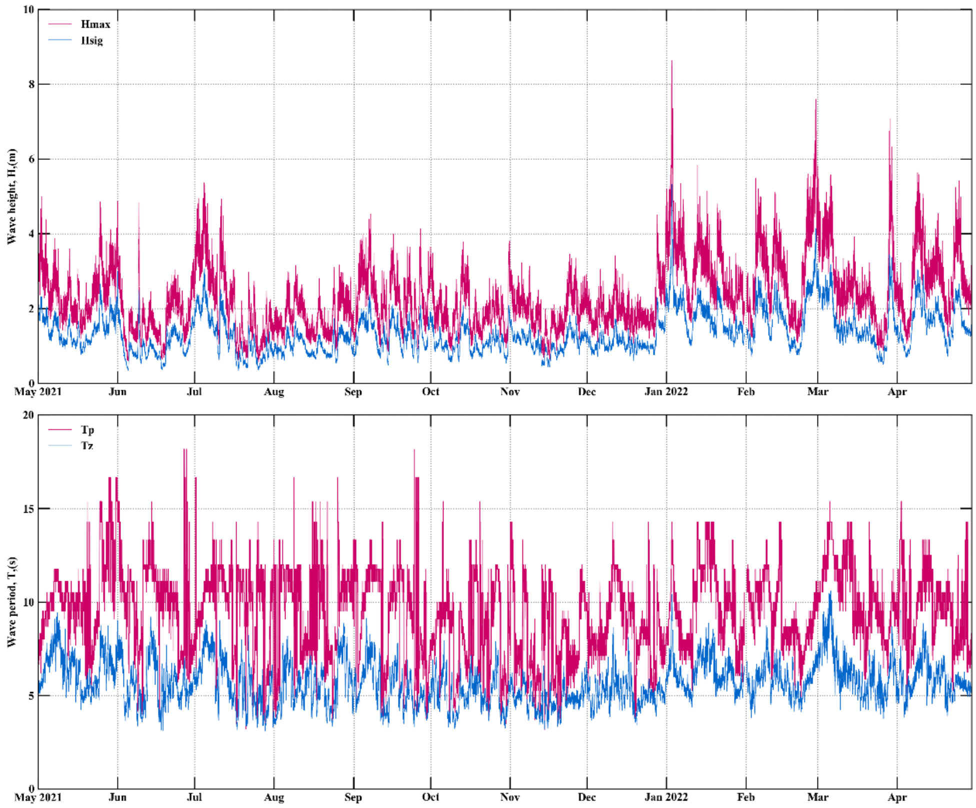


Figure 2.6 Tweed Heads buoy – daily wave recordings

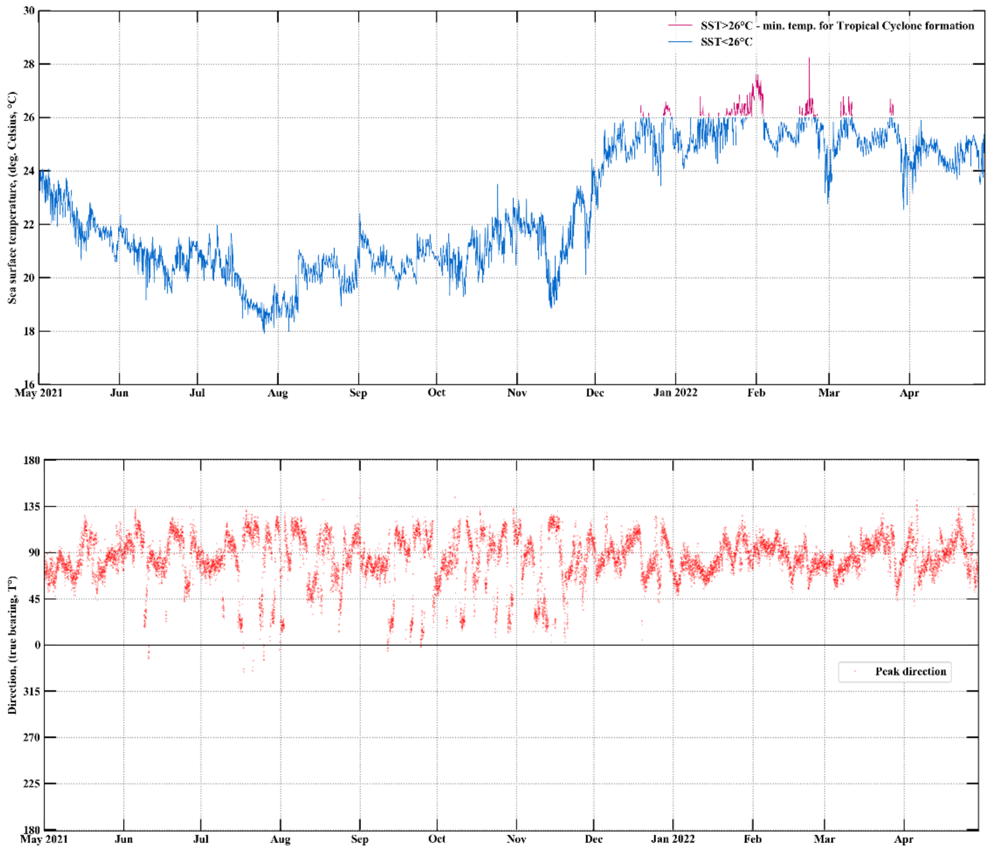
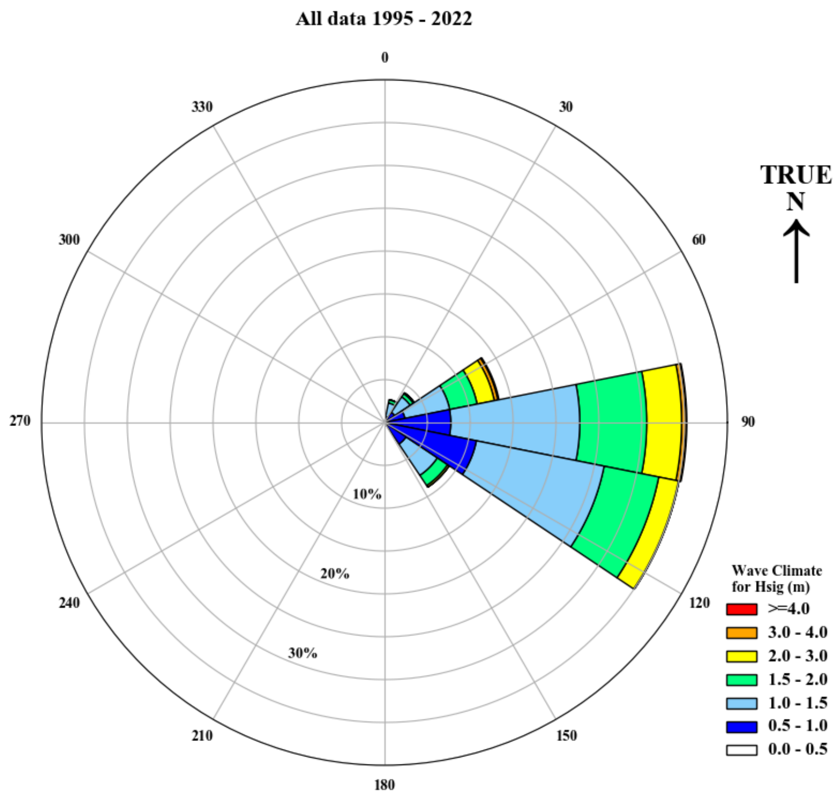


Figure 2.7 Tweed Heads buoy – sea surface temperature and peak wave directions



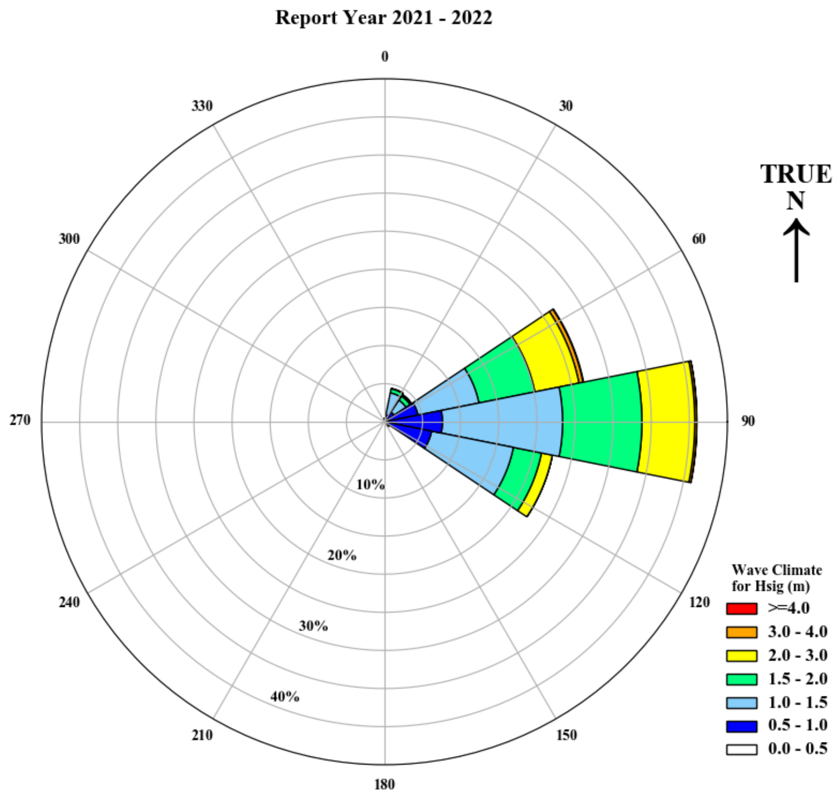


Figure 2.8 Tweed Heads buoy – directional wave rose

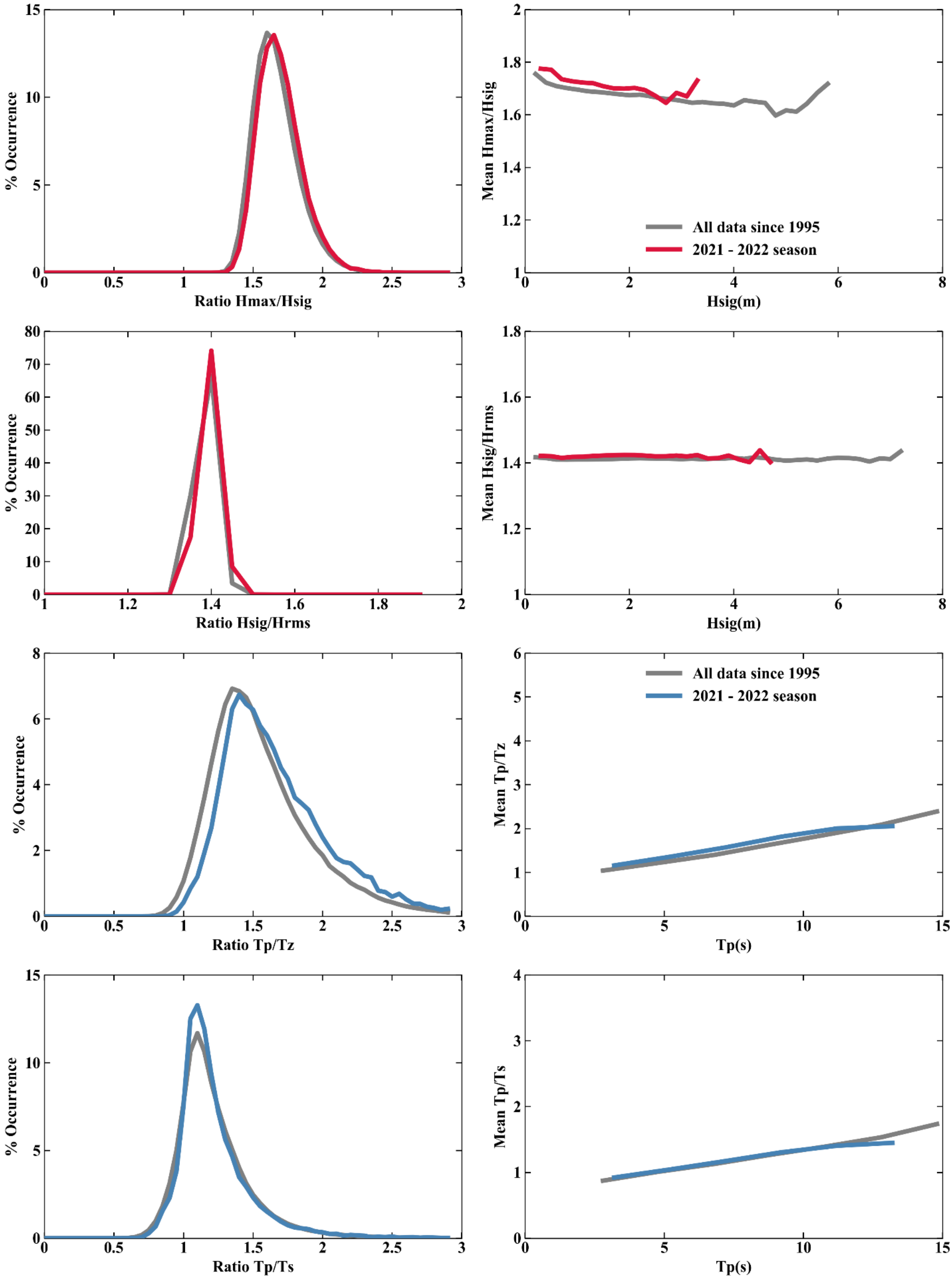


Figure 2.9 Tweed Heads buoy – wave parameter relationships

Tweed Heads – Offshore

Near real time data feed: Tweed Offshore wave monitoring page

Details of data collection	
2021 – 2022 season	
Maximum possible analysis days (last record - first record)	365
Total number of days used in analysis	340.23
Gaps in data used in analysis(days)	24.7
Number of records used in analysis	16,920
All data since 1995 – 2022	
Maximum possible analysis years (last record – first record)	2.49
Total number of years used in analysis	2.49
Gaps in data used in analysis (years)	0.43
Number of records used in analysis	37,430

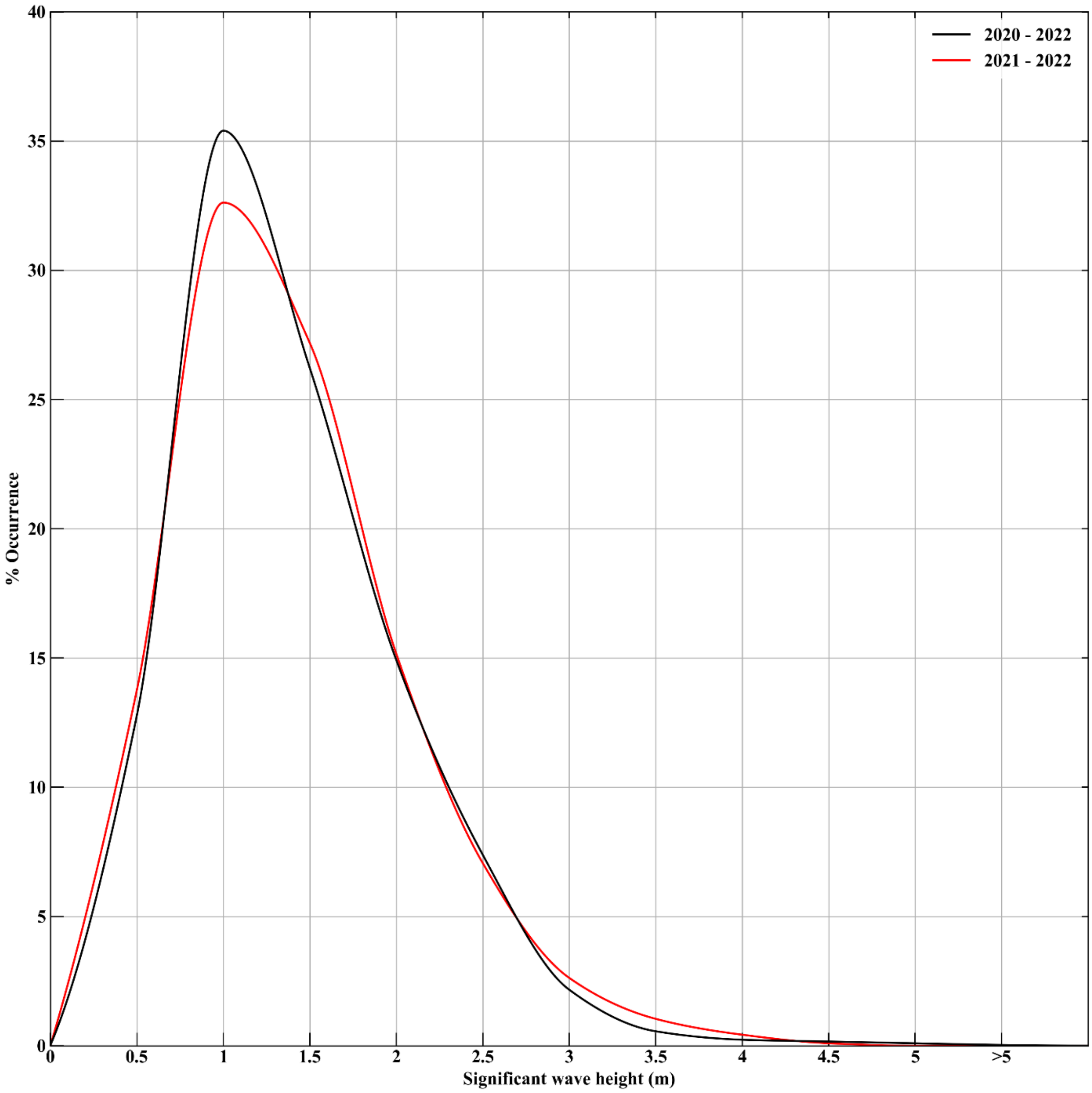


Figure 3.1 Tweed Heads offshore buoy – H_s percentage (%) occurrence

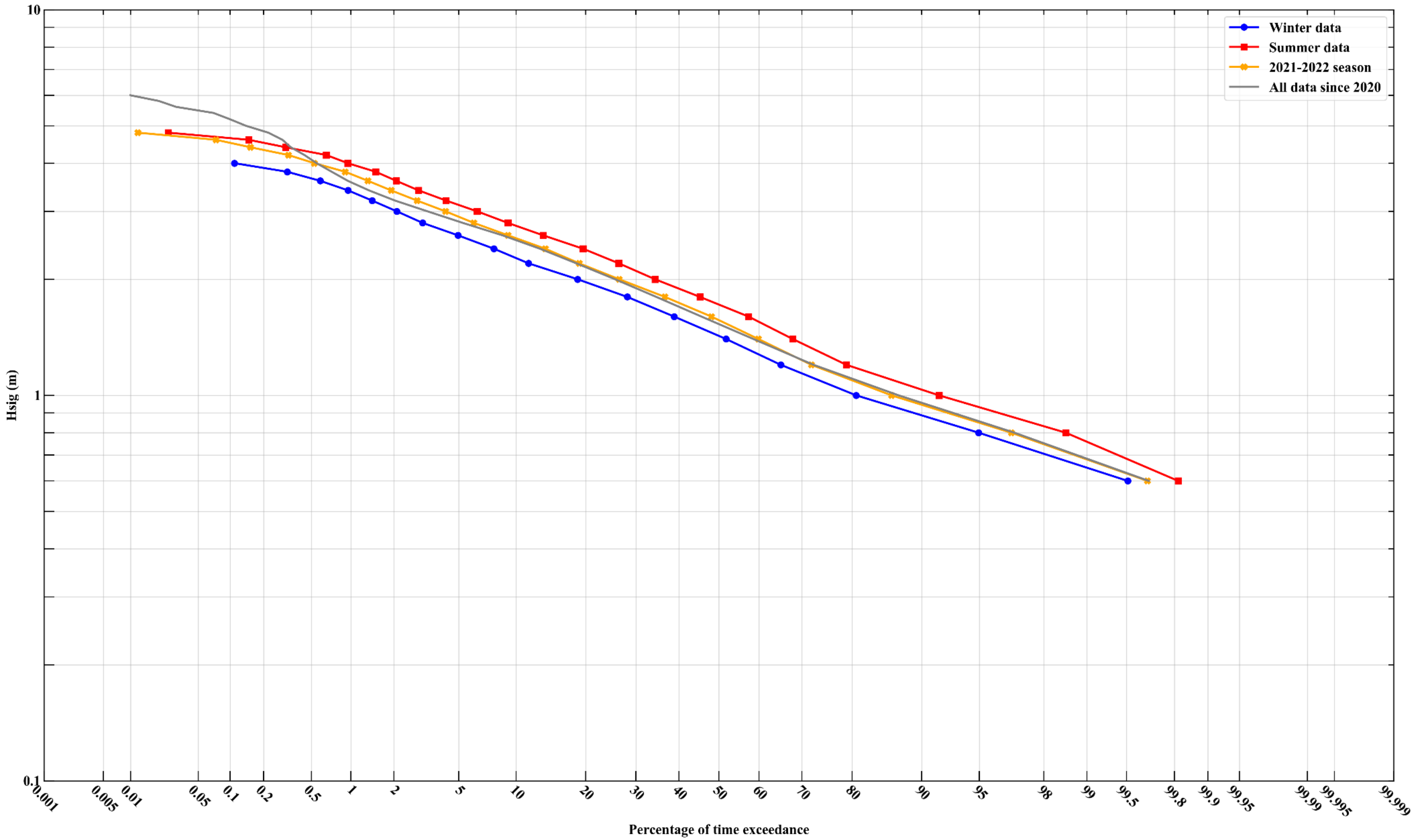


Figure 3.2 Tweed Heads offshore buoy – percentage (of time) exceedance of wave heights (H_s) for all wave periods (T_p)

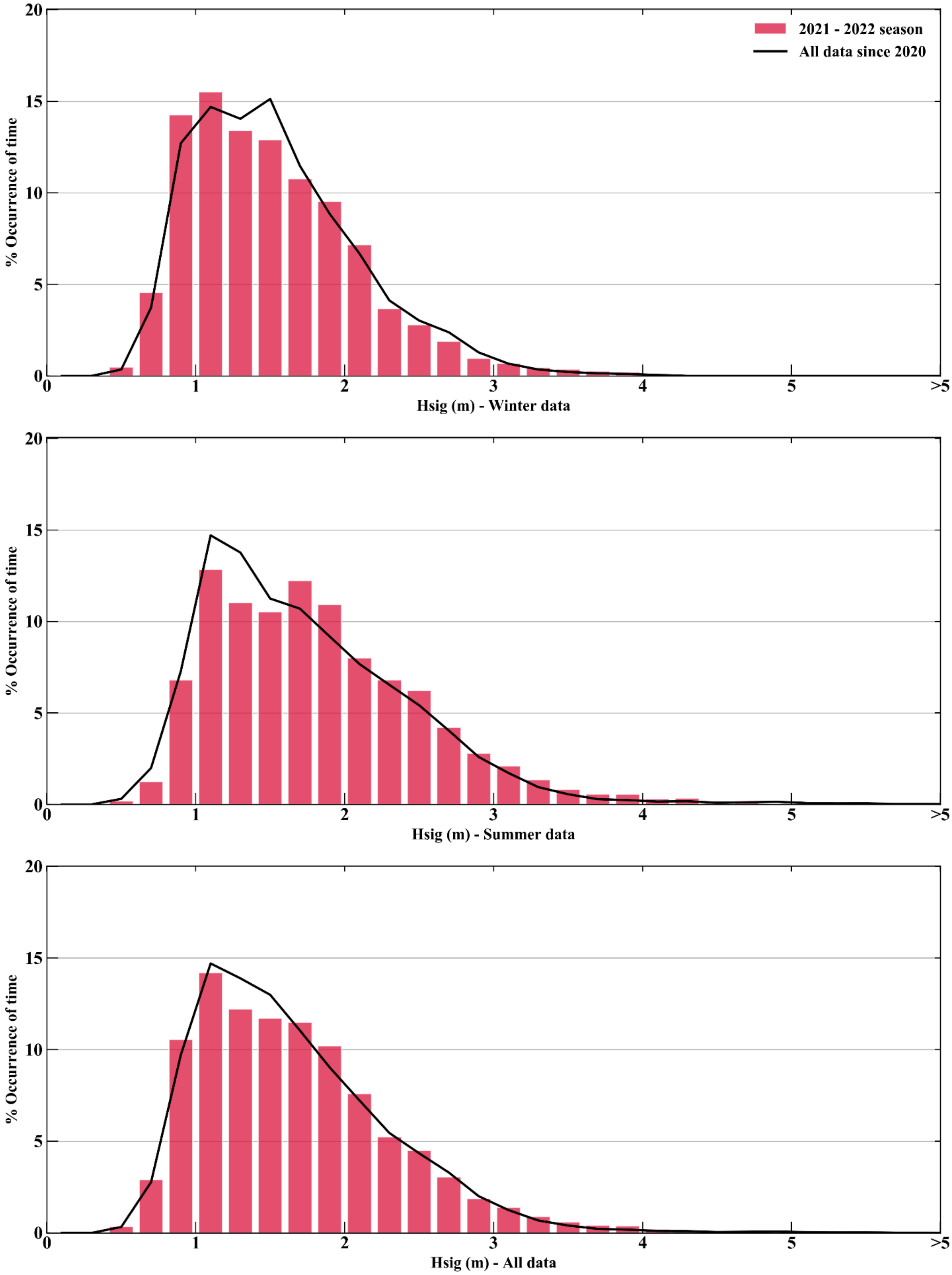


Figure 3.3 Tweed Heads offshore buoy – histogram percentage (of time) occurrence of wave heights (H_s) for all wave periods (T_p)

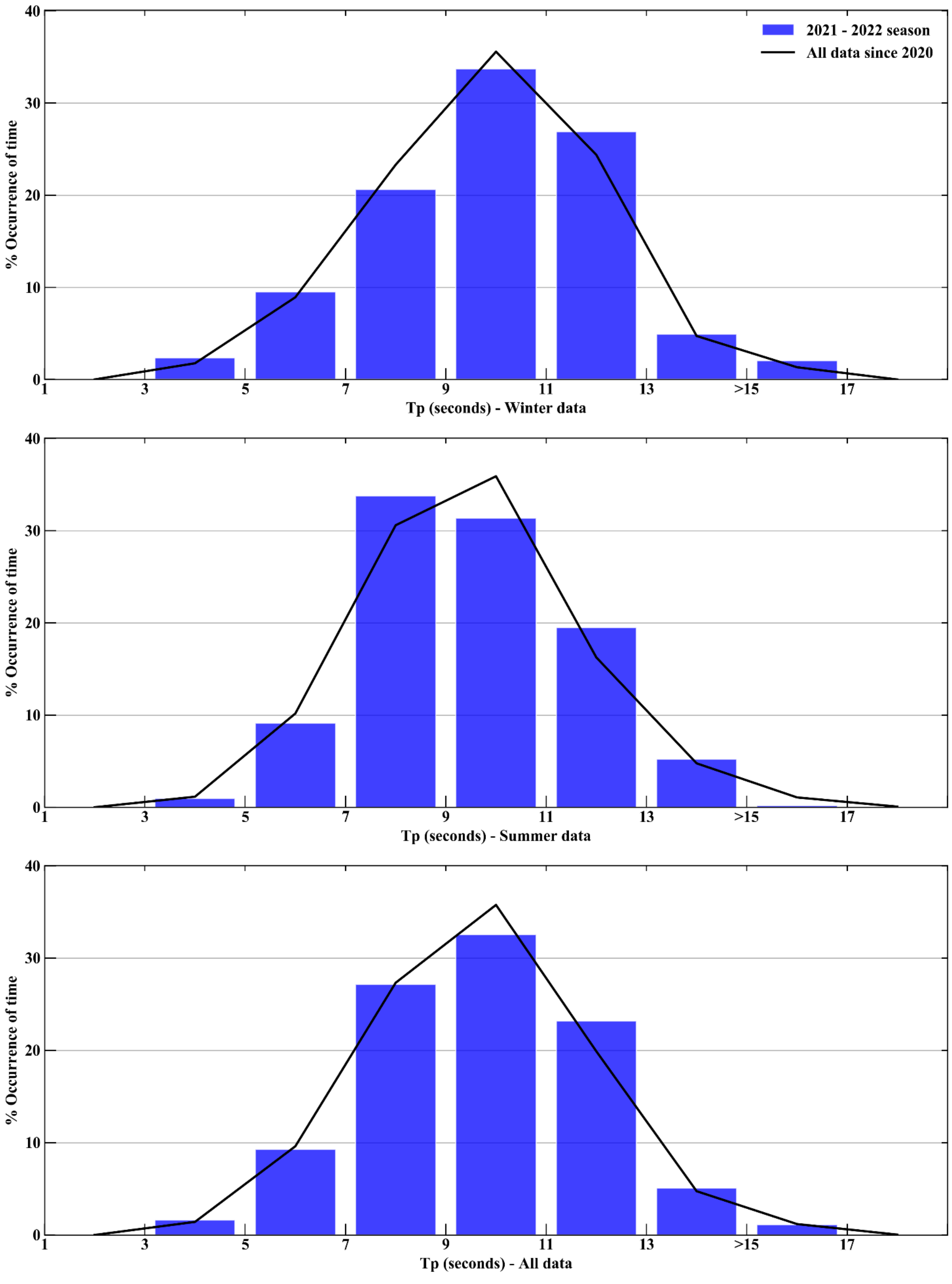


Figure 3.4 Tweed Heads offshore buoy – histogram percentage (of time) occurrence of wave periods (T_p) for all wave heights (H_s)

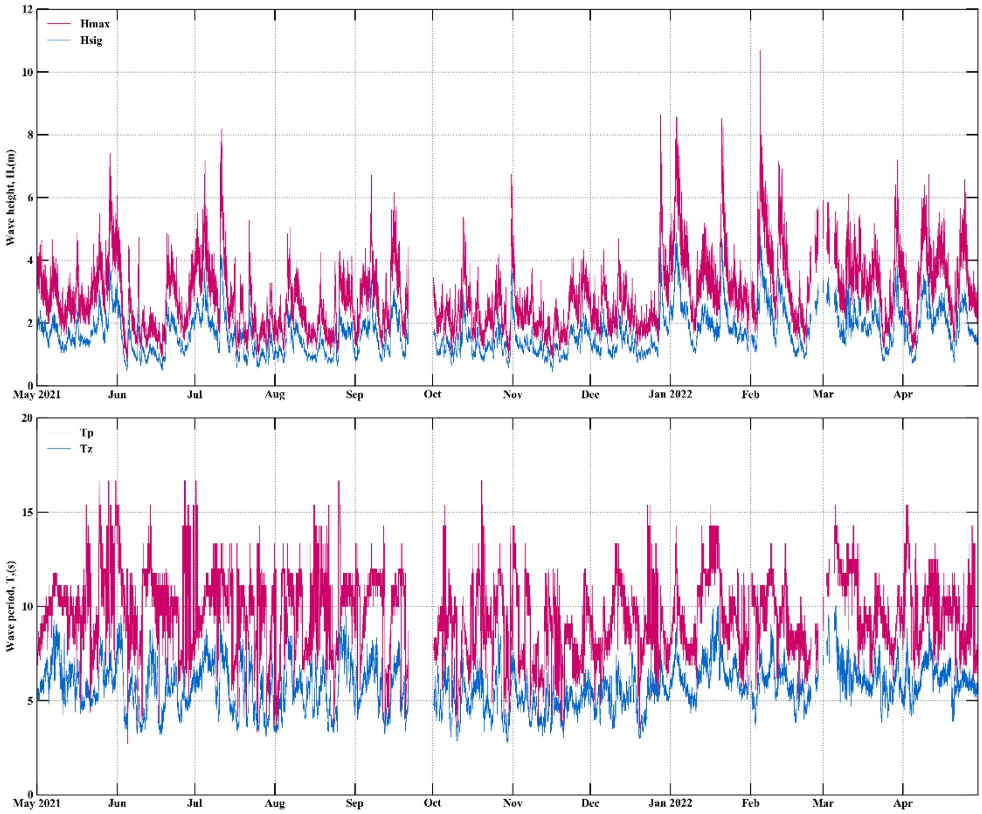


Figure 3.5 Tweed Heads offshore buoy – daily wave recordings

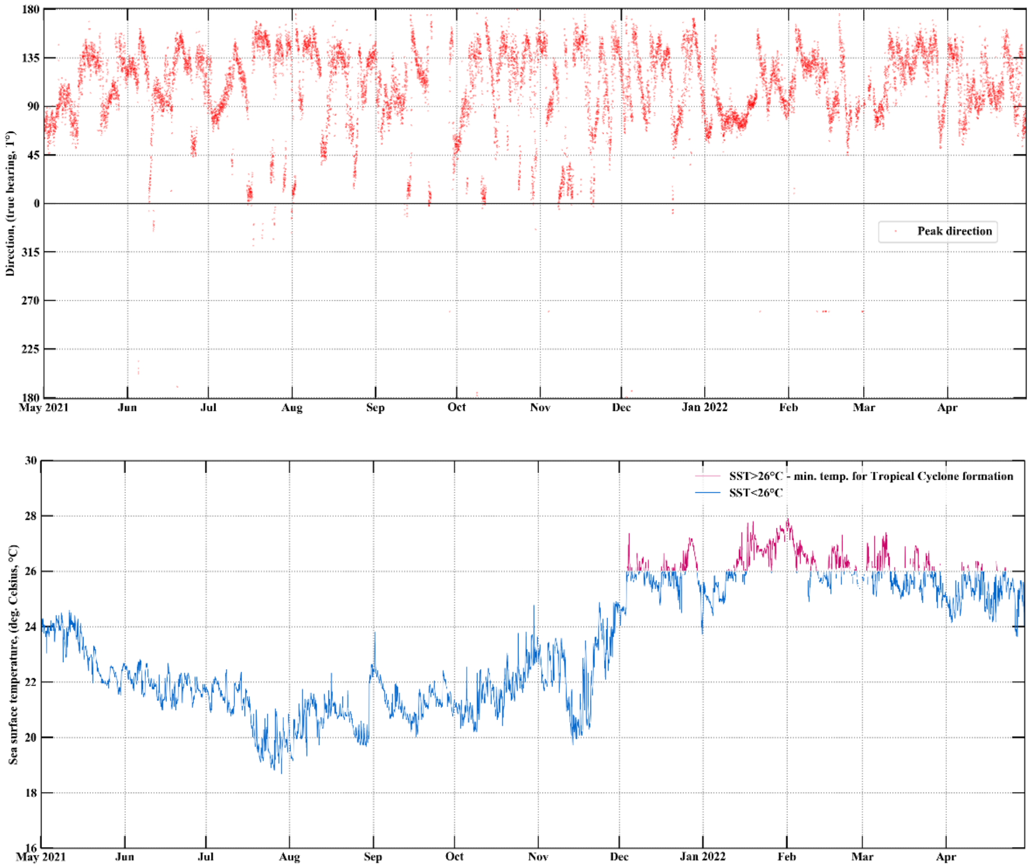


Figure 3.6 Tweed Heads offshore buoy – sea surface temperature and peak wave directions

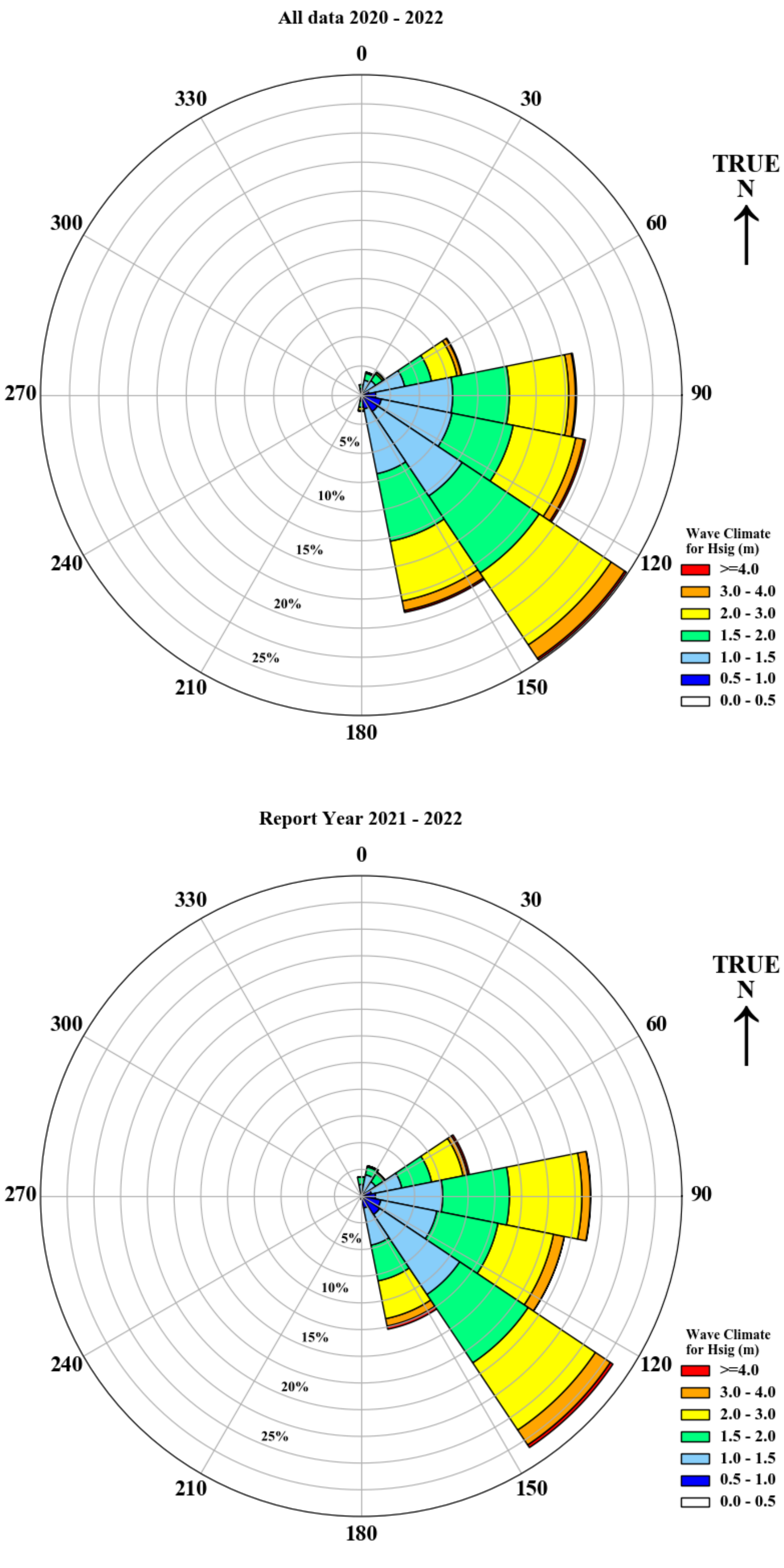


Figure 3.7 Tweed Heads offshore buoy – directional wave rose

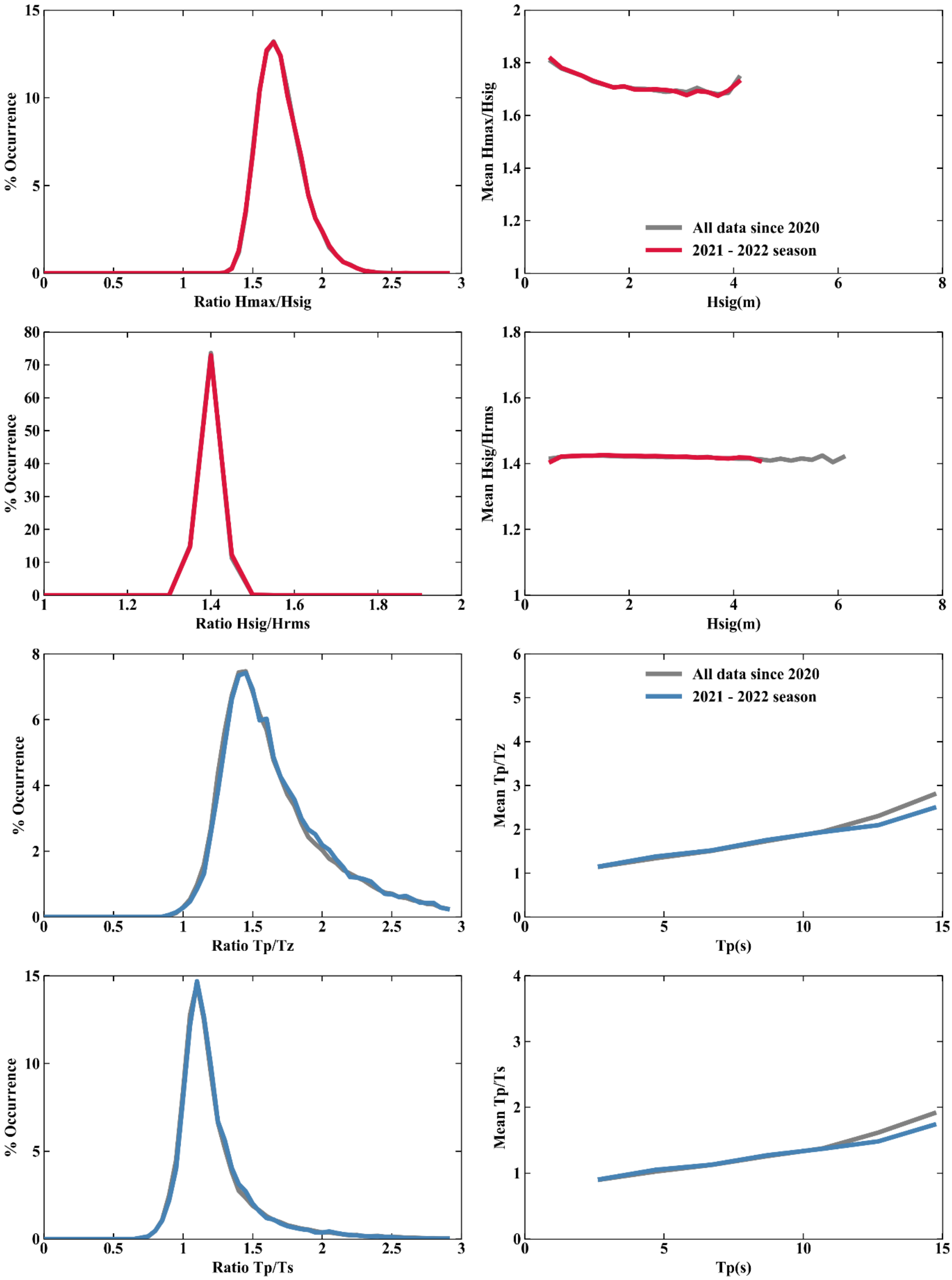


Figure 3.8 Tweed Heads offshore buoy – wave parameter relationships

Brisbane

Near real time data feed: Brisbane wave monitoring page

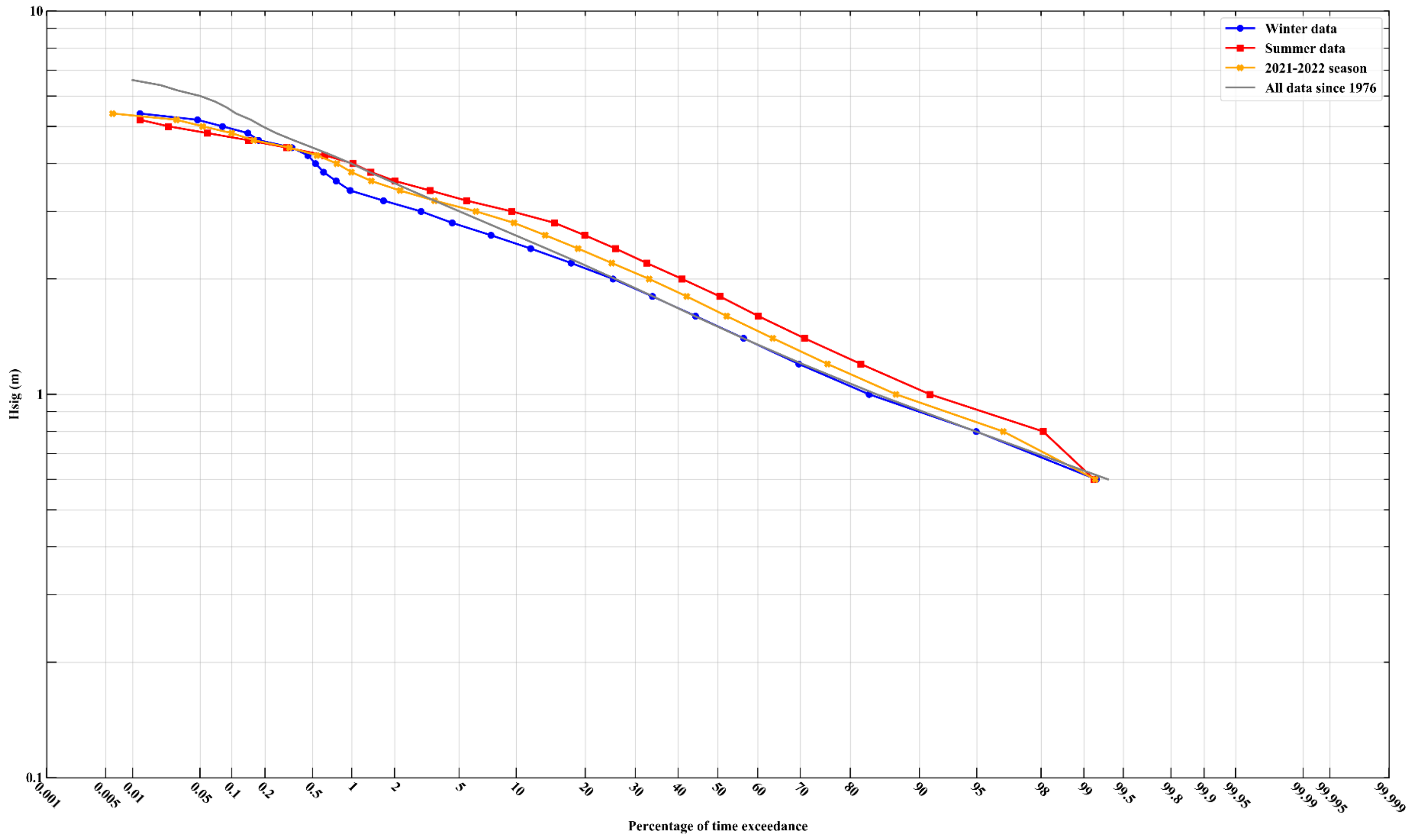


Figure 4.1 Brisbane buoy – percentage (of time) exceedance of wave heights (H_s) for all wave periods (T_p)

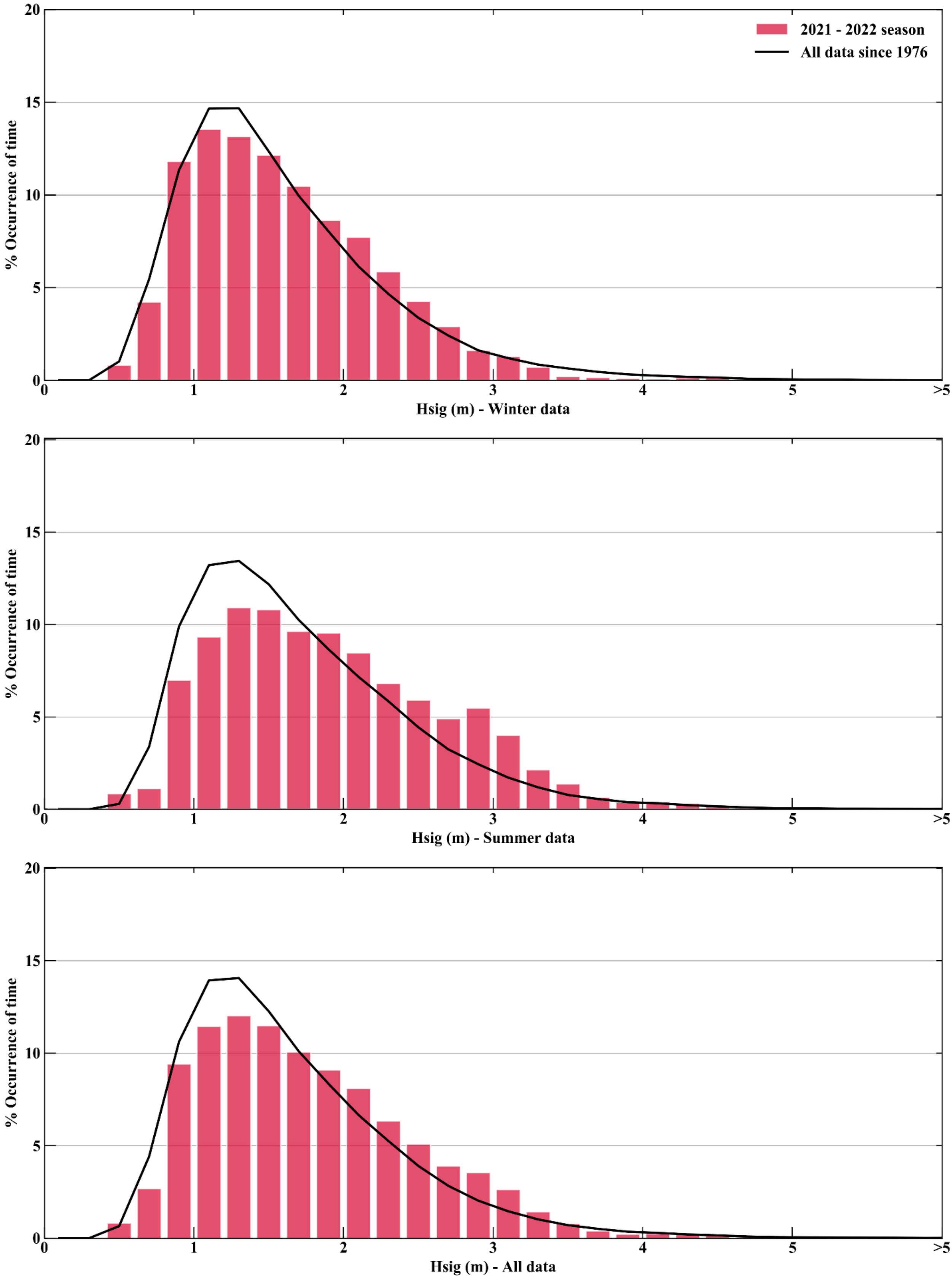


Figure 4.2 Brisbane buoy – histogram percentage (of time) occurrence of wave heights (H_s) for all wave periods (T_p)

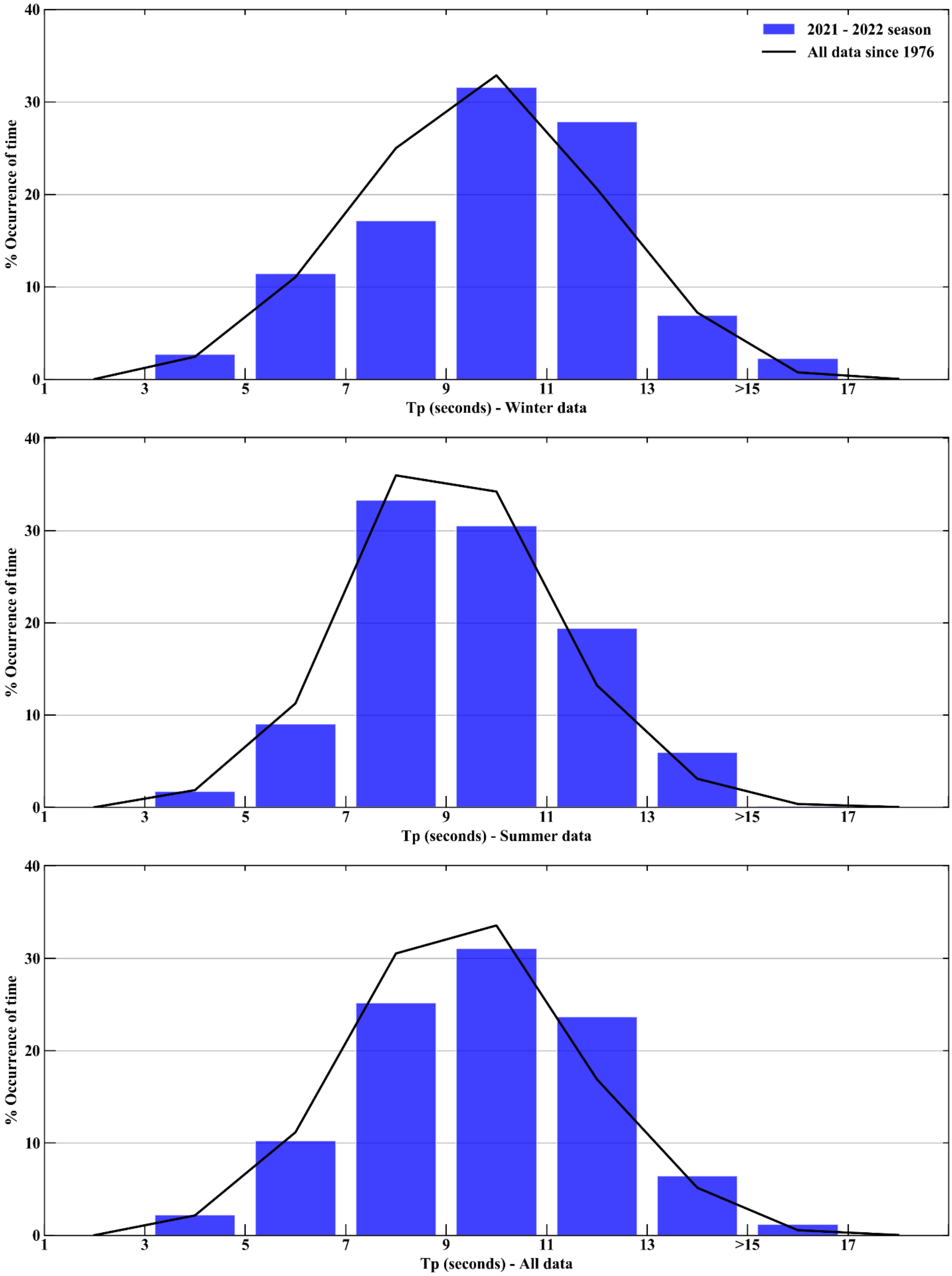


Figure 4.3 Brisbane buoy – histogram percentage (of time) occurrence of wave periods (T_p) for all wave heights (H_s)

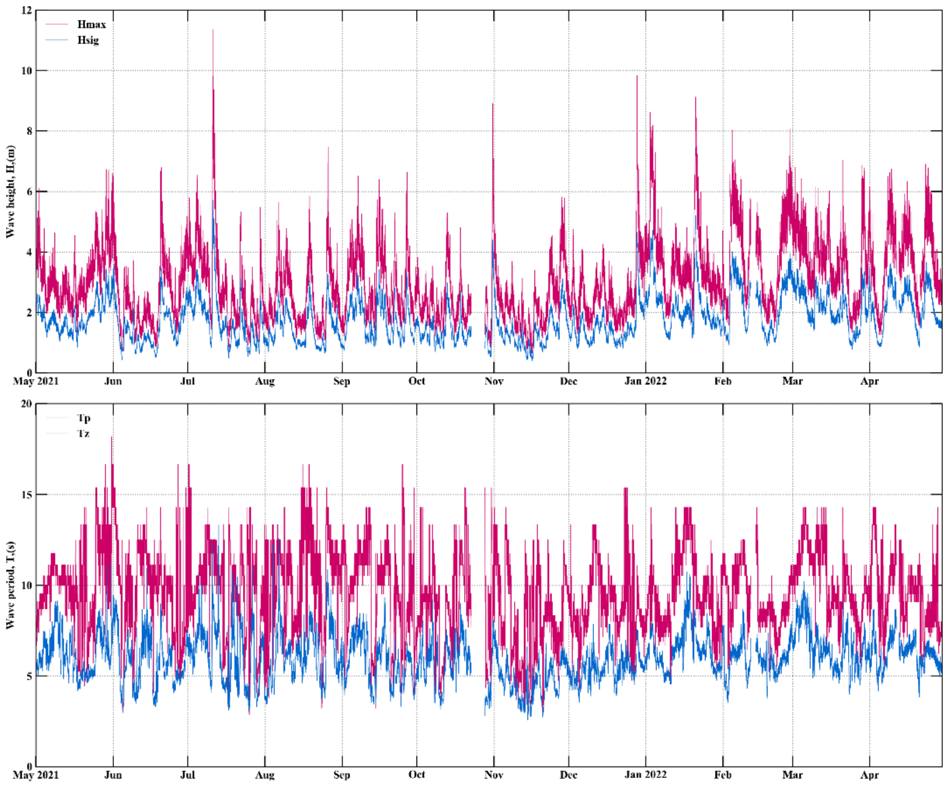


Figure 4.4 Brisbane buoy – daily wave recordings

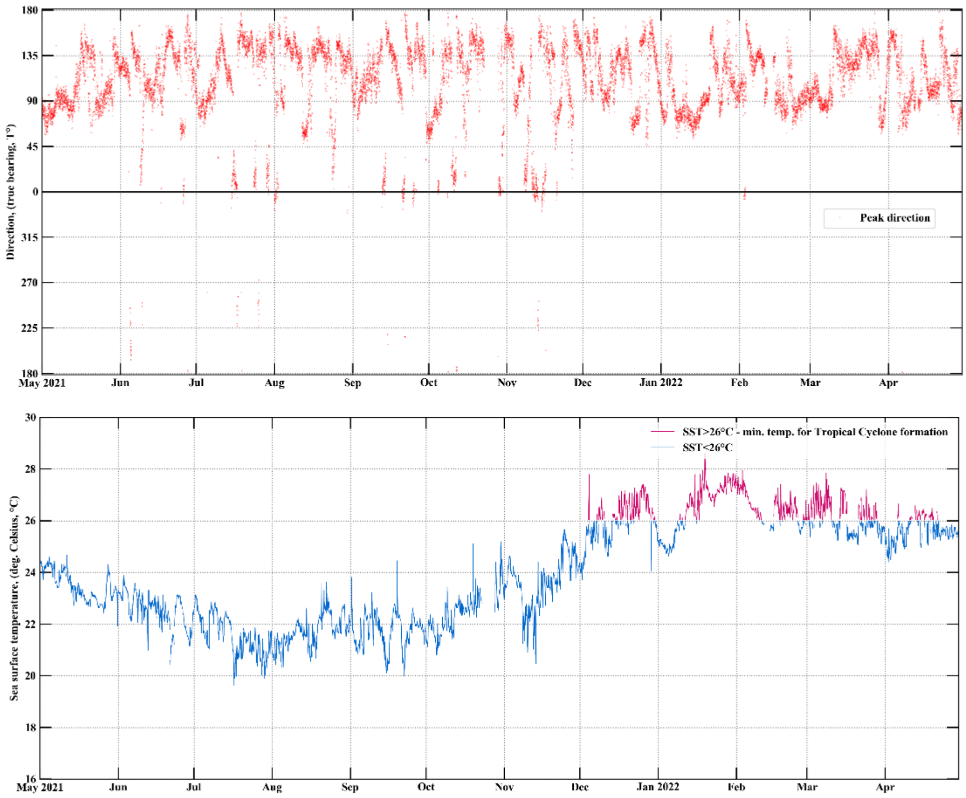


Figure 4.5 Brisbane buoy – sea surface temperature and peak wave directions

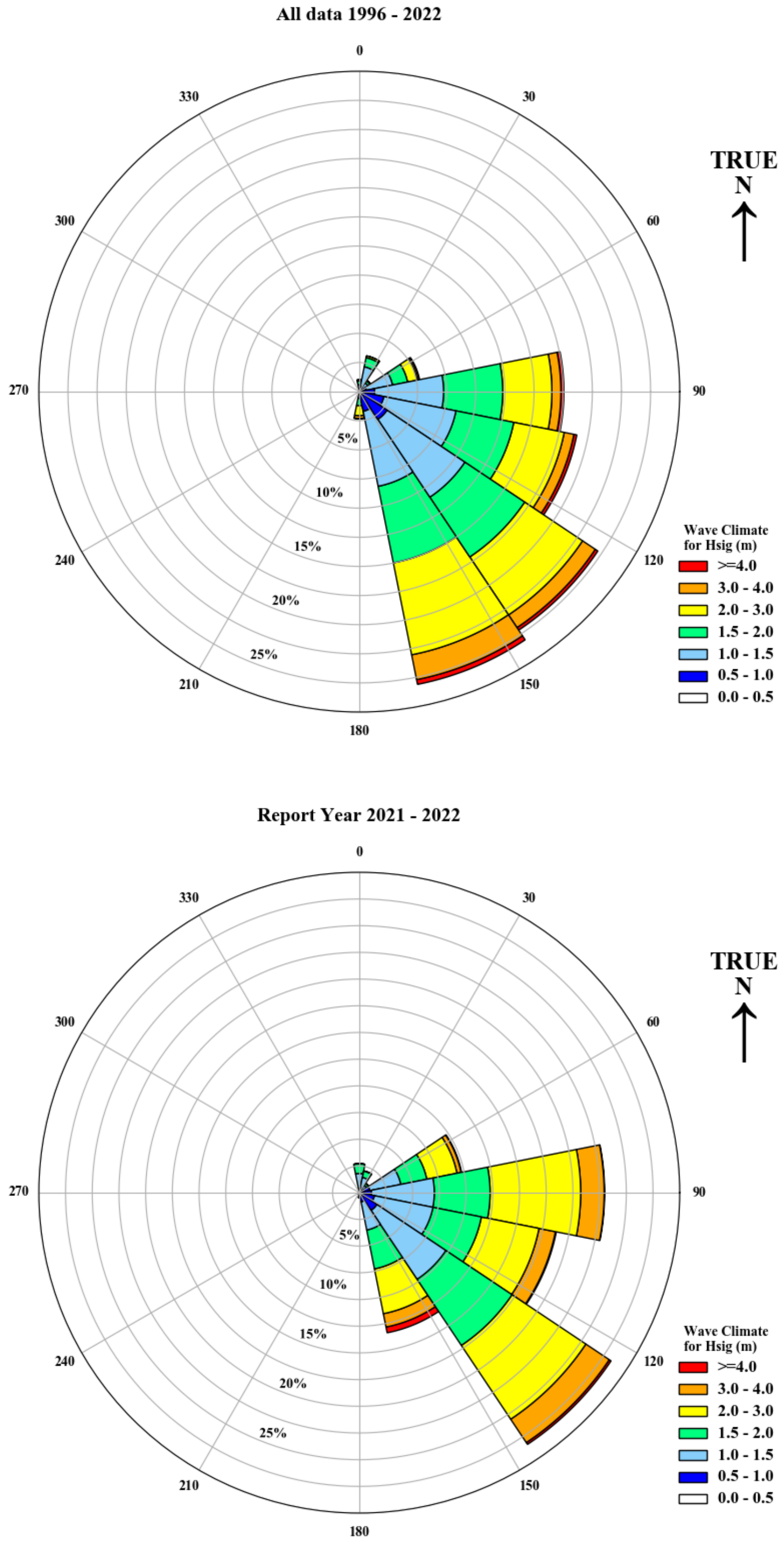


Figure 4.6 Brisbane buoy – directional wave rose

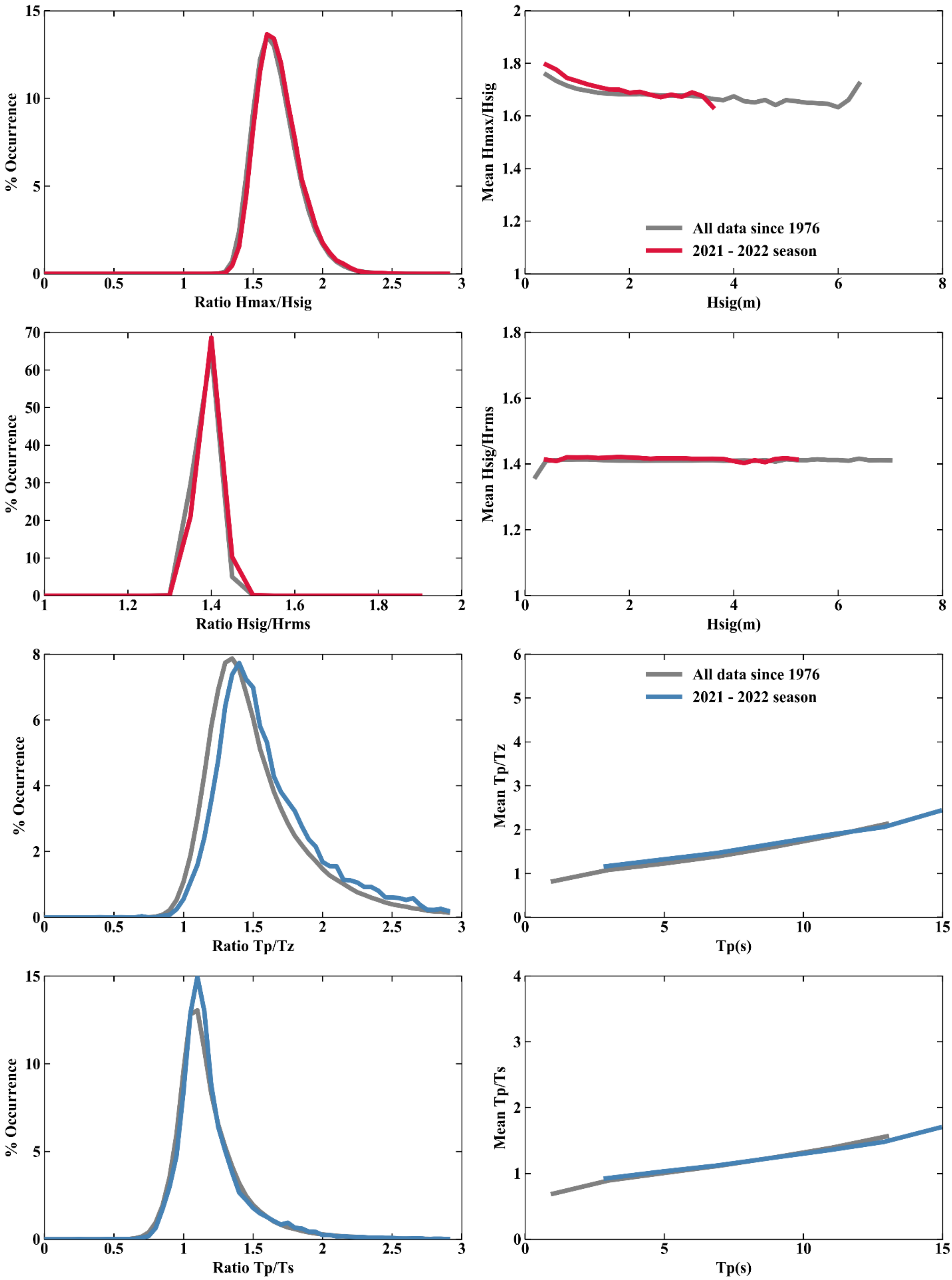


Figure 4.7 Brisbane buoy – wave parameter relationships

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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 DES), 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.

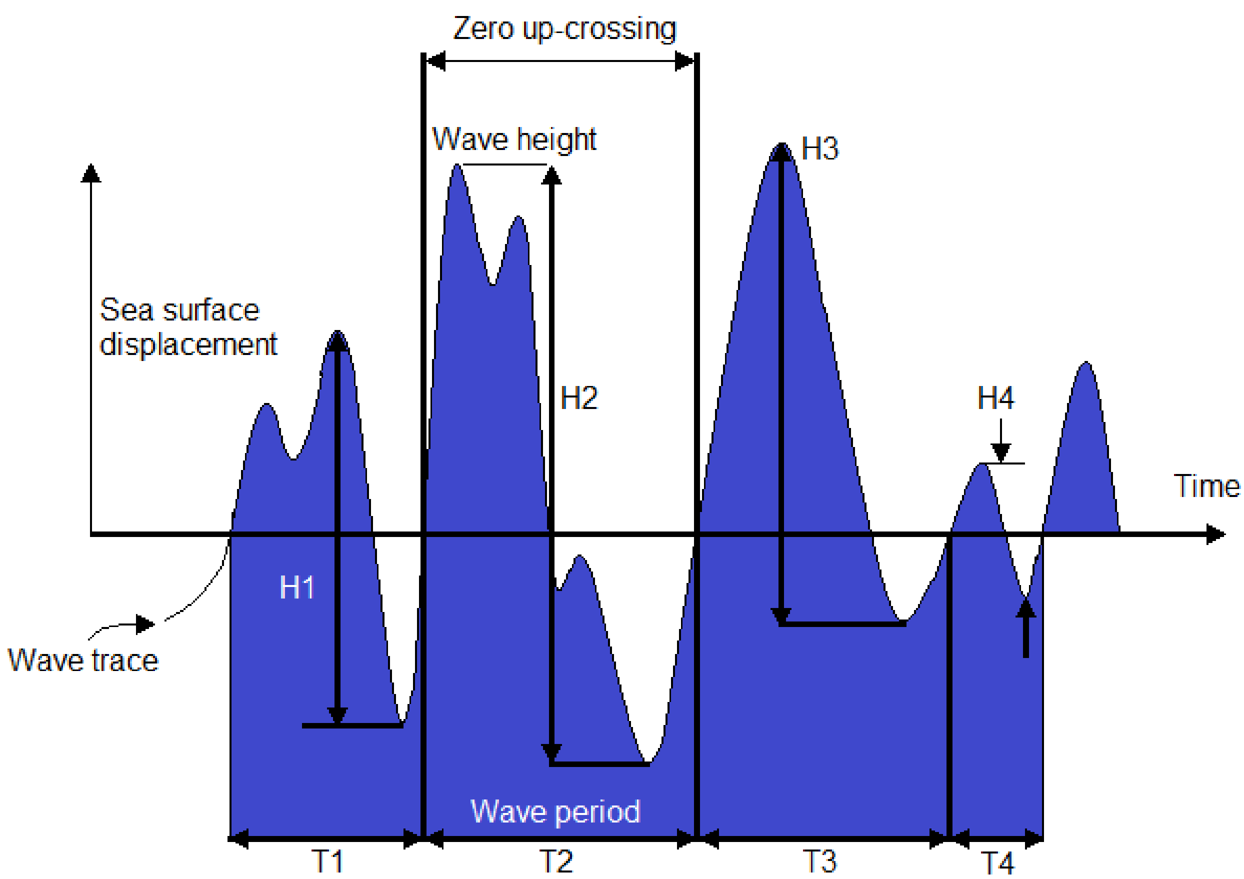

Figure A-1: An example of zero up-crossing method.

Appendix B – Glossary of Terms

Parameter	Description
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.
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).
Direction (Dir; Dir_p)	The direction that peak period (T_p) 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.
H_{10}	Average of the highest 10% of all waves in a record.
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.
H_{m0}	Estimate of the significant wave height from frequency domain $4\sqrt{m_0}$.
H_{max}	The maximum zero up-crossing wave height (in metres) in a 26.6-minute record.
H_{rms}	Root mean square wave height from the time domain.
H_s (H_{sig}, 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.
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.
T_{02}	Average period from spectral moments zero and two, defined by $\sqrt{m_0/m_2}$.
T_c	The average crest period (in seconds) in a 26.6-minute record.
T_{H10}	The period of the H10 waves.
T_{Hmax}	Period of maximum height, zero up-crossing.
T_{Hsig}	The average period of the highest one-third of zero up-crossing wave heights.
T_p	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).
T_z	The average of the zero up-crossing wave periods (in seconds) in a 26.6-minute record.
T_{zmax}	The maximum zero crossing in a record.
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.

Appendix C – 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
Tweed Heads Wave Climate Summary 2018–2019	Report No. 2019.1	01 May 2018–30 April 2019
Tweed Heads Wave Climate Summary 2019–2020	Report No. 2020.1	01 May 2019–30 April 2020
Tweed Heads Wave Climate Summary 2020–2021	Report No. 2021.1	01 May 2020–30 April 2021