Department of Environment and Science

Queensland Wave Climate

Wave Monitoring Annual Summary

November 2017 – October 2018

Queensland Government

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

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April 2021

Front page picture: Gold Coast 15-09-2017; Source: DES-QGHL

Contents

List of Tables

List of Figures

Executive Summary

This summary of wave climate in Queensland is prepared annually by the Queensland Government Hydraulic Laboratory (QGHL) of the Department of Environment and Science (DES) (known formerly as the Department of Science, Information Technology and Innovation (DSITI)). Annual wave reports supplement the reporting ability of the QGHL by providing information on wave climates in Queensland. The information presented here summarises the primary analyses of wave data recorded using Datawell Waverider buoys positioned off the Queensland coastline from November 1 2017 to October 31 2018.

The wave monitoring program utilises the Waverider system, manufactured by Datawell of the Netherlands, to measure the sea surface fluctuations at each offshore location. Directional Waverider buoys are operated at all sites, except Bundaberg, where a non-directional Waverider buoy is deployed. The directional buoys also record temperature in the bottom of the hull; the temperature record is called Sea Surface Temperature (SST) in this report.

For all stations, the wave data have been statistically compared to the long-term average conditions at each site. Also provided are brief details of the recording equipment, the methods of handling raw data, quality checks and the type of analyses employed.

The data covers all of the seasonal variations for one year, and includes the 2017–18 cyclone season, which extended from November 1 through to April 30. This period is also classified as summer while the remainder of the year 01 May to 31 October is classified as winter in these reports.

Cyclone season 2017 – 2018 experienced a number of small events and Tropical Cyclones that predominantly stayed well off the East Coast of Australia. TC Iris and TC Linda had the greatest effect on the Queensland coastline, causing dangerous surf conditions and high winds. The information on severe weather periods and TC's was obtained from the Bureau of Meteorology database.

Introduction

This summary of wave climate in Queensland is one of a series of technical wave reports prepared annually by the Queensland Government Hydraulic Laboratory of the Department of Environment and Science (DES). Annual wave reports supplement the reporting ability of DES's QGHL by providing information on wave climates in Queensland. The information presented here summarises the primary analyses of wave data recorded using Datawell Waverider buoys: DWR-MkIII, DWR-G and DWR4 positioned off the Queensland coastline from November 2017 to October 2018.

The data covers all of the seasonal variations for one year, and includes the 2017–18 cyclone season, which extends from 01 November through to 30 April. This period is also classed as 'summer' while the remainder of the year (May to October) is classed as 'winter' in these reports. For all stations, the wave data collected for the current year is statistically compared to the long-term average conditions at the site. Brief details of the recording equipment, the methods of handling raw data and the type of analyses employed are provided within this report.

Wave monitoring sites

As part of its long-term data collection program, DES has maintained a network of wave recording stations along the Queensland coast since 1968.

The network of wave recording stations is grouped into two categories:

Long-term sites: These core sites provide long-term wave climate along the Queensland coast for coastal and disaster management purposes. The stations are fully funded and operated by DES.

Partnership sites: The operation of these sites will vary in duration, and they are associated with specific projects to assess wave conditions or to manage maritime activities. These stations are operated by DES in conjunction with, and jointly funded by, partner agencies.

Table 1 Wave monitoring stations November 2017 to October 2018

Long-term	Joint project	Joint project partners
Brisbane	Tweed Heads	Tweed River Entrance Sand Bypassing Project and City of Gold Coast
Bundaberg	Gold Coast	City of Gold Coast
Emu Park	Palm Beach	The City of Gold Coast
Mackay	Caloundra	Port of Brisbane Pty Ltd
Townsville	North Moreton	Port of Brisbane Pty Ltd
Cairns	Mooloolaba	Department of Transport and Main Roads
	Gladstone	Gladstone Ports Corporation
	Hay Point	North Queensland Bulk Ports Corp Ltd
	Abbot Point	North Queensland Bulk Ports Corp Ltd
	Weipa	North Queensland Bulk Ports Corp Ltd

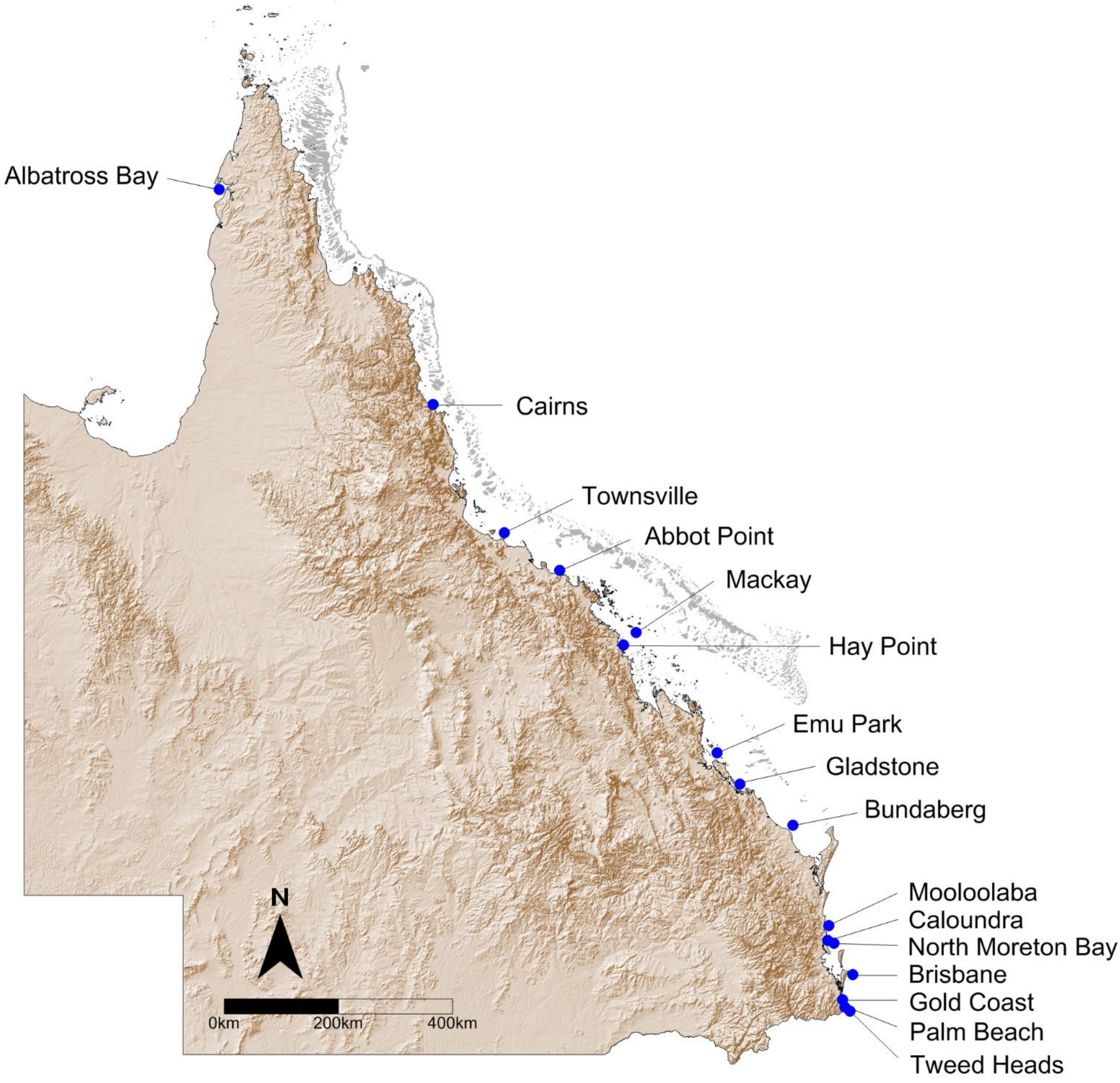


Figure 1 DES wave monitoring sites in Queensland

Table 2 Wave monitoring history: some early (starting 1968) short-term records from the Gold Coast region not listed.

Site	Start date	End date	Restart	Directional start date	Total years	Directional years
Tweed Heads	13/01/1995	-	-	13/01/1995	23.8	22.8
Palm Beach	06/06/2017	-	-	06/06/2017	1.4	1.42
Gold Coast	21/03/1987	-	-	17/07/2007	31.6	11.3
Brisbane	31/10/1976	-	-	20/01/1997	42	22.8
North Moreton Bay	08/03/2010	-	-	08/03/2010	8.7	8.7
Caloundra	01/05/2013	-	-	01/05/2013	5.5	5.5
Mooloolaba	20/04/2000	-	-	11/05/2005	18.5	13.4
Bundaberg	08/09/2015	-	-	08/09/2015	3.1	3.1
Gladstone	23/09/2009	-	-	23/09/2009	9.1	9.1
Emu Park	24/07/1996	-	-	24/07/1996	22.3	22.3
Hay Point	24/04/1977	25/05/1987	3/04/1993	31/10/2009	35.7	9.0
Mackay	19/09/1975	-	-	13/03/2002	42.1	16.6
Abbot Point	17/01/2012	-	-	17/01/2012	6.8	6.8
Townsville	20/11/1975	-	-	29/10/2008	43.1	10
Cairns	04/05/1975	-	-	26/02/2016	43.5	2.7
Albatross Bay (Weipa)	22/12/1978	-	-	25/11/2008	40.9	10.9

Wave monitoring equipment

For the monitoring period documented in this summary report the wave monitoring program utilised the Waverider buoy system manufactured by Datawell of the Netherlands to measure the sea surface fluctuations at coastal locations. Directional Waverider buoys were in operation at all sites except Bundaberg during the period of this report.

Accelerometer Buoy: DWR-MkIII

The DWR MkIII 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.

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 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).

Accelerometer Buoy: SG non-directional

The non-directional Waverider buoy SG at Bundaberg measures in the same way as the DWR MkIII, but without wave direction and sea surface temperature segments.

Accelerometer Buoy: DWR4

The newest addition to the fleet is a Datawell next generation directional Waverider called DWR MK4 The DWR4 has an increased sampling frequency which is a significant increase in resolution (CIU, 2017). This improvement is achieved by increasing heave measurements from the accelerometer to 12bit floating point notation. This is a significant improvement compared to the DWR MkIII and DWR-G buoys and ultimately will give a more accurate heave measurement due to the increased frequency of the DWR4, as explained in DSITI (2018).

The spectral scheme is calculated by the overlapping segmented (50% overlap) Welch' method combined with the more commonly used Hann window. The overlapping segments and segment averaging ensure a smoother spectra.

The DWR4 includes a surface current meter which uses three acoustic transducers in the hull of the buoy (Datawell 2017). The current is determined at roughly one metre water depth, by measuring the Doppler Shift of reflected 2 MHz pings. Every 10 minutes, the magnitude and direction of the surface current are measured. The transducers all face 30 degrees down and are 120 degrees laterally apart and each transducer measures the projection of the current velocity along its axis.

GPS Buoys

The directional Waverider buoys DWR-G at the Tweed Heads, North Moreton Bay, Caloundra, Mooloolaba, Hay Point, and Albatross Bay (Weipa) sites use the GPS satellite system to calculate the velocity of the buoy as it moves with the passing waves. The GPS based Waverider calculates velocity 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 2, which shows a satellite directly overhead and a satellite at the horizon. In practice the DWR-G system uses signals from several satellites to determine three-dimensional buoy motion.

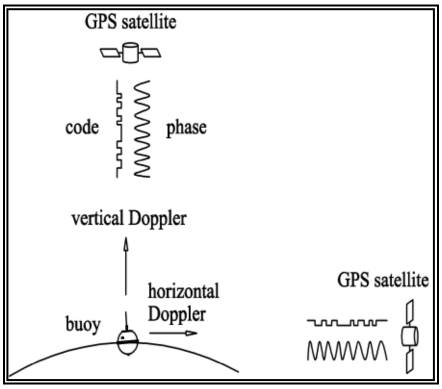


Figure 2 The GPS wave measurement principle (Datawell, 2010)

Data collection

At all wave sites, the vertical buoy displacement representing the instantaneous water level and calculated directional data are transmitted to a receiver station as a frequency modulated high-frequency (hf) radio signal. The directional Waverider receiver stations on shore are each comprised of a computer system connected to a Datawell receiver/digitiser. The water level data at each site is digitised at 0.78 second intervals (1.28 Hz) and stored in bursts of 2,048 points (approximately 26 minutes.

The 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. Data outputs are downloaded every hour to a central computer system in Brisbane for checking, further processing, and archiving. Data are also stored on-board each buoy as a data backup should communication of data to the receiver station fail.

Quality checks

Waverider buoys used by the 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 (2017b) 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.

Data losses

Data losses can be divided into two categories:

1. Losses due to equipment failure.
2. Losses during data processing from 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. The various sources of data loss 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.

Data analysis

The computer-based, wave-recording systems at all sites record data at 30-minute intervals. Raw data transmitted from the buoys are 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 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. Temperature is also recorded with an internal sensor imbedded in the hull of the buoy, this data is reported as Sea Surface Temperature (SST) every 30 minutes. The zero up-crossing analysis is equivalent in both the accelerometer and GPS systems. Wave parameters in this report from the time and frequency domain analysis include the following:

Table 3 Parameters involved in the analysis

Parameter	Description
S(f)	Energy density spectrum (frequency domain)
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)
Dir	The direction (frequency domain) from which the peak period waves (Tp) are coming (in ° True)
SST	Sea surface temperature (in ° Celsius) sensor mounted inside the buoy.

These parameters form the basis for the summary plots and tables included in this report and provide the basic parameters used for coastal engineering and disaster management purposes.

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.

Major Meteorological events

Two major meteorological events occurred during the record period and recorded waves that ranked amongst the top ten highest waves.

On March 11 2018 a tropical low formed in the Coral Sea and tracked south towards the Queensland coast developing into Tropical Cyclone Linda on the 13th of March 2018. TC Linda weakened to a low-pressure system on the 14th and weakened off the south-east Queensland coast by March 16. TC Iris formed shortly after and entered Australian waters on March 24, Iris weakened to a low-pressure system on March 25 and redeveloped again on April 2 before weakening on April 6.

Table 4 Tropical Cyclones in the Queensland region during the 2017–2018 season

Name	Start Time (AEDT)	End Time (AEDT)	Category	Central Pressure (hPa)
Linda	11/03/2018 04:00 pm	16/03/2018 04:00 pm	1	994
Iris	20/03/2018 04:00 am	09/04/2018 04:00 pm	2	1002

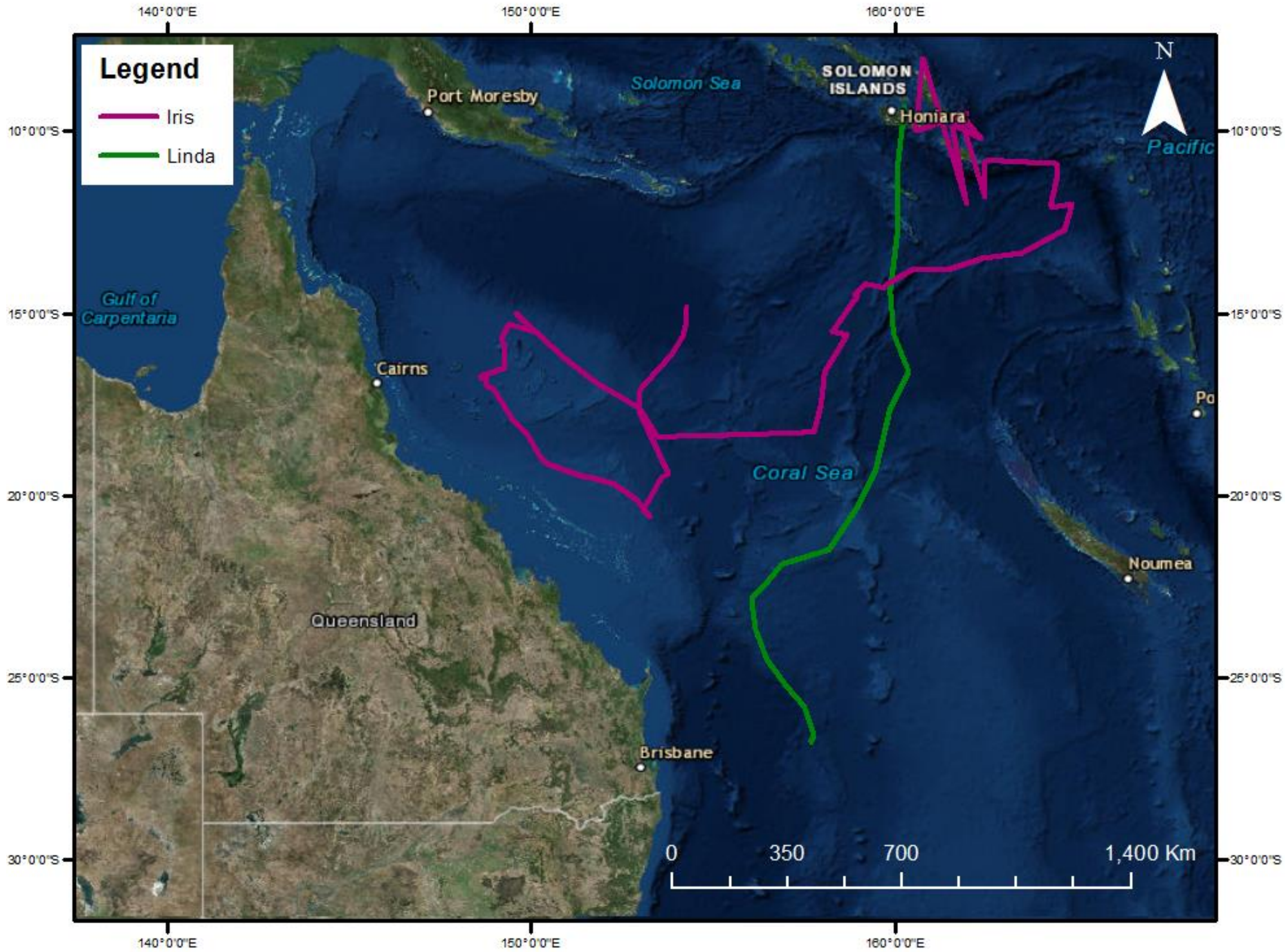


Figure 3 Tropical cyclones affecting Queensland coastline during the 2017- 2018 season

Queensland wave climate

Tweed Heads

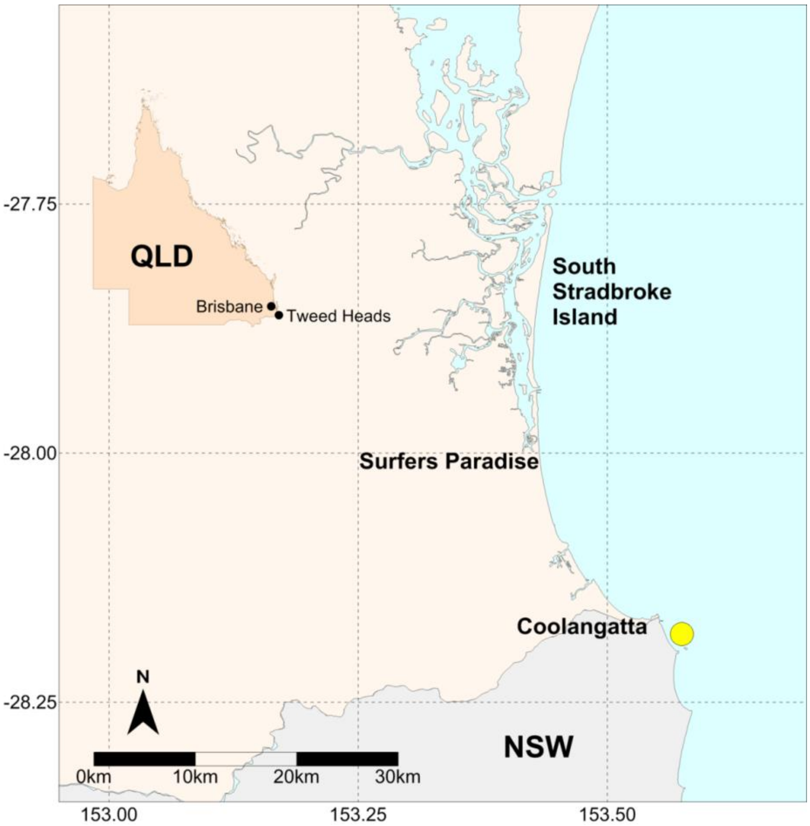


Figure 4 Tweed Heads – Locality plan

Table 5 Tweed Heads – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	13/01/1995	0.34 (years)	360,250	23.8
2017-18	01/11/2017	9.19 (days)	17,078	1

Table 6 Tweed Heads – buoy deployments during the 2017–18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
28°10.664' S	153°34.590' E	DWR-GPS	24	17/04/2016	03/07/2018
28° 10.700' S	153° 34.519' E	DWR-GPS	25	03/07/2018	29/06/2018
28° 10.715' S	153° 34.635' E	DWR-GPS	25	29/06/2018	current
28° 10.575' S	153° 34.590' E	DWR4	25	06/06/2017	current

Tweed Heads – seasonal overview

The Tweed Heads wave monitoring site has been operational for nearly 24 years with data return of 98.6 per cent. The data return over November 2017 to October 2018 was good, with gaps of 9.19 days equivalent to 97.5 per cent data return, the buoy was replaced twice during the report period (Table 6).

The Tweed Heads GPS wave buoy was exposed to eight significant events during the reporting period. The event that generated the largest wave conditions occurred on October 15 2017 (Table 8), with a significant wave height (H_s) of 4.5 m and a maximum wave height (Hmax) of 7.8 metres. The highest waves during this period didn't make it to the top ten highest waves at Tweed Heads (Table 7).

The Tweed Heads site currently has two wave buoy's deployed, in order to analyse and compare differences between the DWR-G and DWR4 (DES, 2018). For the purpose of this report only the data from the DWR-G has been analysed, as both buoys are considered comparable. See Appendix B for a comprehensive analysis of the differences between the DWR-G and DWR4 at Tweed Heads.

The temperature (sea surface temperature, SST) measured in the buoy hull ranged from 18 °C to 28 °C (Figure 6). The SST from mid-January through to the start of April was predominantly warm enough for tropical cyclone development, with periodic warm swings in December and early January.

The monthly average H_s (Figure 7) generally fell within one standard deviation (sd) of the long term mean. except during November and October where the average H_s was above 1 sd and July and August where the mean was below 1 sd.

H_s throughout the 2017-2018 period was generally consistent with historic data, with a slightly lower occurrence in wave heights greater than 4 m (Figure 8). The summer months experienced higher waves more frequently than winter when H_s was below 2 m, while winter showed slightly higher wave heights than summer when H_s was over 2 m. Histograms of the occurrence of H_s (Figure 9) indicate a higher occurrence of waves 0.8 - 1.0 m during winter, while during summer there was a lower occurrence of waves between 0.8 -1.2 m. Histograms of the occurrence of Tp (Figure 10) show a very similar distribution between the reporting period and historic data with the most frequently occurring Tp ranging from 9 to 11 seconds. The winter period shows that Tp between 9 -11 seconds is higher than that of the historic data.

The ratios between different wave parameters such as Hmax/ H_s were generally consistent between this reporting period and all of the historic data, these are plotted in Figure 11. The ratio of Tp/Tz and Tp/Ts shows a lower kurtosis for this period compared to the entire record.

The plot of wave direction (Figure 6) show dominant easterly wave directions with infrequent swings to the north-northeast. The dominance of east to east-southeast incident wave direction is reflected in the directional wave rose plot (Figure 12) with the most common H_s of 1.0 to 1.5 metres.

Table 7 Tweed Heads – highest waves

Rank	Date (H_s)	H_s (m)	Date (H_{max})	H_{max} (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	9.7

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

Table 8 Tweed Heads – significant meteorological events with threshold H_s of 2.4 metres

Date	H_s (m)	Hmax (m)	Tp (s)	Event
5/12/2017 19:00	2.4 (2.6)	4.1 (4.6)	9.7	A low-pressure trough extended along the length of the east coast preceding thunderstorms and heavy rain.
17/01/2018 7:00	2.7 (2.9)	4.2 (5.2)	14.7	A low-pressure system developed in the Tasman Sea, with a low-pressure trough off the east coast.
1/02/2018 12:30	2.6 (2.8)	4.3 (4.8)	12	A high-pressure system moved from the Great Australian Bight to the Tasman Sea extending a ridge of high-pressure along the east coast.
18/02/2018 13:30	3.4 (3.6)	5.0 (6.4)	14.2	TC Gita was located to the southeast of New Caledonia on February 15 before passing over the Tasman Sea and weakening to a low-pressure system on February 19.
15/03/2018 11:00	2.8 (3.1)	4.3 (6.0)	11	TC Linda developed in the northeaster Coral Sea on the March 13 before weakening into a low-pressure system.
30/03/2018 0:00	2.7 (2.9)	4.7 (6.2)	11.2	TC Iris entered Australian waters on March 24 weakening to a low-pressure system. Remnants of TC Iris stayed off the central QLD coast from March 29 until the end of the month.
7/06/2018 9:00	2.7 (3)	4.2 (5.3)	9.6	A high-pressure system in the Tasman Sea extended along the east coast.
15/10/2018 22:30	4.1 (4.5)	6.6 (7.8)	10.9	A low-pressure system developed on October 14 in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

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

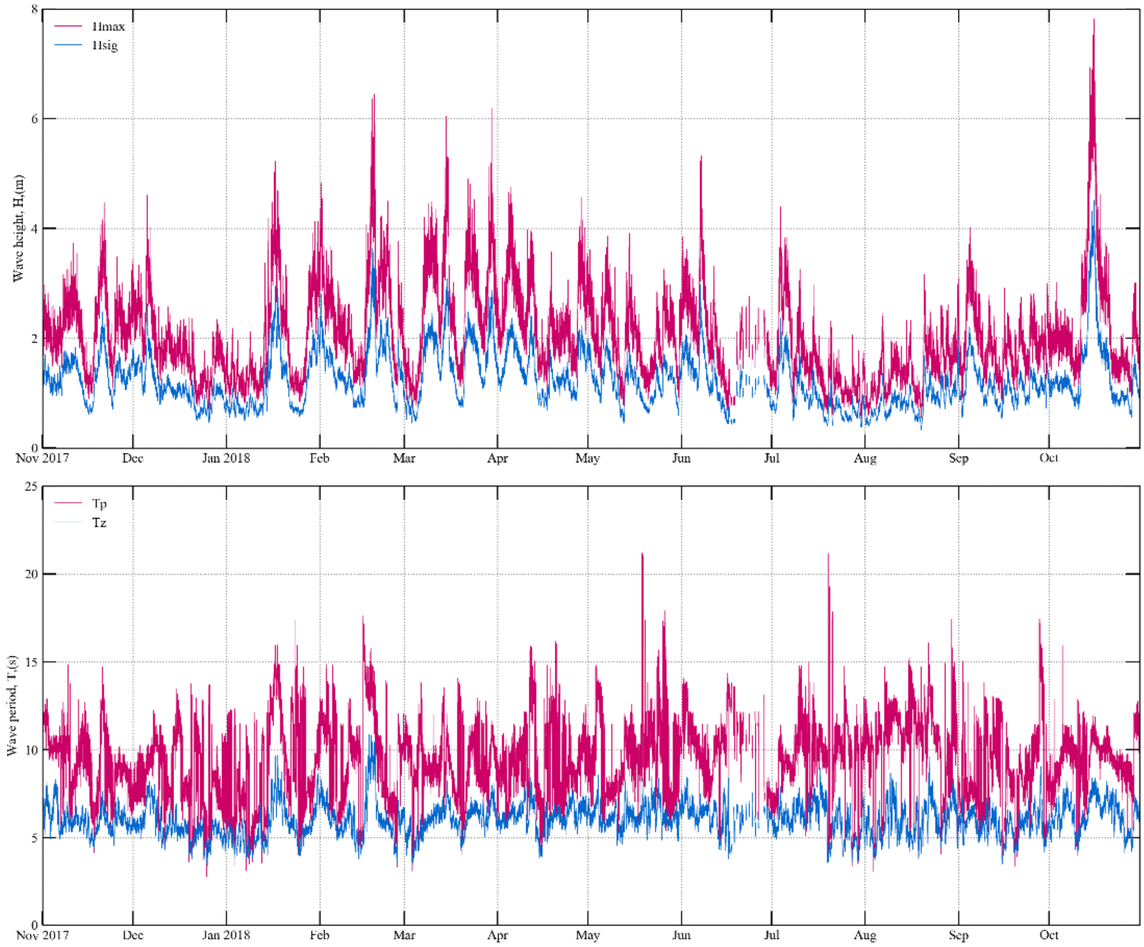


Figure 5 Tweed Heads – daily wave recordings

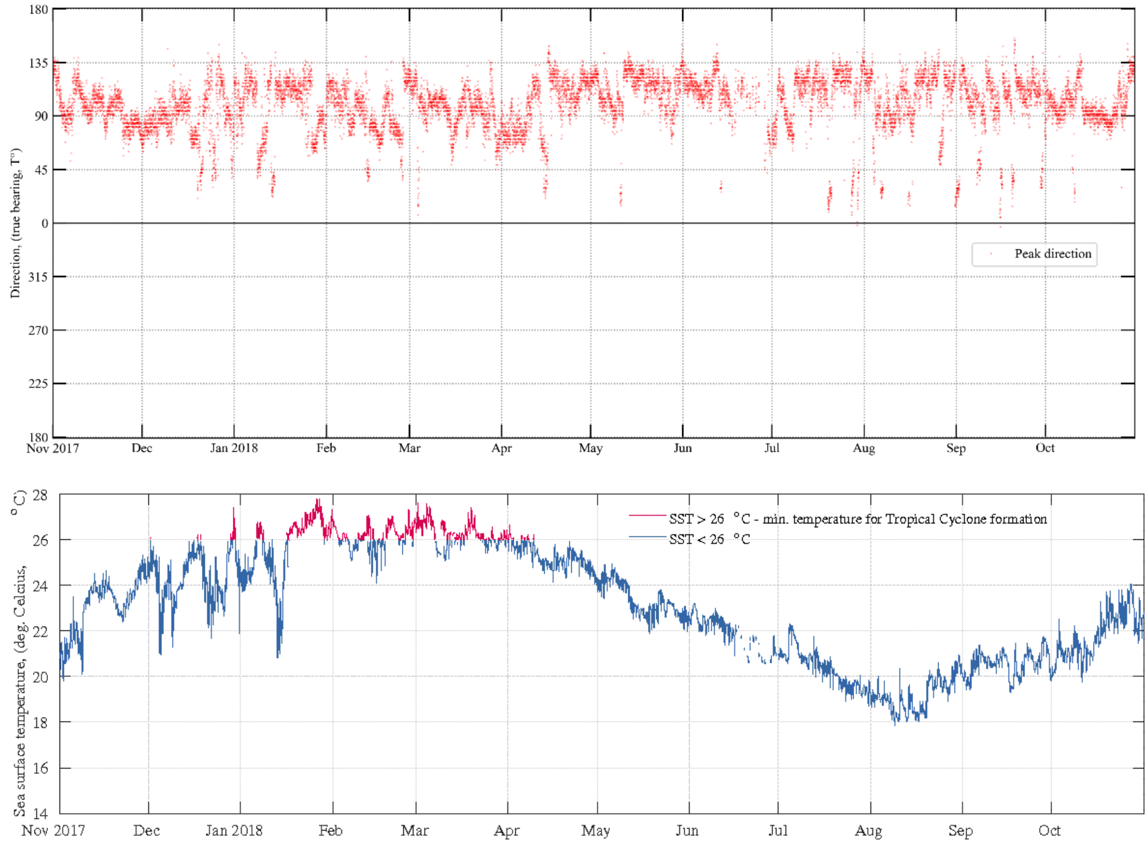


Figure 6 Tweed Heads – peak wave direction and sea surface temperature

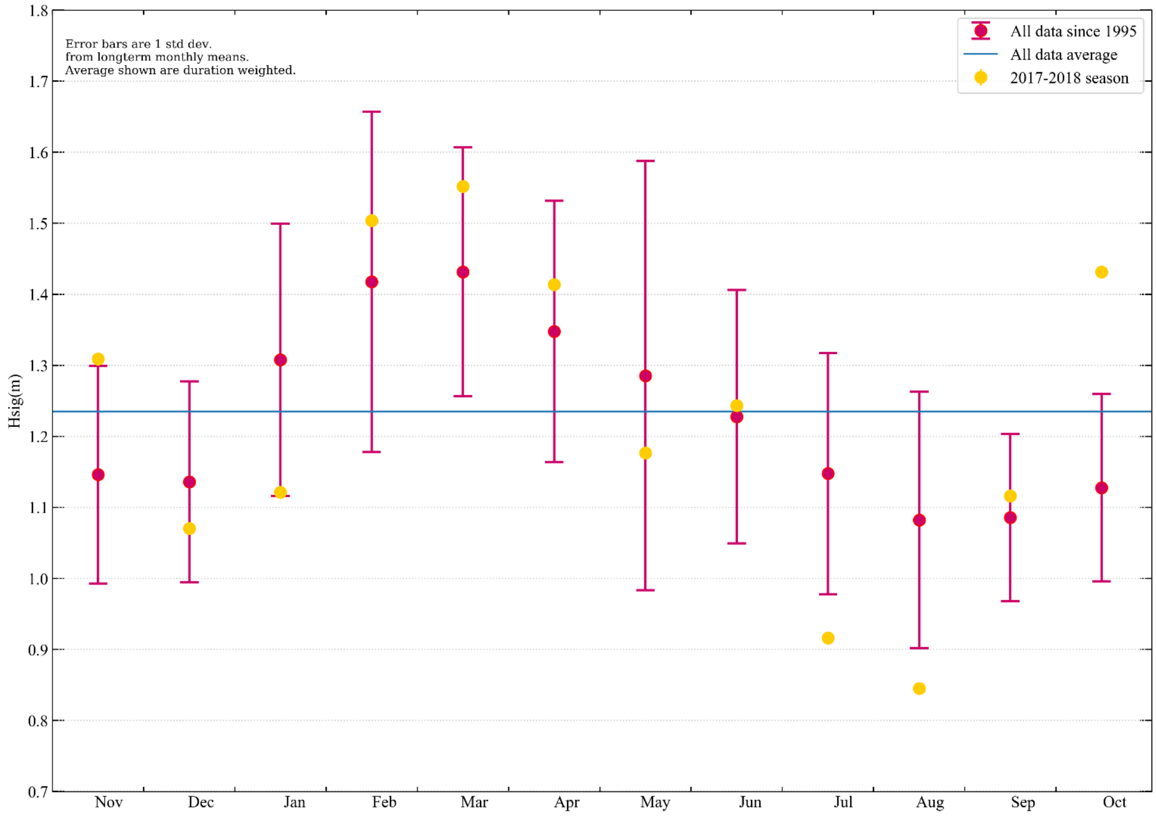


Figure 7 Tweed Heads – monthly average wave height (H_s) for 2017-18 and for all data

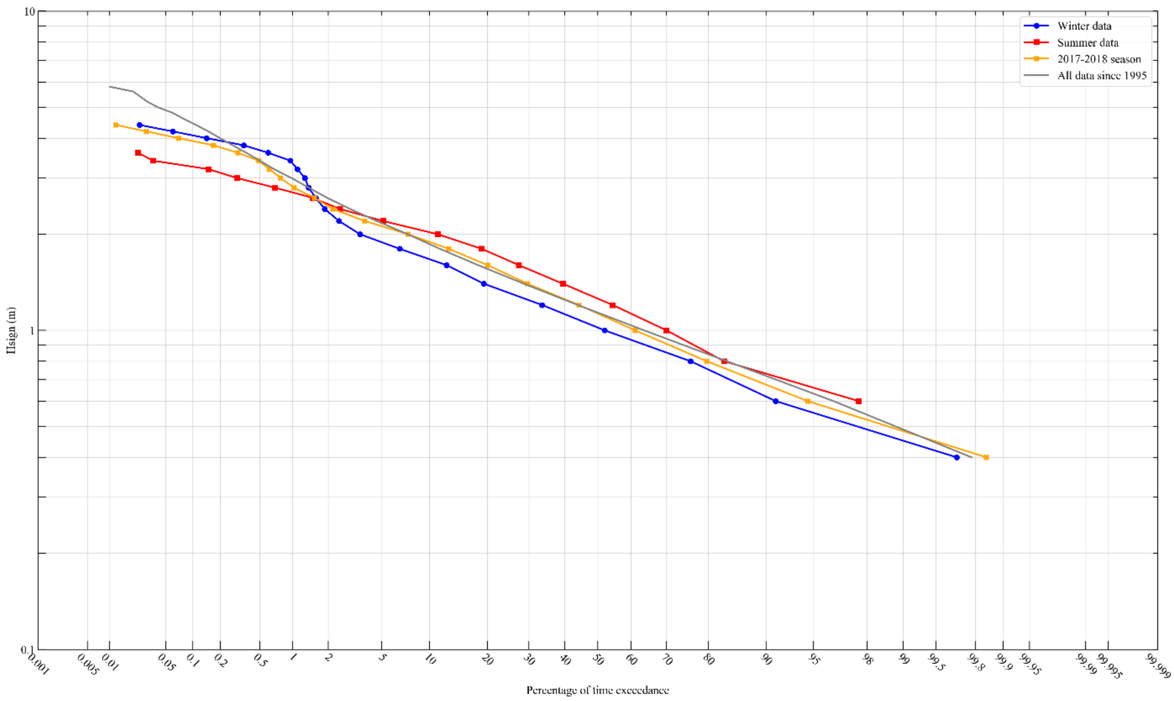


Figure 8 Tweed Heads – percentage exceedance of wave height (H_s) for all wave periods (T_p)

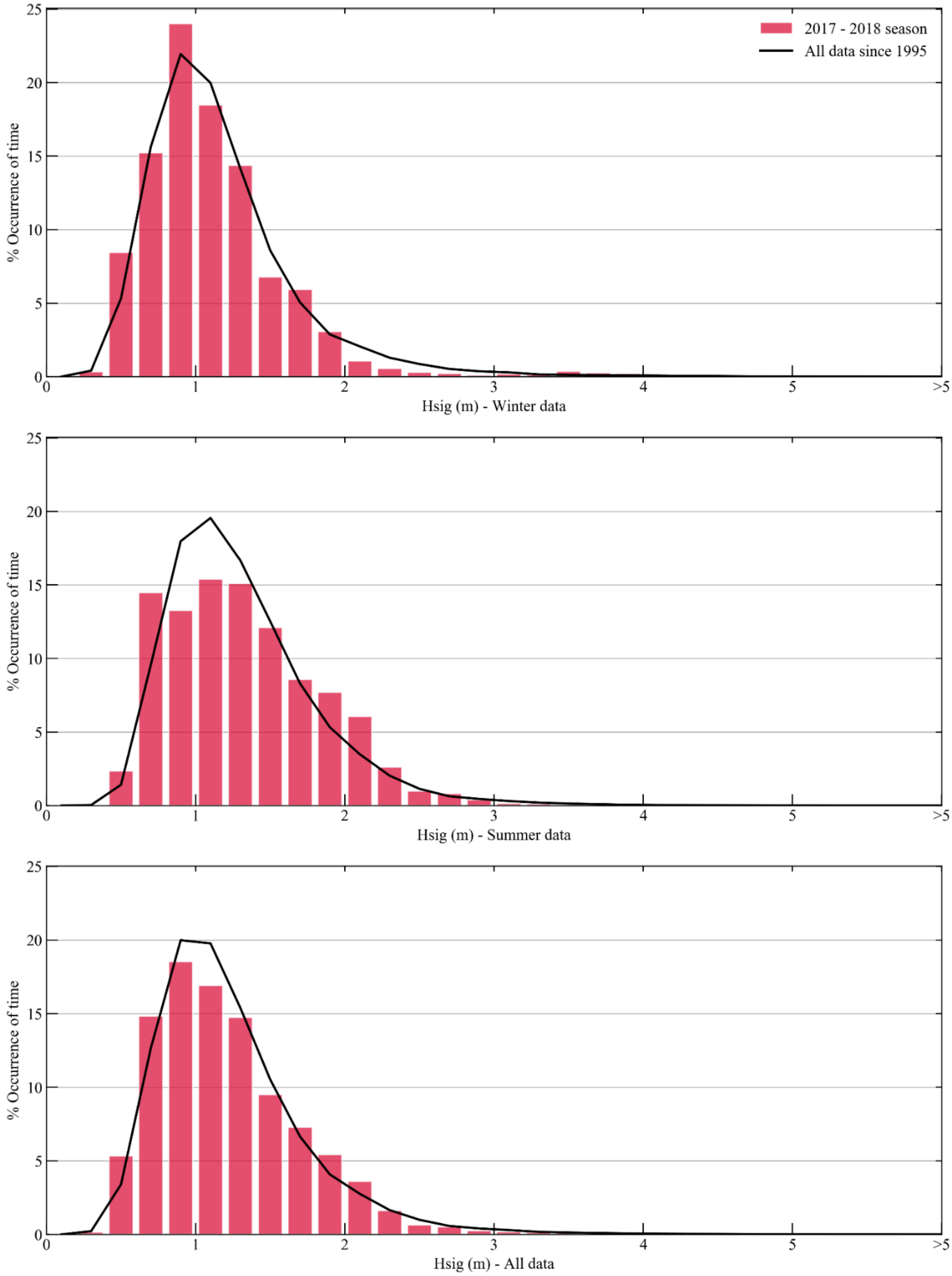


Figure 9 Tweed Heads – histogram percentage (of time) occurrence of wave heights (H_s)

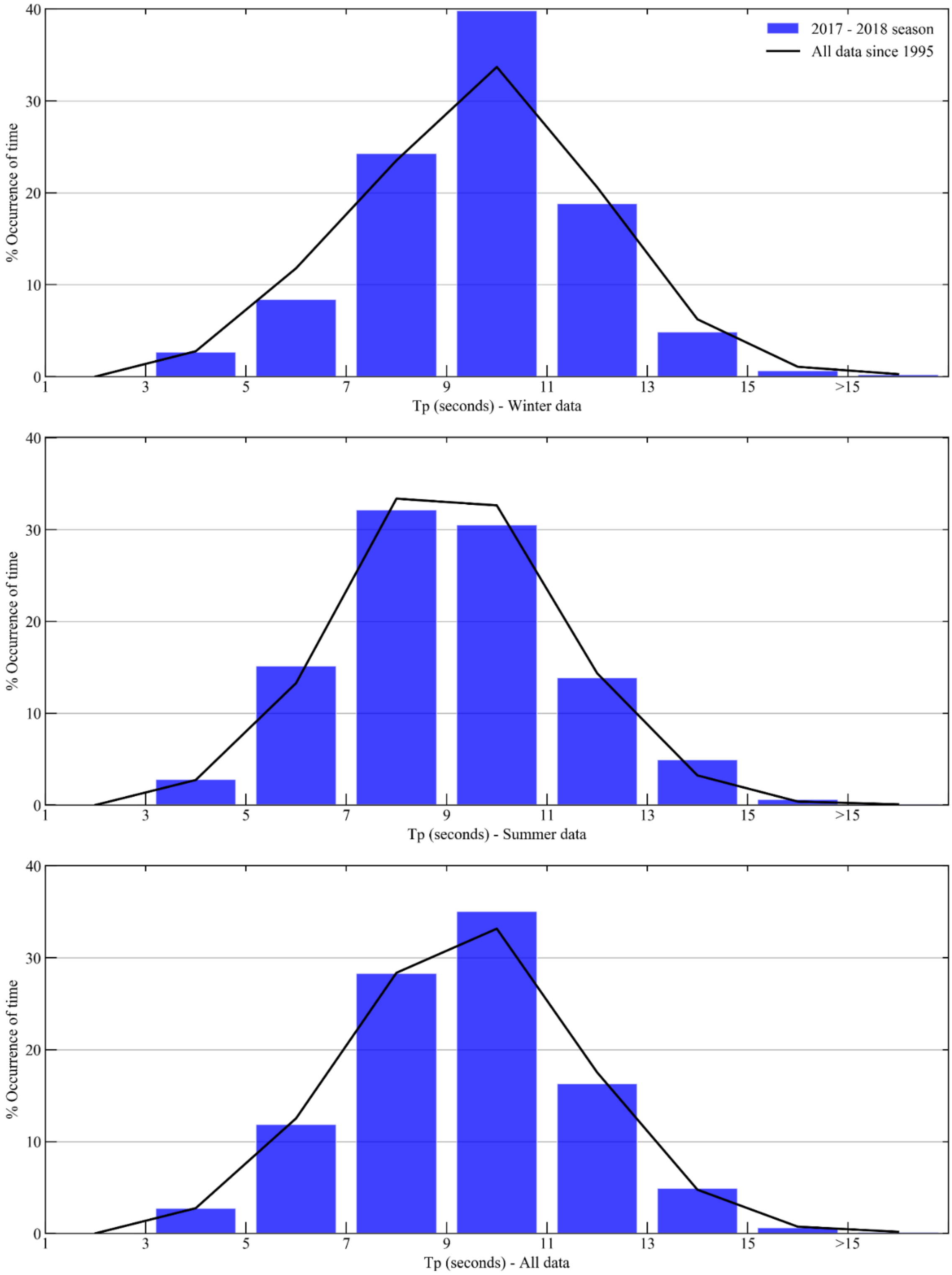


Figure 10 Tweed Heads – histogram percentage (of time) occurrence of wave periods (T_p)

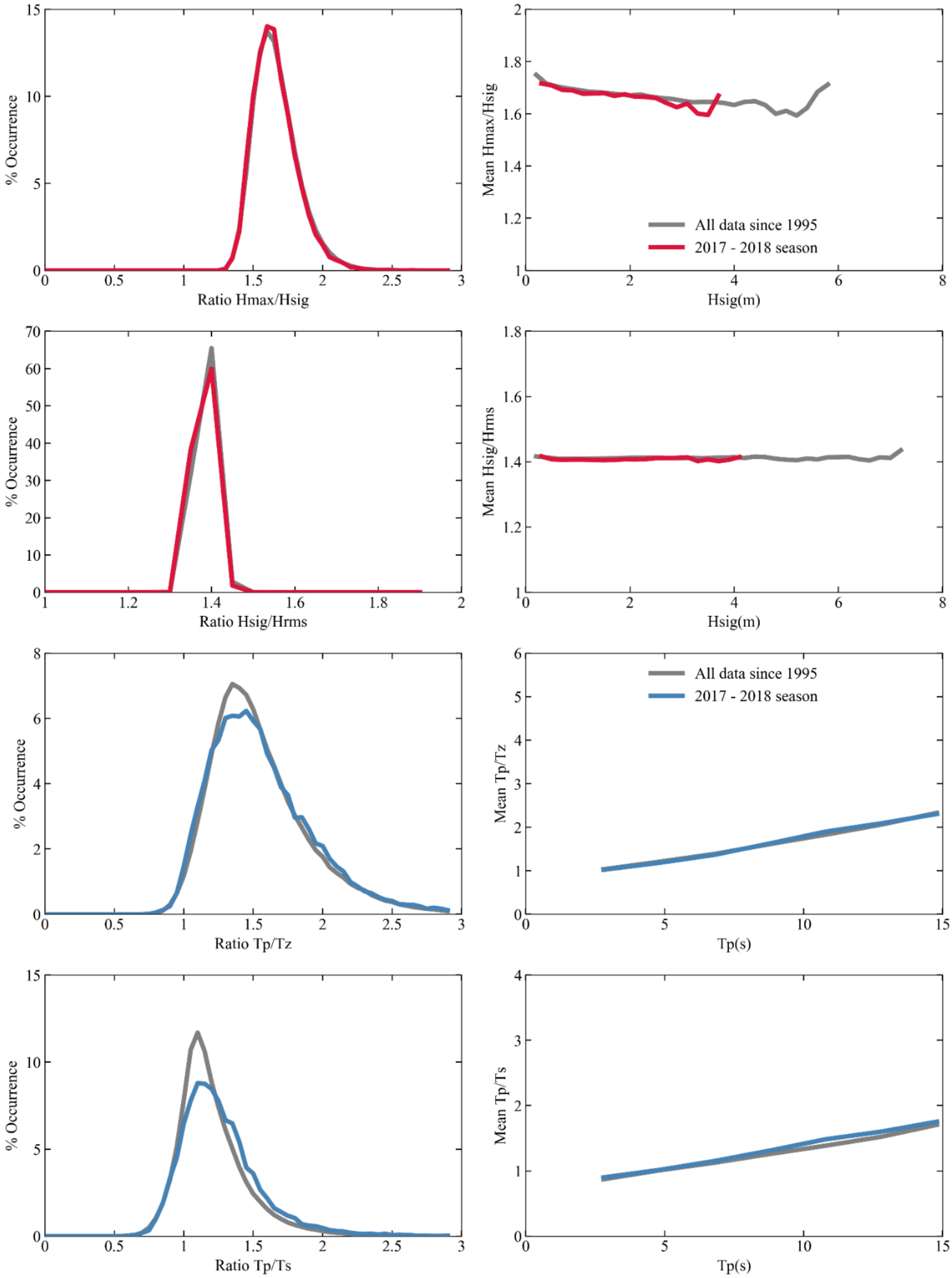
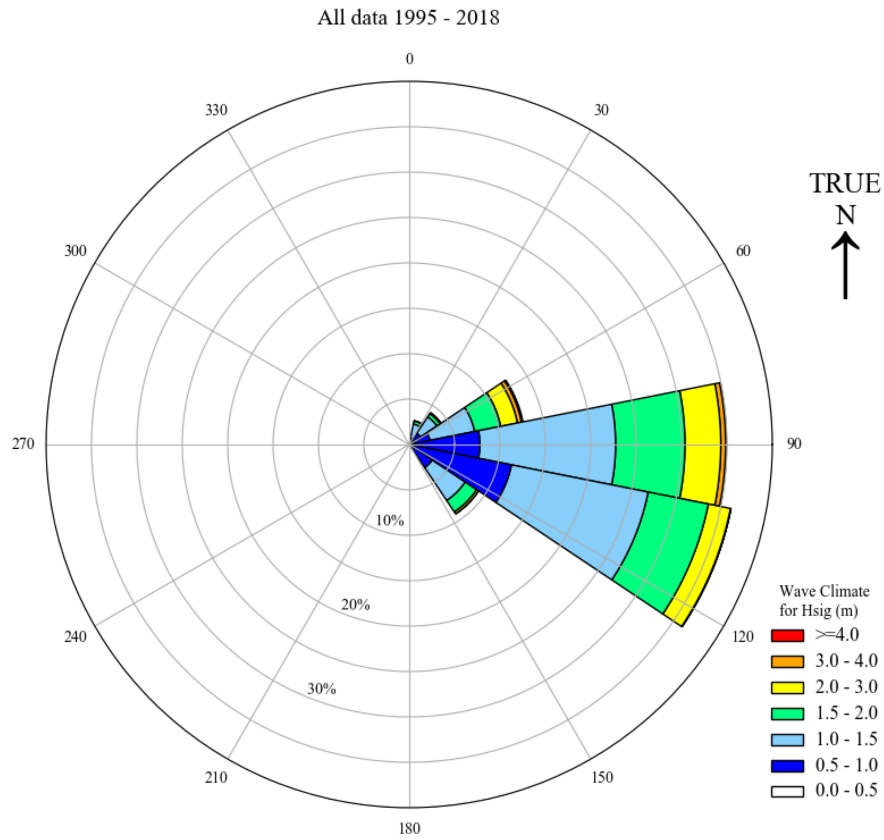


Figure 11 Tweed Heads – wave parameter relationships



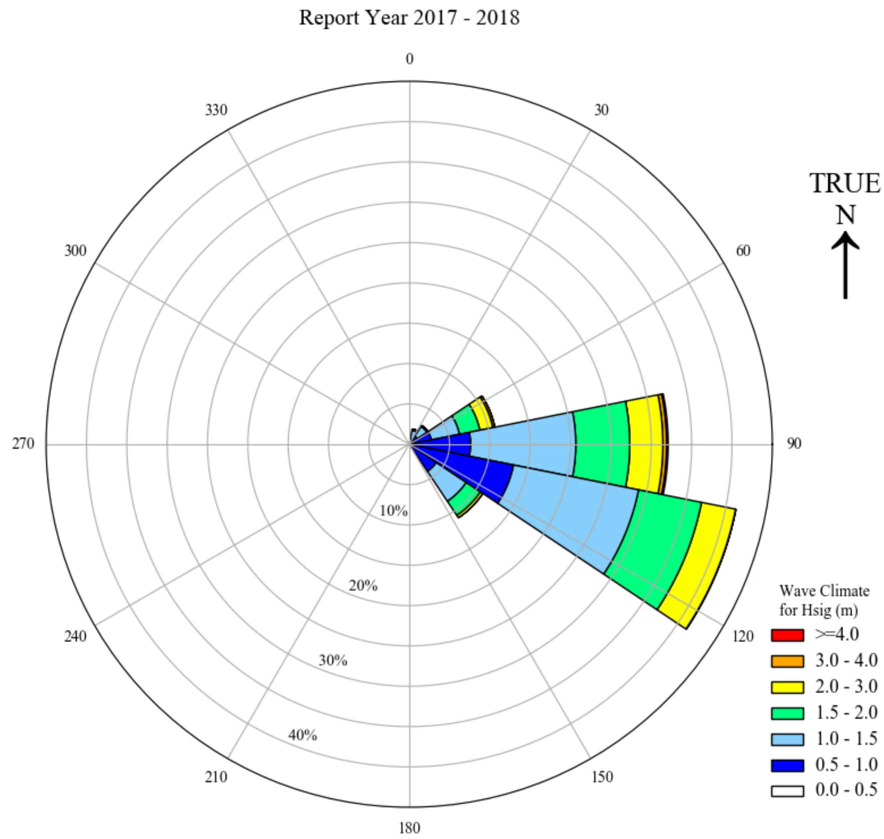


Figure 12 Tweed Heads – directional wave rose

Palm Beach

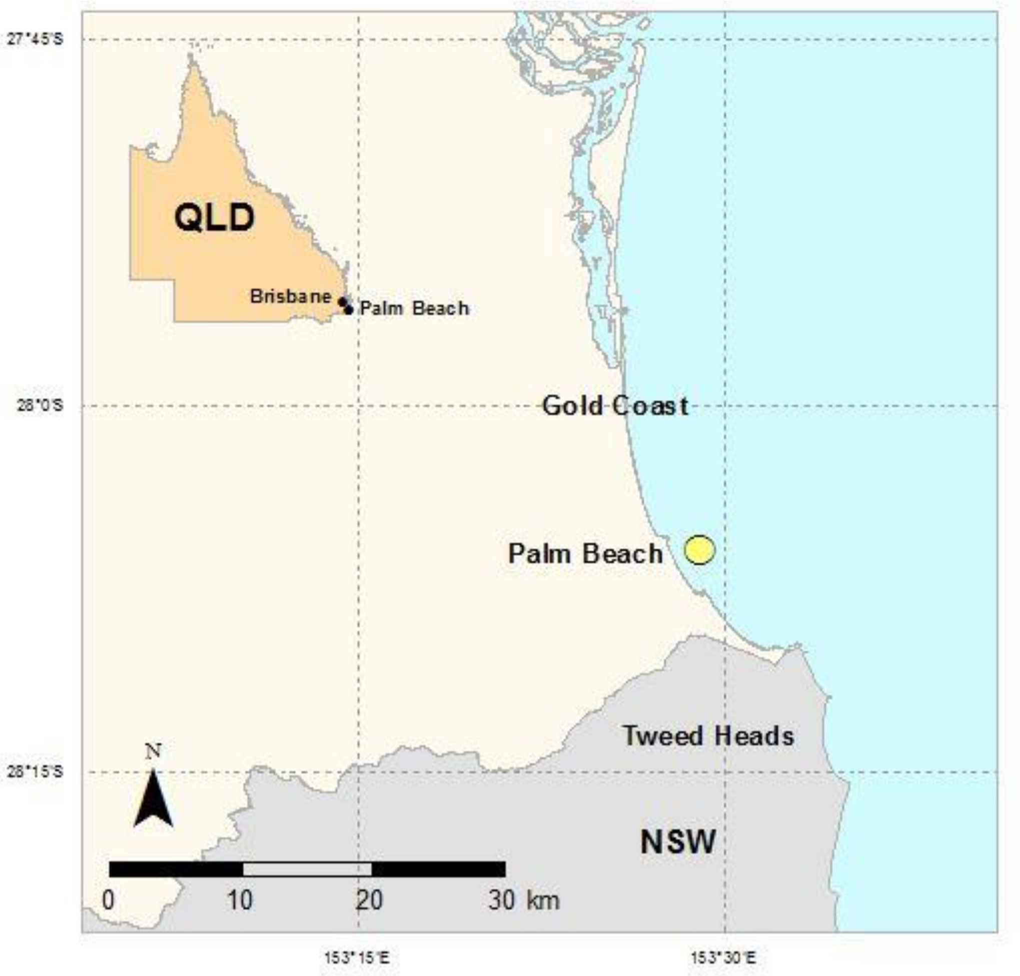


Figure 13 Palm Beach– Locality plan

Table 9 Palm Beach – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	06/06/2017	1.1 day	24,575	1.42
2017-18	01/11/2017	3.1 day	7,055	1

Table 10 Palm Beach – buoy deployments during the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
28°05.957' S	153°29.073' E	DWR4	23.3	06/06/2017	29/08/2018
28° 05.895' S	153° 29.064' E	DWR4	24	29/08/2018	current

Table 11 Palm Beach – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	16/10/2018 1:00	4	15/10/2018 23:30	7.8
2	18/02/2018 11:00	3.4	15/03/2018 1:30	6.1
3	15/03/2018 10:30	3	16/10/2017 6:00	6.1
4	13/06/2017 21:00	2.9	18/02/2018 23:00	5.6
5	17/10/2017 15:30	2.8	13/06/2017 21:00	5.4
6	7/06/2018 12:00	2.8	29/03/2018 3:30	5.2
7	29/03/2018 3:30	2.7	7/06/2018 8:30	4.9
8	20/06/2017 6:00	2.6	20/06/2017 4:30	4.5

Table 12 Palm Beach – significant meteorological events with threshold H_s of 2.5 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
18/02/2018 11:00	2.9 (3.4)	4.7 (5.4)	13.3	TC Gita located southeast of New Caledonia on the 15th before passing over the Tasman Sea and weakening to a low-pressure system on the 19th.
15/03/2018 10:30	2.7 (3.0)	4.9 (5.5)	11.1	TC Linda developed in the north-eastern Coral Sea on the 13th before weakening into a low-pressure system.
30/03/2018 1:30	2.5 (2.7)	4.1 (5.2)	11.1	TC Iris entered Australian waters on the 24th then weakened to a low-pressure system, remnants of TC Iris stayed off the central QLD coast until the end of the month.
7/06/2018 12:00	2.5 (2.8)	4.2 (4.8)	10	A high-pressure system in the Tasman Sea extended up the east coast.
16/10/2018 1:00	3.8 (4.0)	6.5 (7.0)	11.1	A low-pressure system developed on the 14th in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

Notes: 1. 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).

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

Palm Beach – seasonal overview

This buoy hasn't been in operation for long, therefore only the recorded data is displayed. Analysis will be done after 2 consecutive years of data.

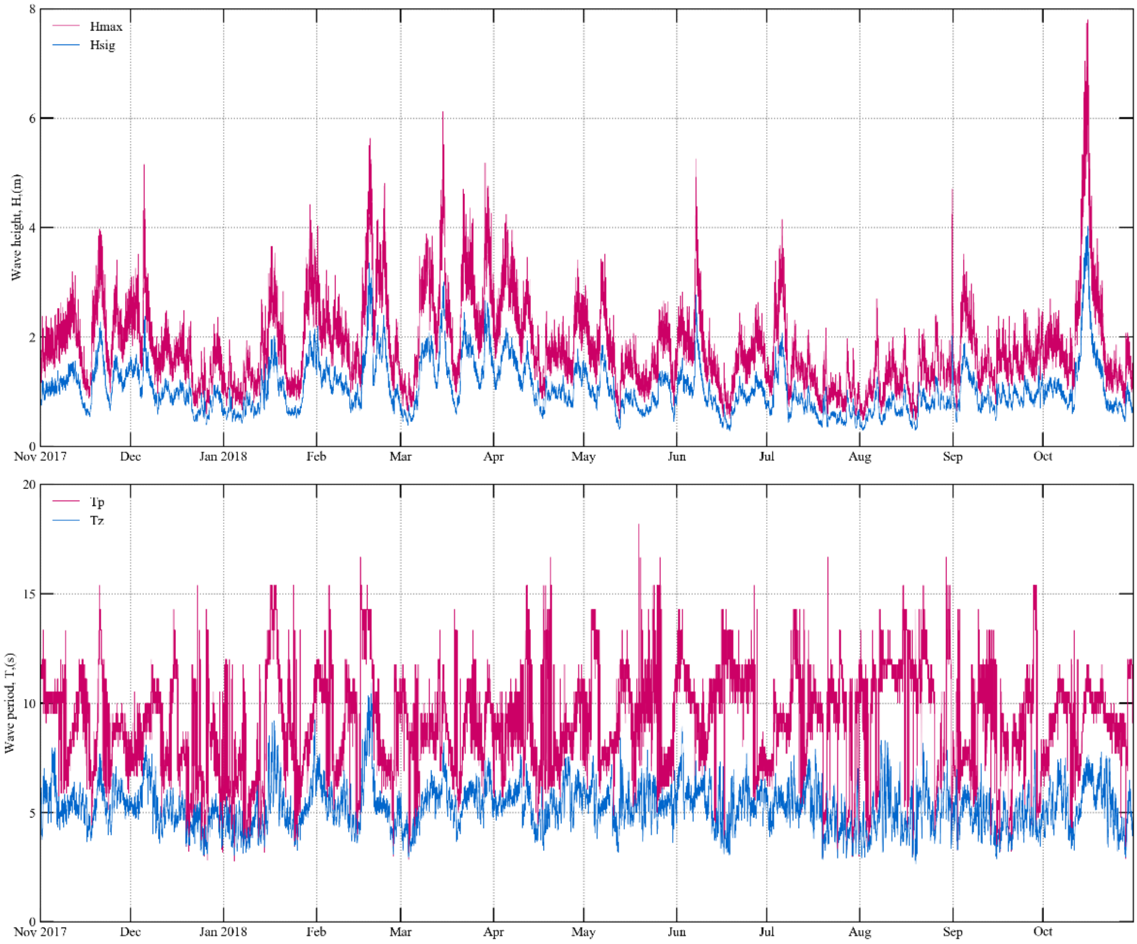


Figure 14 Palm Beach – daily wave recordings

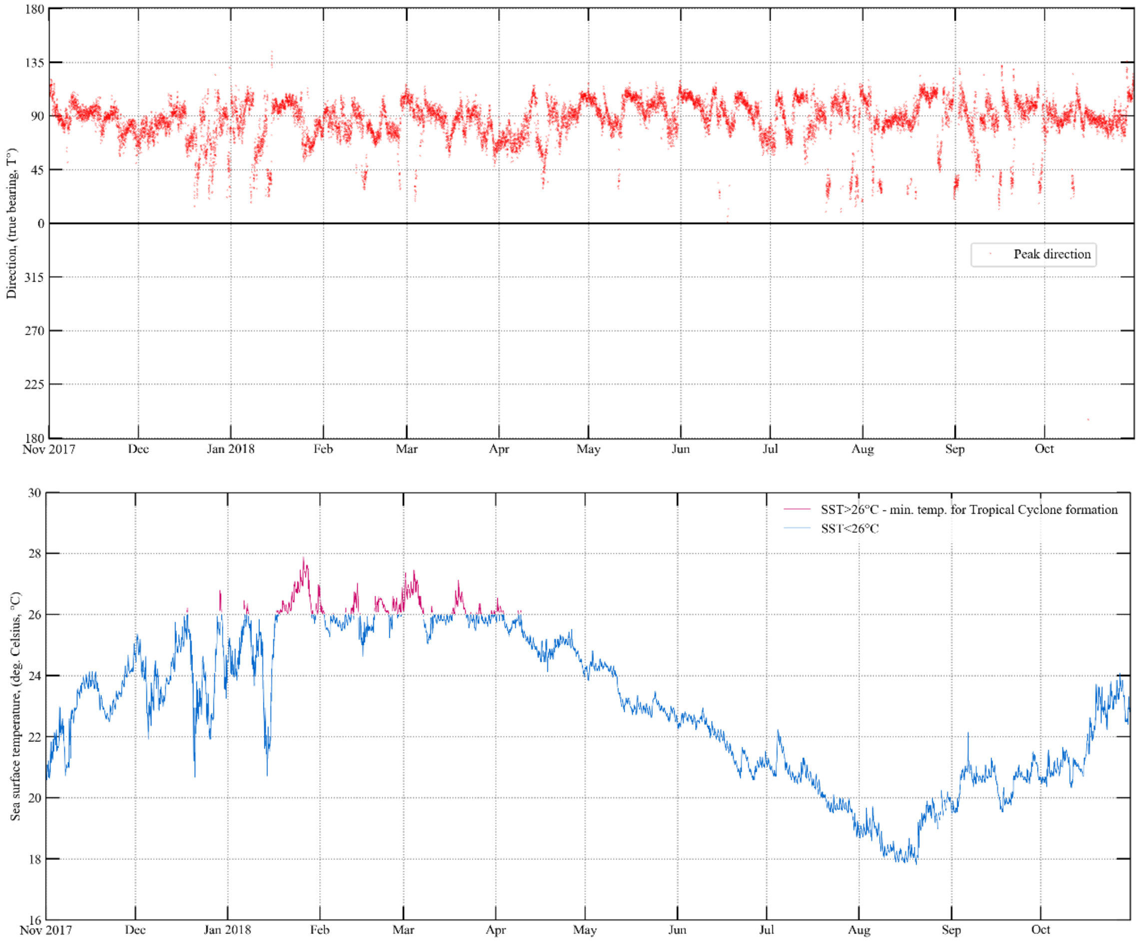


Figure 15 Palm Beach – peak wave direction and sea surface temperature

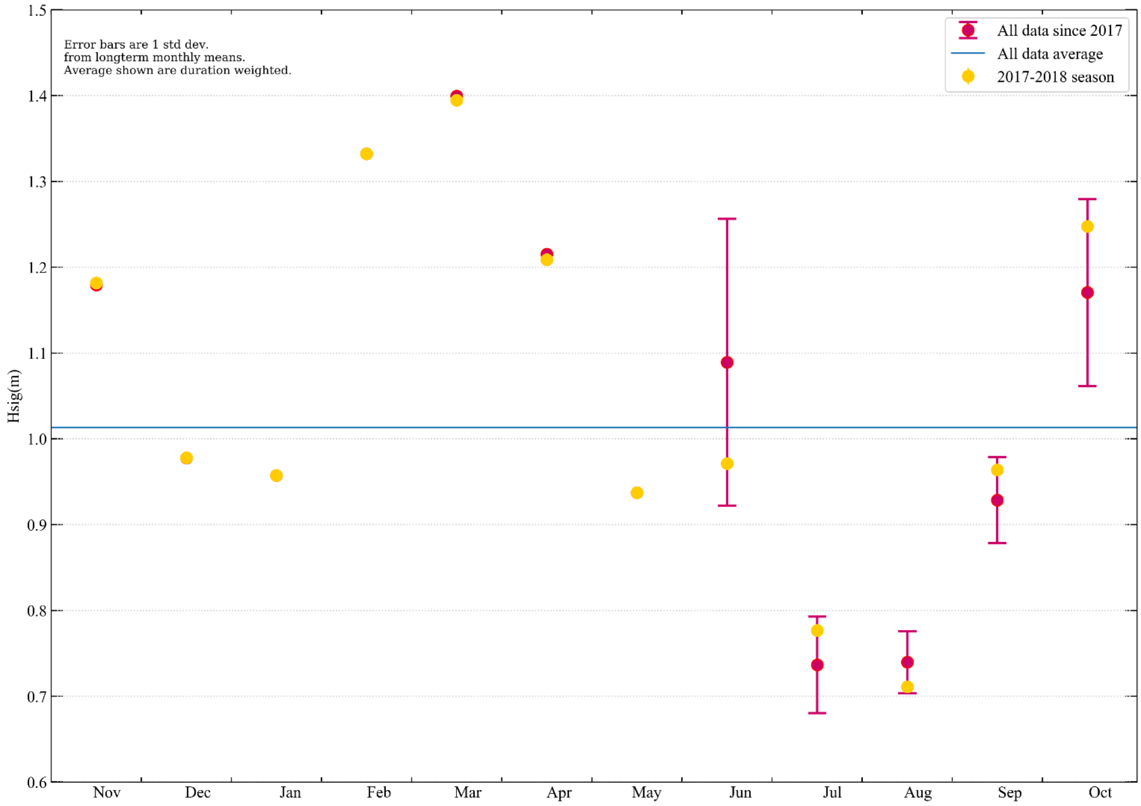


Figure 16 Palm Beach - monthly average wave height (H_s) for 2017-18 and for all data

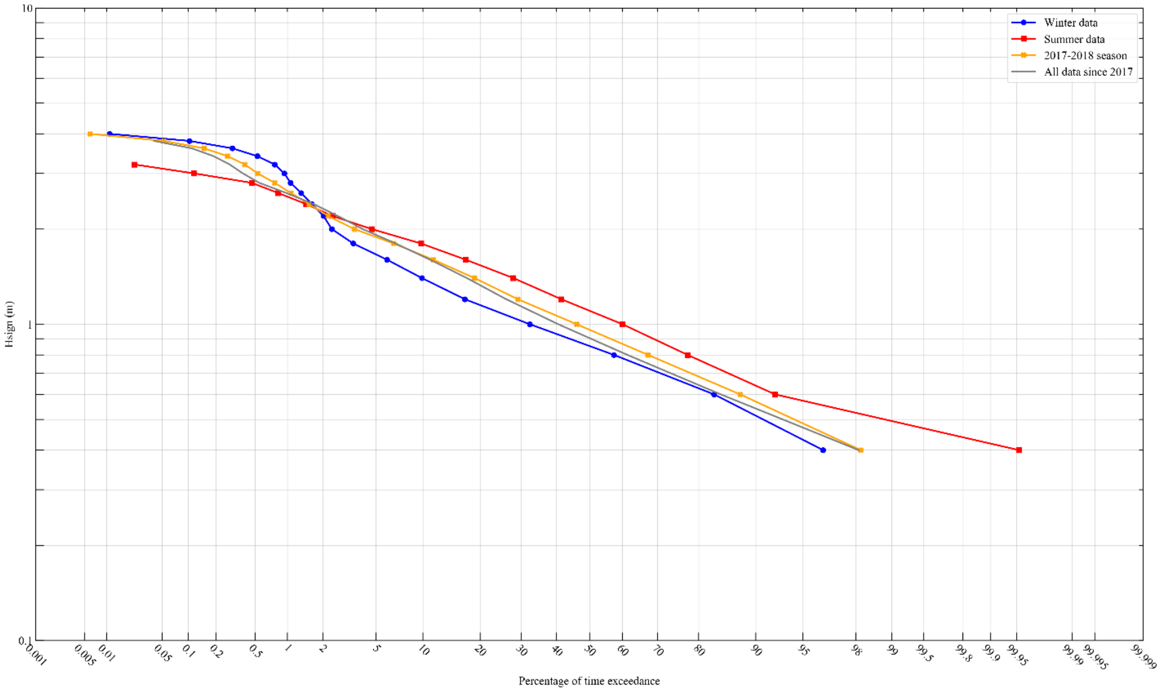


Figure 17 Palm Beach - percentage exceedance of wave height (H_s) for all wave periods (T_p)

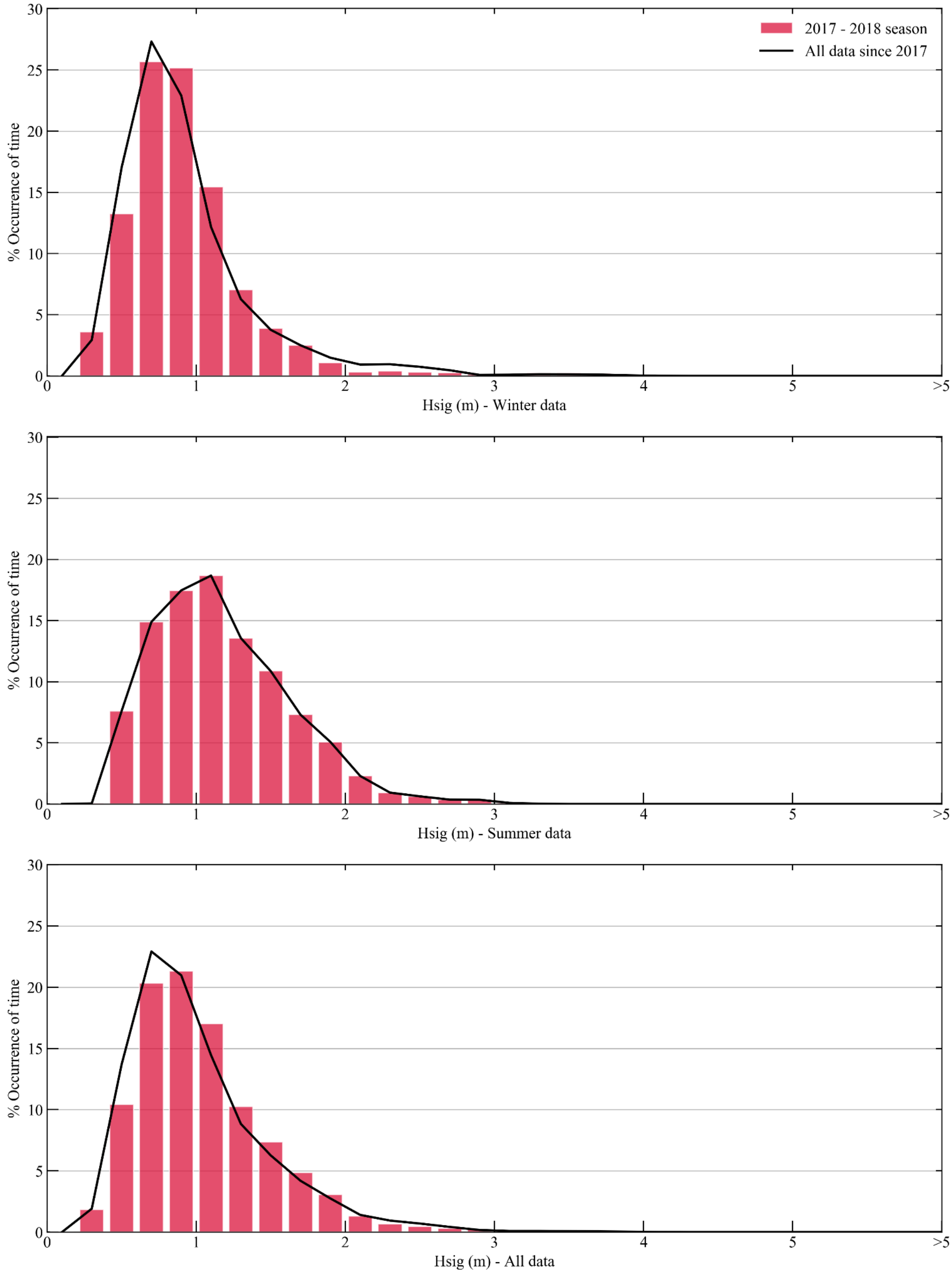


Figure 18 Palm Beach - histogram percentage (of time) occurrence of wave height (H_s)

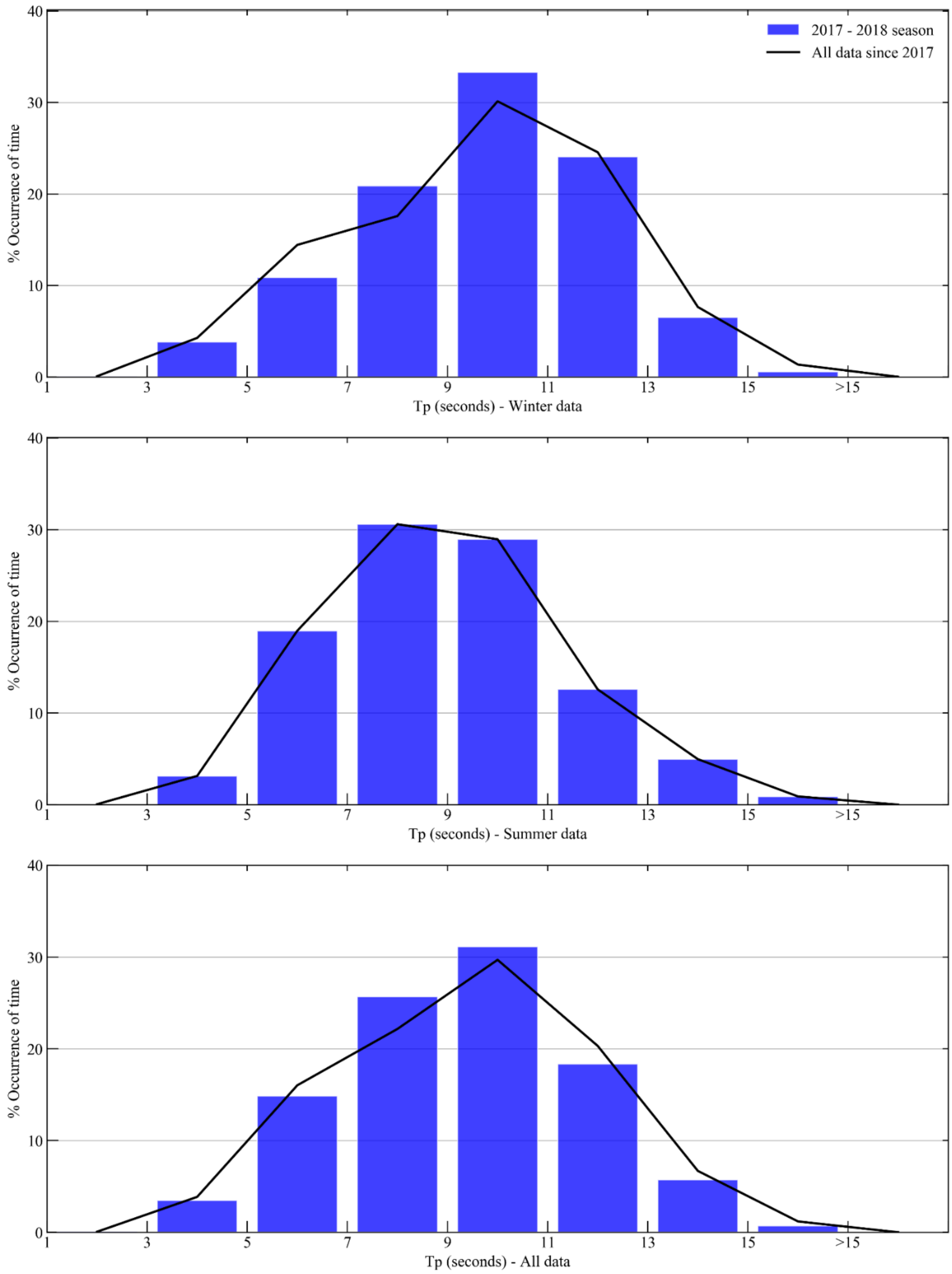


Figure 19 Palm Beach - histogram percentage (of time) occurrence of wave periods (T_p)

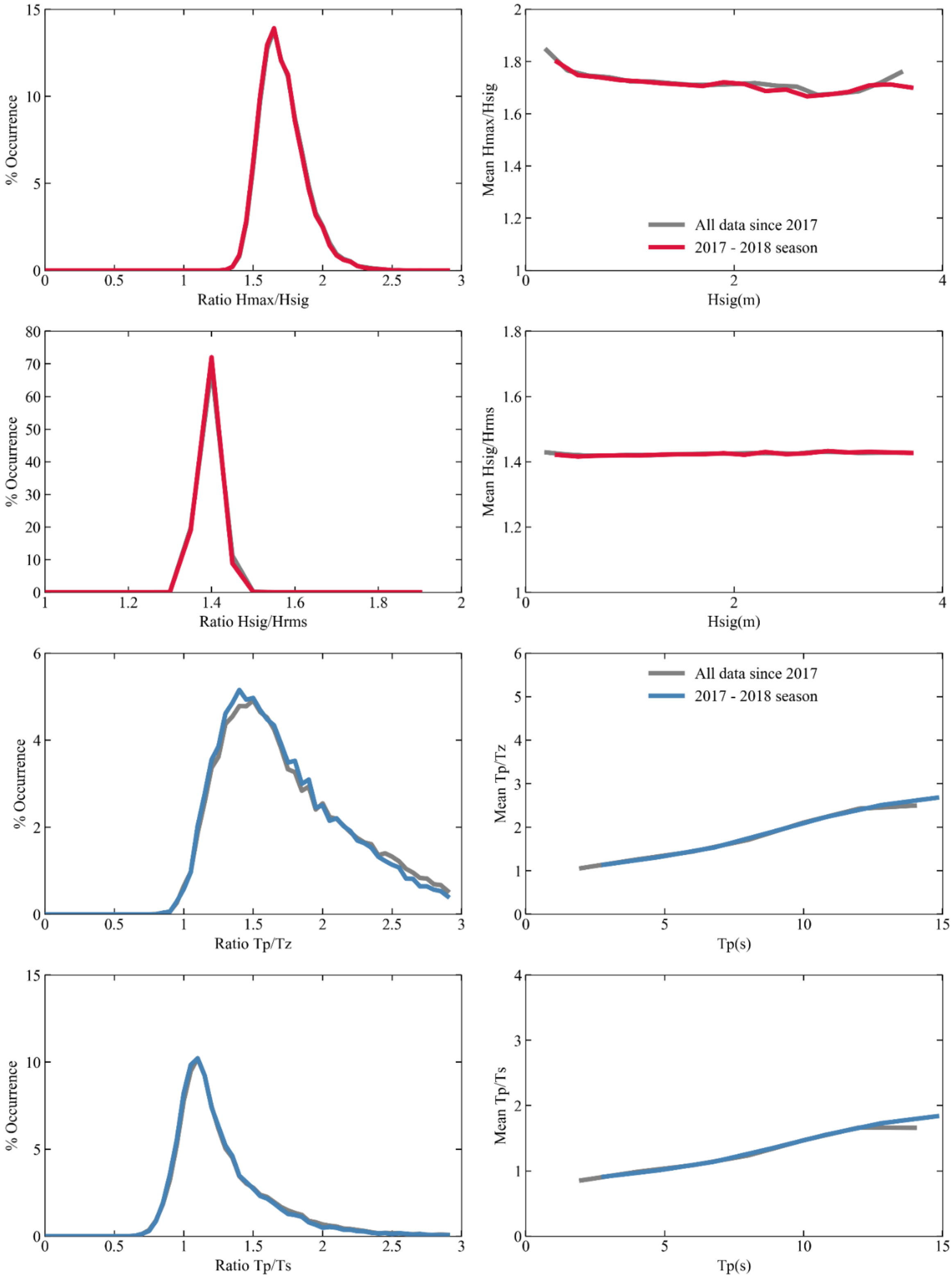
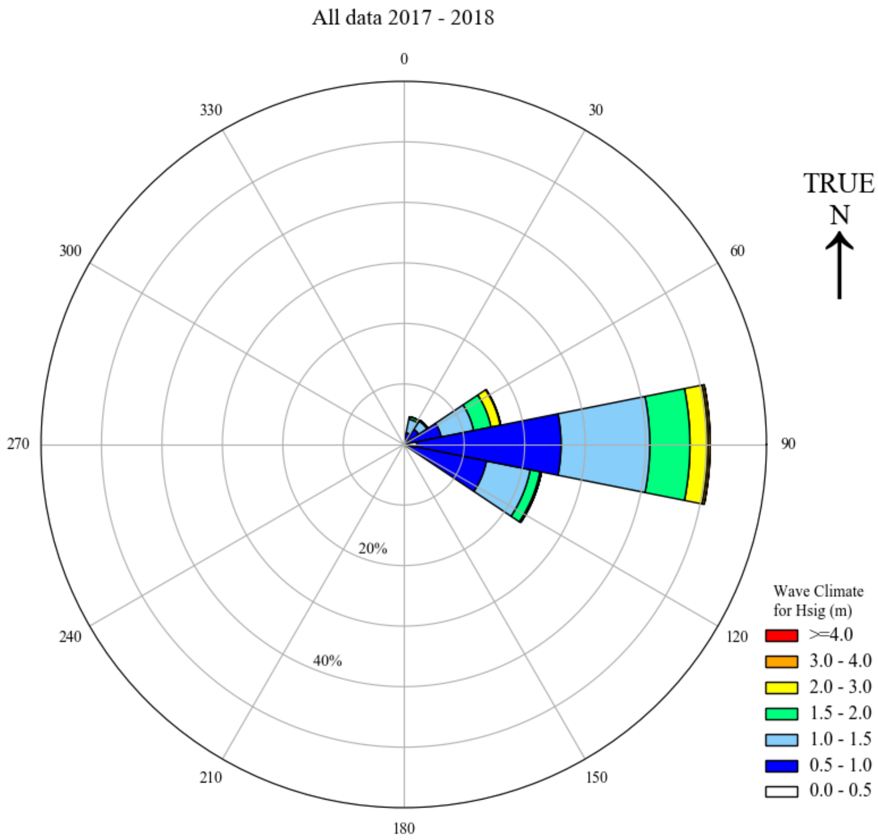


Figure 20 Palm Beach - wave parameter relationships



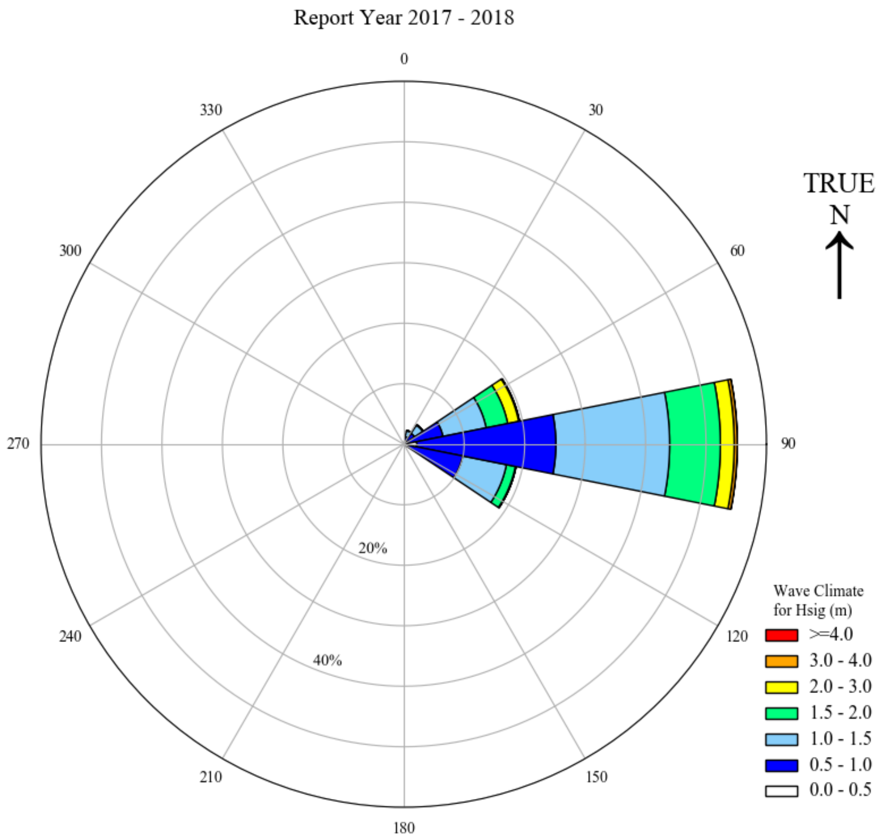


Figure 21 Palm Beach - directional wave rose

Gold Coast

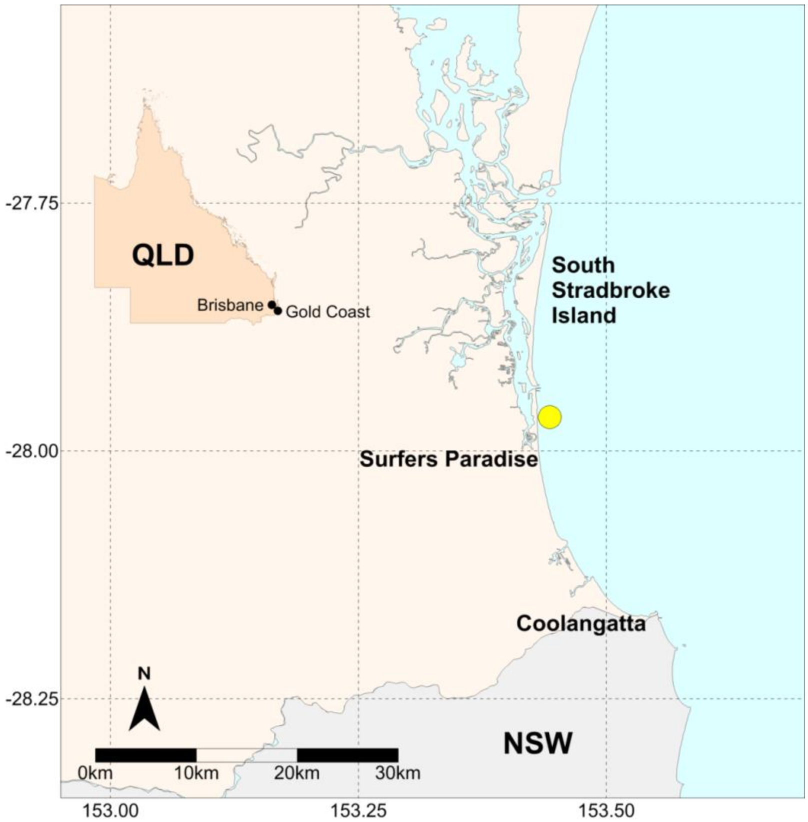


Figure 22 Gold Coast – locality plan

Table 13 Gold Coast – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	21/03/1987	3.41 years	390,203	31.69
2017-18	01/11/2017	3.46 days	17353	1

Table 14 Gold Coast – buoy deployments during the 2017-18 season

Latitude	Longitude	Type Buoy	Depth (m)	Deployed date	Removal date
27°57.865' S	153°26.505' E	DWR-MkIII	16	09/08/2017	19/10/2018
27° 57.948' S	153° 26.552' E	DWR-MkIII	16	19/10/2018	current

Gold Coast – seasonal overview

The Gold Coast wave buoy has been operational for almost 32 years with an overall data return of 89.2 per cent. The data return for the period November 2017 to October 2018 was excellent, with total gaps of 3.46 days, equivalent to 99 percent data return. The buoy was replaced once during the reporting period on the 19th of October (Table 14).

The Gold Coast wave buoy was subjected to three significant events during the reporting periods (Table 16). The largest waves occurred during the low-pressure event on the 15th of October with a H_s of 4.5 m and H_{max} of 7.6 metres. None of the recorded waves ranked in the highest wave recordings at the Gold Coast (Table 15). Peaks in wave heights from the three significant meteorological events (Table 16) are clearly seen in the daily wave recording time series (Figure 23).

The SST measured in the buoy hull showed a range of 19 °C to 29 °C (Figure 24). The SST from mid-December to end-April was periodically warm enough for tropical cyclone development.

The monthly average H_s for the recording period fell within one sd of the entire record except for November and October which were above the 1 sd and July and August where the average is below -1 sd (Figure 25).

The wave climate during the reporting period was equivalent to the wave climate of the whole record, with the exception of summer when H_s over 2 m was less frequent, as seen in the percentage exceedance plot (Figure 26). Wave heights in summer were generally higher than winter except for higher, less frequently occurring waves. Histograms for occurrence of H_s (Figure 27) show a lower occurrence of the 0.8 – 1.2m waves during summer and the 0.8 – 1.0 m waves during winter for the reporting period compared to the whole record. Histograms of the occurrence of T_p (Figure 28) show a similar distribution between the reporting period and entire record with a higher per cent occurrence of 9 – 11 second waves in winter. T_p for all data is normally spread and is concentrated around 7 to 11 seconds for summer and 9 to 11 seconds for winter.

The ratios between different wave parameters such as H_{max}/H_s were generally consistent between this reporting period and all of the historic data, these are plotted in Figure 29.

The time series for wave direction (Figure 24) shows a dominant east to east-southeast wave direction with occasional swings throughout the year to the northeast. This is also reflected in the directional wave rose plots (Figure 30). The wave directions for the reporting period are very similar to the entire record.

Table 15 Gold Coast – highest waves

Rank	Date (Hs)	H_s (m)	Date (Hmax)	H_{max} (m)
1	03/05/1996 06:30	7.1	03/05/1996 06:30	12.0
2	28/01/2013 10:30	6.3	17/03/1993 04:30	11.0
3	23/05/2009 03:30	6.1	05/03/2006 05:00	10.7
4	05/03/2004 23:00	5.9	22/05/2009 12:30	10.6
5	17/03/1993 12:30	5.7	05/03/2004 22:00	10.6
6	25/04/1989 21:00	5.6	12/06/2012 07:00	10.5
7	12/06/2012 07:00	5.5	28/01/2013 09:30	10.5
8	05/03/2006 08:00	5.3	25/04/1989 09:30	10.0

9	04/06/2016 20:00	5.1	15/02/1995 10:30	9.2
10	15/02/1995 07:00	5.0	04/06/2016 20:00	9.1

Table 16 Gold Coast – significant meteorological events with threshold H_s of 3 metres.

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
18/02/2018 17:00	3.2 (3.4)	5.5 (6.8)	14.2	TC Gita was located to the southeast of New Caledonia on the 15th before passing over the Tasman Sea and wakening to a low-pressure system on the 19th.
15/03/2018 4:30	2.7 (3)	4.6 (6.7)	11.5	TC Linda developed in the northeastern Coral Sea on the 13th before weakening into a low-pressure system.
15/10/2018 23:30	4.3 (4.5)	6.8 (7.6)	11.3	A low-pressure system developed on the 14th in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

Notes: 1. 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).

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

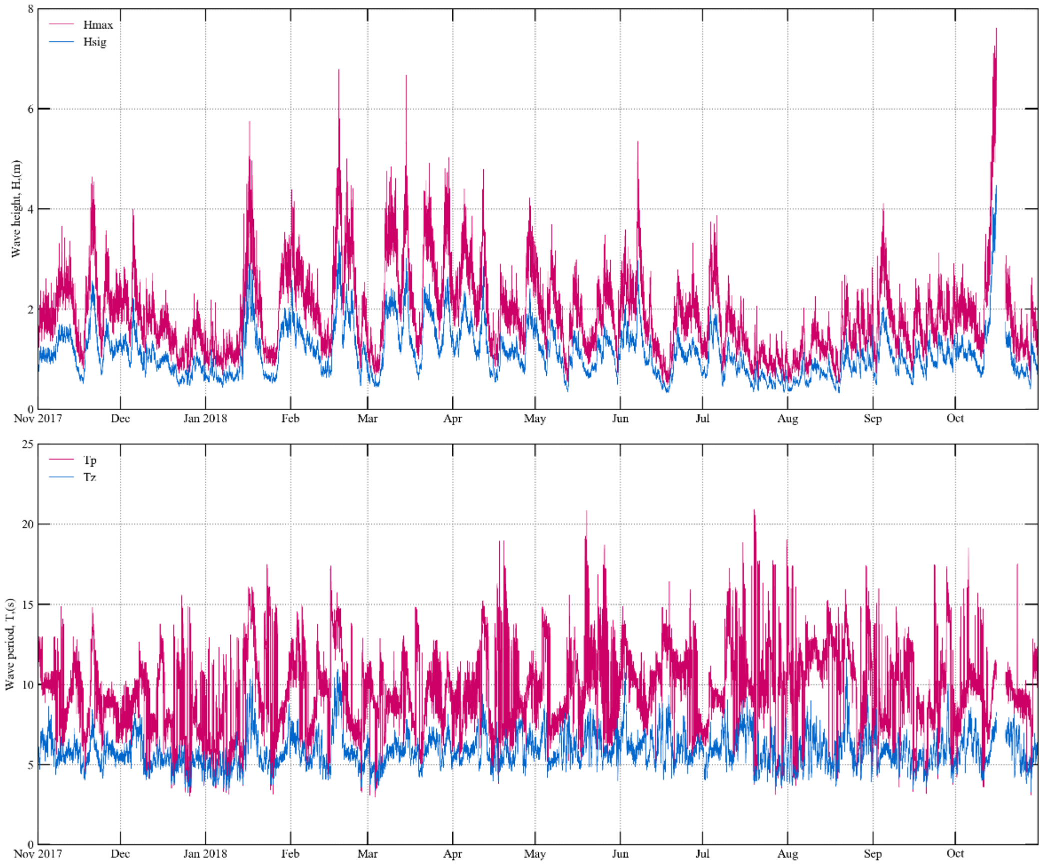


Figure 23 Gold Coast – daily wave recordings

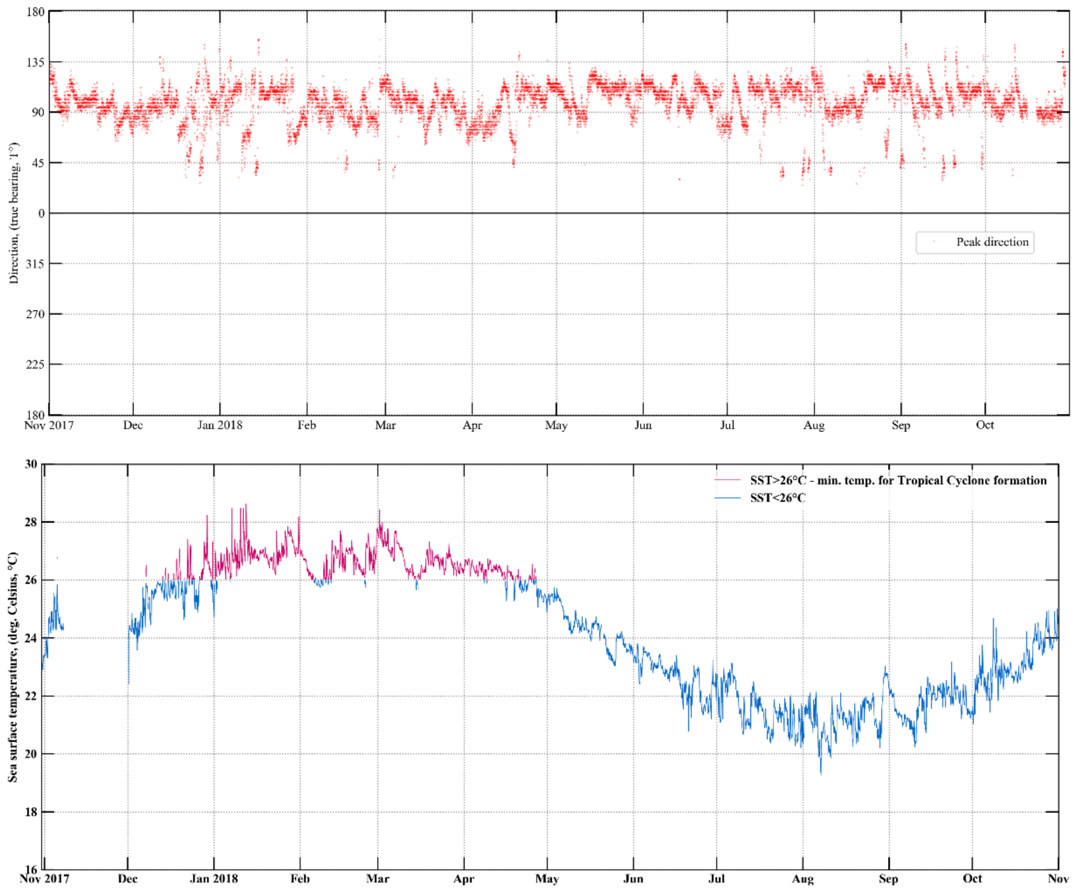


Figure 24 Gold Coast – peak wave direction and sea surface temperature

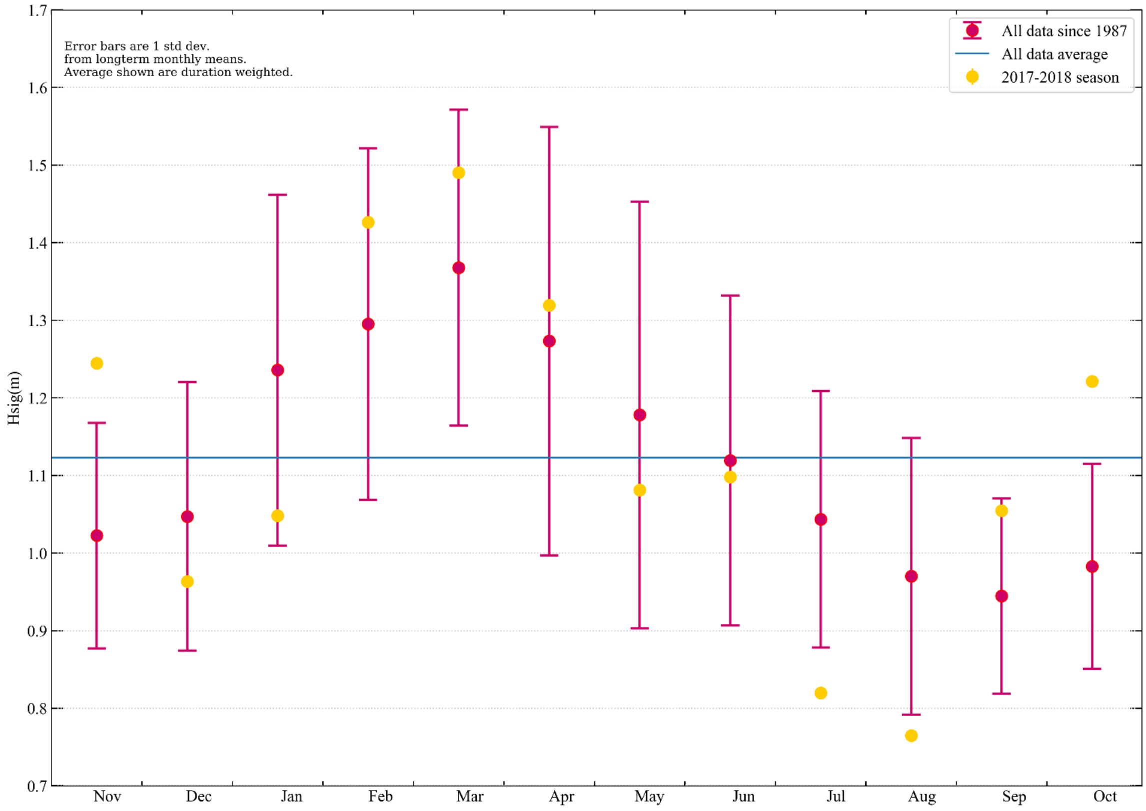


Figure 25 Gold Coast – monthly average wave height (H_s) for 2017-18 and for all data

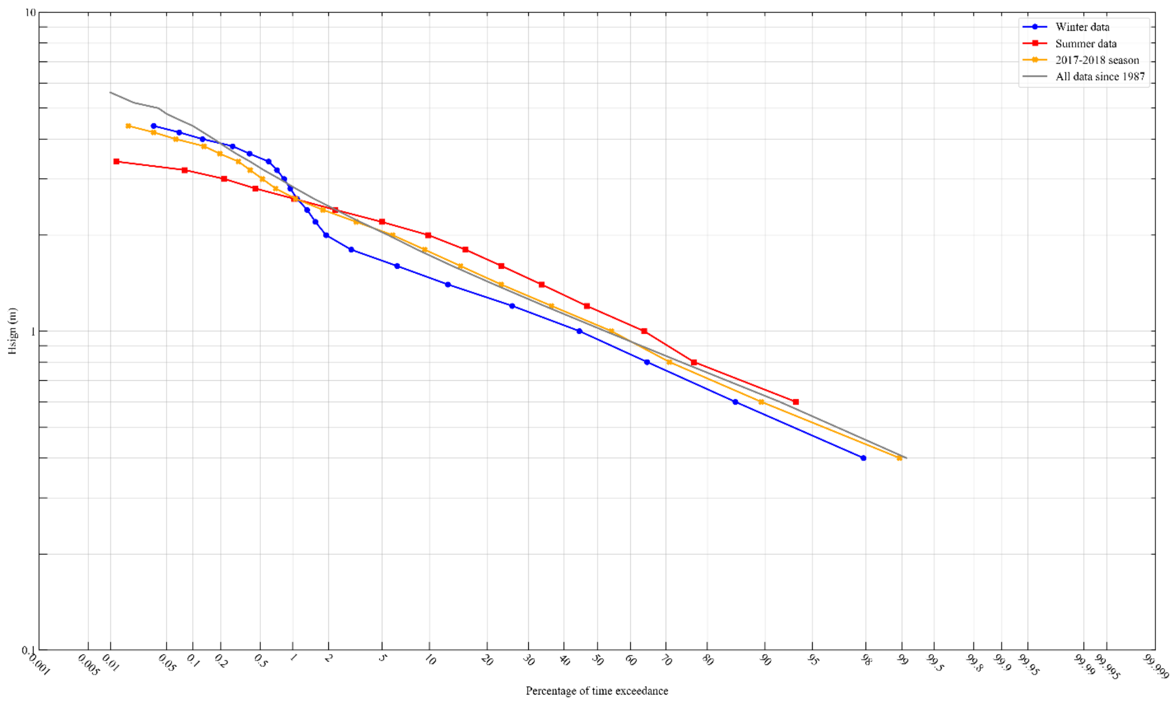


Figure 26 Gold Coast – percentage exceedance of wave height (Hs) for all wave periods (T_p)

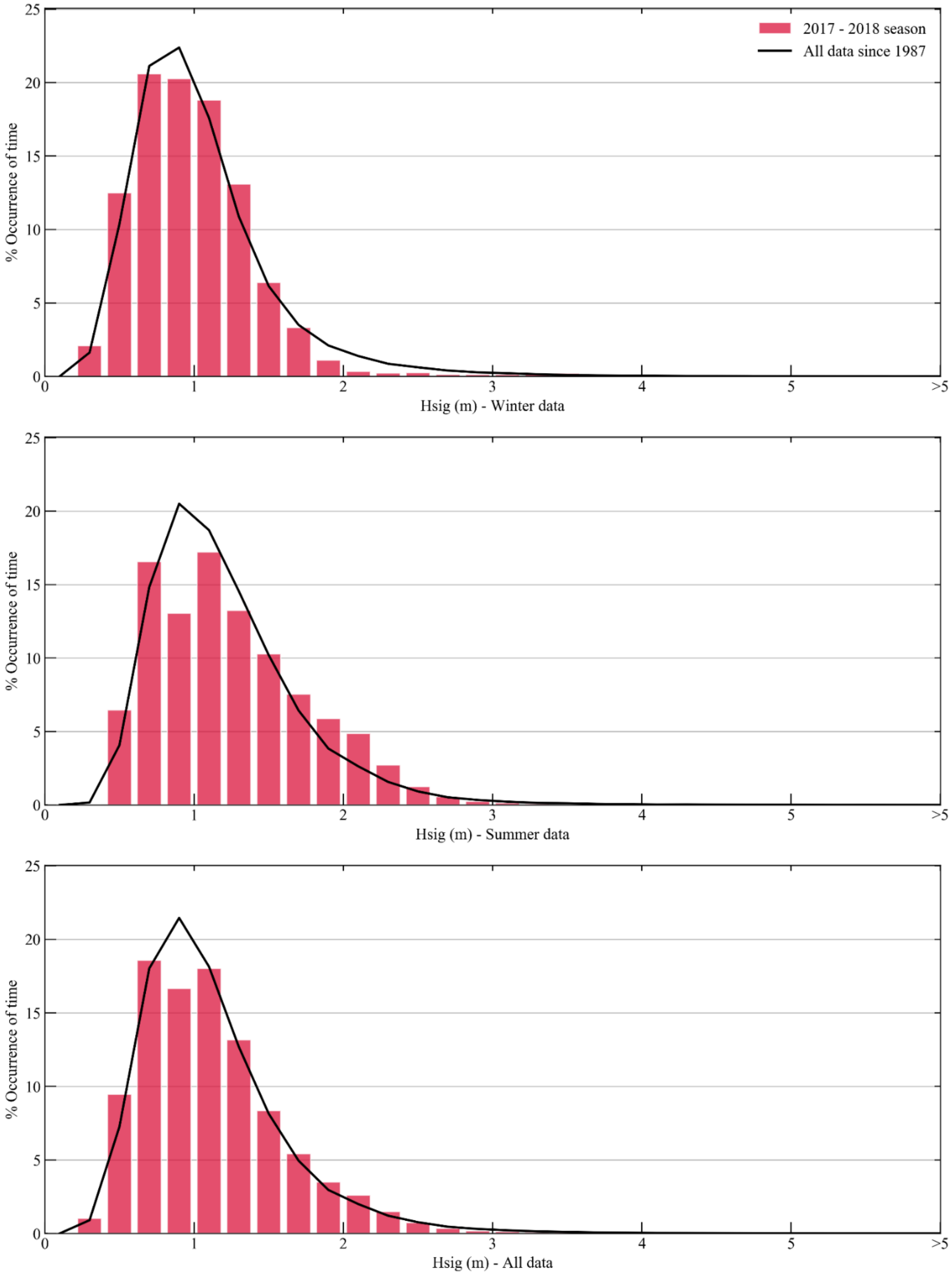


Figure 27 Gold Coast – histogram percentage (of time) occurrence of wave heights (H_s)

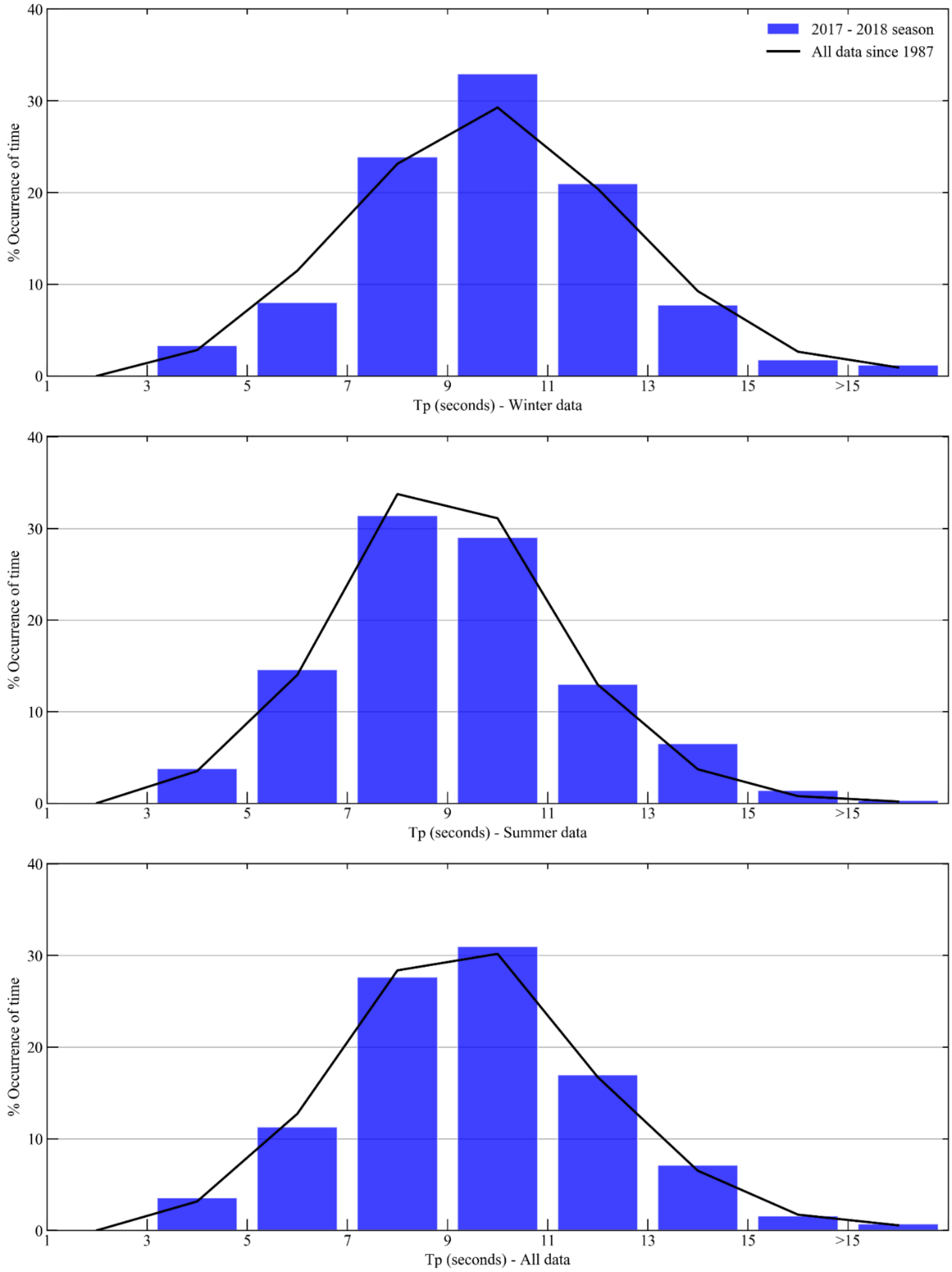


Figure 28 Gold Coast – histogram percentage (of time) occurrence of wave periods (T_p)

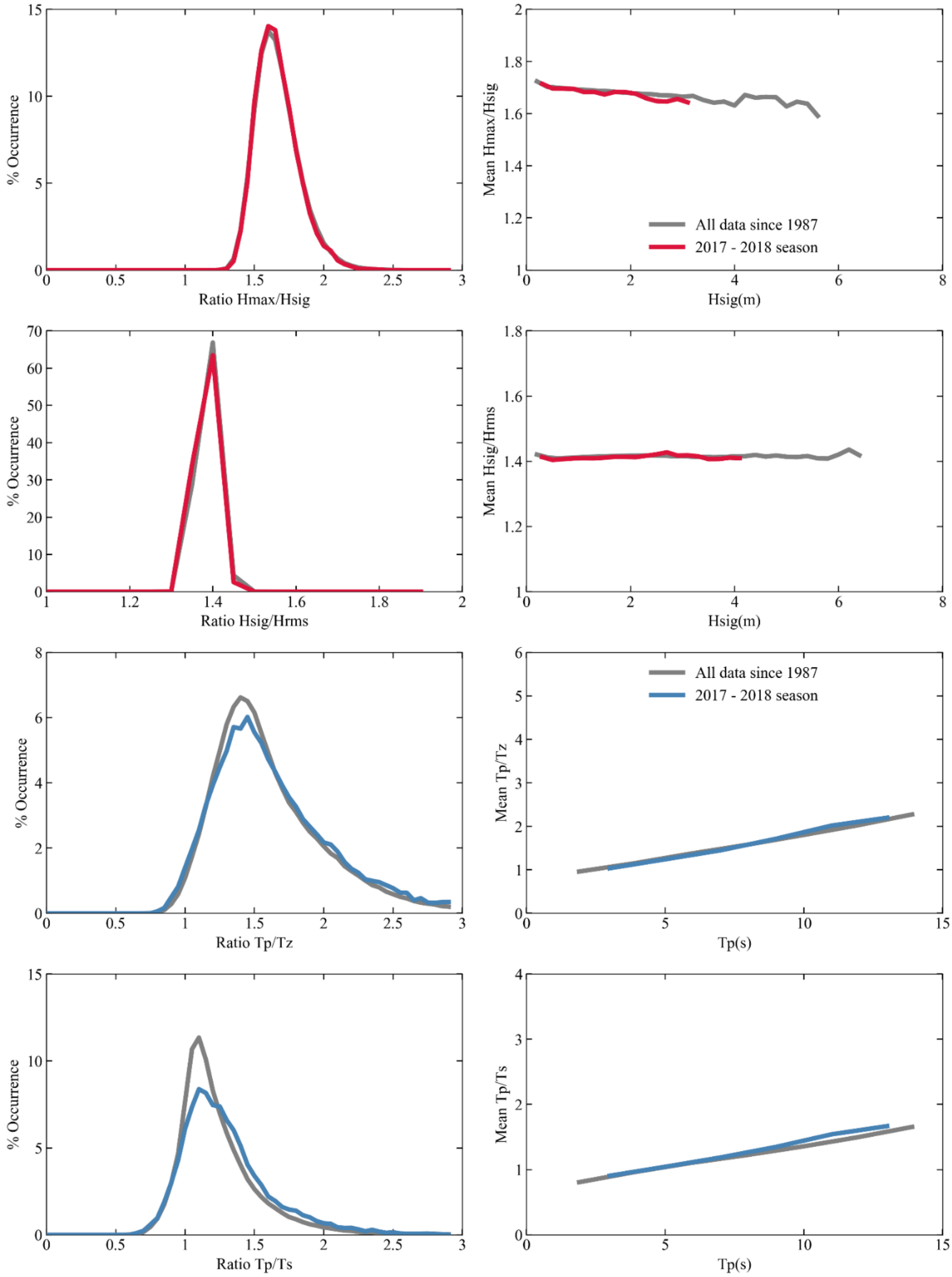


Figure 29 Gold Coast – wave parameter relationships

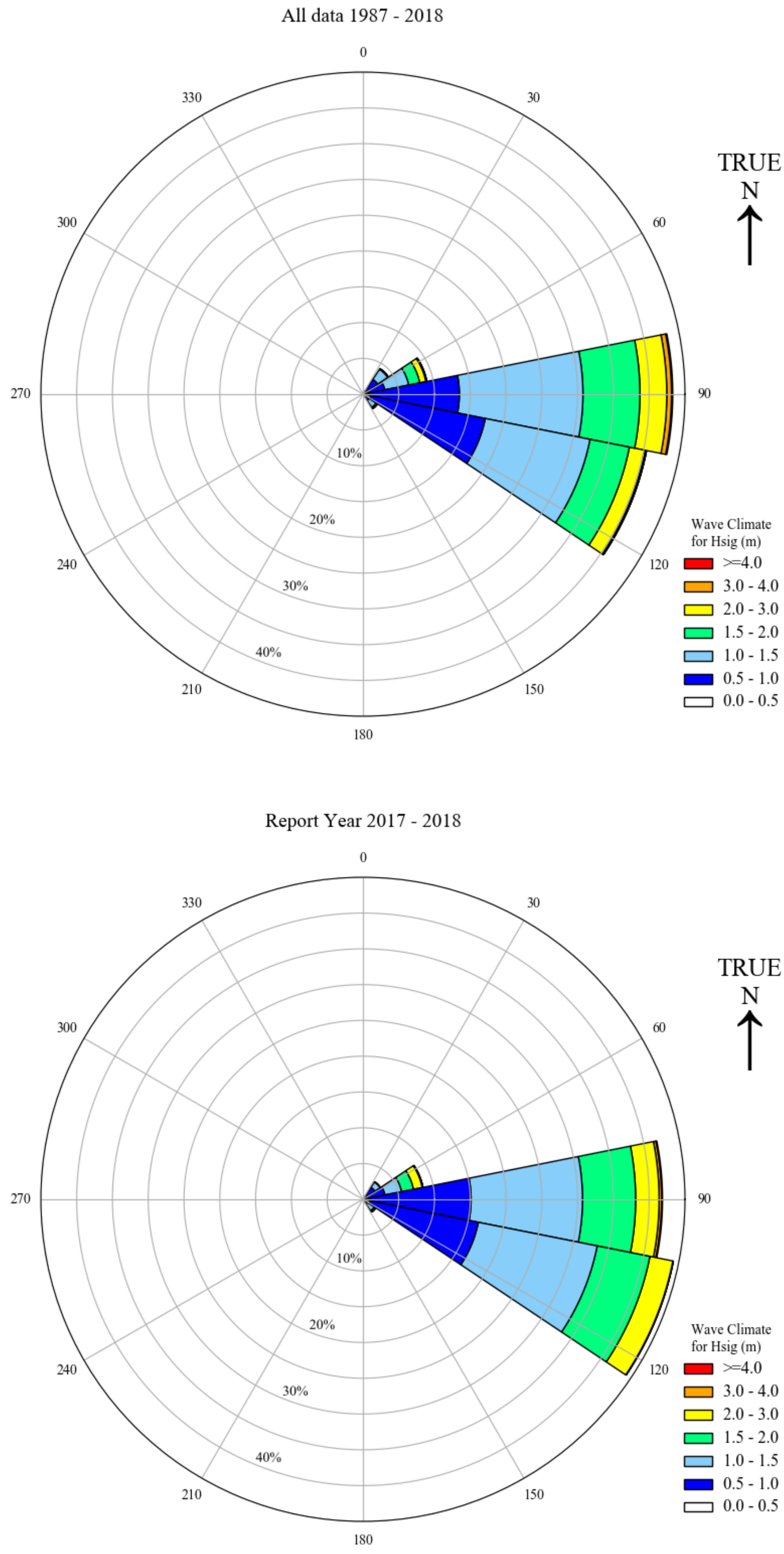


Figure 30 Gold Coast – directional wave rose

Brisbane

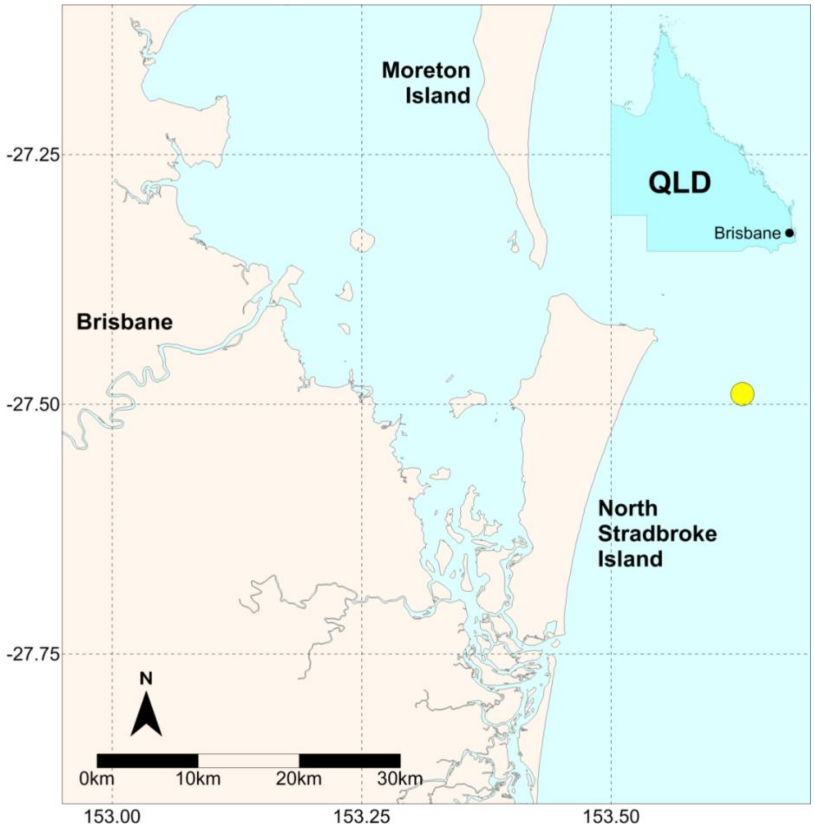


Figure 31 Brisbane – Locality plan

Table 17 Brisbane – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	31/10/1976	NA	387,777	42
2017 - 2018	01/11/2017	24.5 days	16,342	1

Table 18 Brisbane – buoy deployments during the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
27°29.721' S	153°37.919' E	DWR4	77	26/09/2017	22/12/2017
27° 29.420' S	153° 38.044' E	DWR4	80	22/12/2017	current

Brisbane – seasonal overview

The Brisbane wave buoy has been operational for 42 years. The data return for the period November 2017 to October 2018 was reasonable, with total gaps of 24.5 days, equivalent to a 93 percent data return. Increases in wave height from the influence of a low-pressure system during October were captured by the wave buoy (Table 20) and recorded the largest waves throughout the reporting period with a H_s of 6 m and H_{max} of 10.5 metres. There were no measured wave heights during the reporting period that ranked in the top ten highest waves for Brisbane (Table 19). The monthly average Hs for the recording period was within one sd of the entire record except for November, March, September and October where Hs was above 1 sd (Figure 34).

The wave climate during the reporting period was very similar to the wave climate of the entire record, as seen in the percentage exceedance plot (Figure 35). Histograms of percentage occurrence of Hs (Figure 36) show a lower occurrence of wave heights: 0.8 to 1.8 m in winter and 1.0 to 2.0 m in summer. A higher percentage occurrence of H_s of 1.8 to 2.2 m in winter and over 2.2 m in summer is also evident. Histograms of the occurrence of Tp (Figure 37) show a similar trend between the reporting period and the long-term record, with a higher occurrence of 9-13 second period waves and lower occurrence of 5-7 second period wave in winter. During summer the percentage occurrence of waves with period 7-11 seconds was lower. Tp most frequently ranged from 7 to 11 seconds overall. The ratio between different wave parameters such as Hmax/Hs and Tp/Ts were consistent between this reporting period and all of the historic data (Figure 38).

Time series for wave direction (

Figure 33) indicates dominant wave directions between south and east with occasional swings to the north. The directional wave rose plots (Figure 39) show that incident wave direction was more frequent from the south to south-east but with a broad spread from east to south. The infrequent swing to the north occurs less than 5 percent of the time. The wave directions for the reporting period are very similar to the entire record. The temperature (sea surface temperature, SST) measured in the buoy hull showed a range of 19 °C to 29 °C (

Figure 33). The SST from mid-December to the end of April was predominantly warm enough for tropical cyclone development.

Table 19 Brisbane – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	17/03/1993 10:30	7.4	4/03/2006 21:00	16.8
2	4/03/2006 9:00	7.2	5/03/2004 17:30	14.3
3	28/01/2013 7:30	7.1	17/03/1993 3:30	13.1
4	5/03/2004 17:30	7	2/05/1996 14:00	12.8
5	2/05/1996 20:30	6.9	16/01/2018 21:30	12.3
6	15/02/1995 6:00	6.4	15/02/1995 6:30	12.2
7	23/08/2008 23:00	6.4	28/01/2013 7:30	12.1
8	12/06/2012 9:30	6.4	15/02/1996 19:00	12.1

9	6/06/2012 19:30	6.3	15/10/2018 22:30	12.1
10	31/12/2007 3:00	6.3	26/03/1998 7:00	11.5

Table 20 Brisbane – significant meteorological events with threshold H_s of 4.0 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
17/01/2018 3:30	5.9	12.3	13.7	A low-pressure system developed in the Tasman sea, with a low-pressure trough off the east coast.
7/03/2018 14:00	4.8	9.9	9.8	TC Hola developed on the 3rd, moving westward, however stayed well off the east coast.
1/06/2018 3:00	4.1	7.2	10.2	A series of cold fronts tracked across the southern coast and southeast Australia at the end of May.
15/10/2018 23:30	6	12.1	11.1	A low-pressure system developed on the 14th in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

Notes: 1. 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).

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

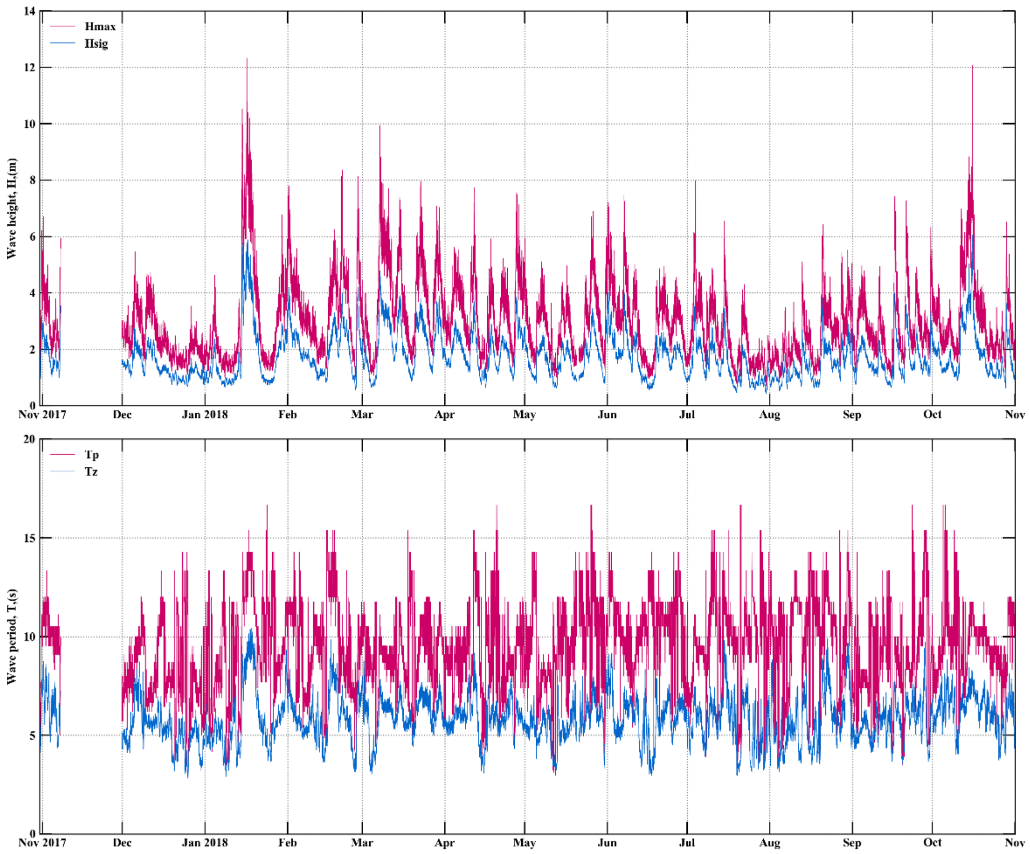


Figure 32 Brisbane – daily wave recordings

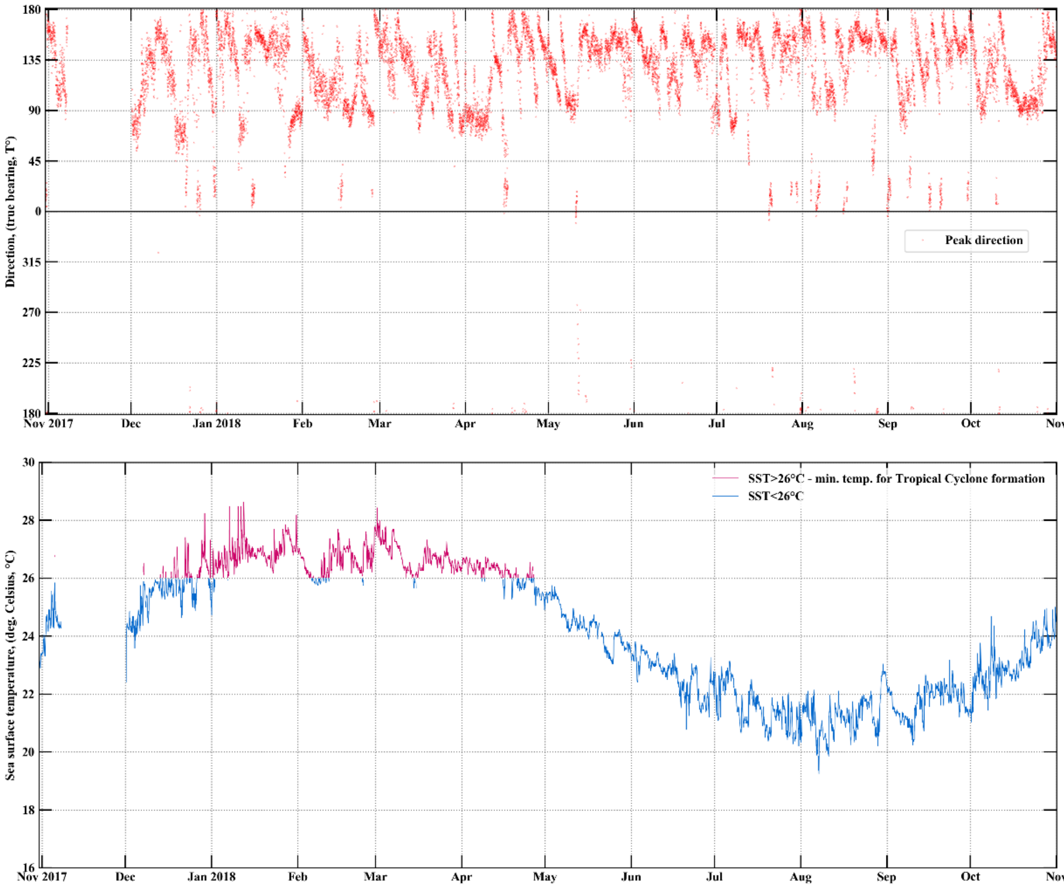


Figure 33 Brisbane – peak wave direction and sea surface temperature

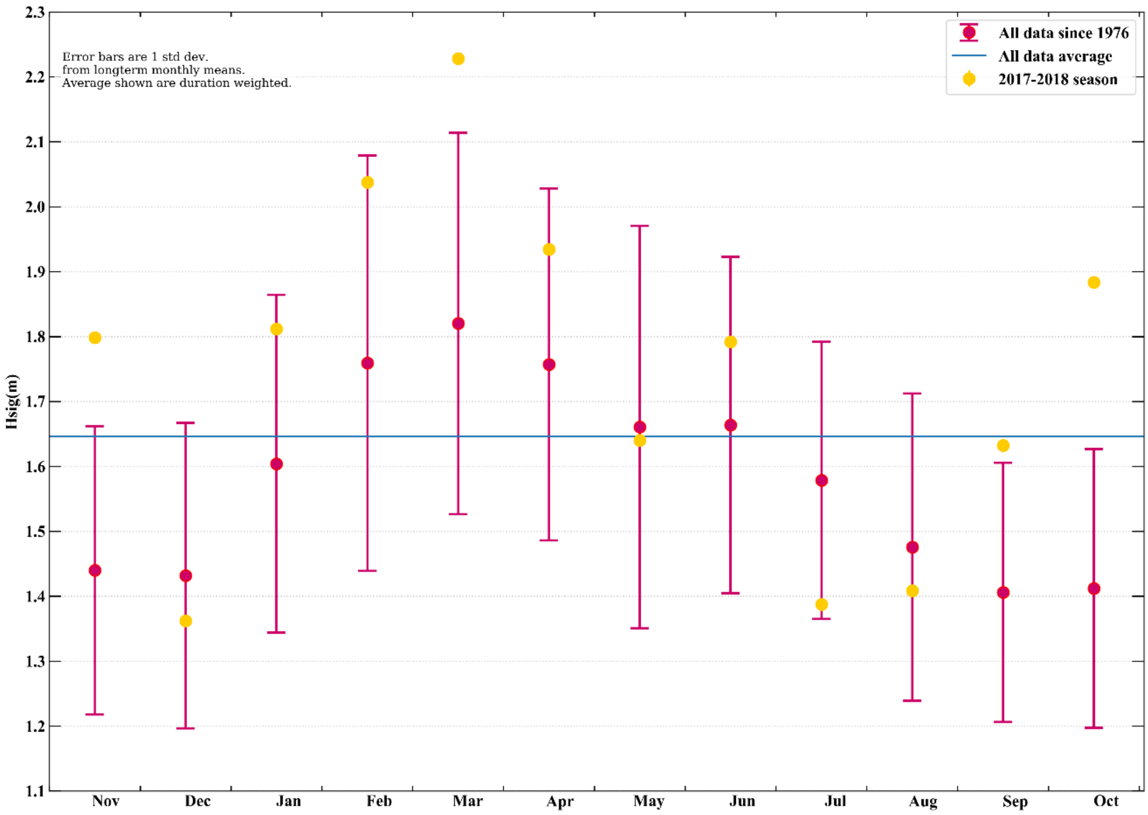


Figure 34 Brisbane – monthly average wave height (H_s) for 2017-18 and for all data

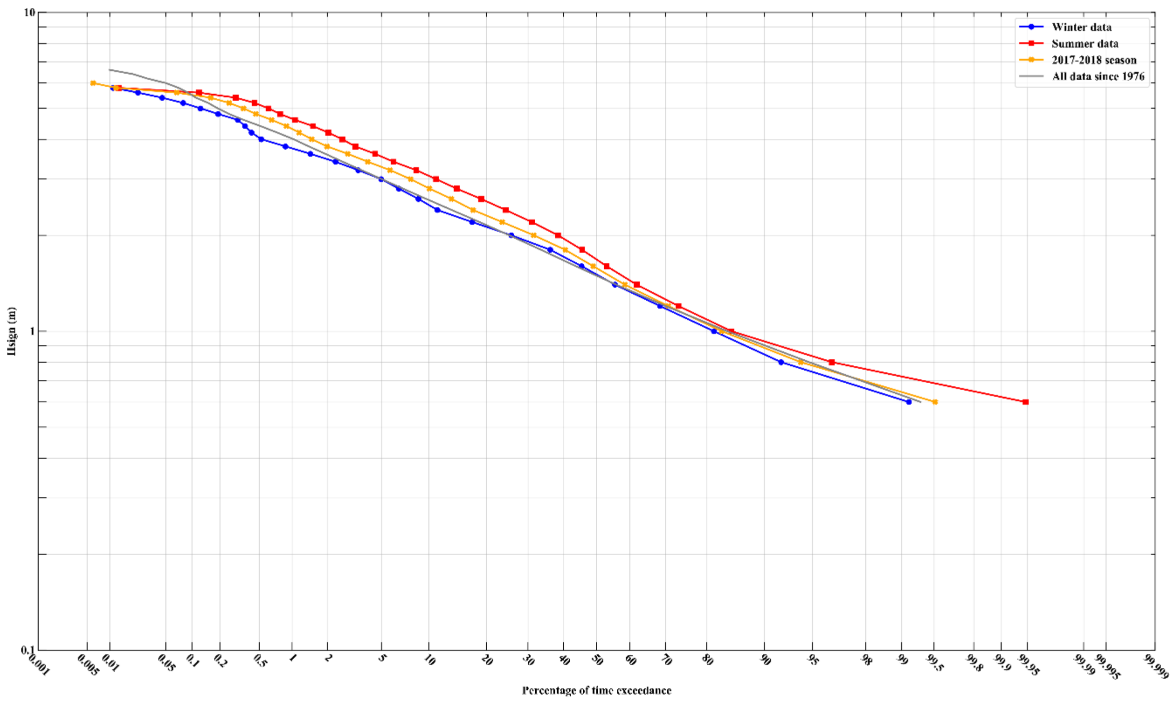


Figure 35 Brisbane – percentage exceedance of wave height (H_s) for all wave periods (Tp)

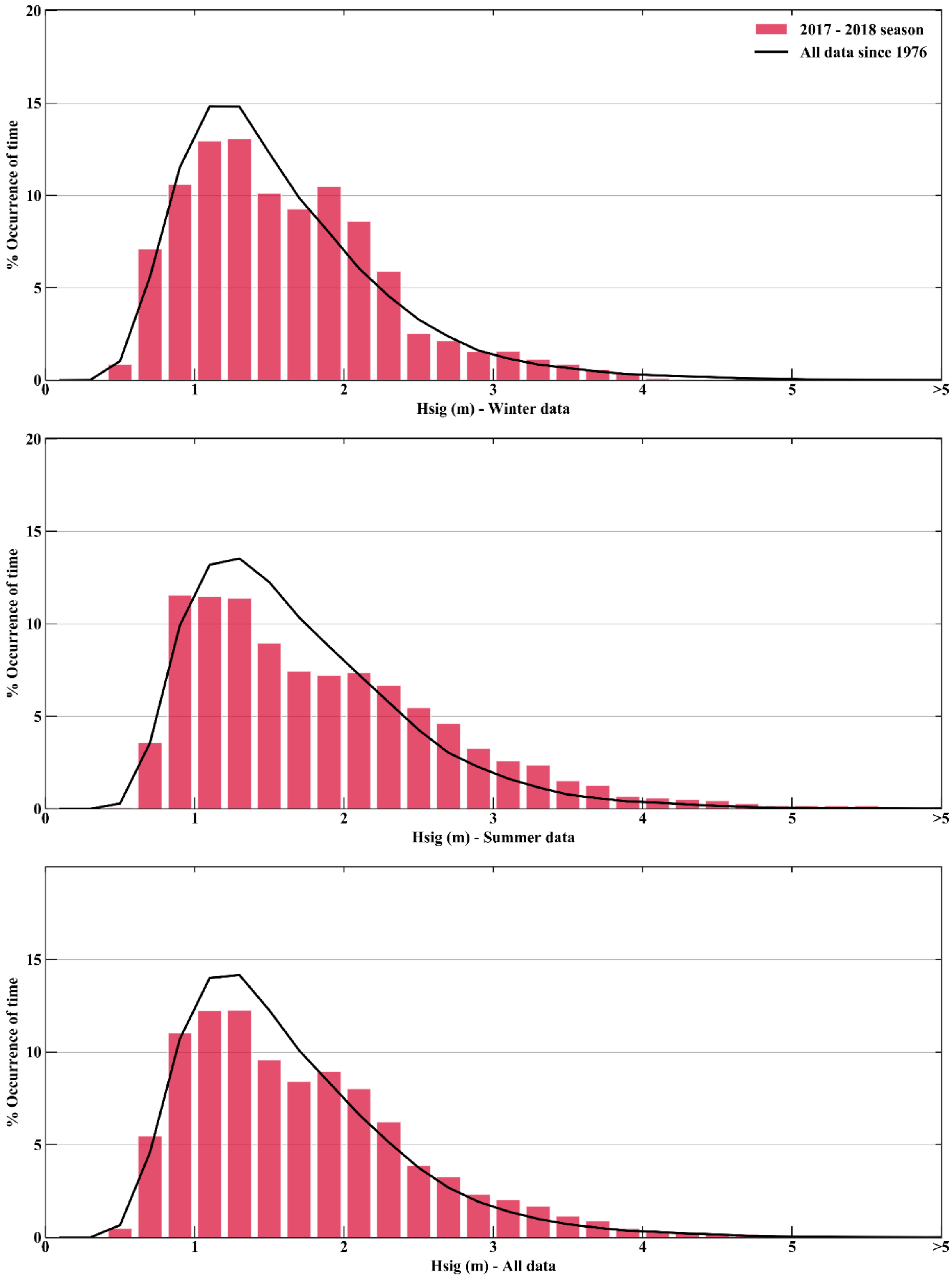


Figure 36 Brisbane – histogram percentage (of time) occurrence of wave heights (H_s)

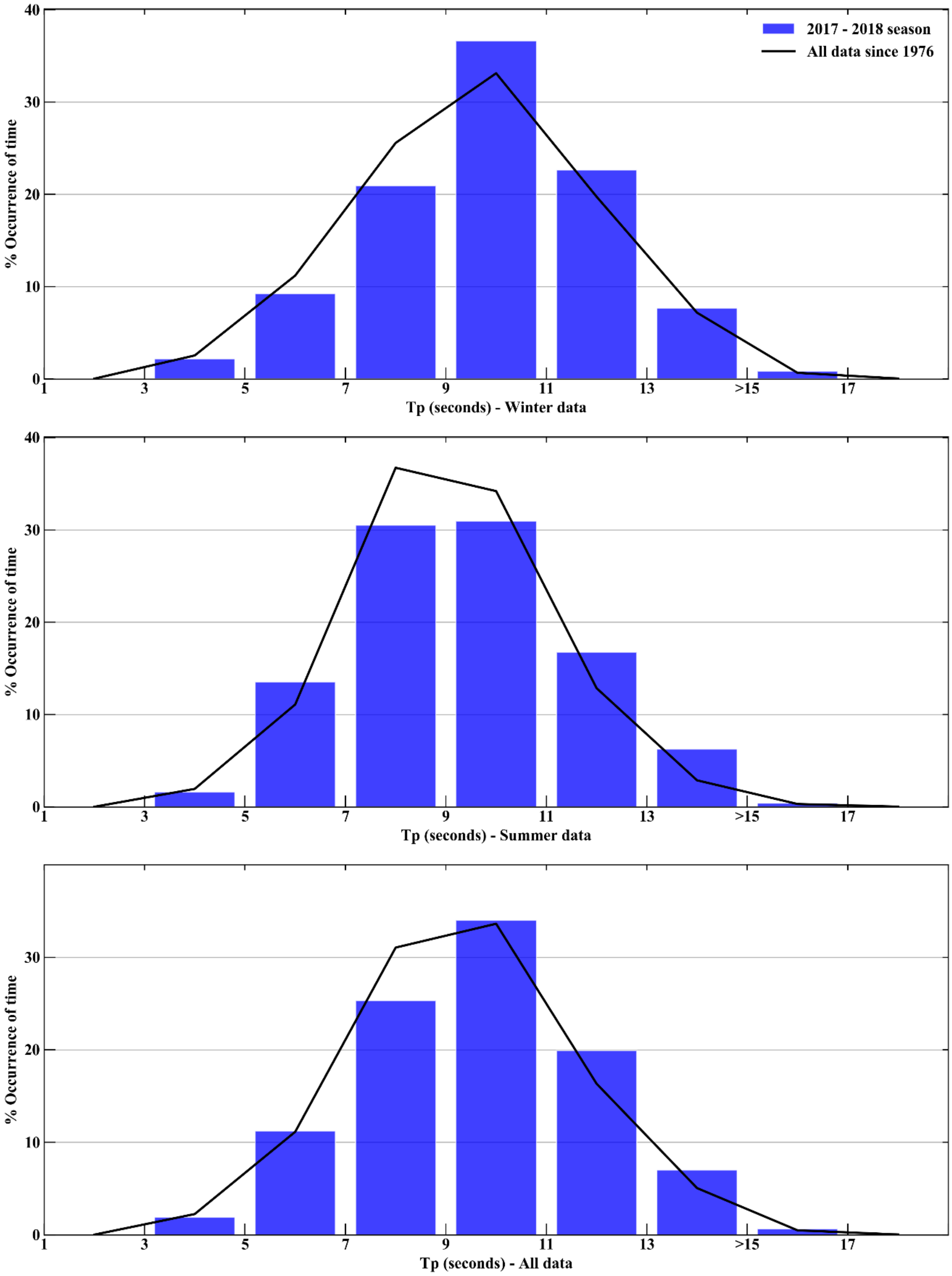


Figure 37 Brisbane – histogram percentage (of time) occurrence of wave periods (T_p)

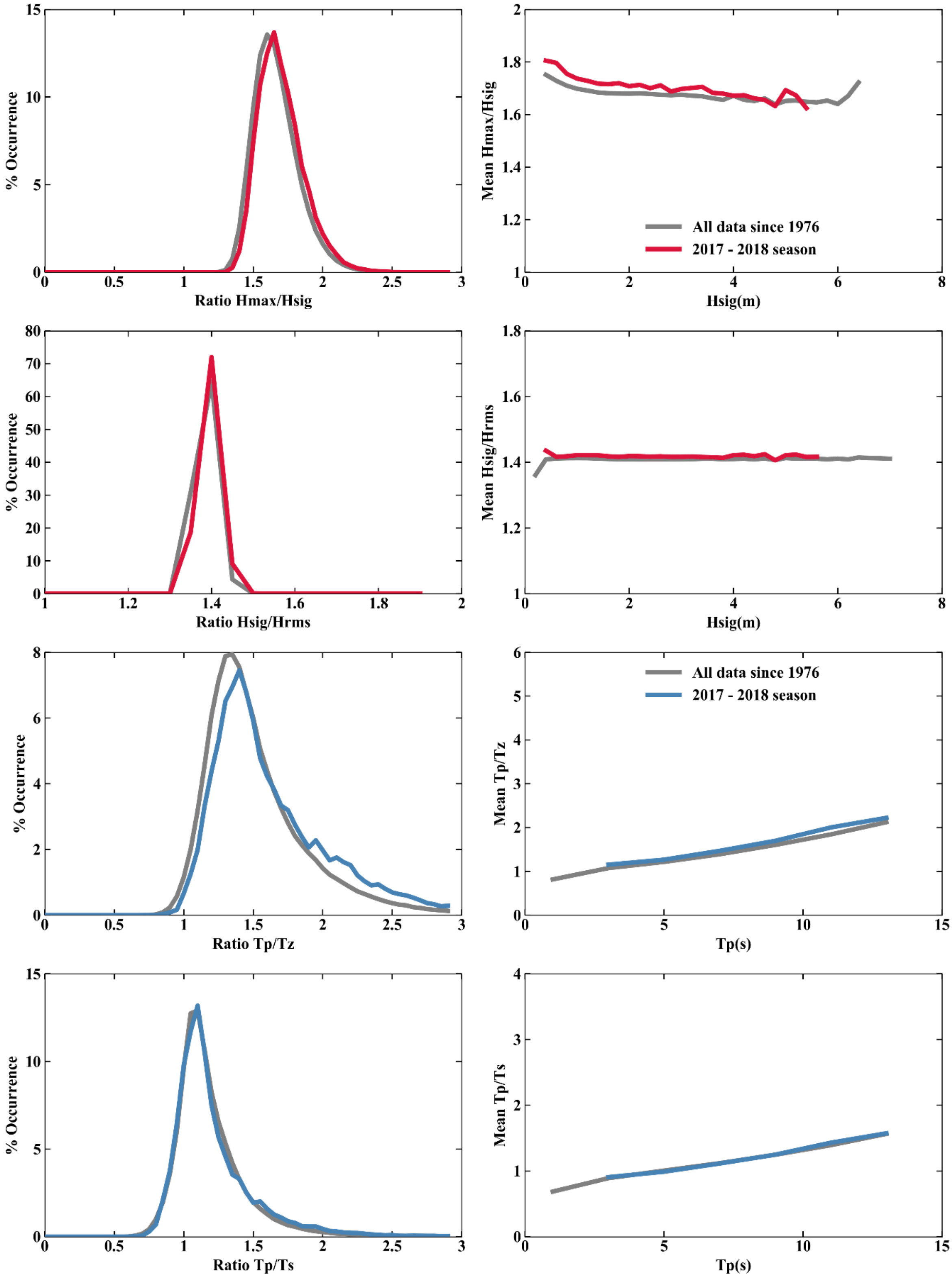


Figure 38 Brisbane – wave parameter relationships

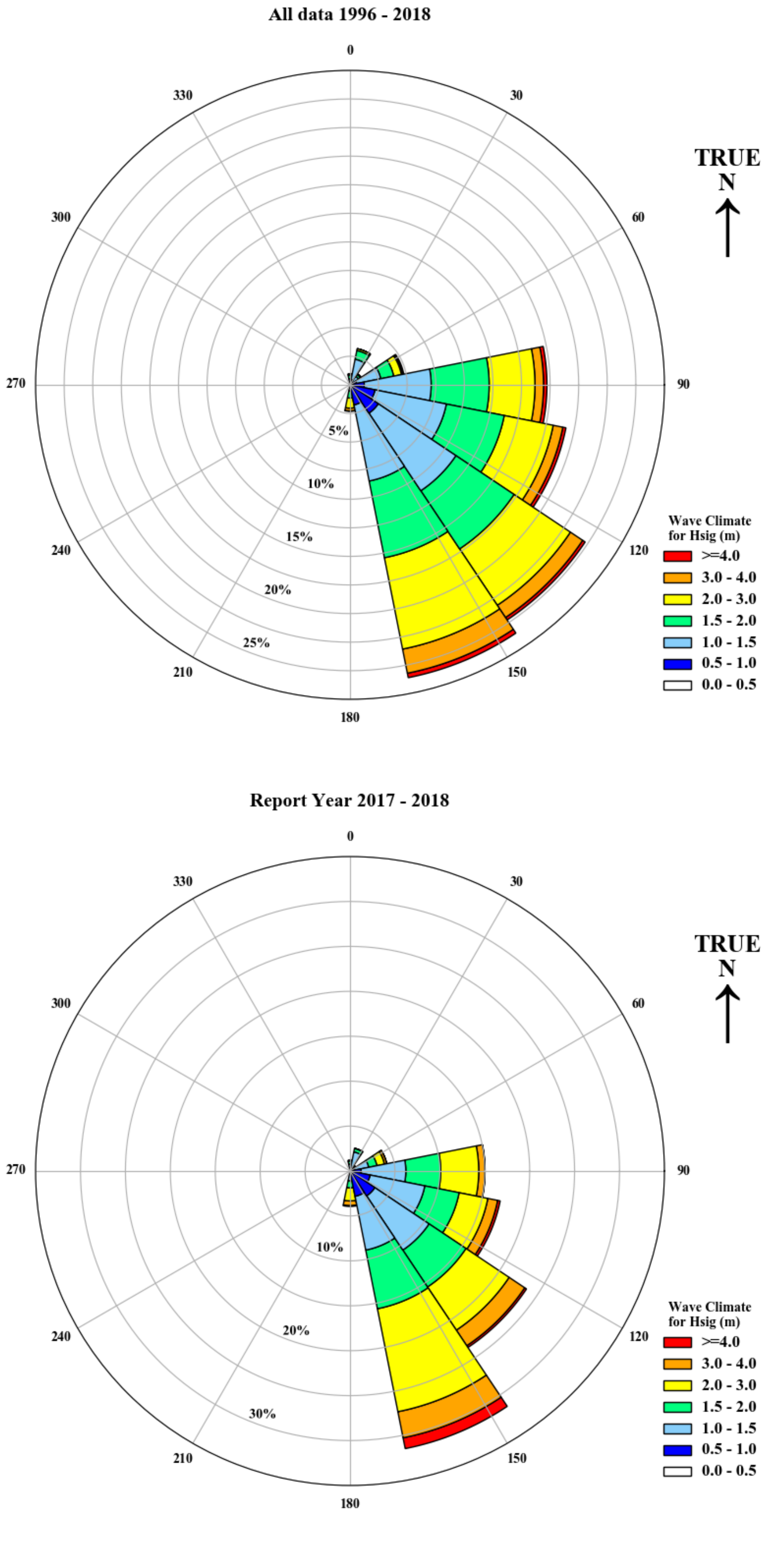


Figure 39 Brisbane – directional wave rose

North Moreton

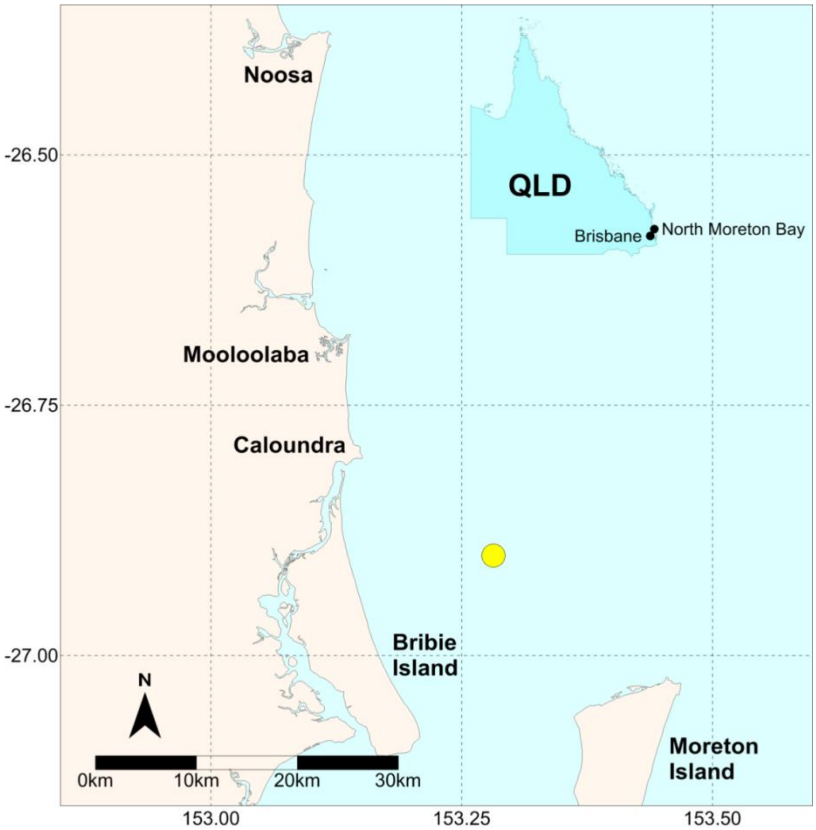


Figure 40 North Moreton – locality plan

Table 21 North Moreton – Wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	31/10/2010	0.07 (years)	142,891	8.24
2017-18	01/11/2017	2.44 (days)	17,402	1

Table 22 North Moreton – buoy deployments during the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
26°53.000' S	153°16.900' E	DWR-GPS	35	28/06/2017	current

North Moreton – seasonal overview

The North Moreton wave buoy has been operational for over 8 years with an overall data return of 98 per cent. The data recorded for the period November 2017 to October 2018 was excellent, with total gaps of 2.44, equivalent to a 99 percent data return. The buoy was not changed throughout the reporting period (Table 21 and Table 22).

Throughout the 2017-2018 reporting period the North Moreton site was subject to five storm events (Table 24), however none of these events had waves large enough to make the top ten highest waves (Table 23).

The SST (Figure 42) measured in the buoy hull ranged from 19 °C to 29 °C. The SST from December to the end of March was predominantly warm enough for tropical cyclone development.

The monthly average for the recording period fell within one sd of the monthly average of the entire record for every month during the reporting period (Figure 43).

The wave climate during the reporting period was similar to the wave climate of the whole record with the exception of wave heights over 3 metres which were less frequent, as seen in the percentage exceedance plot. The summer months resulted in more frequent waves below 2.5 m compared to the reporting period (Figure 44). Histograms for occurrence of H_s (Figure 45) show a higher occurrence of waves of 0.8 – 1.0 m for summer and a greater occurrence of the modal 0.4 – 0.6 m H_s waves during winter for the reporting period compared to the long term record. Histograms of the occurrence of peak wave periods (Tp) (Figure 46) for the recording period show a good comparison for the reporting period compared to the long term record.

The ratios between different wave parameters such as Hmax/H_s were consistent between this reporting period, with slight variations seen in Tp/Tz and Tp/Ts, these are plotted in Figure 47.

The time series for wave direction (Figure 42) shows a peak wave direction generally from the east, with swings to the north throughout spring and early summer. This is also reflected in the directional wave rose plots (Figure 48). The wave directions for the reporting period are very similar to the entire record.

Table 23 North Moreton – highest waves

Rank	Date (H_s)	H_s (m)	Date (Hmax)	Hmax (m)
1	27/01/2013 22:00	5.9	27/01/2013 23:30	10.3
2	01/05/2015 15:30	4.9	01/05/2015 13:30	9.6
3	04/06/2016 09:00	4.1	30/03/2017 19:30	7.5
4	25/12/2011 07:00	3.9	25/12/2011 07:00	7.3
5	30/03/2017 19:00	3.8	04/06/2016 09:30	6.5
6	19/02/2013 11:30	3.5	19/02/2013 15:30	6.3
7	28/06/2012 02:30	3.2	19/02/2015 11:00	6.2
8	17/01/2012 06:30	3	28/06/2012 05:30	5.7
9	12/10/2010 13:30	3	22/08/2011 08:30	5.7
10	19/02/2015 12:30	3	27/03/2014 22:30	5.7

Table 24 North Moreton – Significant meteorological events with threshold H_s of 2.2 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
18/02/2018 12:30	2.5 (2.8)	4.6 (5.9)	14.2	TC Gita was located to the southeast of New Caledonia on the 15th before passing over the Tasman Sea and wakening to a low-pressure system on the 19th.
15/03/2018 11:00	2.5 (2.9)	4.0 (4.7)	10.8	TC Linda developed in the northeaster Coral Sea on the 13th before weakening into a low-pressure system.
30/03/2018 0:30	2.5 (2.7)	4.1 (5.3)	11.3	TC Iris entered Australian waters on the 24th weakening to a low-pressure system. Remnants of TC Iris stayed off the central QLD coast from the 29th until the end of the month.
5/04/2018 3:30	2.3 (2.5)	3.7 (4.7)	9.2	Ex-TC Iris redeveloped on the 2nd and tracked south before being downgraded to an ECL on the 6th.
15/10/2018 22:30	2.9 (2.9)	4.7 (5.4)	11	A low-pressure system developed on the 14th in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

Notes: 1. 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).

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

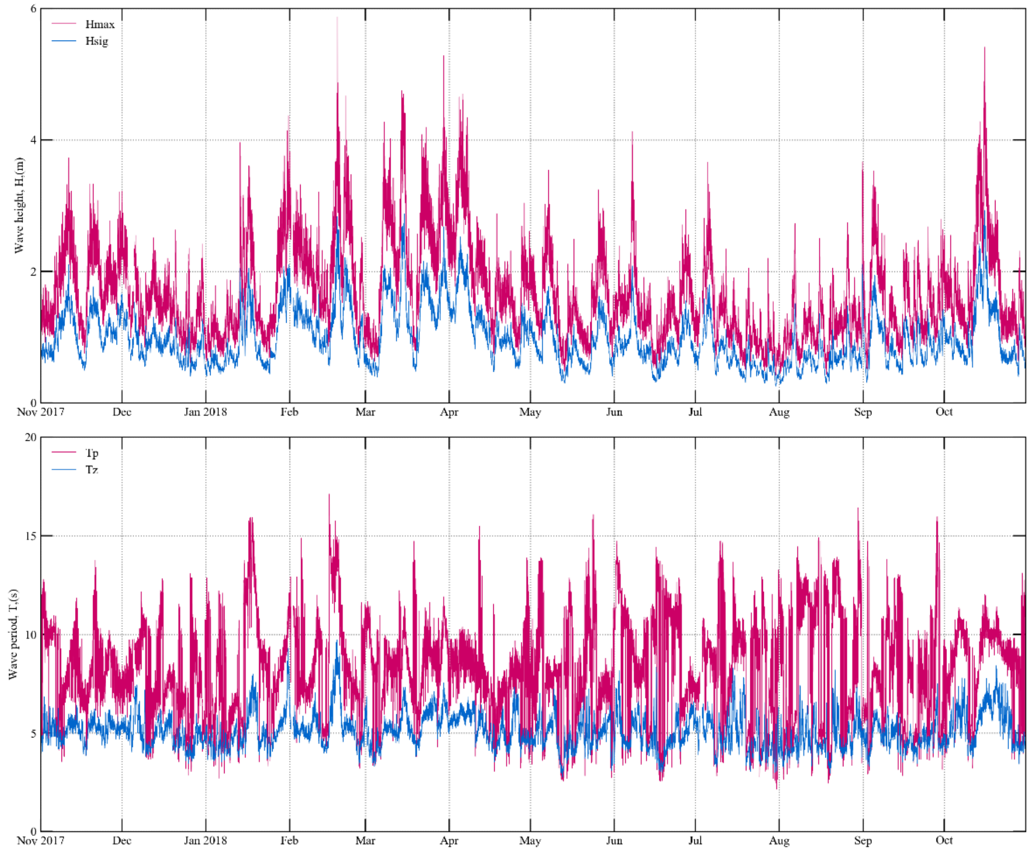


Figure 41 North Moreton – daily wave recordings

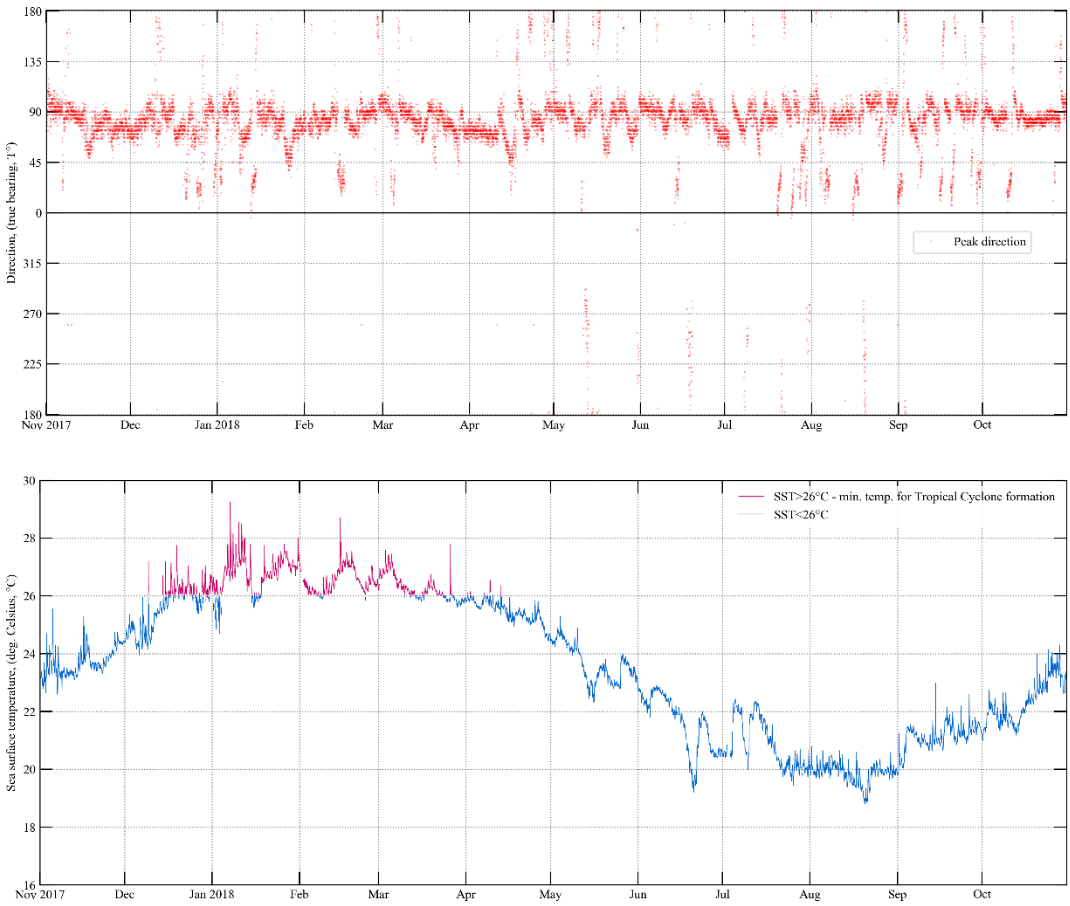


Figure 42 North Moreton – peak wave direction and sea surface temperature

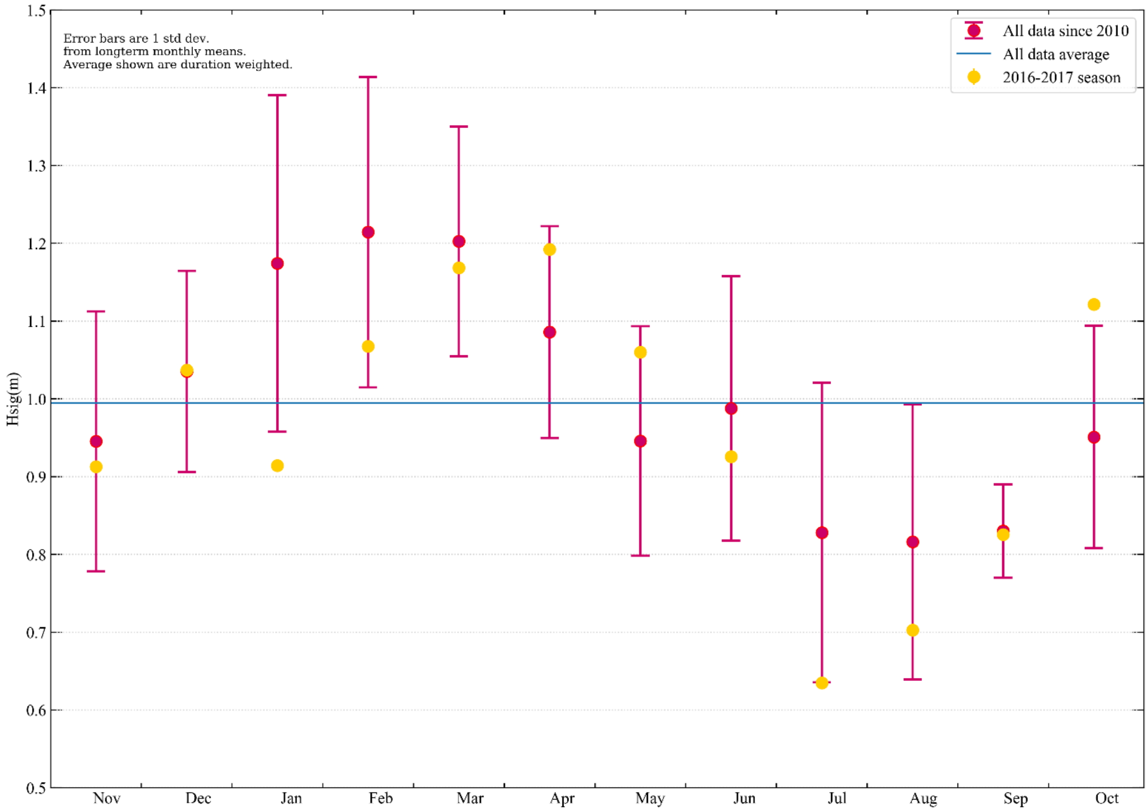


Figure 43 North Moreton – monthly average wave height (H_s) for 2017-18 and for all data

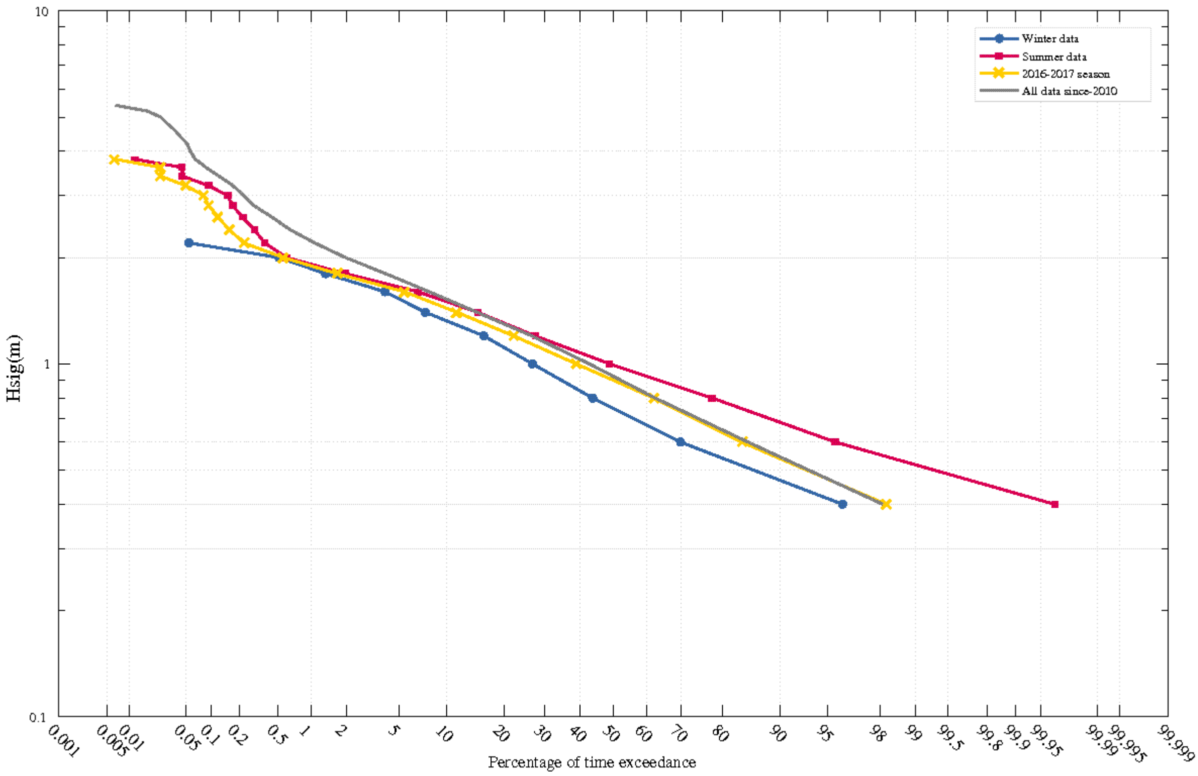


Figure 44 North Moreton – percentage exceedance of wave height (H_s) for all wave periods (Tp)

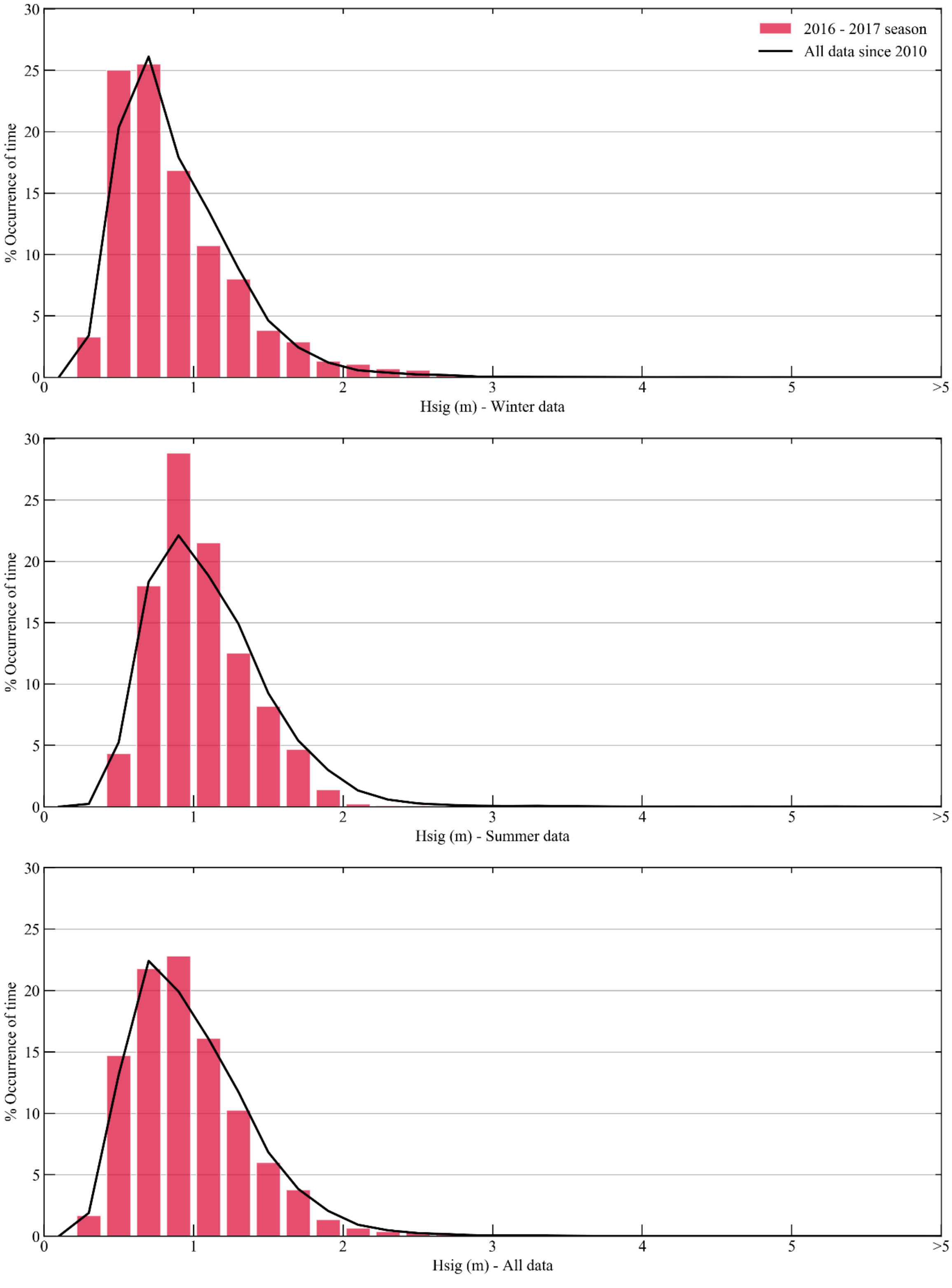


Figure 45 North Moreton – histogram percentage (of time) occurrence of wave heights (H_s)

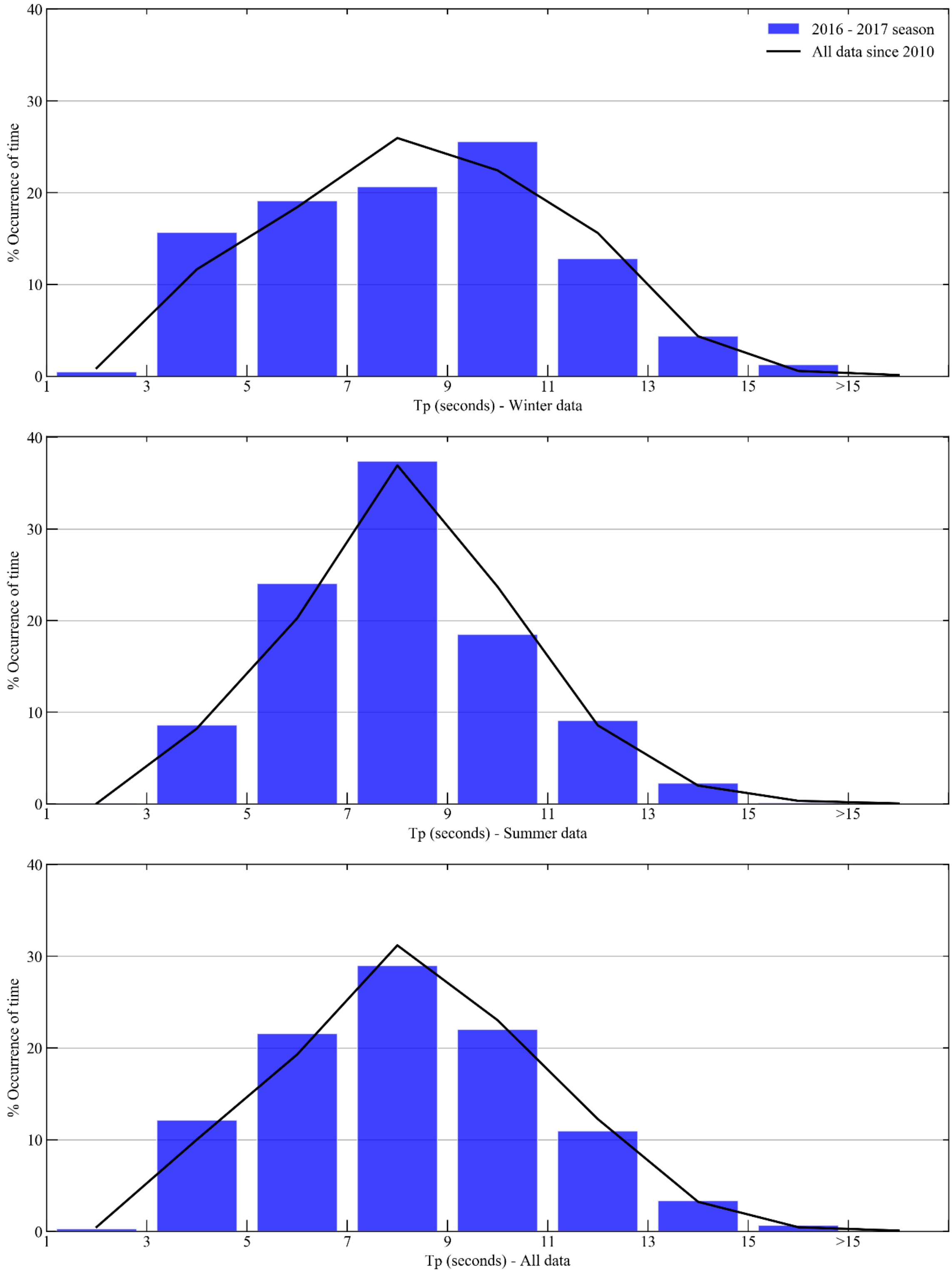


Figure 46 North Moreton – histogram percentage (of time) occurrence of wave periods (T_p)

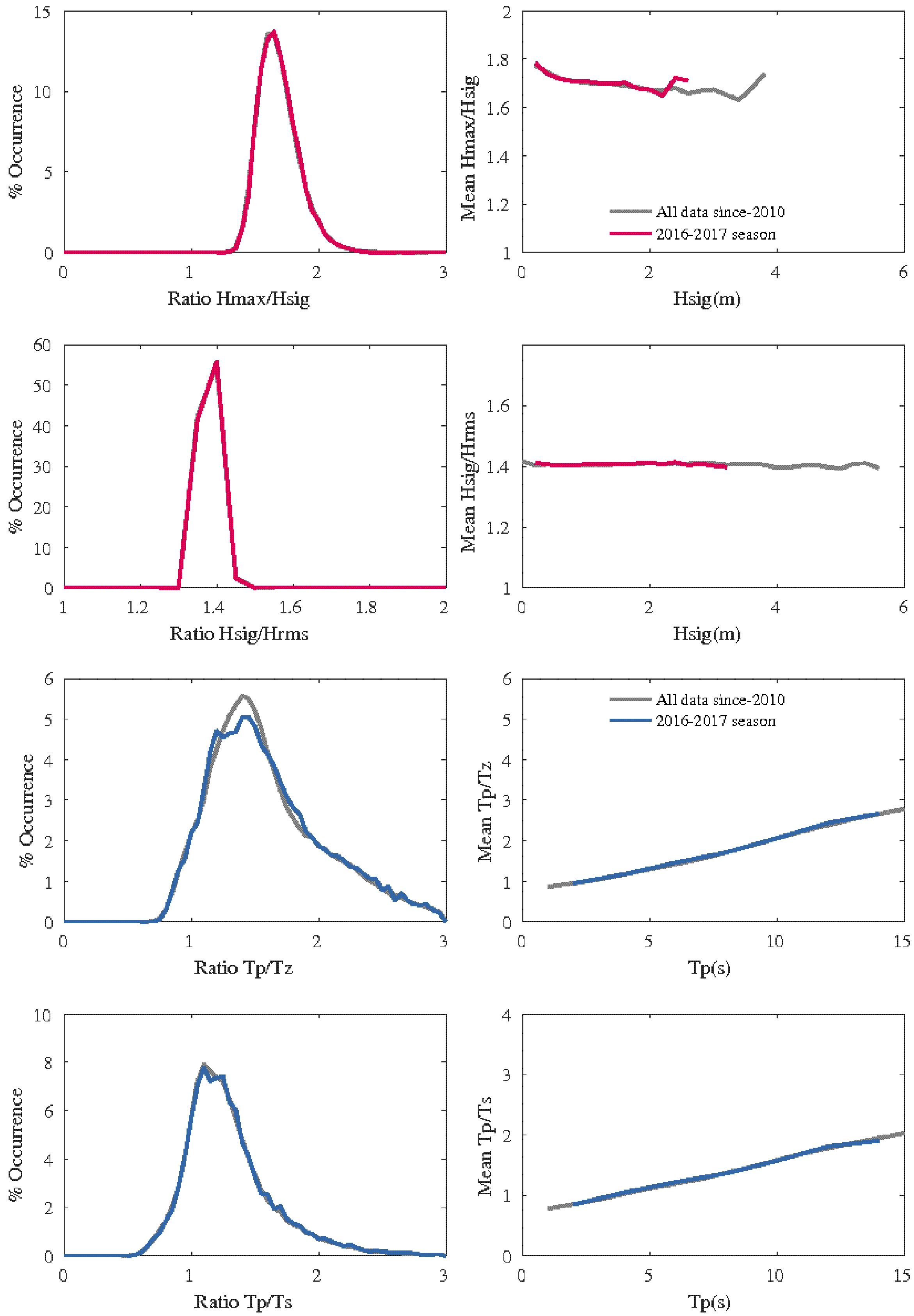
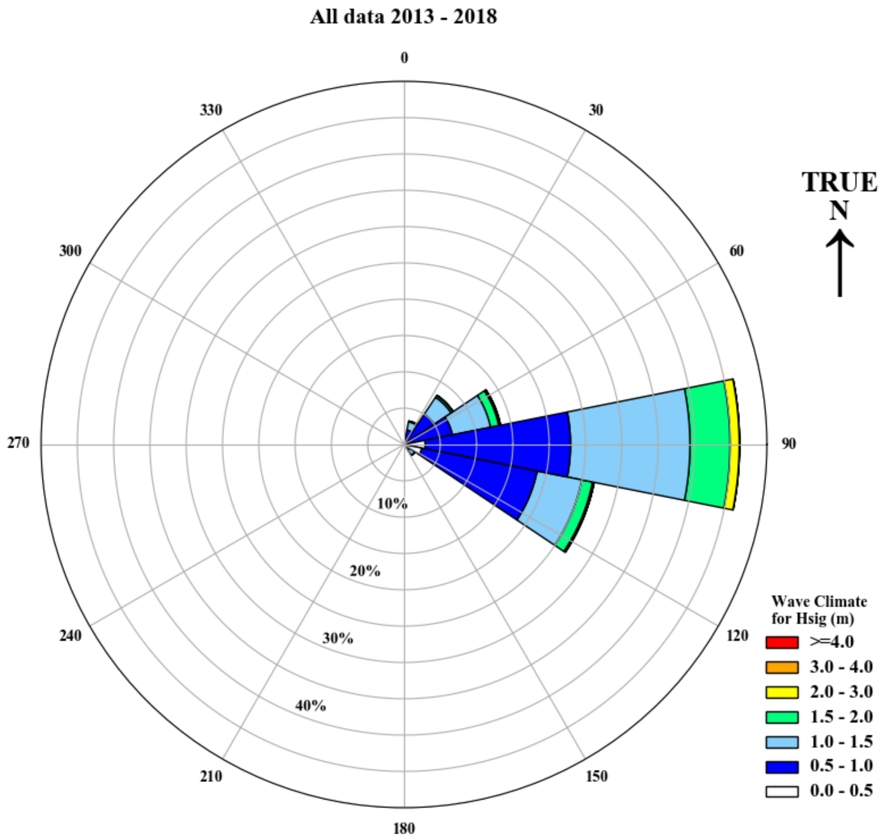


Figure 47 North Moreton – wave parameter relationships



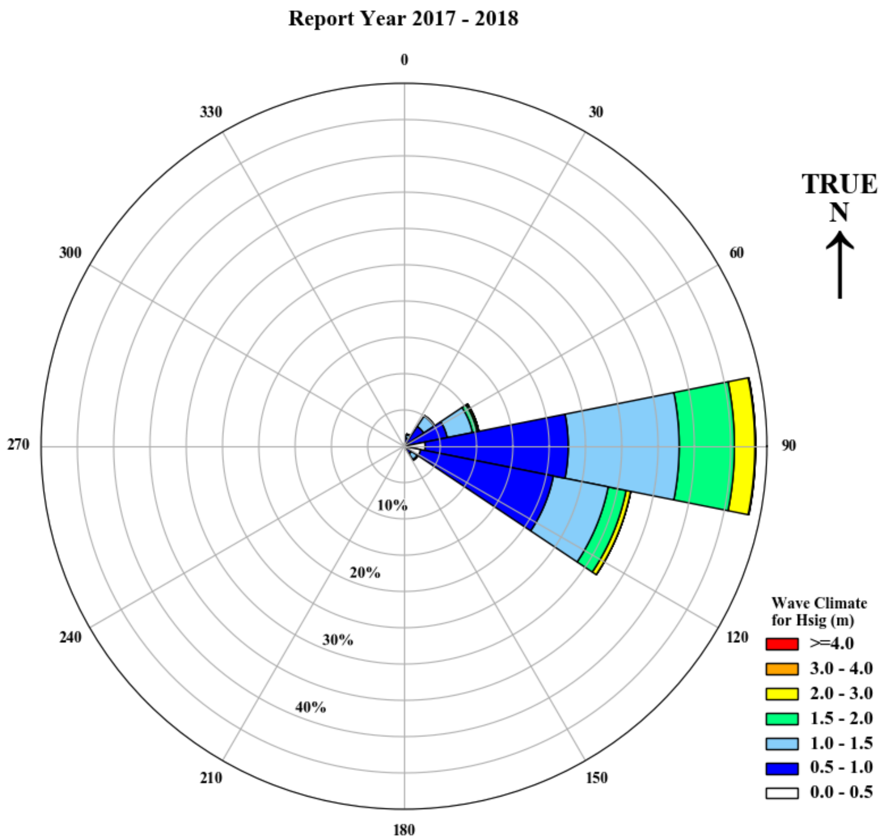


Figure 48 North Moreton – directional wave rose

Caloundra

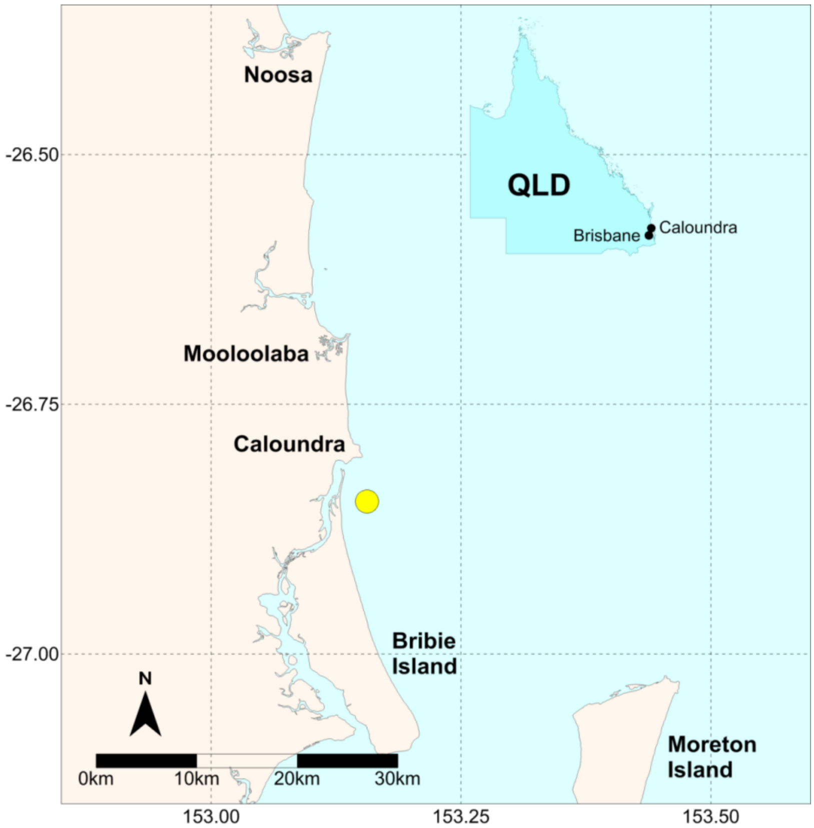


Figure 49 Caloundra – Locality plan

Table 25 Caloundra – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	01/05/2013	0.22 years	92,916	5.52
2017-18	01/11/2017	7.17 days	17,176	1

Table 26 Caloundra – buoy deployments for 2017-18 season

Latitude	Longitude	Type Buoy	Depth (m)	Deployed date	Removal date
26° 50.802' S	153° 09.300' E	DWR-MkIII	18	01/01/2017	14/04/2018
26° 50.798' S	153° 09.348' E	DWR-MkIII	17	14/04/2018	current

Caloundra – seasonal overview

The Caloundra wave buoy has been operational since 01 May 2013 with an overall data return of 97.6 per cent. The data record for the period November 2016 to October 2017 was good, with total gaps of 7.17 days, equivalent to 98.3 per cent data return. The buoy was replaced once during the reporting period, see Table 26.

The Caloundra site was subject to five significant wave events during the reporting period (Table 28) which resulted in five top ten H_s and three top-ten for H_{max}. A low-pressure event during October generated the highest wave for the reporting period (Table 28) as seen in the time series of wave heights for Caloundra (Figure 50). The largest waves were on 15-16 of October with a H_s of 3.7 m and a maximum wave height (H_{max}) of 5.5 m, both ranked third and fifth respectively for the Caloundra site. Except for November, March, April, and October all of the monthly average H_s (Figure 52) for the recording period fell within one standard deviation (sd) of the monthly average of the entire record.

The wave climate during the reporting period was similar to the wave climate of the whole record however waves lower than 2.5 m H_s were more frequent in summer and wave heights below 2.0 m were less frequent in winter (Figure 53). Histograms for occurrence of H_s (Figure 54) show a higher occurrence of H_s of 0.6-0.8 m and lower occurrence of 1.0-1.2 m waves during winter and lower than H_s of 0.8-1.2 m in summer. The histogram for all data is comparable to all of the historical recorded data. Histograms for occurrence of peak wave period (Tp) (Figure 55) show a period of 7 to 11 seconds is most common throughout the year, with 9 to 11 seconds occurring more often in winter and 7 to 9 seconds more often in summer compared to historical data.

The time series for wave direction (Figure 51) show waves predominantly from the east, swinging at times to northeast. Directional wave rose plots (Figure 57) show the dominant east to east south-easterly wave directions. The temperature (sea surface temperature, SST) measured in the buoy hull showed a range of 18° C to 29 °C (Figure 51). The SST from mid-December to early March was warm enough for tropical cyclone development.

Table 27 Caloundra – highest waves

Rank	Date (H_s)	H_s (m)	Date (Hmax)	Hmax (m)
1	1/05/2015 17:00	4.5	1/05/2015 15:00	7.5
2	4/06/2016 16:30	3.9	30/03/2017 18:30	7
3	15/10/2018 22:30	3.7	4/06/2016 10:00	6.7
4	30/03/2017 18:30	3.7	19/02/2015 7:30	6.2
5	19/02/2015 7:30	3.2	16/10/2018 0:00	5.5
6	17/10/2017 13:00	2.8	16/10/2017 14:30	5.4
7	15/03/2018 0:00	2.7	27/03/2014 22:00	4.8
8	29/03/2018 23:00	2.7	14/03/2018 23:30	4.8
9	18/02/2018 22:30	2.7	19/06/2016 19:30	4.7
10	27/03/2014 21:00	2.6	29/03/2018 21:30	4.6

Table 28 Caloundra – Significant meteorological events with threshold H_s of 2.2 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
18/02/2018 22:30	2.4 (2.7)	3.9 (4.5)	14.1	TC Gita was located to the southeast of New Caledonia on the 15th before passing over the Tasman Sea and weakening to a low-pressure system on the 19th.
15/03/2018 0:00	2.5 (2.7)	4.2 (4.8)	9.9	TC Linda developed in the north-eastern Coral Sea on the 13th before weakening to a low-pressure system.
29/03/2018 23:00	2.6 (2.7)	4.0 (4.6)	11.3	TC Iris entered Australian waters on the 24th weakening to a low-pressure system. Remnants stayed off the central QLD coast from March 31.
5/04/2018 8:00	2.3 (2.4)	3.8 (4.5)	9	Ex-TC Iris redeveloped on the 2nd and tracked south before being downgraded to an ECL on the 6th.
15/10/2018 22:30	3.4 (3.7)	5 (5.5)	11.2	A low-pressure system developed on the 14th in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

Notes: 1. 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).

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

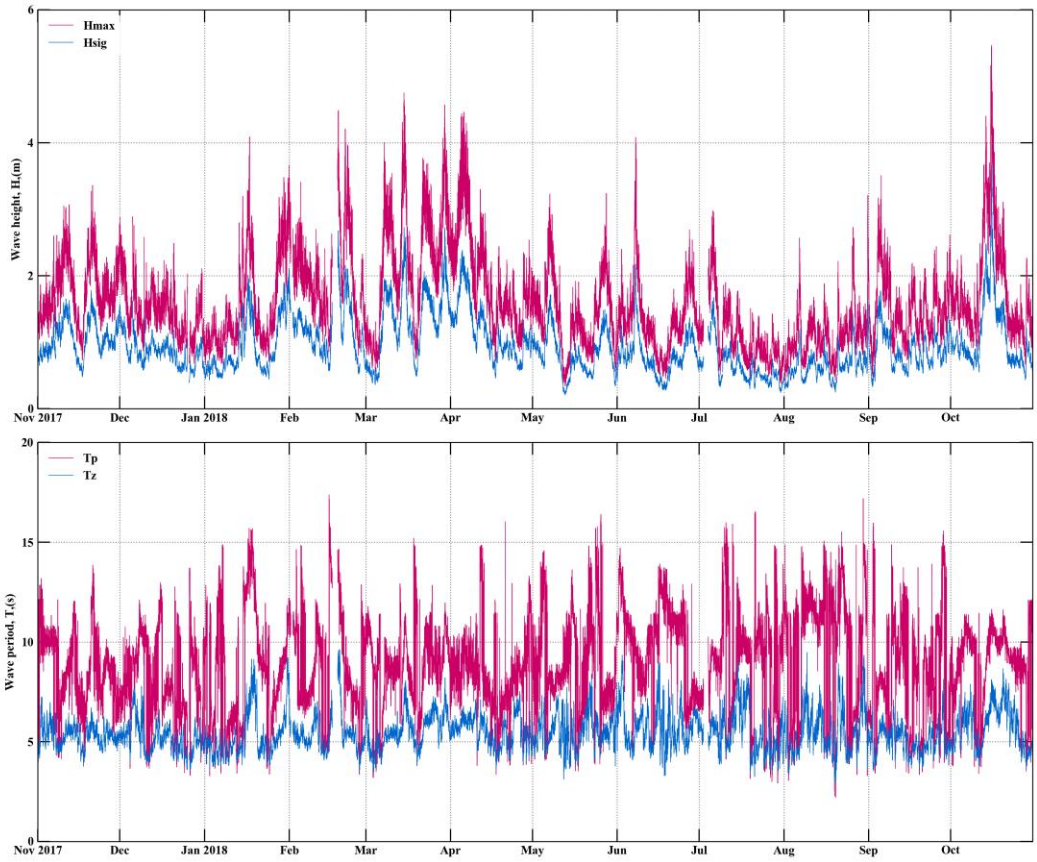


Figure 50 Caloundra – daily wave recordings

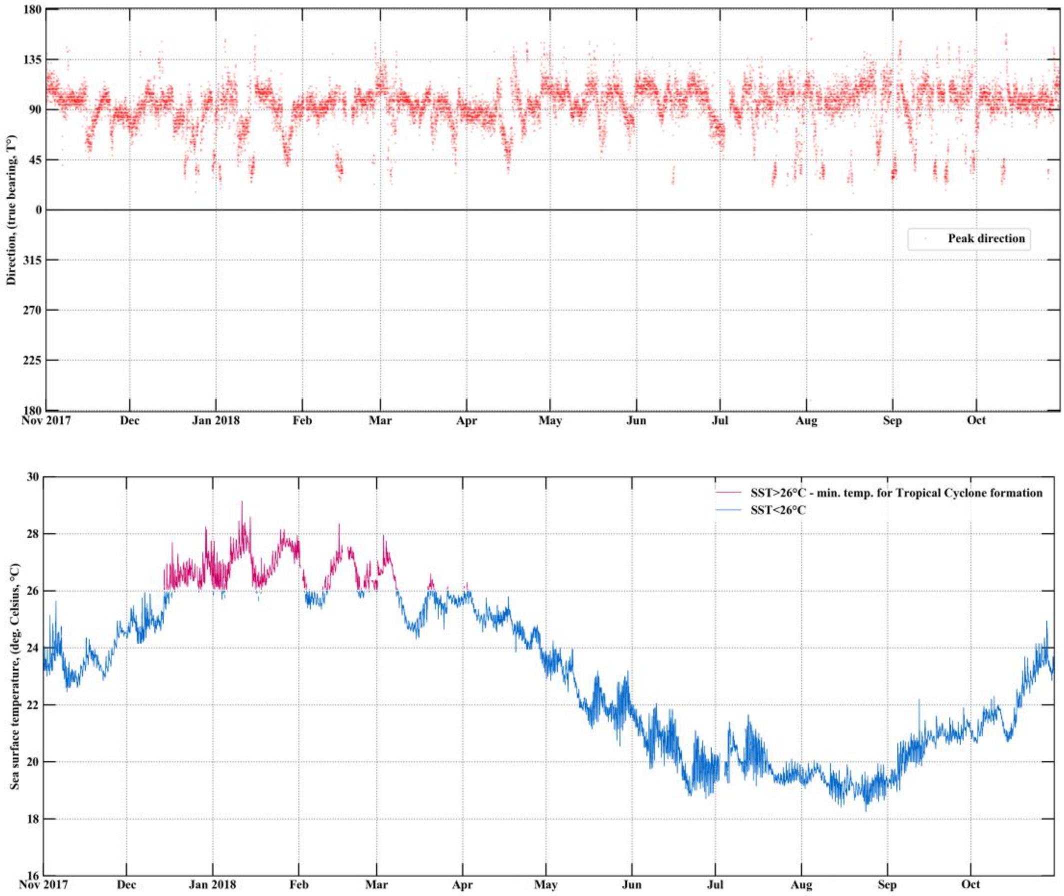


Figure 51 Caloundra – peak wave direction and sea surface temperature

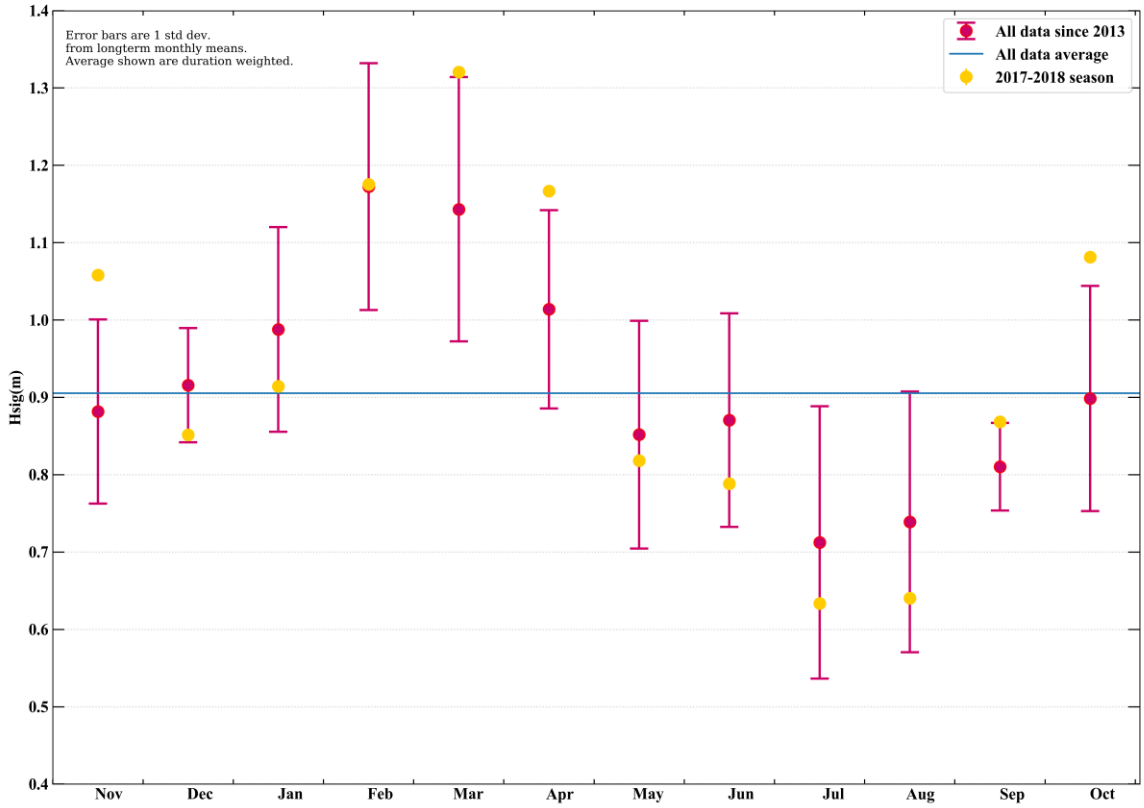


Figure 52 Caloundra – monthly average wave height (H_s) for 2017-18 and for all data

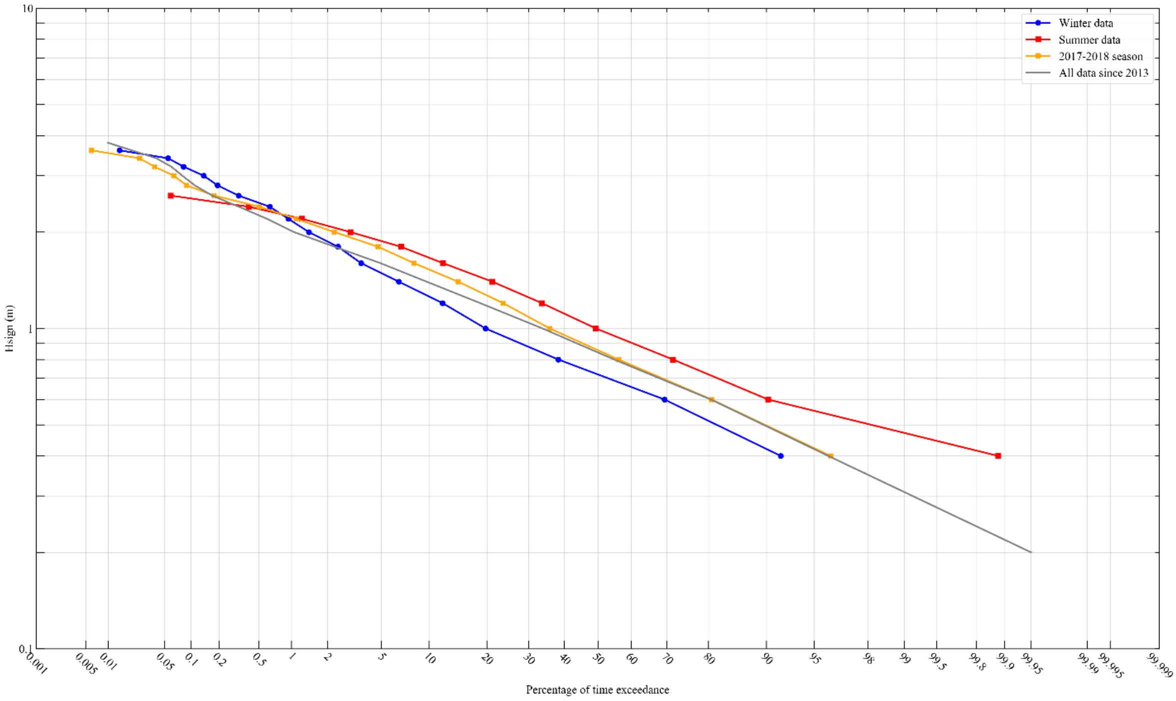


Figure 53 Caloundra – percentage exceedance of wave height (H_s) for all wave periods (T_p)

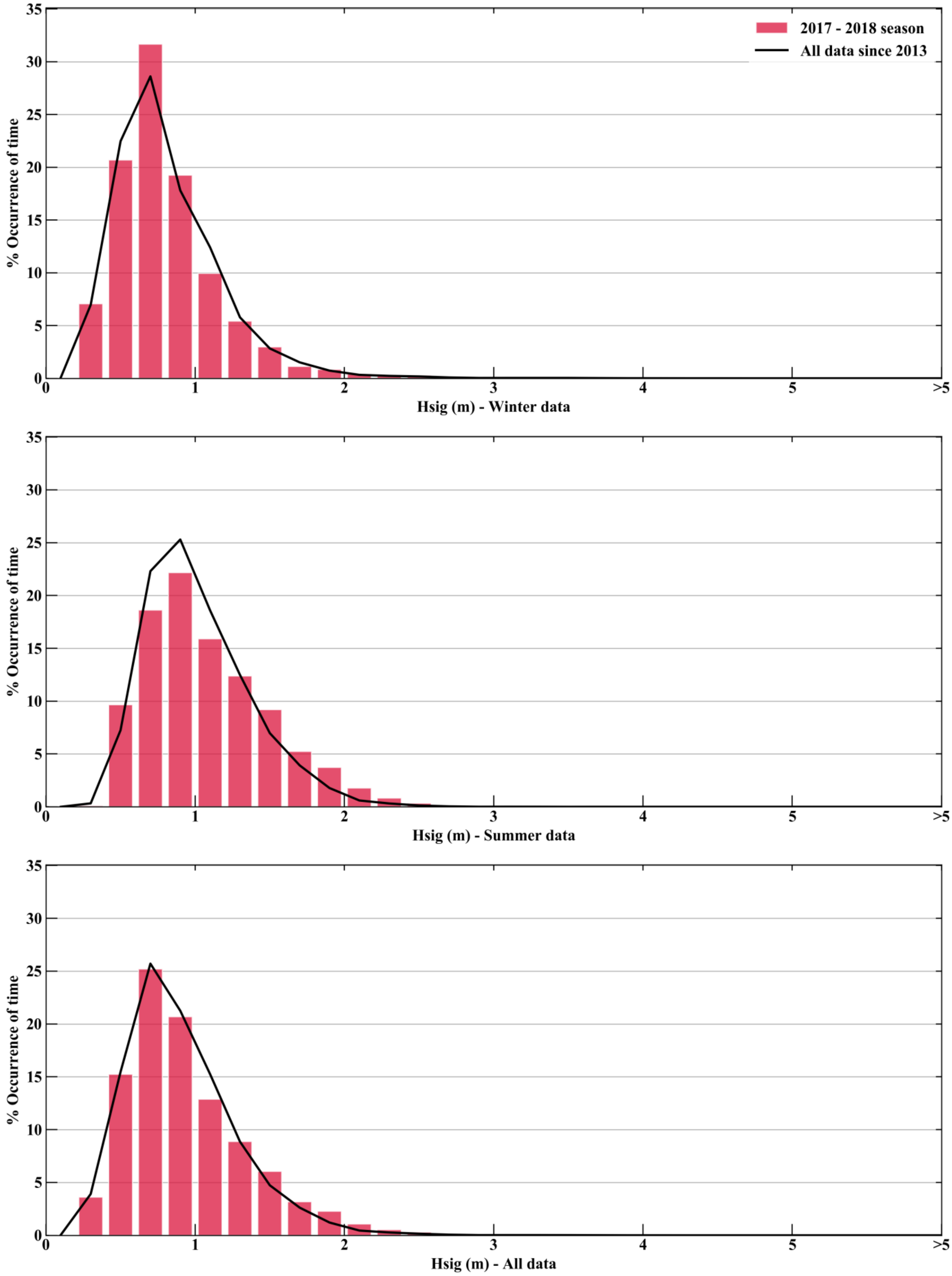


Figure 54 Caloundra – histogram percentage (of time) occurrence of wave heights (H_s)

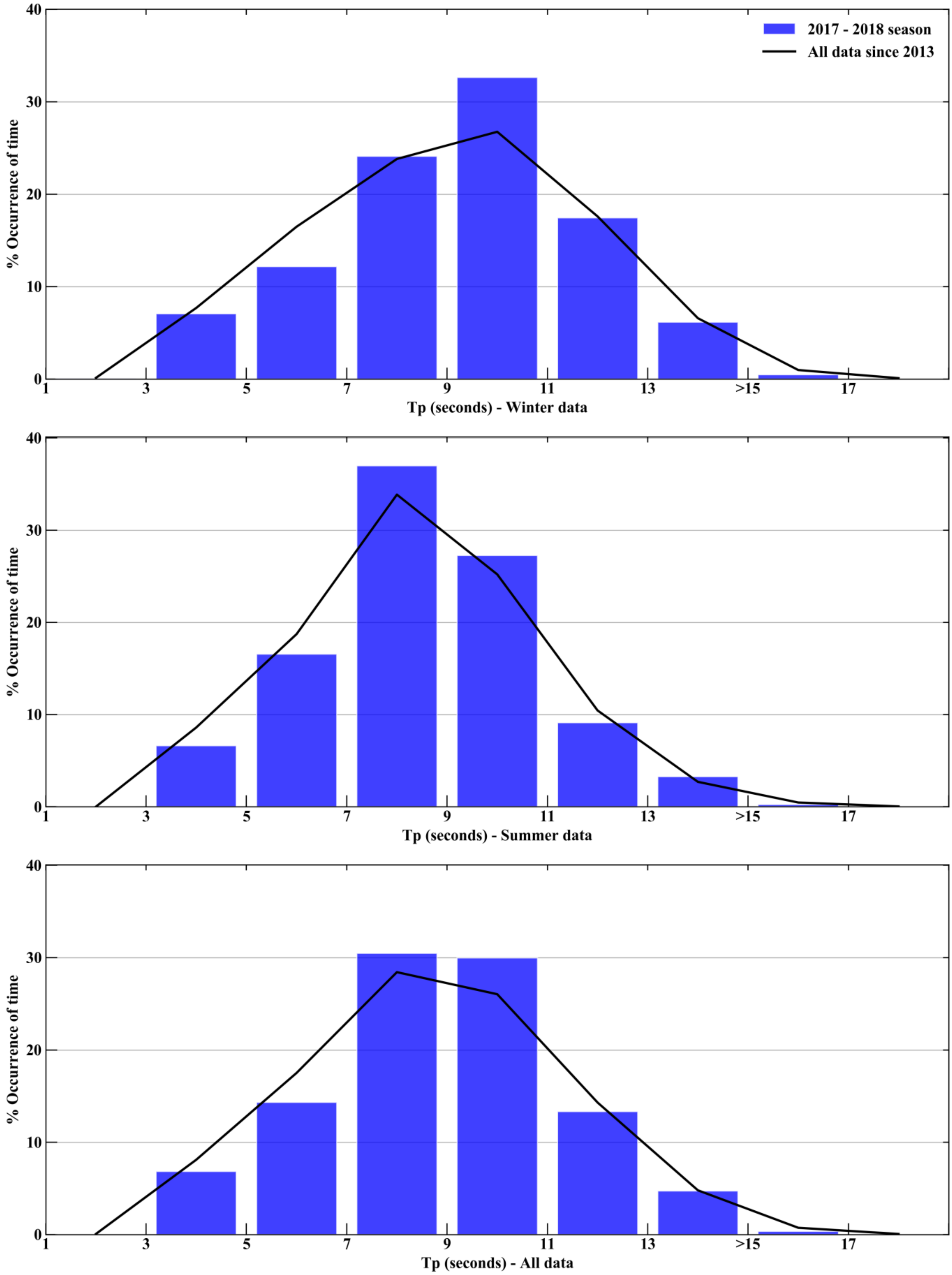


Figure 55 Caloundra – histogram percentage (of time) occurrence of wave periods (T_p)

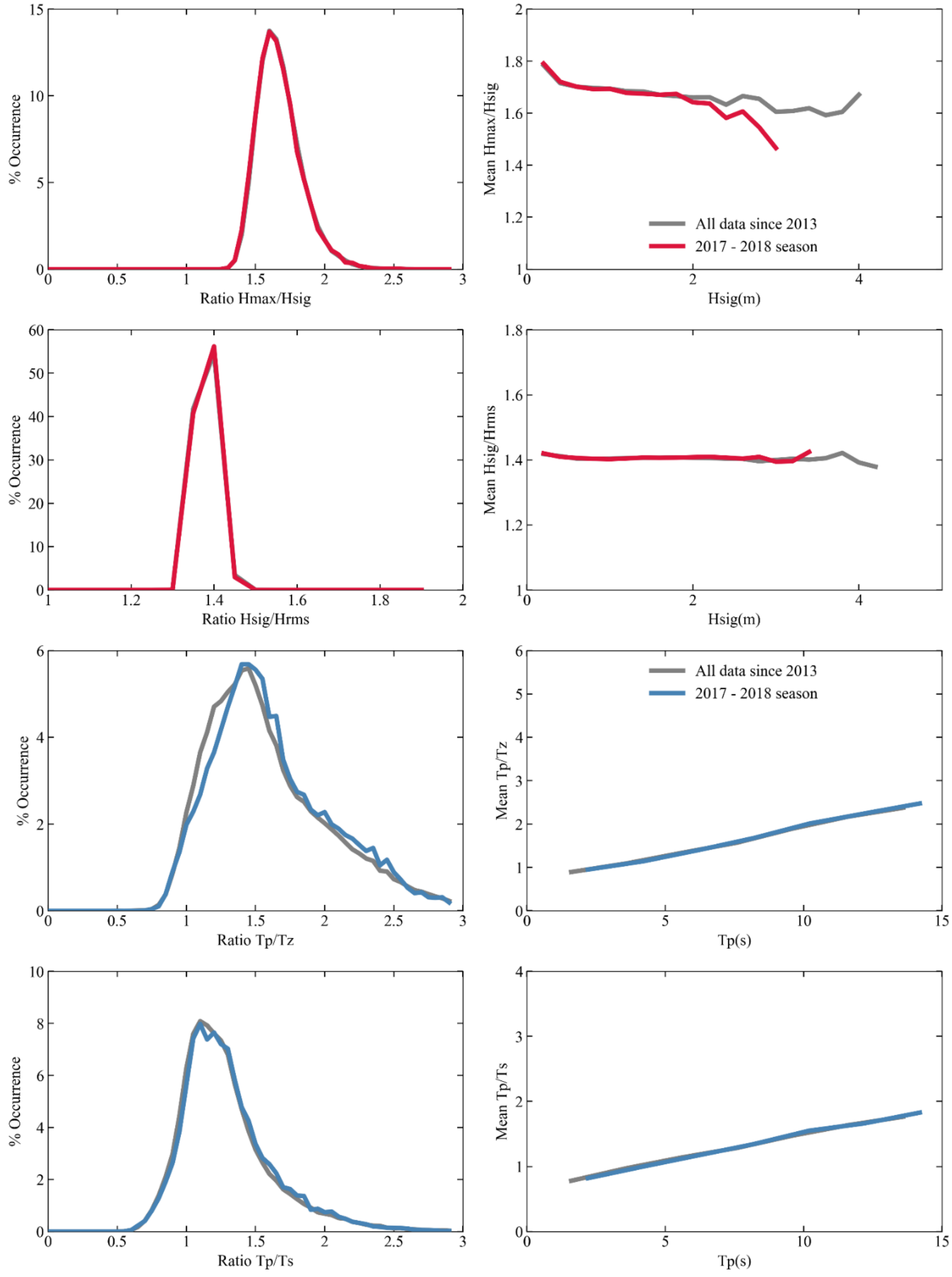
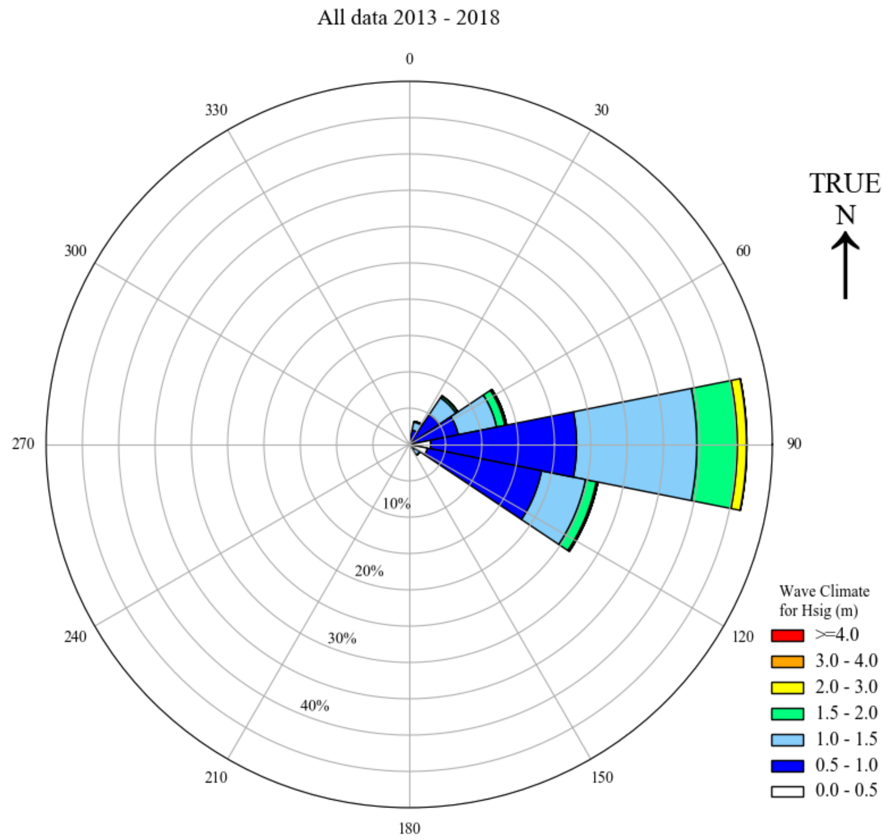


Figure 56 Caloundra – wave parameter relationships



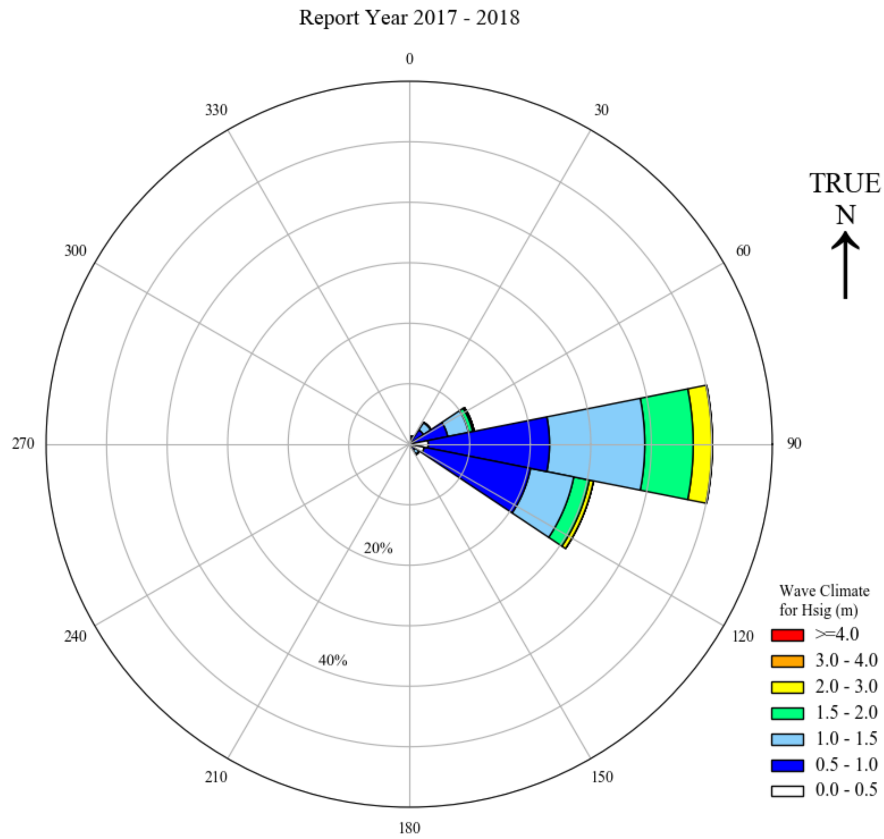


Figure 57 Caloundra – wave rose

Mooloolaba

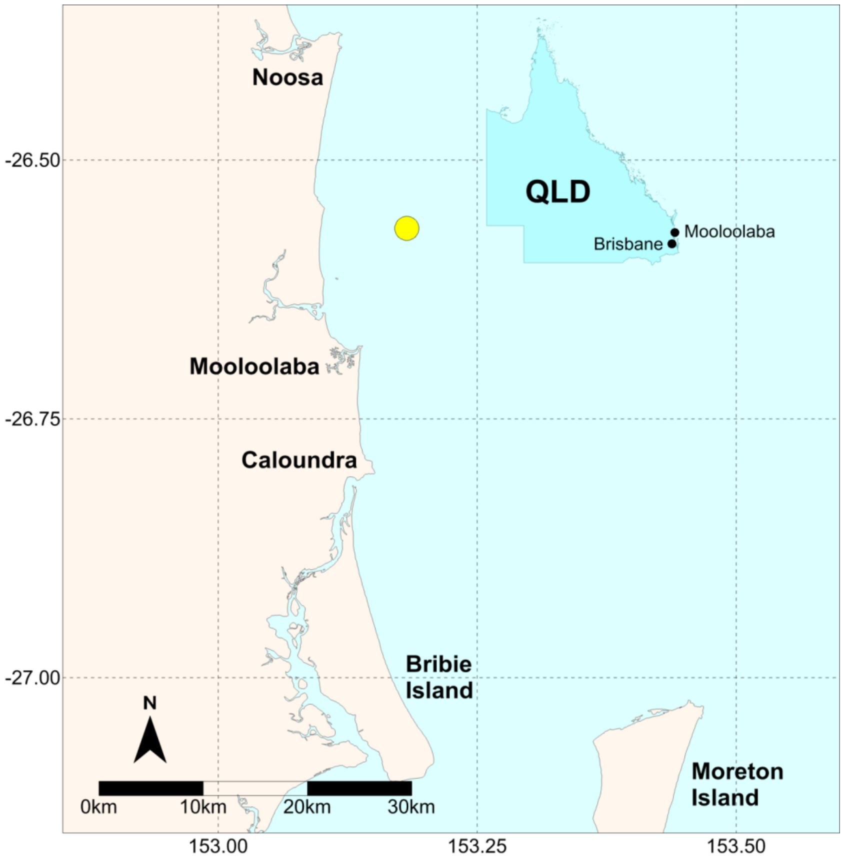


Figure 58 Mooloolaba – locality plan

Table 29 Mooloolaba – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	01/05/2000	0.83 years	304,417	18.53
2017-18	01/11/2017	0.67 days	17,487	1

Table 30 Mooloolaba – buoy deployments for 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
26° 33.940' S	153° 10.929' E	DWR-GPS	33	07/02/2017	13/04/2018
26° 33.941' S	153° 10.931' E	DWR-GPS	33	13/04/2018	current

Mooloolaba – seasonal overview

The Mooloolaba wave buoy has been operational for over 18 years with an overall data return of 96.6 per cent. The data record for the period November 2017 to October 2018 was excellent, with total gaps of 0.67 days, equivalent to 99.8 per cent data return. The buoy was replaced once during the reporting period (Table 30).

During the reporting period the buoy recorded 10 events where the wave heights were greater than 2.6 m H_s. The highest was recorded during a low-pressure system that developed on the 14th of October (Table 32) with a H_s of 4.3 m and Hmax of 7.3 m. This highest wave did not rank in the top ten of the overall wave record (Table 31). Peaks in wave heights can be seen from these events in the time series for daily wave recordings (Figure 59).

The temperature (sea surface temperature, SST) measured in the buoy hull showed a range of 20 °C to 28.5 °C (Figure 60). The SST from the middle of December to the end of March was warm enough for tropical cyclone development.

The monthly average H_s for the recording period fell within one standard deviation (sd) of the entire record, except for the months November, July, and October (Figure 61).

The wave climate for the reporting period was very similar to the wave climate for the entire record, as seen in the percentage exceedance plot for H_s (Figure 62). The summer period shows a higher frequency of waves < 3 m to the winter season. Histograms of occurrence of Hs (Figure 63) show a similar distribution of wave heights, with a lower occurrence during summer for Hs between 0.8 m 1.8 metres. Histograms of the occurrence of peak wave periods (T_p) (Figure 64) show a higher occurrence of the 9-11 seconds T_p range during winter and higher occurrence of 7-9 second waves in summer. The overall data of the reporting period shows similar occurrences compared to all data up until now.

The ratios between different wave parameters such as H_{max}/H_s were generally consistent between this reporting period and all0 of the historic data with the exception of T_p/T_s which were slightly skewed towards a smaller ratio, these are plotted in Figure 65.

Time series for wave direction (Figure 60) shows waves predominantly from the east to east-south-east with occasional swings to NNE. The directional wave rose plots (Figure 66) corroborate this. The wave directions for the reporting period are very similar to the entire record.

Table 31 Mooloolaba – highest waves

Rank	Date (H_s)	H_s (m)	Date (H_{max})	H_{max} (m)
1	05/03/2004 16:00	5.9	05/03/2004 15:30	12.1
2	28/01/2013 05:30	5.6	28/01/2013 05:00	10.5
3	03/03/2006 06:30	5.3	01/05/2000 18:30	10
4	01/05/2015 15:30	5.2	01/05/2015 17:30	9.2
5	01/05/2000 19:30	5.1	03/03/2006 06:30	9.2
6	24/08/2007 01:00	5.1	31/12/2007 08:00	8.9
7	30/05/2008 20:30	4.5	24/08/2007 01:30	8.5
8	30/12/2007 22:00	4.4	25/12/2011 07:30	8.4
9	25/12/2011 08:30	4.3	04/06/2016 21:00	8.2
10	28/06/2012 07:00	4.3	28/06/2012 04:30	7.9

Table 32 Mooloolaba – significant meteorological events with threshold H_s of 2.5 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
15/01/2018 2:00	2.9 (3.1)	4.4 (4.7)	7.3	A low-pressure system developed in the Tasman sea, with a low-pressure trough off the east coast.
18/02/2018 13:30	3.2	5.8	13.9	TC Gita was located to the southeast of New Caledonia on the 15th before passing over the Tasman Sea and weakening to a low-pressure system on the 19th.
21/02/2018 11:00	3.1 (3.2)	5.1 (5.8)	8.5	A ridge of high-pressure extended along the east coast of Australia on the 20th.
7/03/2018 21:30	2.7 (3.0)	4.7 (5.9)	8.1	TC Hola developed on the 3rd, moving westward, but stayed well off the east coast.
15/03/2018 2:00	3.1 (3.3)	5.0 (5.9)	9.4	TC Linda developed in the north-eastern Coral Sea on the 13th before weakening to a low-pressure system.
22/03/2018 8:00	2.5 (2.7)	4.5 (5.3)	9.9	Low-pressure system in the Coral sea developed on the 21^{st}.
29/03/2018 16:30	2.8 (3.1)	4.8 (6.4)	10.7	TC Iris entered Australian waters on the 24th weakening to a low-pressure system. Remnants stayed off the central QLD coast from March 30.
5/04/2018 23:00	2.7 (2.9)	4.2 (5.6)	10.1	Ex-TC Iris redeveloped on the 2nd and tracked south before being downgraded to an ECL on the 6th.
7/06/2018 17:00	2.9 (2.9)	4.3 (5.1)	9.9	A high-pressure system in the Tasman Sea extended up the east coast.
15/10/2018 23:00	3.9 (4.3)	6.0 (7.3)	11	A low-pressure system developed on the 14th in the Coral Sea with a low-pressure trough extending north.

Denotes peak H_s event

Notes: 1. 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).

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

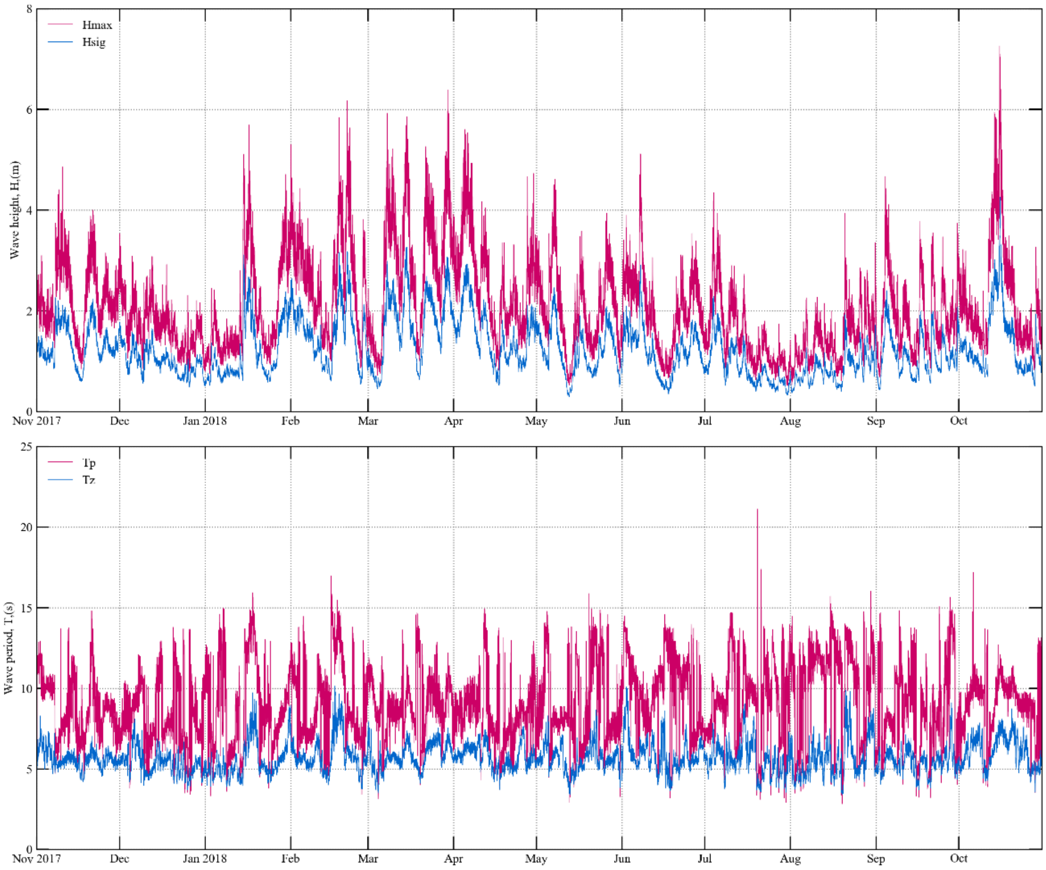


Figure 59 Mooloolaba – daily wave recordings

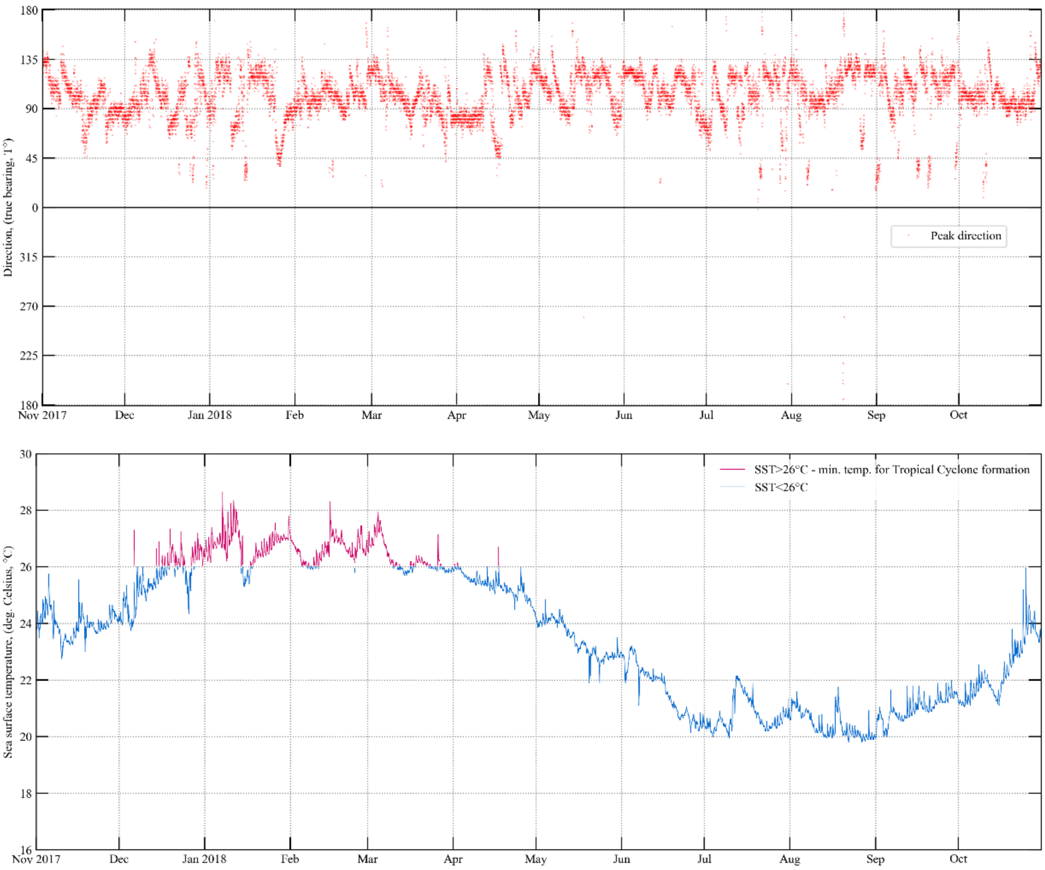


Figure 60 Mooloolaba – peak wave direction and sea surface temperature

Figure 61 Mooloolaba – monthly average wave height (H_s) for 2017-18 and for all data

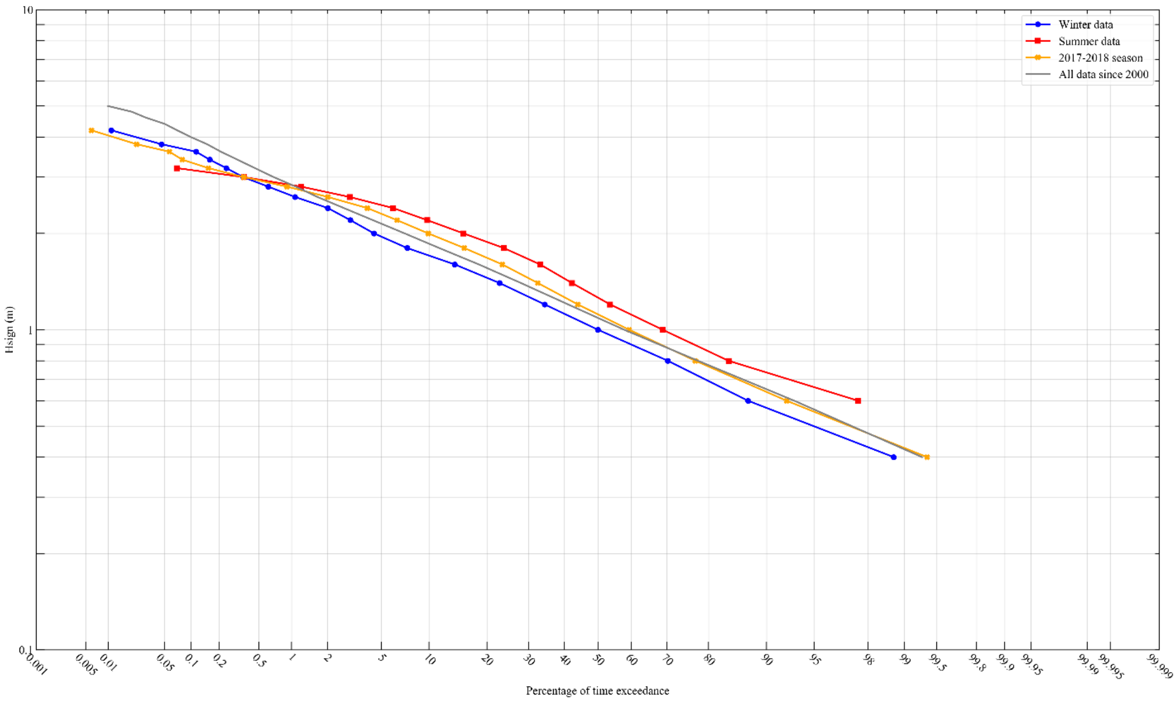


Figure 62 Mooloolaba – percentage exceedance of wave height (H_s) for all wave periods (T_p)

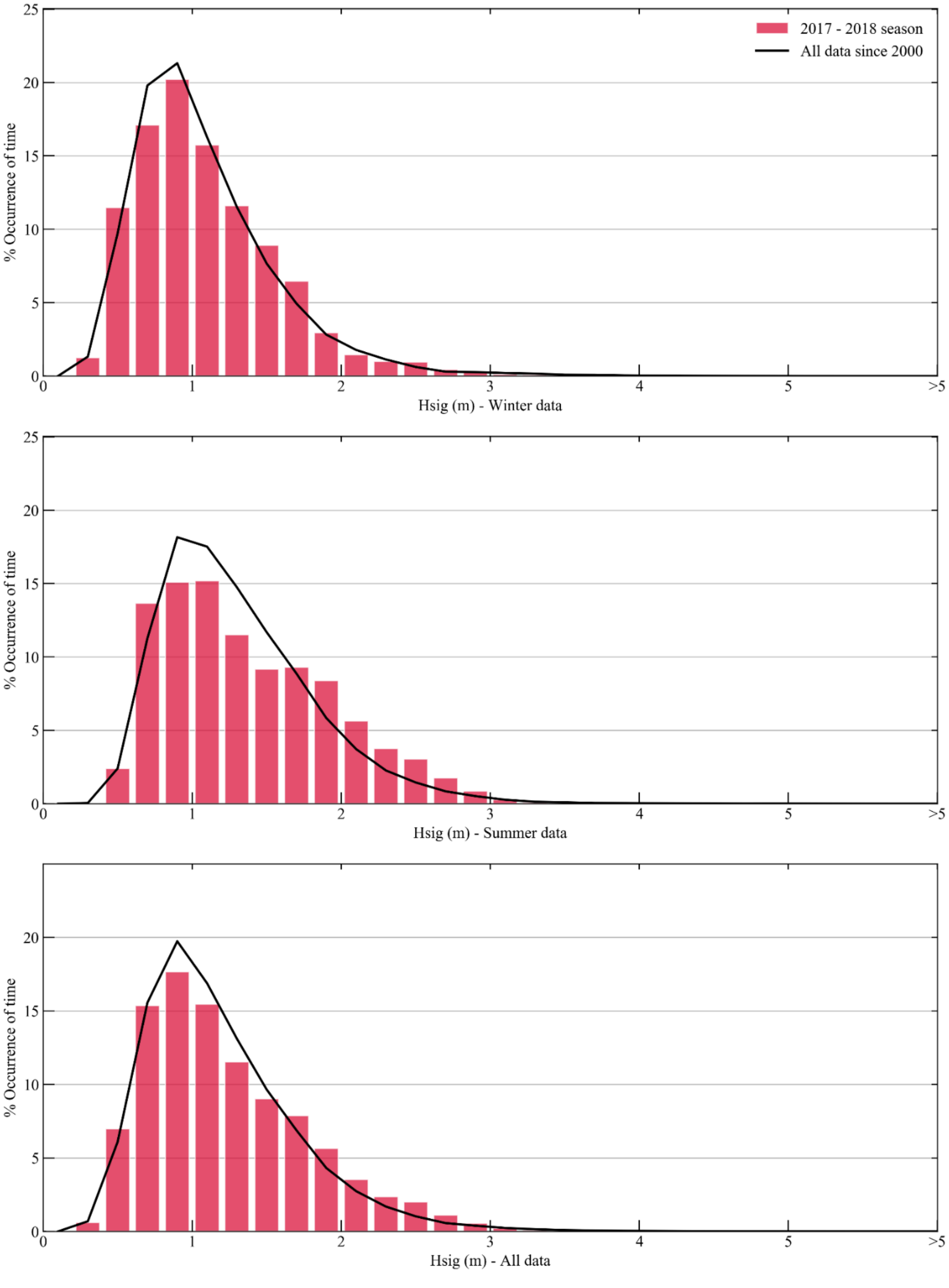


Figure 63 Mooloolaba – histogram percentage (of time) occurrence of wave heights (H_s)

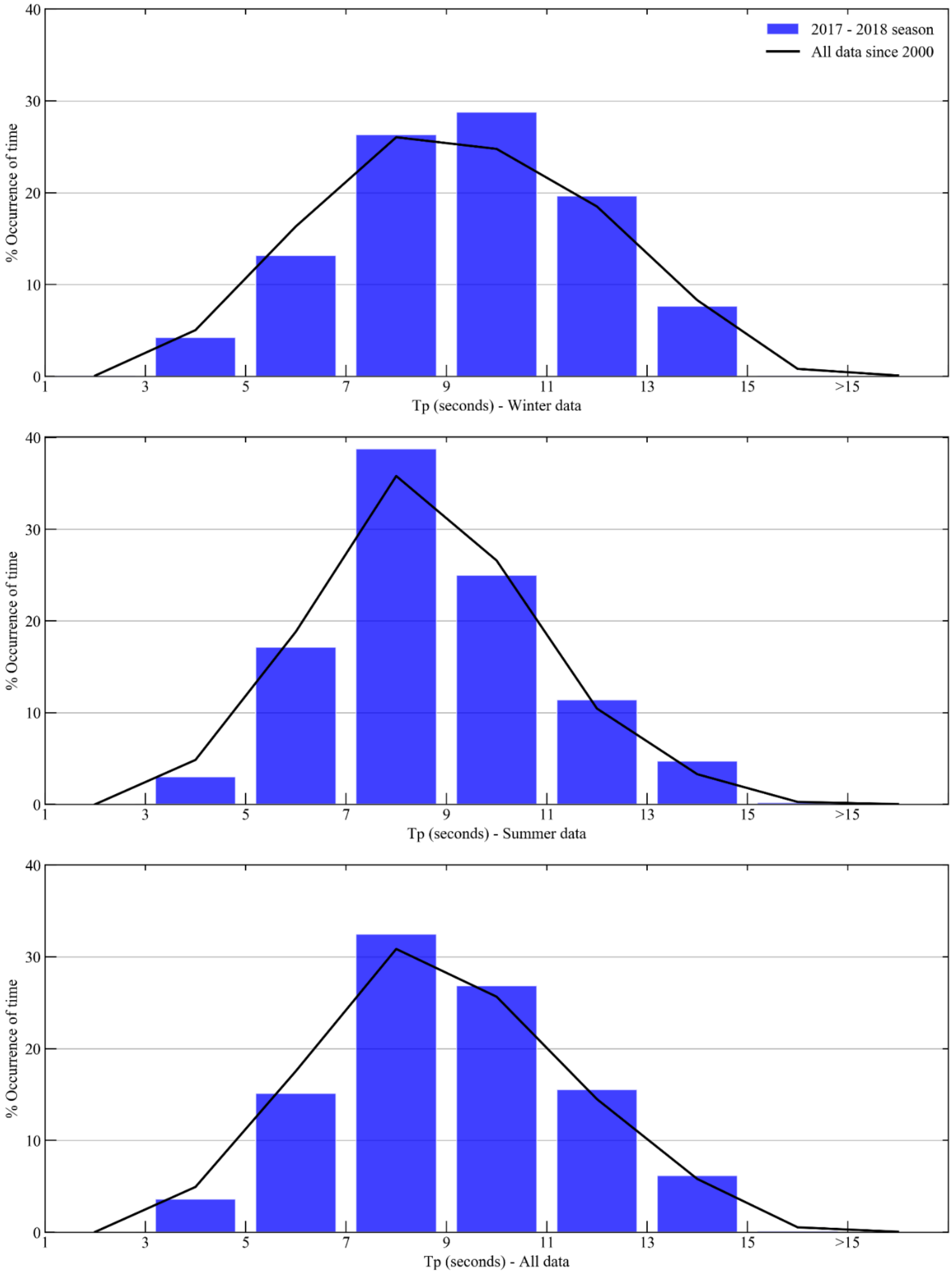


Figure 64 Mooloolaba – histogram percentage (of time) occurrence of wave periods (T_p)

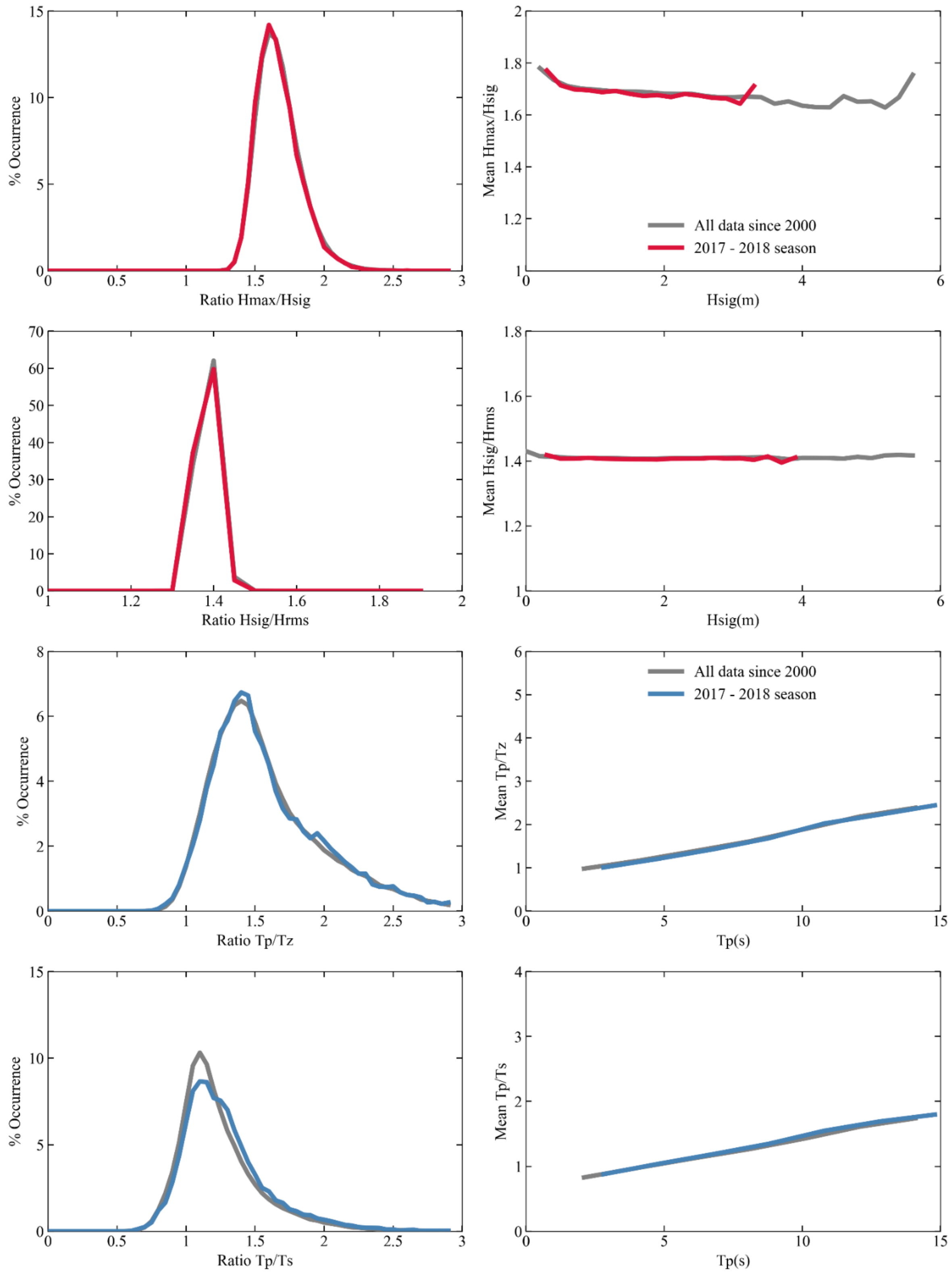
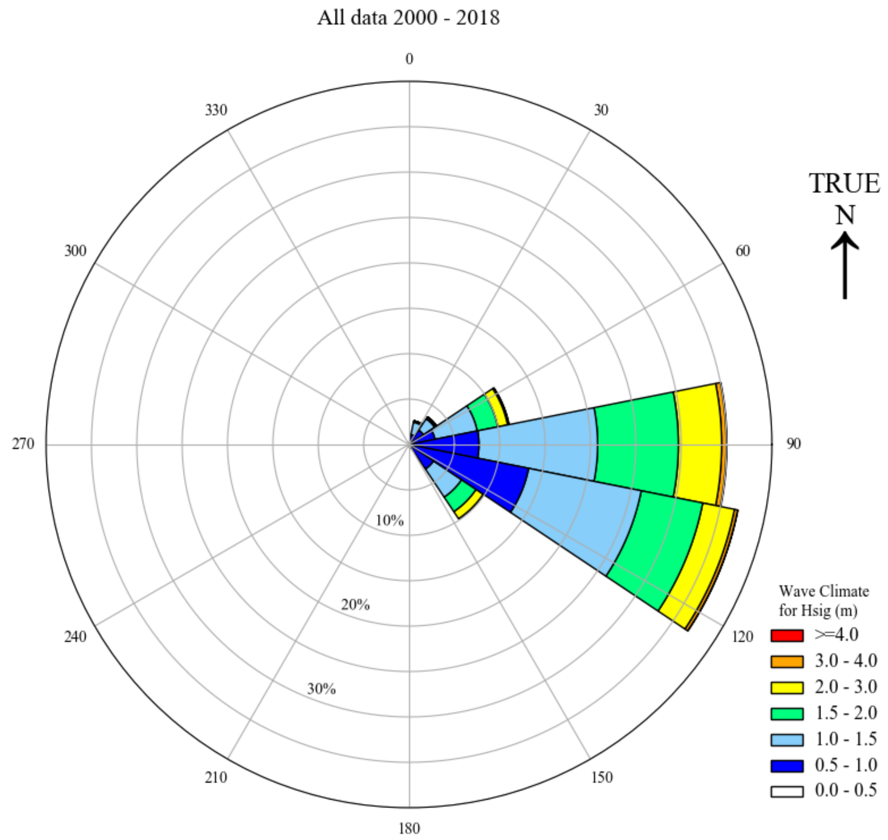


Figure 65 Mooloolaba – wave parameter relationships



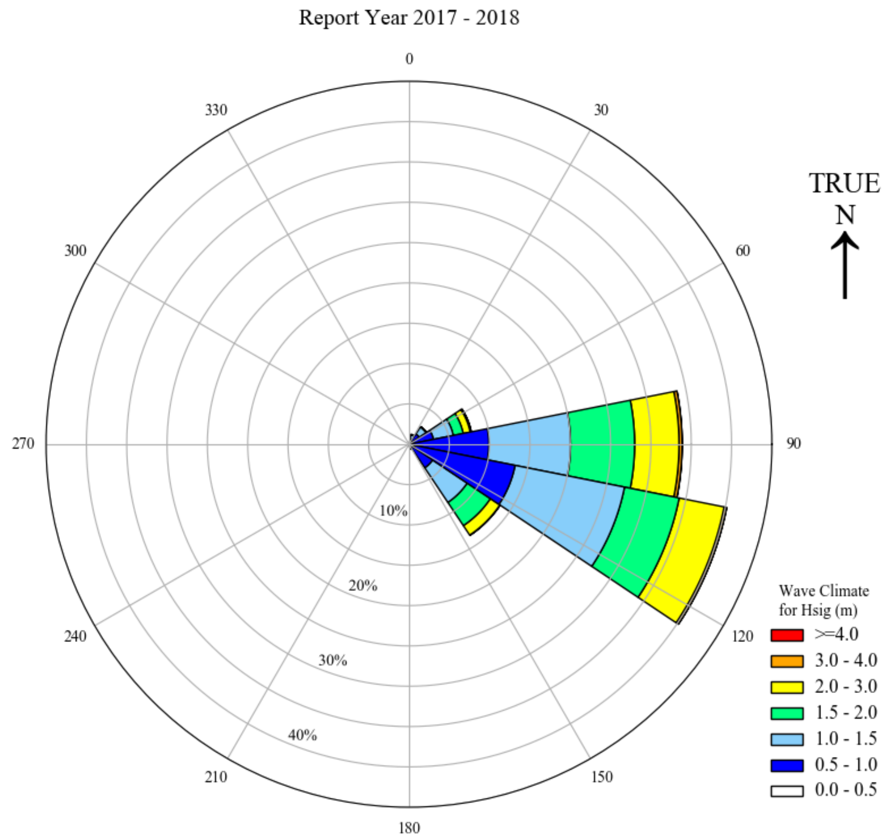


Figure 66 Mooloolaba – directional wave rose

Bundaberg

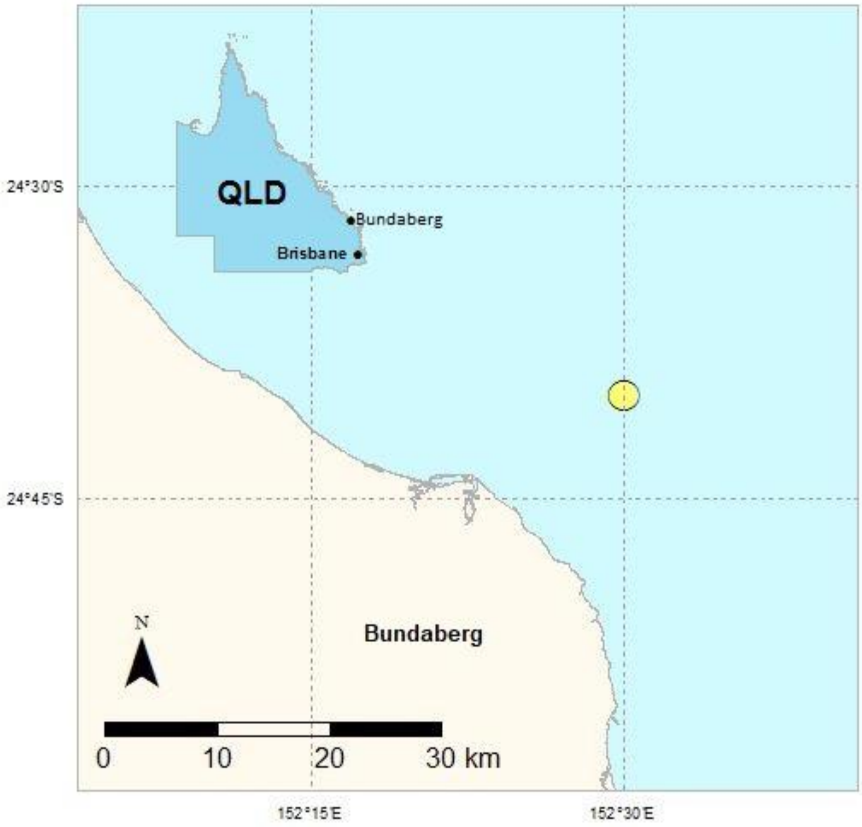


Figure 67 Bundaberg – locality plan

Table 33 Bundaberg – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	08/09/2015	0.35 years	13,626	3.14
2017-18	01/11/2017	81.10 days	48,760	1

Table 34 Bundaberg – buoy deployments for 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
24°39.989' S	153°30.068' E	SG	19.5	19/10/2016	05/12/2017
24° 40.000' S	152° 30.035' E	SG	20	05/12/2017	17/04/2018
24° 40.085' S	152° 29.993' E	SG	18	17/04/2018	current

Bundaberg – seasonal overview

Bundaberg has a SG buoy which doesn't record wave direction or sea surface temperature.

The Bundaberg wave buoy has been operational for just over three years with an overall data return of 88.8 per cent. The data recorded for the period November 2016 to October 2017 was okay, with total gaps of 81.1 days, equivalent to a 77.7 per cent data return. The buoy was replaced twice during the reporting period, see Table 34.

There were five significant wave events during the reporting period, and due to the short dataset of the Bundaberg wave monitoring site, some waves made it into the top ten ranks (Table 35 and 36). Notably, a H_s of 2.3 m during the passage of TC Hola ranked third.

The monthly average Hs for the recording period fell within one standard deviation (sd) of the entire record, except for November and March (Figure 69).

The wave climate for the 2017-2018 period was very similar to the wave climate for the entire record, as seen in the percentage exceedance plot for H_s (Figure 70). Overall, the winter period has a lower wave height frequency and for summer it has an overall higher frequency of moderate wave heights compared to the season.

Histograms of occurrence of H_s (Figure 71) show a similar distribution of wave heights. Histograms of the occurrence of peak wave periods (Tp) (Figure 72) show a similar occurrence with the overall data.

The ratios between different wave parameters such as Hmax/Hs were generally consistent between this reporting period and all of the historic data, these are plotted in Figure 73.

Table 35 Bundaberg – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	30/03/2017 13:30	3.1	30/03/2017 12:00	5.6
2	16/10/2017 19:30	2.3	17/10/2017 2:30	4.8
3	8/03/2018 1:30	2.3	16/12/2018 23:00	4.3
4	16/07/2016 6:00	2.3	8/03/2018 1:30	4.2
5	4/01/2016 23:30	2.2	3/02/2018 21:30	4.2
6	16/12/2018 23:00	2.2	28/11/2018 20:30	4.2
7	3/12/2015 16:00	2.1	16/07/2016 16:00	4.1
8	3/02/2018 23:30	2.1	29/03/2018 21:00	4.1
9	14/03/2018 17:00	2.1	14/03/2018 11:30	4.1
10	6/12/2018 7:00	2	4/01/2016 21:30	4

Table 36 Bundaberg– significant meteorological events with threshold Hs of 1.8 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
15/01/2018 1:30	1.8 (1.9)	3.2 (3.4)	5.7	A low-pressure trough extended along the length of the East Coast preceding thunderstorms and heavy rainfall.
3/02/2018 23:30	1.9 (2.1)	3.3 (4.1)	5.9	A high-pressure system moved from the Great Australian Bight to the Tasman sea extending a ridge of high-pressure along the east coast.
8/03/2018 1:30	2.2 (2.3)	3.8 (4.2)	6.3	TC Hola developed on March 3, moving westward, however Hola stayed well off the east coast.
14/03/2018 17:00	1.9 (2.1)	3.4 (4.0)	6.1	TC Linda developed in the north-eastern Coral Sea on March 13 before weakening into a low-pressure system.
29/03/2018 19:30	1.8 (1.9)	3.1 (3.1)	5.8	TC Iris entered Australian waters on March 24 weakening to a low-pressure system. Remnants stayed off the central QLD coast from the 29th until the end of the month.

Denotes peak H_s event

Notes: 1. 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).

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

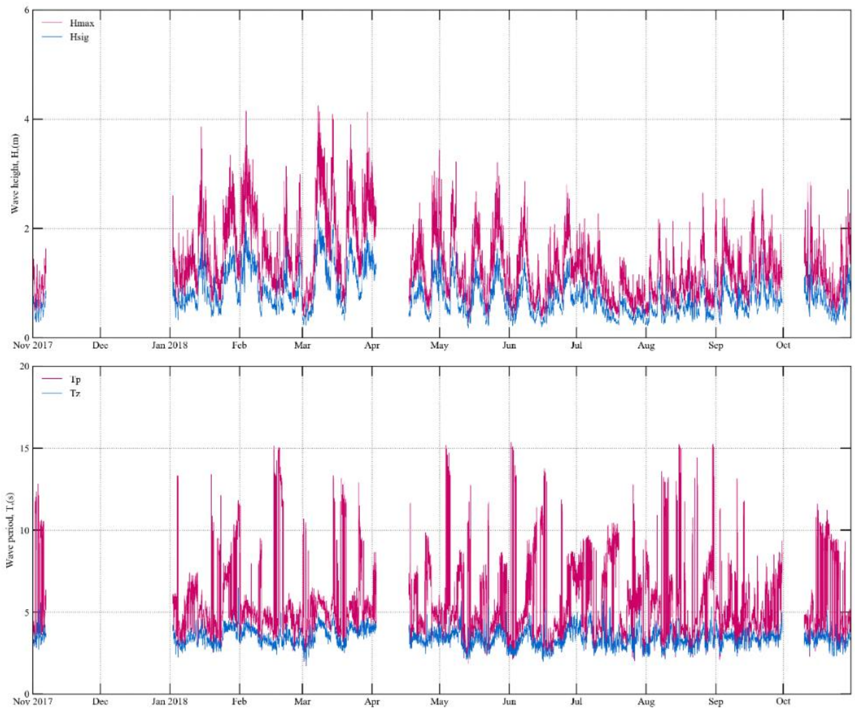


Figure 68 Bundaberg – daily wave recordings

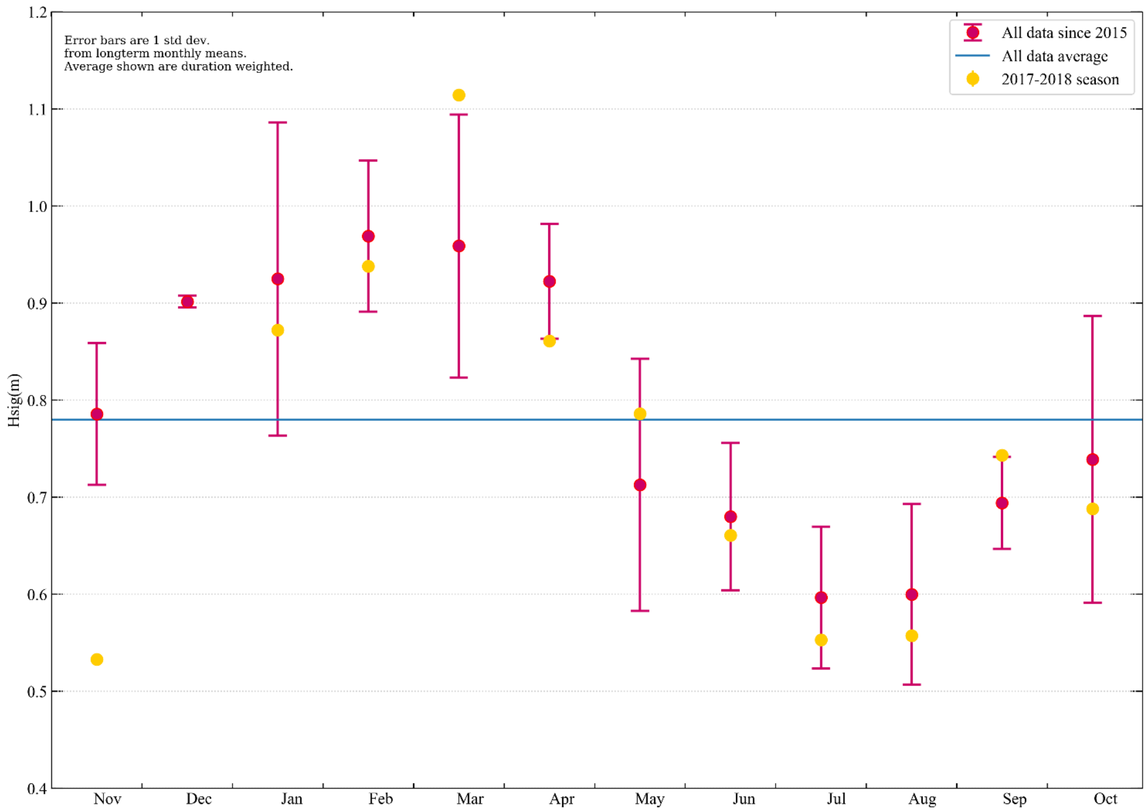


Figure 69 Bundaberg - monthly average wave height (H_s) for 2017-18 and for all data

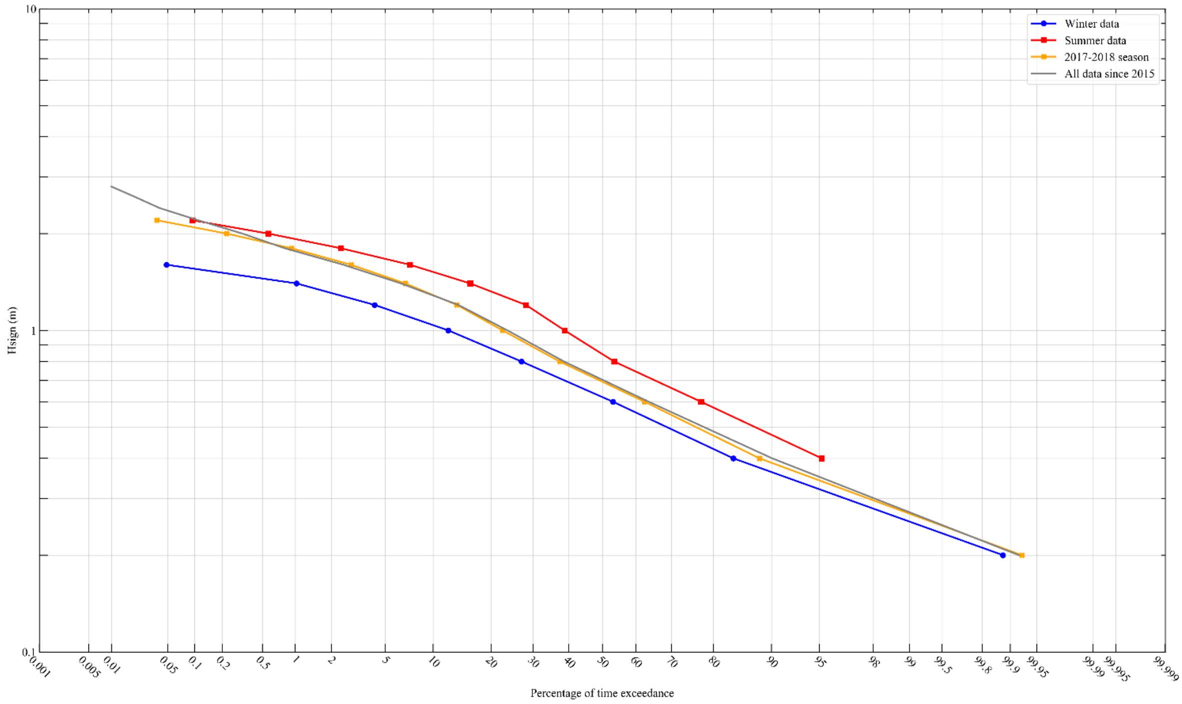


Figure 70 Bundaberg – percentage exceedance of wave height (H_s) for all wave periods (T_p)

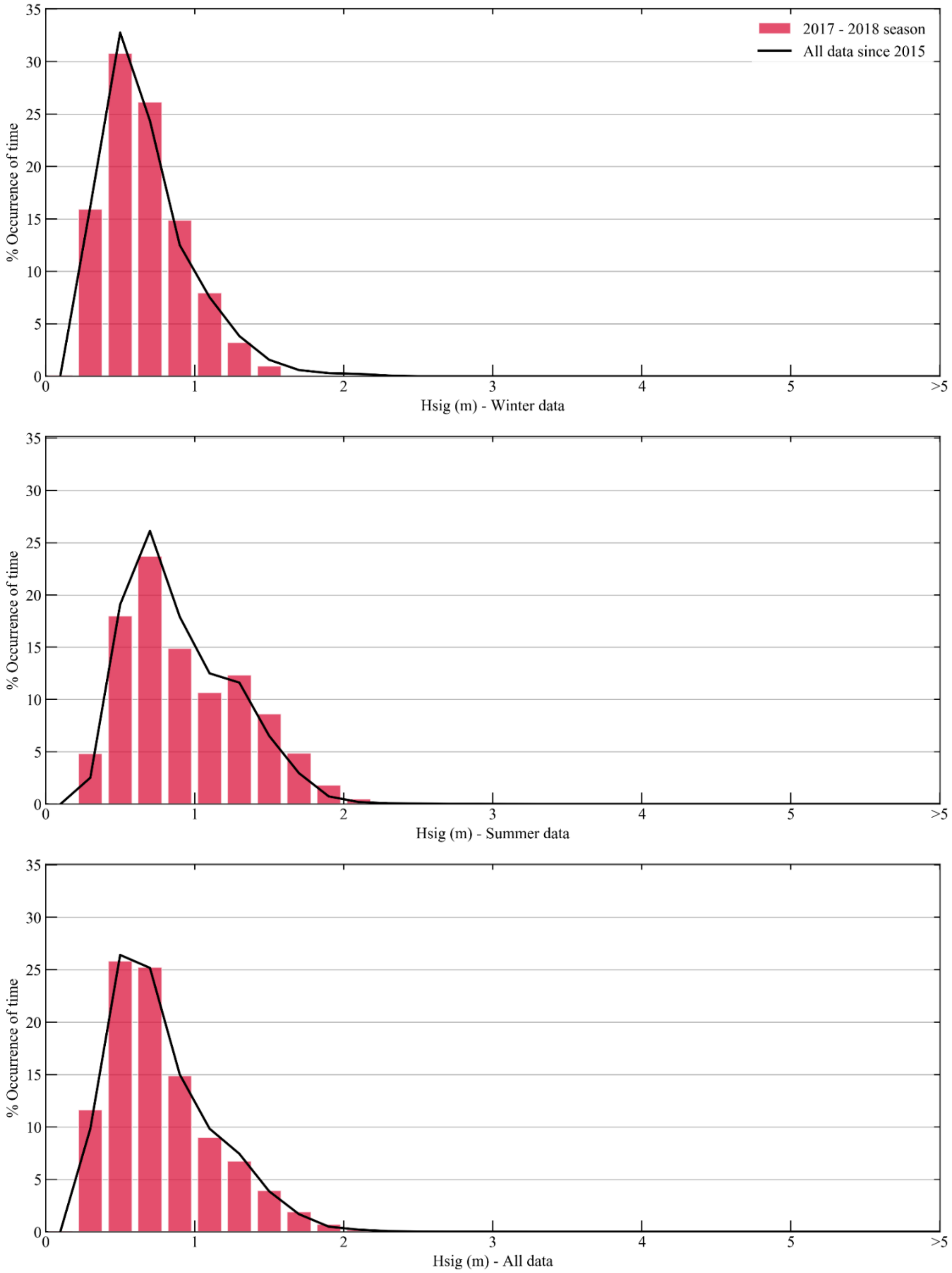


Figure 71 Bundaberg – histogram percentage (of time) occurrence of wave heights (H_s)

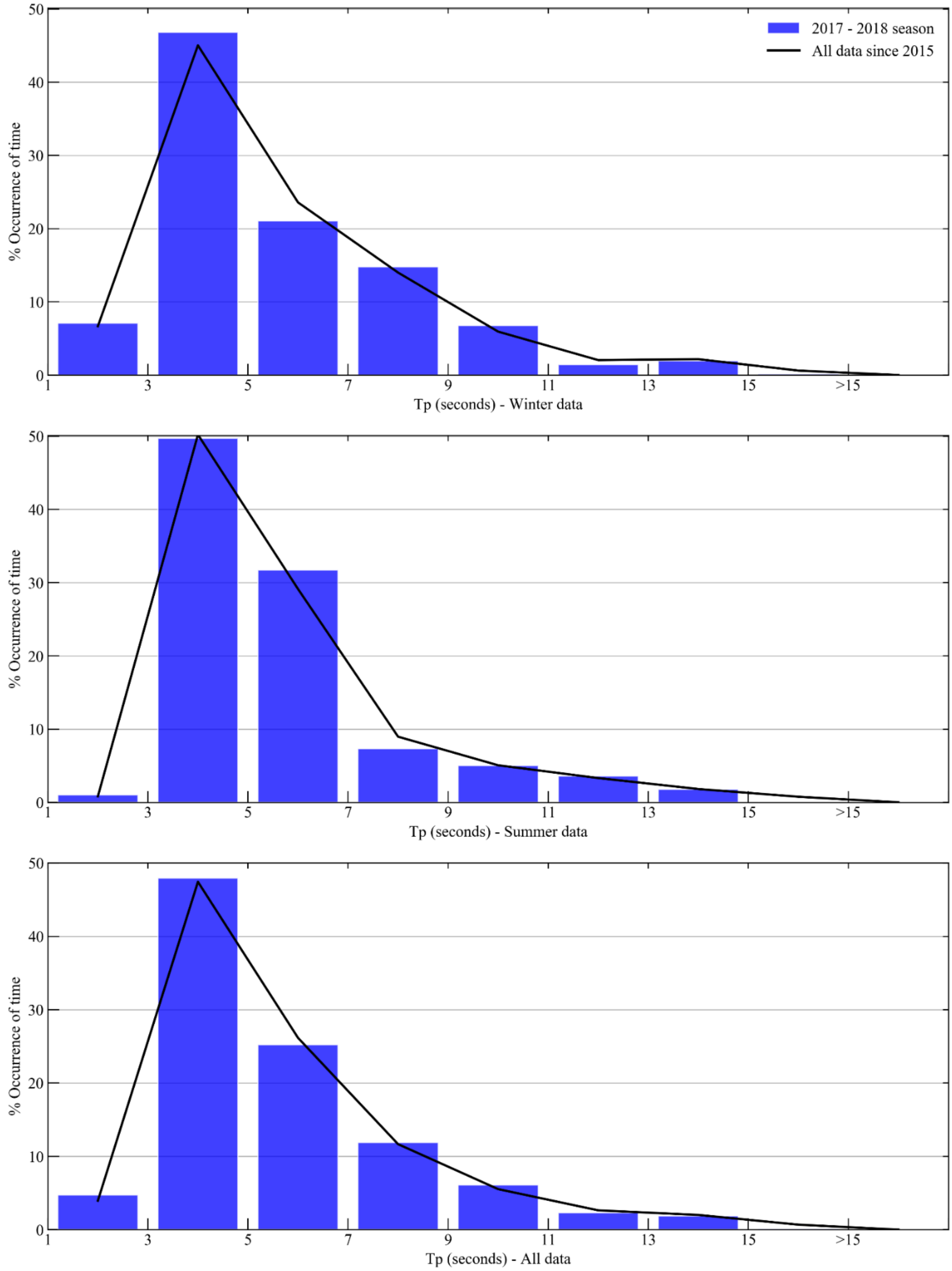


Figure 72 Bundaberg – histogram percentage (of time) occurrence of wave periods (T_p)

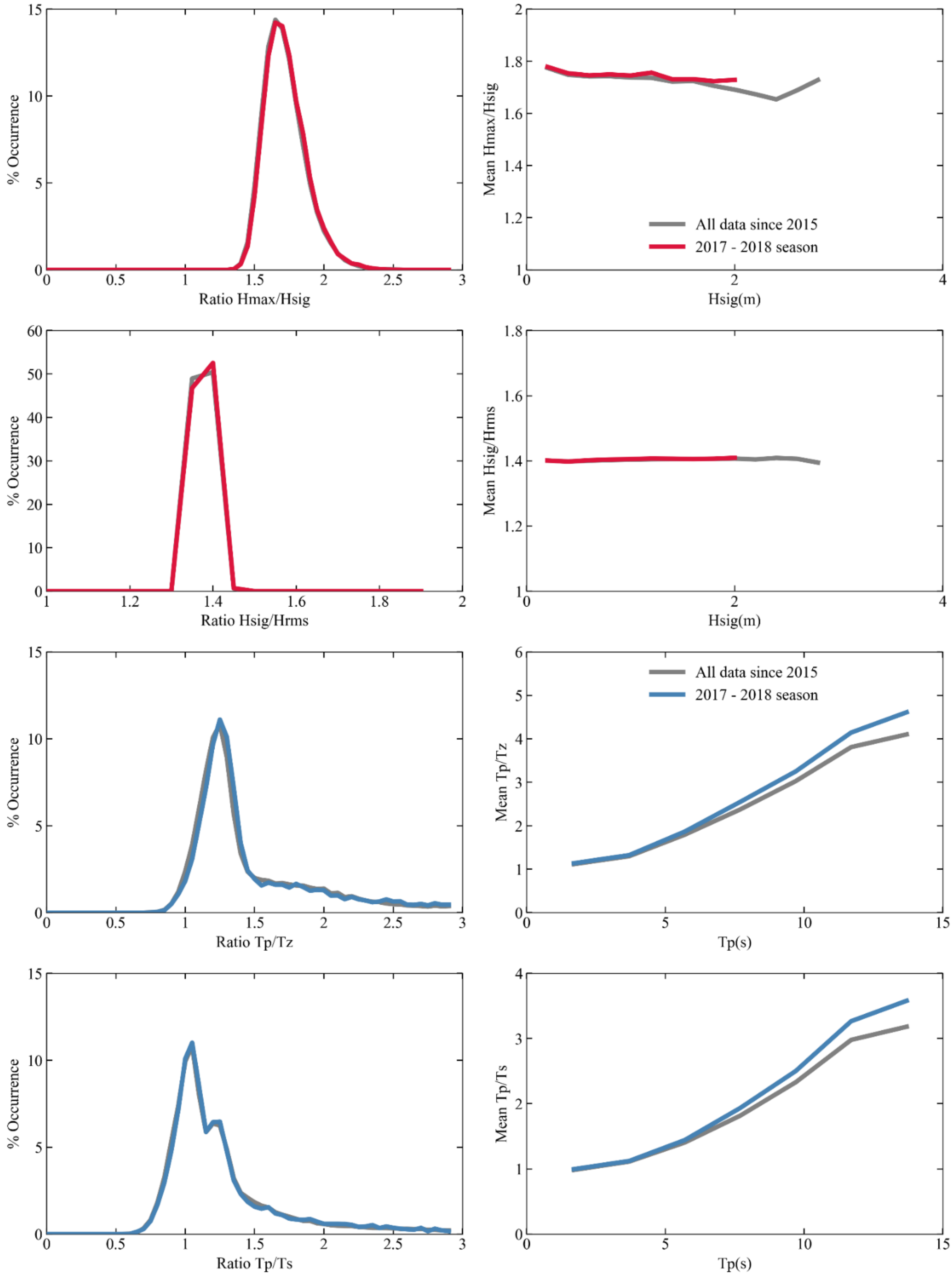


Figure 73 Bundaberg – wave parameter relationships

Gladstone

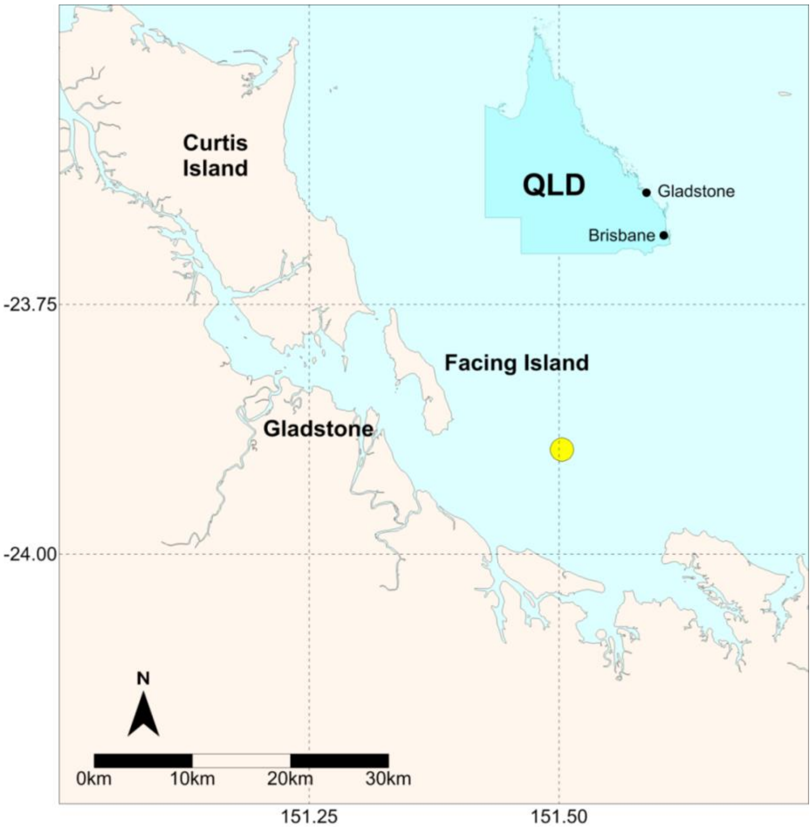


Figure 74 Gladstone – Locality plan

Table 37 Gladstone – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	23/09/2009	0.16 (years)	155,912	9.11
2017-18	01/11/2017	4.17 (days)	17,319	1

Table 38 Gladstone – buoy deployments during the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
23°53.746' S	151°30.197' E	DWR-MkIII	15.3	27/10/2016	3/11/2017
23° 53.753' S	151° 30.183' E	DWR-MkIII	15.5	3/11/2017	current

Gladstone – seasonal overview

The Gladstone wave buoy has been operational for just over nine years with an overall data return of 98.2 per cent. The data recorded for the period November 2017 to October 2018 was excellent, with total gaps of 4.17 days, equivalent to a 98.8 per cent data return. The buoy was replaced once during the reporting period, (Table 38).

There were no significant meteorological events throughout the reporting period (Table 40) that increased wave heights above the 2.0 m threshold. One H_{max} value made it into the top ten ranks at number ten with a H_{max} of 4 m (Table 39).

The SST was over the threshold for cyclone development (26.5 °C) from December 2017 to the end of March 2018, (Figure 76).

The monthly average Hs for the recording period fell within one sd of the entire record (Figure 77), except for the December, April, and September where the monthly average was outside the 1 sd from the average for all data.

The wave climate for the 2017-2018 period was very similar to the wave climate for the entire record, as seen in the percentage exceedance plot for H_s (Figure 78). Overall, the winter period has a lower frequency of wave heights and summer has an overall higher frequency compared to the 2017-2018 season. Histograms of occurrence of H_s (Figure 79) show a similar distribution of wave heights, with a higher occurrence for H_s 0.4 - 0.6 m in winter than the historic data. Histograms of the occurrence of T_p (Figure 80) also show a similar distribution of wave period with higher occurrence 5-7 second waves and lower occurrence of 9-15 second waves in summer and winter.

The ratios between different wave parameters such as H_{max} / H_s were generally consistent between this reporting period and all of the historic data with the exception of T_p /T_z and T_p /T_s which were slightly skewed towards a larger ratio, these are plotted in Figure 81.

The plot of wave direction over the 2017-18 season (Figure 76) showed a dominant Easterly (slightly North of East) direction with an occasional swing to the North during summer and an occasional swing to the South in winter. The dominance of incident wave direction is reflected in the directional wave rose plot (Figure 82) along with the most common wave height (H_s) of 0.5 m to 1.0 metres.

Table 39 Gladstone – highest waves

Rank	Date	Hs (m)	Date	Hmax (m)
1	1/02/2010 20:00	3.2	30/03/2017 11:00	6.8
2	25/01/2013 2:00	3.2	1/02/2010 20:00	6.1
3	30/03/2017 11:00	3.2	1/02/2014 1:00	6
4	20/02/2015 15:00	3	25/01/2013 14:00	5.8
5	16/07/2016 9:00	2.9	20/02/2015 16:30	5.5
6	1/02/2014 1:00	2.8	16/07/2016 9:00	5.5
7	20/03/2010 10:30	2.3	20/03/2010 21:00	4.7
8	16/01/2012 22:00	2.3	12/04/2013 3:00	4.5
9	12/04/2013 4:00	2.3	16/01/2012 23:00	4.5
10	13/03/2010 12:30	2.2	8/03/2018 8:30	4

Table 40 Gladstone – significant meteorological events with threshold H_s of 2.0 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
No significant events reported				

Denotes peak H_s event

Notes: 1. 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).

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

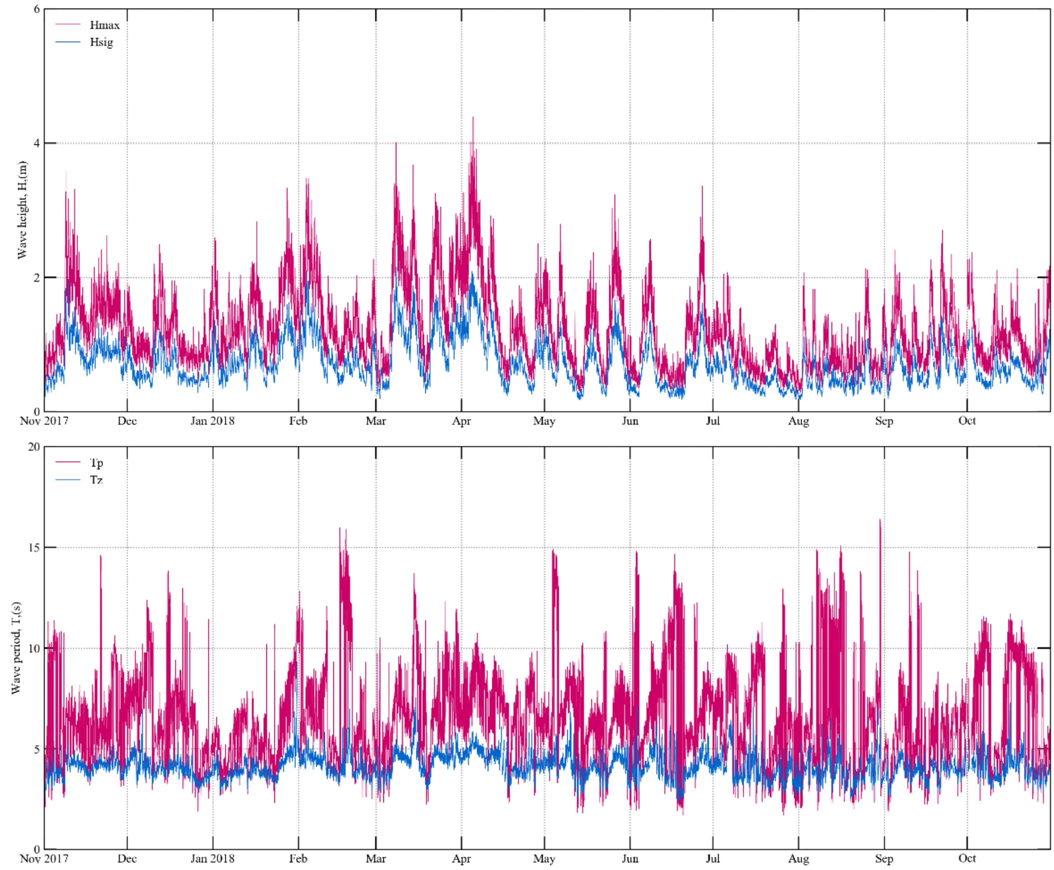


Figure 75 Gladstone – daily wave recordings

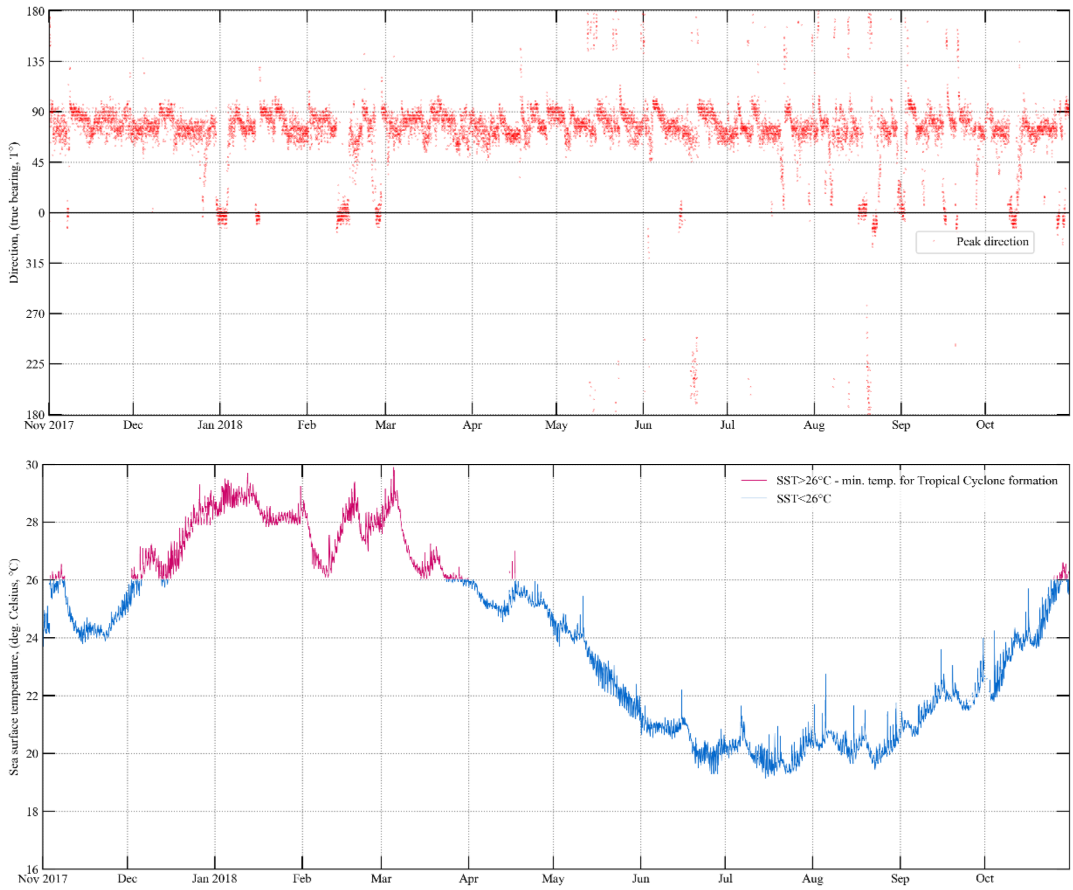


Figure 76 Gladstone – peak wave direction and sea surface temperature

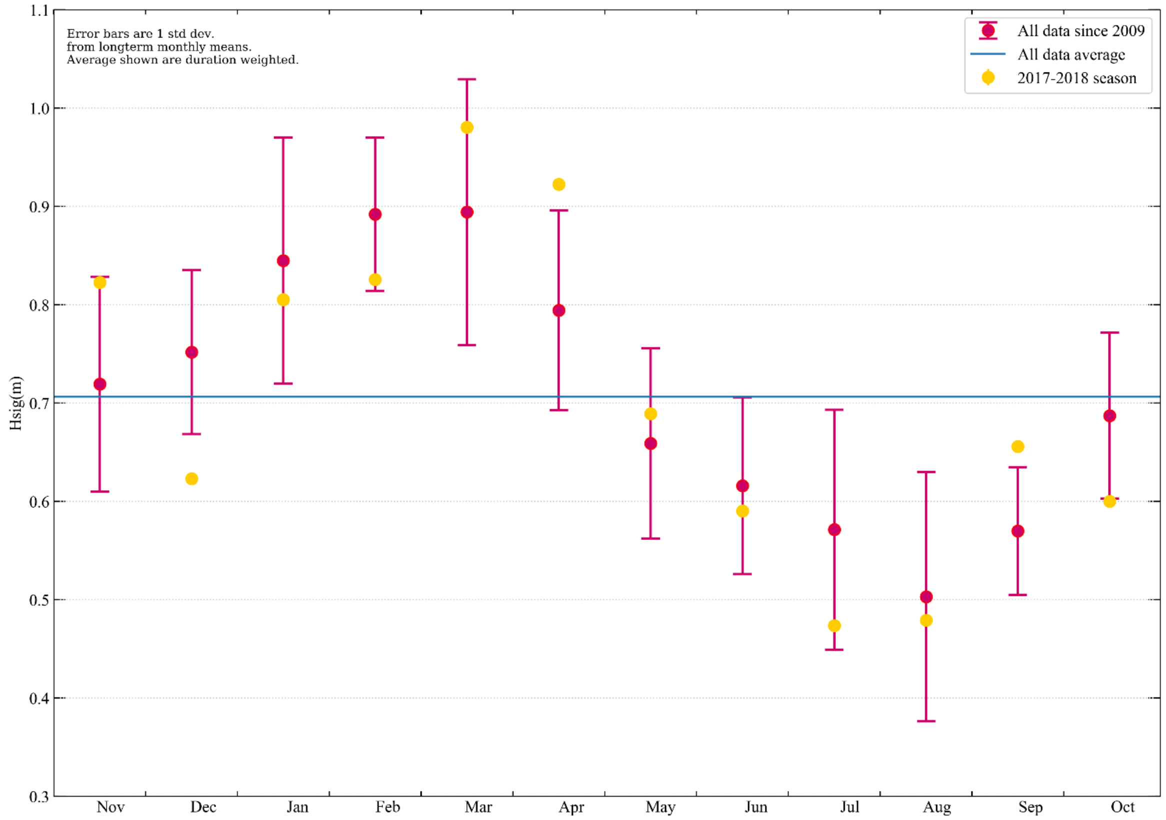


Figure 77 Gladstone – monthly average wave height (H_s) for 2017-18 and for all data

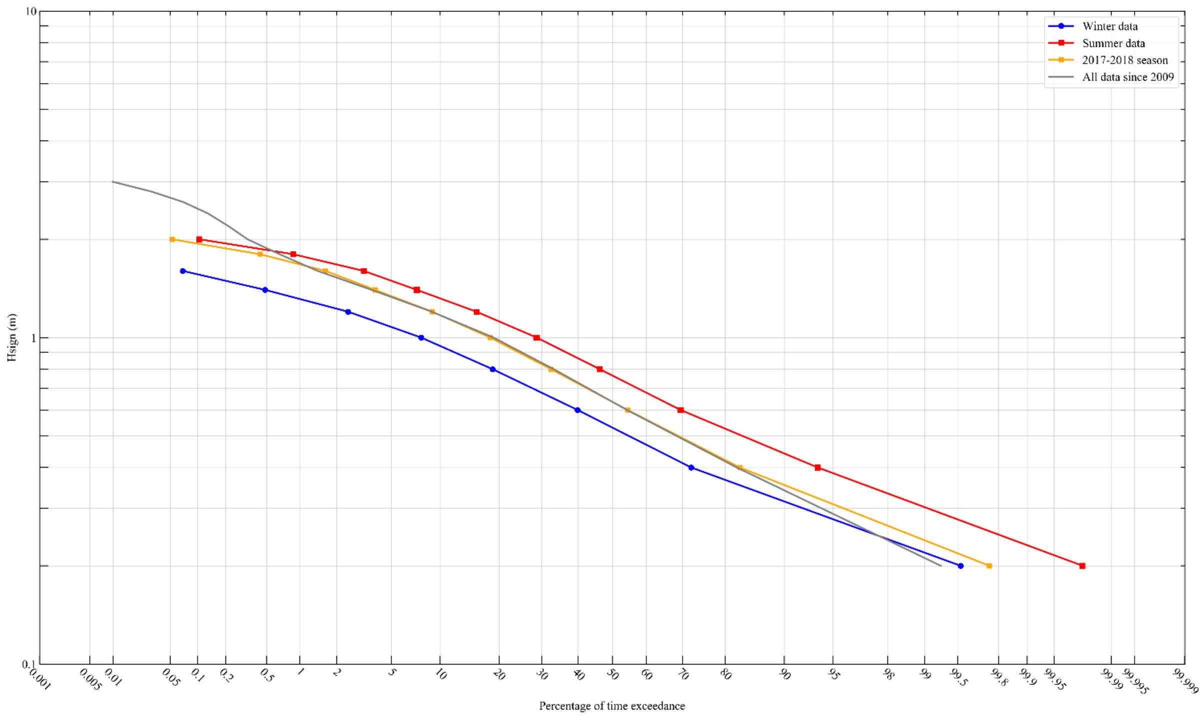


Figure 78 Gladstone – percentage exceedance of wave height (H_s) for all wave periods (T_p)

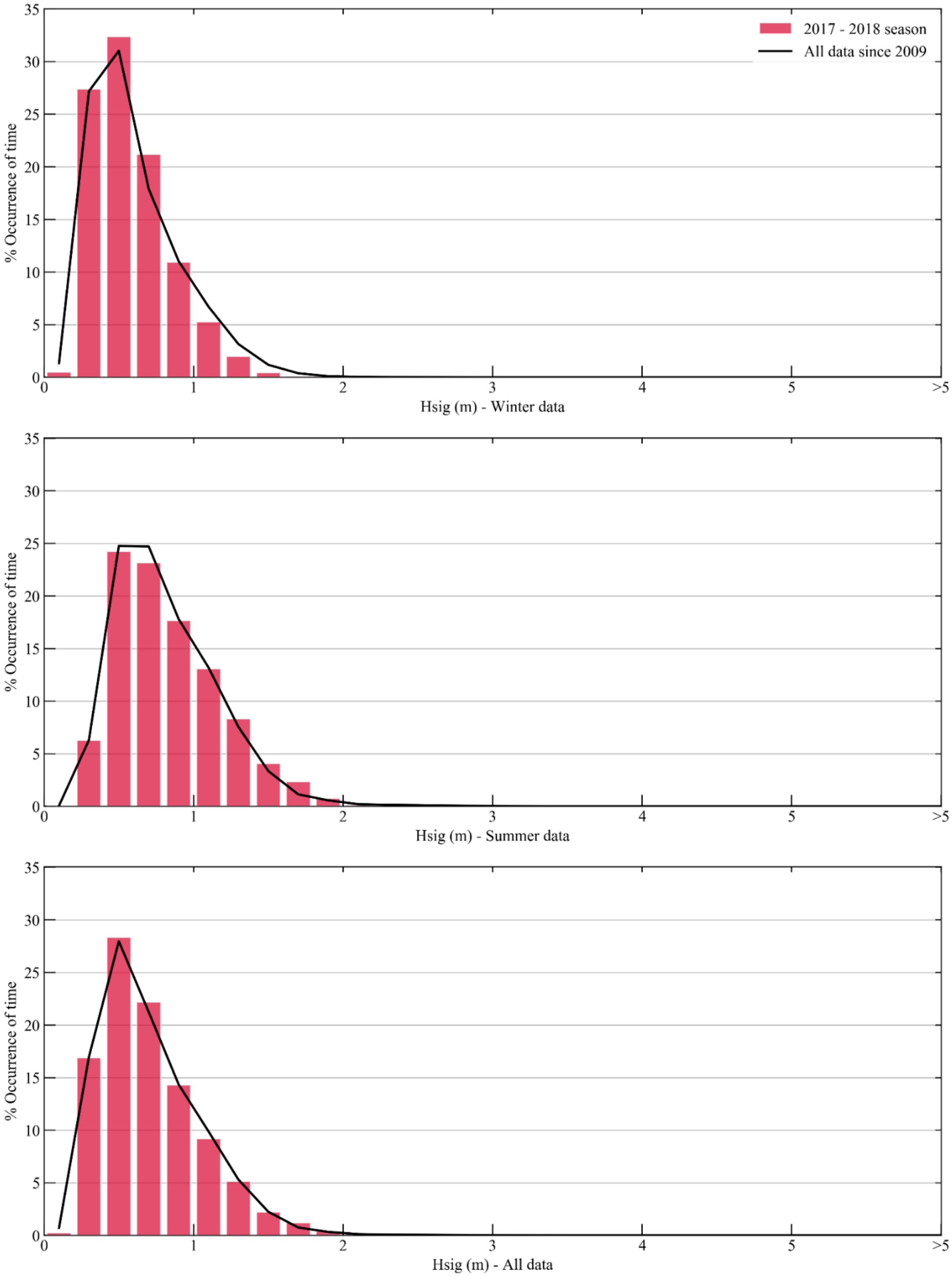


Figure 79 Gladstone – histogram percentage (of time) occurrence of wave heights (H_s)

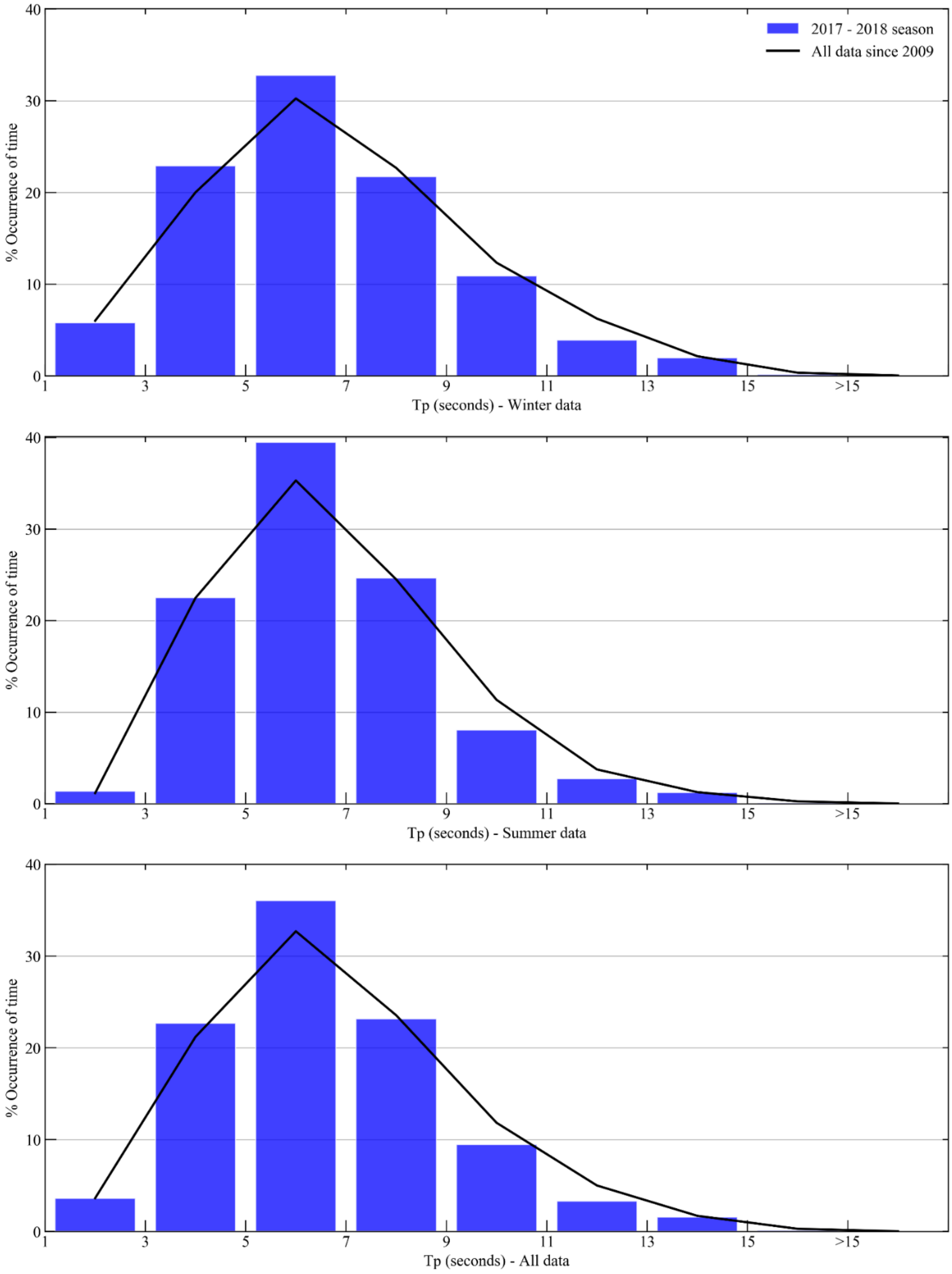


Figure 80 Gladstone – histogram percentage (of time) occurrence of wave periods (T_p)

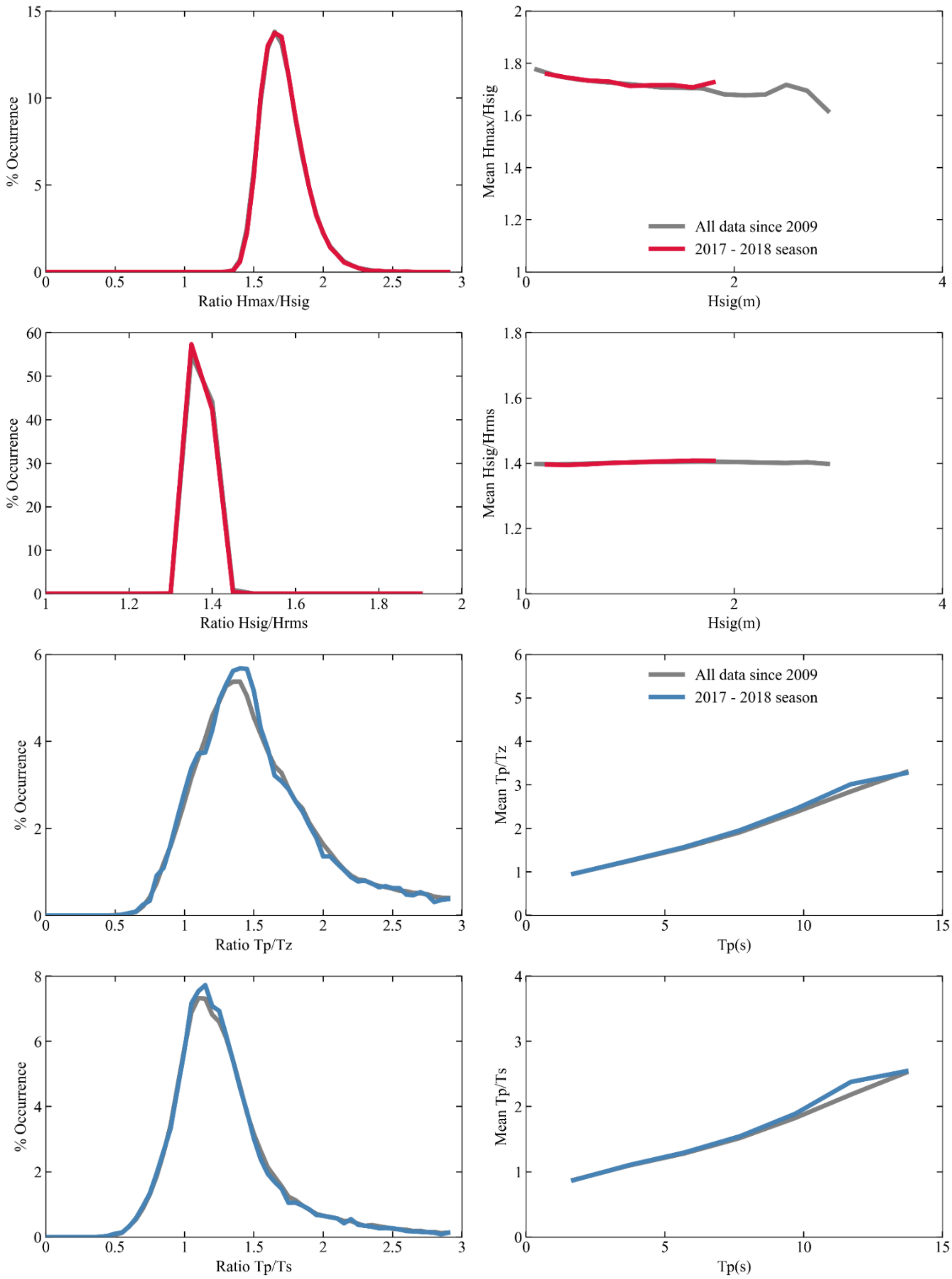
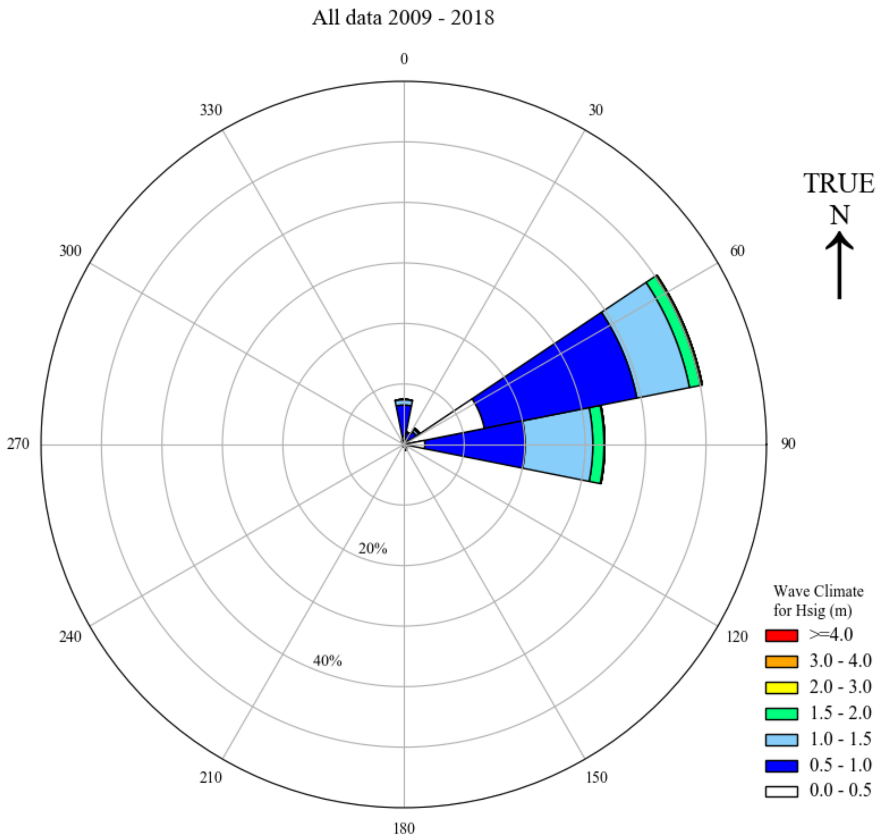


Figure 81 Gladstone – wave parameter relationships



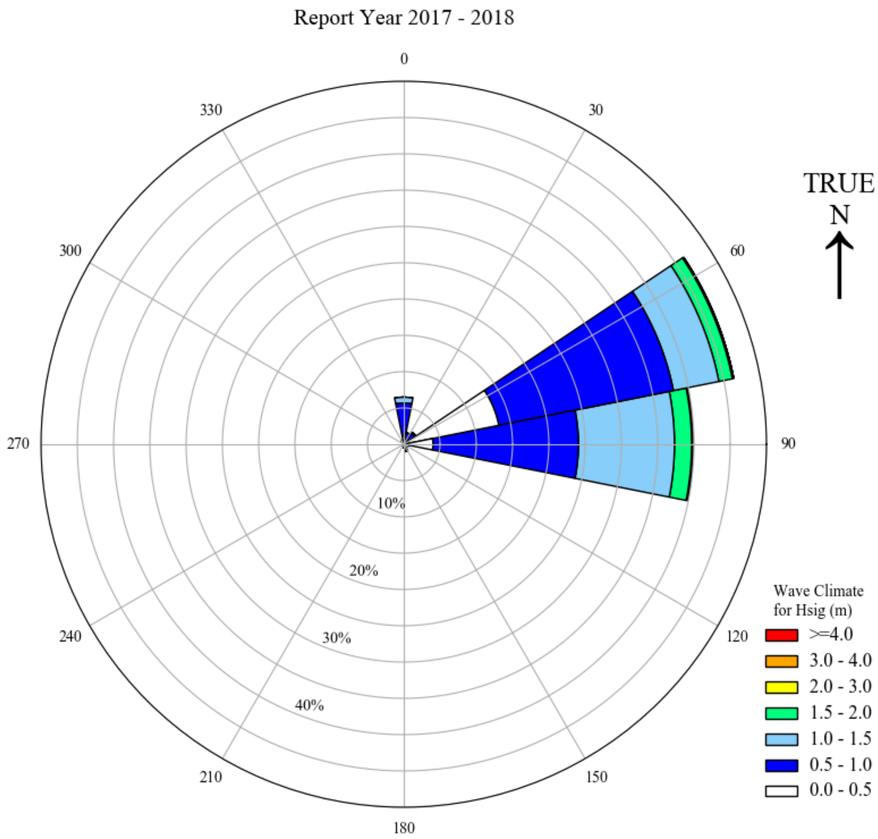


Figure 82 Gladstone – directional wave rose

Emu Park

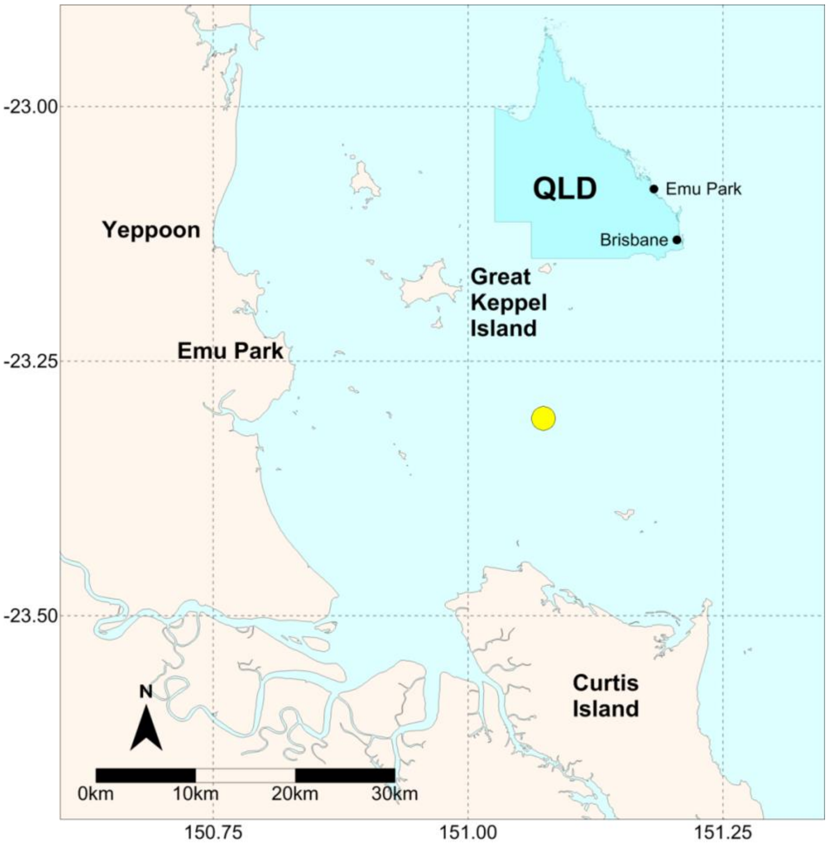


Figure 83 Emu Park – locality plan

Table 41 Emu Park – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	24/07/1996	1.0 years	321,824	22.27
2017-18	01/11/2016	25.29 days	16,305	1

Table 42 Emu Park – buoy deployments during the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
21°18.228' S	151°04.300' E	DWR-MkIII	19	24/05/2017	19/04/2018
23° 18.244' S	151° 04.273' E	DWR-MkIII	18	19/04/2018	current

Emu Park – seasonal overview

The Emu Park wave buoy has been operational for just over 22 years with an overall data return of 95.5 per cent. The data recorded for the period November 2017 to October 2018 was good, with total gaps of

25.29 days, equivalent to 93 per cent data return (Table 41). The buoy was replaced once during the reporting period on the 19th of April, see Table 42.

During the reporting year there were two significant weather events however neither of these events generated wave heights large enough to make it into the top ten highest waves (Table 43).

The temperature (sea surface temperature, SST) measured in the buoy hull showed a range of 20 °C to 30 °C (Figure 85). The SST from December to April was warm enough for tropical cyclone development.

The monthly average H_s was greater than one standard deviation (sd) of the long-term mean during November, and lower than one sd in December and July (Figure 86).

Percentage exceedance of H_s (Figure 87) shows wave heights were lower during the winter months and higher during the summer months during the reporting period and compared to historic data. The overall percent exceedance during the reporting period was mostly similar to the entire record with generally lower percent exceedance for wave height over 0.4 m. Histograms of occurrence of H_s show general similarity to the entire record, however a higher occurrence of H_s 0.4 - 0.6 m is apparent for winter, summer, and the 2017-2018 period. The histograms for T_p show similarity to the historic data (Figure 89).

The ratios between different wave parameters such as H_{max}/H_s and T_p/T_z is consistent between this reporting period and all of the historic data (Figure 90).

Directional wave rose plots (Figure 85 and Figure 91) show dominant incident waves from the east-north-east to east-south-east, which is a similar distribution to the entire record. The directional spread is also reflected in the peak wave directions (Figure 85).

Table 43 Emu Park – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	20/02/2015 13:30	4.0	01/02/2010 03:30	8.2
2	25/01/2013 11:00	3.9	25/01/2013 11:30	7.4
3	30/03/2017 08:30	3.8	30/03/2017 08:30	7.0
4	01/02/2010 02:00	3.7	20/02/2015 14:00	7.0
5	16/07/2016 12:00	3.7	09/03/1997 11:30	6.9
6	31/01/2014 06:30	3.5	31/01/2014 04:00	6.7
7	28/08/1998 06:30	3.2	16/07/2016 12:00	6.6
8	04/06/2002 13:00	3.2	28/08/1998 08:00	6.4
9	09/03/1997 19:30	3.1	04/06/2002 17:30	6.4
10	20/03/2010 16:00	3	20/03/2010 12:30	5.9

Table 44 Emu Park – significant meteorological events with threshold H_s of 2.5 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
3/02/2018 22:00	2.5 (2.6)	4.0 (5.1)	7.3	A high-pressure system moved from the Great Australian Bight to the Tasman sea extending a ridge of high-pressure along the east coast.
8/03/2018 10:00	2.5 (2.6)	4.0 (5)	7.1	TC Hola developed on the March 3, moving westward, however Hola stayed well off the east coast.

Denotes peak H_s event

Notes: 1. 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).

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

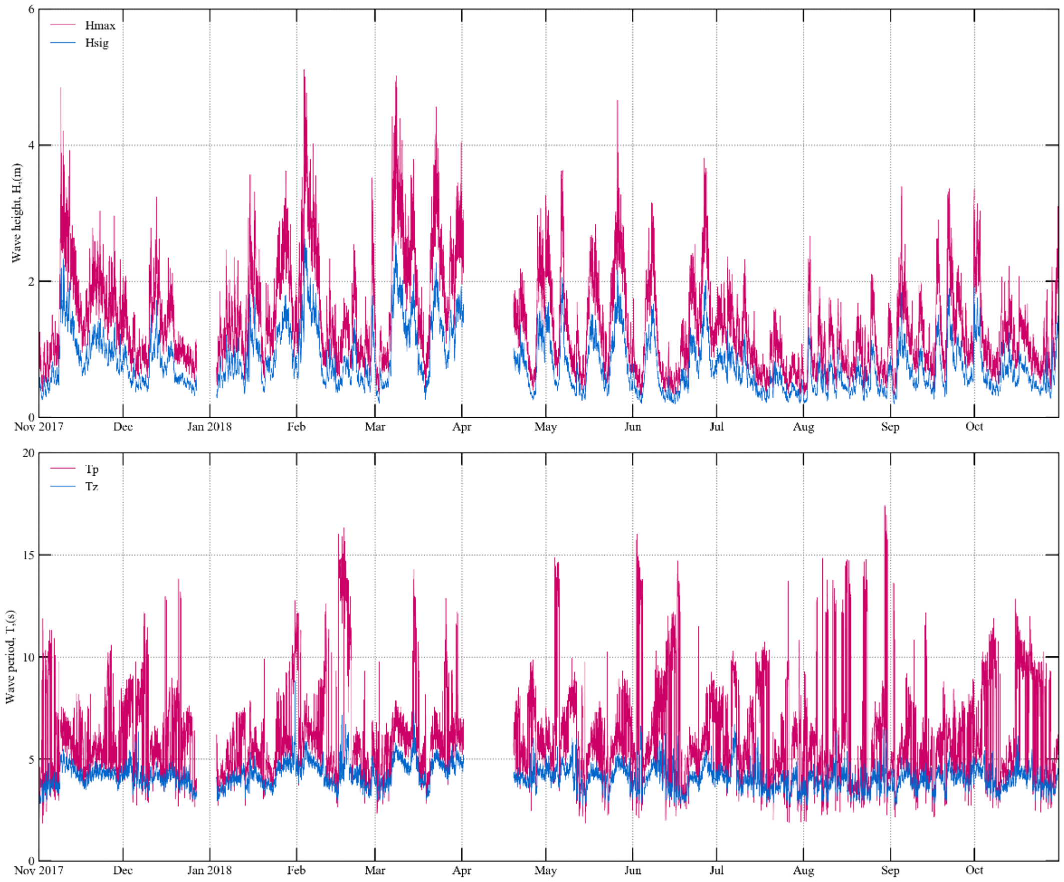


Figure 84 Emu Park – daily wave recordings

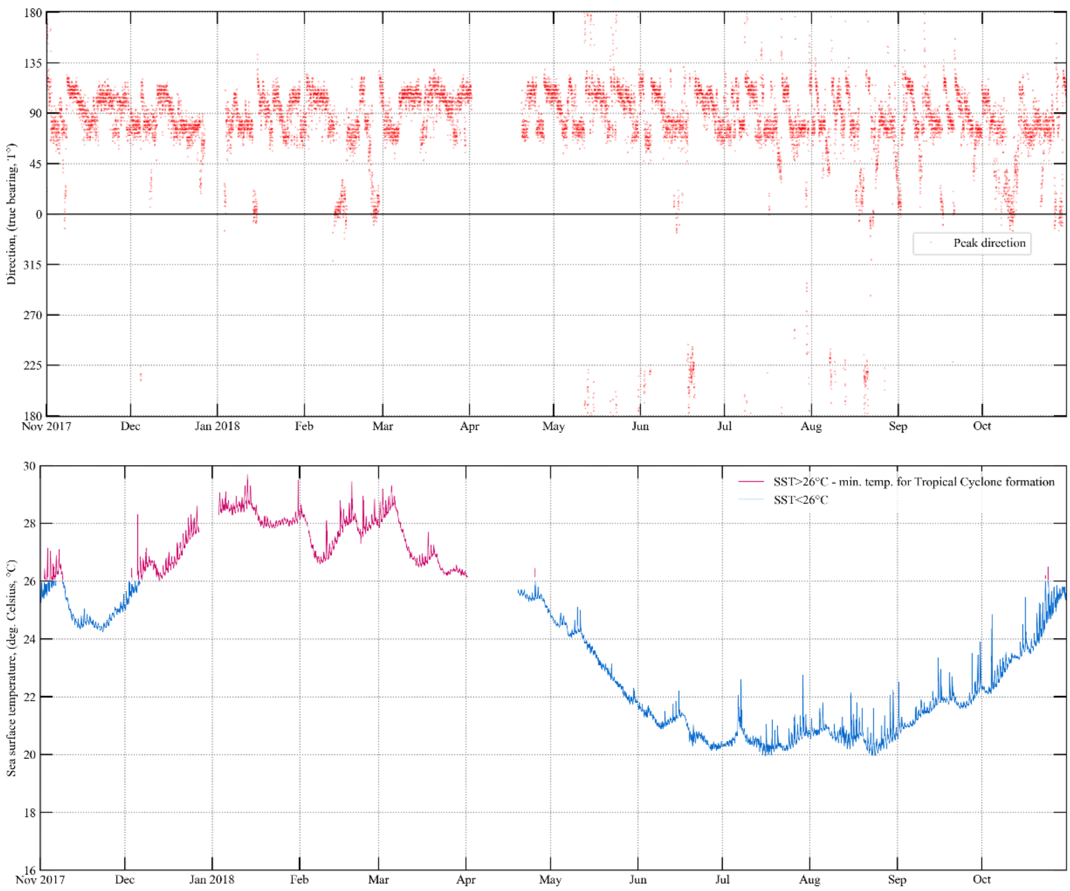


Figure 85 Emu Park – peak wave direction and sea surface temperature

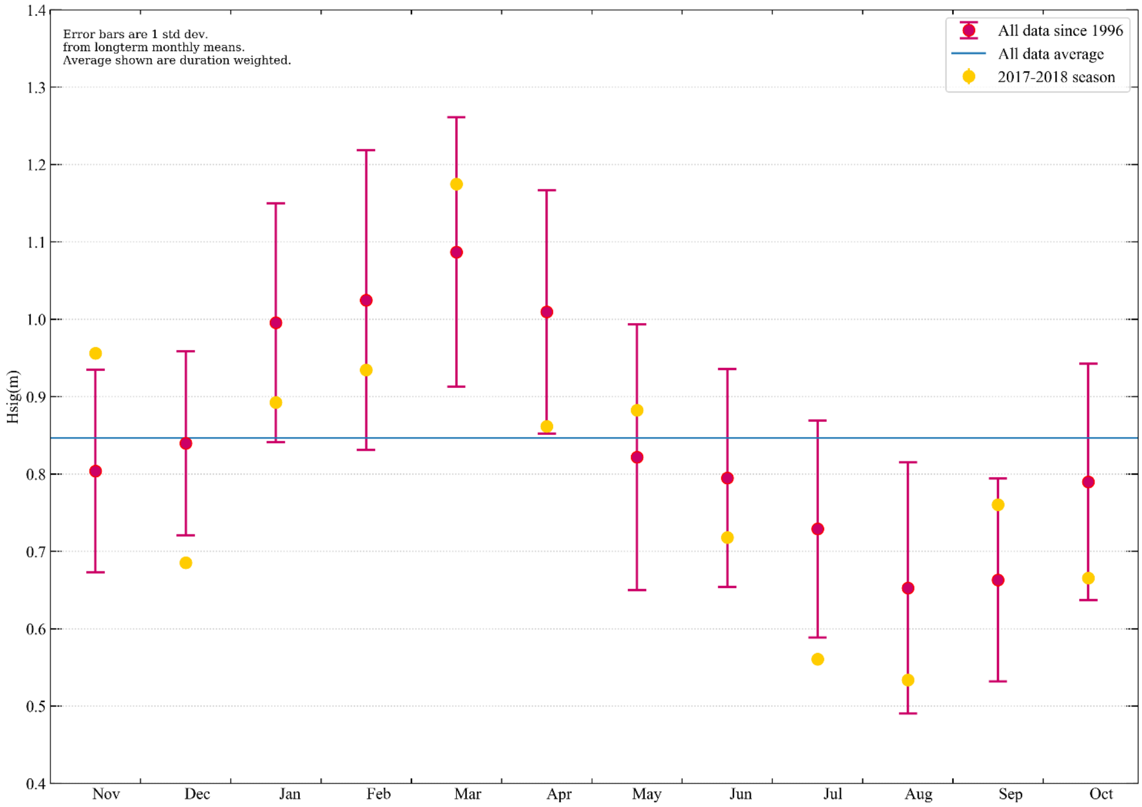


Figure 86 Emu Park – monthly average wave height (H_s) for 2017-18 and for all data

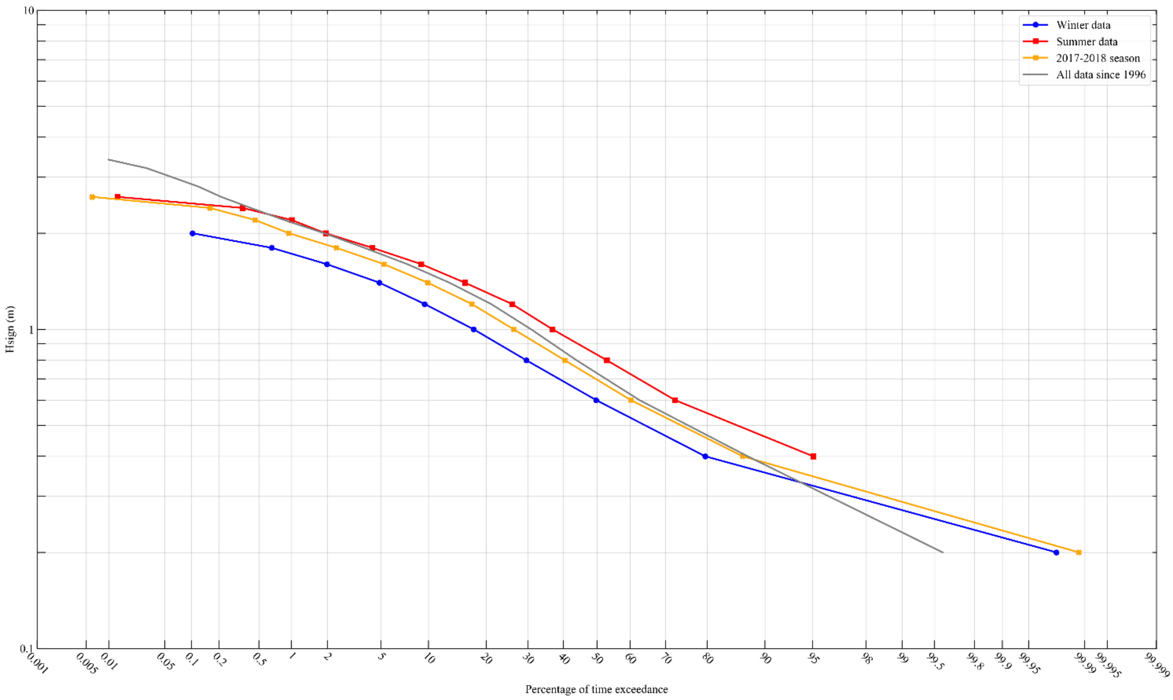


Figure 87 Emu Park – percentage exceedance of wave height (H_s) for all wave periods (T_p)

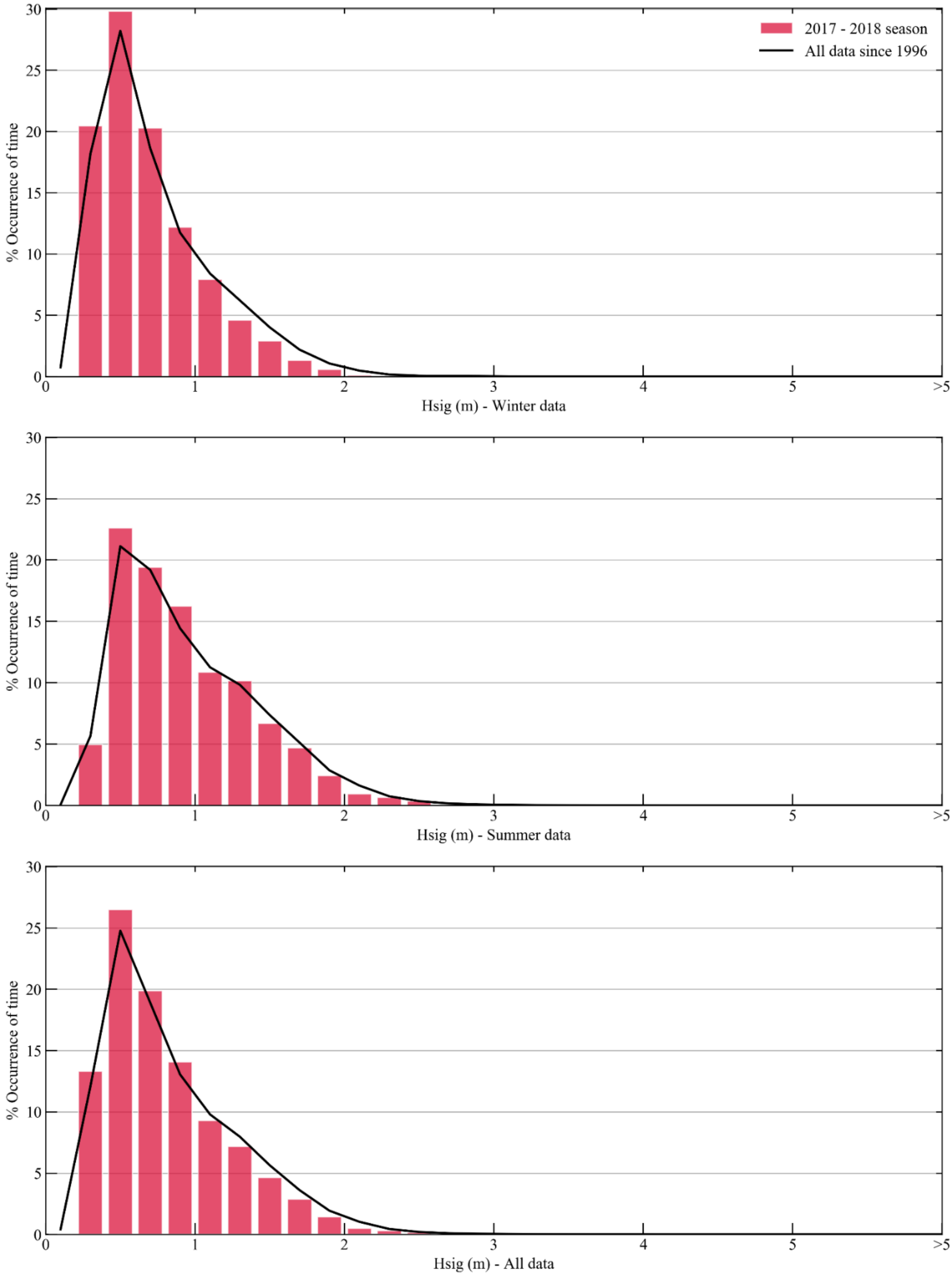


Figure 88 Emu Park – histogram percentage (of time) occurrence of wave heights (H_s)

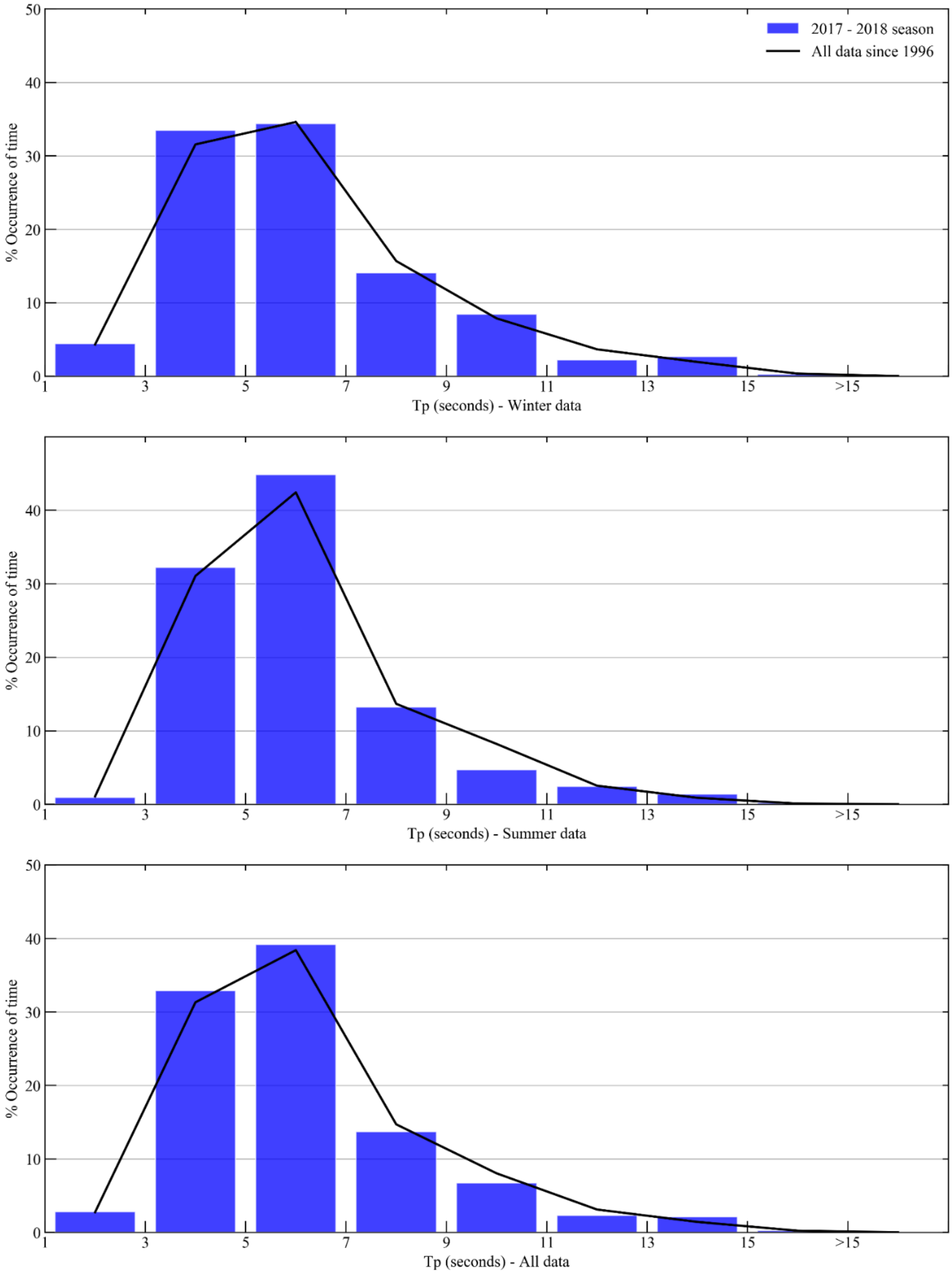


Figure 89 Emu Park – histogram percentage (of time) occurrence of wave periods (T_p)

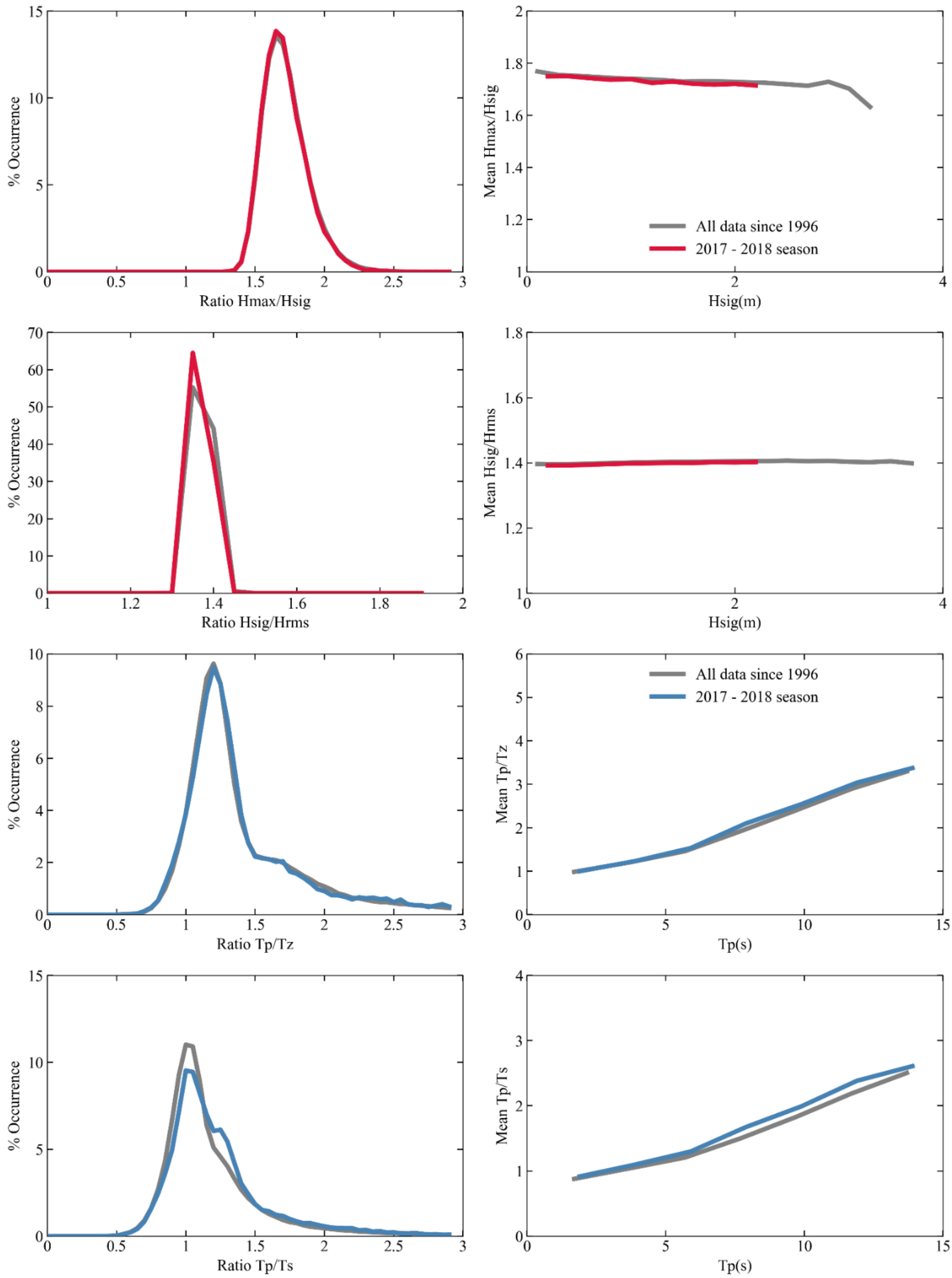
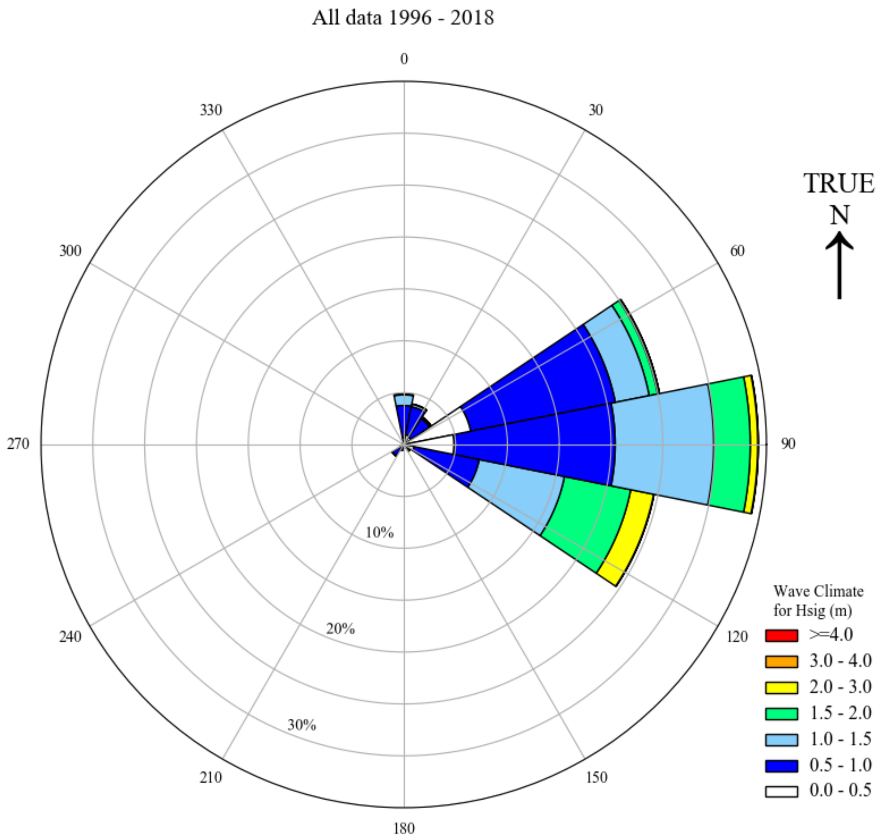


Figure 90 Emu Park – wave parameter relationships



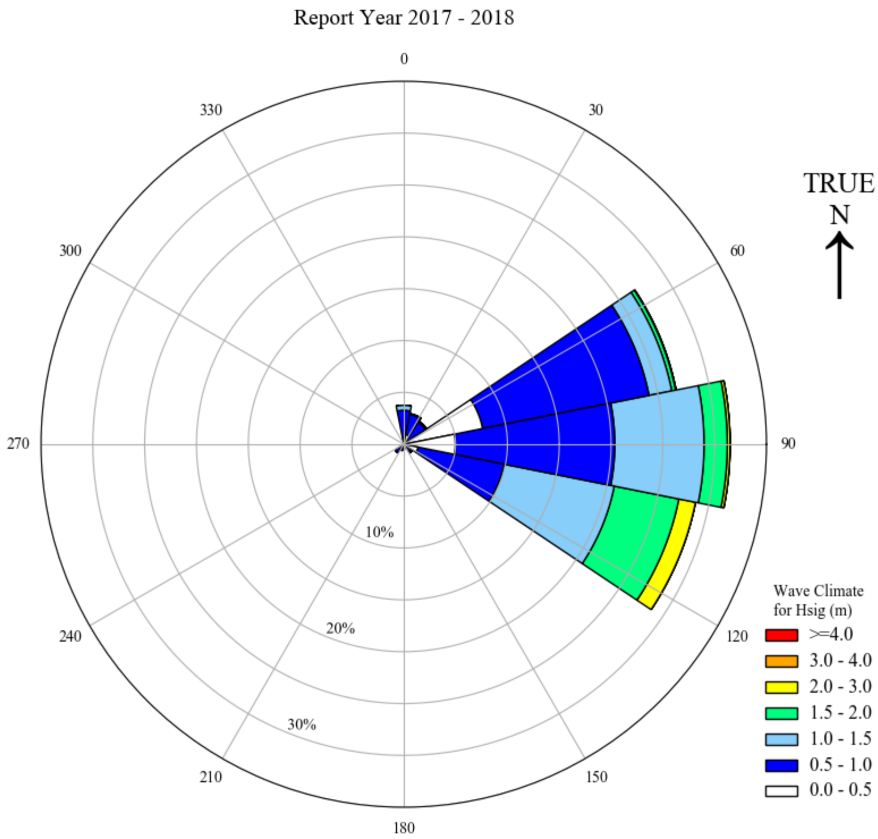


Figure 91 Emu Park – directional wave rose

Hay Point

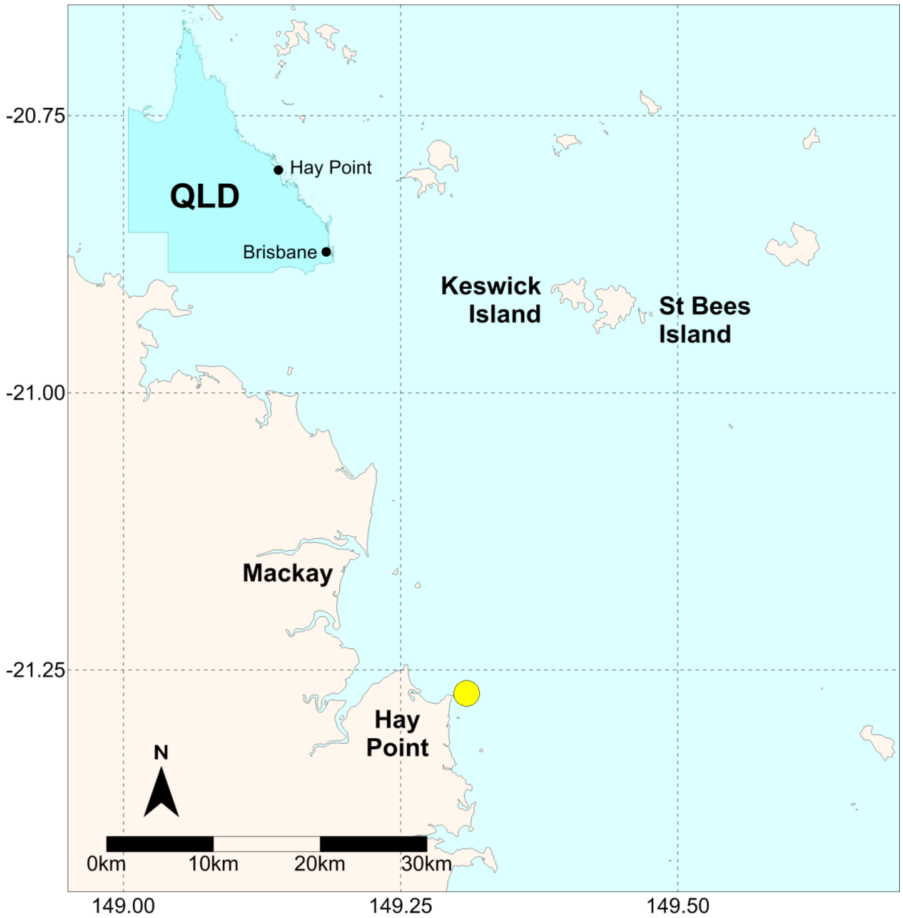


Figure 92 Hay Point – locality plan

Table 45 Hay Point – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	24/04/1977	na	394,216	41.6
2017-18	01/11/2017	2.04 days	17,421	1

Table 46 Hay Point – buoy deployments for the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
21°16.325' S	149°18.720' E	DWR-GPS	12.6	04/06/2016	30/1/2018
21° 16.332' S	149° 18.696' E	DWR-GPS	8.8	30/1/2018	current

Hay Point – seasonal overview

The Hay Point wave buoy has been operational for almost 42 years. The data record for the period of November 2017 to October 2018 was good, with total gaps of 2.04 days, equivalent to 99.4 per cent data return (Table 45). The buoy was replaced once during the reporting period on the 30th of January. (Table 46).

During the reporting period there were three significant weather events that impacted Hay Point. Only one event was significant enough to make the top 10 highest waves (Table 47). The passage of TC Iris generated a H_s of 2.7 m in seventh place and Hmax of 5.6 m in sixth place.

SST ranged from 19 °C to 31.5 °C (Figure 94) and was high enough for tropical cyclone development (26 °C) periodically from November through April and towards the end of the reporting period in mid-October 2018, SST increased above 26.5 °C.

The monthly average H_s sometimes fell within one sd of the long-term mean. November was above one sd, while December, February, July, August and October were below one sd of the mean (Figure 95).

Percentage of time exceedance of H_s (Figure 96) shows larger waves occurring more often throughout summer in comparison to winter. The overall wave climate during the reporting period was similar to the wave climate of the whole record, however were slightly below average for waves < 1 m. This is also reflected in the histogram of the occurrence of H_s with waves between 0.8 – 1 m being lower than average during winter, summer, and the 2017-2018 period, however waves in the 0.2 - 0.4m range were more frequent than the historic data (Figure 97 and Figure 98). The most common T_p was 3–5 seconds, with periods during winter and summer having similar distribution.

The ratios between different wave parameters such as H_{max}/ H_s, H_s/H_{rms} and T_p/T_z were consistent between this reporting period and all of the historic data (Figure 99). The ratio T_p/T_s has slightly decreased compared to the historic data.

Peak wave direction (Figure 94) was predominately from the east, with occasional swings to the north and south. Directional wave rose plots (Figure 100) confirm the dominant incident wave direction from the east to east south-east. Wave directions for the reporting period are very similar to the entire record.

Table 47 Hay Point – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	21/03/2010 1:30	4	30/01/2014 22:00	7
2	30/01/2014 22:00	3.7	10/03/1997 10:00	6.8
3	28/03/2017 11:00	3.6	28/03/2017 9:00	6.6
4	9/03/1997 20:00	3.1	21/03/2010 4:30	6.3
5	31/01/2010 7:30	2.8	24/02/1996 2:00	5.6
6	16/02/2008 17:30	2.8	3/04/2018 23:00	5.6
7	3/04/2018 23:30	2.7	17/02/2008 21:00	5.4
8	1/02/1978 3:00	2.6	10/02/1999 18:00	5.3

9	29/08/1998 18:00	2.5	7/01/2017 5:30	5.3
10	24/01/2005 23:30	2.5	19/01/2004 18:00	5

Table 48 Hay Point – significant meteorological events with threshold H_s of 2.0 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
5/02/2018 0:30	2.0 (2.2)	3.3 (4.2)	5.8	A high-pressure system moved from the Great Australian Bight to the Tasman sea extending a ridge of high-pressure along the east coast.
8/03/2018 18:30	2.0 (2.1)	3.5 (4.1)	6.2	TC Hola developed on the March 3, moving westward, however Hola stayed well off the east coast.
3/04/2018 23:30	2.5 (2.7)	4.1 (5.6)	7	Ex-TC Iris redeveloped on the April 2 and tracked south before being downgraded to an East Coast Low on April 6.

Denotes peak H_s event

Notes: 1. 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).

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

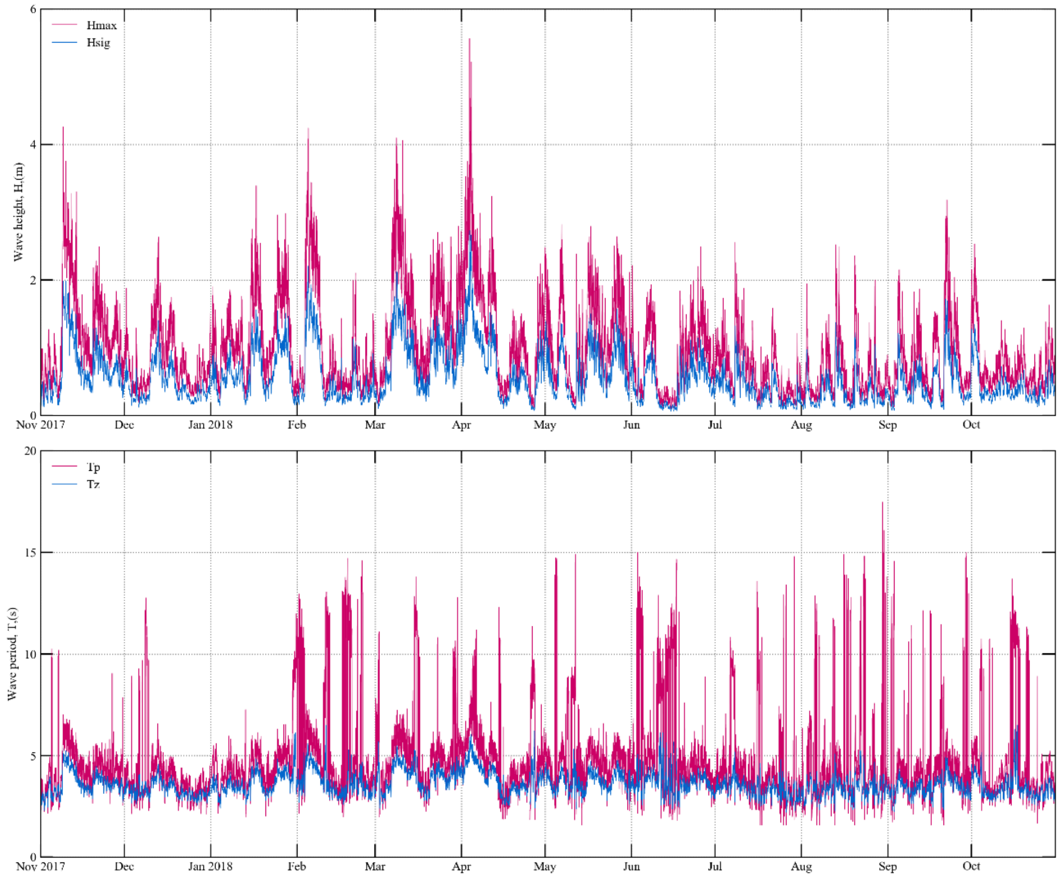


Figure 93 Hay Point – daily wave recordings

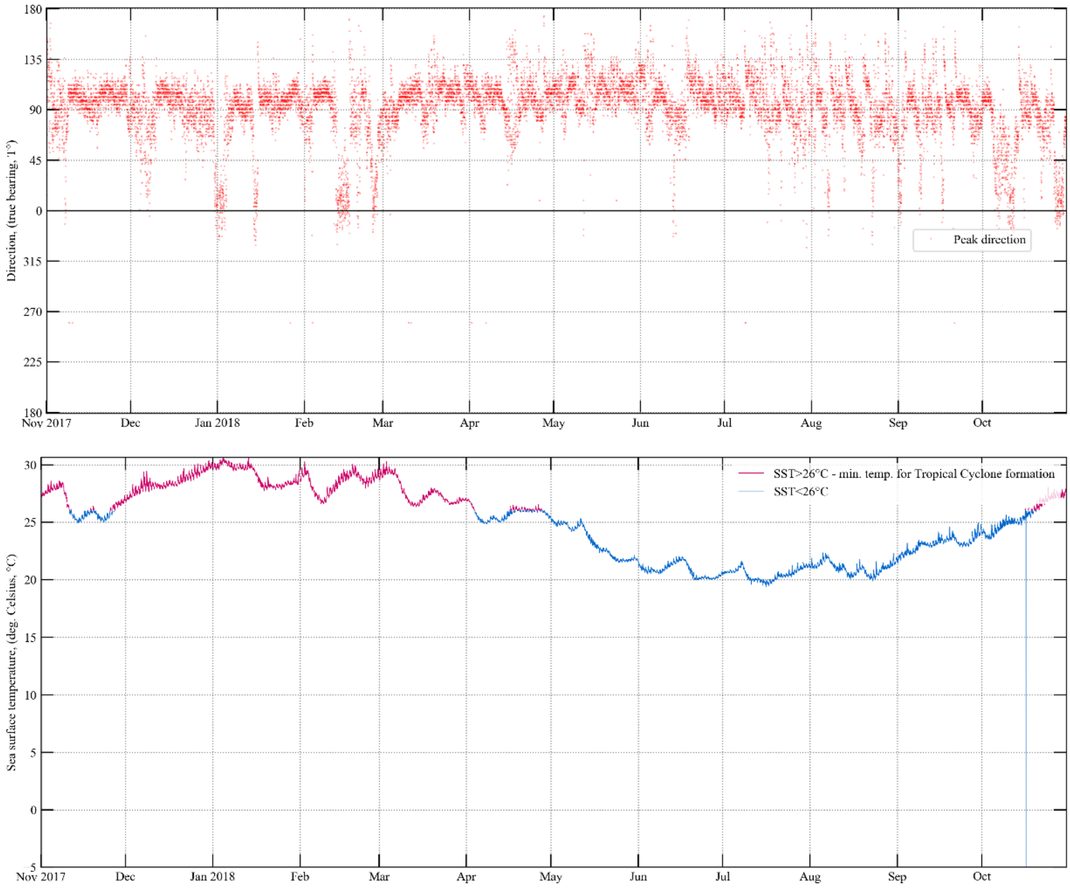


Figure 94 Hay Point – peak wave direction and sea surface temperature

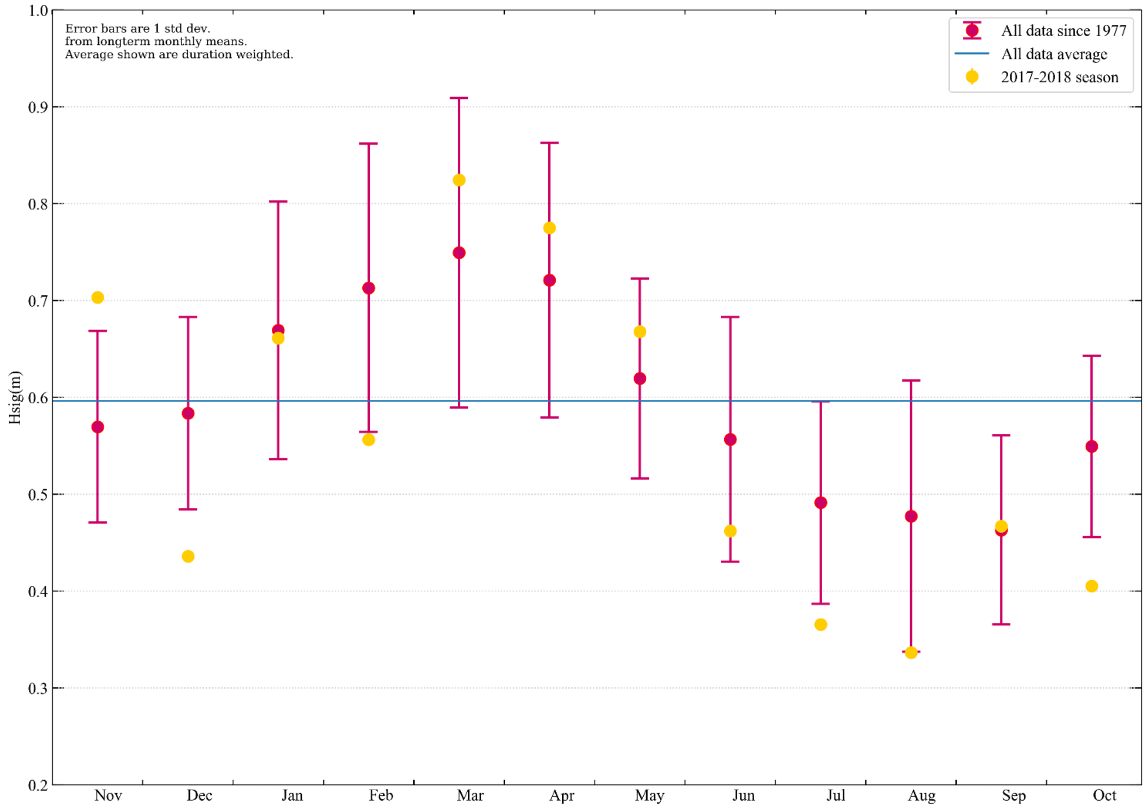


Figure 95 Hay Point – monthly average wave height (H_s) for 2017-18 and for all data

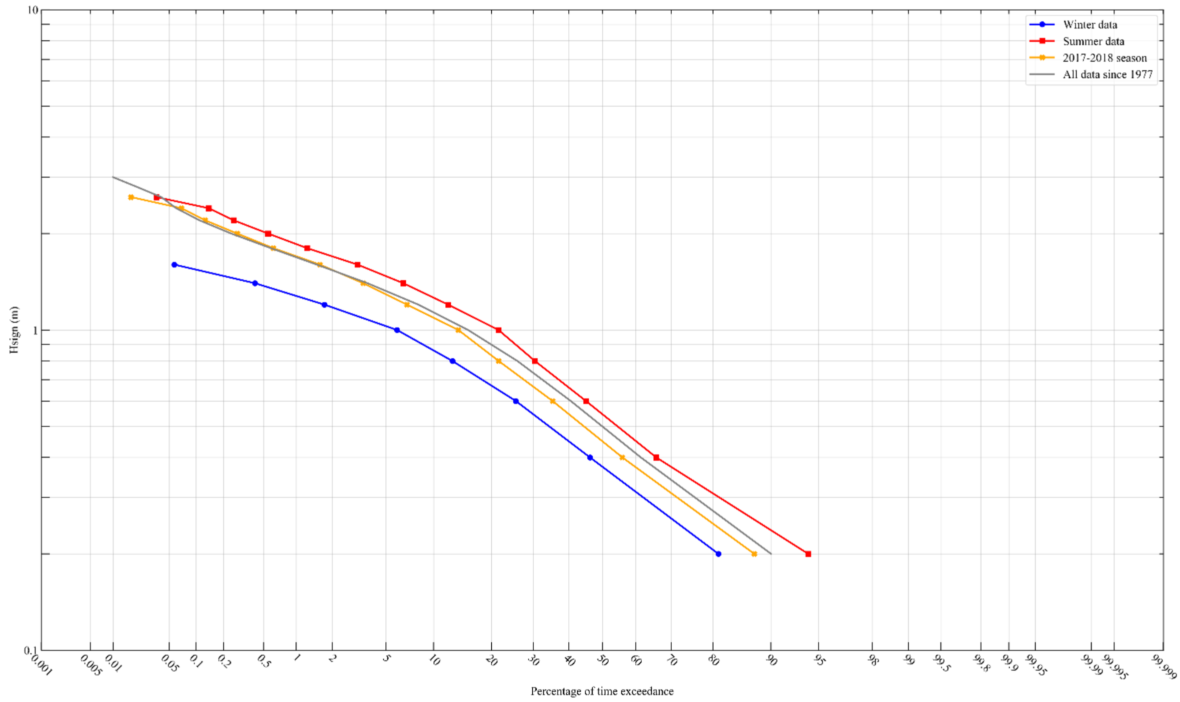


Figure 96 Hay Point – percentage exceedance of wave height (H_s) for all wave periods (T_p)

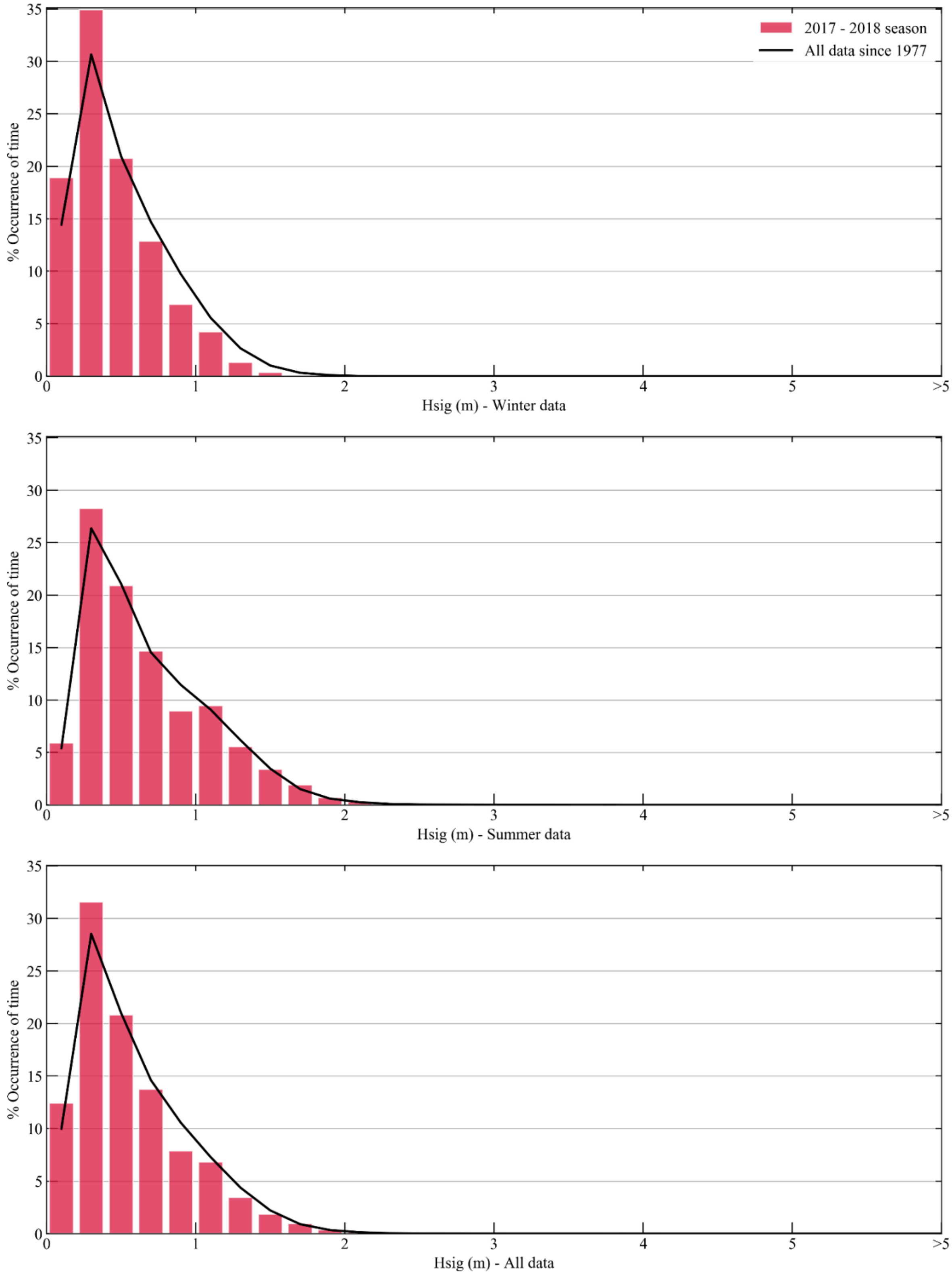


Figure 97 Hay Point – histogram percentage (of time) occurrence of wave heights (H_s)

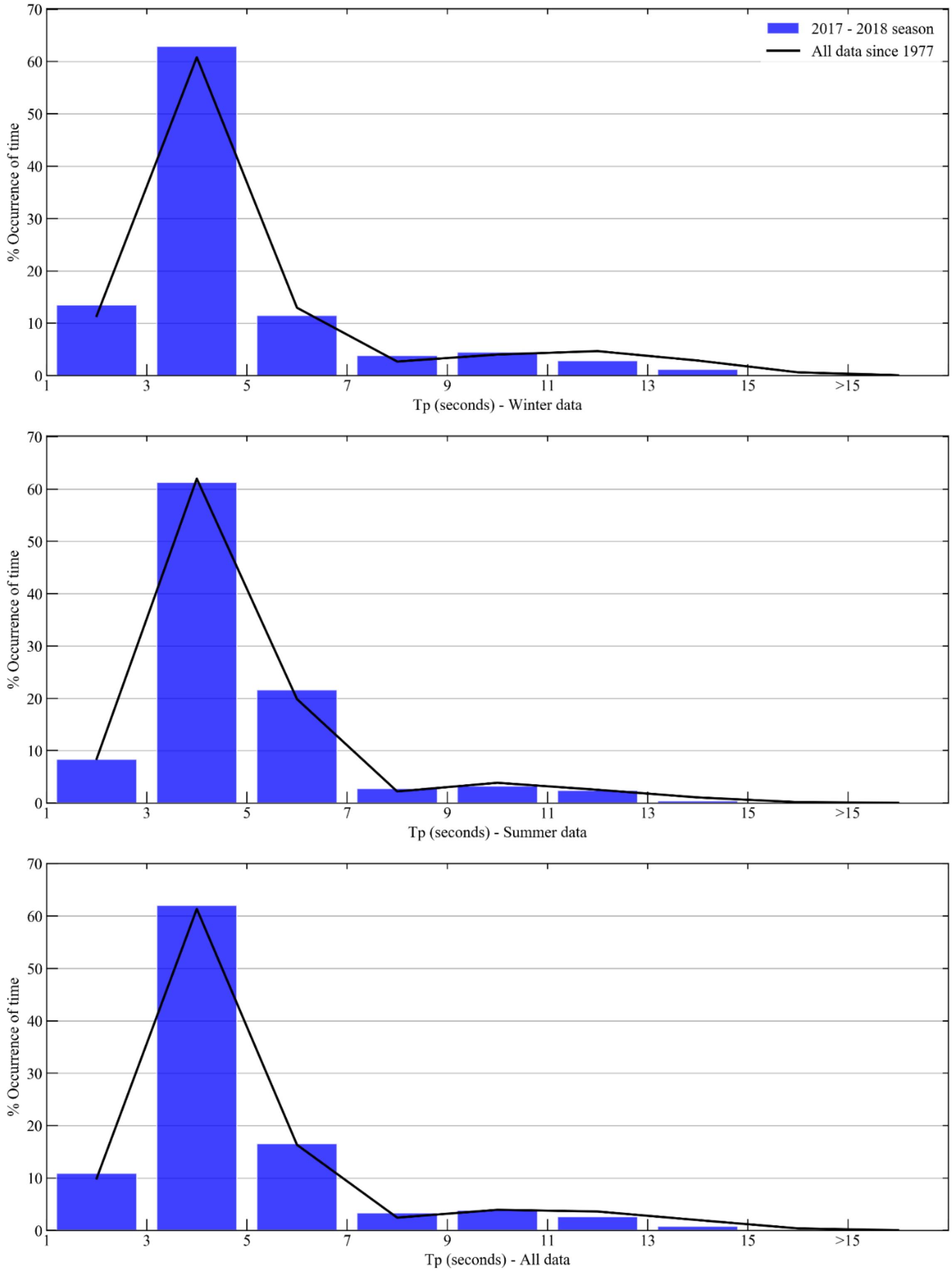


Figure 98 Hay Point – histogram percentage (of time) occurrence of wave periods (T_p)

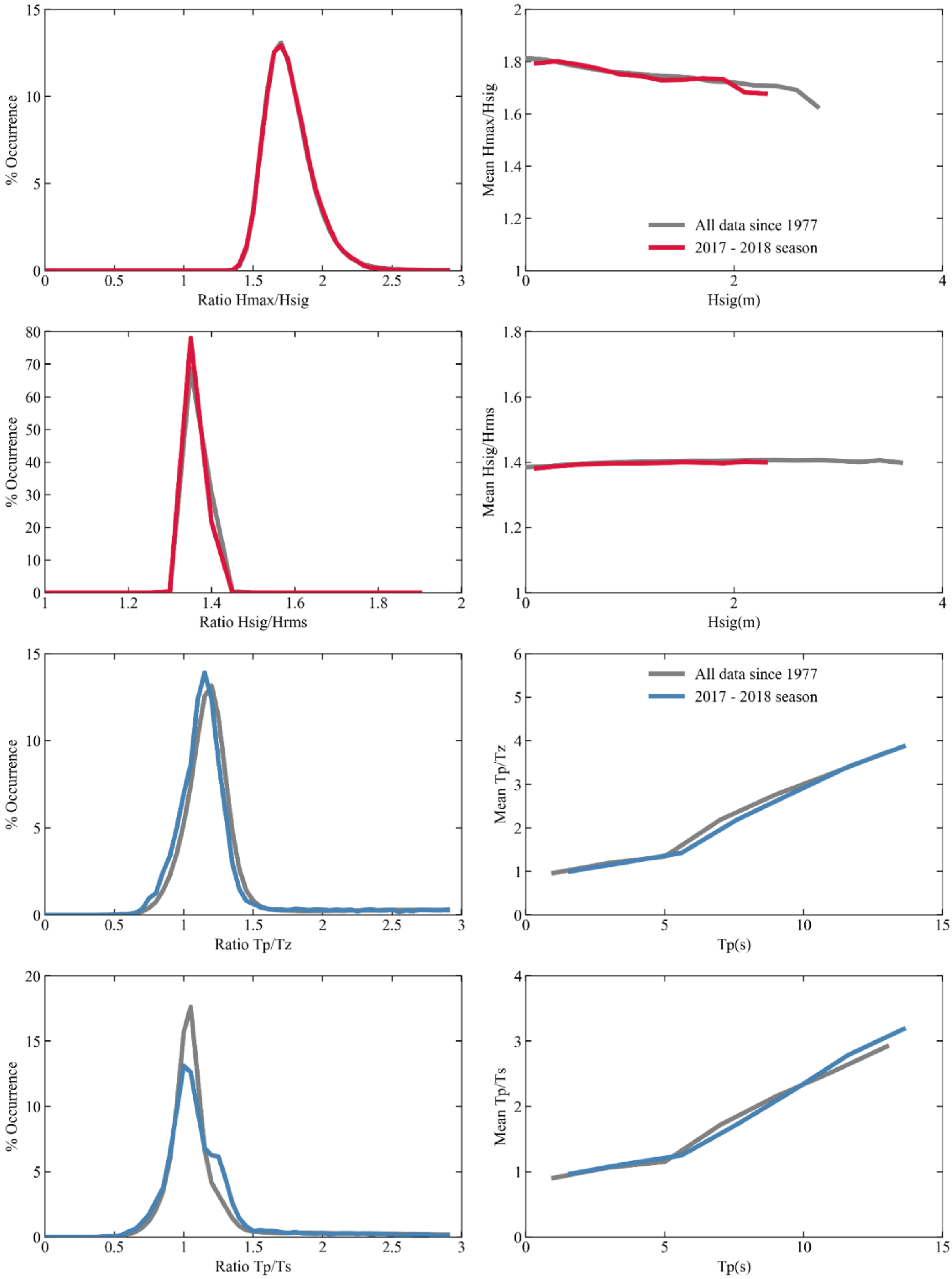
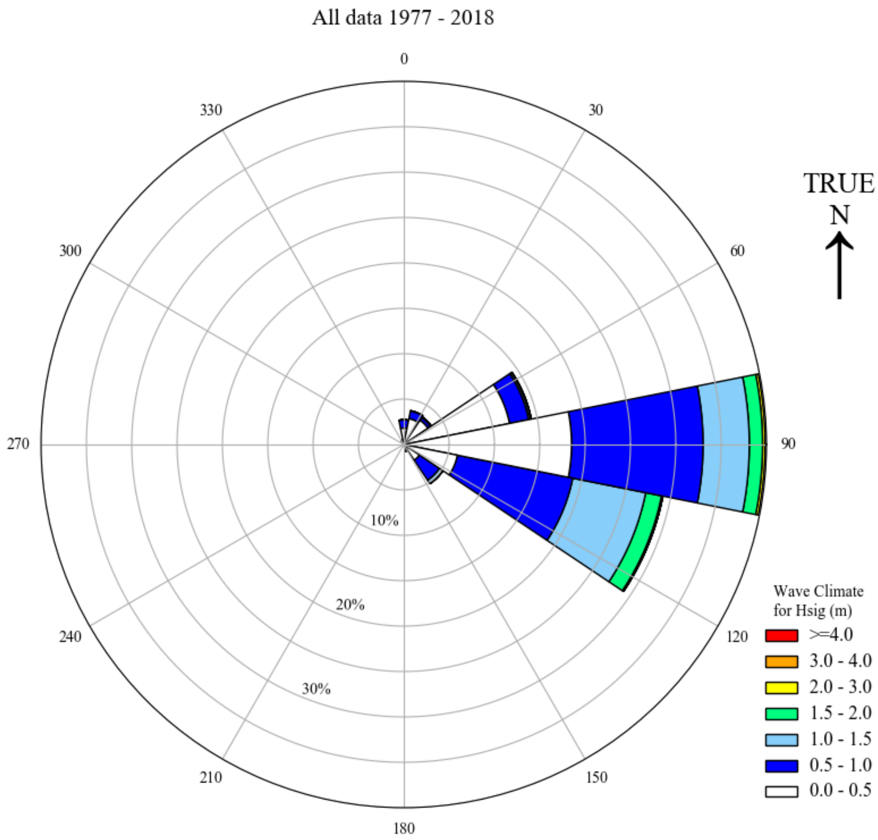


Figure 99 Hay Point – wave parameter relationships



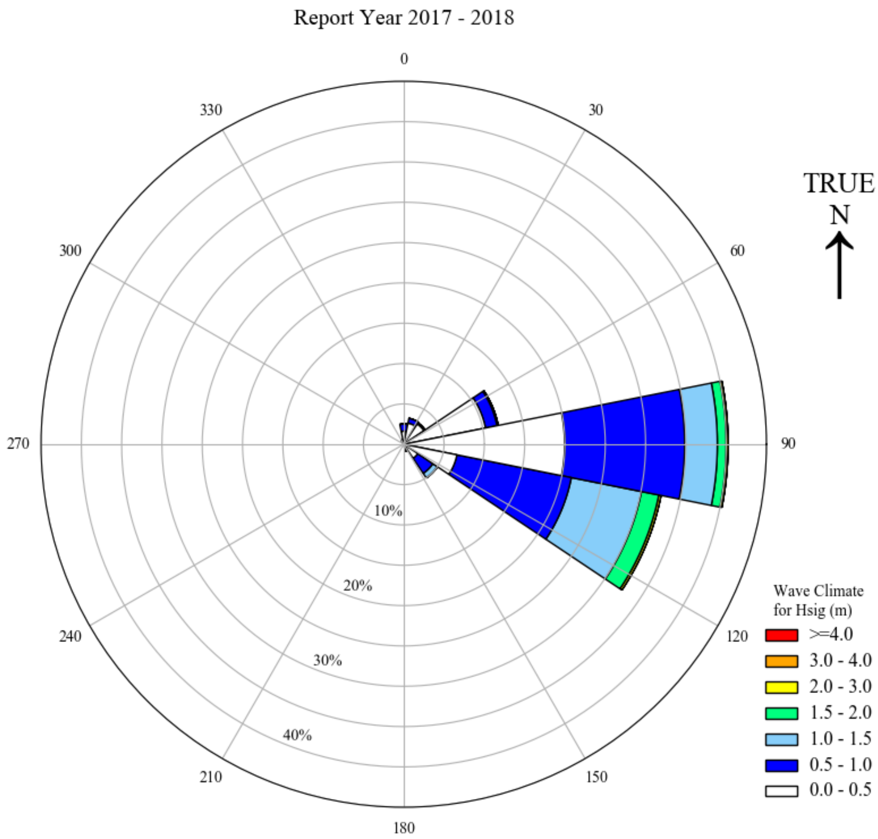


Figure 100 Hay Point – directional wave rose

Mackay

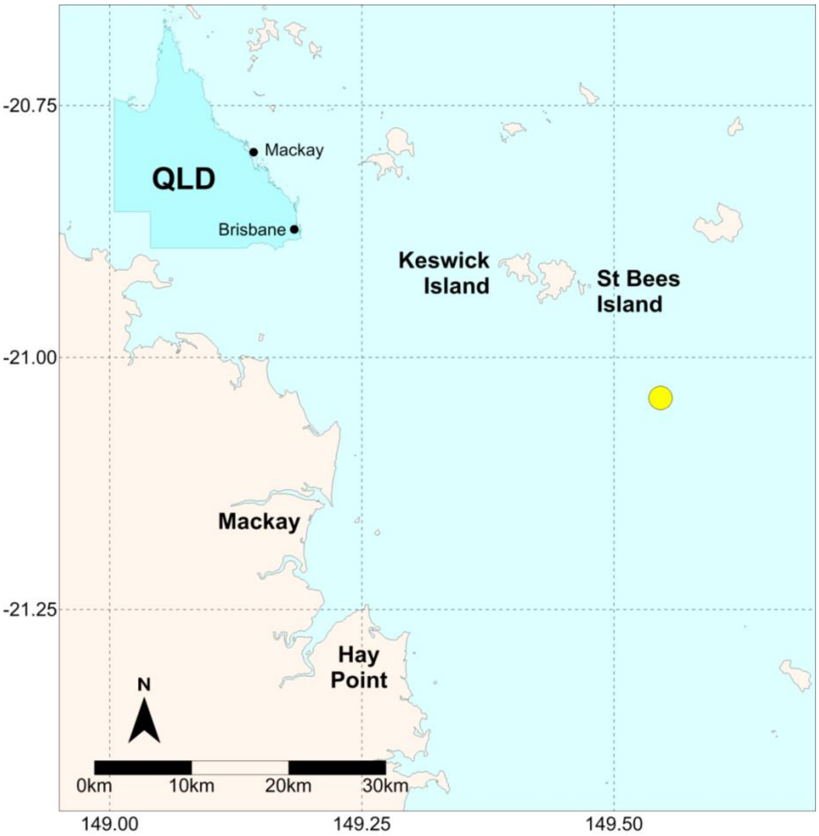


Figure 101 Mackay – locality plan

Table 49 Mackay – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	19/09/1975	na	346,560	43.1
2017-18	1/11/2017	3 days	17,376	1

Table 50 Mackay – buoy deployments during the 2016-17 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
21°02.240' S	149°32.800' E	Mk4	34	03/05/2017	current

Mackay – seasonal overview

The Mackay wave buoy has been operational for just over 43 years. The data record for the period from November 2017 to October 2018 was excellent, with total gaps of 3 days, equivalent to 99.1 per cent data return. The wave buoy was not replaced during the reporting period (Table 50).

There were five significant events during the reporting period (

Table 52) that exceeded the 2.5 m threshold. The passage of ex-TC Iris generated a H_s of 4.8 m ranked as the fifth highest wave and H_{max} of 8.5 m also ranked fifth.

Peak wave direction was predominately from between east and north-east (Figure 103) with swings to the south. The SST ranged from 21 °C to 31 °C (Figure 103). The SST was high enough for tropical cyclone development from November through April.

Monthly average H_s (Figure 104) was higher than the mean plus one sd in November, March, April and May.

Percentage exceedance of H_s (Figure 105) shows a slightly higher percent exceedance of all wave heights between the reporting period and historic data. Overall wave heights were consistently lower percent exceedance in winter than in summer for the 2017-2018 period. Histograms of percentage occurrence of H_s (Figure 106) show similar distribution between the reporting period and the entire record. H_s of 0.4-0.6 m had lower than average percentage occurrence in the summer months and higher in winter. The histogram of percent occurrence of T_p show a similar trend to the overall wave record with the exception of higher occurrence of 9-11 second waves in winter and higher occurrence of 5-7 second and lower occurrence of 7-11 second waves in summer.

The ratios between different wave parameters such as H_{max}/H_s, H_s/H_{rms} and T_p/T_s were consistent between this reporting period and all of the historic data (Figure 108). The ratio of T_p/T_z is slightly skewed compared to the historic data.

Directional wave rose plots (Figure 109) also show the dominant east-south-east wave direction for the reporting period observed in the time series and very similar to the entire record.

Table 51 Mackay – highest waves

Rank	Date (H_s)	H_s (m)	Date (H_{max})	H_{max} (m)
1	20/03/2010 22:30	5.7	30/01/2014 19:30	10
2	30/01/2014 19:30	5	21/03/2010 0:00	9.4
3	28/03/2017 5:00	5	28/03/2017 4:30	8.7
4	10/03/1997 0:00	4.8	9/03/1997 11:00	8.5
5	4/04/2018 2:00	4.1	4/04/2018 14:30	8.2
6	1/03/1979 3:00	4	8/03/2009 17:00	7.7
7	12/03/2020 0:00	3.9	11/03/2020 22:00	7.6
8	27/12/1990 3:41	3.9	19/01/2004 19:30	7.5
9	5/06/2002 0:00	3.8	4/03/2002 15:00	7.3
10	19/02/2015 22:30	3.6	6/02/2015 21:00	7.3

Table 52 Mackay – significant meteorological events with threshold H_s of 2.5 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
9/11/2017 6:30	2.6 (2.8)	4.4 (5.7)	7.4	A ridge of high-pressure extended from the Tasman sea along the Queensland coast.
5/02/2018 0:00	3.1 (3.4)	5.1 (6.3)	8.7	A high-pressure system moved from the Great Australian Bight to the Tasman sea extending a ridge of high-pressure along the east coast.
8/03/2018 22:00	3.1 (3.3)	5.5 (6.4)	8.2	TC Hola developed on March 3, moving westward, however Hola stayed well off the east coast.
4/04/2018 12:00	3.9 (4.1)	6.9 (8.2)	8.8	Ex-TC Iris redeveloped on April 2 and tracked south before being downgraded to an East Coast Low on the April 6.
20/08/2018 7:00	2.5 (2.6)	4.5 (6)	6.6	A low-pressure system in the Tasman Sea brought a cold front and low-pressure trough.

Denotes peak H_s event

Notes: 1. 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).

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

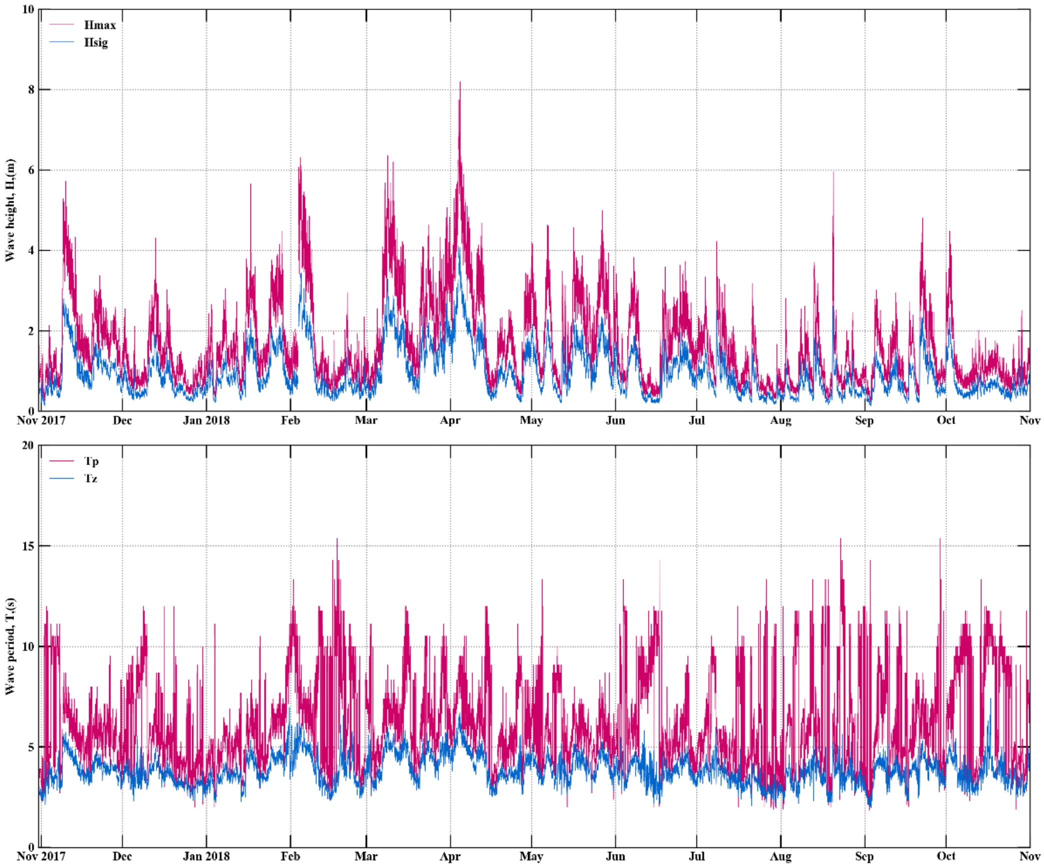


Figure 102 Mackay – daily wave recordings

Figure 103 Mackay – peak wave direction and sea surface temperature

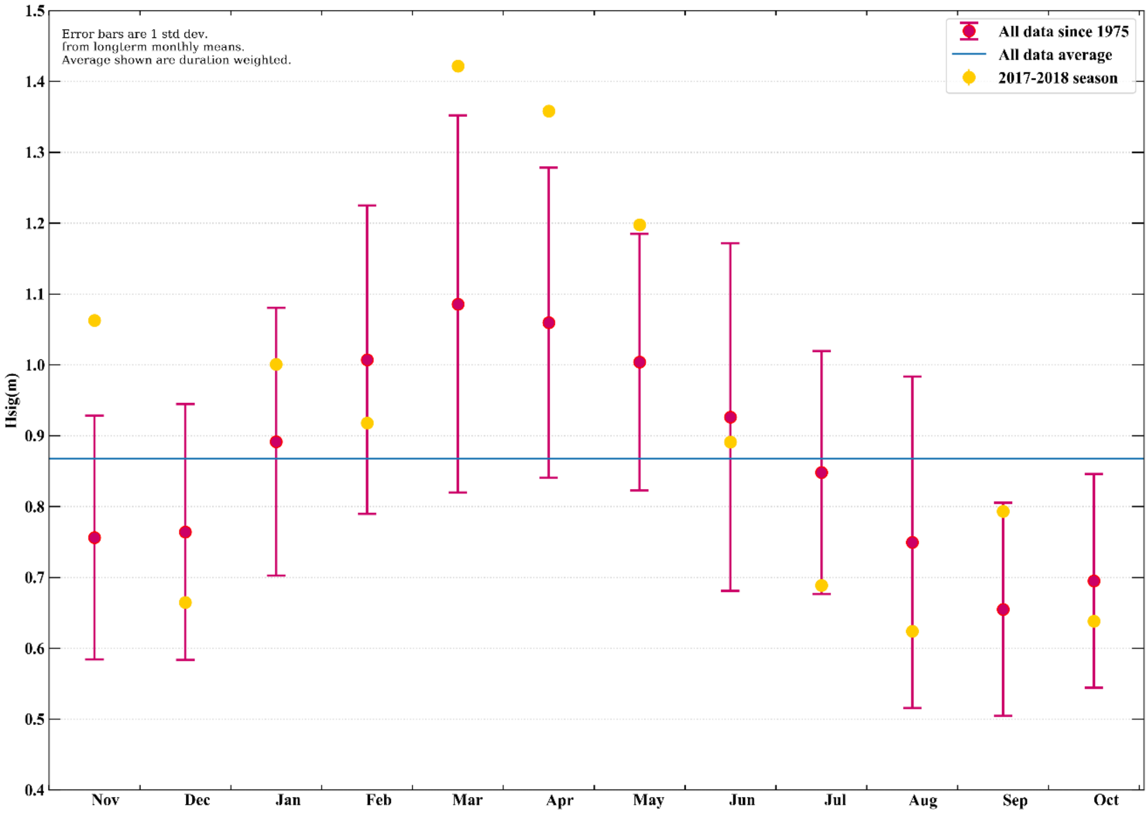


Figure 104 Mackay – monthly average wave height (H_s) for 2017-18 and for all data

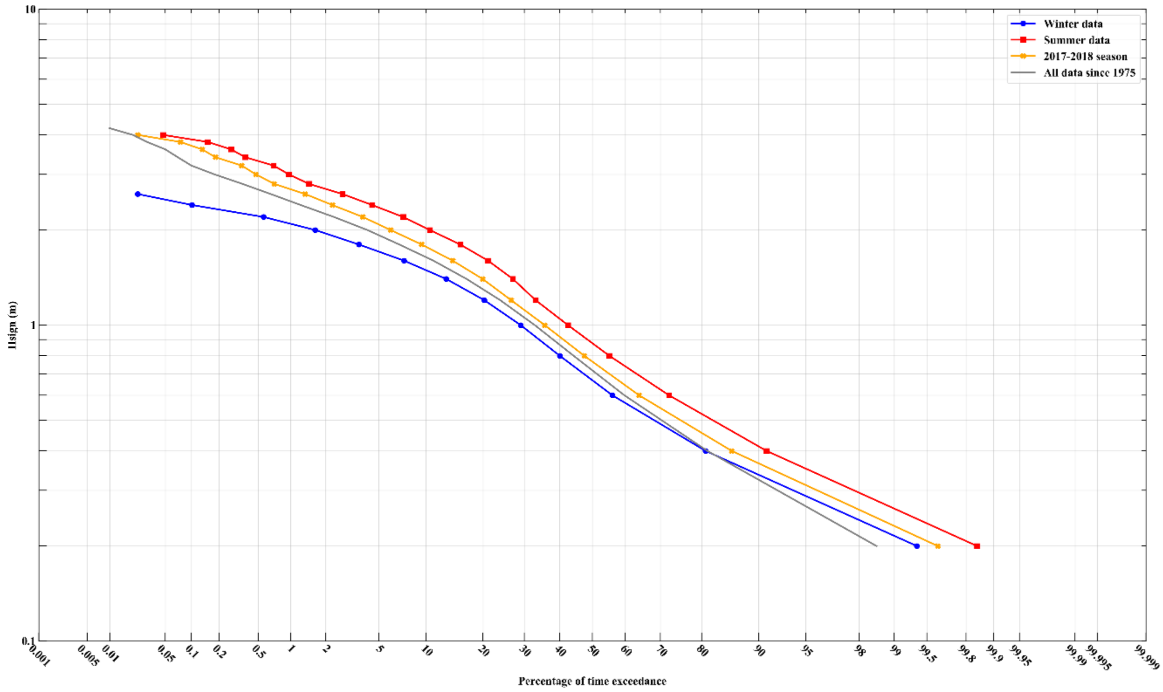


Figure 105 Mackay – percentage exceedance of wave height (H_s) for all wave periods (T_p)

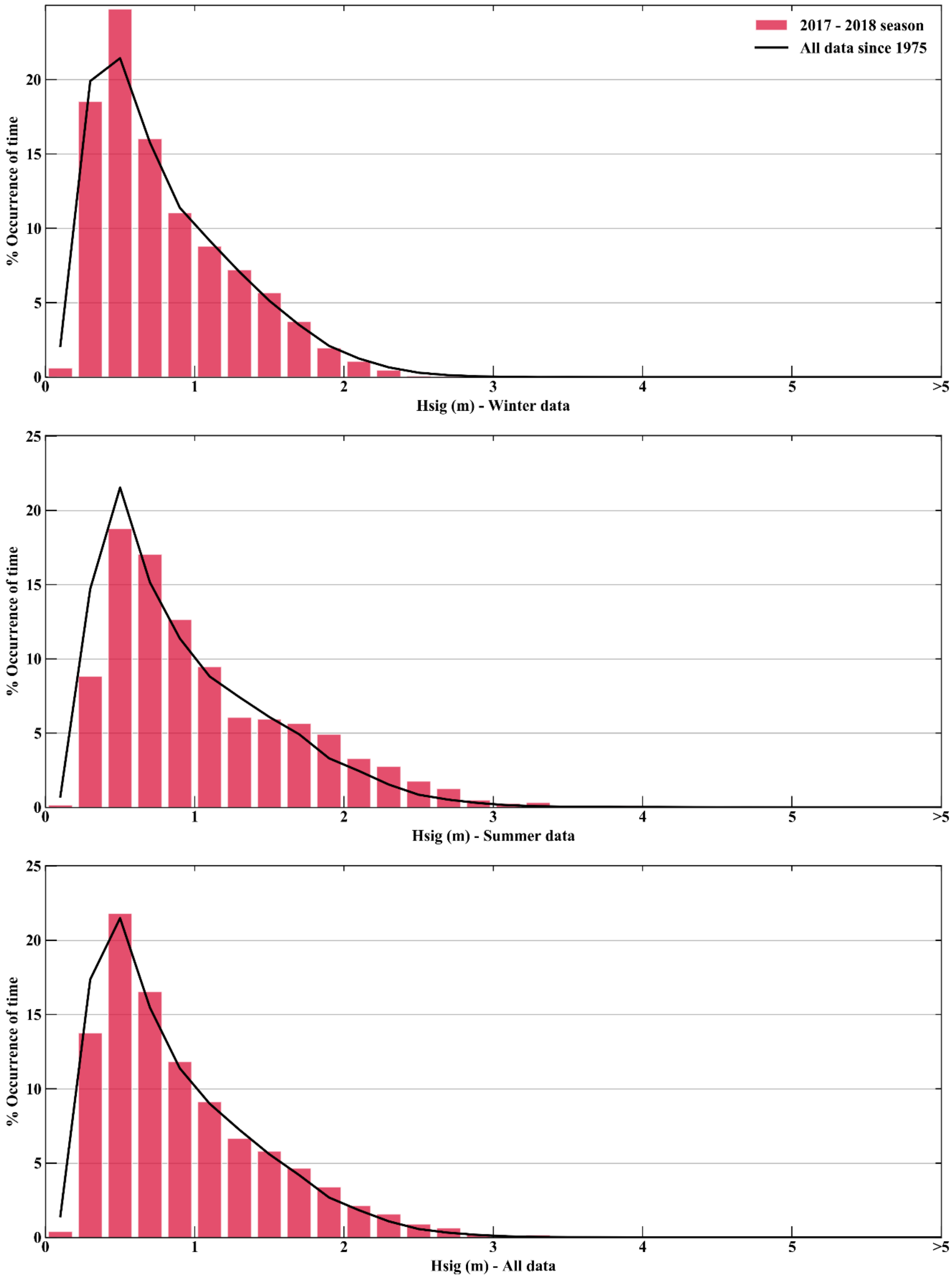


Figure 106 Mackay – histogram percentage (of time) occurrence of wave heights (H_s)

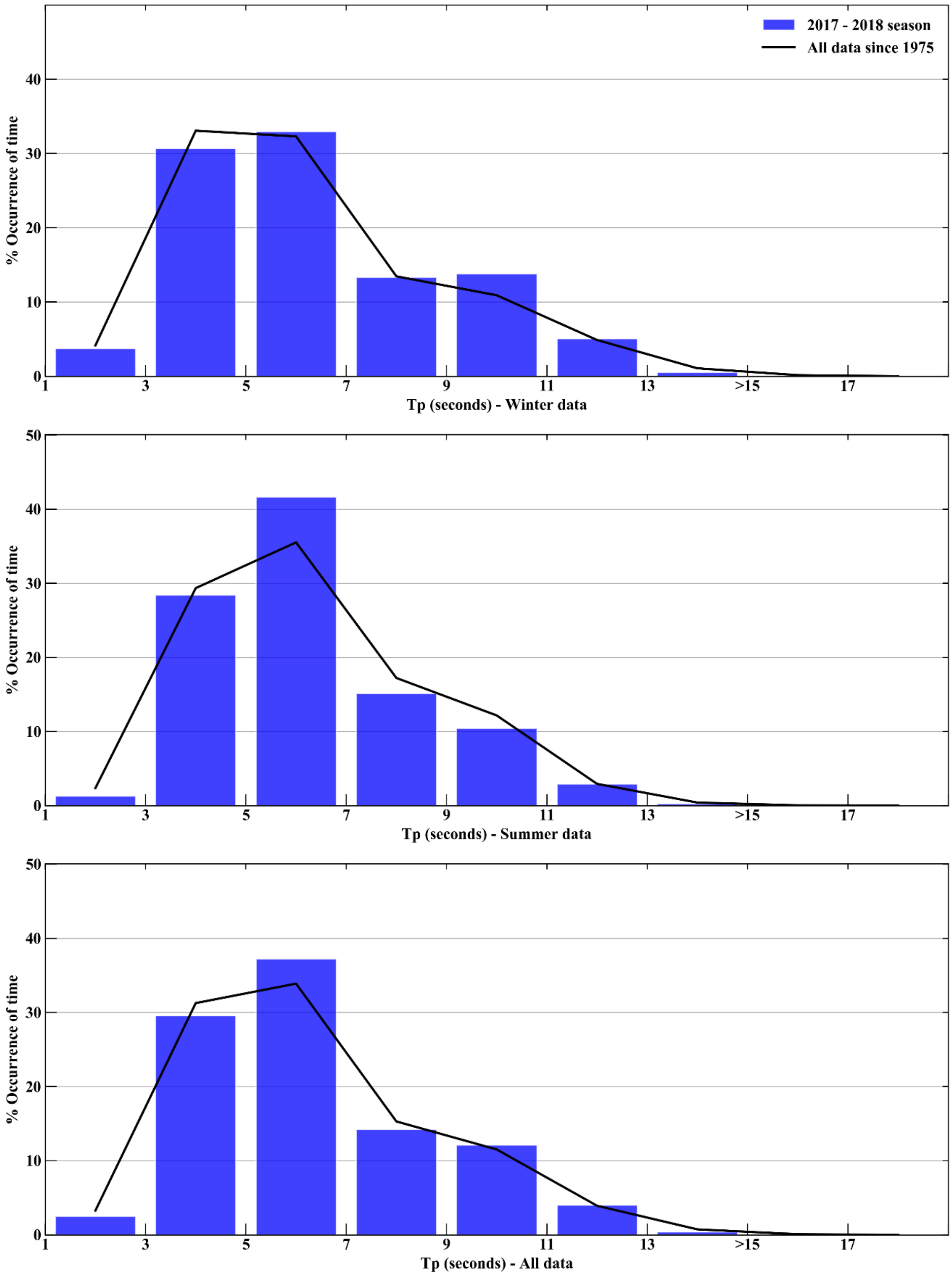


Figure 107 Mackay – histogram percentage (of time) occurrence of wave periods (T_p)

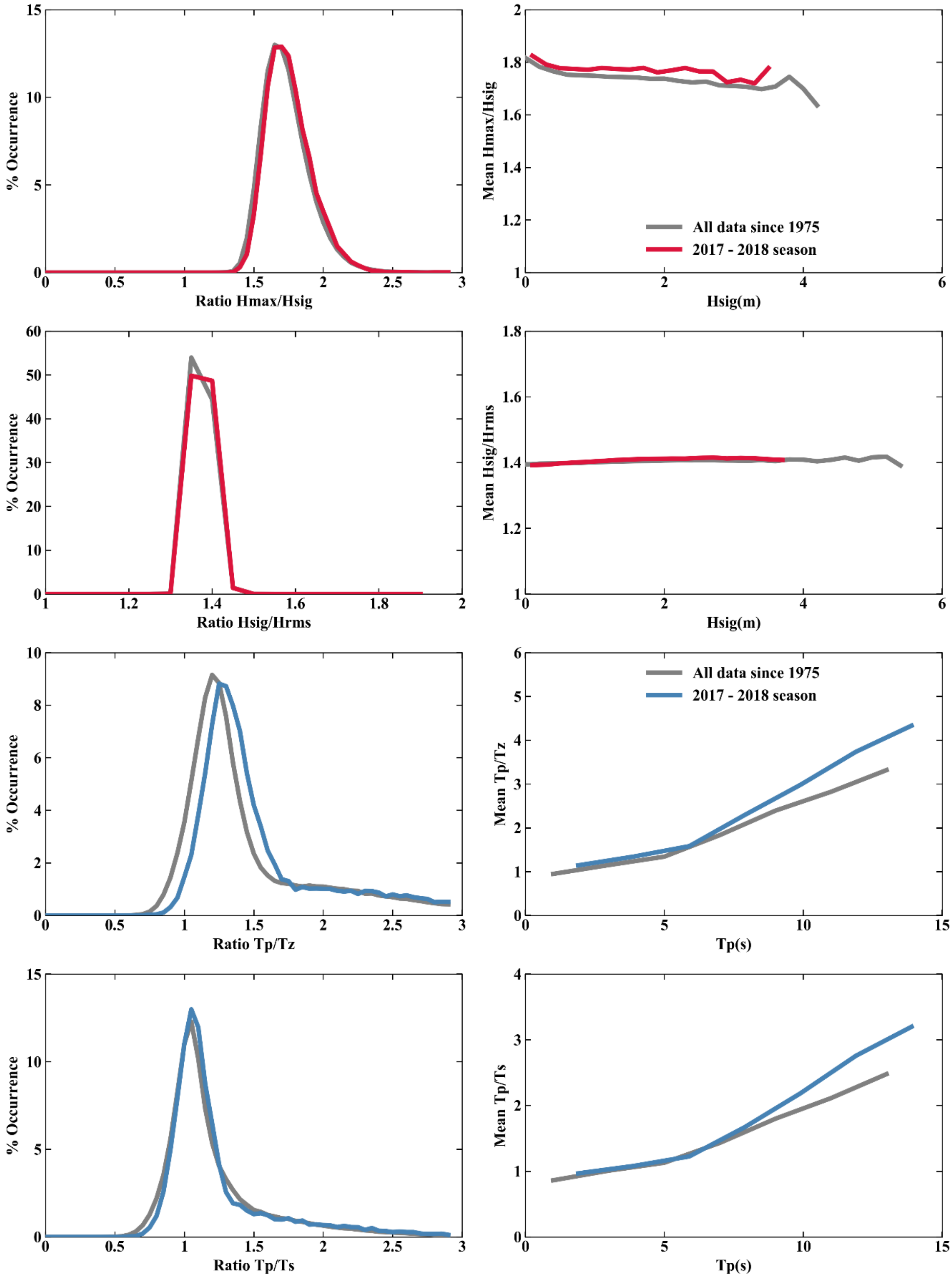
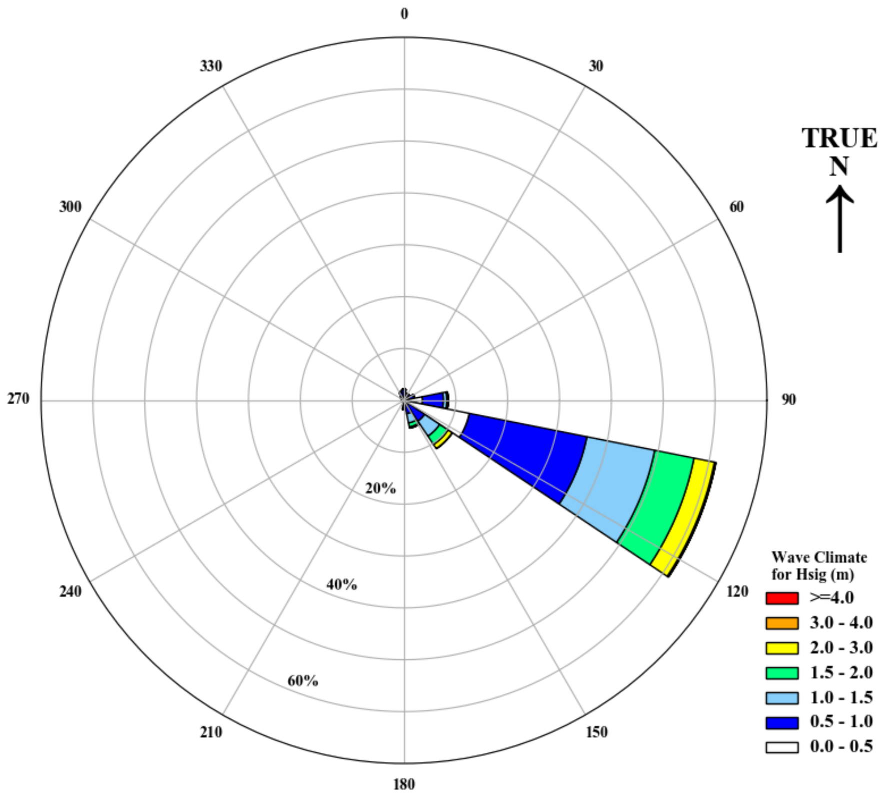


Figure 108 Mackay – wave parameter relationships

All data 1995 - 2018



Report Year 2017 - 2018

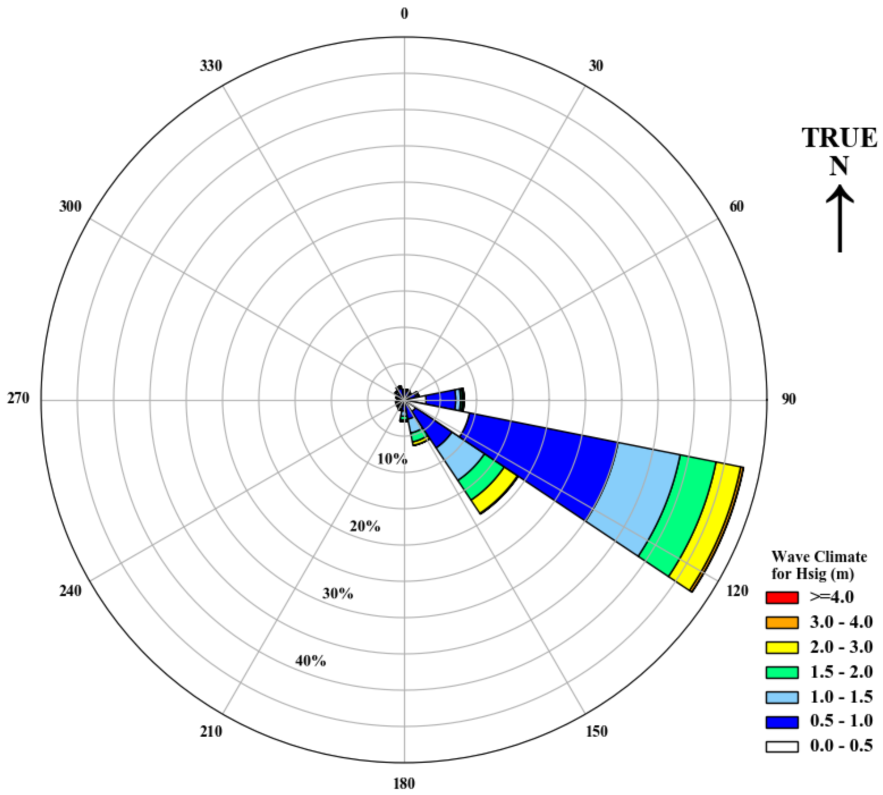


Figure 109 Mackay – directional wave rose

Abbot Point

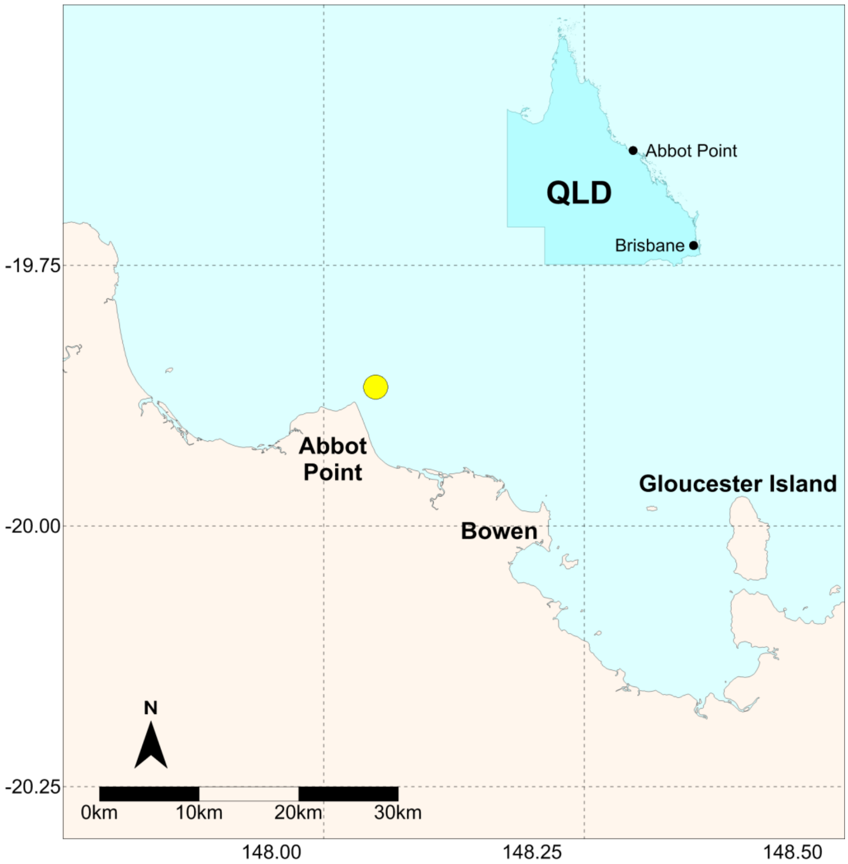


Figure 110 Abbot Point – locality plan

Table 53 Abbot Point – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	17/01/2012	0.15 years	116,173	6.8
2017-18	01/11/2016	2.4 days	17,403	1

Table 54 Abbot Point – buoy deployment for the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
19°51.987' S	148°05.899' E	DWR-MkIII	15	14/02/2017	27/07/2018
19° 51.988' S	148° 05.916' E	DWR4	15	27/07/2018	current

Abbot Point – seasonal overview

The Abbot Point wave buoy has now been operational for nearly seven years. The data recorded for the period from November 2017 to October 2018 was excellent, with total gaps of 2.4 days, equivalent to 99.3 percent data return (Table 53). The wave buoy was replaced on July 27 2018 (Table 54).

No significant events were reported at Abbot Point during the 2017-2018 period, subsequently no waves were reported that made it into the top ten highest waves (Table 55 and Table 56).

Peak wave direction (Figure 112) was predominately from the east with swings to the north in late summer. SST values ranged from 21 °C to 30.5 °C (Figure 112) and the SST was high enough for tropical cyclone development from November to the end of April.

The monthly average H_s generally fell within one standard deviation (sd) of the long term mean except for November, March and September where the monthly mean was higher than one sd of the long term mean (Figure 113).

Percentage exceedance of H_s (Figure 114) suggest lower wave heights during winter and higher during summer. The data for the recorded season is similar to the historical data with a lower frequency for H_s greater than 1.5 m during this season compared to the entire record. The percent occurrence of H_s (Figure 115) indicates a higher occurrence of waves of 0.4 m. The most common T_p was between 3 - 5 seconds in both summer and winter (Figure 116).

The wave parameters for the recorded period are similar to the historical data with T_p/T_z ratio slightly lower (Figure 117).

Directional wave rose plots (Figure 118) highlight the dominant east-north-easterly incident wave direction for this reporting period and over the six years of operation.

Table 55 Abbot Point – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	13/04/2014 14:30	3.8	13/04/2014 14:30	6.5
2	24/01/2013 16:00	3.0	24/01/2013 19:00	5.5
3	28/03/2017 20:30	2.9	29/03/2017 0:00	5.4
4	21/03/2012 03:00	1.9	12/04/2013 00:00	3.6
5	12/04/2013 00:00	1.8	13/06/2016 10:30	3.6
6	02/02/2012 07:00	1.7	20/03/2012 23:00	3.4
7	12/04/2012 15:00	1.6	15/01/2014 10:30	3.4
8	03/10/2015 15:00	1.6	11/07/2012 04:00	3.3
9	09/03/2014 15:00	1.6	12/04/2012 15:00	3.3
10	11/07/2012 03:00	1.5	01/12/2013 22:30	3.2

Table 56 Abbot Point – significant meteorological events with threshold H_s of 2.5 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
No significant events reported				

Denotes peak H_s event

Notes: 1. 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).

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

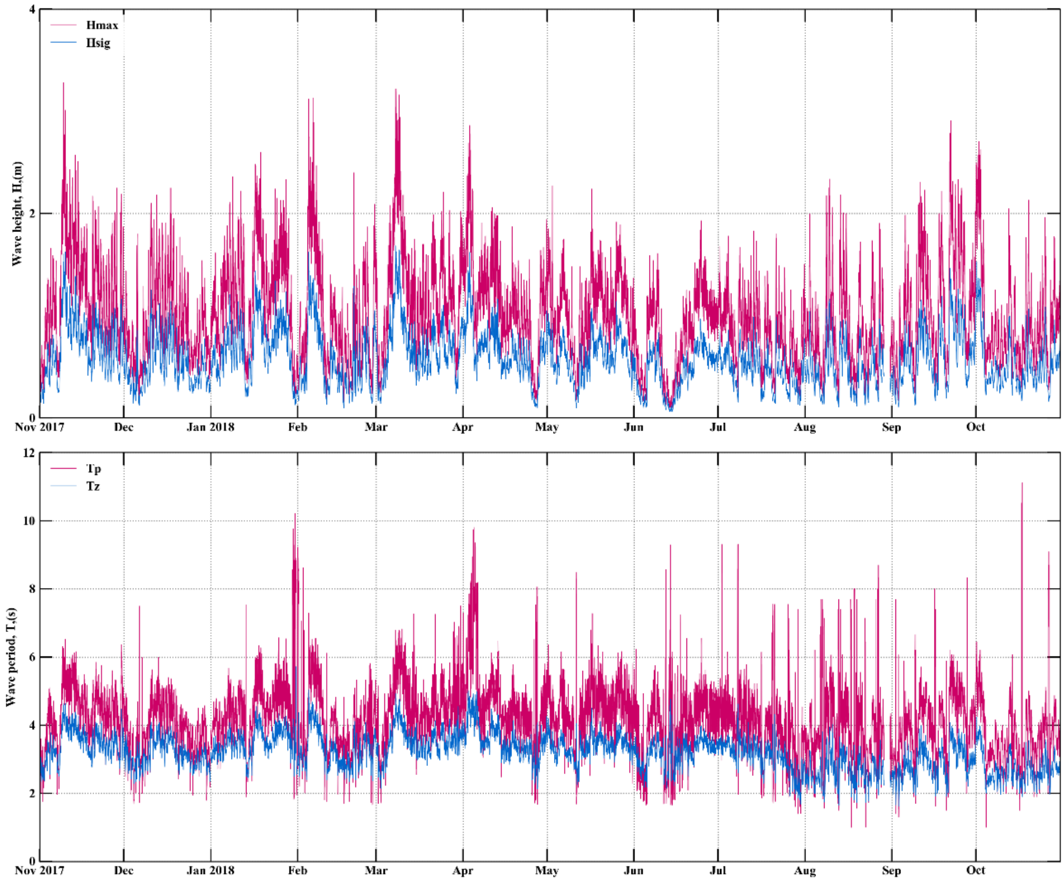


Figure 111 Abbot Point – daily wave recordings

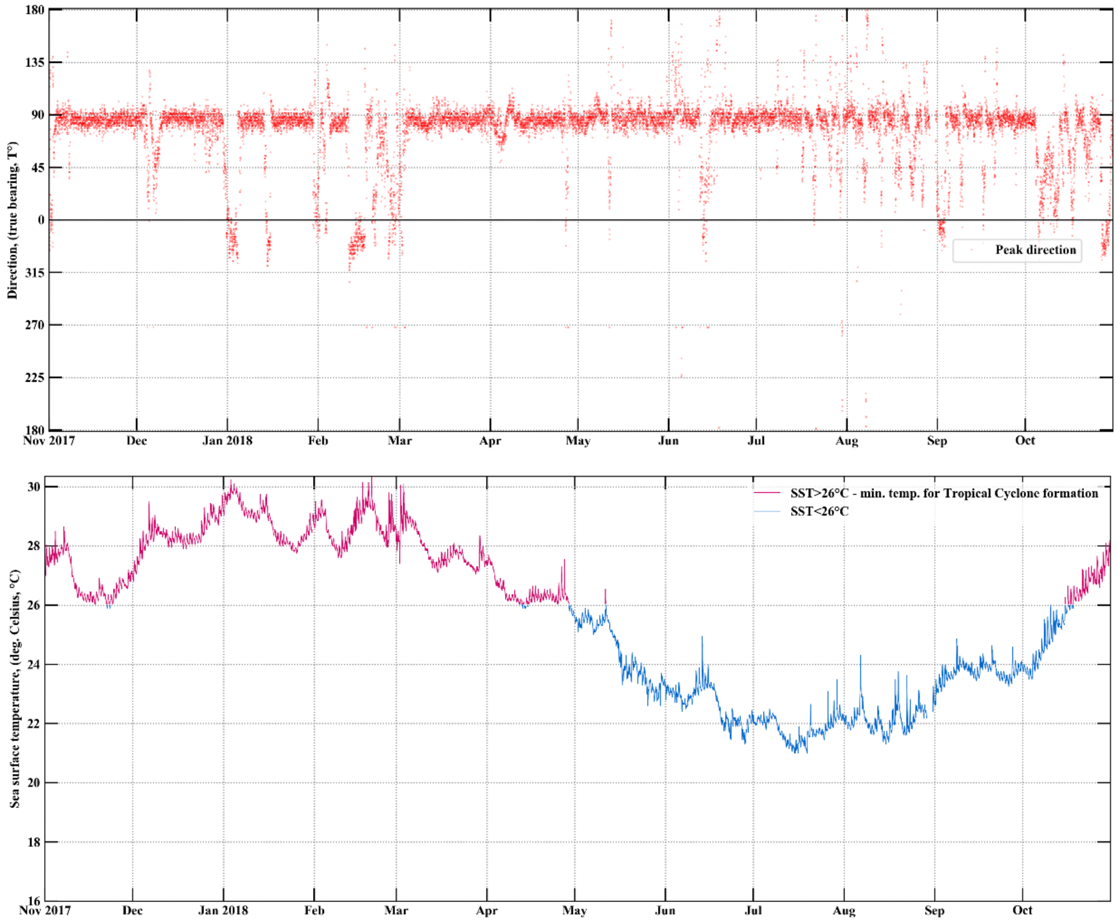


Figure 112 Abbot Point – peak wave direction and sea surface temperature

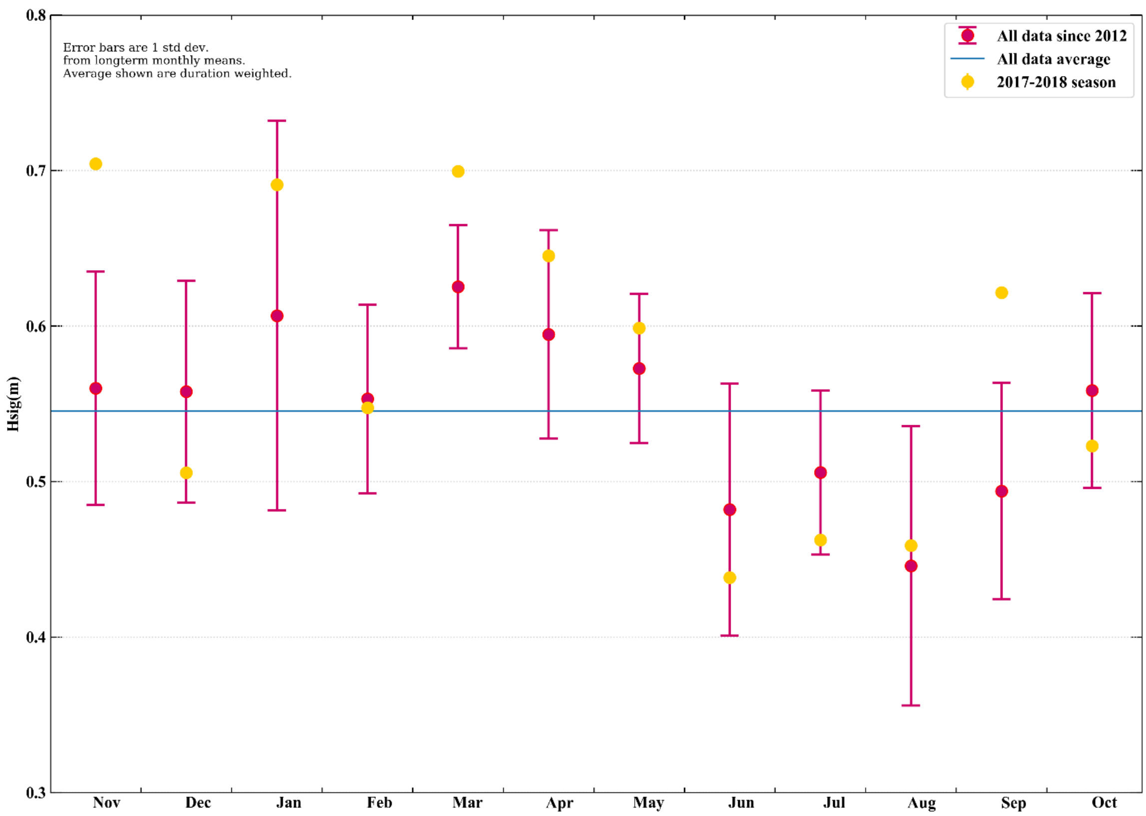


Figure 113 Abbot Point – monthly average wave height (H_s) for 2017-18 and for all data

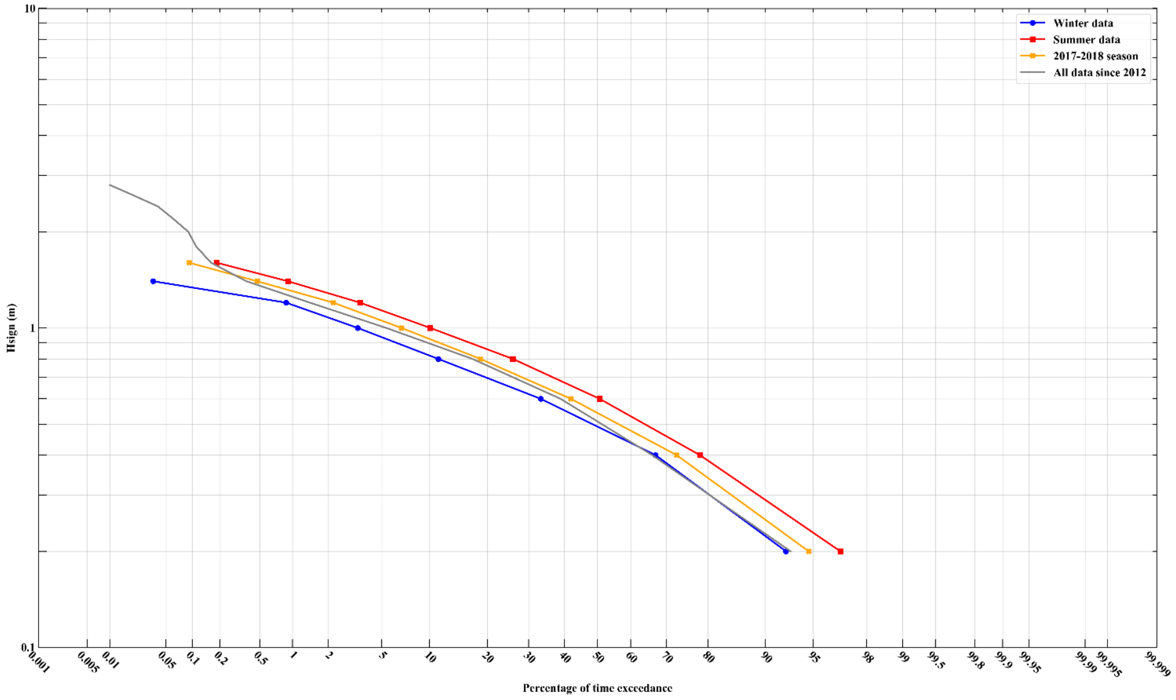


Figure 114 Abbot Point – percentage exceedance of wave height (H_s) for all wave periods (T_p)

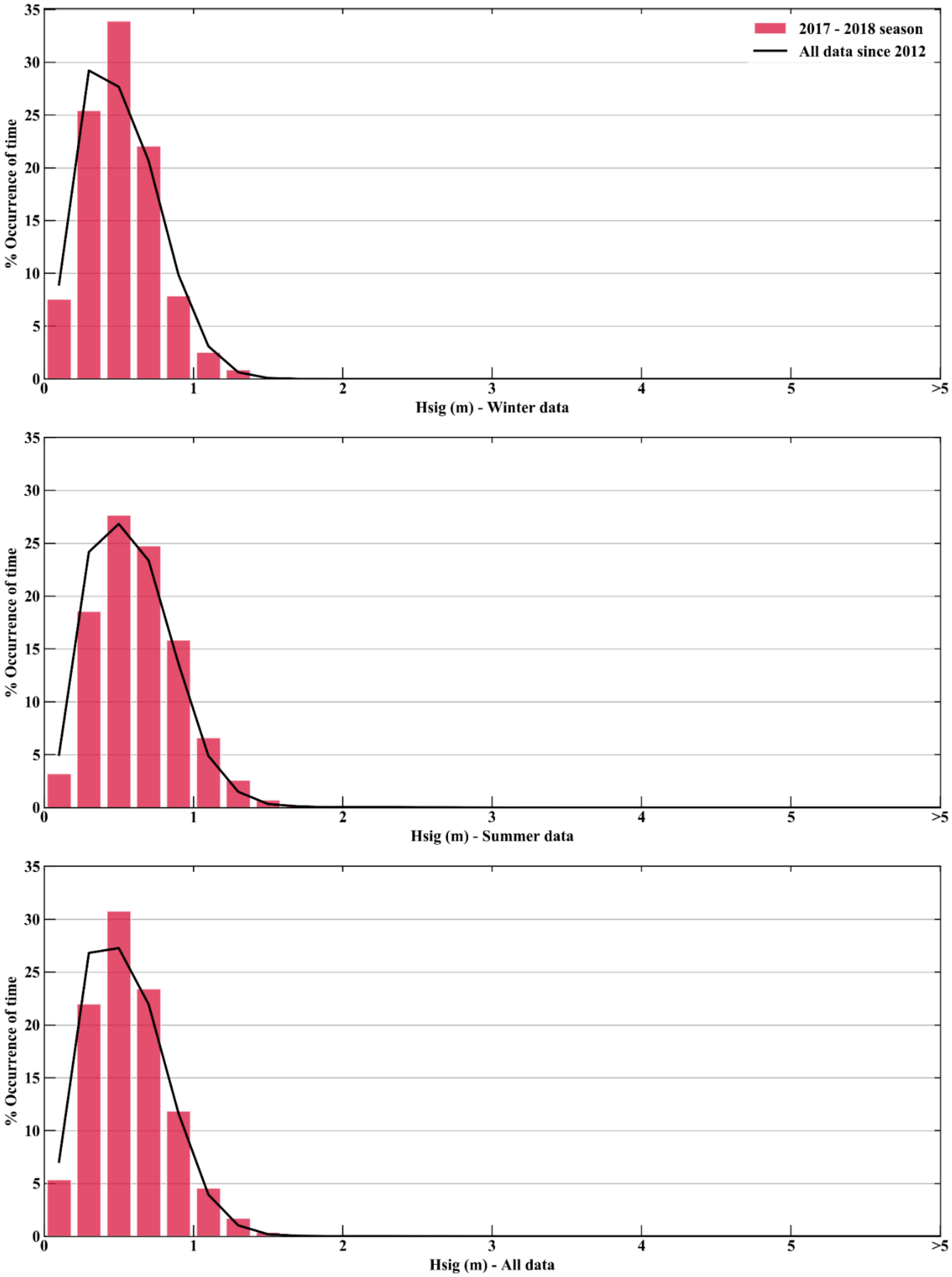


Figure 115 Abbot Point – histogram percentage (of time) occurrence of wave heights (H_s)

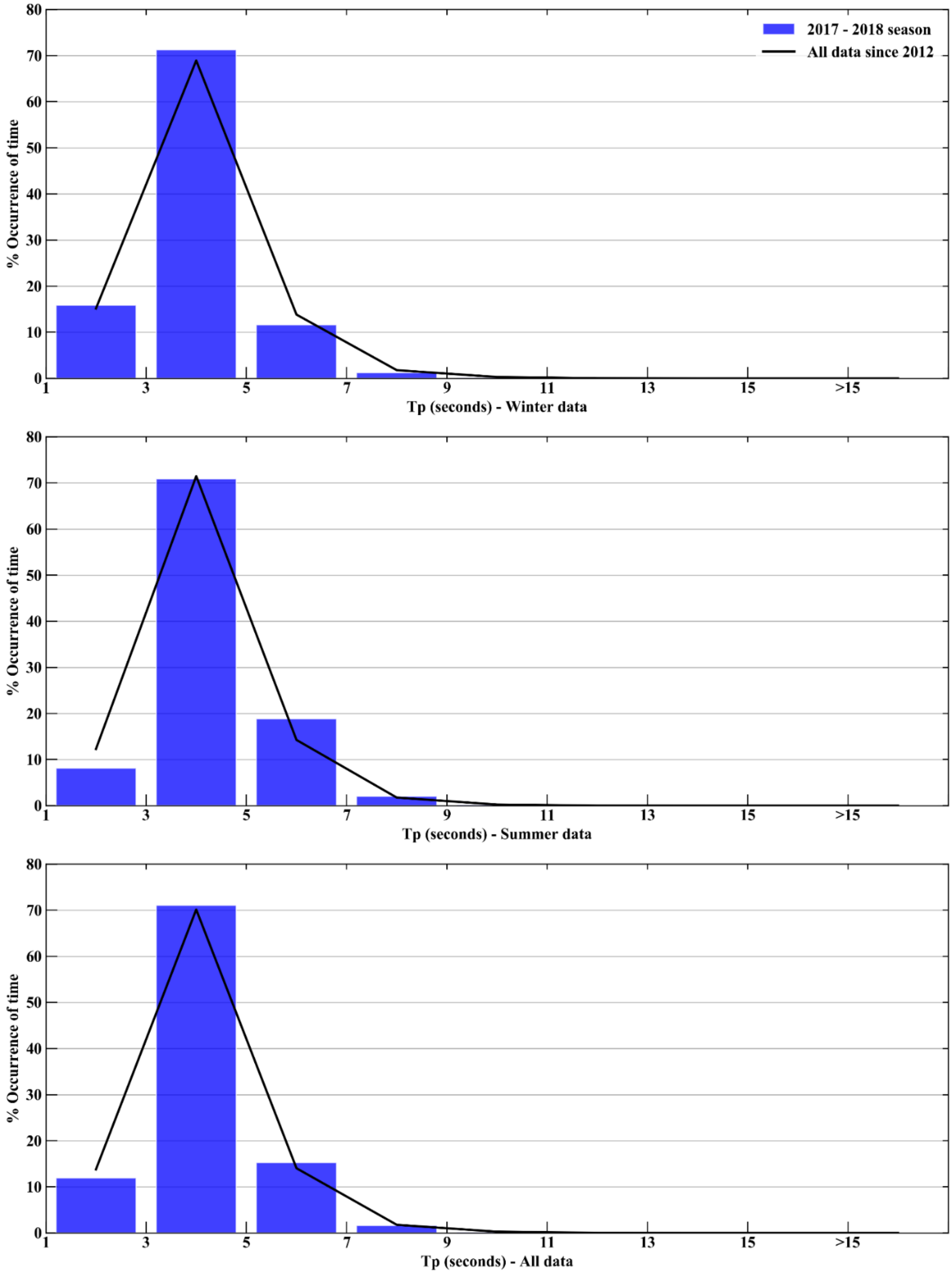


Figure 116 Abbot Point – histogram percentage (of time) occurrence of wave periods (T_p)

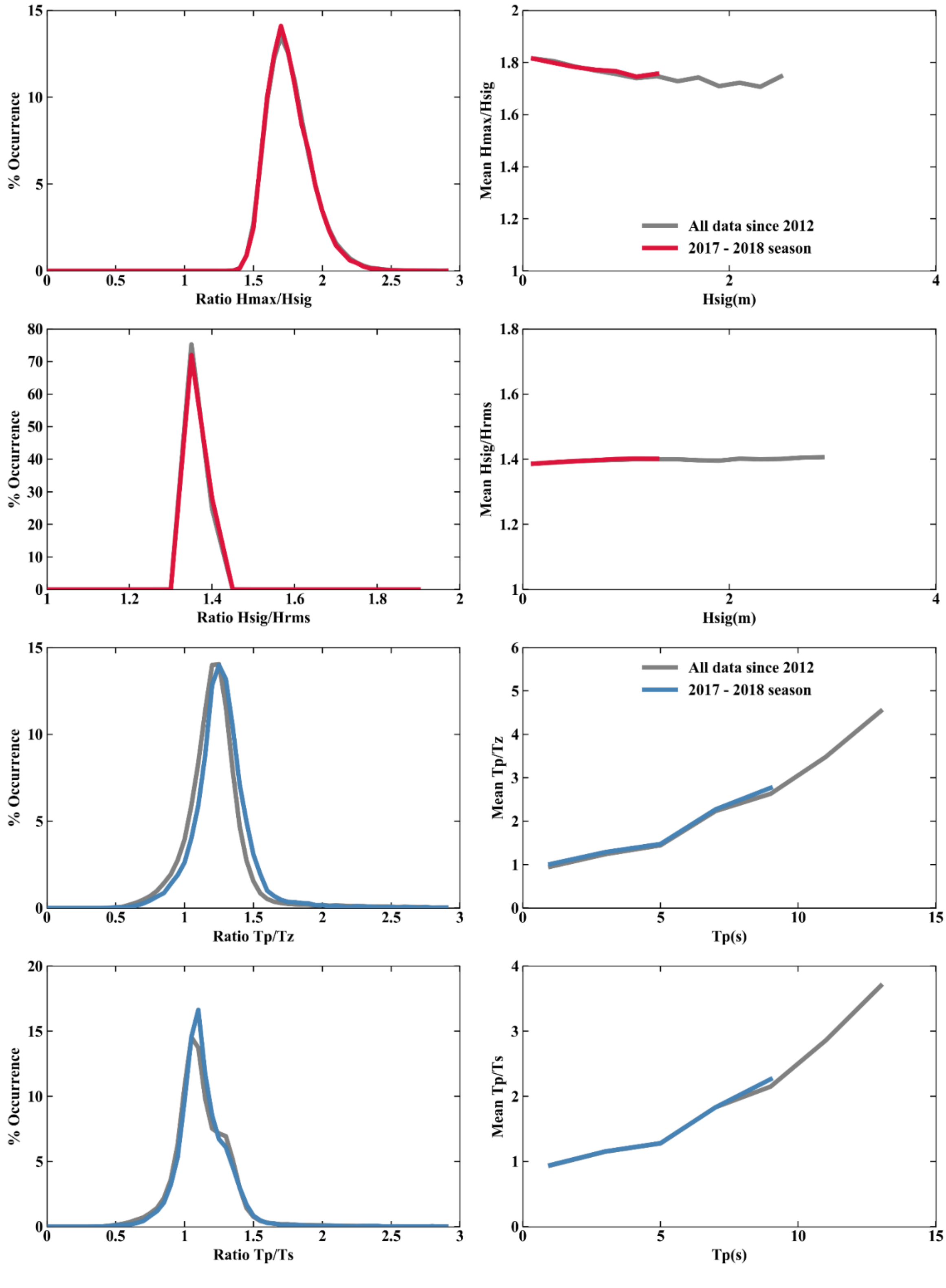
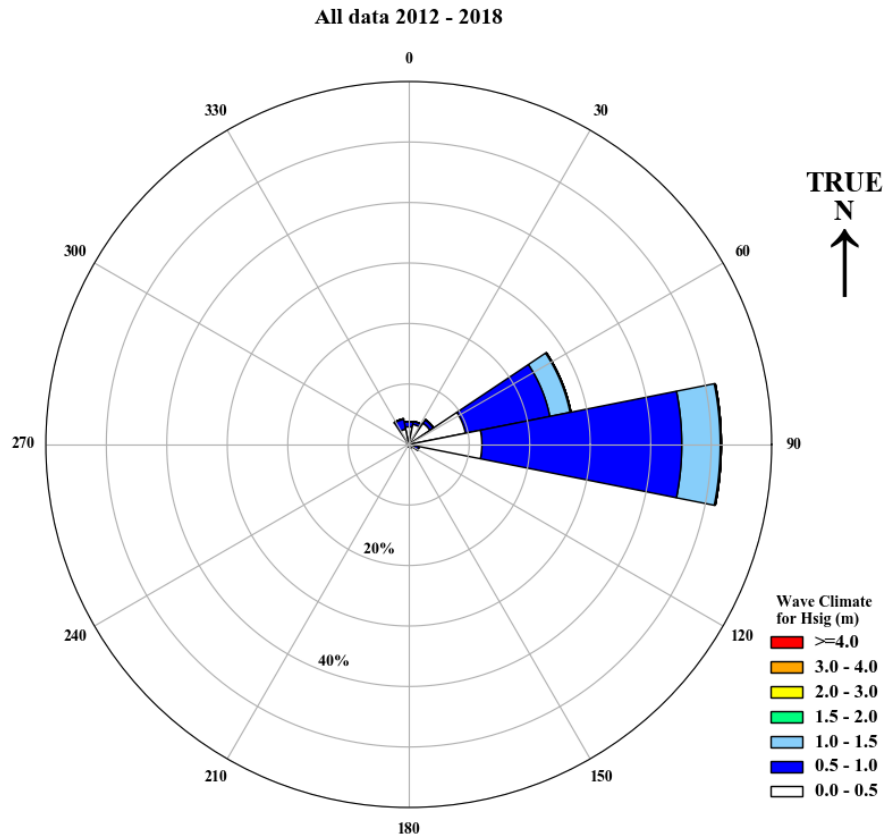


Figure 117 Abbot Point – wave parameter relationships



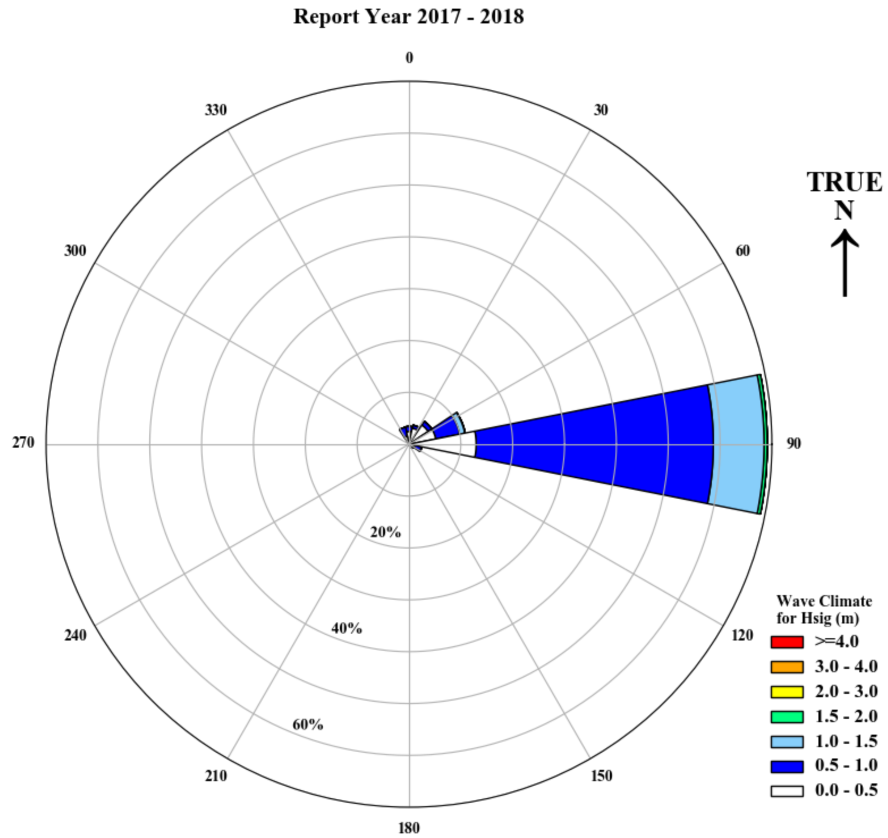


Figure 118 Abbot Point – directional wave rose

Townsville

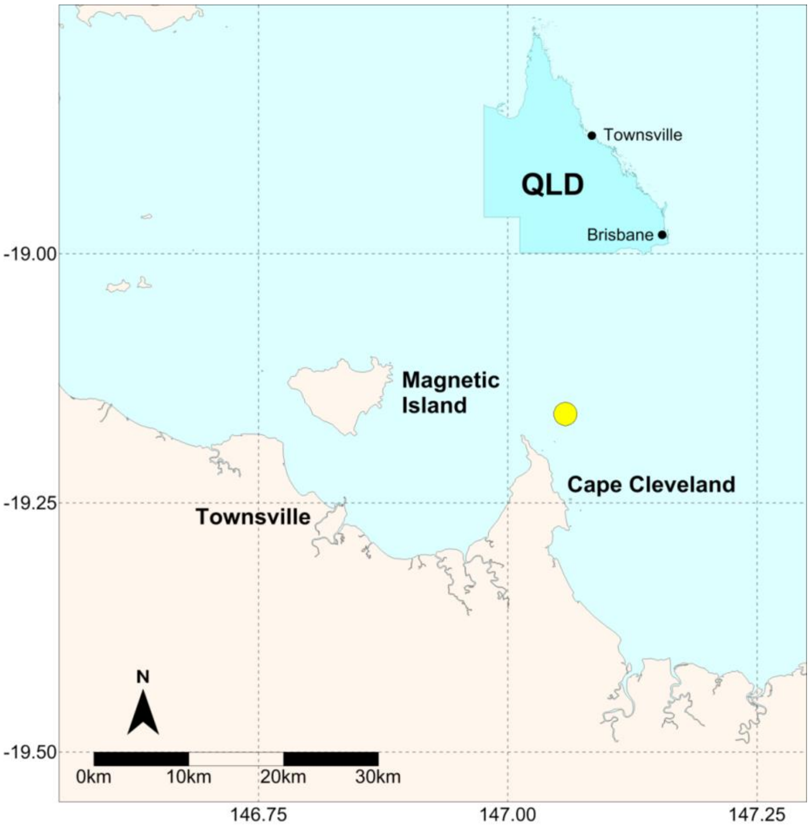


Figure 119 Townsville – locality plan

Table 57 Townsville – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	20/11/1975	na	366,895	42.95
2017-18	01/11/2017	5.63 (days)	17,249	1

Table 58 Townsville – buoy deployments during the 2016-17 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
19°09.584' S	147°03.503' E	DWR-MkIII	16	30/12/2016	24/07/2018
19° 10.606’ S	147° 04.482’ E	DWR-MkIII	16	24/07/2018	current

Townsville – seasonal overview

The Townsville wave buoy has been operational for nearly 43 years. During the period from November 2017 to October 2018 there was a total data gap of 5.63 days, equivalent to 98.4 per cent data return (Table 57). The buoy was replaced once during the reporting period on 24th of July 2018 (Table 58).

There were three significant storm events in the 2017-2018 period (Table 60) none of which made it into the top ten highest waves (Table 59). Time series of daily wave recordings (Figure 120) show clear increases in wave heights, but not above 3.8 m for Hmax or 2.1 m for H_s.

Peak wave direction (Figure 121) was predominately from the east with an occasional swing to the north-east, north and south-east. SST ranged from 21.5 °C to 33 °C (Figure 121). The SST was high enough for tropical cyclone development November through April and at the end of October.

Monthly average H_s (Figure 122) was within one sd for the entire reporting period.

Wave climate for the reporting period was very similar to the wave climate of the entire record with the exception of lower exceedance levels for waves over 2 m throughout the 2017-2018 period. The summer wave heights were consistently higher than the historic data, while winter wave heights were consistently lower (Figure 123). Histograms for percentage occurrence of H_s (Figure 124) and T_p (Figure 125) were also similar between the reporting period and the whole record however H_s of 0.4-0.6 m was more frequent, and 1.0-2.0 m less frequent in winter than average.

The ratios between different wave parameters such as H_{max}/H_s and H_s/H_{rms} were consistent between this reporting period and all of the historic data (Figure 126). While the ratio T_p/T_s slightly decreased and T_p/T_z slightly increased compared to the historic data.

Directional wave rose plots (Figure 127) highlight the dominant easterly direction for the reporting period which was very similar to the entire record.

Table 59 Townsville – highest waves

Rank	Date (Hs)	Hs (m)	Date (Hmax)	Hmax (m)
1	03/02/2011 01:30	5.5	03/02/2011 01:00	10.1
2	13/01/2009 08:00	3.7	13/01/2009 07:30	6.6
3	13/04/2014 09:00	3.6	13/04/2014 09:30	6.4
4	24/03/1997 02:00	3.6	24/03/1997 03:00	6.0
5	30/01/2010 22:30	3.0	24/01/2013 07:30	5.4
6	23/12/1990 09:27	3.0	10/01/1998 15:00	5.4
7	10/01/1998 15:00	2.9	20/03/2006 08:00	5.3
8	20/03/2006 08:00	2.9	30/01/2010 20:30	5.2
9	03/03/1979 03:00	2.8	11/02/1999 18:30	5.1
10	24/01/2013 06:30	2.7	01/02/1986 20:49	4.9

Table 60 Townsville – significant meteorological events with threshold H_s of 1.8 metres.

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
9/11/2017 17:00	1.9 (1.9)	3.5 (3.9)	6.8	A high-pressure ridge in the Tasman sea extended along the Queensland coast.
6/02/2018 21:30	1.9 (1.9)	3.0 (3.1)	5.6	A high-pressure system moved from the Great Australian Bight to the Tasman Sea extending a ridge of high-pressure along the east coast.
8/03/2018 4:00	1.9 (2.1)	3.4 (4.1)	7.3	TC Hola developed on March 3, moving westward, however Hola stayed well off the east coast.

Denotes peak H_s event

Notes: 1. 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).

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

Figure 120 Townsville – daily wave recordings

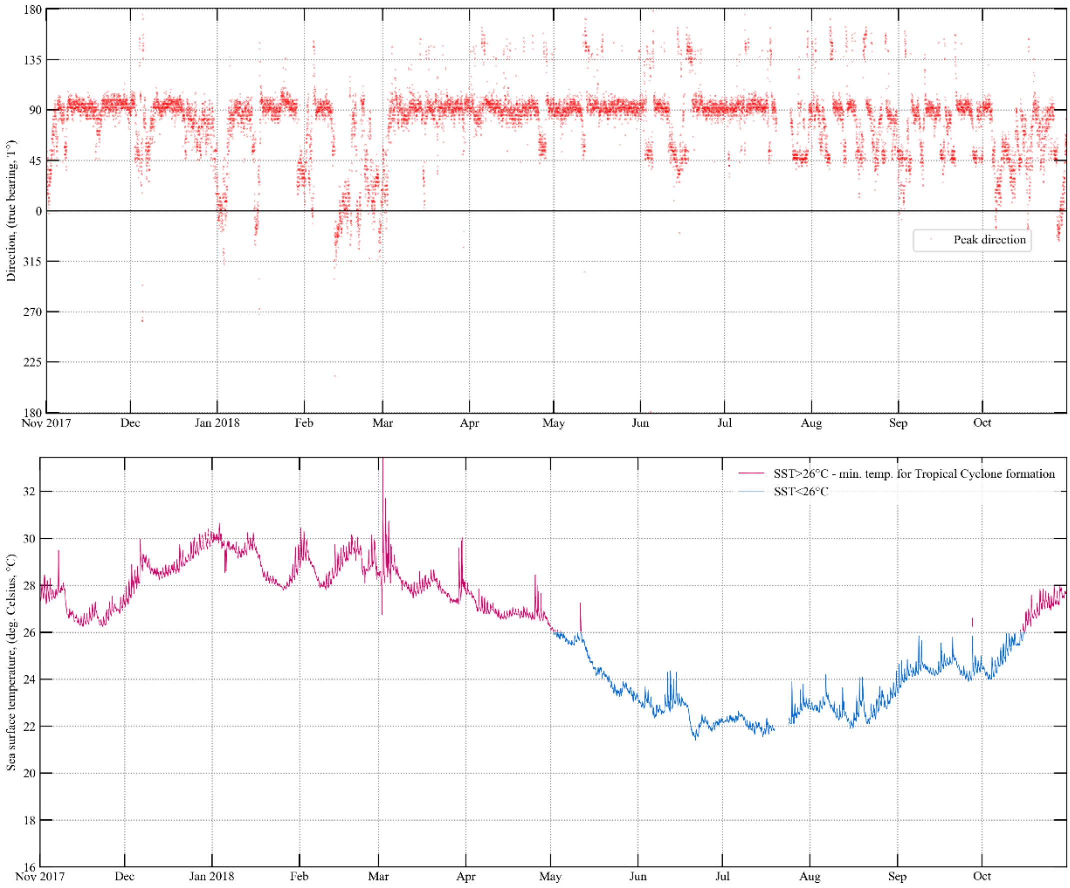


Figure 121 Townsville – peak wave direction and sea surface temperature

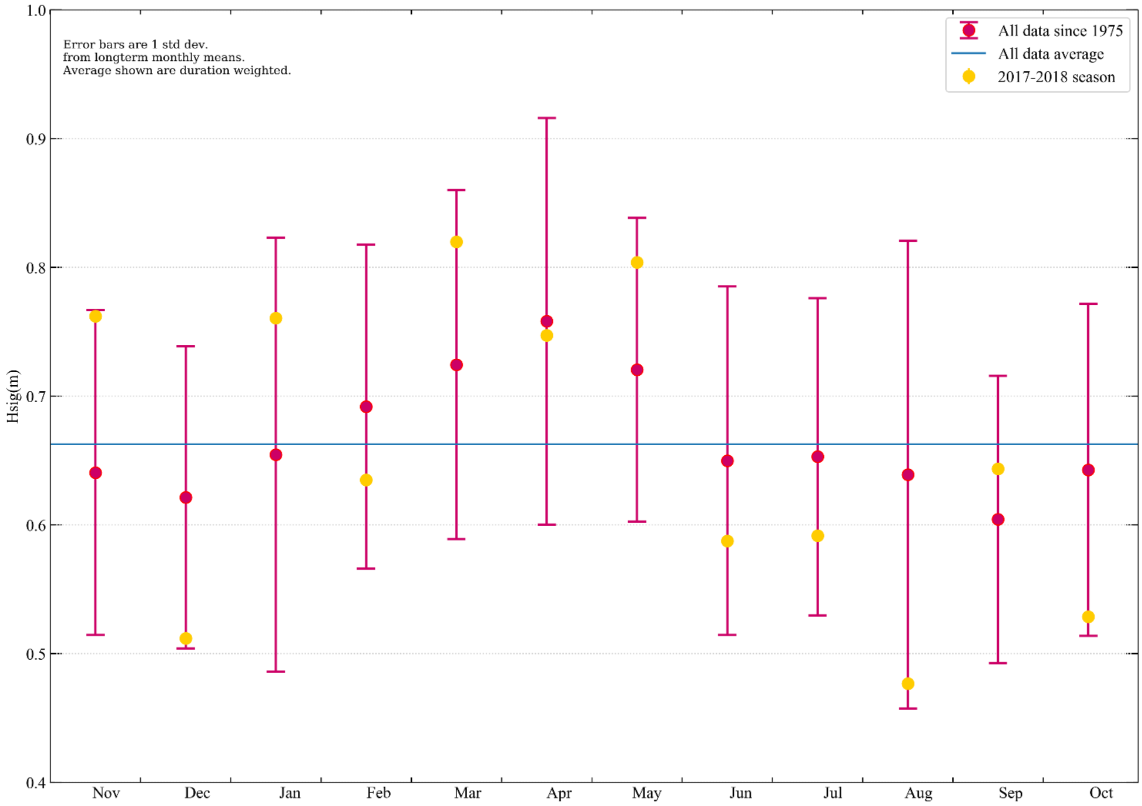


Figure 122 Townsville – monthly average wave height (H_s) for 2017-18 and for all data

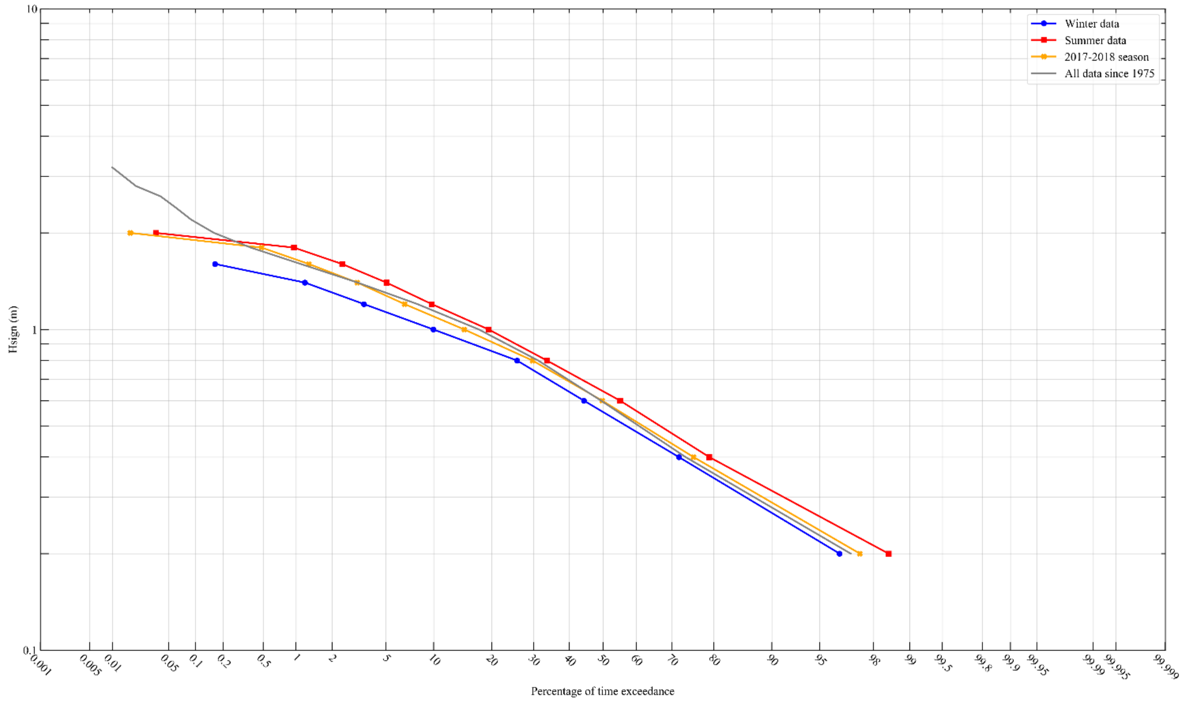


Figure 123 Townsville – percentage exceedance of wave height (H_s) for all wave periods (T_p)

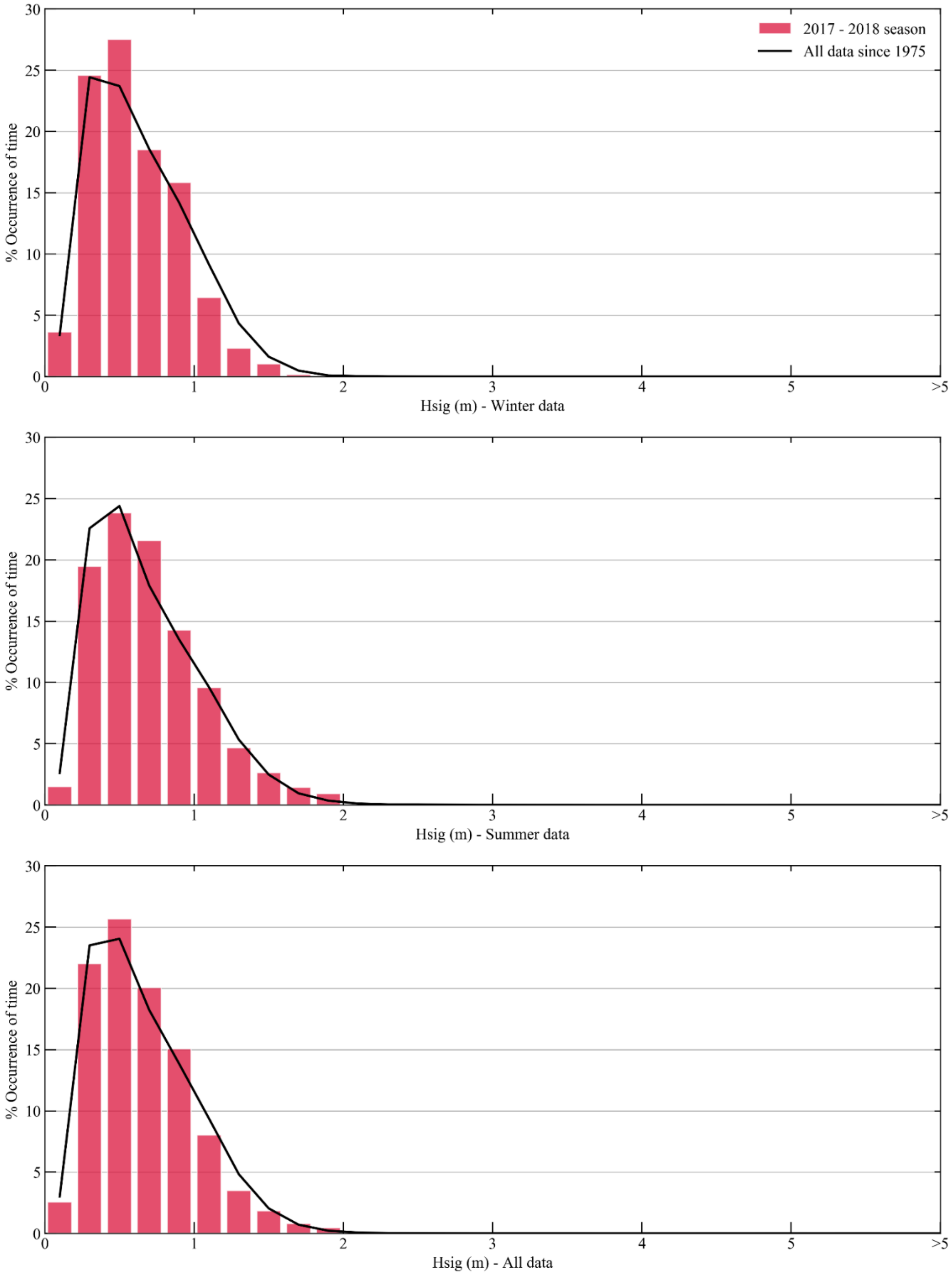


Figure 124 Townsville – histogram percentage (of time) occurrence of wave heights (H_s)

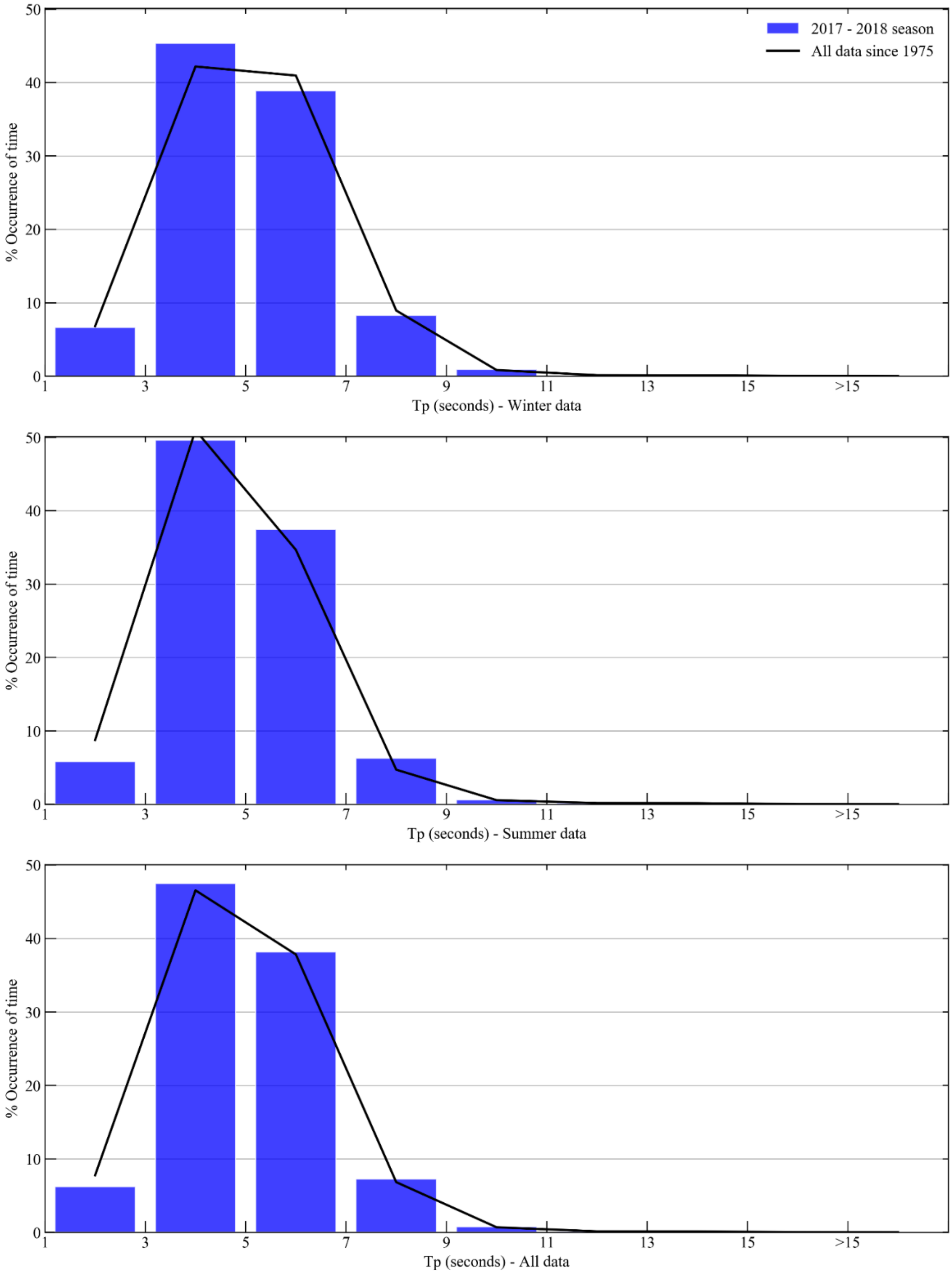


Figure 125 Townsville – histogram percentage (of time) occurrence of wave periods (T_p)

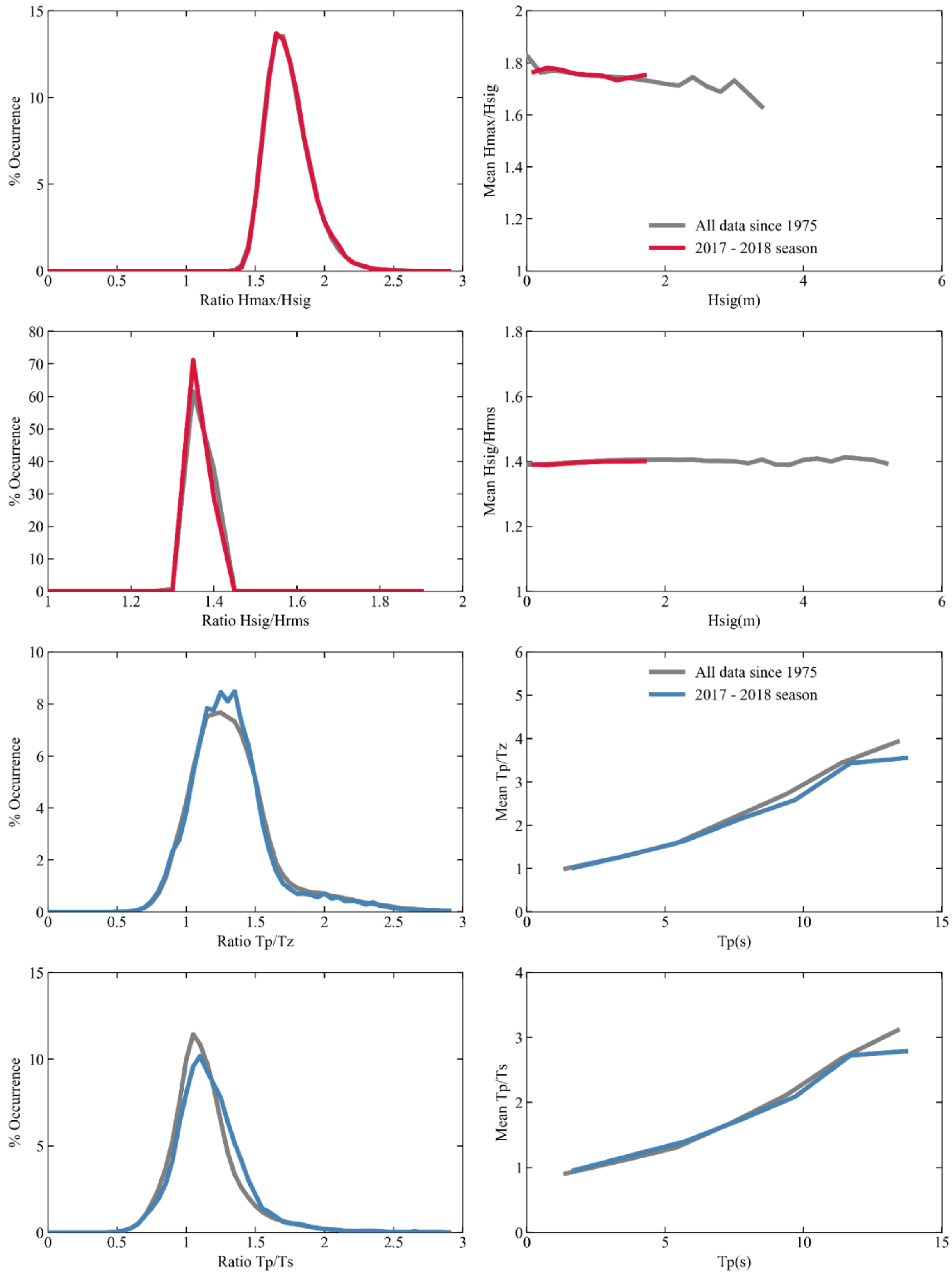
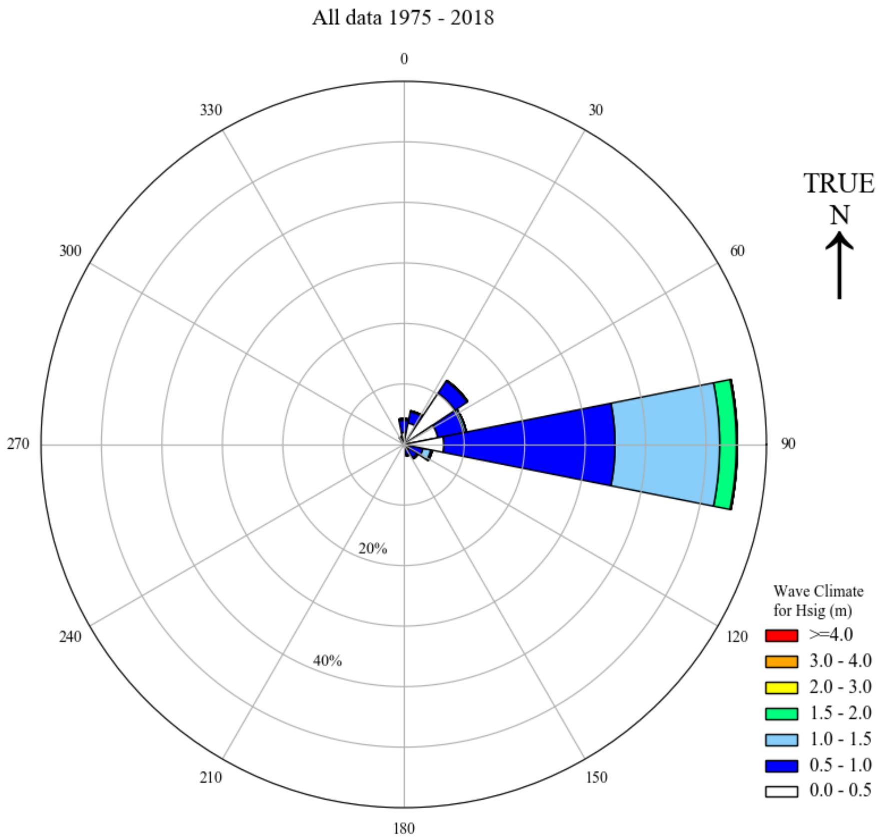


Figure 126 Townsville – wave parameter relationships



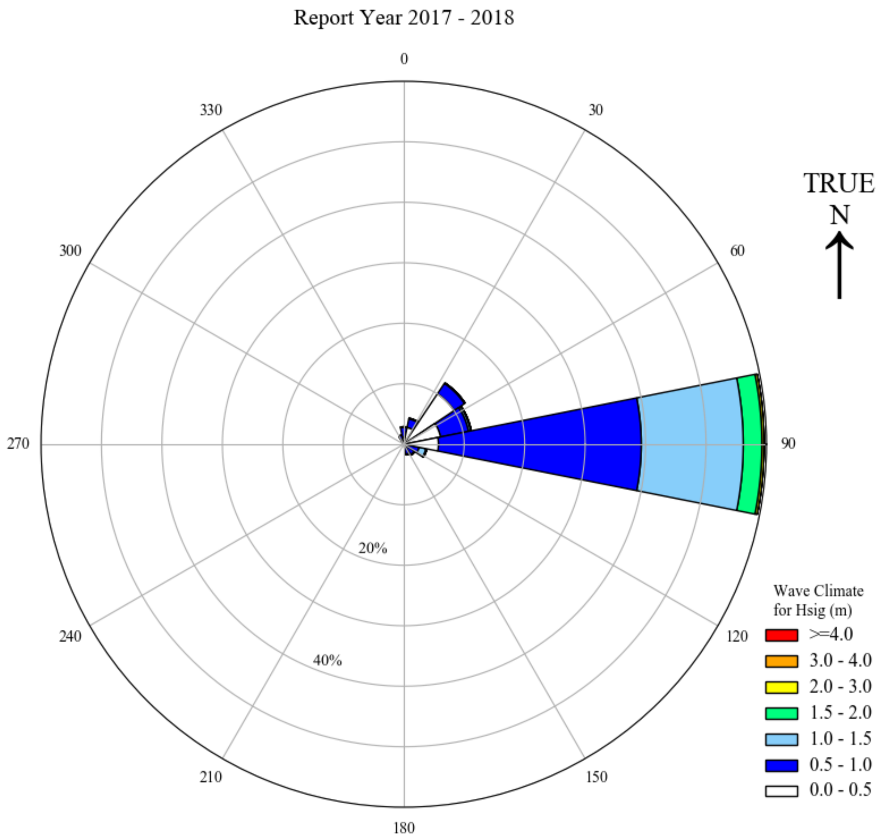


Figure 127 Townsville – directional wave rose

Cairns

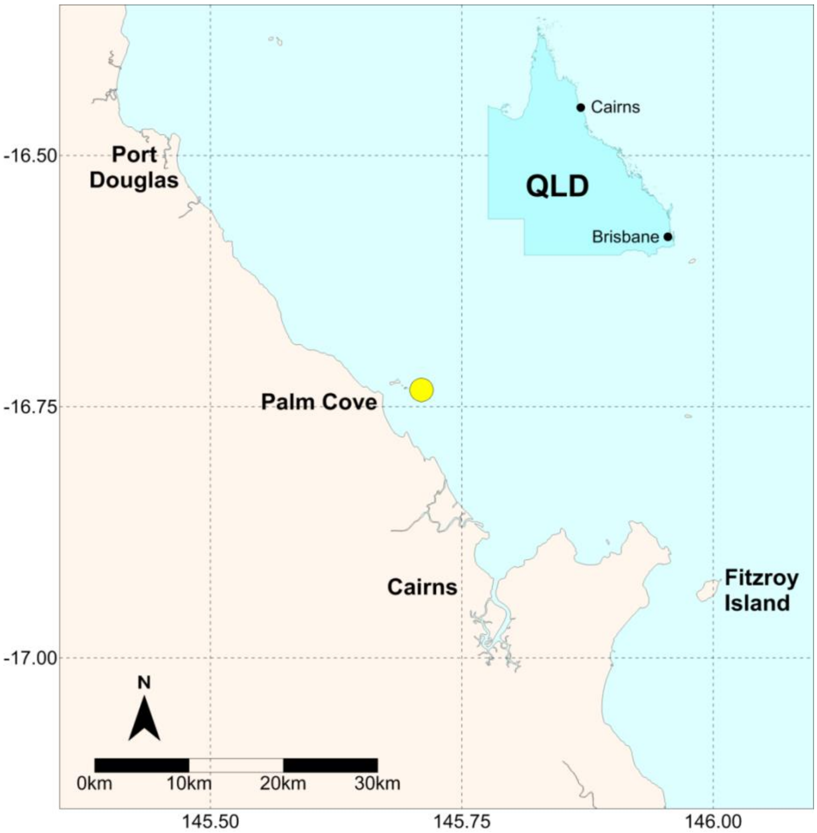


Figure 128 Cairns – locality plan

Table 61 Cairns – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	04/05/1975	NA	377,260	43.50
2017-18	01/11/2017	8.19 (days)	17,126	1

Table 62 Cairns – buoy deployments for the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
16°44.000' S	145.42.370' E	DWR-MkIII	13	4/08/2017	20/02/2018
16° 44.030' S	145° 42.642' E	DWR-MkIII	13	20/02/2018	current

Cairns – seasonal overview

The Cairns wave buoy has been operational for 43.5 years. The data for the period November 2017 to October 2018 only had gaps of 1.15 days, equivalent to 99.68 per cent data return (Table 61). The buoy was replaced once during the reporting period on the February 20 2018 for the annual buoy change (Table 62).

There were no significant meteorological events during the reporting period (Table 63).

Figure 129 shows the daily wave heights and period. Recording of SST showed that the SST was high enough for the development of cyclones from November until middle of April and during a brief period in October (Figure 130).

The monthly average Hs (Figure 131) was within one standard deviation (sd) of the historic monthly mean, except for August and October which were below the sd of historic data. The percentage exceedance of Hs (Figure 132) was lower for all wave heights compared with the historical data except during winter and all data from the 2017-2018 season where H_s below 0.4 m were exceeded more frequently than the historic exceedance.

The histogram of percentage occurrence for H_s (Figure 133) shows that H_s of 0.2-0.4 m occurred more frequently in summer and 0.8-1.0 m less frequently in winter. The histogram of Peak wave period (T_p) (Figure 134) was also similar between the reporting period and the entire record except that T_p of 3-5 seconds was more frequent and 5-7 seconds less frequent in summer.

The ratios between different wave parameters such as H_{max}/H_s were consistent between this reporting period and all of the historic data, these are plotted in Figure 135. The ratio T_p/T_z and T_p/T_s is slightly increased compared to the historic data.

The general wave direction was from the north east through to south-east with an occasional swing to the south (Figure 130 and Figure 136).

Table 63 Cairns – highest waves

Rank	Date (H_s)	H_s (m)	Date (H_{max})	H_{max} (m)
1	12/04/2014 15:30	3.4	12/04/2014 14:00	5.6
2	27/02/2000 21:30	2.8	28/02/2000 1:00	5
3	11/02/1999 21:00	2.5	23/01/2013 23:00	4.7
4	3/02/2011 4:30	2.4	11/02/1999 22:00	4.6
5	23/01/2013 23:30	2.3	23/12/1990 20:54	4.5
6	23/12/1990 20:54	2.2	3/02/2011 4:00	4.1
7	10/12/2018 2:00	2	12/01/2009 7:00	3.4
8	19/03/1990 8:42	1.9	10/12/2018 2:30	3.4
9	31/01/1977 9:00	1.9	3/01/1979 3:00	3.3
10	12/01/2009 7:00	1.9	31/01/1977 9:00	3.2

Table 64 Cairns – significant meteorological events with threshold H_s of 1.5 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
No significant events reported				

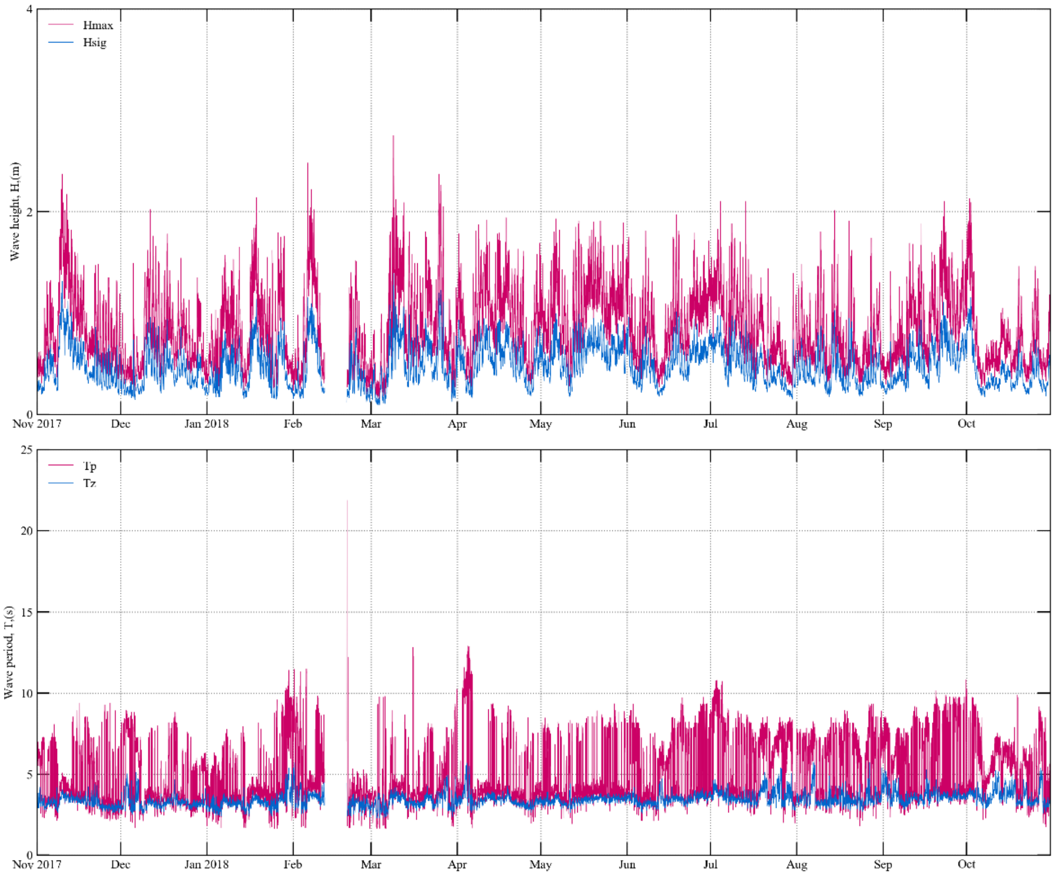


Figure 129 Cairns – daily wave recordings

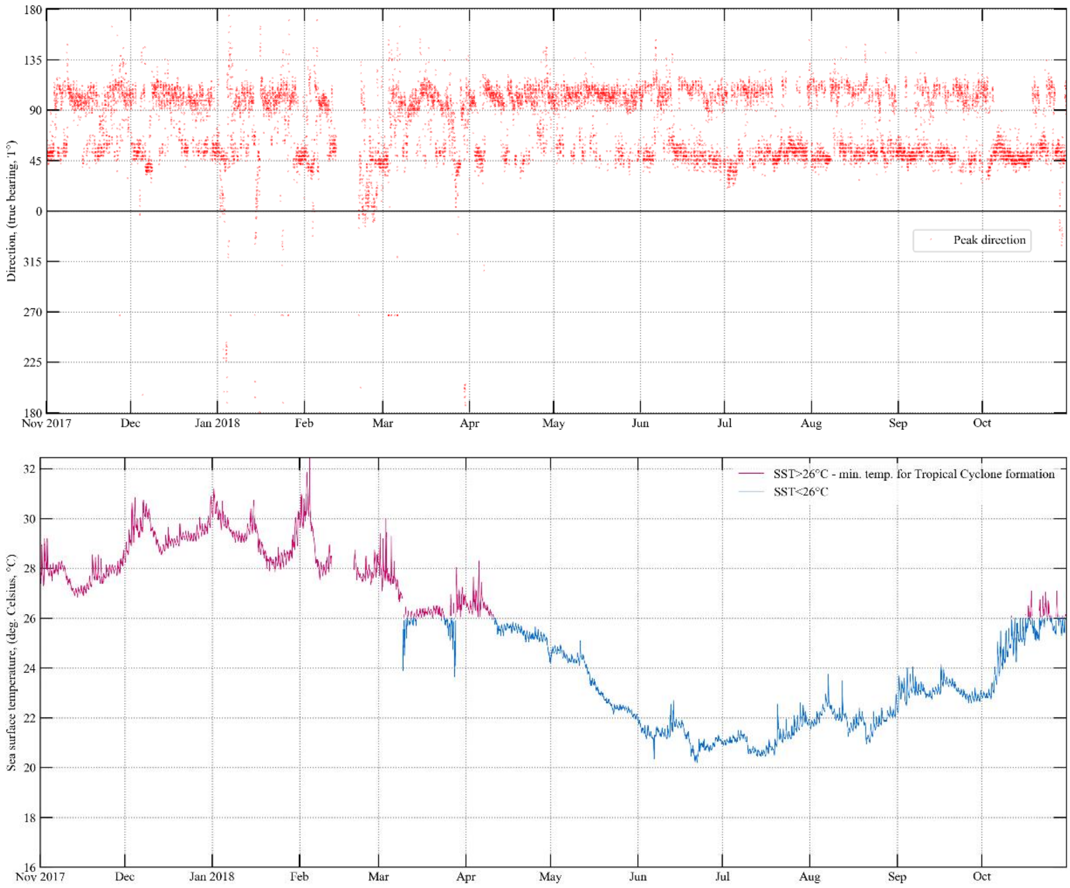


Figure 130 Cairns – peak wave direction and sea surface temperature

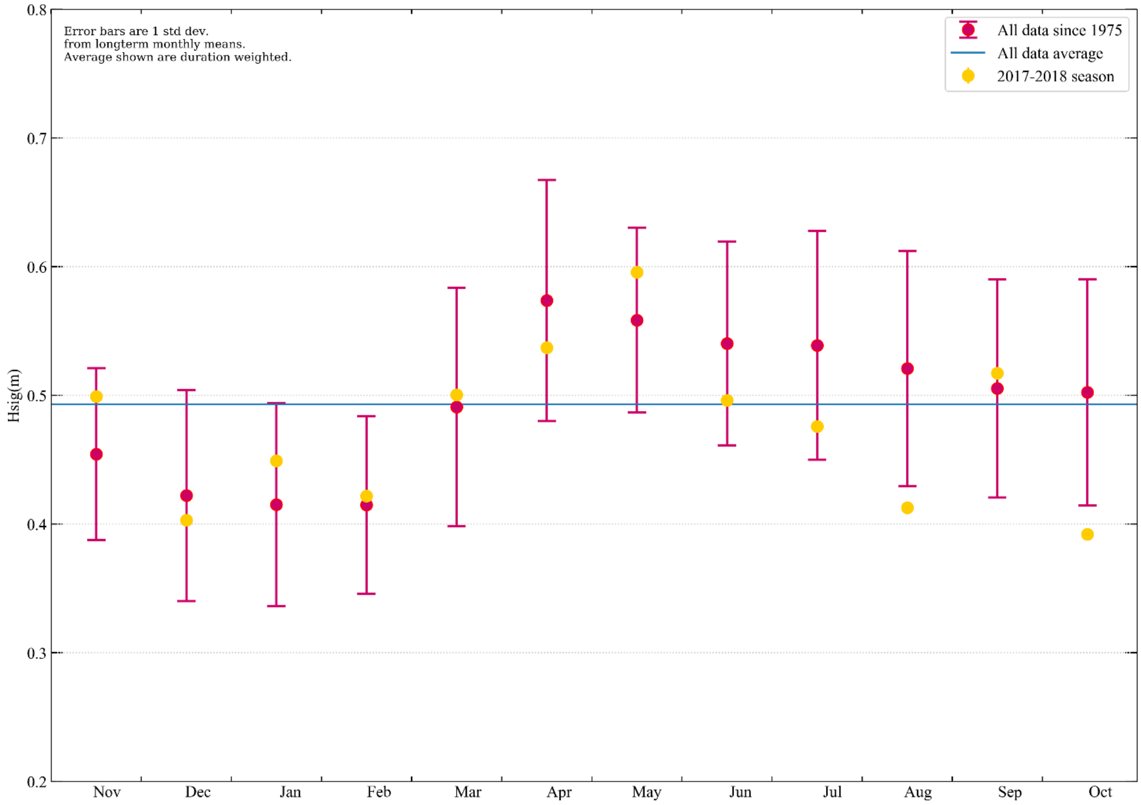


Figure 131 Cairns – monthly average wave height (H_s) for 2017-18 and for all data

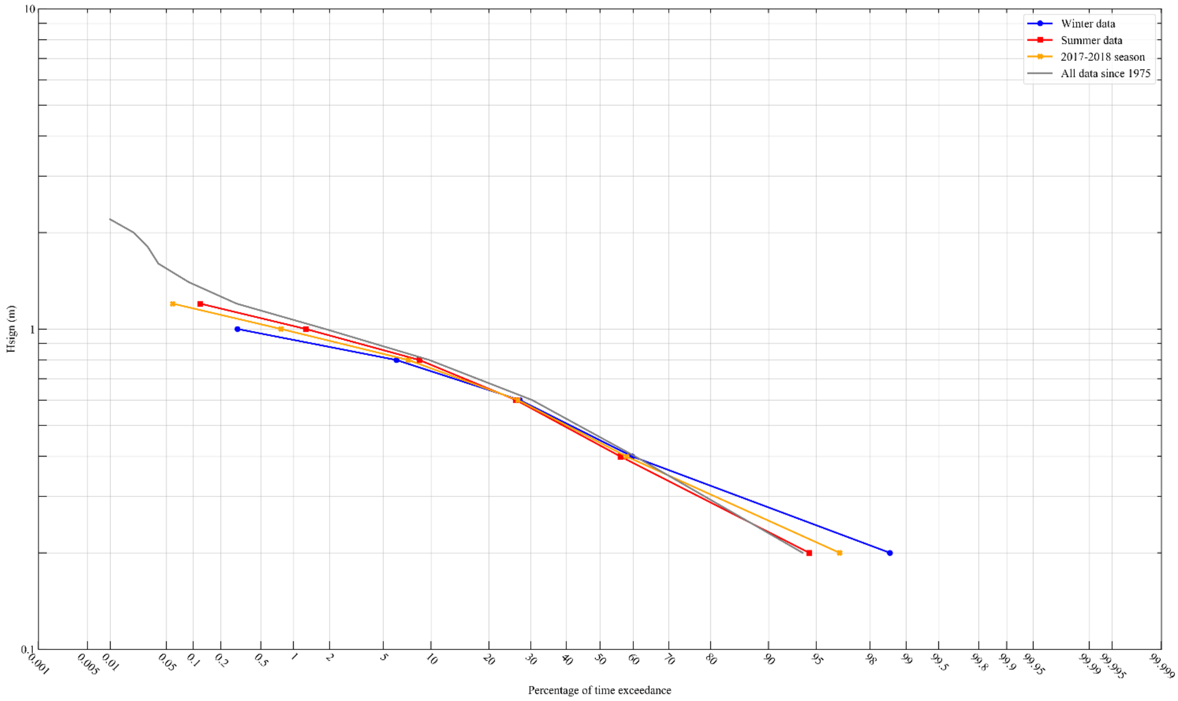


Figure 132 Cairns – percentage exceedance of wave height (H_s) for all wave periods (T_p)

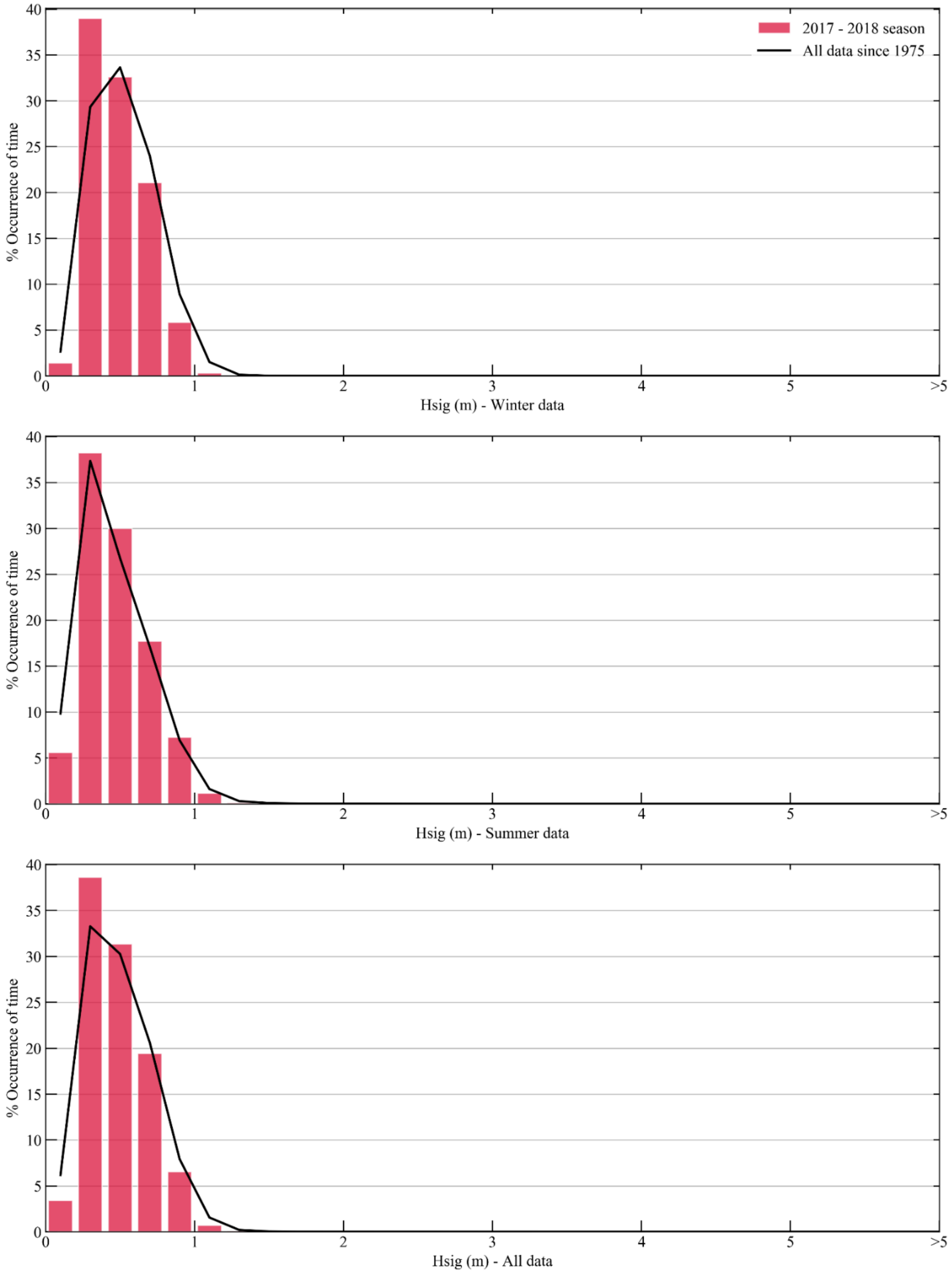


Figure 133 Cairns – histogram percentage (of time) occurrence of wave heights (H_s)

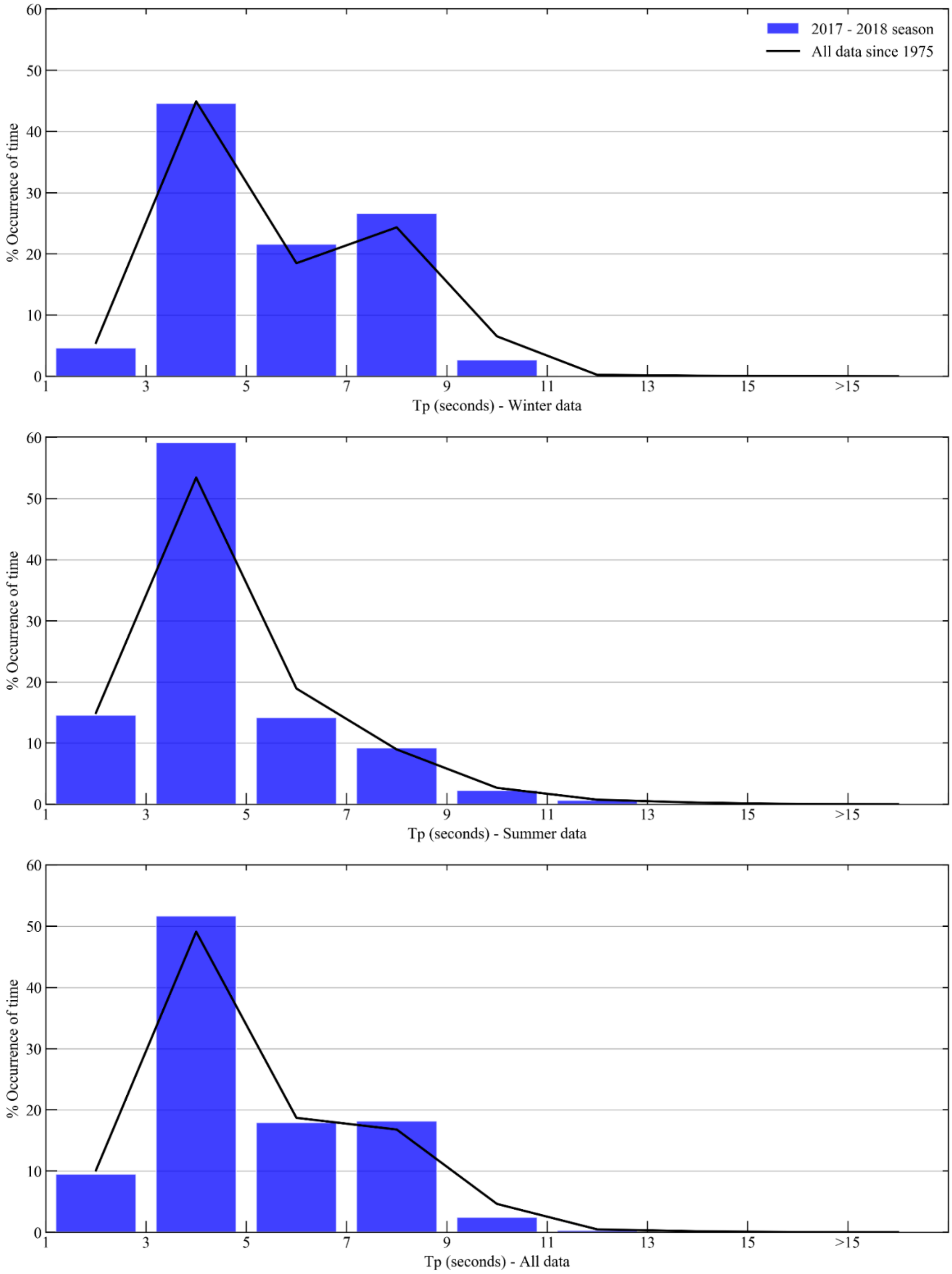


Figure 134 Cairns – histogram percentage (of time) occurrence of wave periods (T_p)

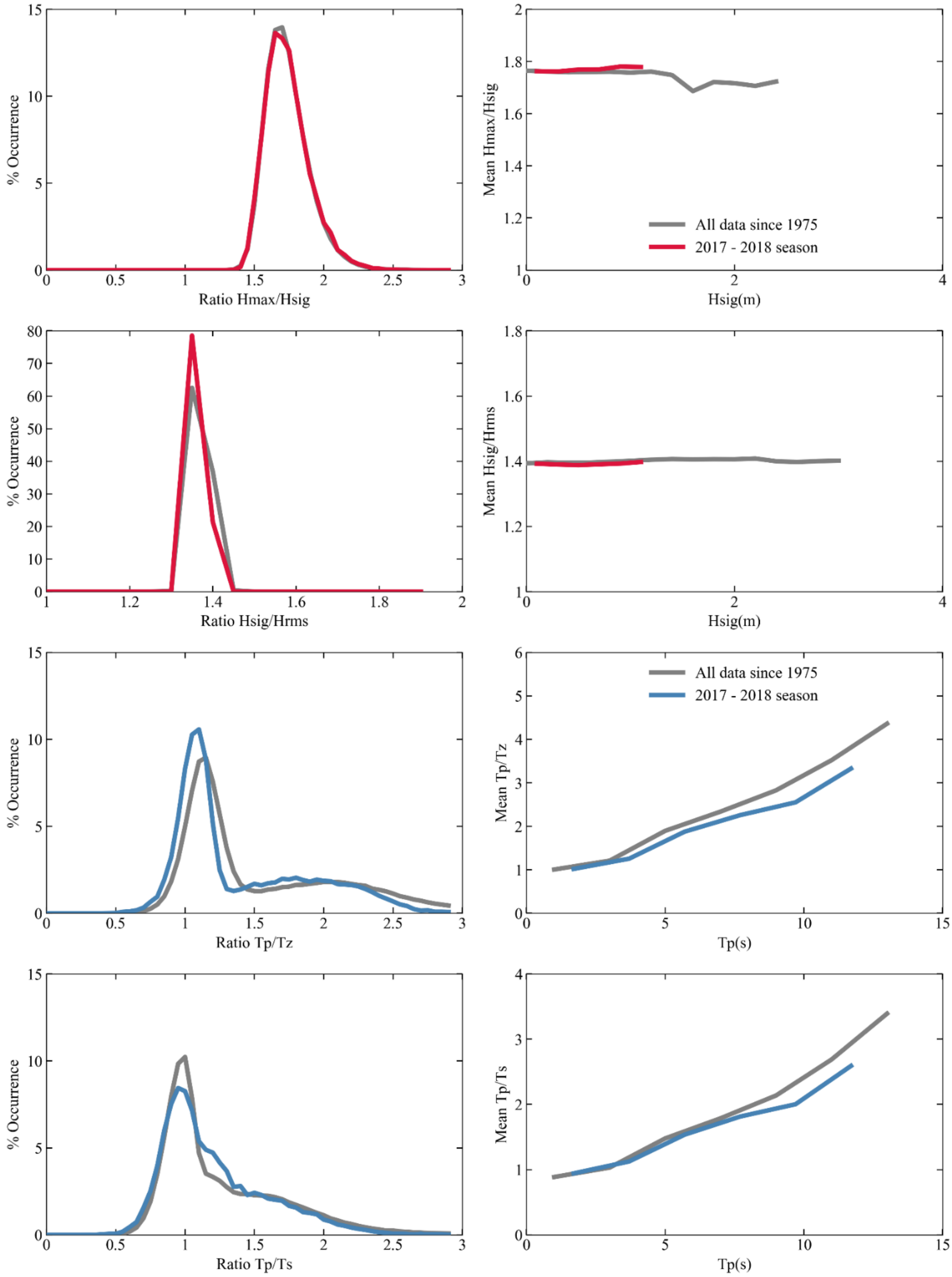
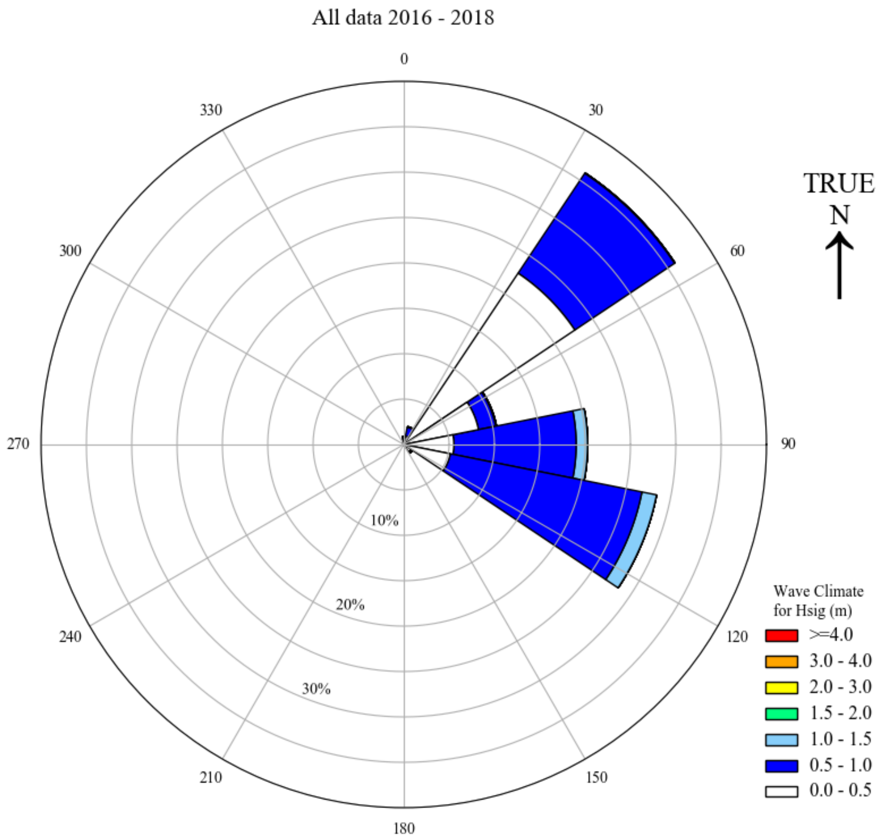


Figure 135 Cairns – wave parameter relationships



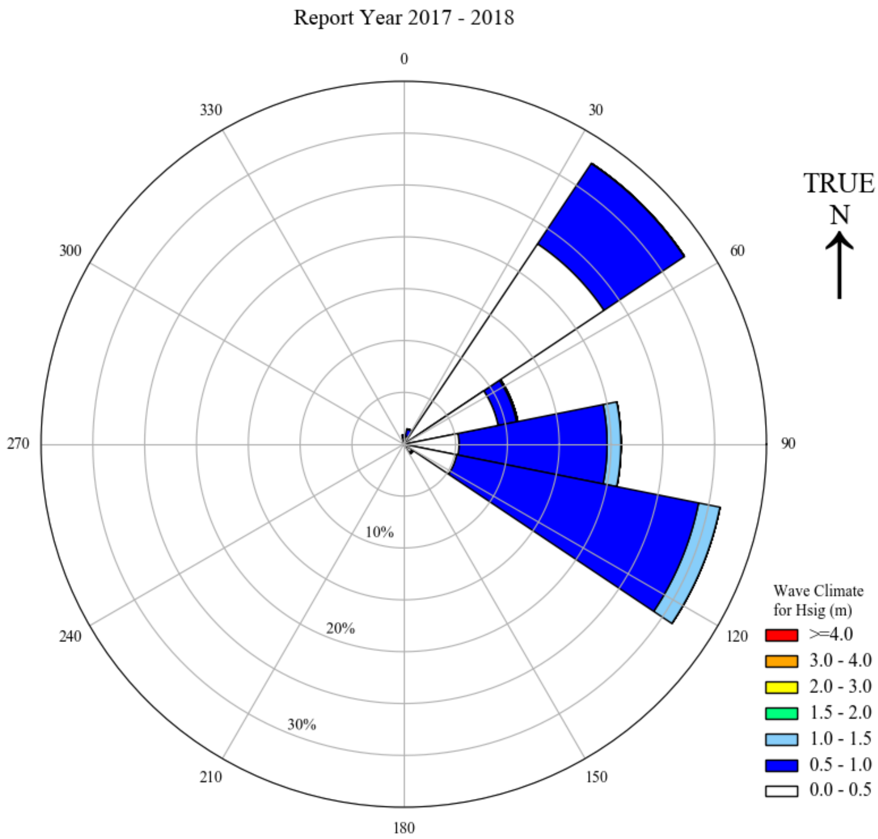


Figure 136 Cairns – directional wave rose

Albatross Bay

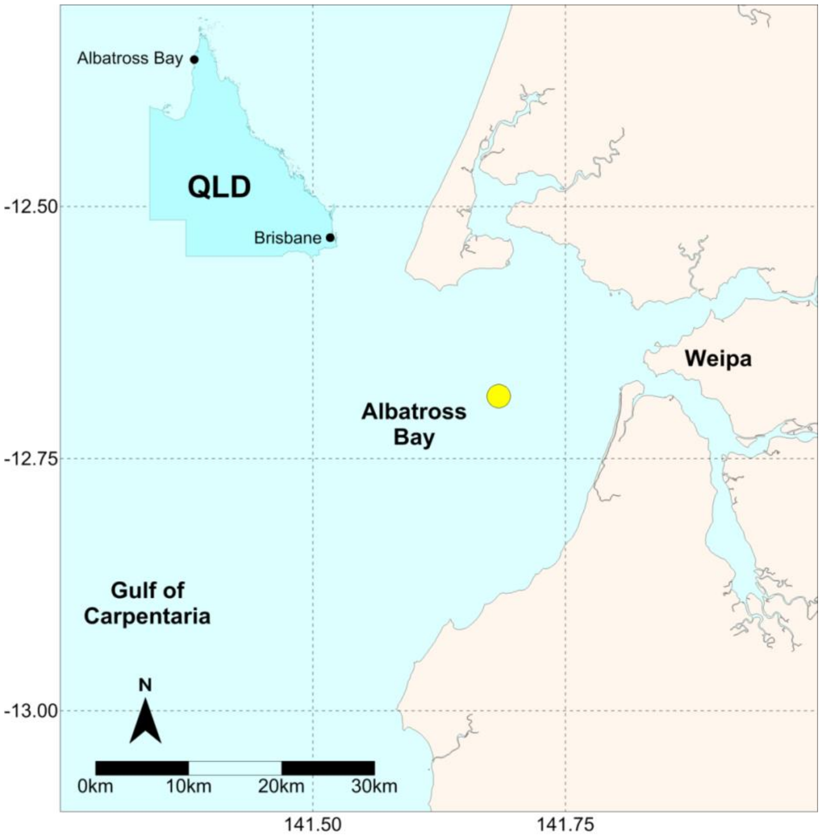


Figure 137 Albatross Bay – locality plan

Table 65 Albatross Bay – wave monitoring history

Data period	Start date	Gaps	Number of records	Total years
All data	21/11/2008	0.32 years	166169	9.93
2017-18	01/11/2017	13.63 days	16865	1

Table 66 Albatross Bay – buoy deployments for the 2017-18 season

Latitude	Longitude	Type buoy	Depth (m)	Deployed date	Removal date
12°41.269' S	141°41.090' E	DWR-GPS	10	10/08/2017	current

Albatross Bay – seasonal overview

The Albatross Bay wave buoy has been operational for just under ten years with an overall data return of 96.7 per cent. The data record for the period November 2017 to October 2018 was good, with total gaps of 13.63 days, equivalent to 96.2 per cent data return (Table 65). The buoy was not replaced during the 2017-2018 reporting period (Table 66).

Four significant events were recorded throughout the 2017-2018 recording period, with wave heights making the top ten highest waves on two occasions (Table 68). The passage of TC Iris off the Queensland coast resulted in the highest H_s event and second highest H_{max} wave at Albatross bay. A high-pressure system event on the 31st of January also generated wave heights ranking 7th for Hs, and 8th for H_{max} (Table 67).

The Sea Surface Temperature (SST) measured in the buoy hull shows the recorded values ranged from 25 °C to 33 °C during the reported year. The SST was high enough for tropical cyclone development for most of the year, except for small periods from June to the middle of August when SST fell below the 26.5 °C threshold (Figure 139).

Monthly average H_s showed variance to the long term mean for March, June, July and October over the recording season, which were all outside of the one sd range (Figure 140).

Overall, wave climate for the reporting period was similar to the wave climate for wave heights below 0.4 m (Figure 141). Wave heights greater than 2.0 m were more frequent for the 2017-2018 periods and summer, compared to the historical data. The winter period has a lower percent exceedance than summer compared to the whole 2017-18 season, with winter only recording waves below 0.8 m in height.

The histograms for percentage occurrence of H_s (Figure 142) and T_p (Figure 143) were very similar between this season and the whole record, with the T_p values between the 1 to 3 second period being the most predominant.

The ratios between different wave parameters such as H_{max}/ H_s were consistent between this reporting period and all the historic data, these are plotted in Figure 144.

The dominance of the incident wave direction is reflected in the directional wave rose plot (Figure 145) with the most common wave height (H_s) of less than 0.5 metres from the south western direction.

Table 67 Albatross Bay – highest waves

Rank	Date (H_s)	H_s (m)	Date (H_{max})	H_{max} (m)
1	24/03/2018 15:00	4.3	22/01/2013 13:00	6.7
2	22/01/2013 13:00	4.1	24/03/2018 15:00	6.6
3	12/01/2009 0:00	3.5	11/01/2009 23:30	5.7
4	30/01/2010 3:00	3.3	30/01/2010 5:30	5.5
5	2/02/2012 8:30	2.7	9/01/2015 8:30	5.4
6	19/03/2012 2:30	2.6	3/02/2012 9:00	5.1
7	31/01/2018 8:00	2.6	19/02/2014 8:00	5
8	19/02/2014 6:30	2.6	31/01/2018 14:00	4.7
9	29/12/2015 8:00	2.4	18/03/2012 19:30	4.3
10	29/12/2011 17:30	2.4	22/01/2011 6:00	4.2

Table 68 Albatross Bay – significant meteorological events with threshold H_s of 1.0 metres

Date	H_s (m)	H_{max} (m)	T_p (s)	Event
31/01/2018 8:00	2.4 (2.6)	3.8 (4.7)	8.2	A high-pressure ridge moved from the Great Australian Bight to the Tasman sea extending along the Queensland coast.
6/03/2018 0:30	1.3 (1.5)	2.2 (2.6)	6.2	TC Hola developed on March 6, moving slowly towards Australian waters.
8/03/2018 19:00	1.0 (1.1)	1.8 (1.9)	6.3	TC Hola drew closer to Australia, however did not enter Australian waters before being downgraded.
24/03/2018 15:00	4.0 (4.3)	5.8 (6.6)	11.6	TC Iris entered Australian waters on the March 24 before weakening to a low-pressure system. Remnants stayed off the central QLD coast from the March 30.

Denotes peak H_s event

Notes: 1. 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).

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

Figure 138 Albatross Bay – daily wave recordings

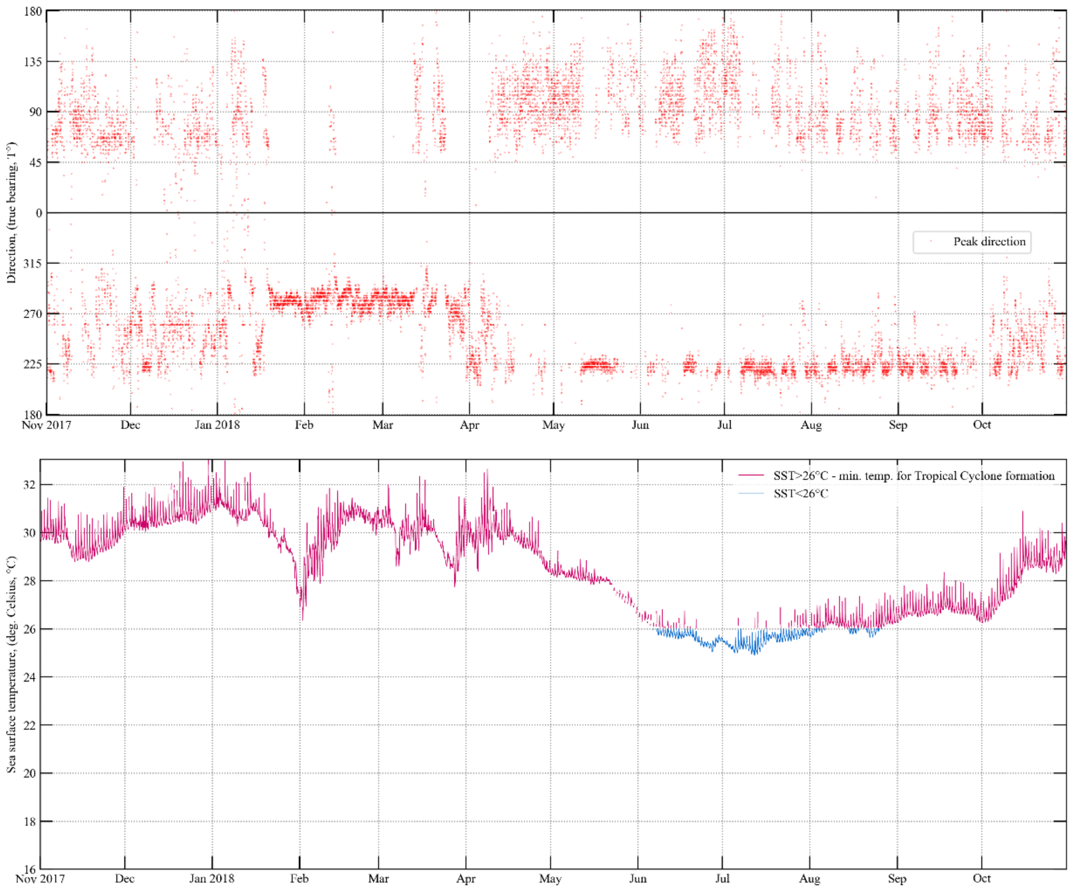


Figure 139 Albatross Bay – peak wave direction and sea surface temperature

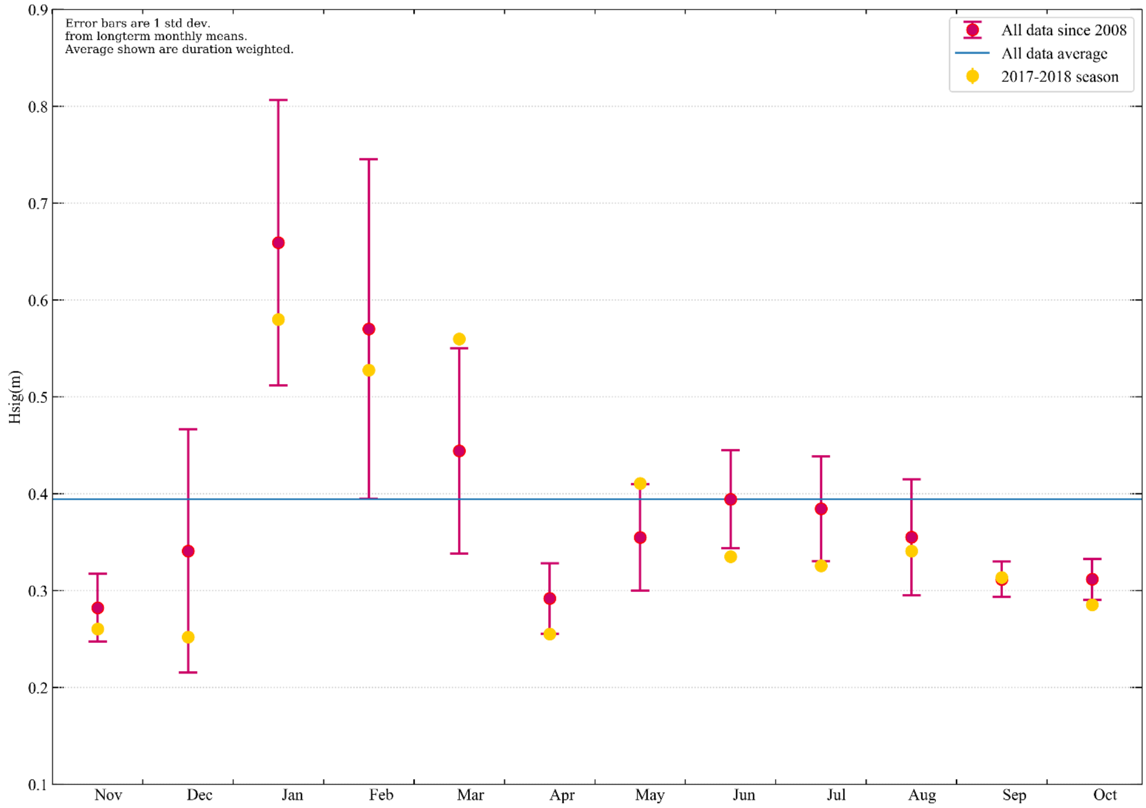


Figure 140 Albatross Bay – monthly average wave height (H_s) for 2017-18 and for all data

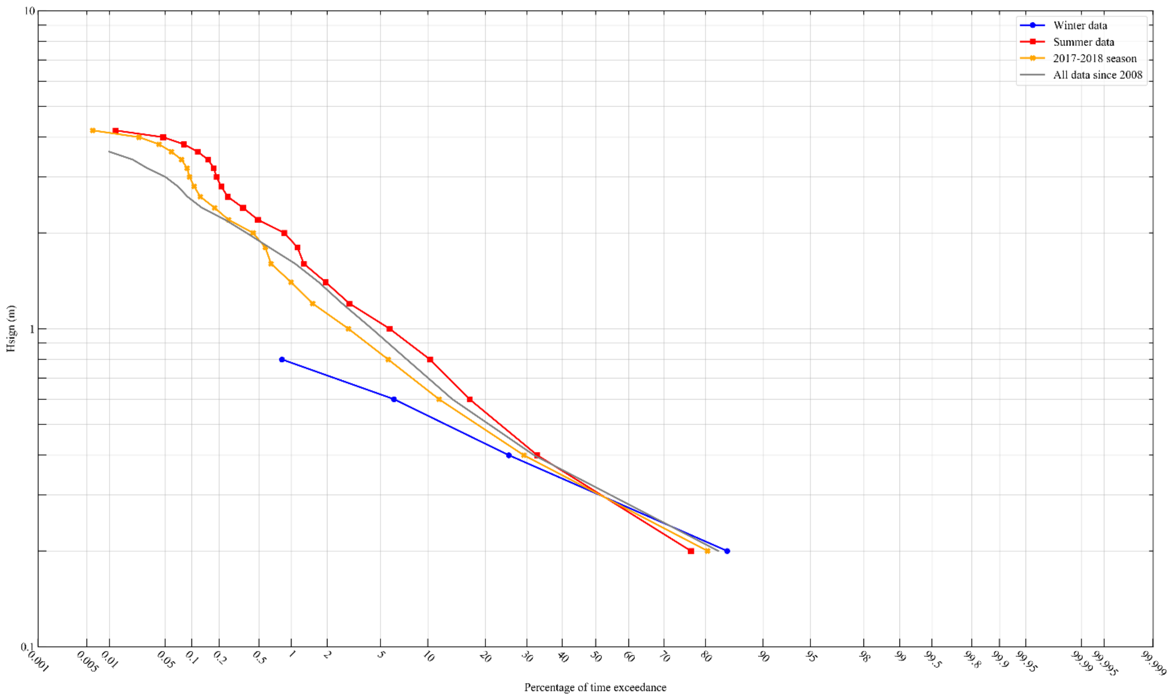


Figure 141 Albatross Bay - percentage exceedance of wave height (H_s)

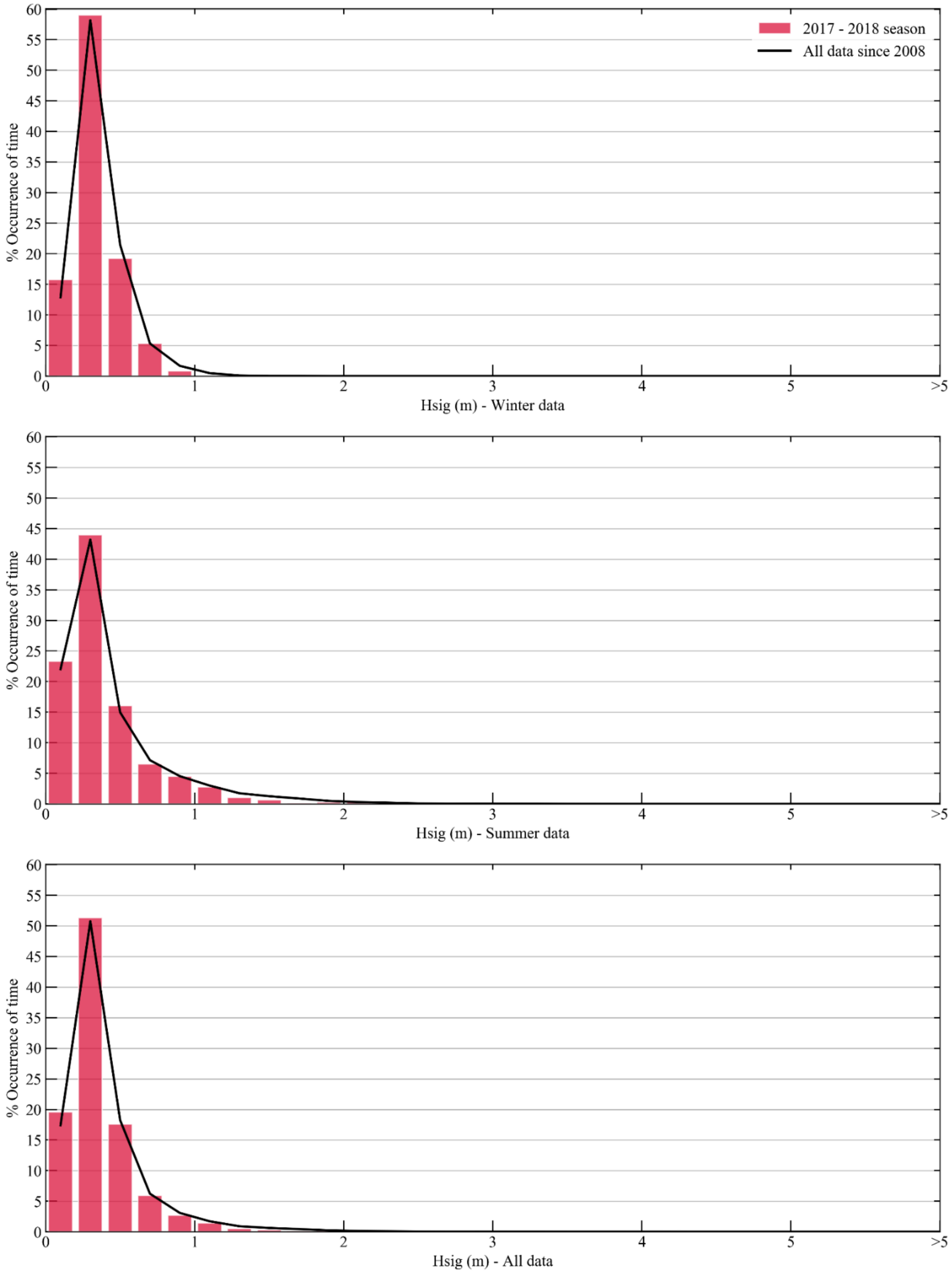


Figure 142 Albatross Bay – histogram percentage (of time) occurrence of wave heights (H_s)

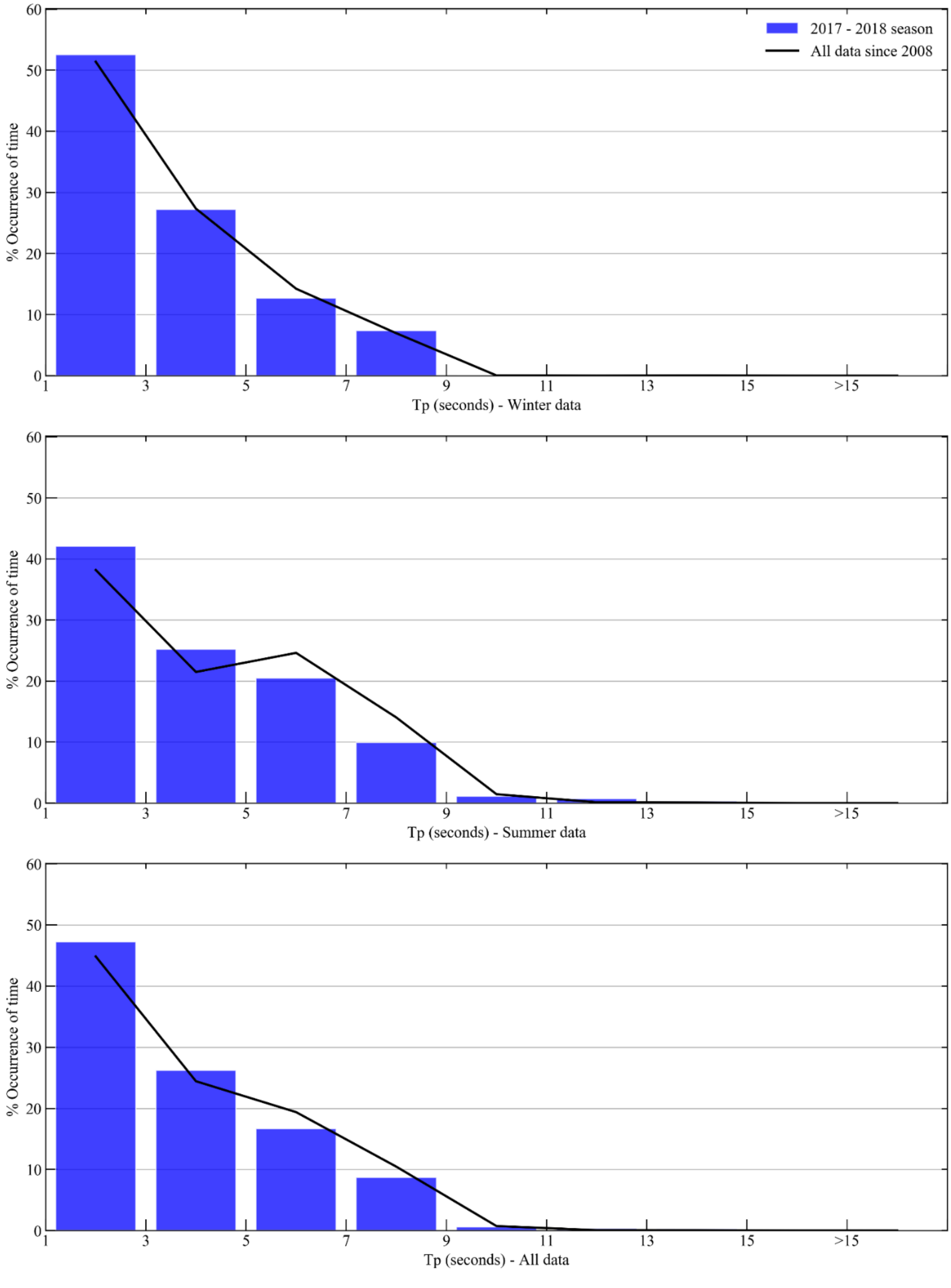


Figure 143 Albatross Bay – histogram percentage (of time) occurrence of wave periods (T_p)

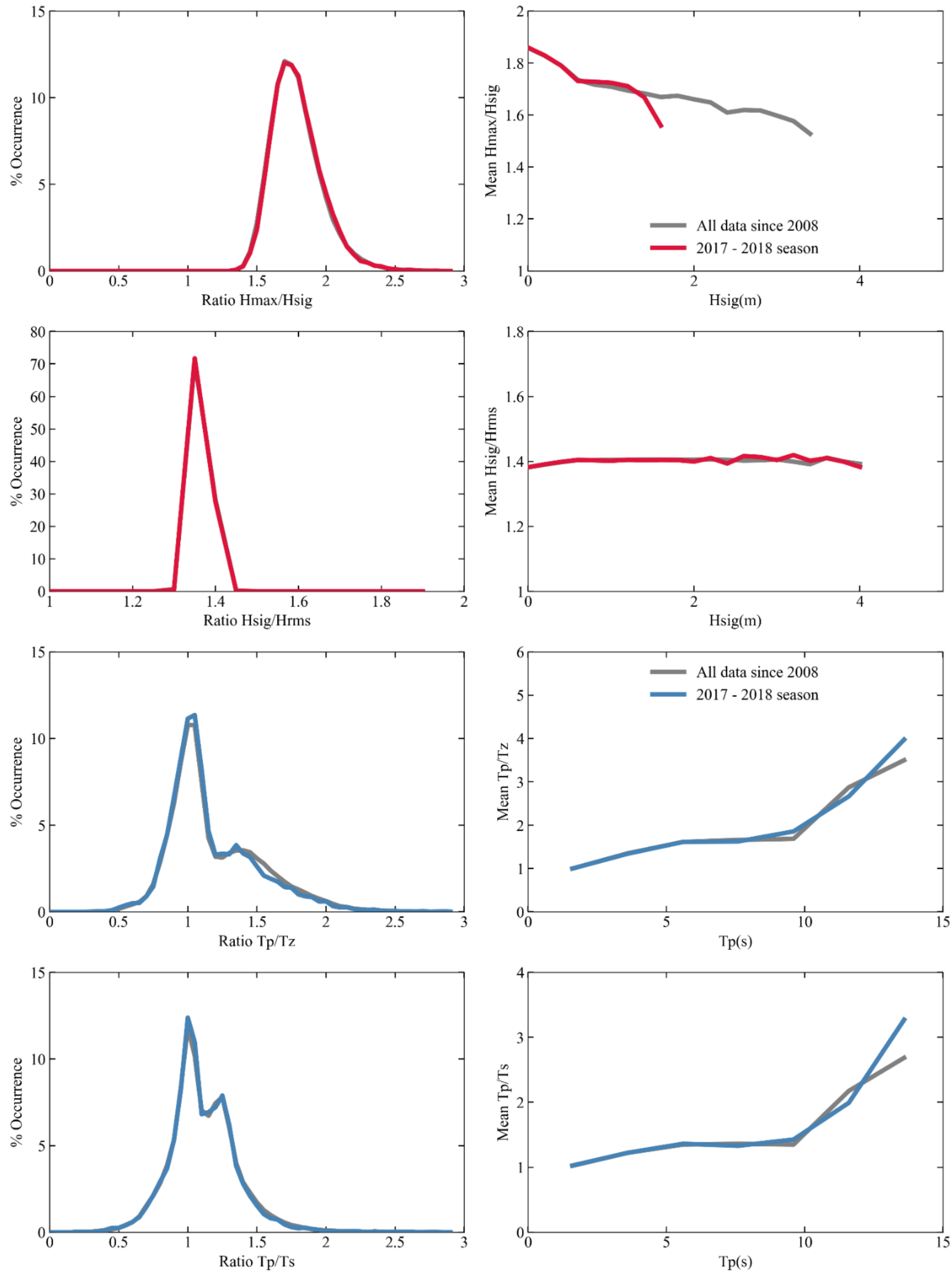
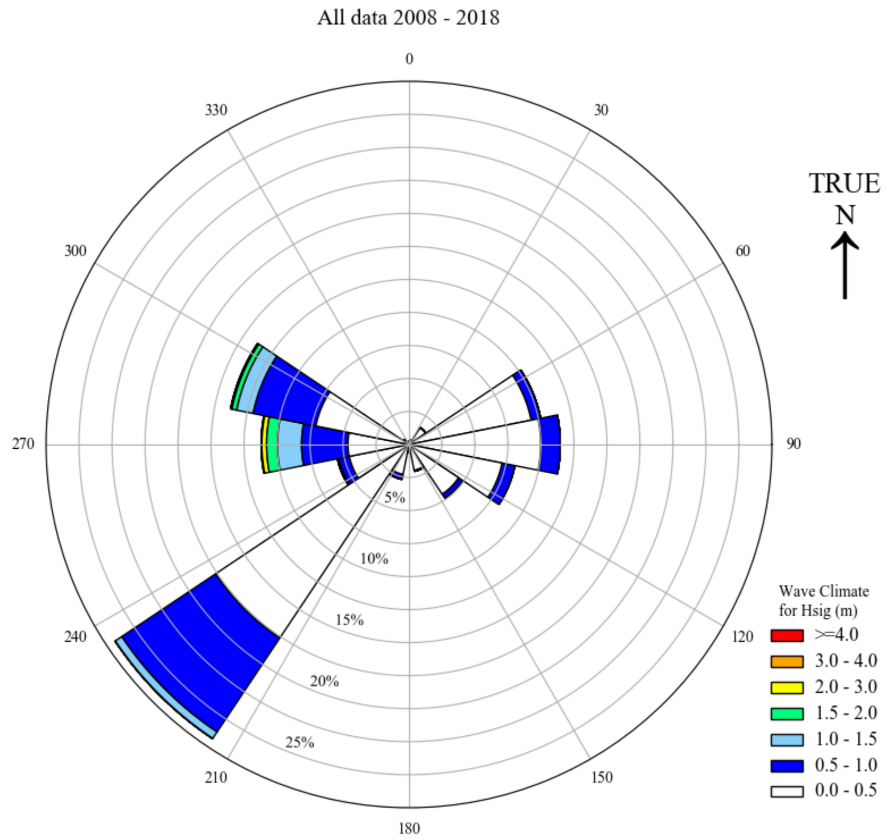


Figure 144 Albatross Bay – wave parameter relationships



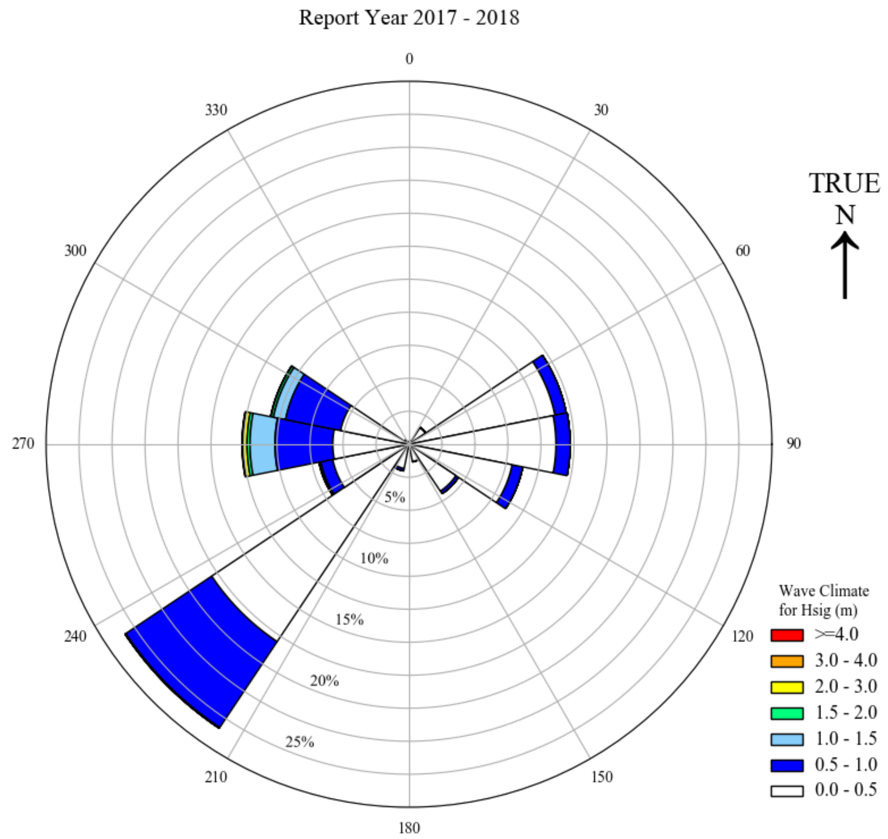


Figure 145 Albatross Bay – directional wave rose

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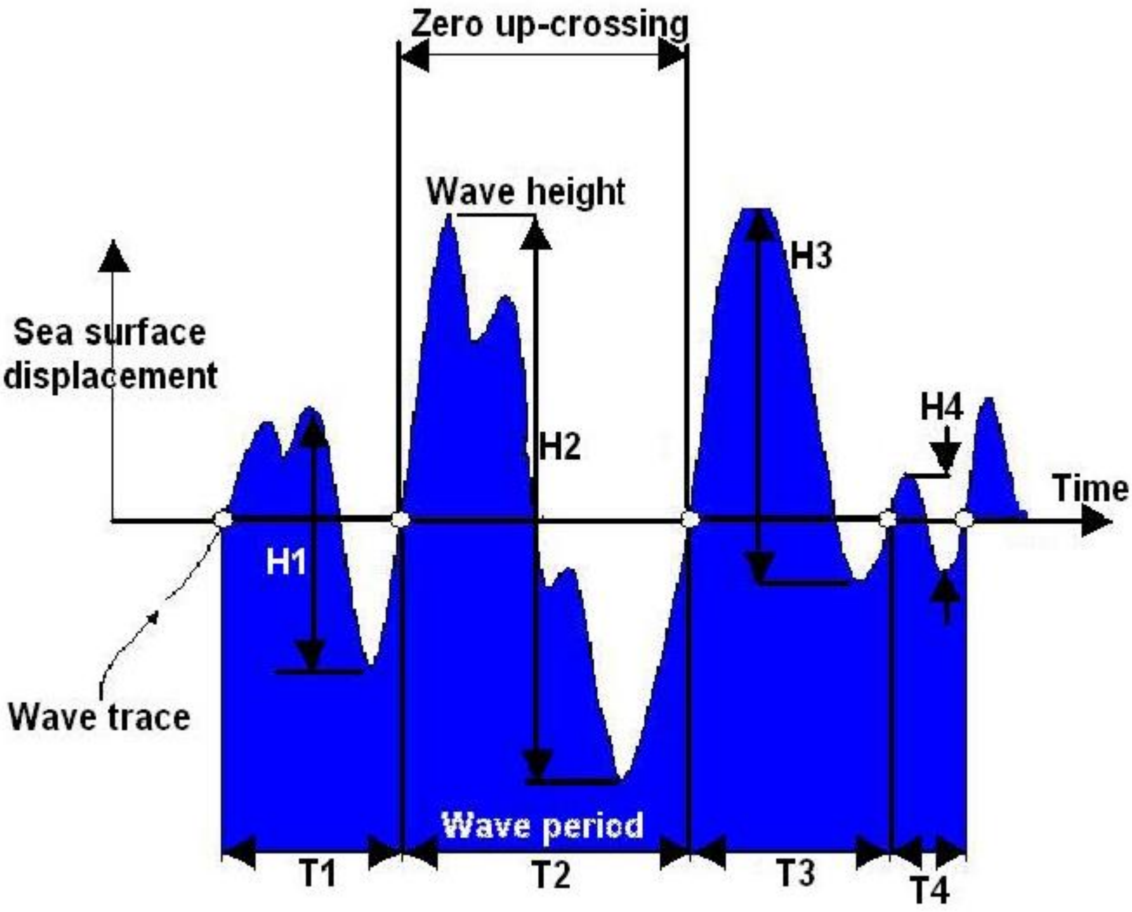
Appendix A Zero up-crossing analysis

Zero up-crossing analysis is a direct, repeatable and widely accepted method to extract representative statistics from wave traces recorded by a wave measuring buoy. A wave is defined as the portion of the record between two successive zero up-crossings of the mean water line. Waves are ranked, with their corresponding periods, and statistical wave parameters are computed in the time domain.



Appendix B Comparison between GPS and Mk4 at Tweed Heads

DES strives for continual improvement regarding the scientific instrumentation utilised as part of Queensland's wave monitoring network. The next generation of waverider buoy is the DWR-Mk4, which are poised to replace older buoy models that are currently used throughout the wave monitoring network. As such a dual deployment of a DWR-G and Mk4 waverider buoy has been arranged at Tweed Heads. The buoys are moored approximately 250m apart as seen in Figure 5.1. There are two major differences between the two units; 1) an increase in sampling frequency for the Mk4 and 2) a change in the calculating method utilised for spectral data. An in-depth report outlining the differences between the two buoy models has been undertaken by DISITI (2017) and can be found as an addendum. A comparison of the data collected from both the DWR-G and Mk4 is provided below (Figure 5.1 and 5.2). It is important to note that due to the nature of the comparison simultaneous records for both devices were necessary, as such corresponding data points to any data outages from one buoy were removed from the record for the other. Comparison is for the period 10/06/2017 – 30/04/2018.

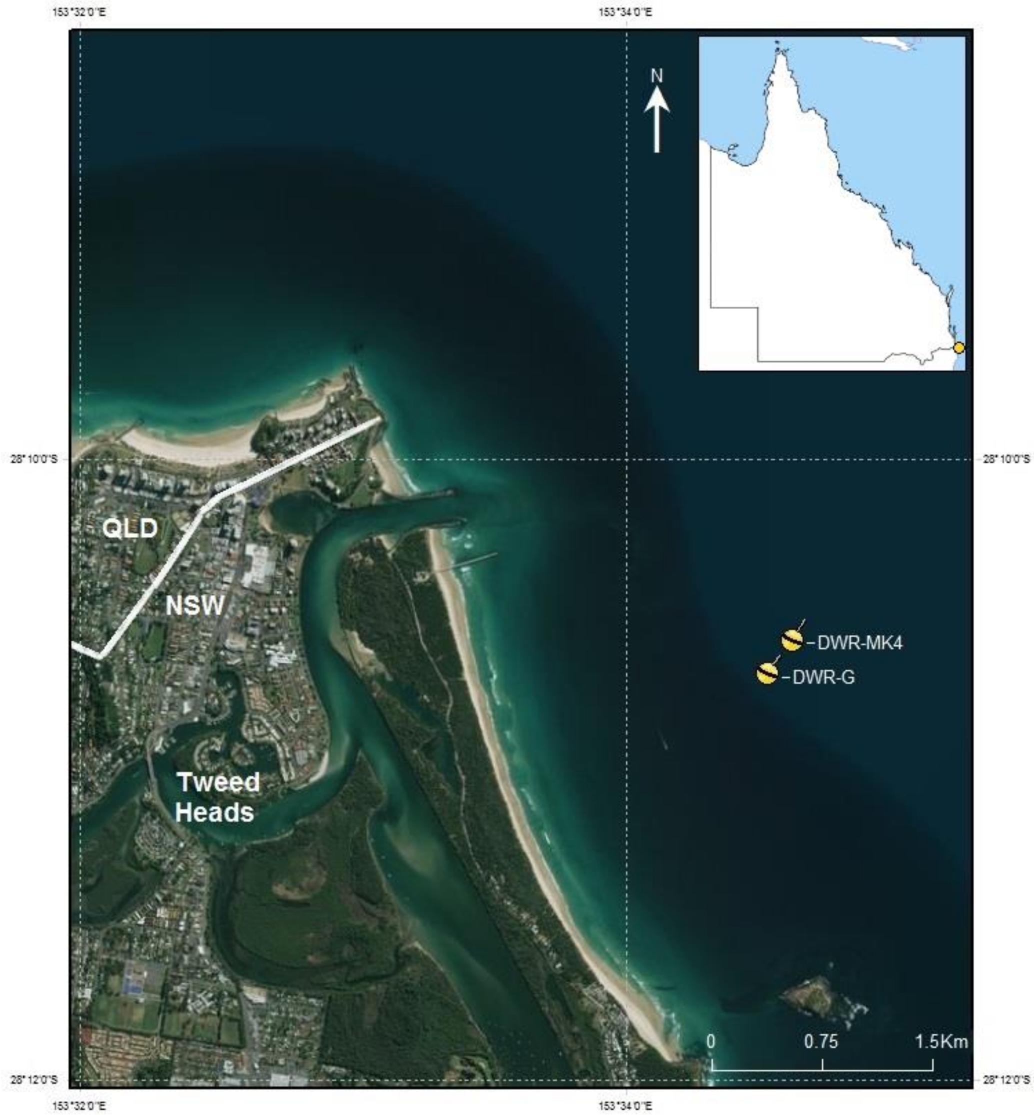


Figure 0.1: Locality plan for the Tweed Heads DWR-G and MK4 buoys

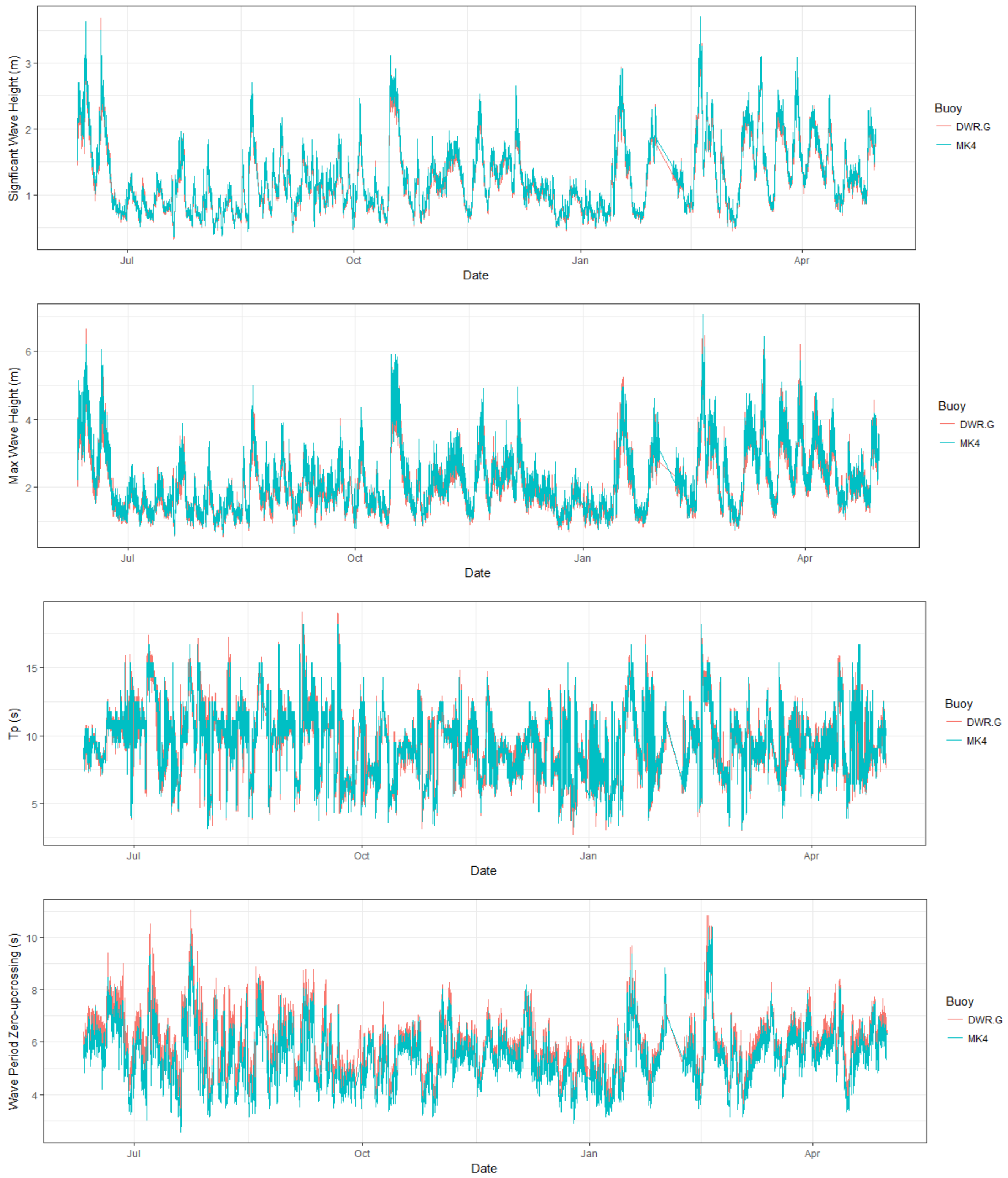


Figure 0.2: Comparison between the Tweed Heads DWR-G and MK4 parameters; H_s, H_{max}, T_p, T_z

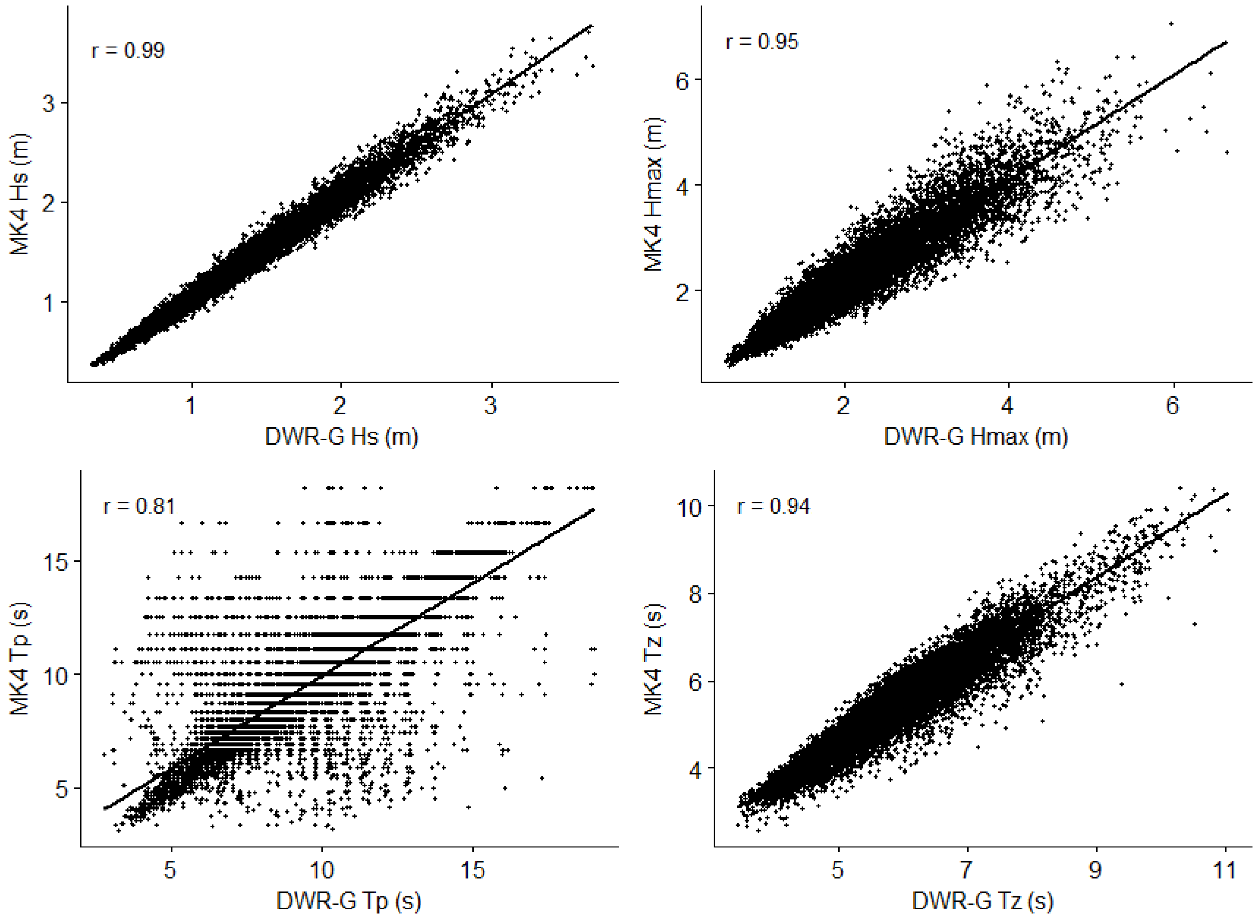


Figure 0.3: Spearmans correlation coefficient between the DWR-G and Mk4 parameters; H_s, H_{max}, T_p and T_z

As seen in Figure 5.3 H_s, H_{max} and T_z between the MK4 and DWR-G have a high correlation (r 0.99, 0.95, 0.94 respectively), T_p on the other hand has a weaker correlation (r 0.81). Whilst both devices calculate T_p in a similar manner, there are differences in both sampling frequency and the amount of spectral bins utilised. As such differences in T_p between the two devices are to be expected. Bimodal sea states also have the potential to effect T_p, due to the potential for each device to pick up alternate peak periods from differing wave fields. For a more in depth comparison of the Mk4 to the MKIII refer to DSITI (2017).

This part has been copied from the Tweed Heads/ Brisbane wave climate annual summary May 2017-April 2018, prepared by CIU.

Appendix C Glossary

Parameter	Description
H_s	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.
T_{Hs}	The average period of the highest one-third of zero up-crossing wave heights
H_{rms}	Root mean square wave height from the time domain
H_{max}	The maximum zero up-crossing wave height (in metres) in a 26.6-minute record.
Kurtosis	The sharpness of the peak of a frequency-distribution curve.
T_c	The average crest period (in seconds) in a 26.6-minute record.
T_z	The average of the zero up-crossing wave periods (in seconds) in a 26.6-minute record.
H_{10}	Average of the highest 10 percent of all waves in a record
T_{H10}	The period of the H10 waves
T_{Hmax}	Period of maximum height, zero up-crossing
T_{zmax}	The maximum zero crossing in a record
H_{m0}	Estimate of the significant wave height from frequency domain $4\sqrt{m_0}$
$T_{0,2}$	Average period from spectral moments zero and two, defined by $\sqrt{m_0/m_2}$
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).
Dir_p	Direction the Peak Period waves are coming from (in °TRUE)
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.