



# Wave data recording program

Tweed Heads/Brisbane wave climate annual  
summary May 2015–April 2016

Coastal Impacts Unit

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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).

The information presented here summarises the primary analyses of wave data recorded using Datawell directional Waverider buoys positioned off Tweed Heads and Brisbane for the period from 01 May 2015 to 30 April 2016. The data recorded covers all of the seasonal variations for one year, and includes the 2015–16 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.

This report has been prepared for the Tweed River Entrance Sand Bypassing Project to summarise the primary analyses of wave data collected at the Tweed Heads and Brisbane wave sites and presents wave climate information for the reporting period from 01 May 2015 to 30 April 2016.

The wave data collected for the current year of recording 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.

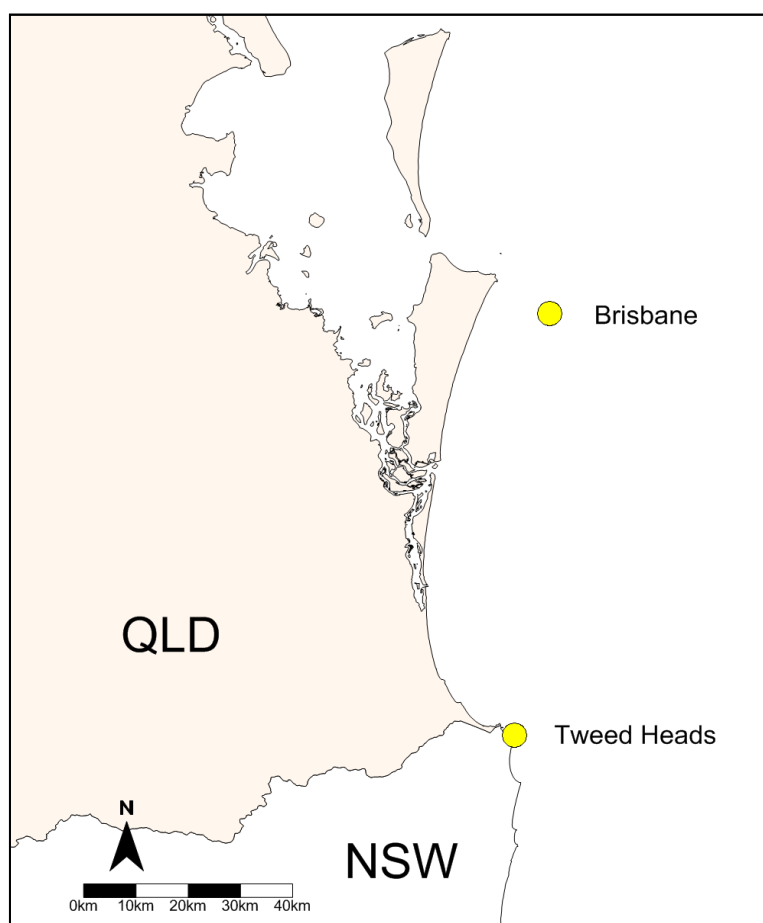


Figure 1.1: Tweed regional wave recording sites – Locality plan

## 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 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.

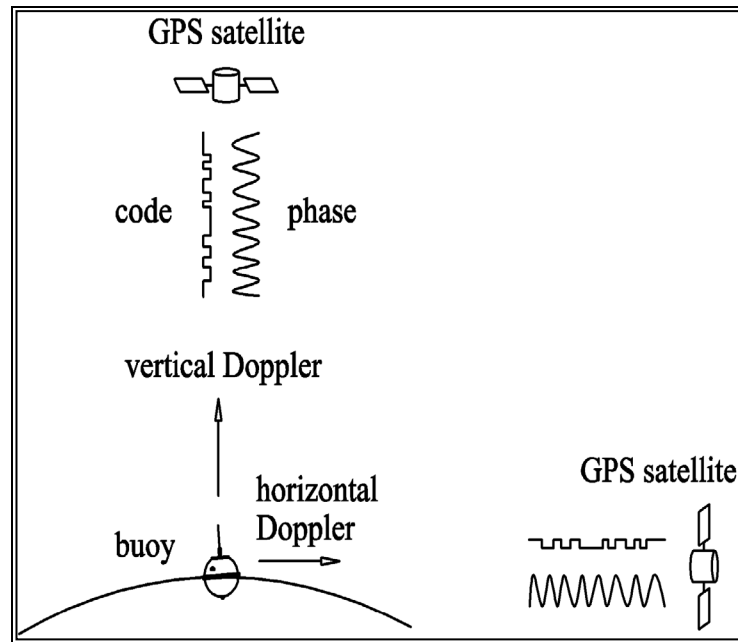
A fluxgate compass provides a global directional reference with which to orient the buoy. The acceleration values that are relative to the buoy are then transformed into values that are relative to the fixed compass. The measured acceleration values are filtered and double integrated with respect to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

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 2048 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<sup>®</sup> 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 128 spectral estimates in bands of 0.01 hertz. 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 128 spectral estimates in bands of 0.005 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 involved in the analysis**

S(f)	energy density spectrum (frequency domain)
Hsig	Significant wave height (time domain), the average of the highest third of the waves in the record.
Hmax	The highest individual wave in the record (time domain).
Hrms	The root mean square of the wave heights in the record (time domain).
Tsig	Significant wave period (time domain), the average period of the highest third of waves in the record.
Tz	The average period of all zero up-crossing waves in the record (time domain).
Tp	The wave period corresponding to the peak of the energy density spectrum (frequency domain).
Tc	The average period of all the waves in the record based on successive crests (time domain).
Direction (Dir; Dir_p)	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 ° 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 (Table 2 and Table 3). Details are presented in the location history plan (Figure 3.1). Data capture rates for each wave site over the seasonal year are presented in Table 4.

**Table 2: Deployment details for the Tweed Waverider buoy**

Latitude	Longitude	Depth (m)	Deployed date	Removal date
28°10.870'S	153°34.485'E	20	17/04/2015	17/04/2016
28°10.664'S	153°34.590'E	24	17/04/2016	current

**Table 3: Deployment details for the Brisbane Waverider buoy**

Latitude	Longitude	Depth (m)	Deployed date	Removal date
27°29.600'S	153°37.960'E	70	31/03/2015	current

**Table 4: Wave recording program percentage data capture May 2015 – April 2016**

Station	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Avg.
Tweed Heads	99.8	99.79	99.8	99.8	99.79	99.8	99.79	99.4	99.8	99.57	99.8	97.64	99.74
Brisbane	99.8	99.79	99.8	99.8	99.79	99.8	99.79	99.8	99.8	99.78	94.62	99.79	99.32

A summary of major meteorological events, where the recorded Hsig value reached the storm threshold wave height of two metres for Tweed Heads and four metres for Brisbane, for the period from 01 May 2015 to 30 April 2016 is shown in Table 5. Wave parameters Hsig, Hmax, Tp, and other relevant information are listed for each event. Weather systems that contributed to the Hsig reaching the storm threshold value are listed in Table 5, and may be direct reproductions of synoptic descriptions provided by the Australian Bureau of Meteorology (bom.gov.au).

**Notes:**

1. Barometric pressure measured in hectopascals (hPa). The Hsig and Hmax values are the maximums recorded for each event and are not necessarily coincident in time. The Tp and Hsig 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 Hsig and Hmax 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. Hsig and Hmax values shown in brackets are unsmoothed values as recorded at the site.

**Table 5: Significant meteorological events May 2015 – April 2016**

Tweed Heads Storm threshold value: 2.0 metres (Hsig)				
Date	Hsig (m)	Hmax (m)	Tp (s)	Event
01/05/2015 22:30	5.1 (5.5)	8.0 (9.0)	10.9	An East Coast Low developed north of Fraser Island during 01 May, bringing powerful surf and damaging winds to much of southeast Queensland on 01 and 02 May.
23/05/2015 08:00	2.1 (2.4)	3.8 (5.1)	11.5	A low pressure system developed on 21 May and intensified while tracking east across the northern Tasman Sea from 22 to 23 May.
31/12/2015 4:30	2.2 (2.4)	3.7 (4.3)	10.2	A tropical low pressure system embedded on the monsoon trough moved gradually south along the Queensland and New South Wales border at the end of the month.
08/01/2016 02:30	2.1 (2.3)	3.5 (4.2)	11.8	A tropical low pressure system moved south along the Queensland and New South Wales border between 05 January and 07 January then migrated east in the central Tasman Sea on 08 January.
10/02/2016 22:30	2.0 (2.3)	3.2 (3.8)	11.2	A low pressure system was located in the Tasman Sea, north of New Zealand's north island from 04 to 09 February.
13/02/2016 14:30	2.0 (2.1)	3.7 (4.0)	8	Tropical cyclone Tatiana was named over the northwest Coral Sea. In the afternoon on 11 February Tatiana tracked south and remained well offshore to the Queensland coast before dissipating on 15 February. South-eastern Queensland beaches encountered some powerful, long period swells.
23/02/2016 10:00	2.1 (2.2)	3.5 (4.2)	12.2	Ex-tropical cyclone <i>Winston</i> moved southward in the eastern Coral Sea, tracking well offshore and parallel to the Queensland coast from 22 to 25 February.
26/02/2016 13:30	3.2 (3.7)	5.2 (6.5)	14.9	Ex-tropical cyclone <i>Winston</i> , though well off the Queensland coast, caused large and long period easterly swells, leading to dangerous surf conditions at beaches south of Sandy Cape
13/03/2016 06:30	2.0 (2.2)	3.2 (3.6)	8.8	A broad easterly fetch developed between a large high pressure system located over New Zealand's north island from 09 to 14 March, and a low pressure system located in the Pacific Ocean, south of Fiji.
25/04/2016 06:30	3.1 (3.2)	5.2 (5.6)	12	A low pressure system formed in the northern Tasman Sea on 24 April and combined with a high pressure system moving east from Victoria into the Tasman Sea, developing a south-easterly fetch focussed on Northern New South Wales and southeast Queensland.



Denotes peak Hsig event



Brisbane Storm threshold value: 4.0 metres (Hsig)				
Date	Hsig(m)	Hmax (m)	Tp (s)	Event
01/05/2015 20:00	5.3 (5.8)	9.1 (10.8)	11.4	An East Coast Low developed north of Fraser Island during 01 May, bringing powerful surf and damaging winds to much of southeast Queensland on 01 and 02 May.
23/05/2015 05:30	4.0 (4.3)	7.0 (8.0)	10.1	A low pressure system developed on 21 May and intensified while tracking east across the northern Tasman Sea from 22 to 23 May.
23/09/2015 20:00	5.2 (5.7)	8.7 (10.7)	11.7	A series of complex low pressure systems in the central Tasman Sea combined with a large high pressure system in the Great Australian Bight to produce a significant southerly fetch aimed toward New South Wales and southeast Queensland.
03/12/2015 14:00	4.5 (4.7)	7.4 (9.3)	10	A series of complex low pressure systems tracked eastward from the Southern Ocean toward New Zealand from 29 November to 03 December developed a significant southerly fetch aimed toward New South Wales and southeast Queensland.
16/01/2016 04:00	4.7 (5.2)	7.3 (8.9)	11.5	A deep polar low pressure system in the Southern Ocean migrated eastward between large high pressure systems located below Western Australia and the Tasman Sea from 13 to 15 January. This resulted in a sharp increase in southerly wave heights late on 15 January and into 16 January.
27/02/2016 15:00	4.5 (4.8)	7.4 (9.1)	8.3	Ex-tropical cyclone Winston, though well off the Queensland coast, caused large and long period easterly swells, leading to dangerous surf conditions at beaches south of Sandy Cape



Denotes peak Hsig event

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–Figure 3.5 and Figure 4.3–Figure 4.5. In each of these three figures for each site, the term ‘All data’ refers to total number of years used in analysis for Tweed Heads (20.98 years) since 13 January 1995 and Brisbane (27.78 years) since 31 October 1977. In addition, similar statistical analysis provides monthly averages of wave heights for the seasonal year and all data.

Daily wave recordings, average water temperature and peak direction (Dir\_p) recordings are shown for the period from 01 May 2015 to 30 April 2016. 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 Hsig 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 2015 to 30 April 2016 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

##### 2015-2016 season

Maximum possible analysis days (last record - first record)	= 365.98
Total number of days used in analysis	= 364.71
Gaps in data used in analysis (days)	= 1.27
Number of records used in analysis	= 17506

##### All data since-1995

Maximum possible analysis years (last record - first record)	= 21.30
Total number of years used in analysis	= 20.98
Gaps in data used in analysis (years)	= 0.31
Number of records used in analysis	= 317011

**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	01/05/2015 22:30	5.5	22/05/2009 07:00	9.7
6	24/05/1999 05:00	5.2	04/03/2006 12:00	9.6
7	04/03/2006 20:30	5.2	25/03/1998 22:30	9.5
8	12/06/2012 10:00	5.2	15/02/1995 15:30	9.3
9	15/02/1995 11:30	5.2	12/06/2012 11:30	9.3
10	30/06/2005 09:00	4.9	02/02/2001 02:00	9.1

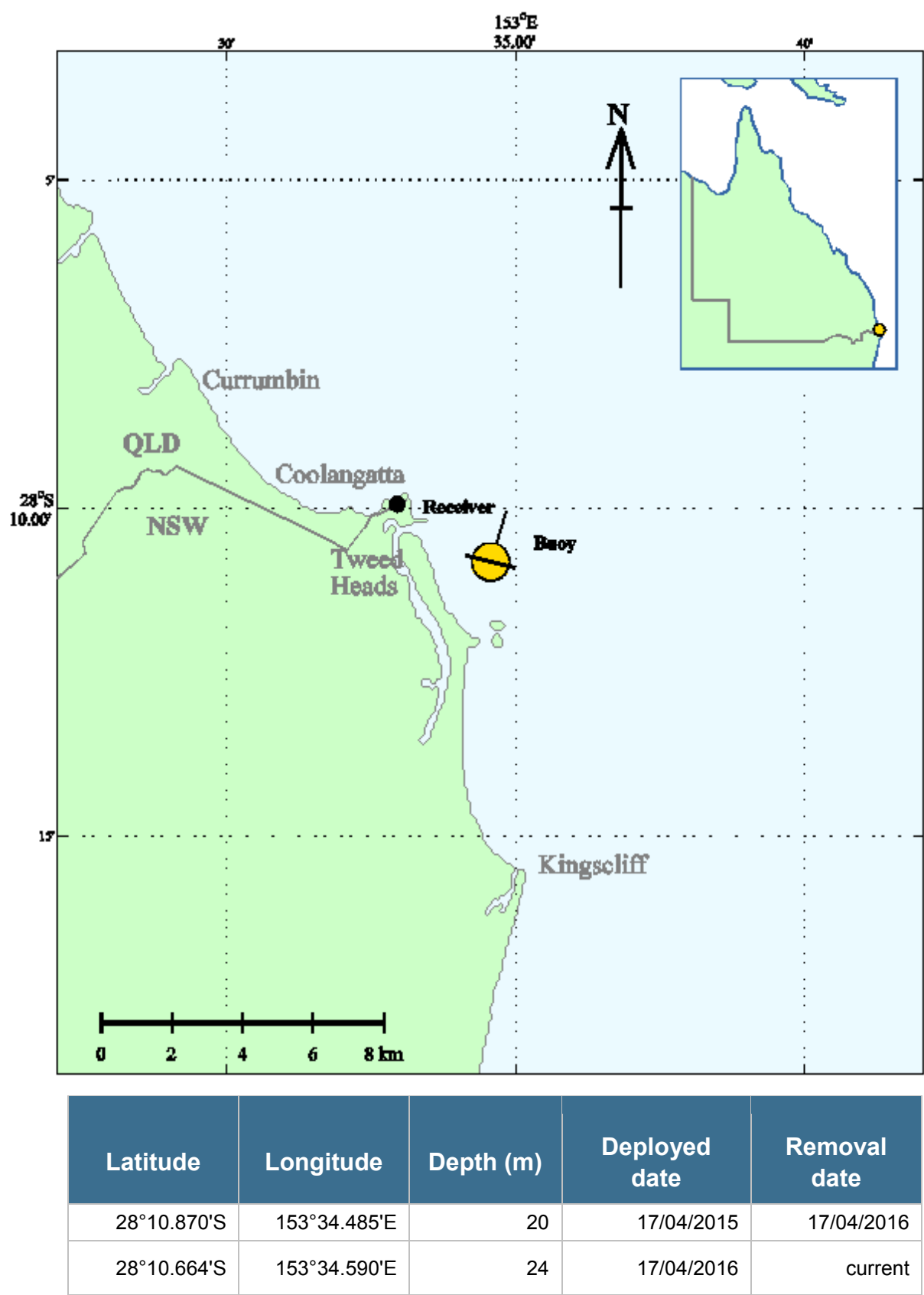


Figure 3.1: Tweed region – Locality plan

**Table 6: Wave conditions 2015–16 – Tweed Heads (see also Figure 3.6)**

Month	Average Hsig (m)	Min Hsig (m)	Max Hsig (m)	Average of Peak Period (Tp) Directions (Ø TRUE)	90% of waves within the range of (m)	No. of Days When Hsig ≥ 2 m	No. of Days When Hsig ≤ 0.75m	Events where Hsig > 3m and date of storm
May-15	1.3	0.45	5.47	96	0.6–2.9	5	9	1st, 2nd
Jun-15	1.2	0.43	2.04	96	0.9–1.7	1	2	
Jul-15	1	0.28	1.81	105	0.5–1.5	0	12	
Aug-15	0.94	0.54	1.52	89	0.7–1.3	0	15	
Sep-15	1.03	0.52	2	97	0.6–1.5	1	14	
Oct-15	1.06	0.51	1.9	95	0.6–1.6	0	13	
Nov-15	0.91	0.54	1.88	88	0.6–1.3	0	22	
Dec-15	1.15	0.4	2.35	91	0.7–1.8	1	7	
Jan-16	1.23	0.53	2.29	97	0.8–1.9	4	5	
Feb-16	1.52	0.57	3.71	88	0.7–2.3	9	4	26th
Mar-16	1.33	0.79	2.15	92	1.0–1.8	2	0	
Apr-16	1.27	0.63	3.24	98	0.7–2.2	4	6	25th
<b>May to April</b>	1.16	0.28	5.47	94	0.7–1.8	27	109	3

**Table 7: Mean Values, Tweed Heads**

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May –Apr
Mean Hsig(m) 2015–16	1.3	1.2	1	0.94	1.03	1.06	0.91	1.15	1.23	1.52	1.33	1.27	1.16
Mean Hsig(m) Average from 1995– 2016	1.33	1.2	1.17	1.1	1.08	1.13	1.14	1.15	1.33	1.48	1.44	1.36	1.25
Average of Peak Period (Tp) Directions (Ø TRUE) 2015–16	96	96	105	89	97	95	88	91	97	88	92	98	94
Average Peak Period (Tp) Directions (Ø TRUE) 1995– 2016	99	100	103	99	94	92	92	93	91	95	93	98	96

Mean Hsig=  $\sum \text{Hsig} / N$

Average of Peak Period (Tp) Directions =  $\sum D / N$

Where:

Hsig= Significant wave height

D = Direction at Peak Period (Tp)

N = number of records



**Table 8: Weighted Mean Values, Tweed Heads (see also Figure 3.6)**

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May-Apr
Weighted Mean Hsig(m) 2015–16	1.59	1.24	1.07	0.97	1.09	1.12	0.95	1.24	1.31	1.62	1.37	1.4	1.25
Weighted Mean Hsig (m) 1995–2016	1.62	1.37	1.31	1.27	1.18	1.23	1.23	1.26	1.48	1.64	1.6	1.49	1.39
Weighted Mean of Peak Period (Tp) Directions (Ø TRUE) 2015–16	83	95	106	88	97	92	89	93	99	87	91	100	93
Weighted Mean of Peak Period (Tp) Directions (Ø TRUE) 1995–2016	88	96	100	94	93	91	94	91	89	93	88	95	93

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

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

Where:

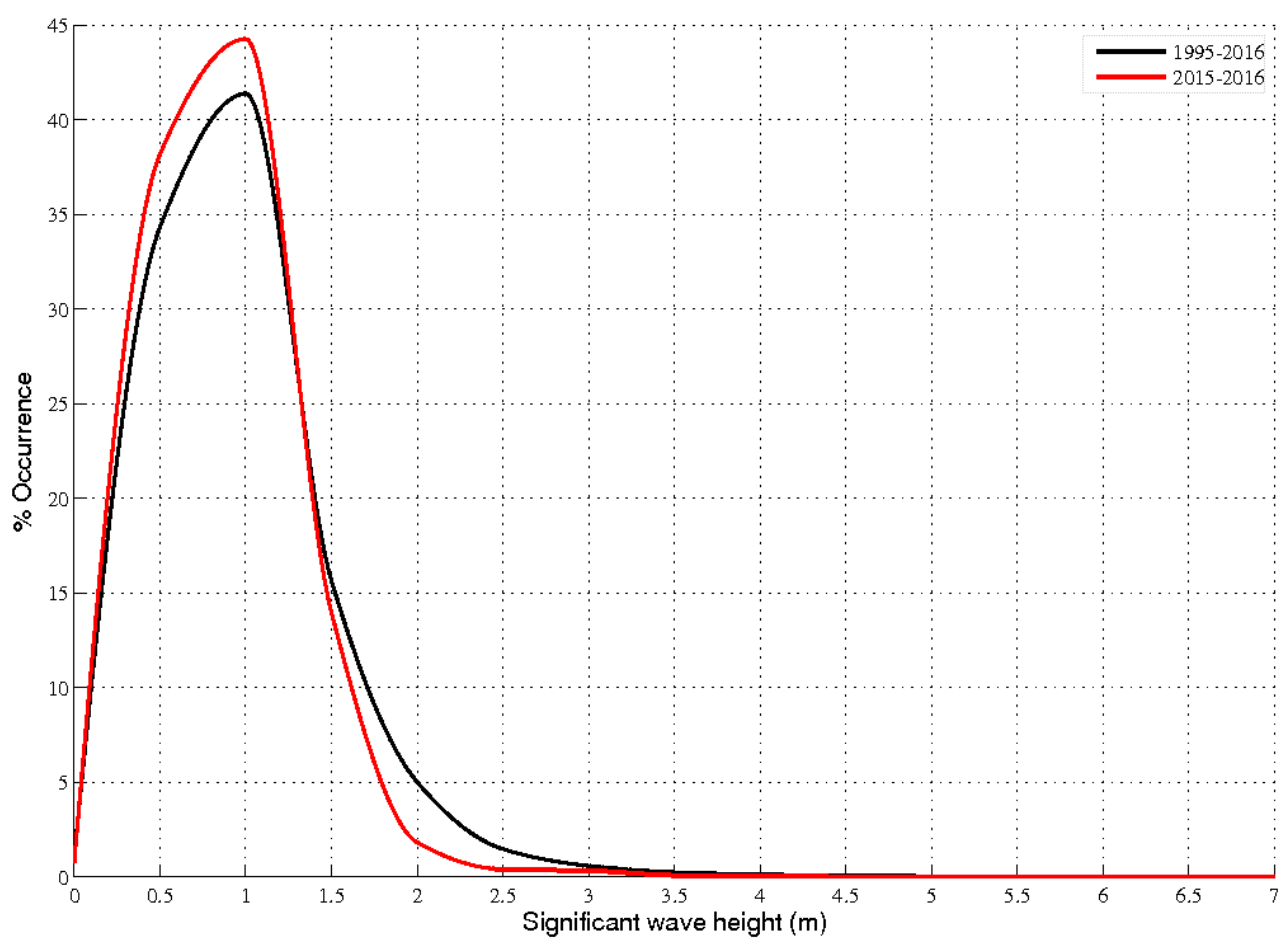
Hsig= Significant wave height

D = Direction at Peak Period (Tp)

N = number of records

**Table 9: Hsig percentage (%) occurrence, Tweed Heads**

Hsig (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 16	1.08	34.34	41.38	15.67	5.02	1.48	0.59	0.23	0.12	0.05	0.02	0.01	0.01	>0.00
May 15–Apr 16	0.77	38.19	44.28	13.98	1.83	0.41	0.34	0.09	0.07	0.02	0.02	0.00	0.00	0.00

**Figure 3.2: Tweed region – Hsig percentage (%) occurrence**

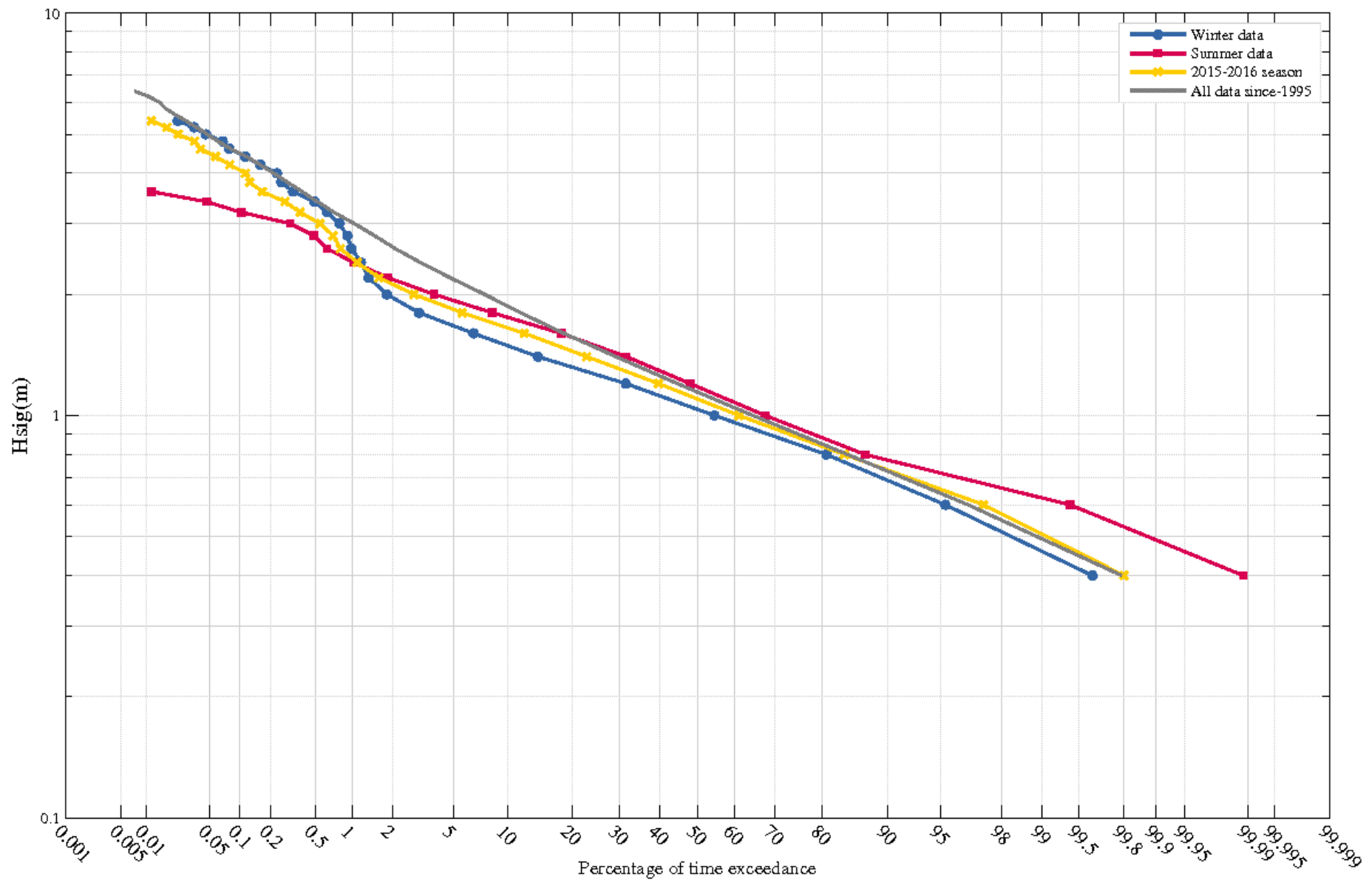


Figure 3.3: Tweed region – Percentage (of time) exceedance of wave heights ( $H_{sig}$ ) for all wave periods ( $T_p$ )

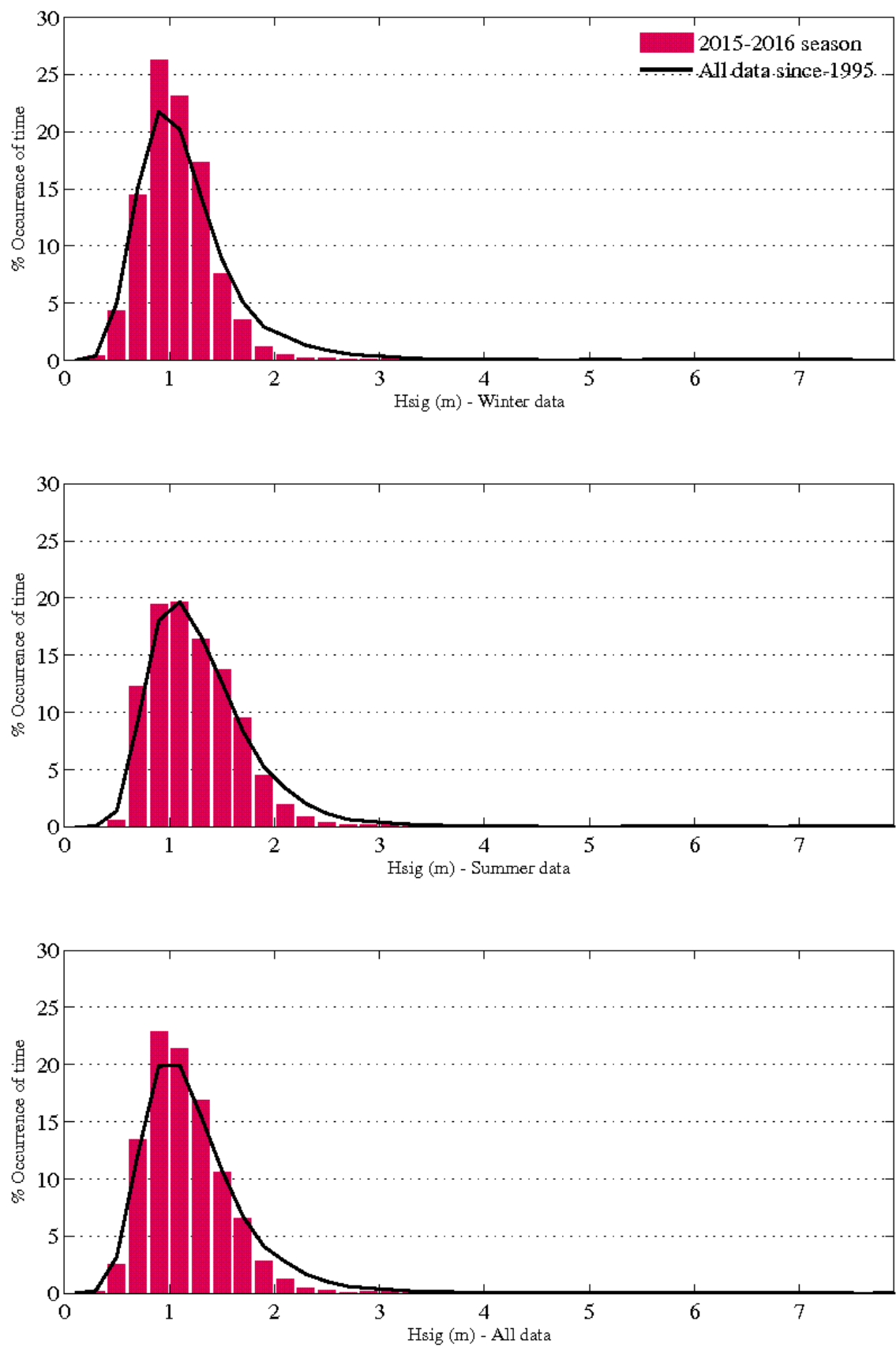
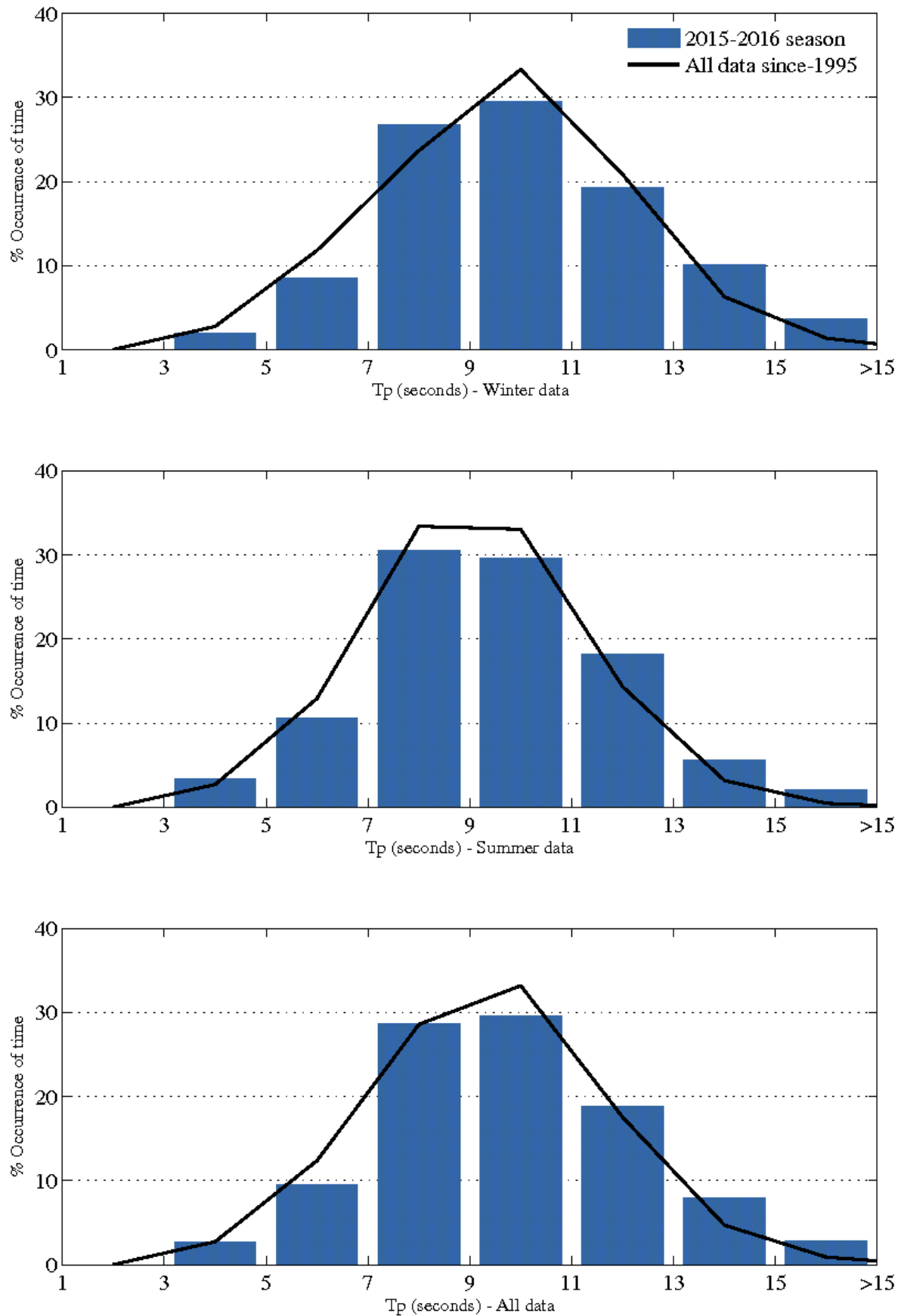
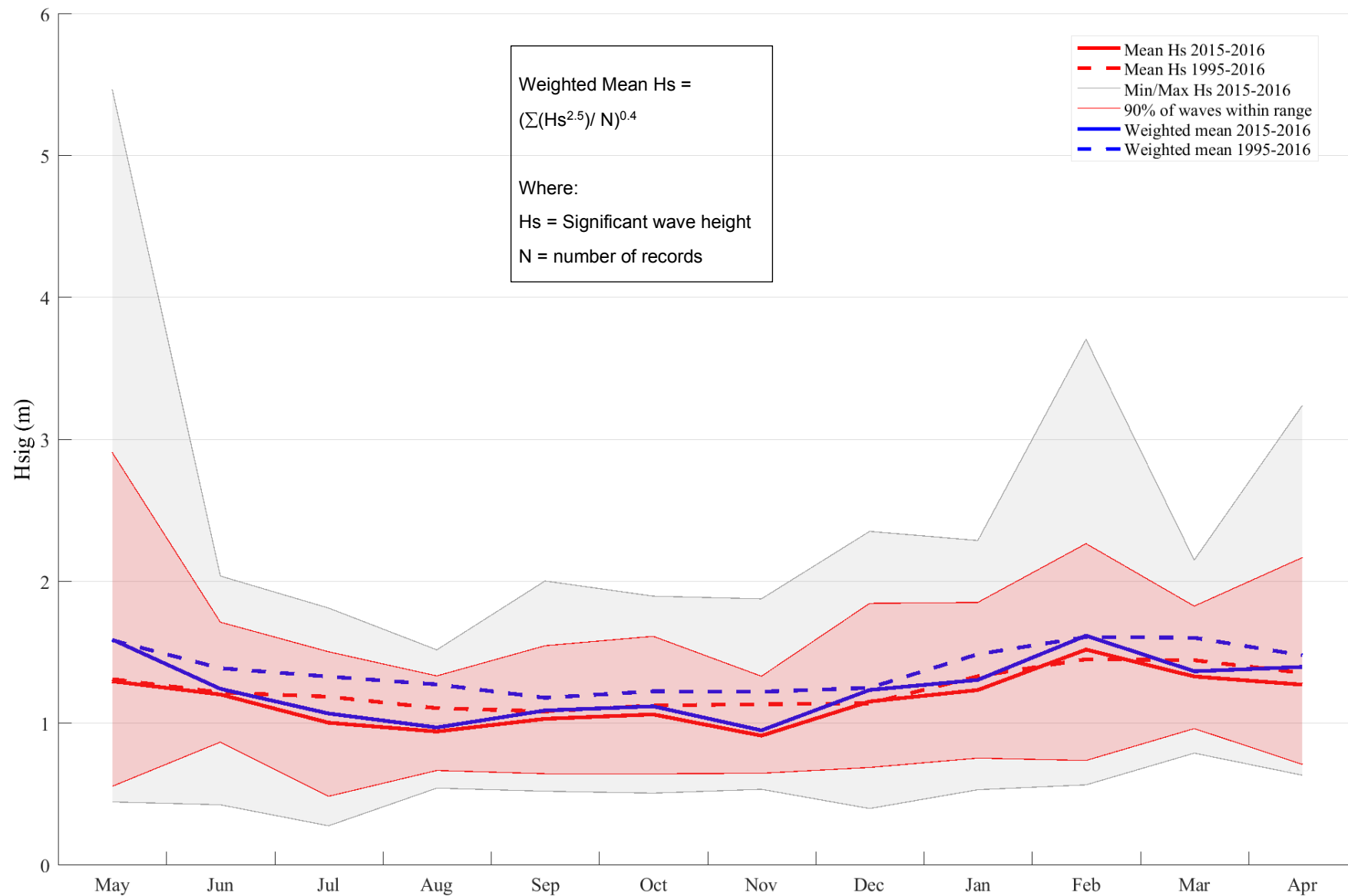


Figure 3.4: Tweed region – Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

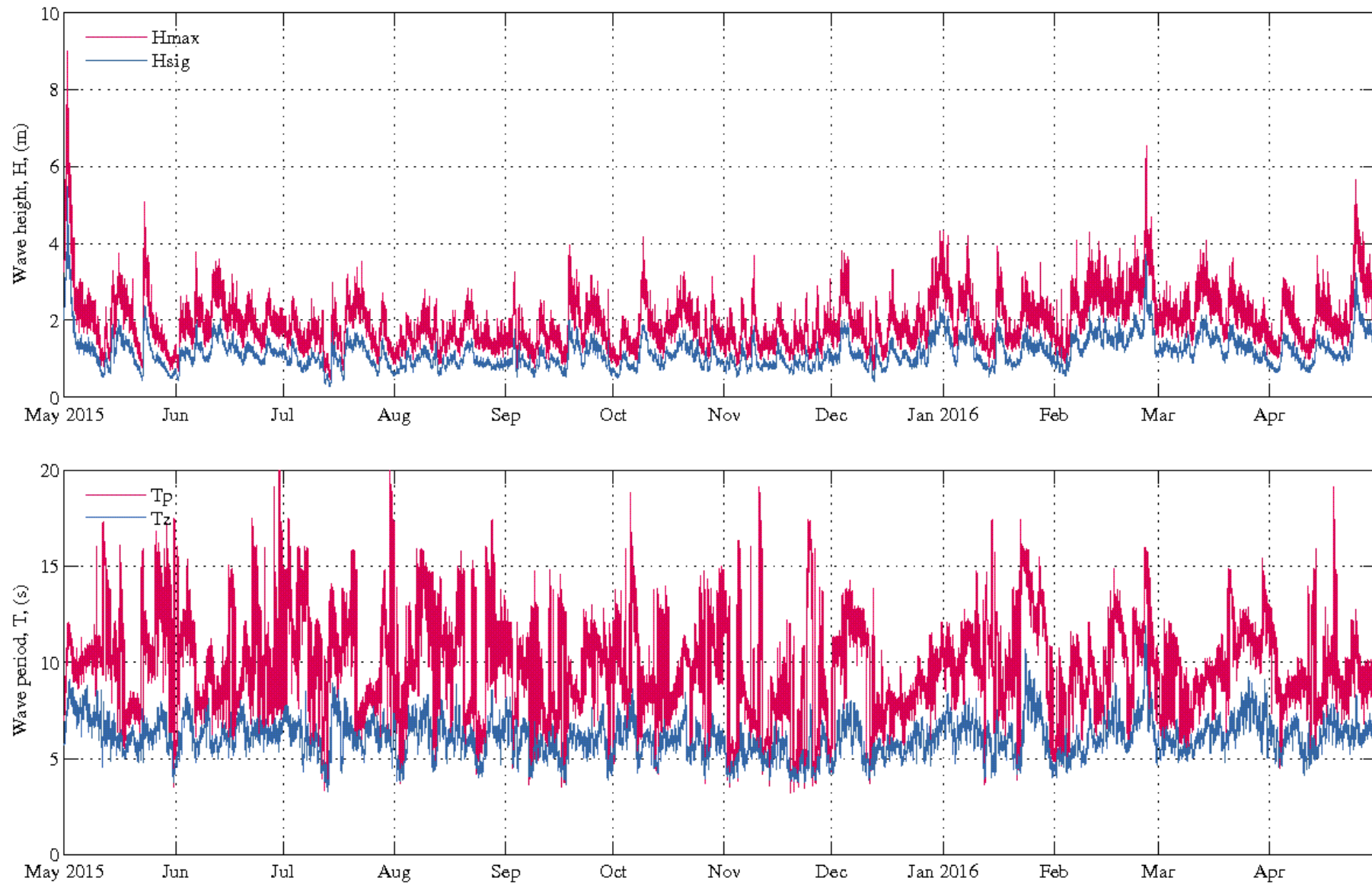


**Figure 3.5: Tweed region – Histogram percentage (of time) occurrence of wave periods ( $T_p$ ) for all wave heights ( $H_{sig}$ )**



**Figure 3.6: Tweed region – Plot of monthly averages for seasonal year and for all data, for wave heights (Hs). The weighted mean Hs provides an indicative potential for sediment transport.**



**Figure 3.7: Tweed region – Daily wave recordings**

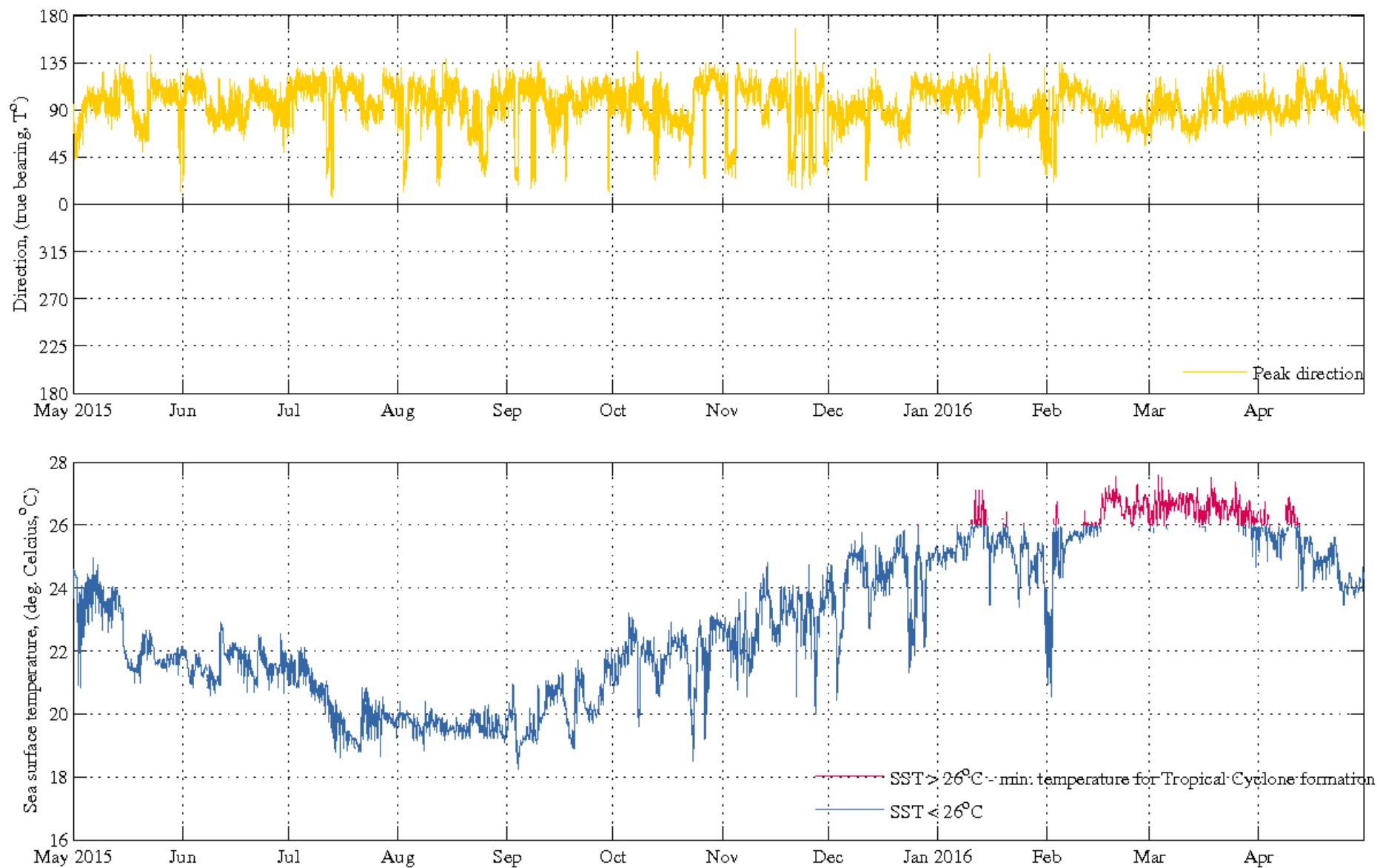


Figure 3.8: Tweed region – Sea surface temperature and peak wave directions

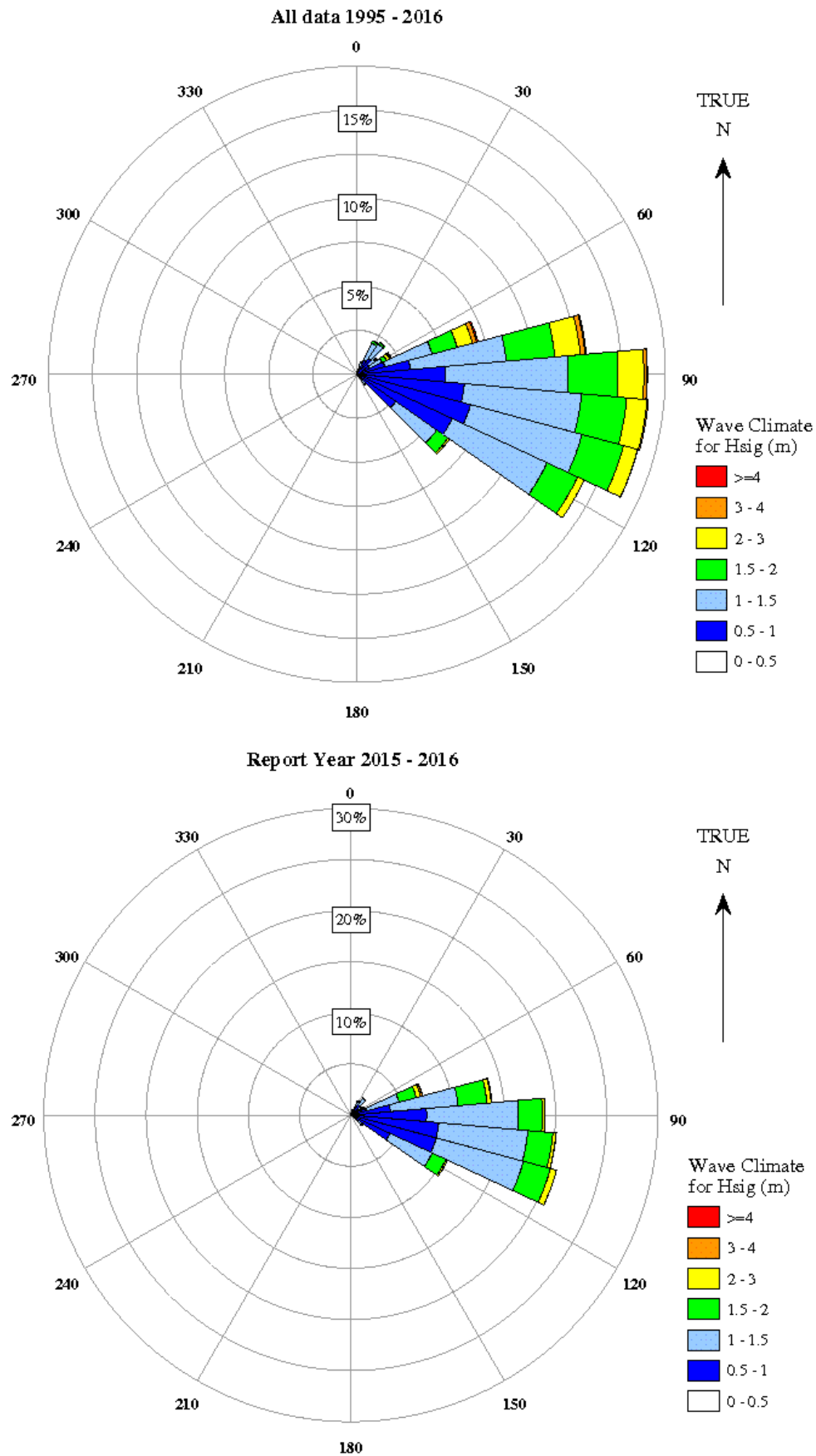


Figure 3.9: Tweed region – Directional wave rose

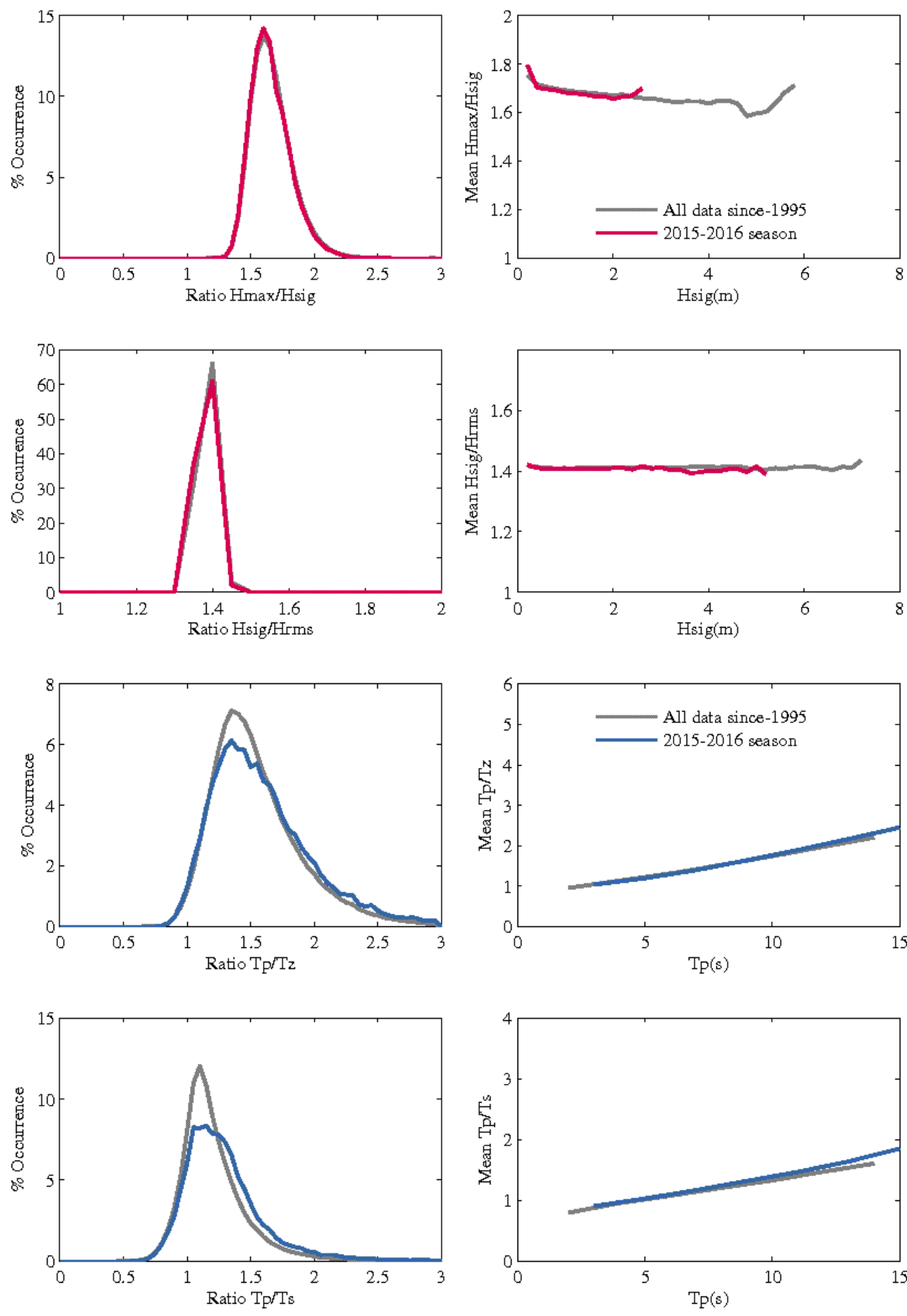


Figure 3.10: Tweed region – Wave parameter relationships

## 4. Brisbane

### Brisbane

#### Wave recording station

##### Details of data collected

##### 2015-2016 season

Maximum possible analysis days (last record - first record)	= 365.98
Total number of days used in analysis	= 363.85
Gaps in data used in analysis (days)	= 2.13
Number of records used in analysis	= 17465

##### All data since-1976

Maximum possible analysis years (last record - first record)	= 39.50
Total number of years used in analysis	= 27.78
Gaps in data used in analysis (years)	= 11.71
Number of records used in analysis	= 345823

**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

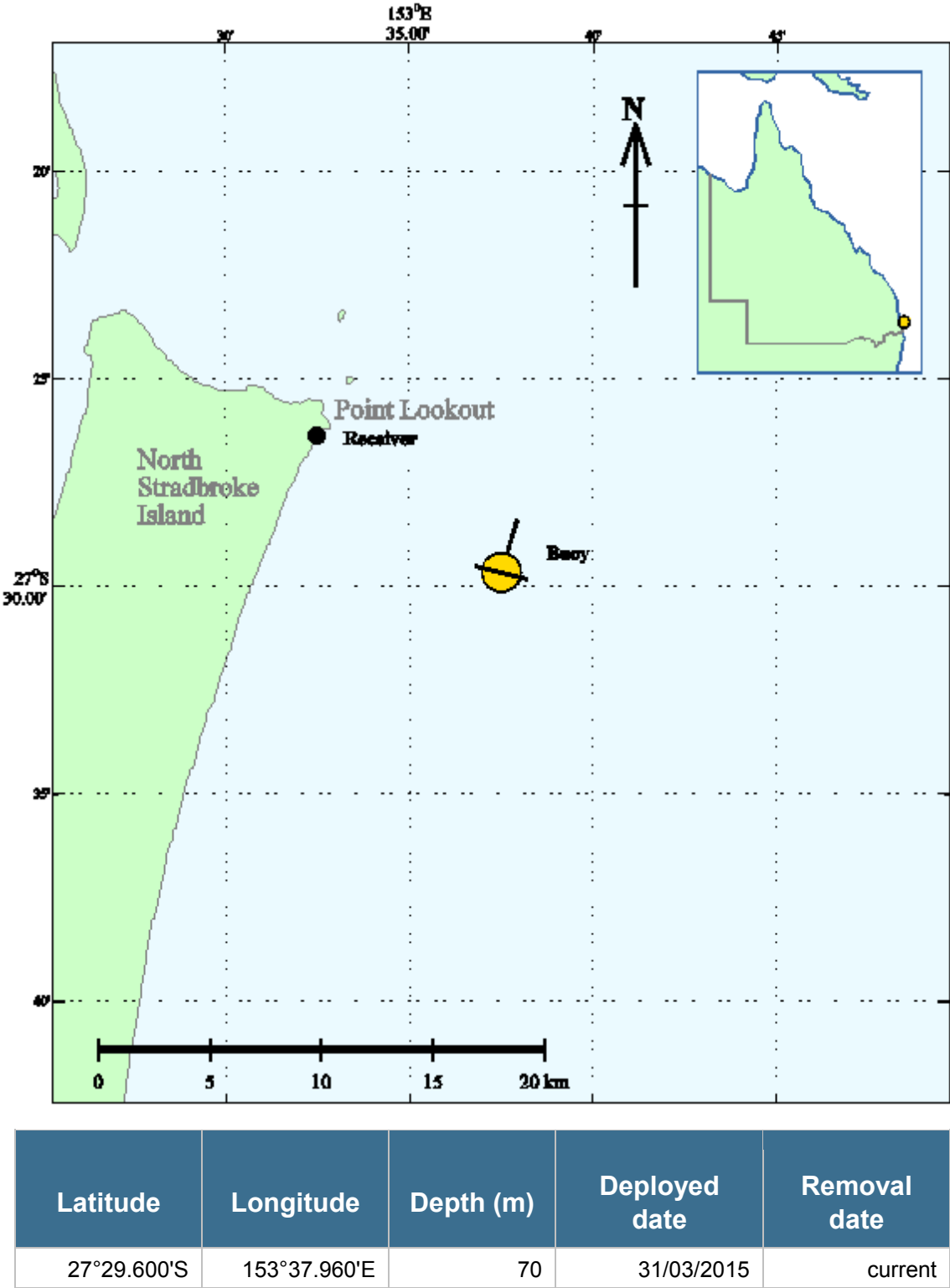


Figure 4.1: Brisbane region – Locality plan

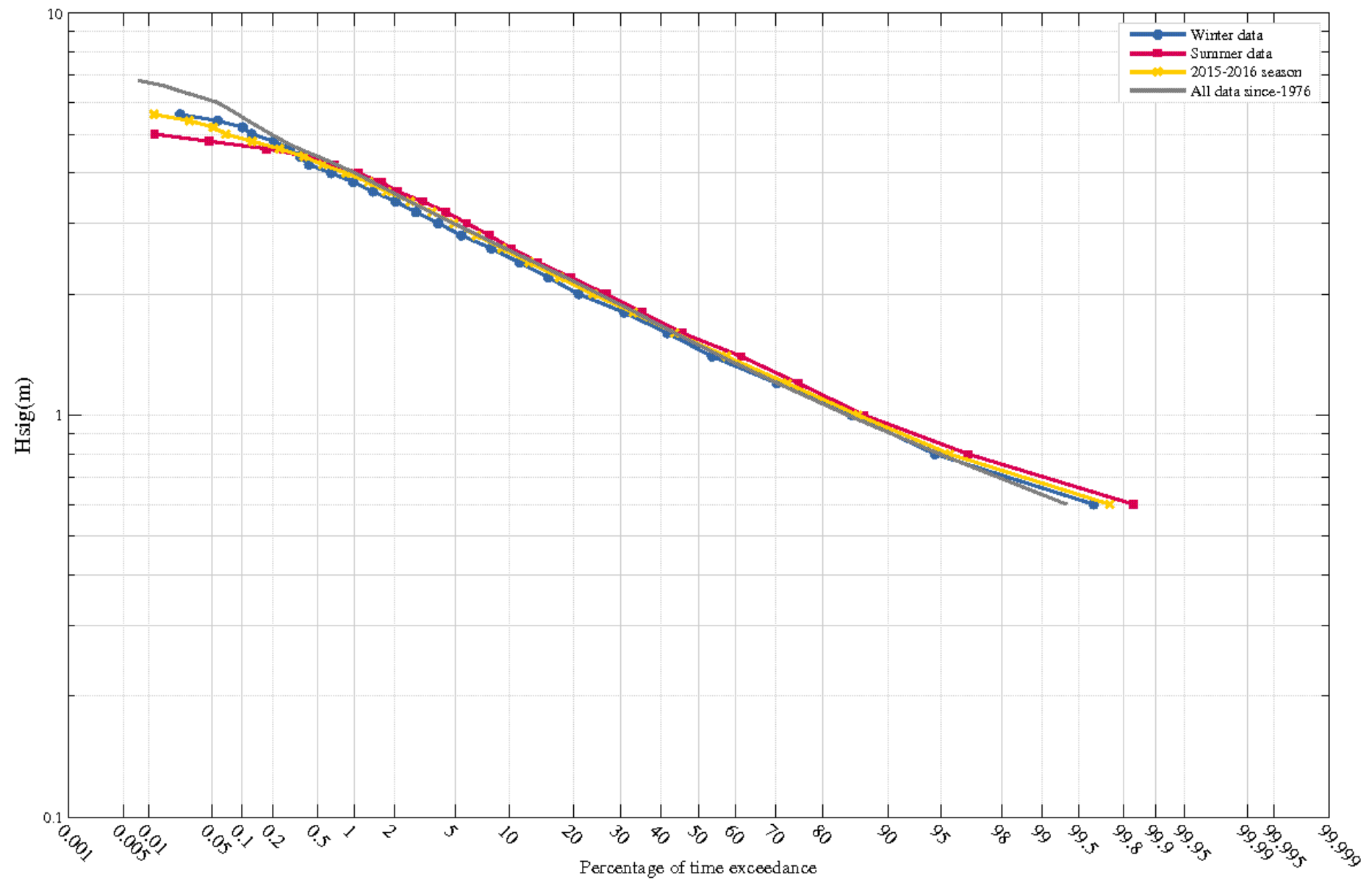


Figure 4.2: Brisbane region – Percentage (of time) exceedance of wave heights ( $H_{sig}$ ) for all wave periods ( $T_p$ )

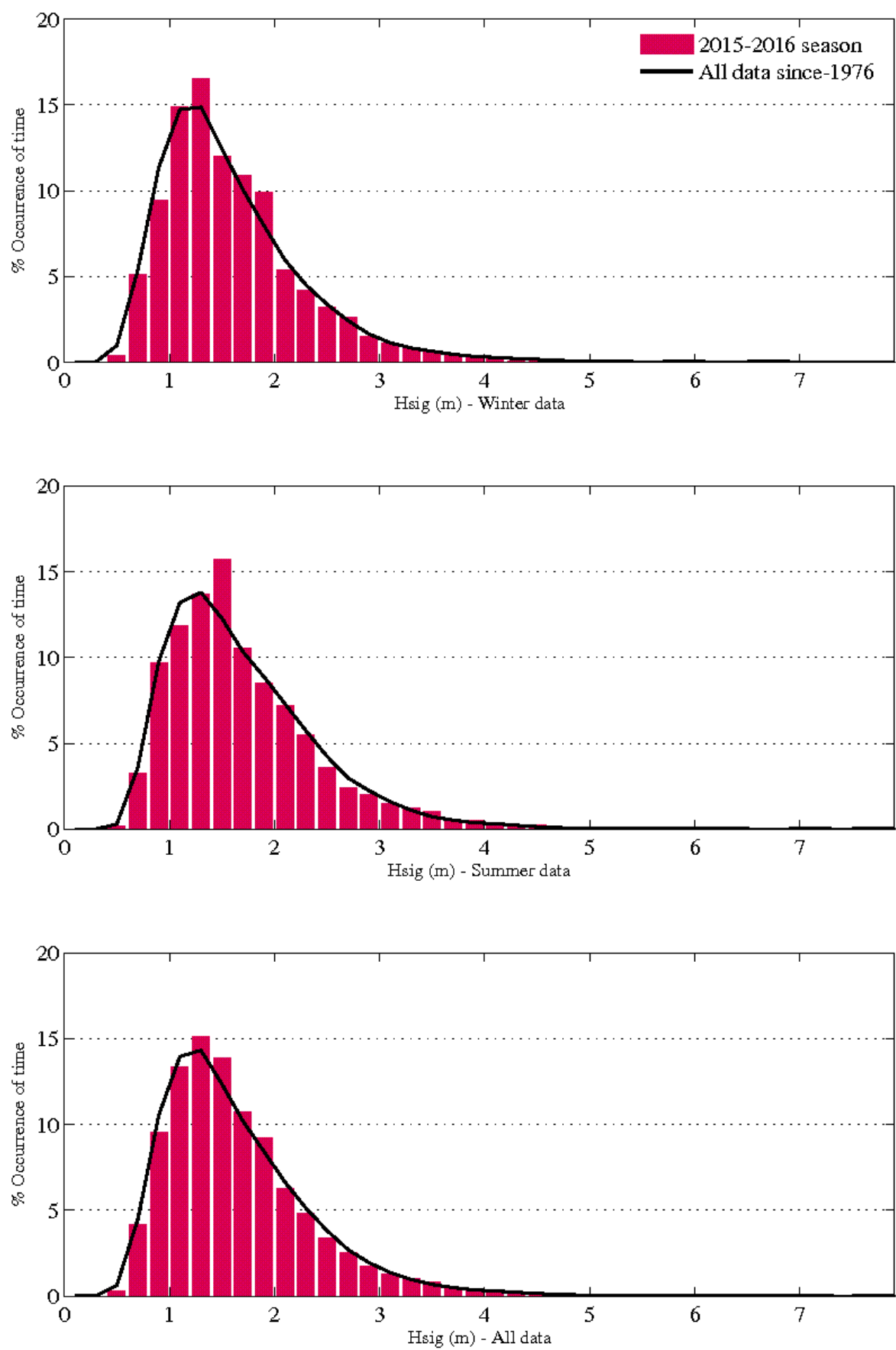
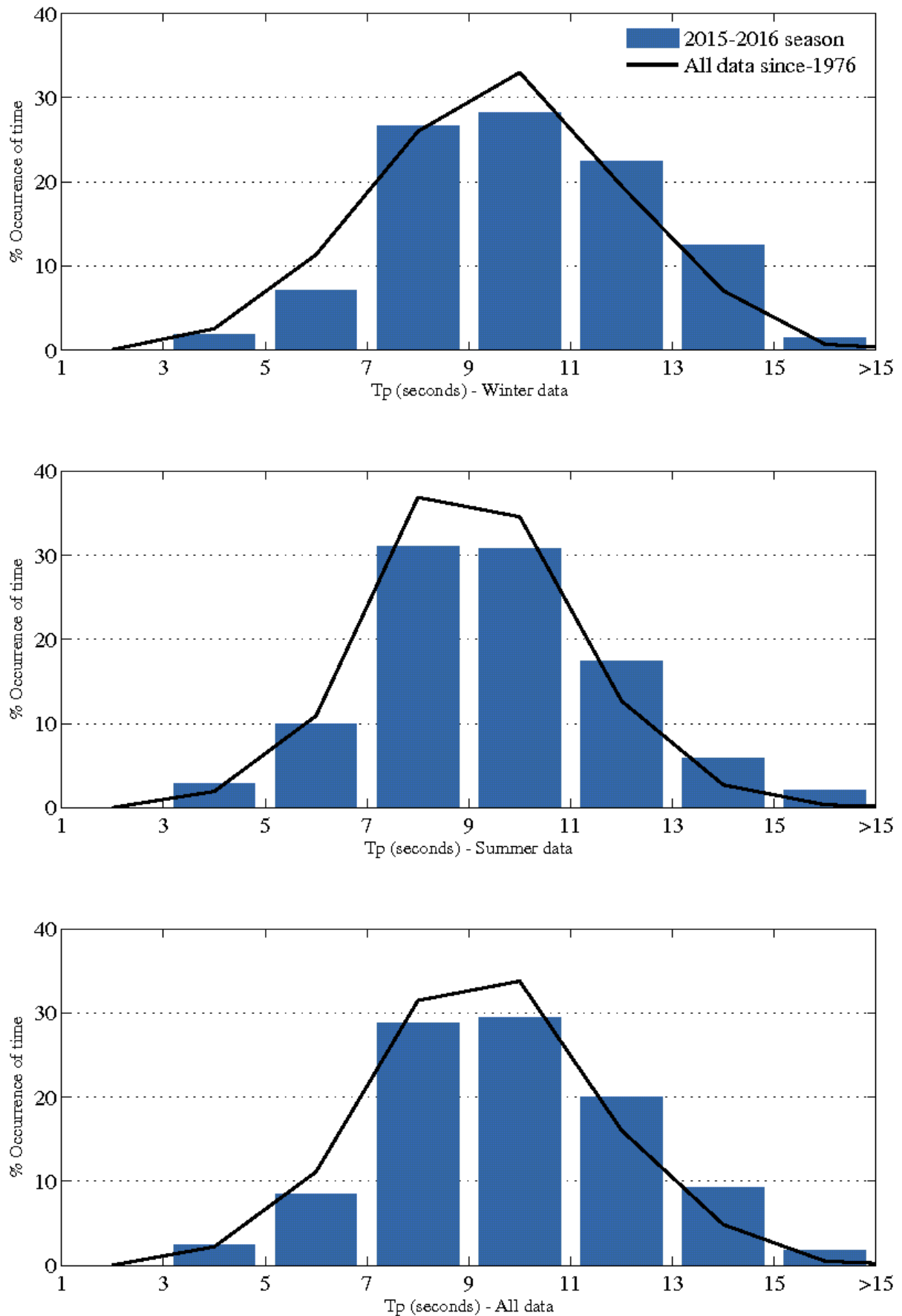
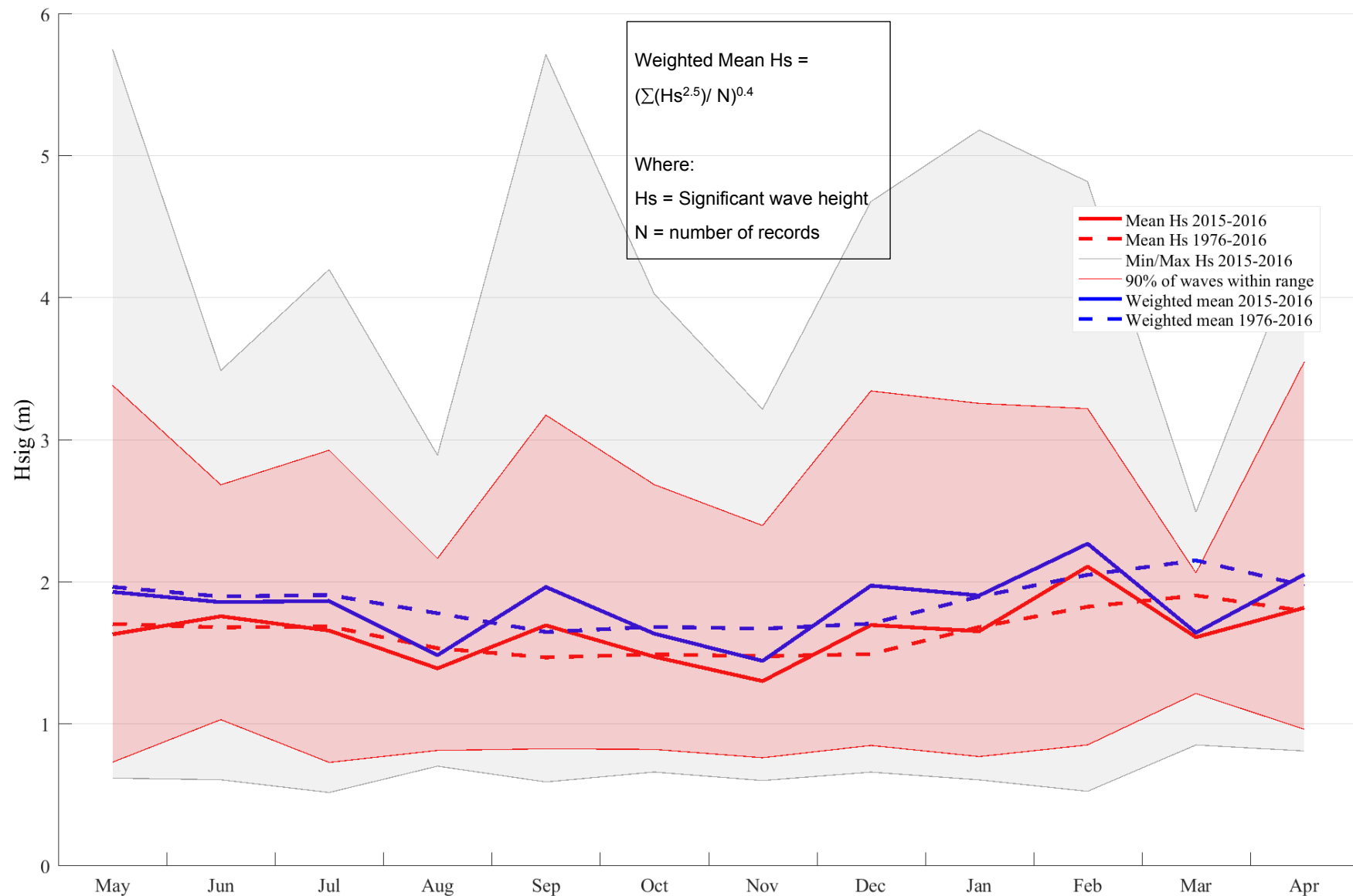


Figure 4.3: Brisbane region – Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)





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



**Figure 4.5: Brisbane region – Plot of monthly averages for seasonal year and for all data, for wave heights (Hs). The weighted mean Hs provides an indicative potential for sediment transport.**

**Figure 4.6: Brisbane region – Daily wave recordings**

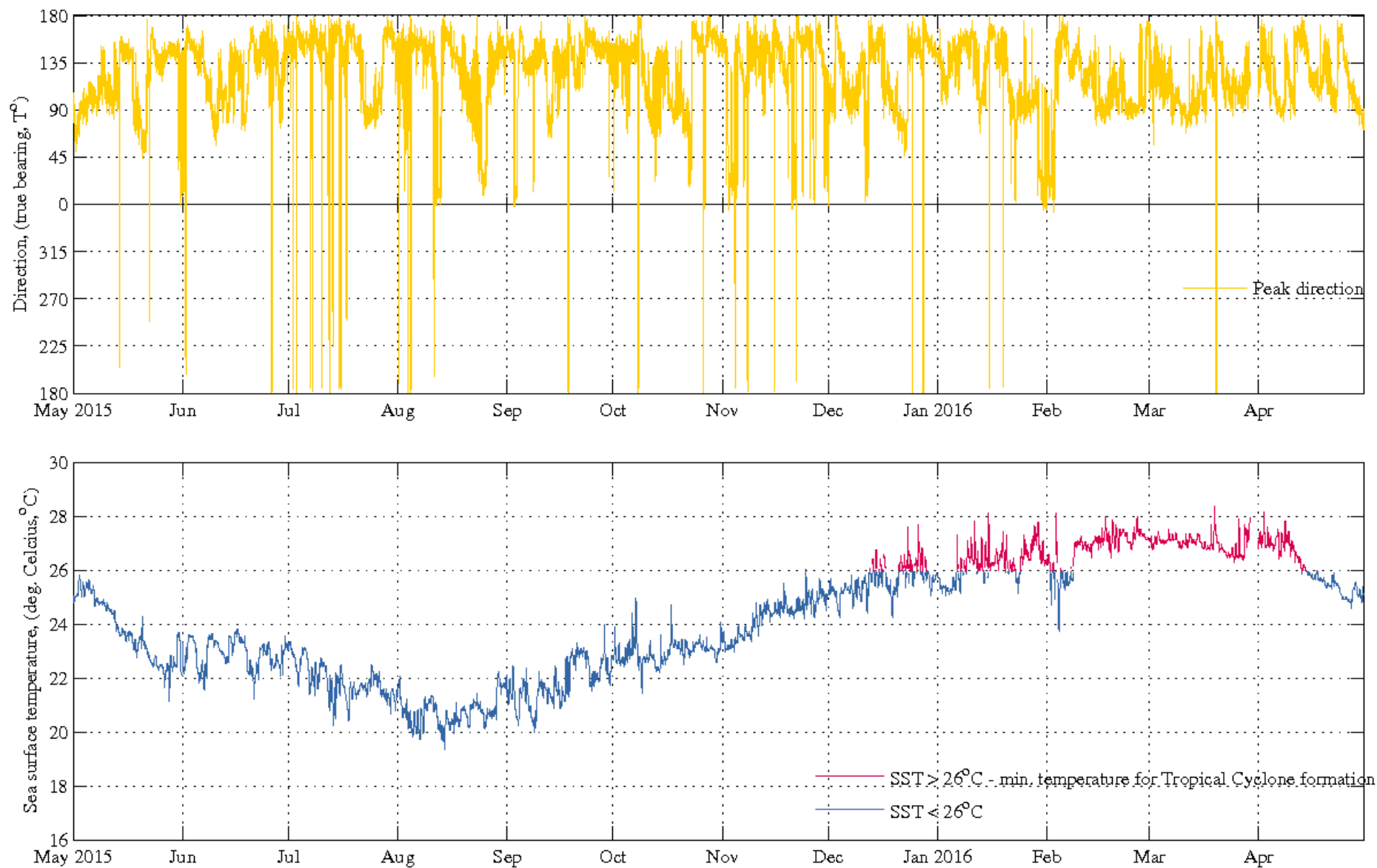


Figure 4.7: Brisbane region – Sea surface temperature and peak wave directions

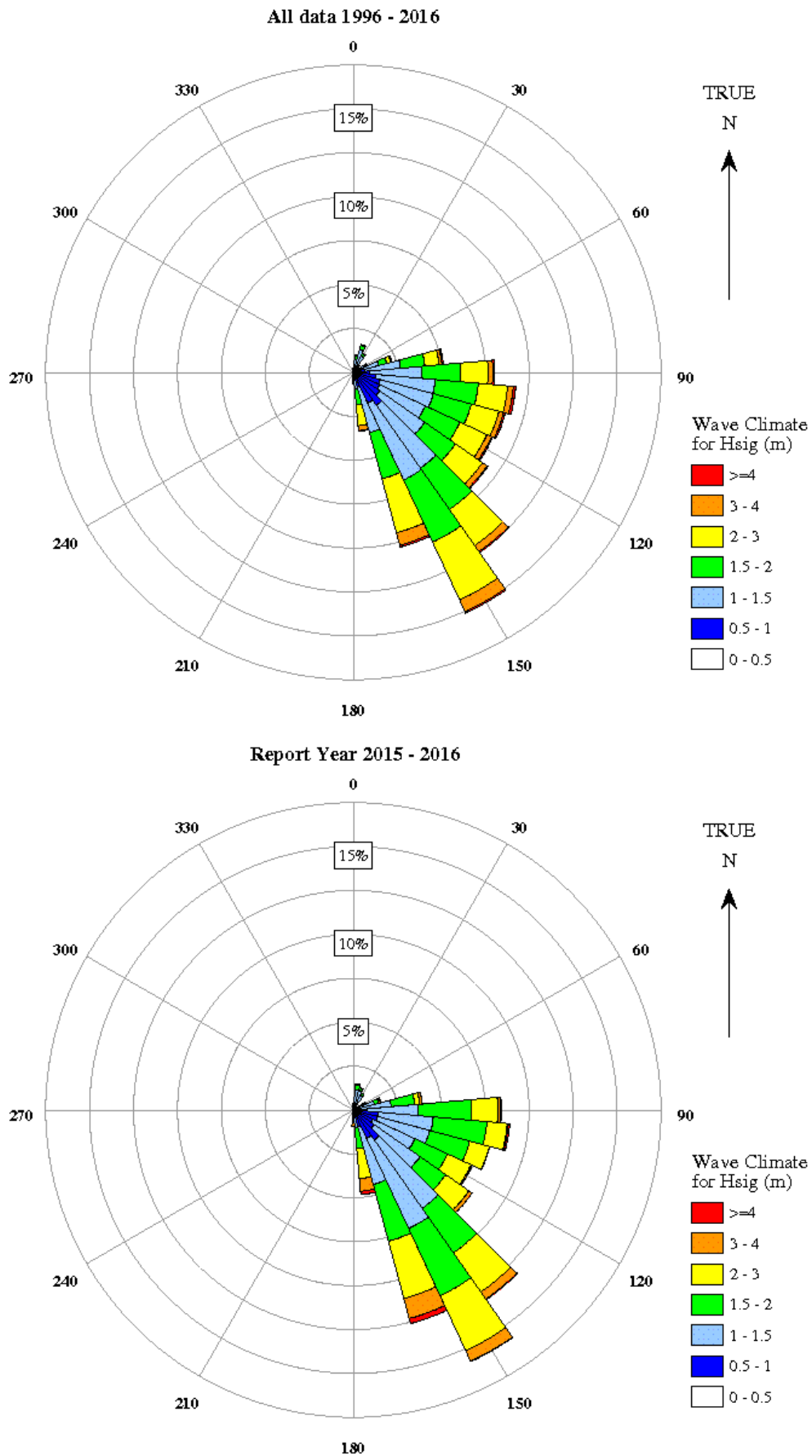


Figure 4.8: Brisbane region – Directional wave rose

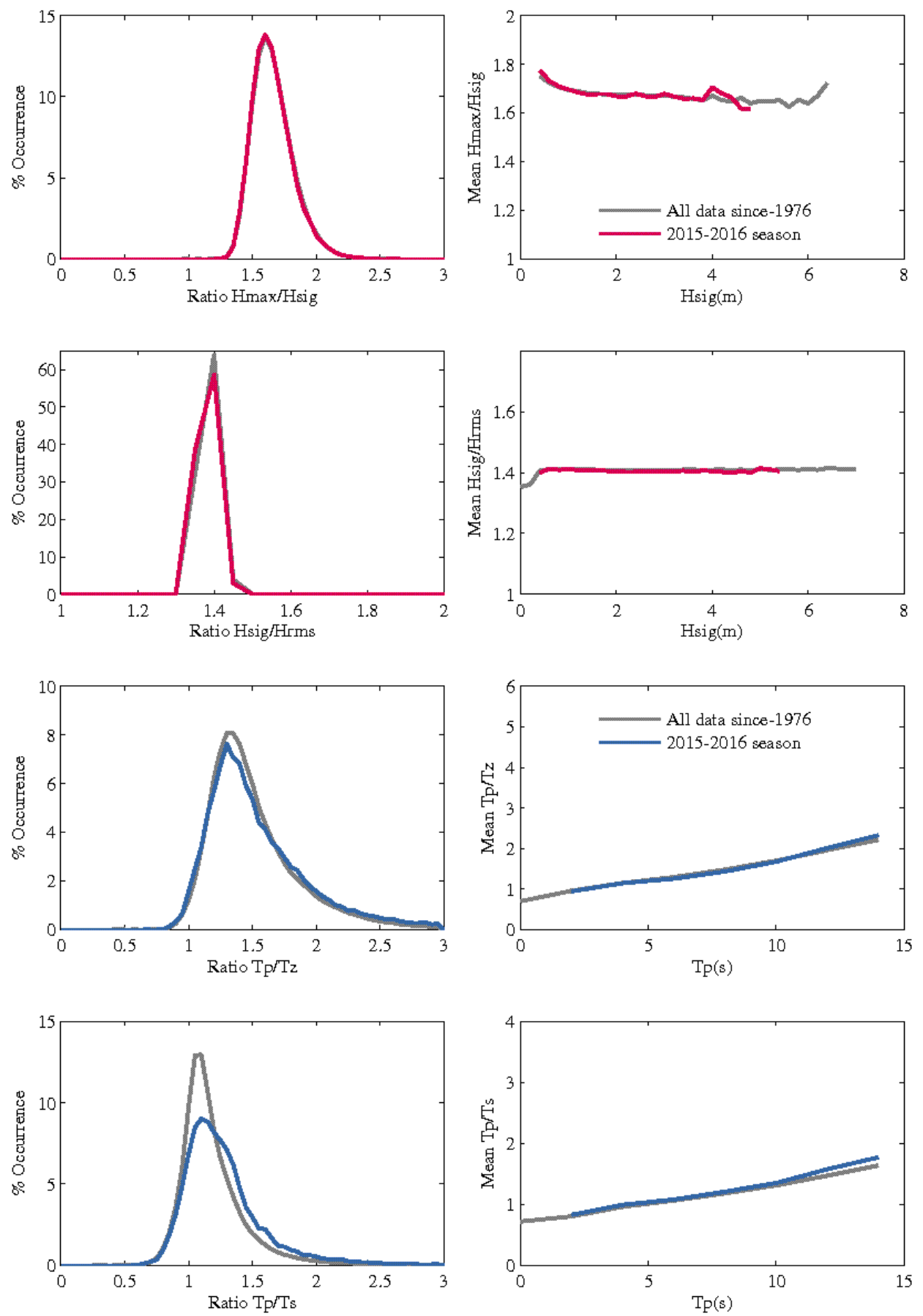


Figure 4.9: Brisbane region – Wave parameter relationships

## 5. References

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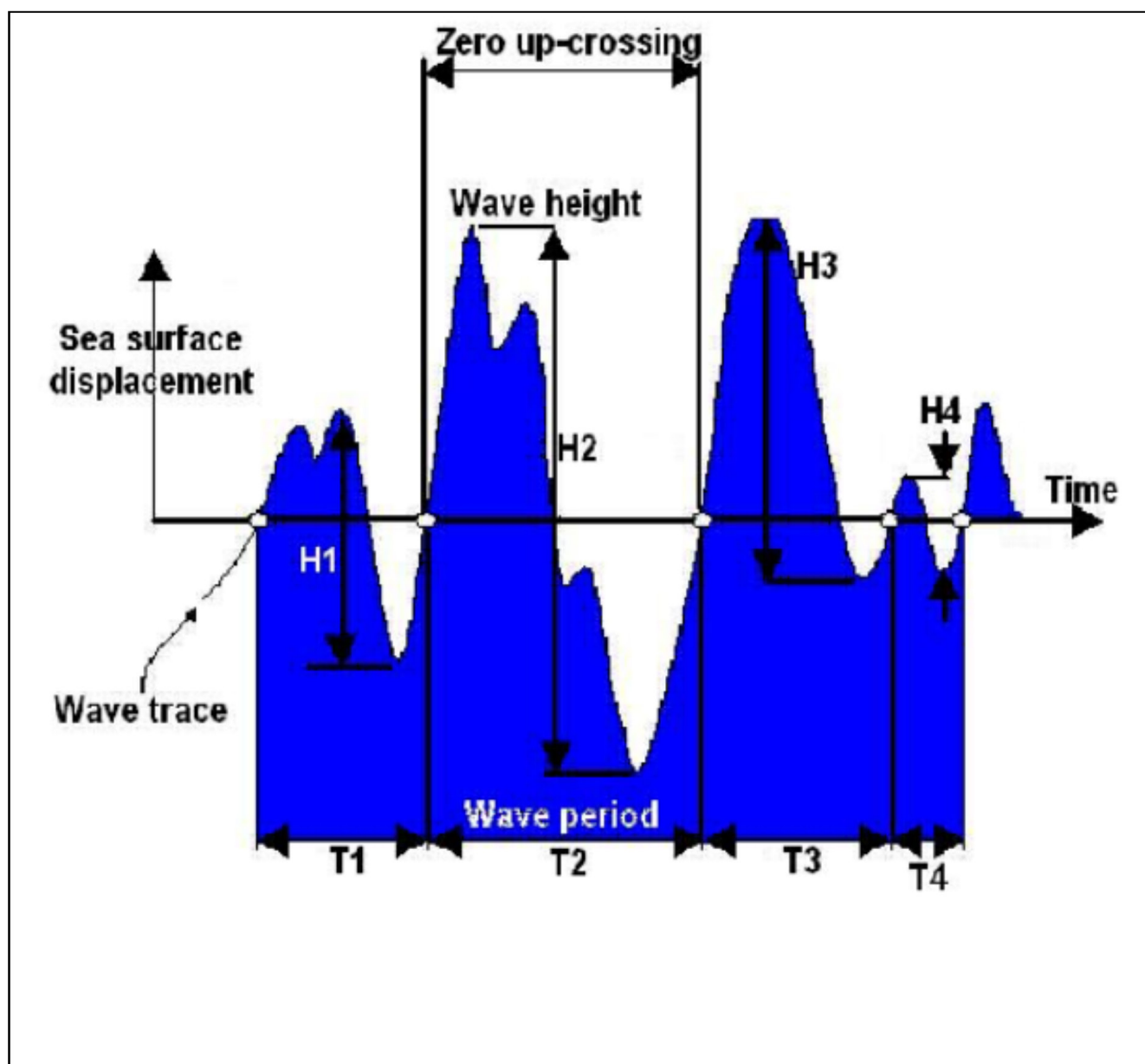
## Appendix A – Zero up-crossing analysis

### Zero crossing analysis

A direct, repeatable, and widely accepted method to extract representative statistics from wave data recorded by a wave measuring buoy. For zero up-crossing (used by DSIT1), 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 percent 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 ° 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