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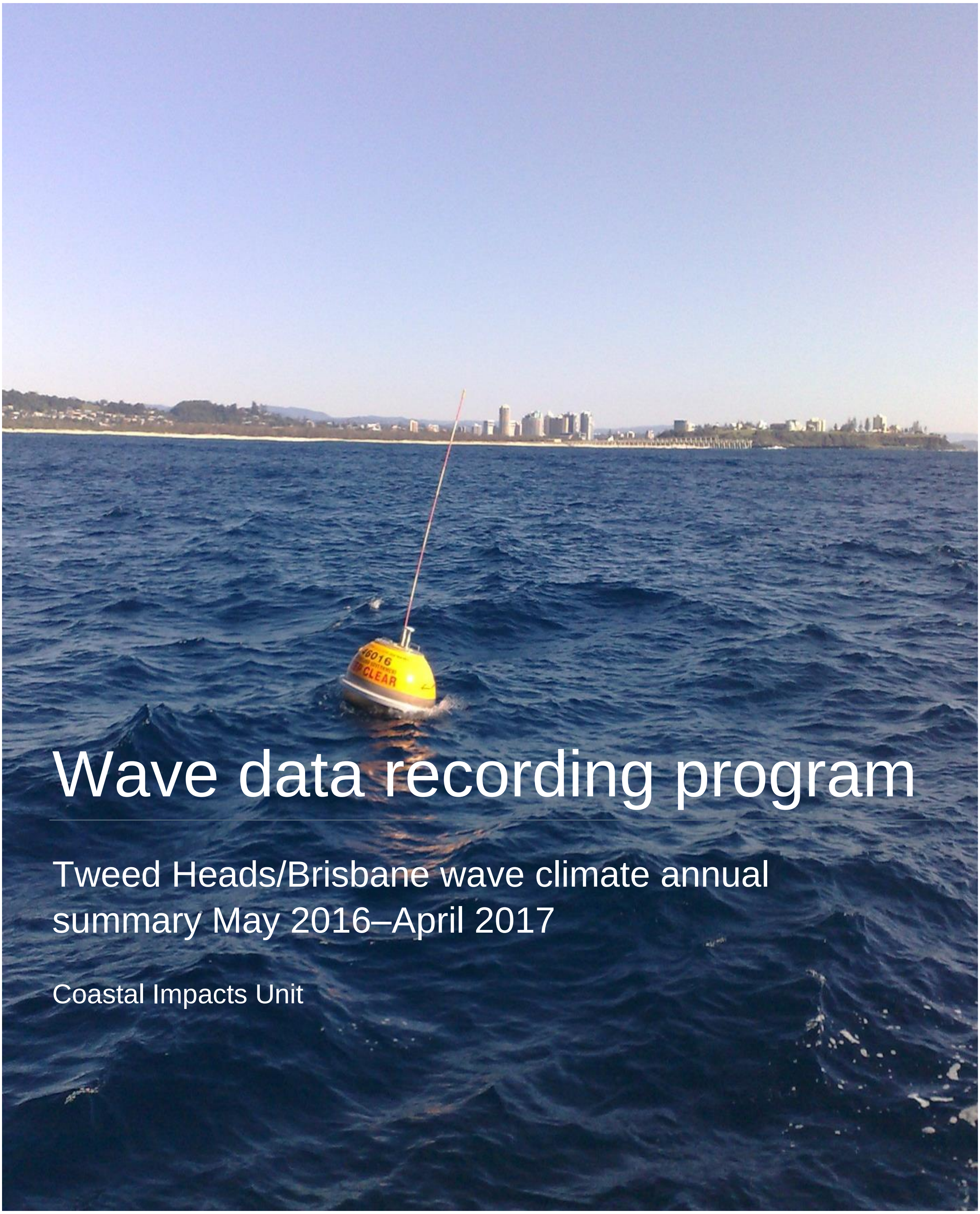

Wave data recording program

Tweed Heads/Brisbane wave climate annual summary May 2016–April 2017

Coastal Impacts Unit

Queensland Government

Prepared by

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Cover photo: Tweed Waverider buoy 13 May 2010

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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 Science, Information Technology and Innovation (DSITI).

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 2016 to 30 April 2017 is presented. The data recorded covers all of the seasonal variations for one year, and includes the 2016–17 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.

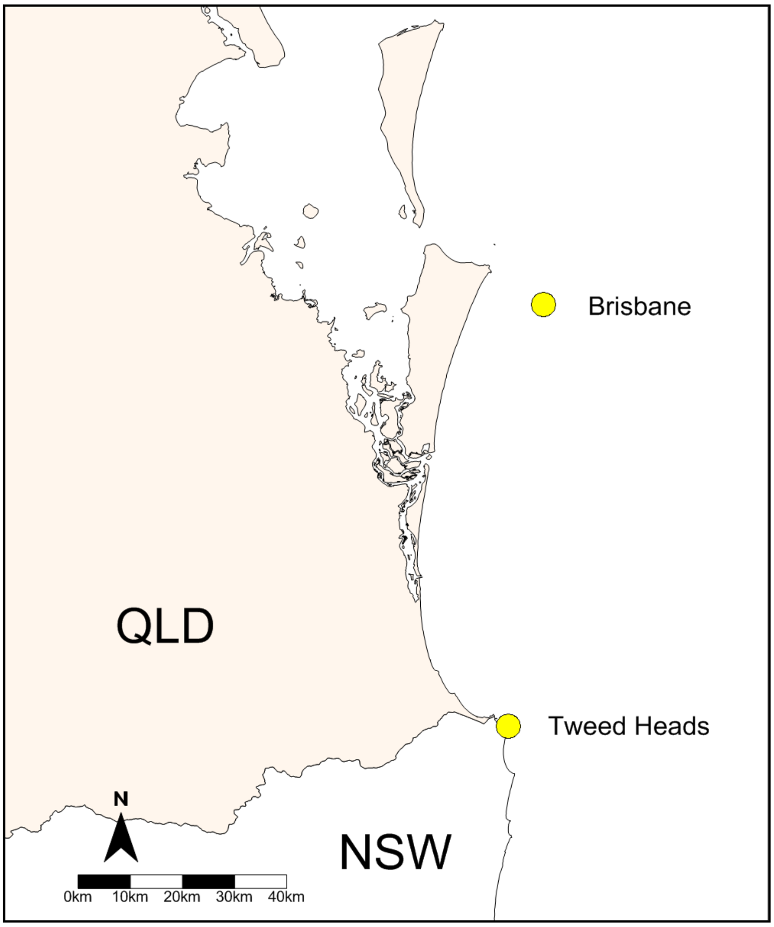

Figure 1.1: Tweed regional wave recording sites – Locality plan

1.1 Recording

DSITI'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 directional Waverider Mk3 buoy at the Brisbane site measured 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.

Only waves with frequencies within the range of 0.033–0.64 Hz can be captured by the buoy, due to physical limitations of the system. 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).

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.

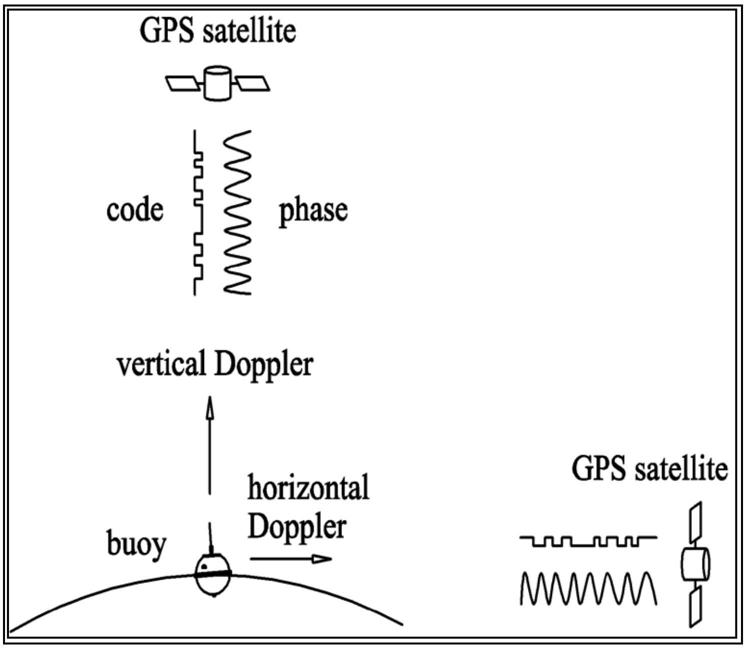

Figure 1.2: The GPS wave measurement principle (Source: Datawell, 2000)

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 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 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 5 of this report.

1.2 Laboratory calibration checks

Waverider buoys used by DSITI are calibrated before deployment and also after recovery. Normally, a buoy is calibrated once every 12 months. Calibration of accelerometer buoys is performed at DSITI's Deagon site using a buoy calibrator to simulate sinusoidal waves with vertical displacements of 2.7 metres. The calibrator is electrically controlled and the frequency may be adjusted from 0.016–0.25 Hz. It is usual to check three frequencies during a calibration. The following characteristics of the buoy are also checked during the calibration procedure:

- compass
- phase and amplitude response
- accelerometer platform stability
- platform tilt
- battery capacity
- power output.

Calibration of the GPS buoy involves placing it in a fixed location on land for a period of several days while it records data. This location should be such that there are no obstructions between the buoy and the orbiting GPS satellites. A GPS buoy in calibration should produce results showing no displacements between records – any differences can be attributed to errors in the transmission signal between the GPS buoy and the orbiting satellites or to faults in the buoy.

There are no adjustments to the recorded wave data, based on the laboratory calibration results. Monthly averages are calculated based on available data and no wave data records are rejected based on low capture rates. Research (Bacon & Carter, 1991 and Allan & Komar, 2001) has suggested rejecting entire records where less than a certain threshold has been recorded. All Queensland wave-recording sites generally have high-percentage capture rates for the seasonal year and thus minimal bias is introduced into calculations.

1.3 Wave recording and analysis procedures

The computer-based, wave-recording systems at Tweed Heads and Brisbane record data at half-hourly intervals.

Raw wave data transmitted from the buoys 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.

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 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.

2. 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, Table 3, Figure 1.1, Figure 3.1 and Figure 4.1). Data capture rates for each wave site over the reporting period are presented in Table 4.

Table 2: Deployment details for the Tweed Heads Waverider buoy

Buoy	Latitude	Longitude	Depth (m)	Calibration date	Deployed date	Removal date
46040	28°10.664'S	153°34.590'E	24	23/03/2016	17/04/2016	current

Table 3: Deployment details for the Brisbane Waverider buoy

Buoy	Latitude	Longitude	Depth (m)	Calibration date	Deployed date	Removal date
30593	27°29.475'S	153°37.955'E	70	30/10/2014	31/10/2015	30/03/2016
74050	27°29.716'S	153°37.905'E	75	28/07/2016	20/05/2017*	current

* Date started using MK4 buoy.

Table 4: Wave recording program percentage data capture May 2016–April 2017

Station	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Avg.
Tweed Heads	99.4	99.0	99.8	98.4	100.0	100.0	99.8	100.0	100.0	99.9	95.0	100.0	99.3
Brisbane	99.8	99.8	99.8	100	96.8	100	99.8	100	100	99.9	98.7	98.5	99.4

A summary of major meteorological events, where the recorded H_{sig} value reached the 3-hours storm threshold wave height of two metres for Tweed Heads and four metres for Brisbane, for the period from 01 May 2016 to 30 April 2017 is shown in Table 5 and Table 6. Wave parameters H_{sig}, H_{max}, T_p, and other relevant information are listed for each event. Weather systems that contributed to the H_{sig} reaching the storm threshold value are listed and may be direct reproductions of synoptic descriptions provided by the Australian Bureau of Meteorology (bom.gov.au).

Table 5: Significant meteorological events May 2016–April 2017, 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
04/06/2016 19:30	5.2 (5.6)	8.1 (9.8)	11.1	An East Coast Low caused heavy rain, flooding, strong winds and erosion along the NSW coast.
12/06/2016 22:00	2.3 (2.5)	3.6 (4.8)	10.9	A low pressure area was located in the Tasman Sea and moved slowly north eastwards from 9 to 12 June 2016.

19/06/2016 15:30	2.5 (2.7)	4.4 (5.4)	7.1	On 17 June a high over the Tasman Sea extended a ridge along the Queensland coast. A low pressure system developed and evolved into an East Coast Low on 20 June.
04/08/2016 9:30	2.9 (3.3)	4.5 (5.9)	11.9	An East Coast Low produced heavy rain and strong winds in north east NSW. Daily rainfall totals reached 239 mm, breaking some August rainfall records. Wind gusts of up to 126 km/h at Evans Head were recorded.
09/09/2016 19:30	2.0 (2.2)	3.5 (3.7)	7.5	In the north a low pressure trough extended across northern Australia into northern New South Wales.
23/11/2016 15:30	2.0 (2.0)	3.6 (3.4)	10.1	A cold front tracked into the Tasman Sea on 23 November.
07/01/2017 11:30	2.0 (2.0)	3.2 (3.5)	7.9	On 07 January, a near stationary high pressure system over the Tasman Sea and a trough across central parts of the continent maintained a hot and dry northeast airstream over eastern Australia.
10/02/2017 14:00	2.5 (2.6)	4.3 (5.0)	11.1	A number of cold fronts tracked over south eastern Australia bringing a cool westerly airflow.
08/03/2017 2:30	3.0 (3.2)	4.5 (5.5)	13.7	Several surface troughs lingered off the east coast, with thunderstorms producing locally heavy rain. A low pressure system developed off the NSW south coast from the afternoon of 03 March before moving eastward.
16/03/2017 8:00	2.2 (2.4)	3.8 (4.8)	9.2	A period of persistent onshore flow became established over southeast Australia from 14 March, with complex surface troughs contributing to widespread coastal rain.
20/03/2017 1:30	2.3 (2.5)	4.1 (5.1)	9.2	A high pressure area developed in the Tasman Sea of the coast of New Zealand producing strong winds.
30/03/2017 22:30	3.4 (3.6)	6.0 (7.3)	8.3	Ex-tropical cyclone Debbie tracked southwards along the Queensland and New South Wales coasts. Along the way it interacted with a cold front and surface trough, producing very heavy rain.
04/04/2017 1:30	2.6 (2.7)	4.2 (5.9)	11.2	A low pressure system developed in the Tasman sea during the first days of the month and moved southwards.
12/04/2017 5:30	2.0 (2.1)	3.2 (3.7)	11.3	A cold front crossed south east Australia on 09 April before developing into a low pressure system off the east coast, producing locally heavy rain, strong winds and thunderstorms.

Denotes peak H_{sig} event

Table 6: Significant meteorological events May 2016–April 2017, Brisbane Waverider buoy

Brisbane Storm threshold value: 4.0 metres (H_{sig})				
Date	H_{sig}(m)	H_{max} (m)	T_p (s)	Event
4/06/2016 21:30	5.2 (5.6)	8.7 (10.3)	11.2	An East Coast Low caused heavy rain, flooding, strong winds and erosion along the NSW coast. A low pressure system build up above land and moved eastward to the Tasman sea.
4/08/2016 12:00	4.0 (4.5)	6.8 (7.8)	12.5	An East Coast Low produced heavy rain and strong winds in north east NSW. Daily rainfall totals reached 239 mm, breaking some August rainfall records. Wind gusts of up to 126 km/h at Evans Head were recorded.
8/03/2017 4:30	4.6 (4.9)	7.5 (10.0)	13.5	Several surface troughs lingered off the east coast, with thunderstorms producing locally heavy rain. A low pressure system developed off the NSW south coast from the afternoon of 03 March before moving eastward.
31/03/2017 14:30	4.7 (5.4)	8.2 (9.6)	11.9	These waves are produced by the ex- tropical cyclone Debbie, which tracked across the Moreton Bay area. Heavy rainfall has been recorded and major riverine flooding occurred.

Denotes peak H_{sig} event

Notes:

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

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 is based on statistical analyses of the parameters obtained from the recorded wave data. Software programs developed by DSITI 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 4.2 to Figure 4.4. In each of these three figures for each site, the term ‘All data’ refers to the combined number of years of operations for each site being 21.98 years for Tweed Heads (since 13 January 1995) and 29.78 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 Hsig are also provided for the Tweed buoy, being a proxy for sediment transport capacity (BMT WBM, 1997).

Daily wave recordings, average water temperature and peak direction (Dir_{Tp}) recordings are shown for the period from 01 May 2016 to 30 April 2017. 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 2016 to 30 April 2017 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

2016-2017 season

Maximum possible analysis days (last record - first record)	=	364.98
Total number of days used in analysis	=	362.42
Gaps in data used in analysis (days)	=	2.56
Number of records used in analysis	=	17396

All data since-1995

Maximum possible analysis years (last record - first record)	=	22.30
Total number of years used in analysis	=	21.98
Gaps in data used in analysis (years)	=	0.31
Number of records used in analysis	=	334407

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

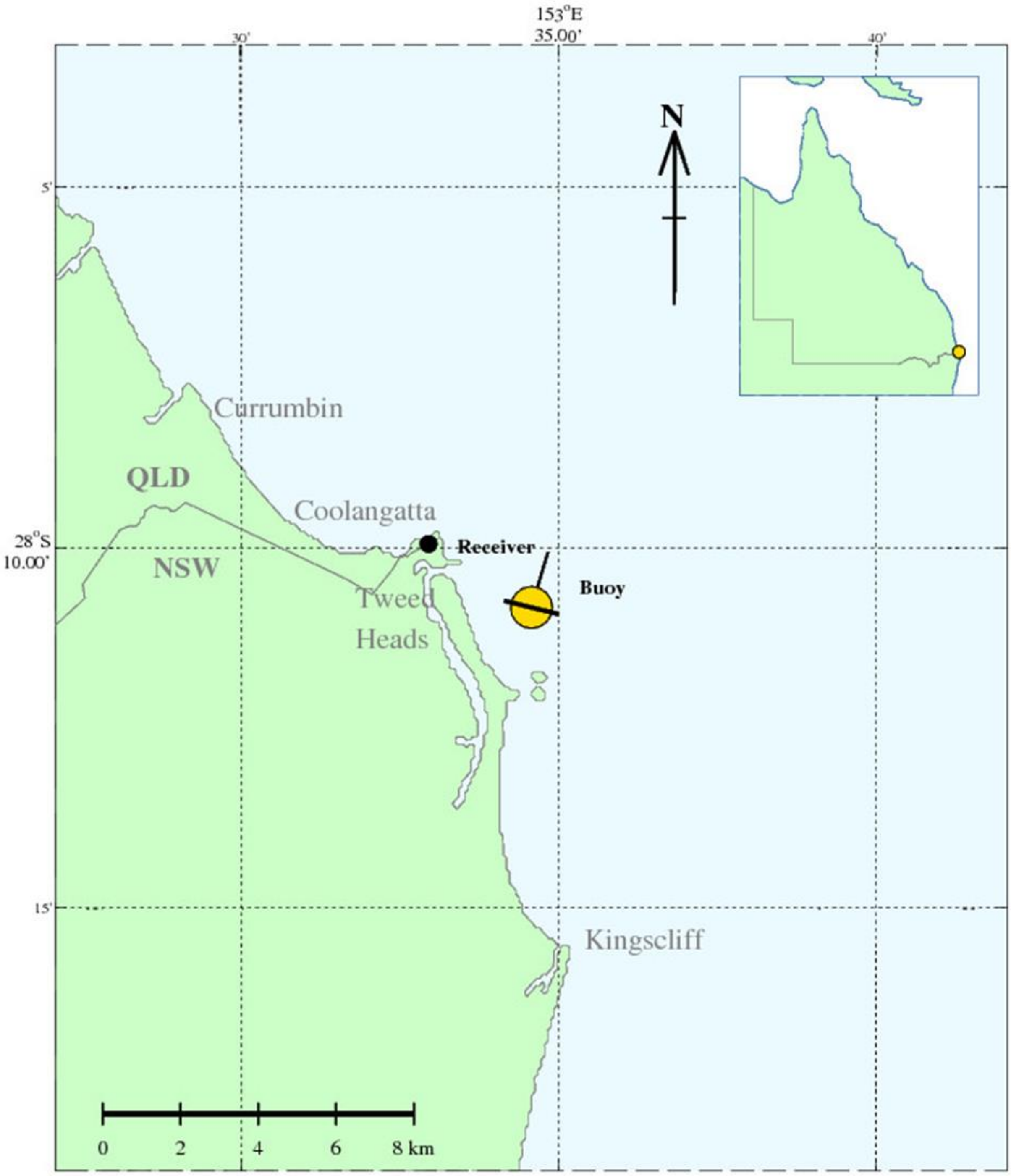

Figure 3.1: Tweed Heads Waverider buoy – Locality plan

Table 7: Wave conditions 2016–17, Tweed Heads Waverider buoy (see also Figure 3.6)

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-16	0.87	0.41	1.56	103	0.5–1.3	0	19	
Jun-16	1.52	0.34	5.57	99	0.6–3.4	12	6	04, 05, 06
Jul-16	0.99	0.36	1.93	106	0.5–1.6	0	15	
Aug-16	1.09	0.36	3.26	106	0.7–1.8	2	10	04
Sep-16	1	0.36	2.23	93	0.5–1.7	2	15	
Oct-16	0.9	0.34	1.95	94	0.4–1.4	0	21	
Nov-16	1.05	0.49	2.18	93	0.6–1.7	1	12	
Dec-16	1.13	0.53	1.86	78	0.7–1.6	0	5	
Jan-17	1.04	0.51	2.13	98	0.7–1.7	2	15	
Feb-17	1.18	0.64	2.59	88	0.8–1.9	3	7	
Mar-17	1.5	0.6	3.62	93	0.8–2.4	12	3	08, 30, 31
Apr-17	1.49	0.53	2.74	98	0.9–2.4	7	1	
May to April	1.14	0.34	5.57	96	0.6–2.0	41	129	

Table 8: 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) 2016–17	0.87	1.52	0.99	1.09	1	0.9	1.05	1.13	1.04	1.18	1.5	1.49	1.14
Mean H_{sig} (m) Average from 1995–2017	1.31	1.22	1.16	1.1	1.08	1.11	1.13	1.15	1.31	1.46	1.45	1.36	1.24
Average direction for peak period Dir_{Tp} ($^{\varnothing}$ True North) 2016–17	103	99	106	106	93	94	93	78	98	88	93	98	96
Average direction for peak period Dir_{Tp} ($^{\varnothing}$ True North) 1995–2017	100	100	103	99	94	92	92	92	92	95	93	98	96

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

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

Where:

H_{sig} = Significant wave height

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

N = number of records

Table 9: Weighted Mean Values, Tweed Heads Waverider buoy (see also Figure 3.6)

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May –Apr
Weighted Mean H_{sig} (m) 2016–17	0.91	1.86	1.07	1.19	1.1	0.96	1.12	1.18	1.11	1.26	1.63	1.58	1.25
Weighted Mean H_{sig} (m) 1995–2017	1.6	1.41	1.29	1.26	1.17	1.22	1.22	1.26	1.46	1.62	1.61	1.49	1.38
Weighted direction for peak period Dir_{Tp} ($^{\varnothing}$ True North) 2016–17	94	83	101	106	78	95	92	78	101	86	91	99	92
Weighted direction for peak period Dir_{Tp} ($^{\varnothing}$ True North) 1995–2017	88	95	100	94	92	91	94	90	89	93	88	95	92

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

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})

N = number of records

Table 10: 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 17	1.14	34.67	41.35	15.44	4.95	1.44	0.57	0.23	0.11	0.05	0.03	0.01	0.01	>0.00
May 16–Apr 17	2.33	40.58	40.80	11.36	3.72	0.63	0.18	0.20	0.09	0.05	0.06	0.01	0.00	0.00

* The highlighted cell colour in Table 10 corresponds to the data presented in Figure 3.2, red for 2016–2017 and black/grey for all data (1995–2017).

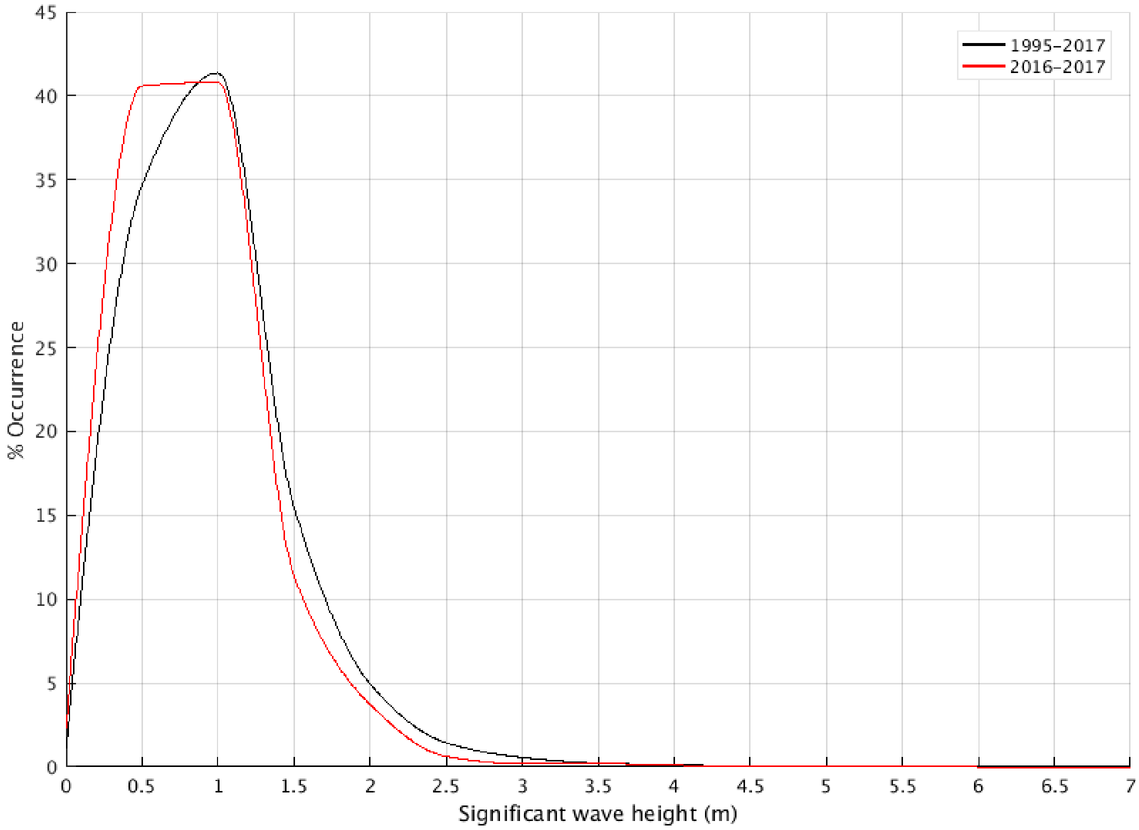

Figure 3.2: Tweed Heads Waverider buoy – H_{sig} percentage (%) occurrence

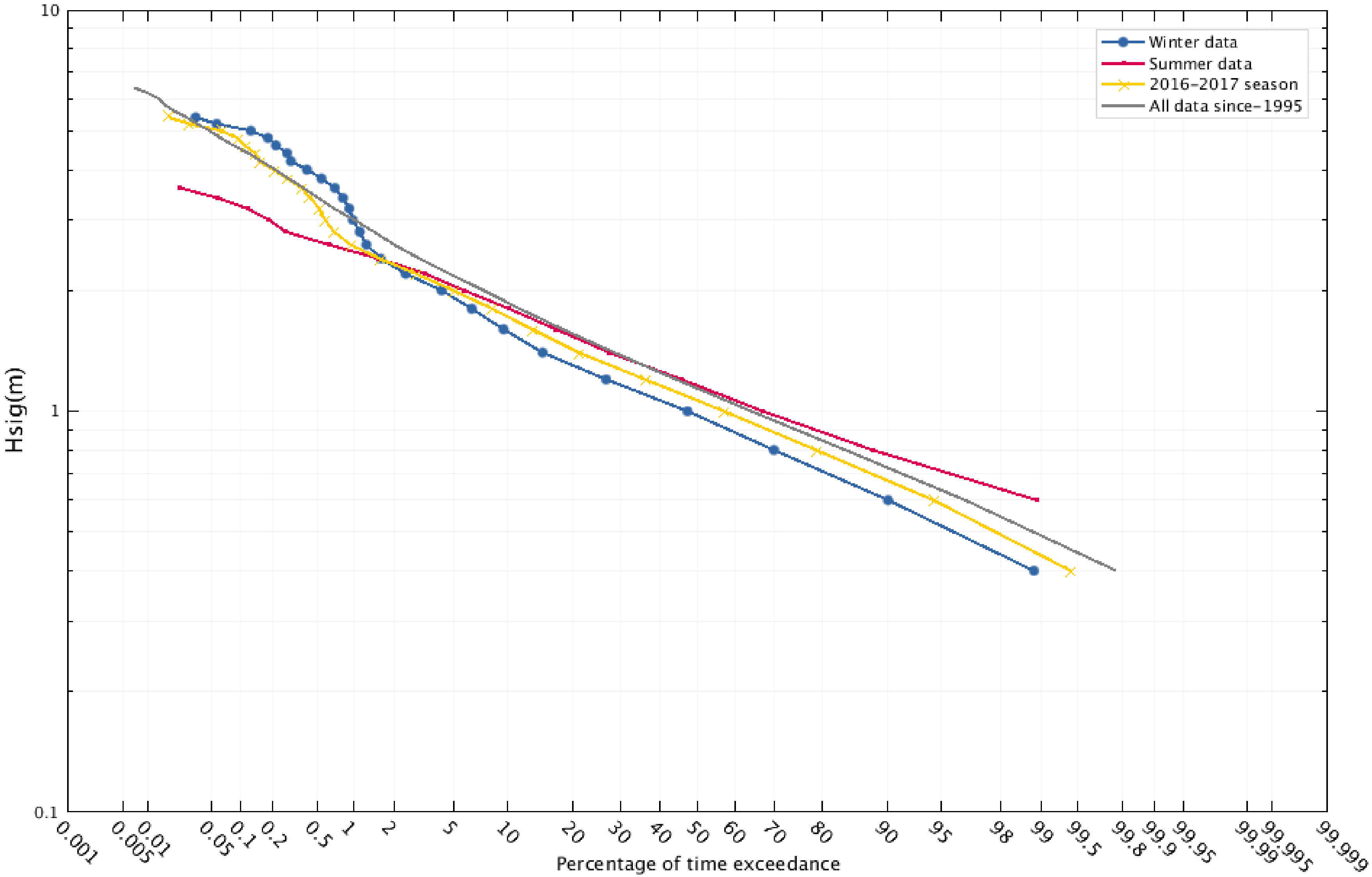

Figure 3.3: Tweed Heads Waverider buoy – Percentage (of time) exceedance of wave heights (H_{sig}) for all wave periods (T_p)

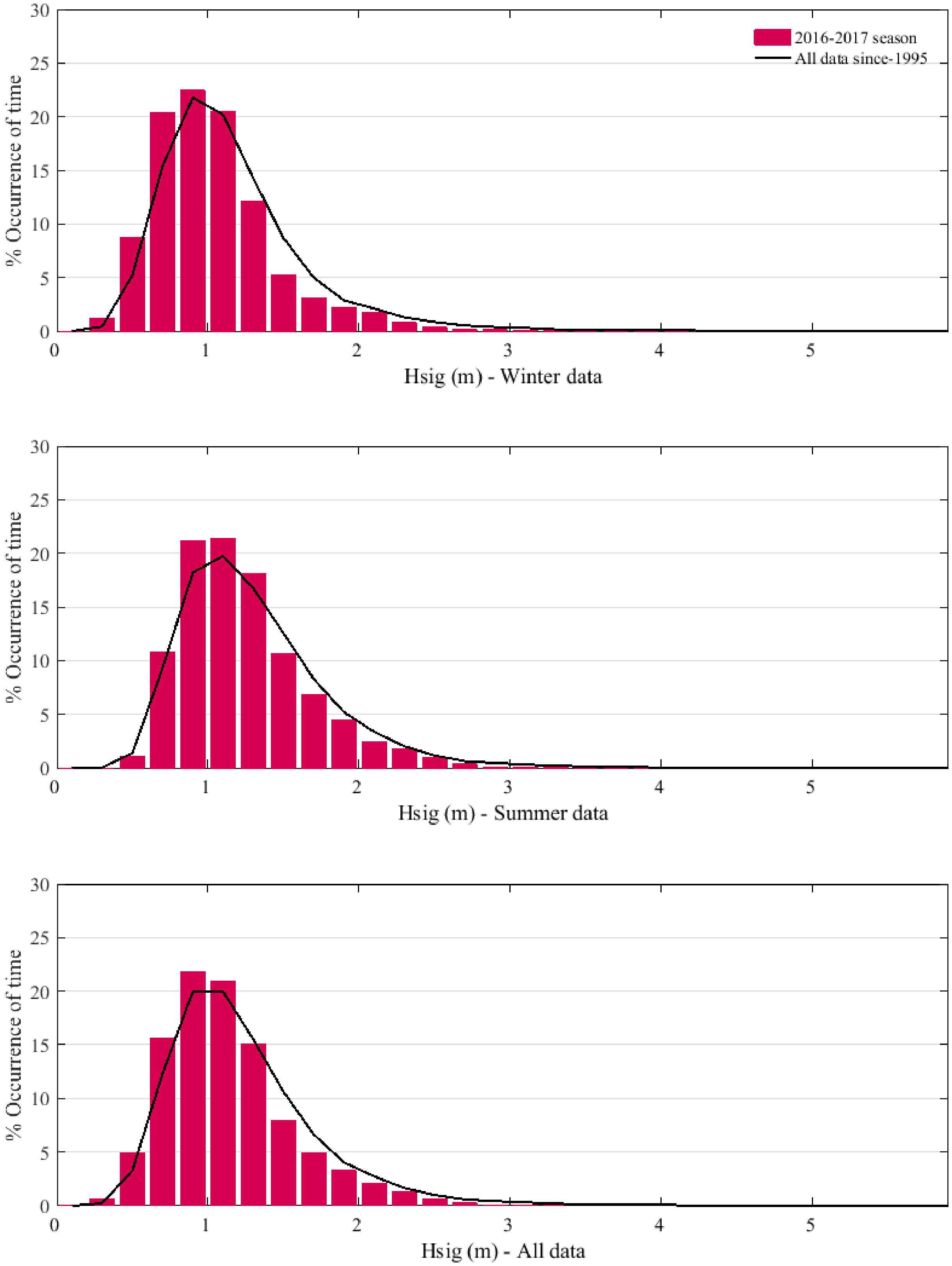

Figure 3.4: Tweed Heads Waverider buoy – Histogram percentage (of time) occurrence of wave heights (H_{sig}) for all wave periods (T_p)

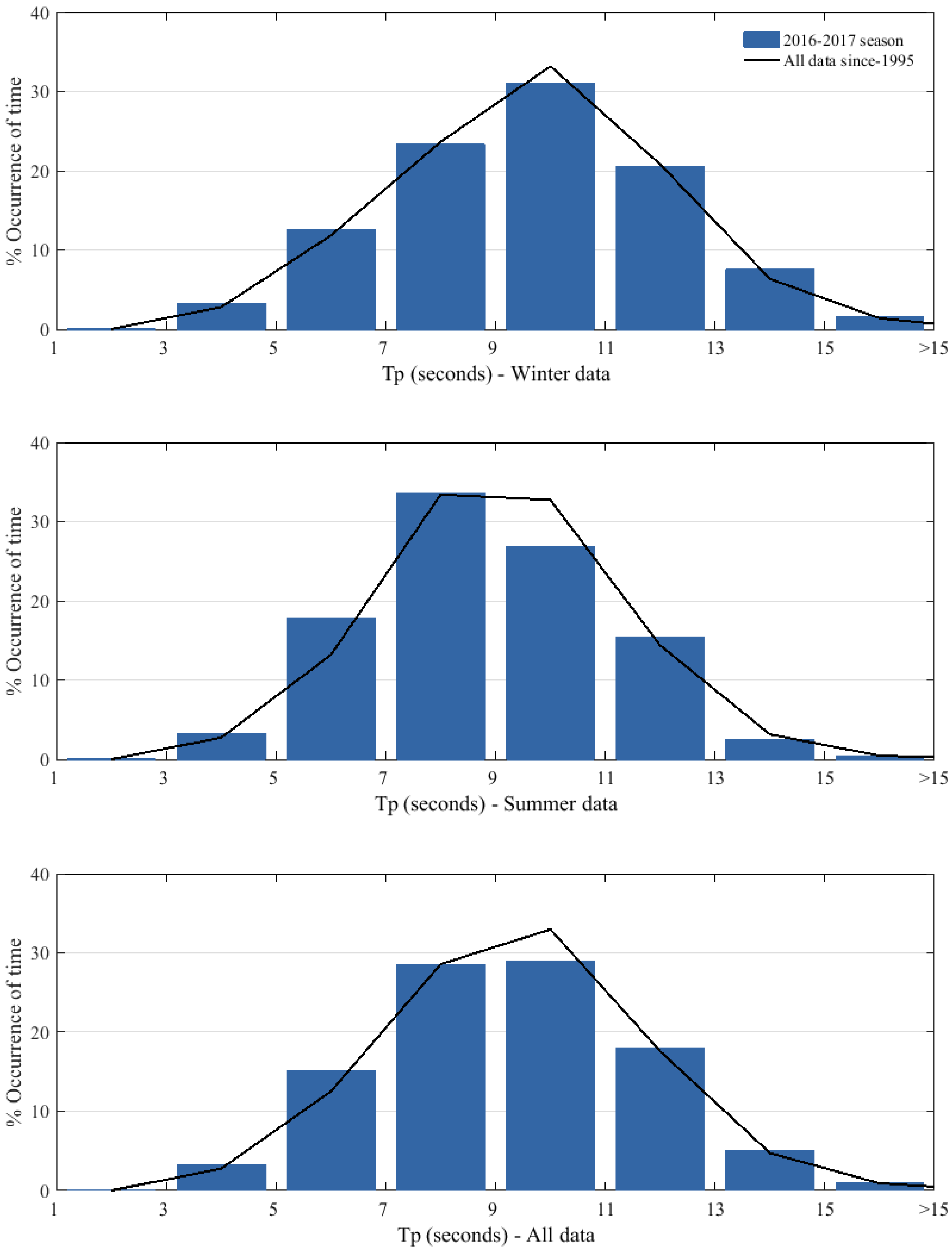

Figure 3.5: Tweed Heads Waverider buoy – Histogram percentage (of time) occurrence of wave periods (T_p) for all wave heights (H_{sig})

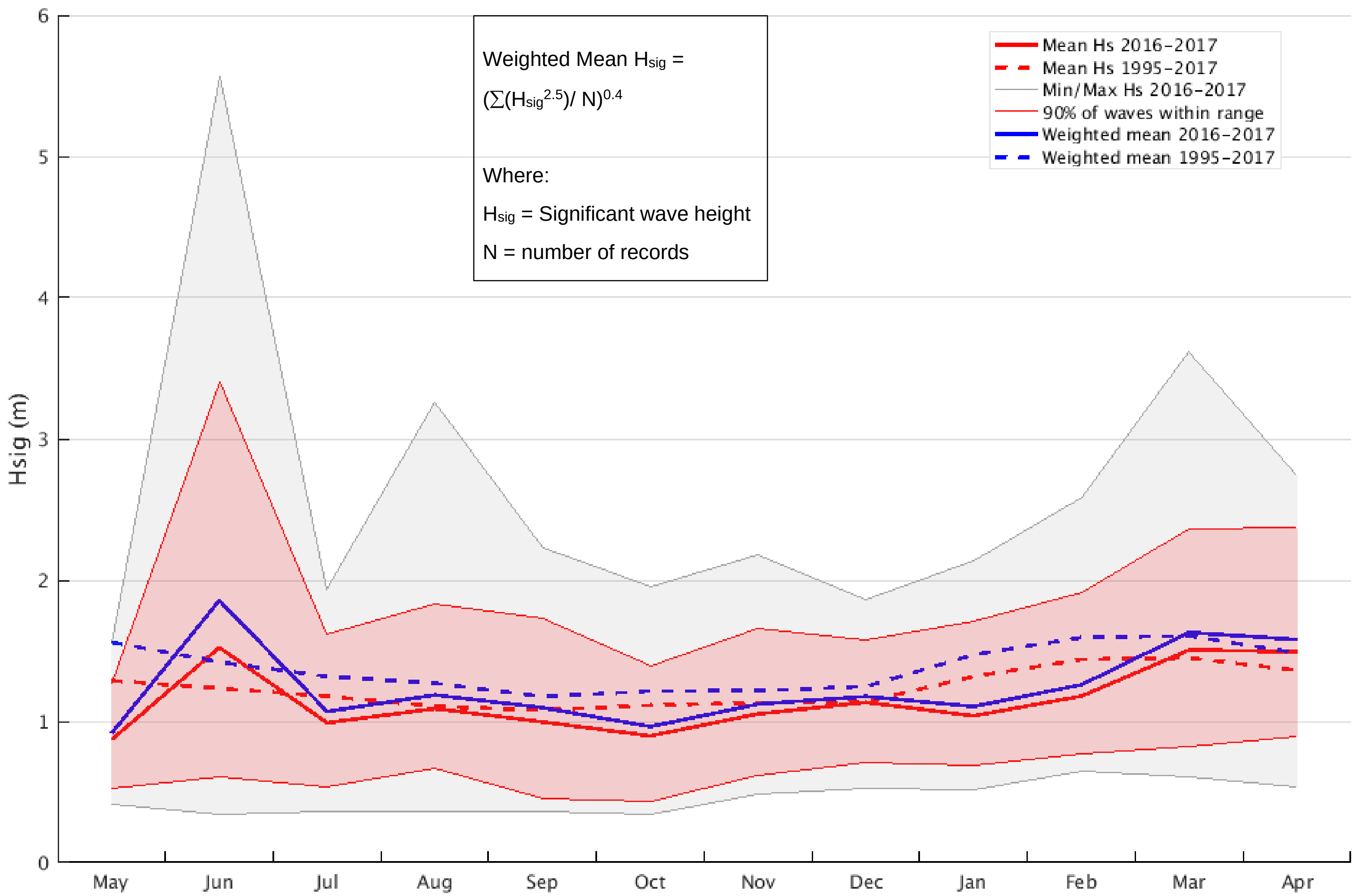

Figure 3.6: Tweed Heads Waverider buoy – Plot of monthly average H_{sig} for seasonal year and for all data. The weighted mean H_{sig} provides an indicative potential for sediment transport.

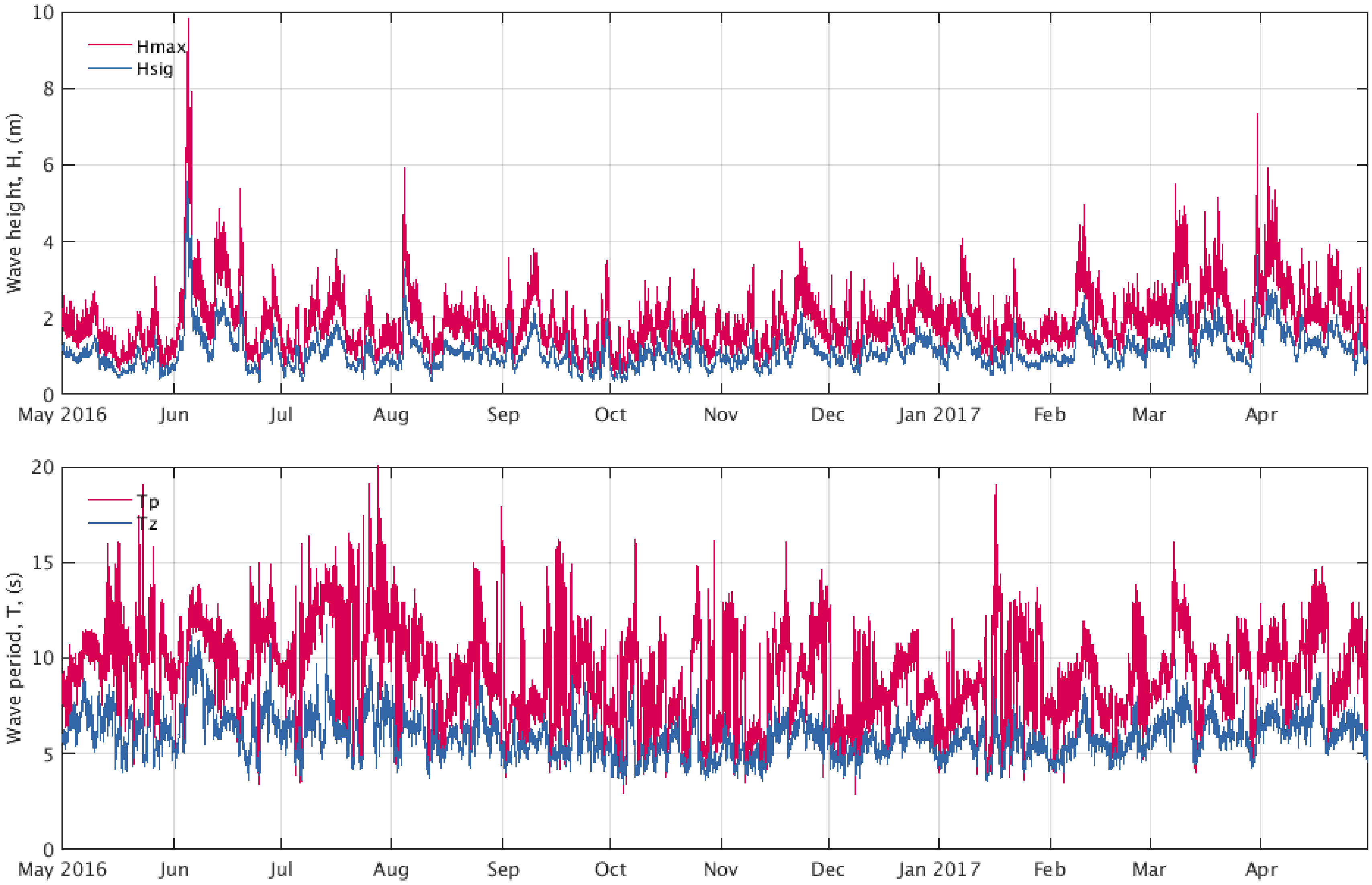

Figure 3.7: Tweed Heads Waverider buoy – Daily wave recordings

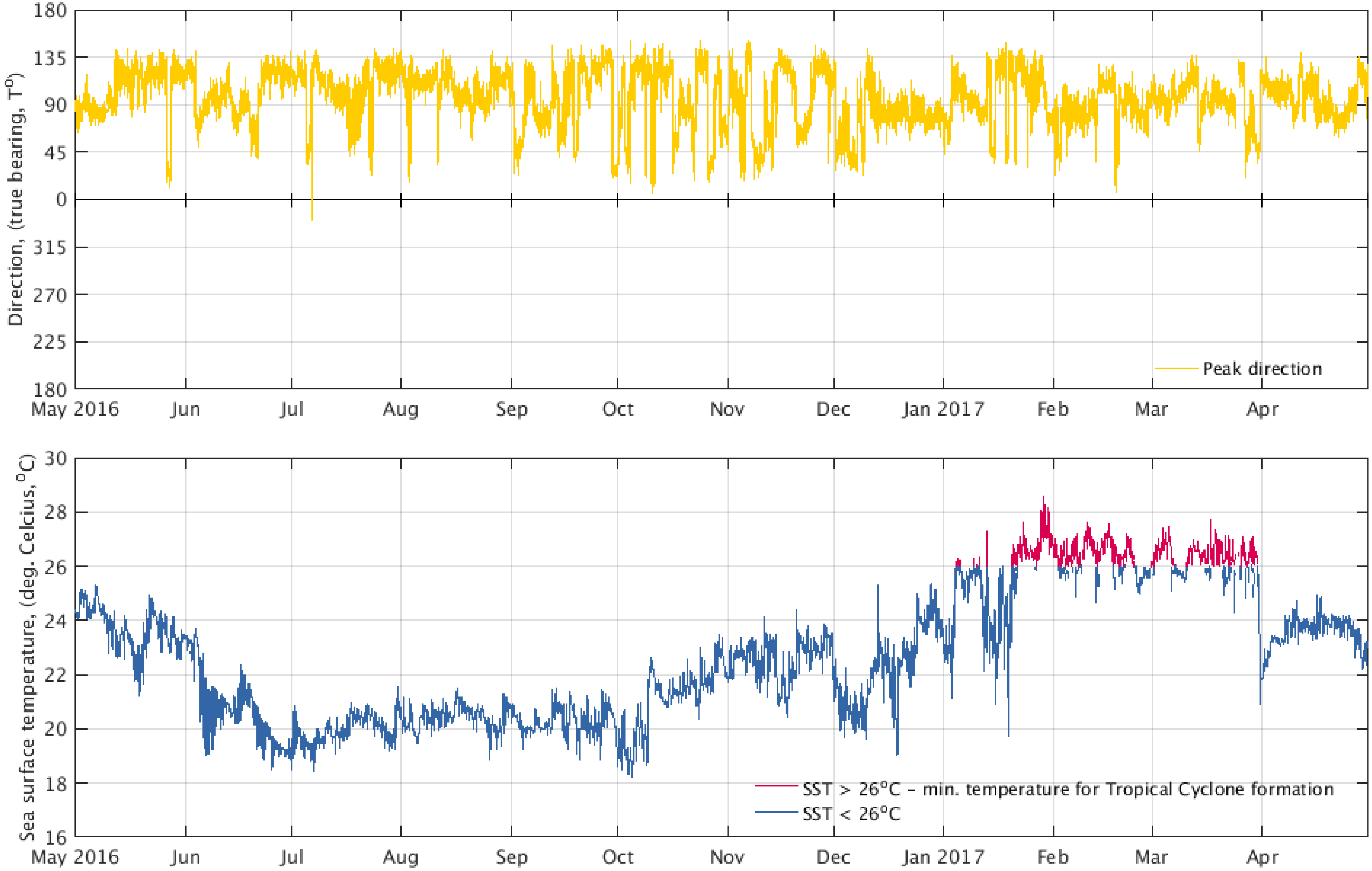

Figure 3.8: Tweed Heads Waverider buoy – Sea surface temperature and peak wave directions

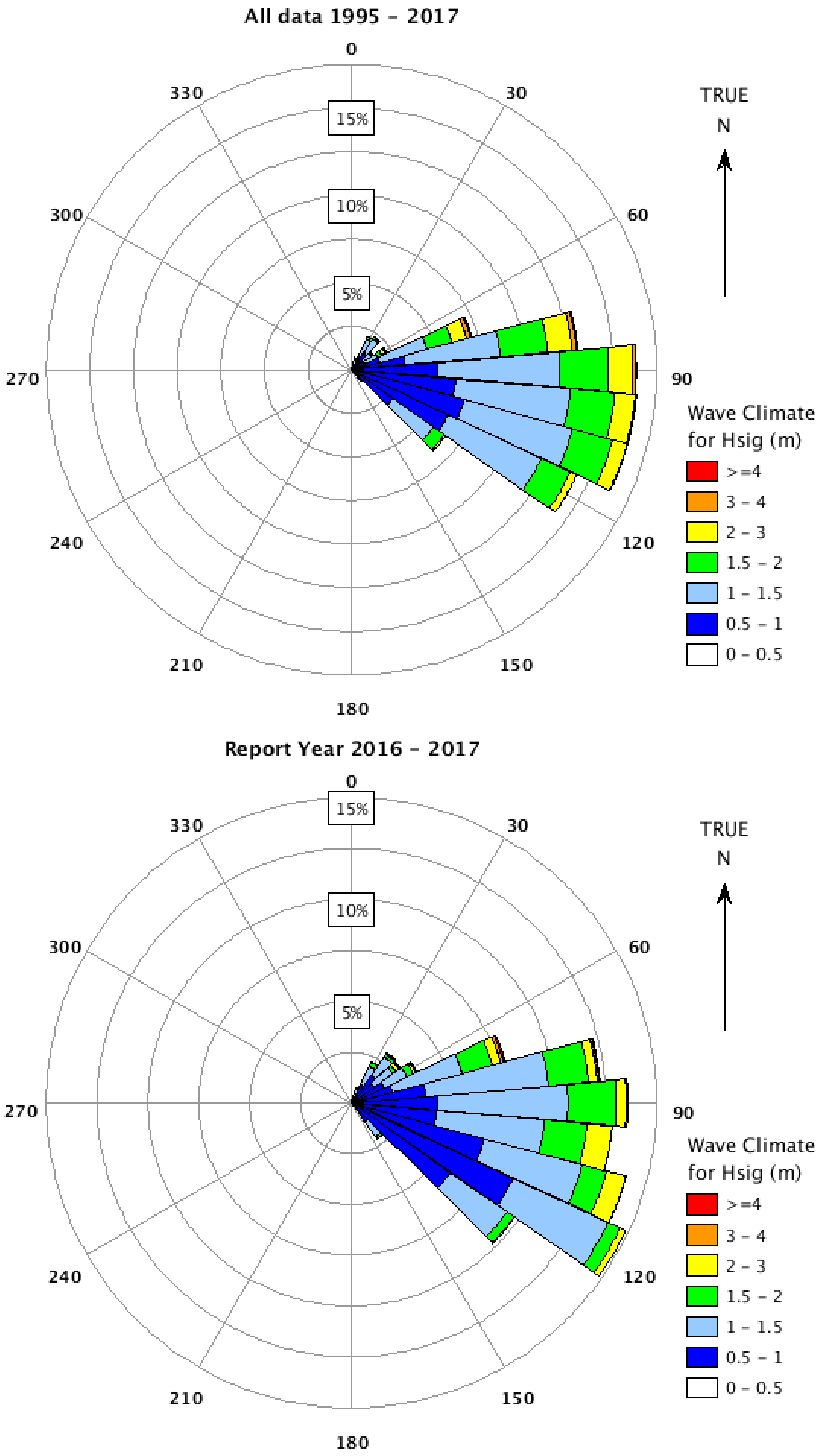

Figure 3.9: Tweed Heads Waverider buoy – Directional wave rose

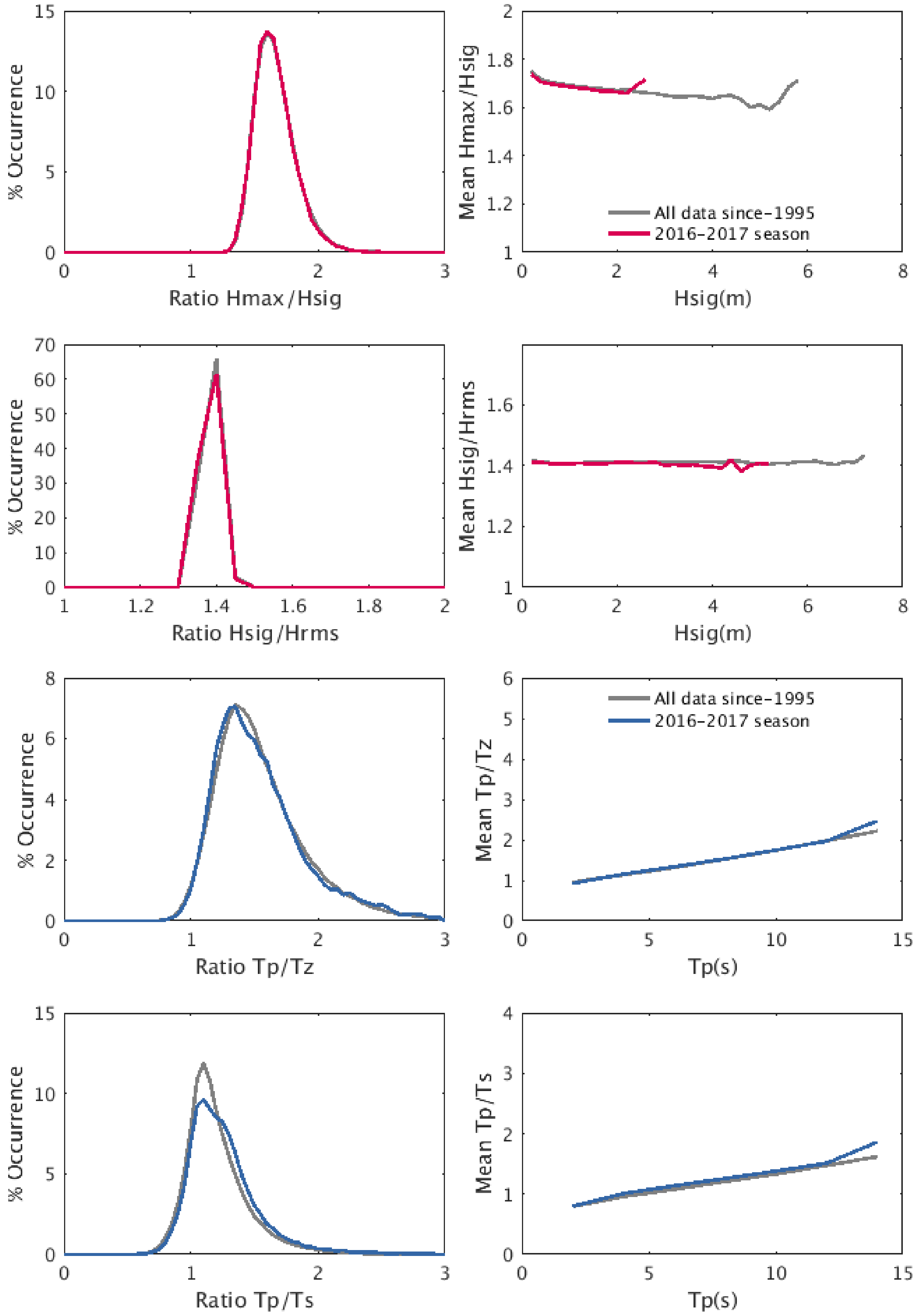

Figure 3.10: Tweed Heads Waverider buoy – Wave parameter relationships

4. Brisbane

Brisbane

Wave recording station

Details of data collected

2016-2017 season

Maximum possible analysis days (last record - first record)	=	364.98
Total number of days used in analysis	=	363.71
Gaps in data used in analysis (days)	=	1.27
Number of records used in analysis	=	17458

All data since-1976

Maximum possible analysis years (last record - first record)	=	40.50
Total number of years used in analysis	=	28.78
Gaps in data used in analysis (years)	=	11.72
Number of records used in analysis	=	363281

Table of highest ranked un-smoothed waves at Brisbane

Rank	Date(Hs)	Hs (m)	Date(Hmax)	Hmax (m)
1	17/03/1993 10:30	7.4	04/03/2006 21:00	16.8
2	04/03/2006 09:00	7.2	05/03/2004 17:30	14.3
3	28/01/2013 07:30	7.1	17/03/1993 03:30	13.1
4	05/03/2004 17:30	7.0	02/05/1996 14:00	12.8
5	02/05/1996 20:30	6.9	15/02/1995 06:30	12.2
6	15/02/1995 06:00	6.4	28/01/2013 07:30	12.1
7	23/08/2008 23:00	6.4	15/02/1996 19:00	12.1
8	12/06/2012 09:30	6.4	24/08/2008 02:00	11.5
9	06/06/2012 19:30	6.3	26/03/1998 07:00	11.5
10	31/12/2007 03:00	6.3	06/06/2012 19:30	11.1

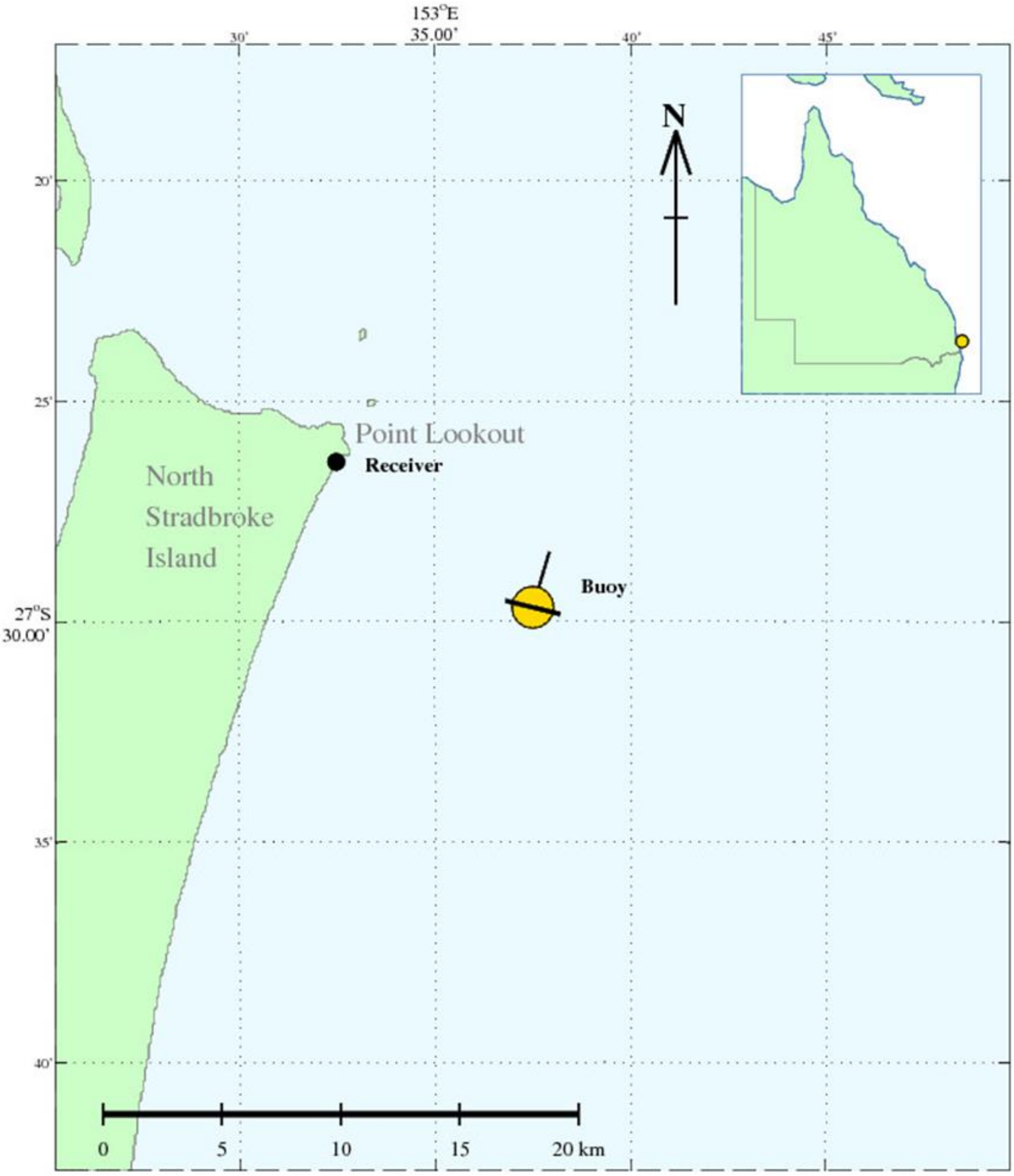

Figure 4.1: Brisbane Waverider buoy – Locality plan

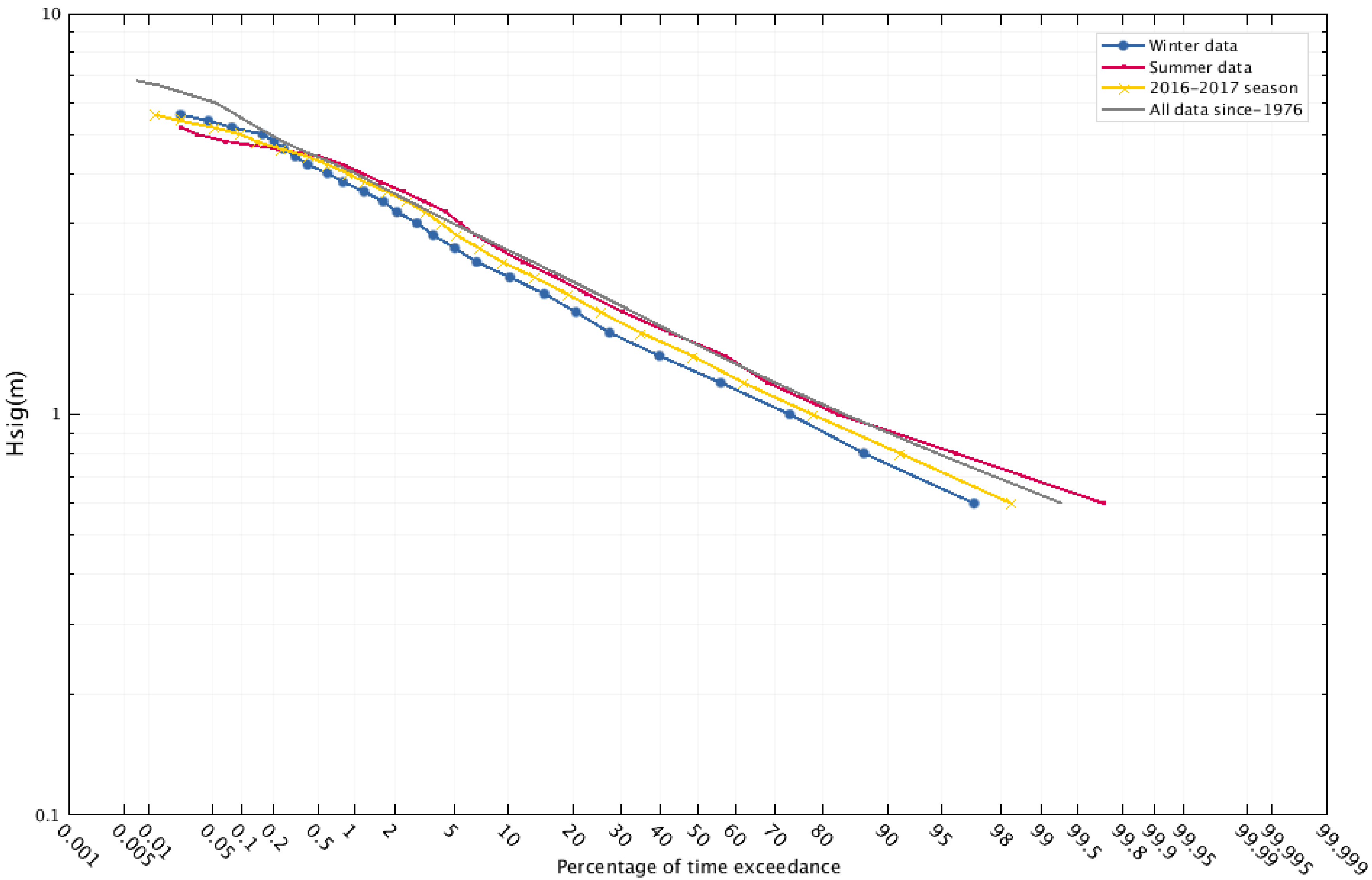

Figure 4.2: Brisbane Waverider buoy – Percentage (of time) exceedance of wave heights (H_{sig}) for all wave periods (T_p)

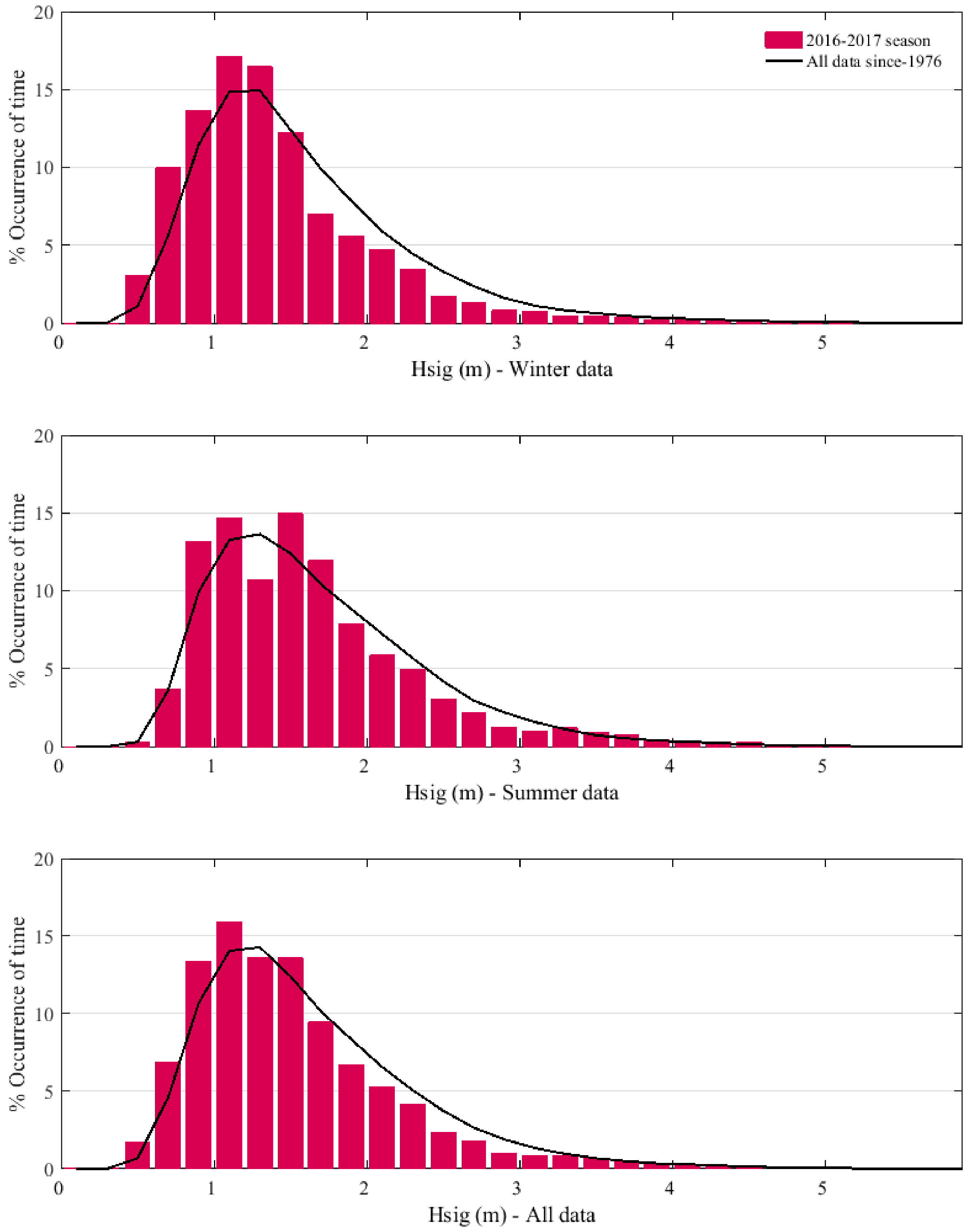

Figure 4.3: Brisbane Waverider buoy – Histogram percentage (of time) occurrence of wave heights (H_{sig}) for all wave periods (T_p)

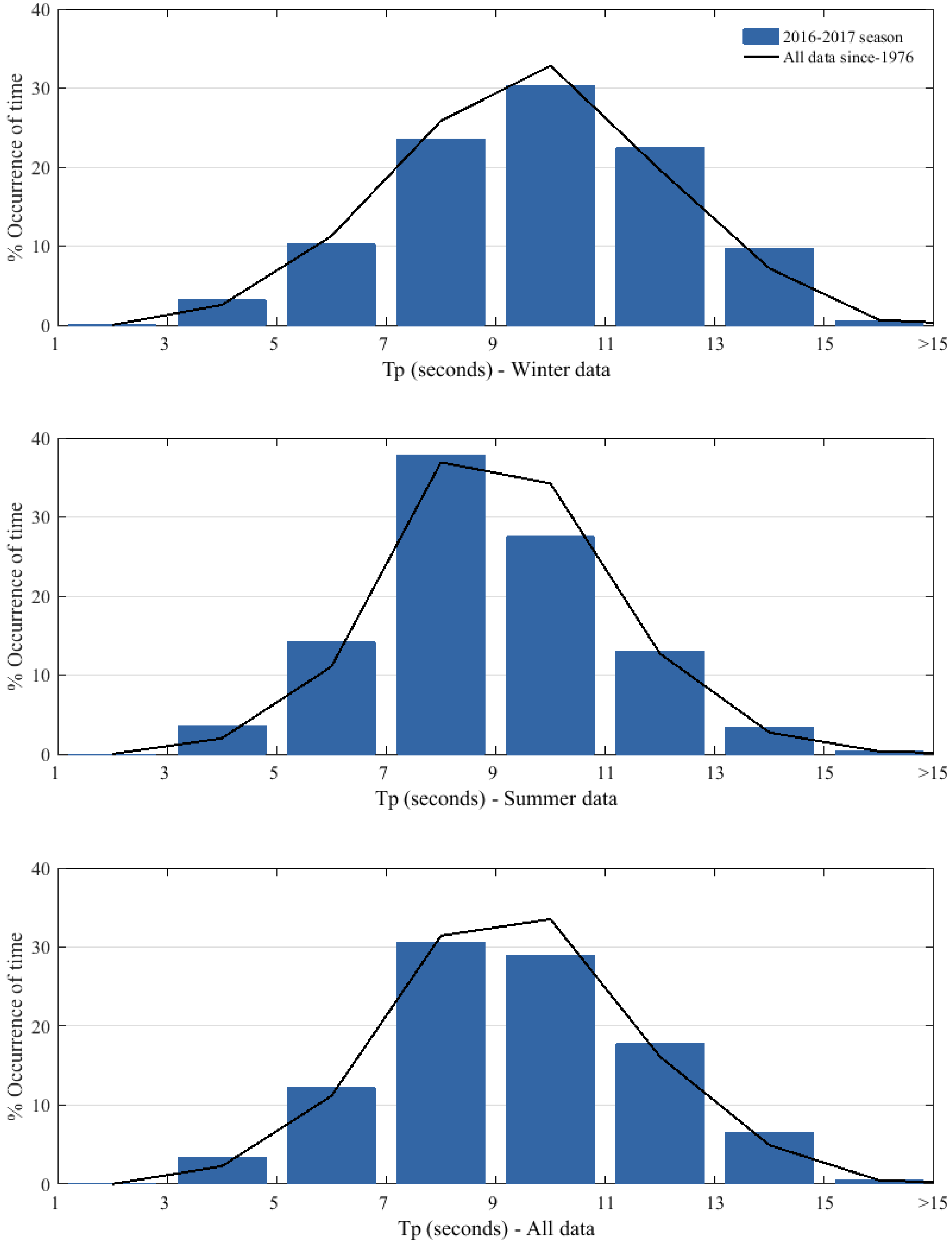

Figure 4.4: Brisbane Waverider buoy – Histogram percentage (of time) occurrence of wave periods (T_p) for all wave heights (H_{sig})

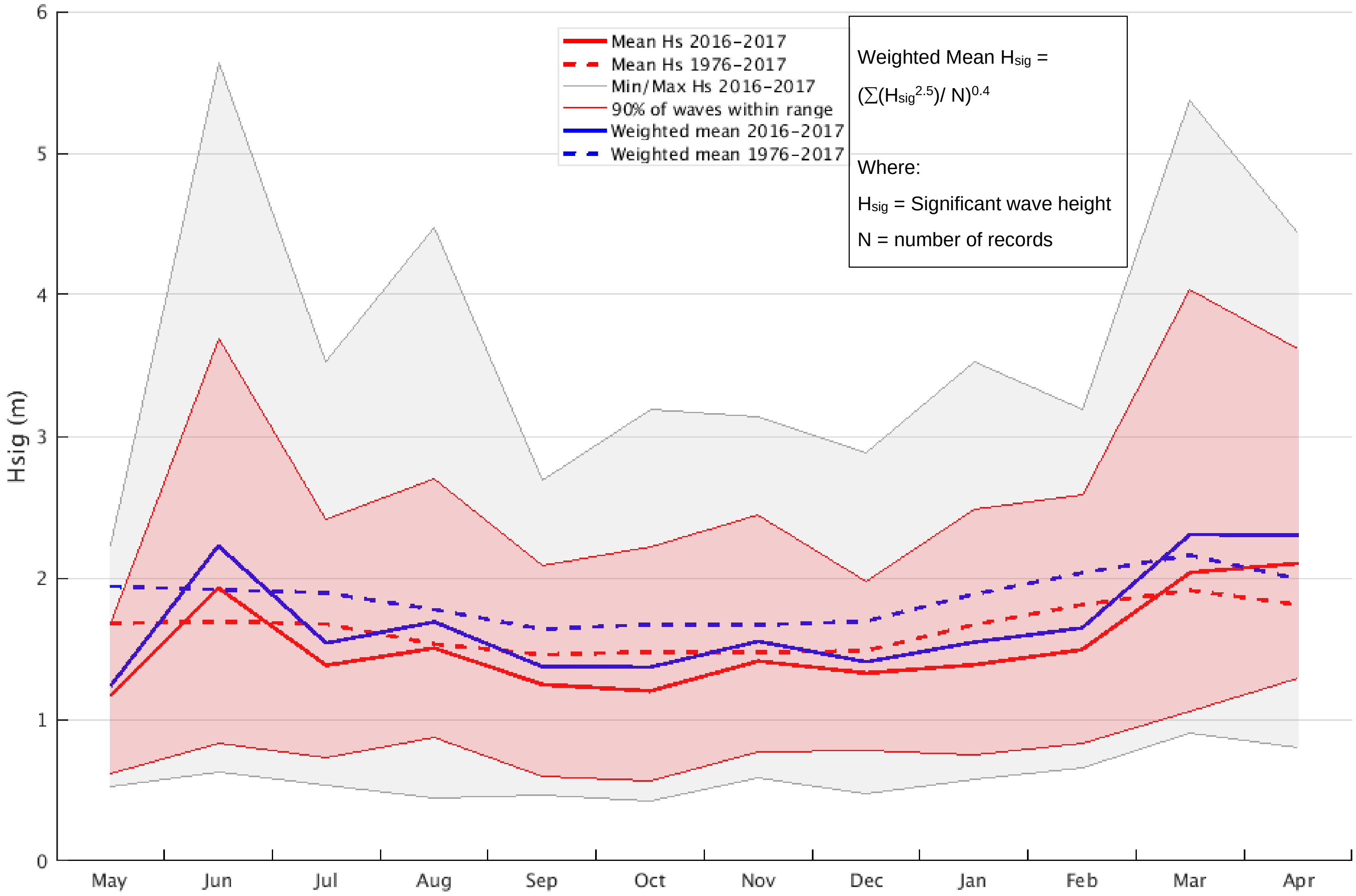

Figure 4.5: Brisbane Waverider buoy – Plot of monthly average H_{sig} for seasonal year and for all data. The weighted mean H_{sig} provides an indicative potential for sediment transport.

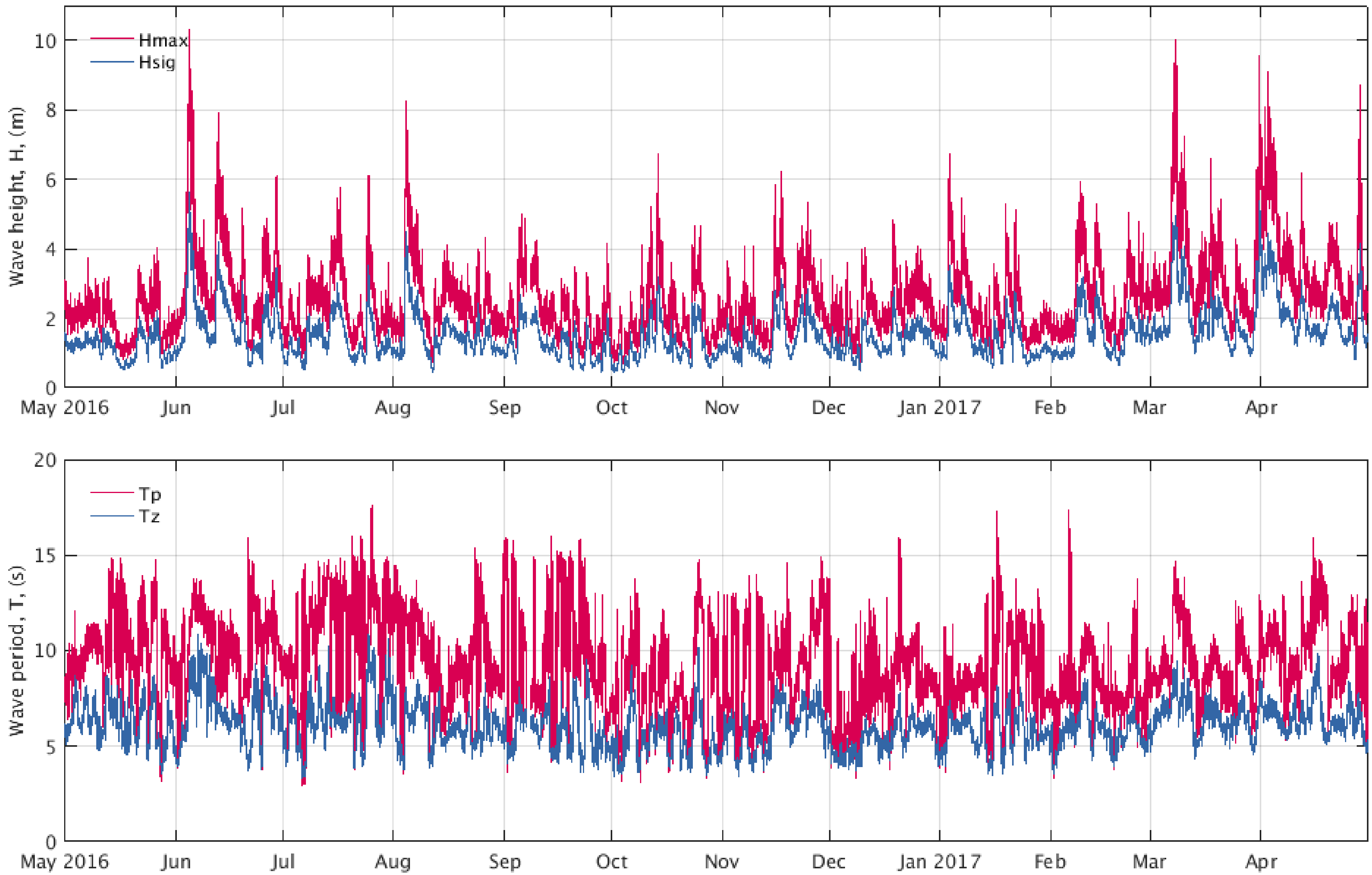

Figure 4.6: Brisbane Waverider buoy – Daily wave recordings

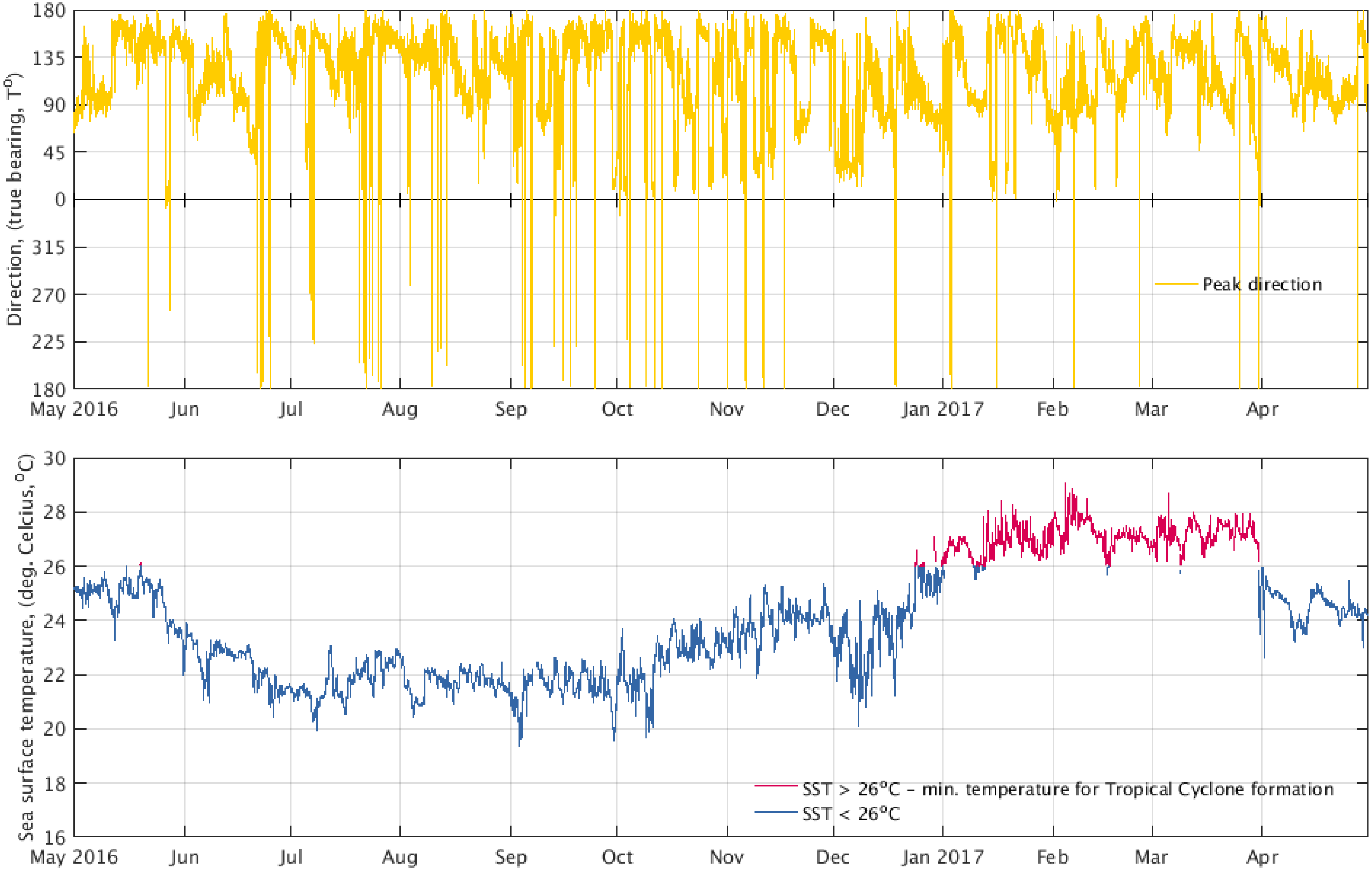

Figure 4.7: Brisbane Waverider buoy – Sea surface temperature and peak wave directions

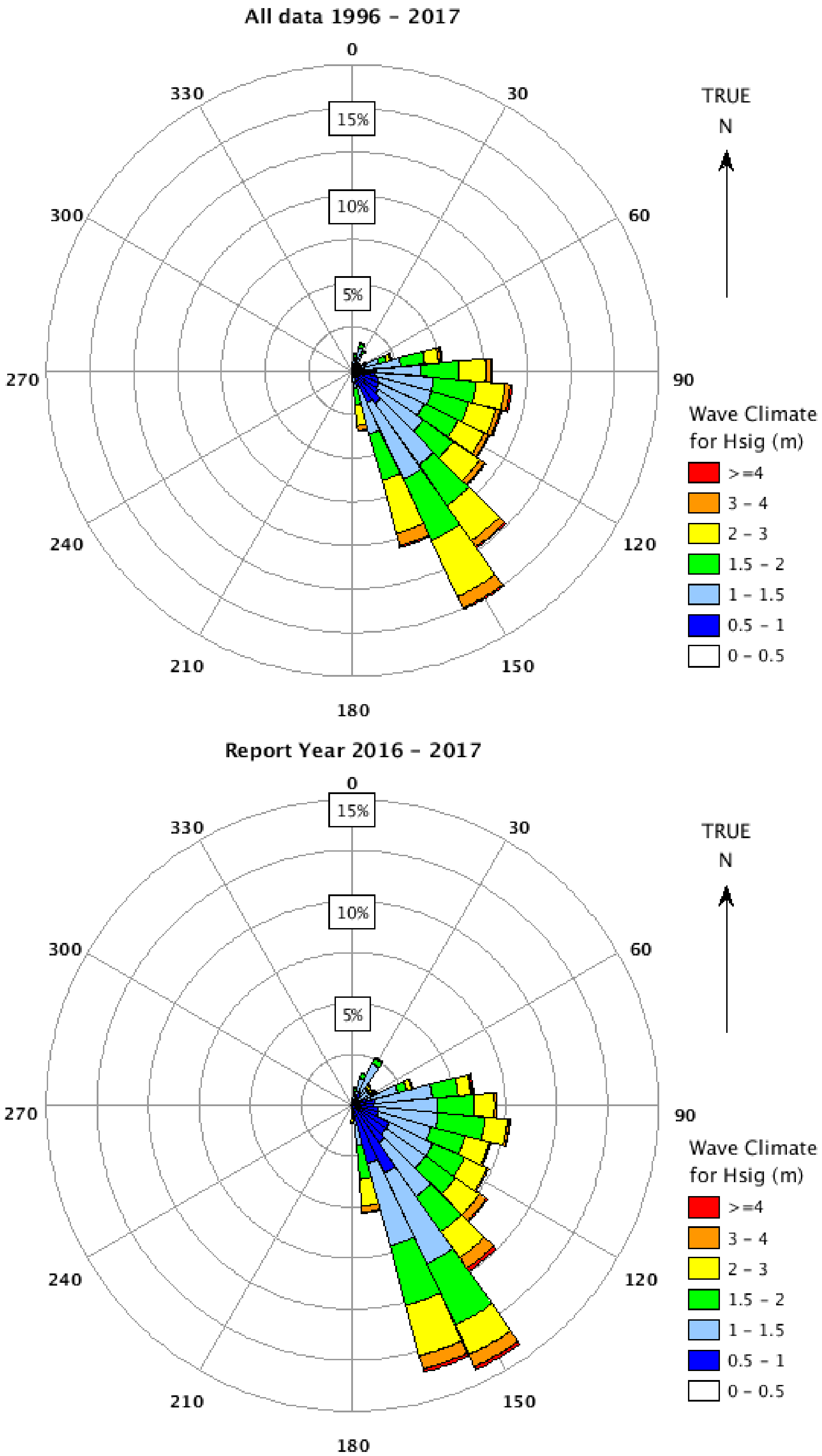

Figure 4.8: Brisbane Waverider buoy – Directional wave rose

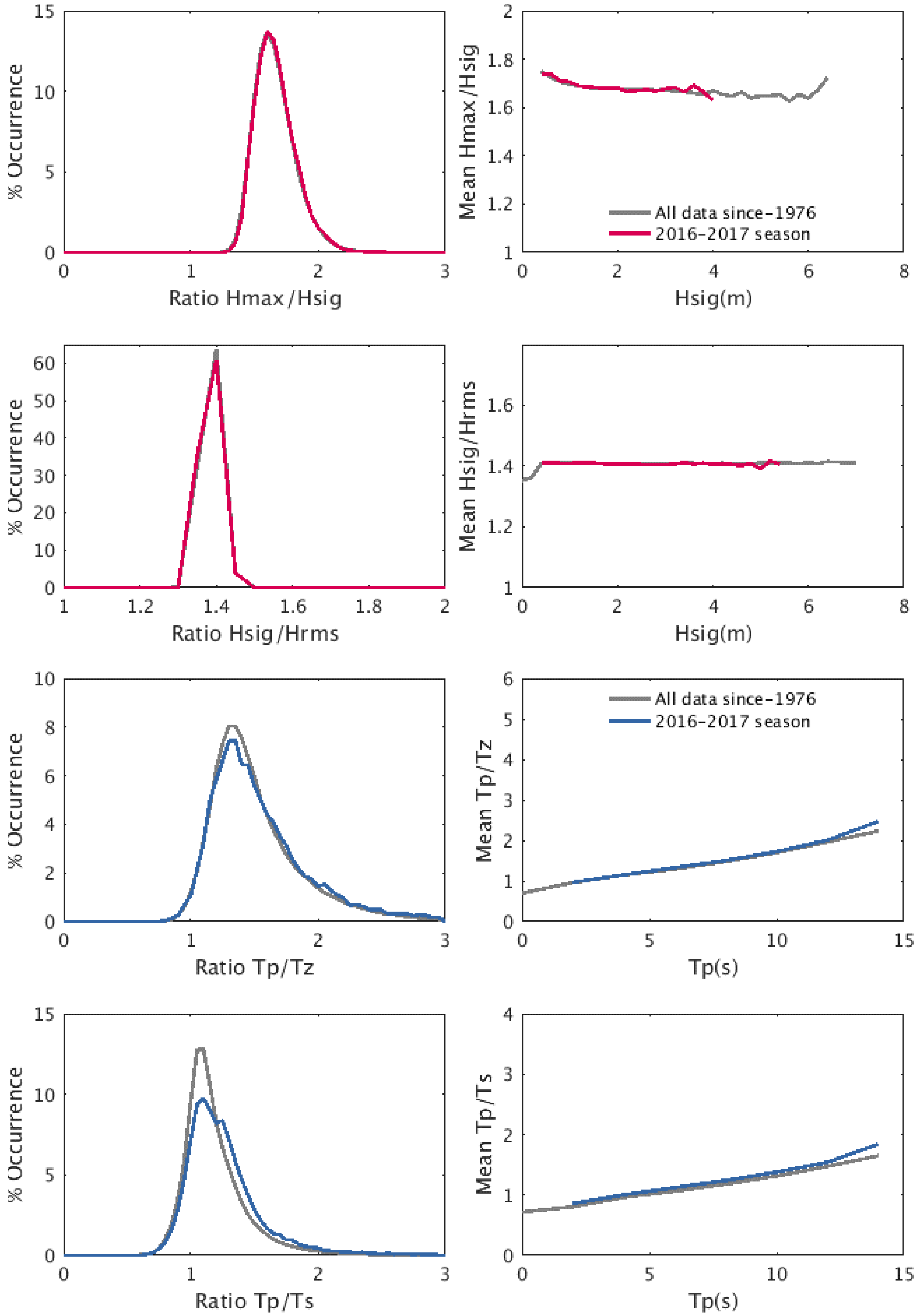

Figure 4.9: Brisbane Waverider buoy – Wave parameter relationships

5. References

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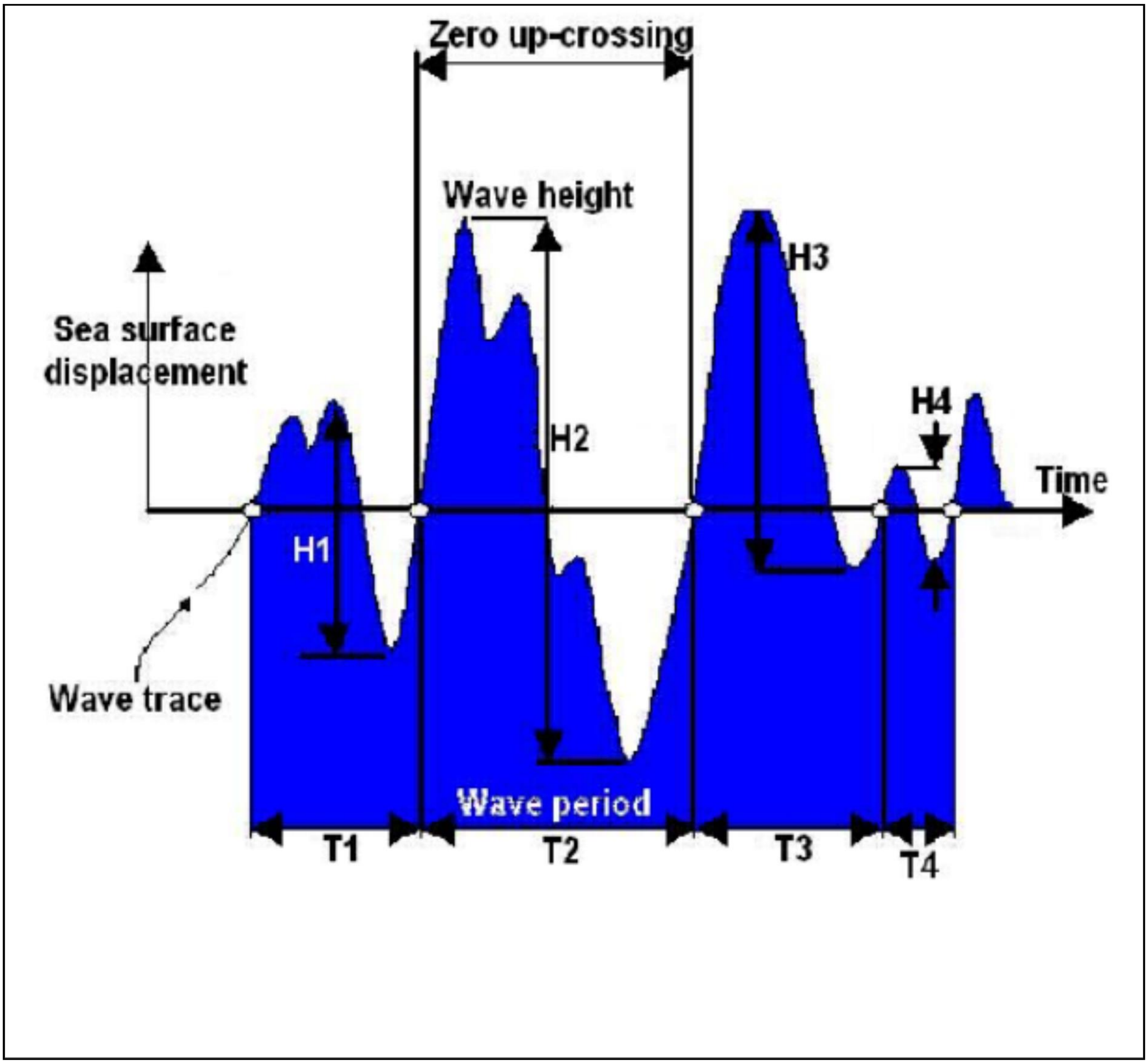
Appendix A – Zero up-crossing analysis

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