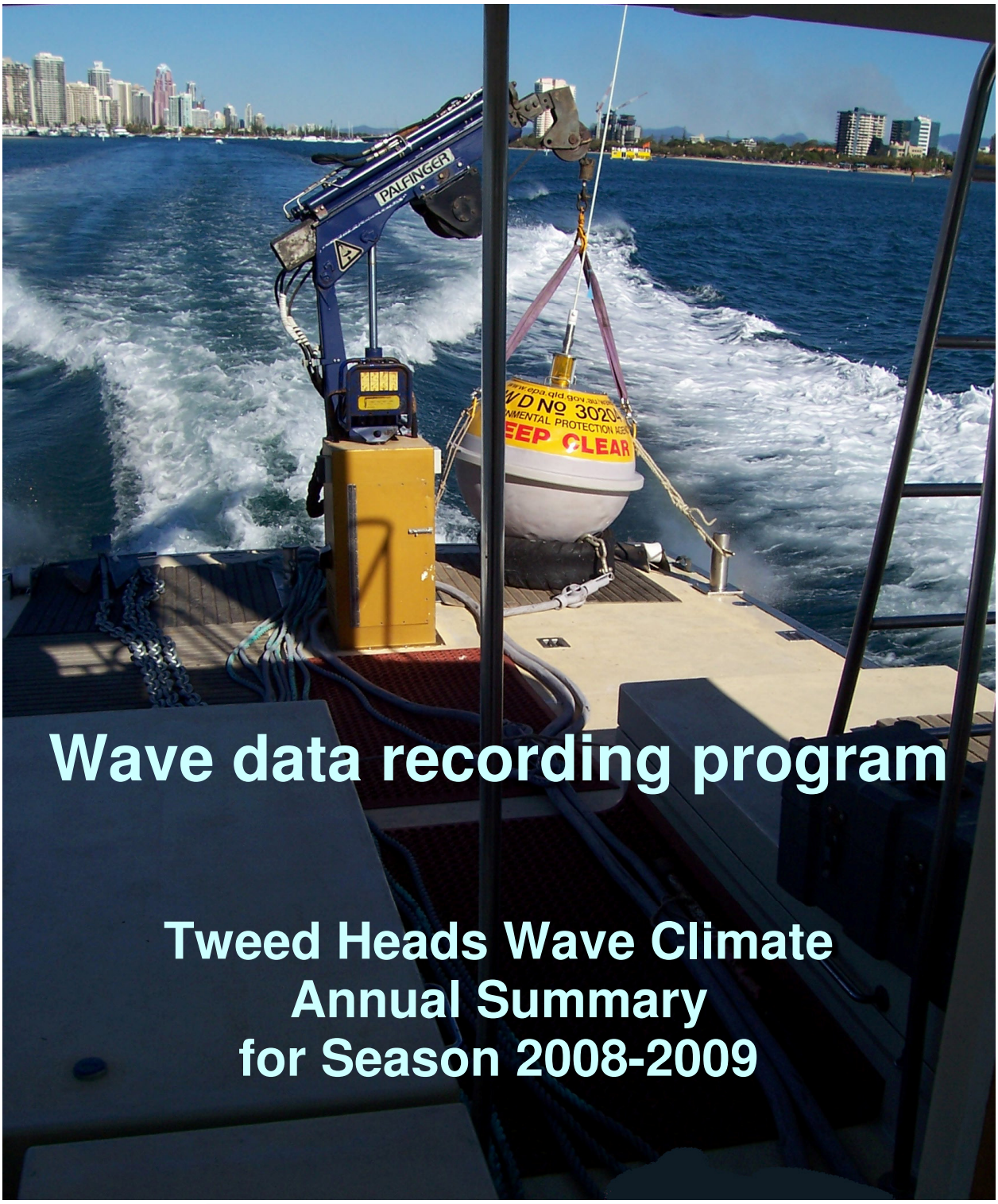

Wave data recording program

Tweed Heads Wave Climate Annual Summary for Season 2008-2009

Department of **Environment** and **Resource Management**

Queensland Government

Coastal Sciences data report No.2009.1
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Foreword

This summary of wave climate from the Tweed Heads and Brisbane wave sites is one of the series of technical wave reports prepared annually by the Department of Environment and Resource Management's (DERM) Coastal Sciences Unit.

Annual wave reports supplement the reporting ability of the DERM's Coastal Sciences Unit by providing timely information on wave climates in Queensland. More comprehensive regional wave data reports provide the more thorough, long-time presentation of regional conditions.

Using the information presented annually, regional reports should be updated every five years.

Annual reports present wave information in a similar format to the existing regional reports; however they also include plots of monthly average significant wave heights and a directional wave rose.

This report covers the year from 1 May through to 30 April of the following calendar year. The start of the year therefore coincides with the commencement of the annual Tweed River Sand Bypassing Project (TRESBP)

Cover photo: Tweed Heads wave buoy prior to deployment.

Abstract

This report summarises the primary analyses of wave data recorded using Datawell directional Waverider buoys positioned off Tweed Heads and Brisbane for the period from 1 May 2008 to 30 April 2009.

The data recorded covers all of the seasonal variations for one year, and includes the 2008–09 cyclone season.

This report has been prepared by the Department of Environment and Resource Management's Coastal Sciences Unit, Environmental Sciences Division. DERM acknowledges the following team members who contributed their time and effort to the preparation of this report:

John Mohoupt; Vince Cunningham; Gary Hart; Jeff Shortell; Colin Newport; Fred Ventura; Kane Nielsen; Martin Hansen; John Ryan and Jim Waldron.

Disclaimer

While reasonable care and attention have been exercised in the collection, processing and compilation of the wave data included in this report, the Coastal Sciences Unit does not guarantee the accuracy and reliability of this information in any way. Neither the Queensland Government nor DERM accepts liability for any decisions or actions taken on the basis of this report.

Department of Environment and Resource Management
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CITY EAST QLD 4002

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1.0 Introduction

The Department of Environment and Resource Management, as part of its long-term data collection program, has maintained a network of wave recording stations along the Queensland coast since 1968.

The network of wave recording stations has been grouped into three categories:

Long-term sites:	These sites form part of long-term data collection activities along the Queensland coast that gather wave statistics used for coastal management purposes. The stations are fully funded and operated by DERM.
DERM project sites:	These sites are of limited duration, associated with some specific coastal activity, which are used to assess wave conditions for coastal investigation projects and/or to help monitor works such as beach nourishment. The stations are fully-funded and operated by DERM, as specific projects.
Joint project sites:	The life of these sites will vary in duration, and they are associated with specific projects, to assess wave conditions or to monitor works. These stations are operated by DERM in conjunction with (and jointly-funded by) other agencies.

The 2008–09 site groups are as follows:

Table A
Wave recording stations for season 2008–09

Long term	DERM project	Joint project	Joint project partners
Brisbane	**Moreton Bay**	**Tweed Heads**	**TRESBP** *
Mackay		**Gold Coast**	**GCCC**+
Townsville		**Caloundra**	**PBC** ^
Cairns		**Mooloolaba**	**DoT** °
Emu Park		**Hay Point**	**PCQ** #
		Weipa	**PCQ** #

* Tweed River Entrance Sand Bypassing Project (joint project of Queensland and New South Wales Governments with support from Gold Coast City Council)

+ Gold Coast City Council

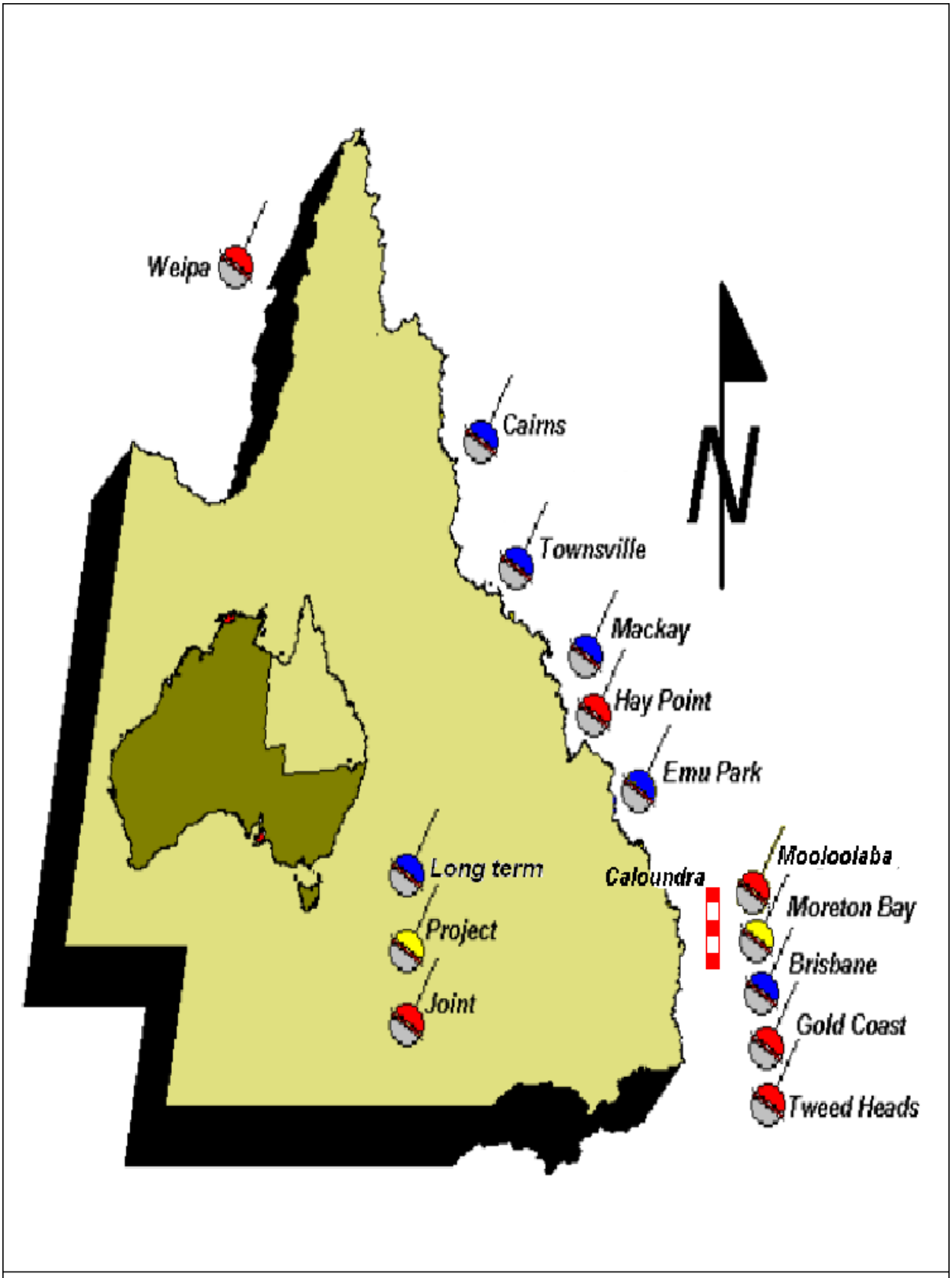
^ Port of Brisbane Corporation

° Department of Transport

Ports Corporation of Queensland

This report has been prepared for the Tweed River Sand Bypassing Project to summarise the primary analysis of wave data collected at the Tweed Heads and Brisbane wave sites and presents wave climate information for the required reporting period of 1 May 2008 to 30 April 2009.

The wave data collected for the current year or recording 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.



Department of Environment and Resource Management
Wave recording sites - Locality plan

Department of **Environment** and **Resource Management**

Queensland Government

Figure A

2.0 Recording equipment configuration

For the duration of this summary report the DERM's Coastal Sciences Unit's wave recording program utilised the Waverider system, manufactured by Datawell of the Netherlands to measure the sea surface fluctuations at an offshore location. Directional Waverider buoys were in operation at Tweed Heads and Brisbane during the period of this report.

The directional Waverider buoy at the Brisbane site:

> …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 coupling between the fixed coils and the coil on the platform. This coupling is measured. The result of the measurement gives the sine of the angles between the coils (x and y axes) and the horizontal plane (= platform plane). By means of a fluxgate compass, the components of the earth magnetic field in the direction of the x and y axes and the direction of the z axis (perpendicular to x and y) are measured.
>
> The position of the buoy with respect to fixed coordinates (north, west and vertical) is fully defined by all these measurements (p, r, Hx, Hy and Hz). A transformation matrix of the relation between vector components in buoy coordinates and fixed coordinates is formed. The acceleration of the buoy is measured in x and y directions (two fixed accelerometers) and in vertical direction (accelerometer mounted on stabilised platform).
>
> With help of the transform matrix and these measured accelerations, the accelerations in direction north-south and west-east can be calculated. Datawell (2000, p8)

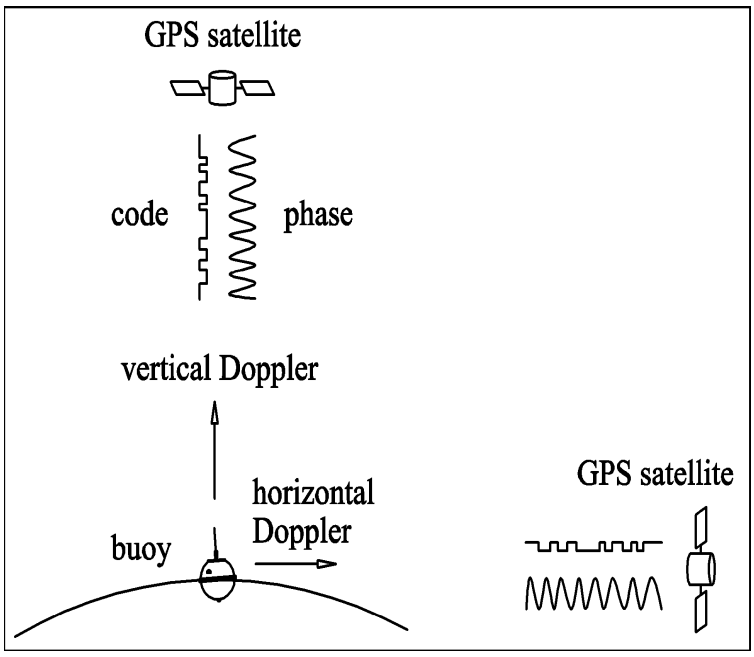


Figure B. The GPS wave measurement principle (Source: Datawell)

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

At both Tweed Heads and Brisbane, the vertical buoy displacement representing the instantaneous water level and calculated directional data are transmitted to a receiver station as a frequency modulated high-frequency radio signal. The directional Waverider receiver stations on shore are each comprised of a PC-based system connected to a Datawell receiver/digitiser. The water level data at each site is digitised at 0·78sec intervals (1·28Hz) and stored in bursts of 2048 points (approximately 26min) on the hard disk of the PC.

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

Further information on the operation of the Waverider buoy and the recording systems can be obtained from the sources listed in section 7.0 of this report.

3.0 Laboratory calibration checks

Waverider buoys used by the DERM are calibrated before deployment and also after recovery. Normally, a buoy is calibrated once every 12 months. Calibration of accelerometer buoys is performed at DERM's Deagon site using a buoy calibrator to simulate sinusoidal waves with vertical displacements of 2·7m. The calibrator is electrically controlled and the frequency may be adjusted from 0·016–0·25Hz. It is usual to check three frequencies during a calibration. The following characteristics of the buoy are also checked during the calibration procedure:

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

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

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

4.0 Wave recording and analysis procedures

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

Raw wave data transmitted from the buoys is analysed in the time domain by the zero up-crossing method and in the frequency domain by spectral analysis using Fast Fourier Transform (FFT) techniques to give 128 spectral estimates in bands of 0·01Hz. 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 0·005Hz.

The zero up-crossing analysis is equivalent in both the Brisbane (accelerometer) and Tweed (GPS) systems.

Wave parameters resulting from the time and frequency domain analysis included the following:

S(f)	energy density spectrum (frequency domain)
Hsig	significant wave height (time domain), the average of the highest third of the waves in the record
Hmax	the highest individual wave in the record (time domain)
Hrms	the root mean square of the wave heights in the record (time domain)
Tsig	significant wave period (time domain), the average period of the highest third of waves in the record
Tz	the average period of all zero up-crossing waves in the record (time domain)
Tp	the wave period corresponding to the peak of the energy density spectrum (frequency domain)
Tc	the average period of all the waves in the record based on successive crests (time domain)
Dir	the direction (frequency domain) from which the peak period waves (Tp) are coming (in º True)
SST	the sea surface temperature (in º Celsius) obtained by a sensor mounted in the bottom of the buoy.

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

5.0 Data losses

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

Analysis of recorded data by the PC-based systems includes some data rejection checks which may result in a small number of spurious and rejected data points being replaced using an interpolation procedure, otherwise the entire series is rejected.

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

In the calculation of wave-climate statistics, each record is assigned a total duration equal to half the recording interval on either side of that record. The durations on the side of those records adjacent to gaps in the data are limited to a maximum value dependent on the nominal-recording interval of those records.

With the nominal-recording interval set at thirty minutes, the maximum allowable total duration of a record is equal to ninety minutes. Any duration on either side of a record greater than 45min (half the maximum allowable total duration) is set to the maximum allowable of exactly 45min and a gap in the data is reported.

6.0 Data presentation

No attempt has been made to interpret the recorded data for design purposes or to apply corrections for refraction, diffraction and shoaling to obtain equivalent deep-water waves. Before any use is made of this data, the exact location of the buoy, and the water depth in which the buoy was moored, should be noted. Details are presented in the location history plan (figures 1.1 and 2.1). Data capture rates for each wave site over the seasonal year are presented in table B.

A summary of major meteorological events, where the recorded Hsig value reached the storm threshold wave height of 2 metres for Tweed Heads and 4 metres for Brisbane, for the period from 1 May 2008 to 30 April 2009 is shown in table C. Wave parameters Hsig, Hmax, Tp, and other relevant information are listed for each event. Only storm and cyclone events that contributed to the Hsig reaching the storm threshold value are listed in the table.

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

The wave-climate data presented in this report is based on statistical analyses of the parameters obtained from the recorded-wave data. Programs developed by DERM provide statistical information on percentage of time occurrence and exceedance for wave heights and periods. The results of these analyses are presented in figures 1.2–1.4 and 2.2-2.4. In each of these three figures for each site, the term *All data* refers to the entire available dataset collected for Tweed Heads since 13 January 1995 (14.25 years) and Brisbane (32 years) since 31 October 1977. In addition, similar statistical analysis provides monthly averages of wave heights for the seasonal year and all data.

Daily wave recordings, average water temperature and peak direction (Dir_p) recordings are shown for the period from 1 May, 2008 to 30 April, 2009. Directional wave roses for the same period are also presented. These summarise wave occurrence at Tweed Heads and Brisbane by indicating their height, direction and frequency. Each branch of a wave rose represents waves coming from that direction with branches divided into Hsig segments of varying range. The length of each branch represents the total percentage of waves from that direction with the length of each segment within a branch representing the percentage of waves, in that size range, arriving from that direction for all wave periods. Calm wave conditions have been defined as below 0.5m and are represented as a percentage inside the centre circle. Note that a 0.2 percent cut-off has been applied to the data as the wave rose is only intended as a visual guide to the wave climate at the site.

This report covers the period from 1 May 2008 to 30 April 2009 to align with the Tweed River Entrance Sand Bypassing Project environmental monitoring periods. For the purposes of analysis, summer has been taken as the period from 1 November to 30 April of the following year and winter covers the period 1 May to 31 October in any one year.

7.0 References

Permanent International Association of Navigation Congresses (1986), *List of Sea State Parameters*

Datawell, *Operations and Service Manual for Directional Waverider* (2000)

Datawell, *Datawell Waverider Reference Manual WR-SG; DWR-MkIII, DWR-G* (2005)

Queensland Transport, *The Official Tide Tables & Boating Safety Guide 2009*

Australian Hydrographic Service, *Australian National Tide Tables 2009*

Bureau of Meteorology, Monthly Weather Reviews

8.0 Other published wave data reports in this series

Cairns Region	Report No. W01.3	2 May 1975 to 30 Apr 1997
Mackay Region	Report No. W03.3	17 Sept 1975 to 30 Oct 1996
Townsville Region	Report No. W04.3	19 Nov 1975 to 30 Apr 1997
Sunshine Coast Region	Report No.W04.1	5 Apr 1974 to 5 Jul 1977
Burnett Heads Region	Report No. W05.2	5 May 1976 to 13 Oct 1988
Abbot Point Region	Report No. W06.2	6 May 1977 to 31 Oct 1996
Weipa Region	Report No. W07.2	21 Dec 1978 to 30 Apr 1997
Gladstone Region	Report No. W08.1	19 Dec 1979 to 16 May 1983
Brisbane Region	Report No. W09.3	30 Oct 1976 to 28 Feb 1997
Bowen Region	Report No. W10.1	14 Sept 1978 to 15 Nov 1984
Moreton Island Region	Report No.W11.1	15 Jun 1983 to 12 Apr 1985
Bramston Beach Region	Report No.W12.1	16 Dec 1981 to 28 Oct 1985
Hay Point Region	Report No. W13.2	22 Mar 1977 to 31 Oct 1996
Gold Coast Region	Report No. W14.2	20 Feb 1987 to 28 Feb 1997
Kirra	Report No. W15.2	25 Aug 1988 to 28 Feb 1997
Repulse Bay	Report No. W16.1	2 Jun 1994 to 22 Oct 1995
Hayman Island	Report No. W17.1	26 Oct 1995 to 14 Oct 1996
Tweed Region	Report No. W18.1	15 Jan 1995 to 28 Feb 1997
Lucinda	Report No. W19.1	2 Mar 1995 to 13 May 1996
Annual summary for season 2000–01	Report No. 2004.3	1 Nov 2000 – 31 Oct 2001
Annual summary for season 2001–02	Report No. 2004.4	1 Nov 2001 – 31 Oct 2002
Annual summary for season 2002–03	Report No. 2004.1	1 Nov 2002 – 31 Oct 2003
Annual summary for season 2003–04	Report No. 2004.6	1 Nov 2003 – 31 Oct 2004
Annual summary for season 2004–05 DRAFT	Report No. 2006.1	1 Nov 2004 – 31 Oct 2005
Annual summary for season 2005–06 DRAFT	Report No. 2006.2	1 Nov 2005 – 31 Oct 2006
Annual summary for season 2006–07 DRAFT	Report No. 2007.2	1 Nov 2006 – 31 Oct 2007
Dunk Island	Report No. 2004.2	13 Jan 1995 – 30 May 2004
Weipa	Report No. 2004.5	23 Dec 1978 – 31 Jan 2004

Table B

Wave recording program—summary of data capture (%) for season 2008–09

Station	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average
Tweed Heads	99.8	100.0	96.6	100.0	100.0	100.0	99.7	99.7	100.0	100.0	100.0	98.4	99.52
Brisbane	99.3	99.6	99.1	100.0	100.0	99.8	97.6	90.3	83.1	88.3	99.1	100.0	96.35

Table C - Significant meteorological events

Tweed Heads – Storm threshold value: 2.0 metres				
Date	**Hs**	**Hmax**	**Tp**	**Event**
02/06/2008 19:30	3.8 (4.1)	5.9 (7.2)	9.4	Trough located on southern Queensland coast, and ridge of high pressure extending along east coast from high east of Tasmania.
15/06/2008 21:00	2.3 (2.6)	3.7 (4.8)	13.9	Low located over northern Tasman Sea, and large high located over Victoria.
05/07/2008 14:00	2.1	3.5	7.9	Firm ridge of high pressure along east coast of Queensland, and slow north-moving surface trough off south coast.
25/07/2008 16:30	2.9 (3.4)	4.6 (5.5)	11.3	Deep low over Coral Sea, rapidly moving south-eastwards.
23/08/2008 20:30	2.3 (2.6)	3.7 (4.6)	12.8	Large high over South Australia extending firm ridge across western and central Qld.
05/09/2008 04:00	3.4 (3.8)	5.5 (6.4)	9.5	Strong high pressure system located over Tasman Sea, and low pressure system near central NSW coast.
11/11/2008 09:30	2.6	4.2 (5.4)	10.0	A 1026hPa north-moving high combined with 1008hPa low east of Fraser Island directing strong S/SE winds along Queensland east coast.
17/11/2008 12:00	2.1	3.5 (4.2)	8.4	A north-moving trough near Fraser Island with a ridge behind the trough.
03/01/2009 20:00	2.3	3.8 (4.6)	9.1	Low located about 260nm east northeast of Gladstone. Large high over Tasman Sea extending firm ridge along southern and central Qld coasts.
09/01/2009 20:00	2.1	3.5 (4.1)	10.6	Ridge of high pressure along New South Wales coast directing strong SE trade winds along SE coast.
14/01/2009 07:00	2.0	3.5	8.4	Monsoon trough near Cairns and firm ridge along southeast and east Queensland coasts providing tight pressure gradient.
31/01/2009 15:30	2.0	3.4	8.8	Vigorous monsoon trough extending across Coral Sea with slow southwards moving 996hPa tropical low located approximately 260km northeast of Cairns.
14/02/2009 17:30	3.1	5.3 (6.1)	9.7	Low located near Cape Moreton moving steadily south south-east.
11/03/2009 10:00	3.4 (3.7)	5.7 (7.4)	10.4	Tropical Cyclone Hamish, Category 2, located 185 kilometres east-northeast of Sandy Cape moving northwest.
23/03/2009 17:30	2.1	3.5 (4.1)	9.9	High over Tasman Sea extended ridge along east Queensland coast. Also, complex low located over north-eastern and eastern Coral Sea.
02/04/2009 03:30	4.2	6.8 (7.6)	10.9	Trough off southern Queensland moving towards coast, and large 1035hPa high over New Zealand.
07/04/2009 03:30	2.1	3.4 (4.2)	11.8	Large 1034hPa high over Great Australian Bight moving slowly east, with strengthening ridge along east Queensland coast.
14/04/2009 08:30	2.2	3.8 (4.2)	7.9	A 1011hPa low off southern Queensland coast moving south south-east, and 1029hPa stationary high near New Zealand.
21/04/2009 19:00	3.1	5.1 (6.3)	12.3	Low northeast of Lord Howe Island and 1029hPa high east of Tasmania.
24/04/2009 06:30	2.1	3.2 (3.9)	12.1	A 1017hPa high over southern Queensland combined with 992hPa low in Tasman Sea.
Brisbane – Storm threshold value: 4.0 metres				
Date	**Hs**	**Hmax**	**Tp**	**Event**
30/05/2008 21:00	4.0	6.6	10.0	Low pressure system developing over Coral Sea northeast of Gladstone
02/06/2008 23:30	4.1 (4.6)	7.1 (8.7)	9.9	Trough located on southern Queensland coast. Ridge of high pressure extending along east coast from high east of Tasmania.
23/07/2008 05:30	4.7 (5.0)	7.8 (9.7)	16.0	Strengthening ridge along tropical Queensland coast and large high across southeast Australia. Low developing along trough over northwest Coral Sea.
23/08/2008 23:00	5.9 (6.4)	9.2 (11.5)	13.5	Large high over South Australia extending firm ridge across western and central Qld.
24/09/2008 19:00	4.1	6.9 (7.7)	10.3	Weakening trough near Capricornia coast, and strengthening ridge of high pressure extending along east Queensland coast.
11/03/2009 03:30	4.1 (4.7)	6.7 (8.8)	10.0	Severe Tropical Cyclone Hamish, Category 3, located 275 kilometres east of Sandy Cape.
30/03/2009 17:00	4.3 (4.7)	6.9 (7.6)	11.2	Large high over Tasman Sea extending firm ridge along east coast of Queensland, with surface trough off southern coast.
02/04/2009 07:30	4.9 (5.1)	7.8 (9.3)	11.0	Trough off southern Queensland moving towards coast, and large 1035hPa high over New Zealand.
22/04/2009 01:30	4.5 (4.8)	7.2 (8.4)	12.4	A 997hPa low northeast of Lord Howe Island and 1029hPa high entering southern Tasman Sea.

Denotes peak event

Notes:

Barometric pressure measured in hectopascals (hPa). The Hsig values and the Hmax values are the maximum values recorded for each event and are not necessarily coincident in time. The Tp values and the Hsig values are coincident as a single event on the date shown. Due to possible statistical errors arising from finite length records used in calculating wave climate, the above storm peak Hsig and Hmax values are derived from the time series smoothed by a simple three hourly moving average following the recommendation of Forristall G.Z., Heideman J.C., Leggett I.M., Roskam B. and Vanderschuren L. (1996), "Effect of Sampling Variability on Hindcast and Measured Wave Heights", J. Waterway, Port, Costal and Ocean Engineering, Vol 122, No. 5, September/October 1996. Thus the un-smoothed data shown in brackets may be of a slightly larger value.

Tweed

Wave recording station

Details of wave recorder station

Maximum Possible Analysis Days (Last record–First record)	=	364.625
Total Days Used in Analysis	=	363.694
Gaps in Data from Selected Dates (Days)	=	1.306
Gaps in Data from Analysed Records (Days)	=	0.931
Number of Records Used in Analysis	=	17420

HAT at nearest standard port: Tweed River breakwater, 1.89m

Table of highest ranked un-smoothed waves at Tweed Heads

Rank	Date (Hs)	Hs	Date (Hmax)	Hmax	
1	03/05/1996 01:00	7.52	03/05/1996 01:00	13.07	
2	06/03/2004 01:00	6.07	06/03/2004 01:00	11.09	
3	21/05/2009 19:30	5.63	30/06/2005 09:00	10.01	
4	04/03/2006 20:30	5.35	**21/05/2009 19:30**	**9.72**	*
5	24/05/1999 05:00	5.23	04/03/2006 20:30	9.70	
6	15/02/1995 11:30	5.19	25/03/1998 21:00	9.51	
7	30/06/2005 09:00	4.90	15/02/1995 11:30	9.34	
8	24/03/2004 06:00	4.81	02/02/2001 15:30	9.10	
9	01/05/2000 23:30	4.72	24/05/1999 05:00	9.05	
10	**02/04/2009 03:30**	**4.63**	24/03/2004 06:00	8.47	

* This event occurred after end date of the report

Wave conditions 2008-09 – Tweed Heads

Month	Average Hs (m)	Min Hs (m)	Max Hs (m)	Average of * Peak Period (Tp) Directions (Ø TRUE)	90% of waves within the range of (m)	No. of Days When Hs >= 2m	No. of Days When Hs <= 0.75m	Events where Hs > 3m and date of storm
May-08	1.2	0.4	3.3	114	0.7–2.3	3	10	30th & 31st
Jun-08	1.4	0.5	4.1	105	0.9–2.7	7	3	2nd & 3rd
Jul-08	1.2	0.4	3.4	97	0.5–2.4	5	11	25th
Aug-08	1.0	0.4	2.6	115	0.5–1.7	3	18	
Sep-08	1.3	0.7	3.8	93	0.8–2.4	4	5	4th & 5th
Oct-08	1.1	0.6	2.1	95	0.8–1.7	1	8	
Nov-08	1.2	0.4	2.6	100	0.6–1.9	5	9	
Dec-08	0.9	**0.4**	1.8	88	0.6–1.3	0	22	
Jan-09	1.4	0.5	2.4	90	0.7–2.0	8	3	
Feb-09	1.4	0.7	3.3	95	0.8–2.3	3	3	14th
Mar-09	1.6	0.7	4.1	84	0.8–3.2	13	7	3rd, 4th, 11th, 29th & 30th
Apr-09	1.8	0.5	**4.6**	81	0.8–3.0	18	3	21st–24th
May to April	1.3	0.4	4.6	96	0.7–2.5	70	102	17 days

Mean Values May 1995 – April 2009, Tweed Heads

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May–Apr
Mean Hs (m) 2008-09	1.2	1.4	1.2	1.0	1.3	1.1	1.2	0.9	1.4	1.4	1.6	1.8	1.3
Mean Hs (m) Average from 1995 to 2008-09	1.4	1.2	1.2	1.2	1.1	1.1	1.2	1.1	1.3	1.6	1.5	1.4	1.3
Average of * Peak Period (Tp) Directions (Ø TRUE) 2008-09	114	105	97	114	93	95	100	88	90	95	83	83	96
Average of * Peak Period (Tp) Directions (Ø TRUE) 1995 to 2008-09	101	101	104	102	92	93	96	93	92	97	95	97	97

* No significant precision (whole degrees) due to directional accuracy of the buoy.

Mean Hs = $\sum H_s / N$

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

Where:
Hs = Significant wave height
D = Direction at Peak Period (Tp)
N = number of records

Weighted Mean Values 1995-2009 – Tweed Heads

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May-April
Weighted Mean Hs (m) 2008–09	1.3	1.6	1.3	1.1	1.4	1.1	1.3	0.9	1.4	1.5	1.9	2.0	**1.4**
Weighted Mean Hs (m) 1995–2009	1.7	1.4	1.4	1.3	1.2	1.2	1.3	1.2	1.5	1.6	1.7	1.5	**1.4**
Weighted Mean of * Peak Period (Tp) Directions (Ø TRUE) 2008–09	104	92	93	115	98	99	97	89	90	94	77	85	**94**
Weighted Mean of * Peak Period (Tp) Directions (Ø TRUE) 1995–2009	88	98	99	98	92	92	99	92	92	95	89	94	**94**

* No significant precision (whole degrees) due to directional accuracy of the buoy.

Weighted mean Hs = $(\sum H_s^{2.5} / N)^{0.4}$
Weighted Mean Direction = $\sum(H_s^{2.5} * D) / \sum H_s^{2.5}$

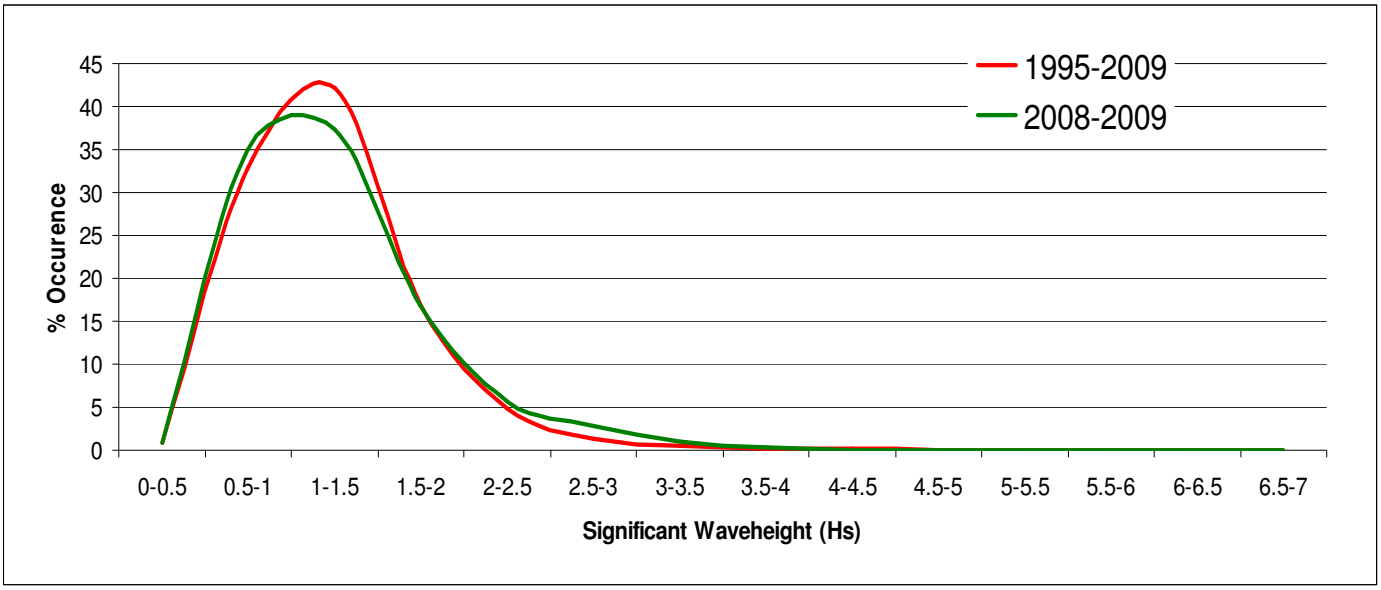
Where:
Hs = Significant wave height
D = Direction at Peak Period (Tp)
N = number of records

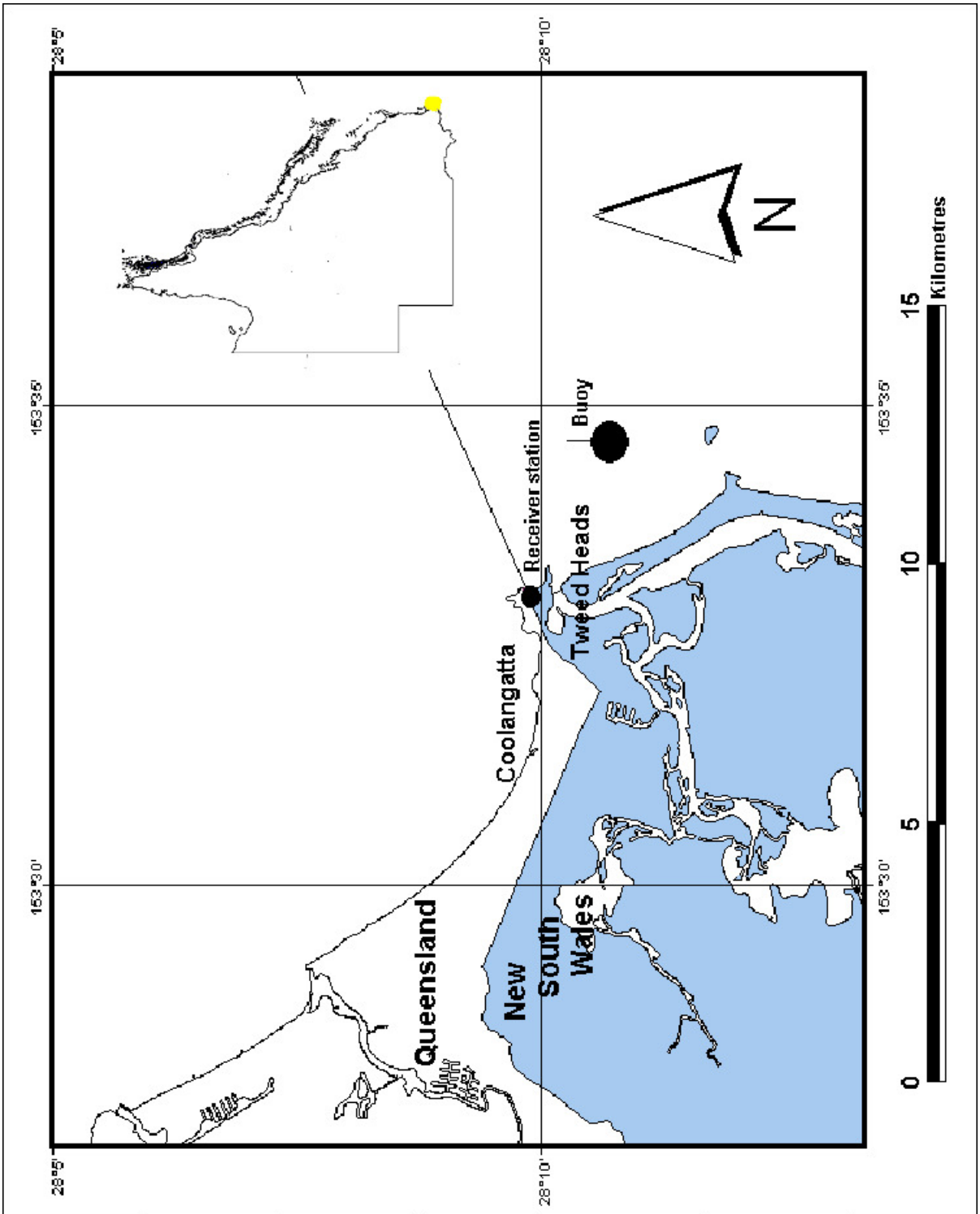
Hs % occurrence May 1995 – April 2009, Tweed Heads

Hs (m)	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	5-5.5	5.5-6	6-6.5	6.5-7
% Occurrence	0.9	32.9	42.2	16.9	4.8	1.4	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0

Hs % occurrence May 2008 – April 2009, Tweed Heads

Hs (m)	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	5-5.5	5.5-6	6-6.5	6.5-7
% Occurrence	0.9	35.1	37.3	16.9	5.6	2.8	1.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0





Latitude	Longitude	Depth (m)	Deployed date	Removal date
28° 10.766	153° 34.592	25	28-Feb-08	07-May-09

Tweed region—Locality plan

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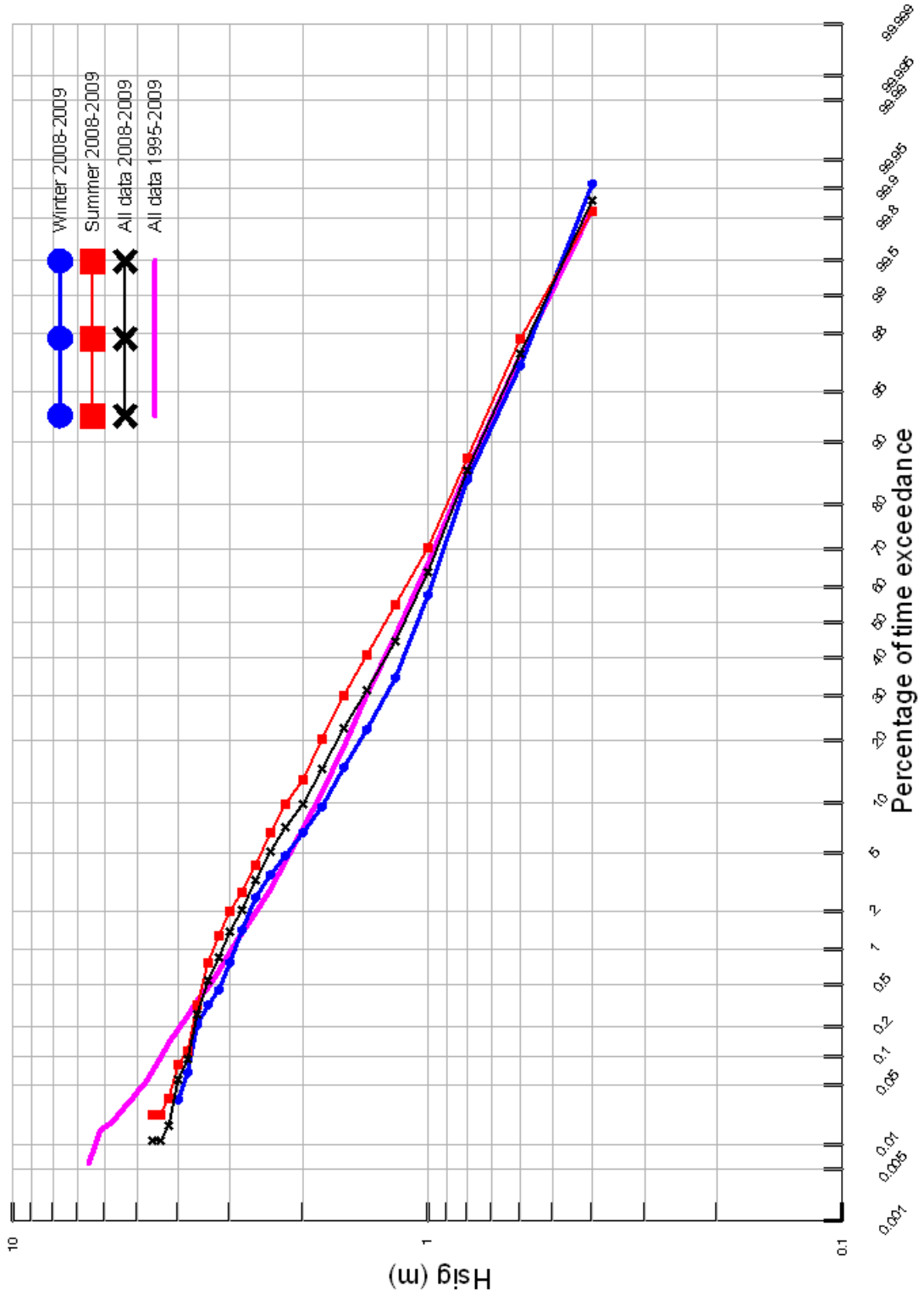
Figure 1.1



Tweed region—Percentage (of time) exceedance of wave heights (Hsig) for all wave periods (Tp)

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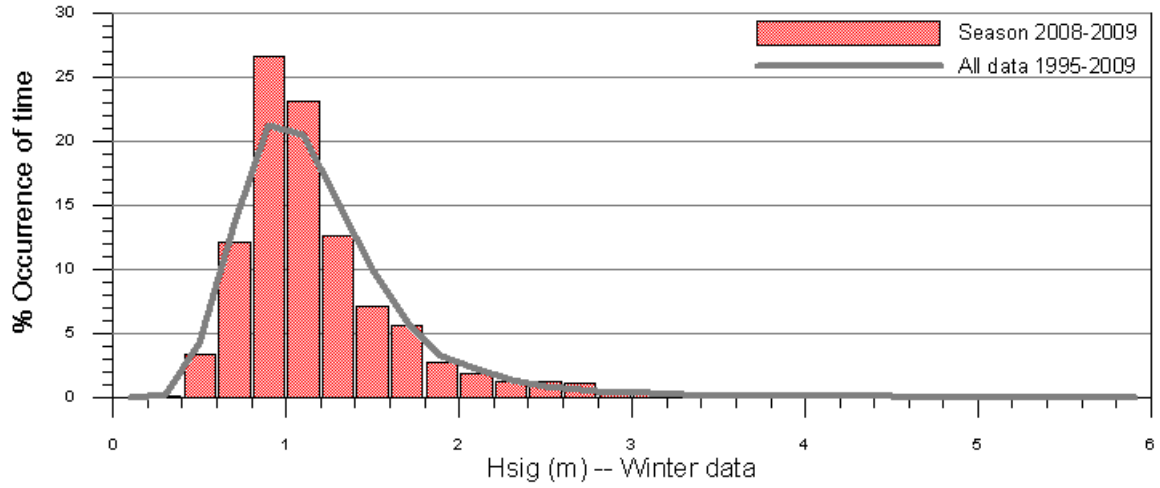
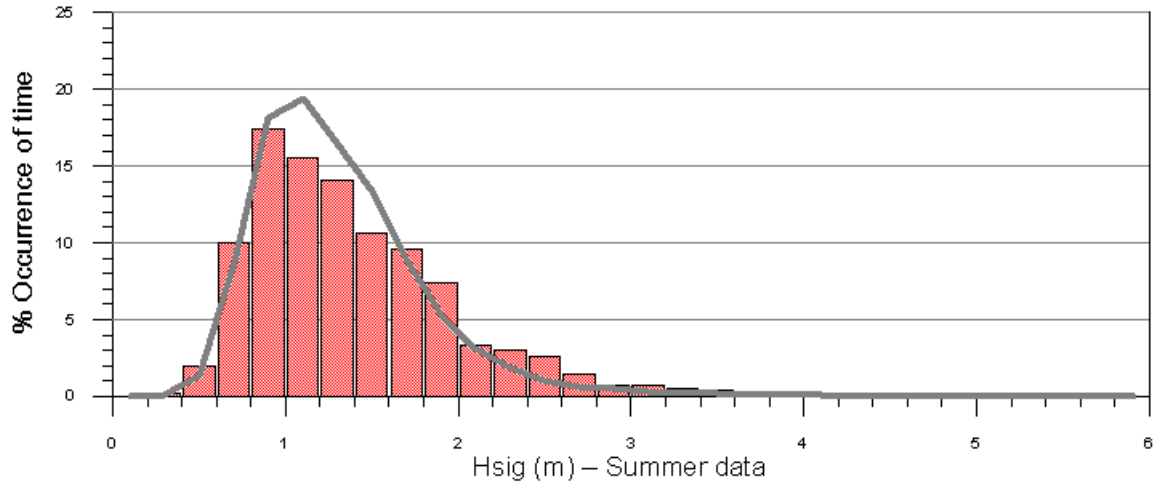
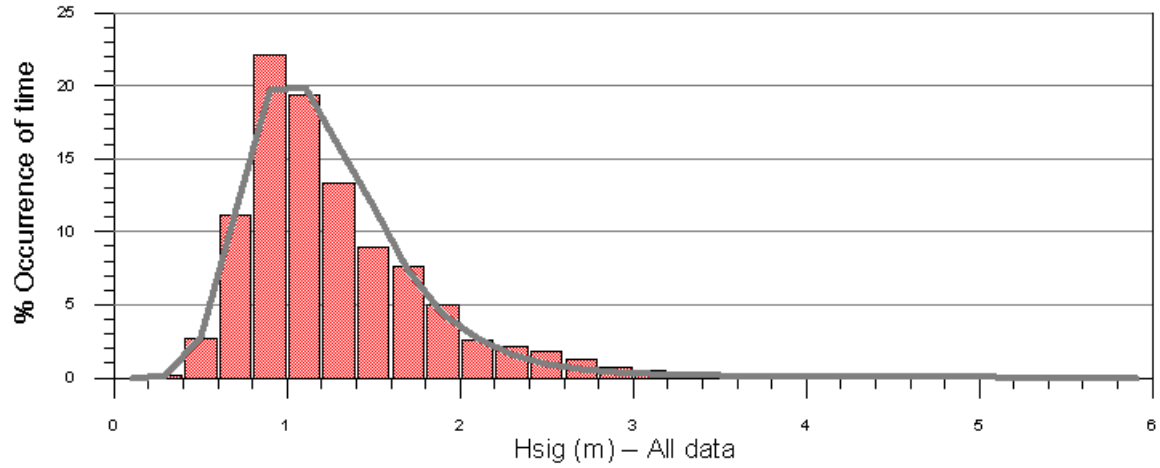
Figure 1.2







Tweed region—Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

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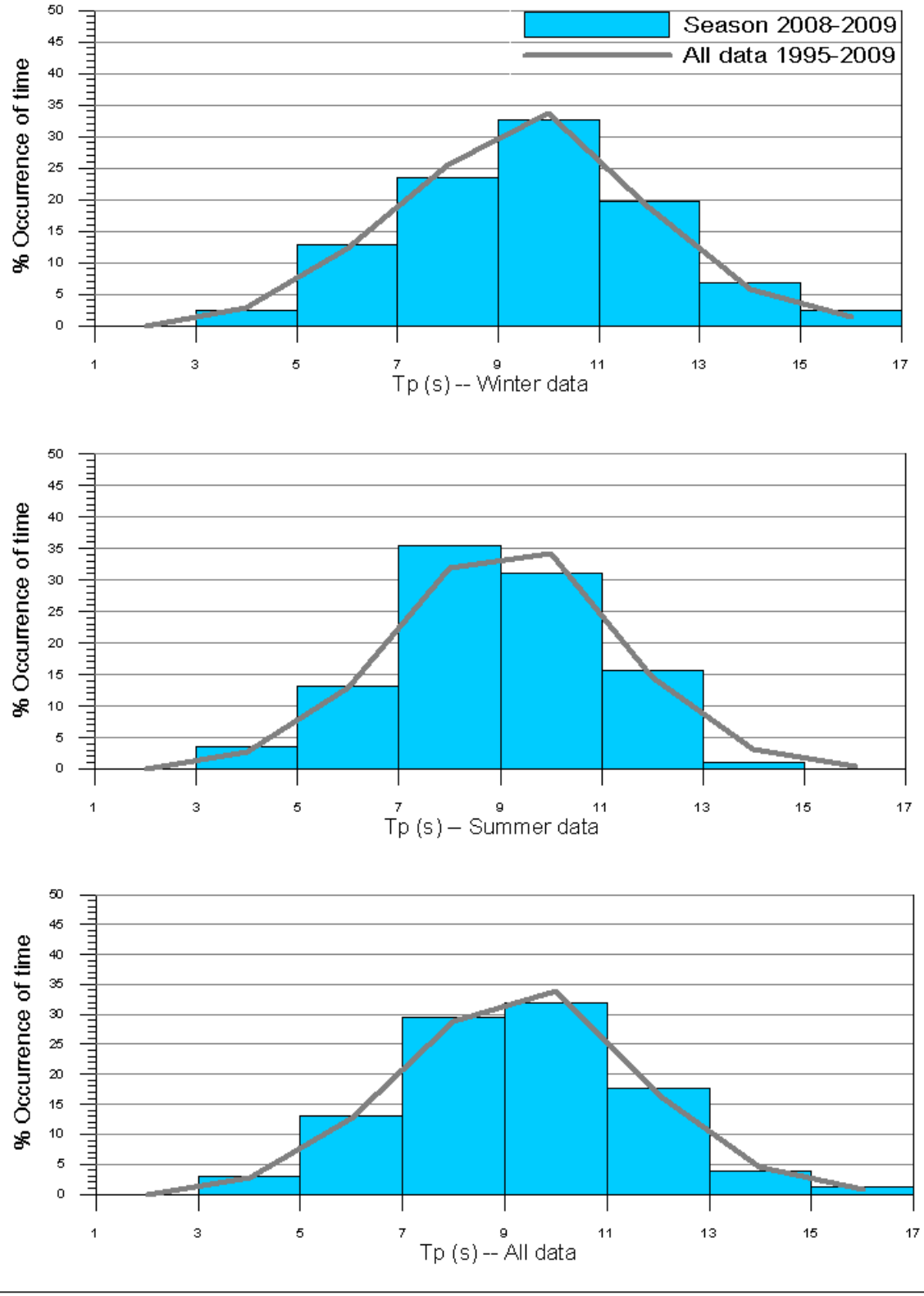
Figure 1.3



Tweed region—Histogram percentage (of time) occurrence of wave periods (Tp) for all wave heights (Hsig)

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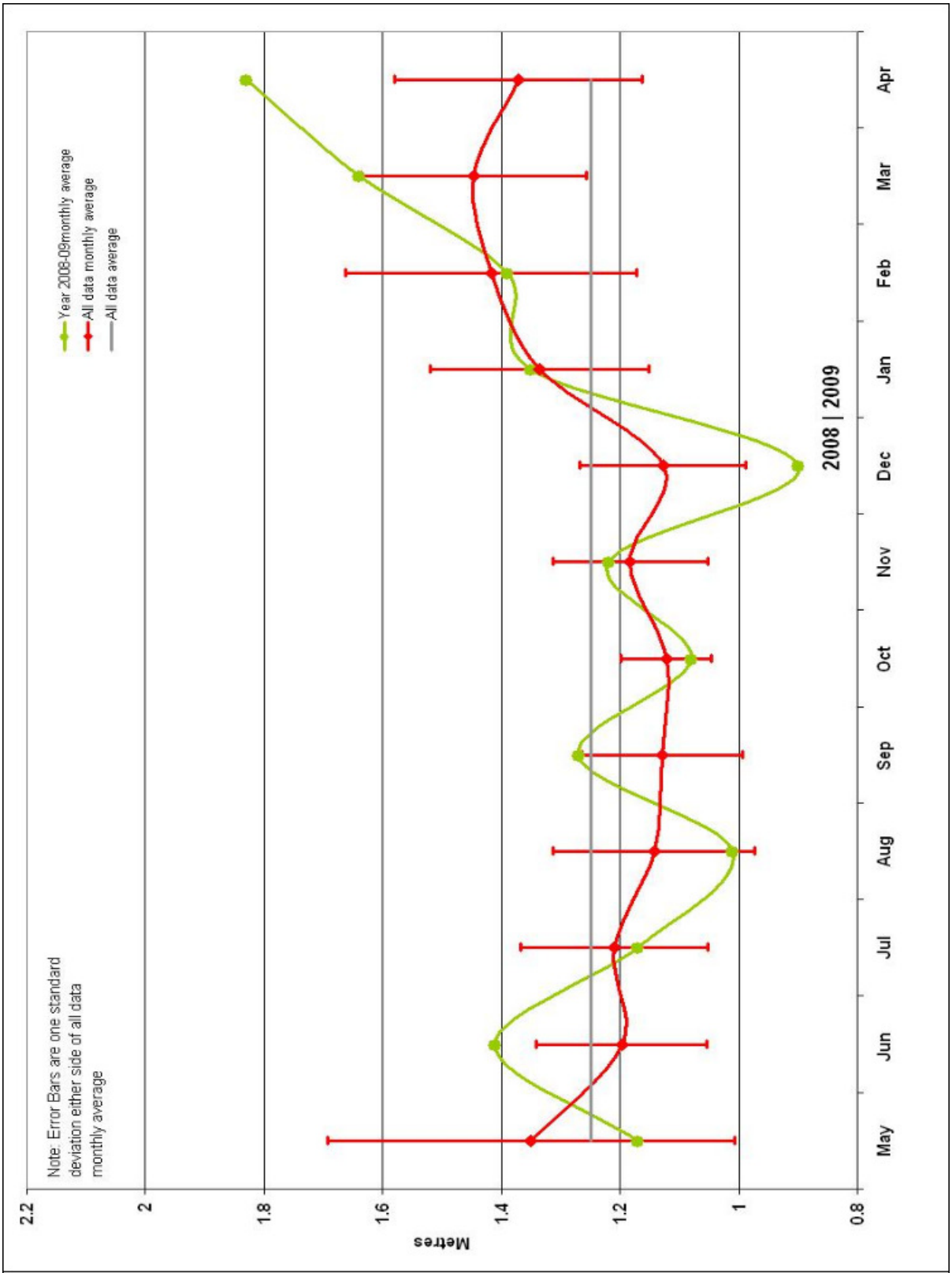
Figure 1.4



Tweed region—Plot of monthly averages for seasonal year and for all data, for wave heights (Hsig)

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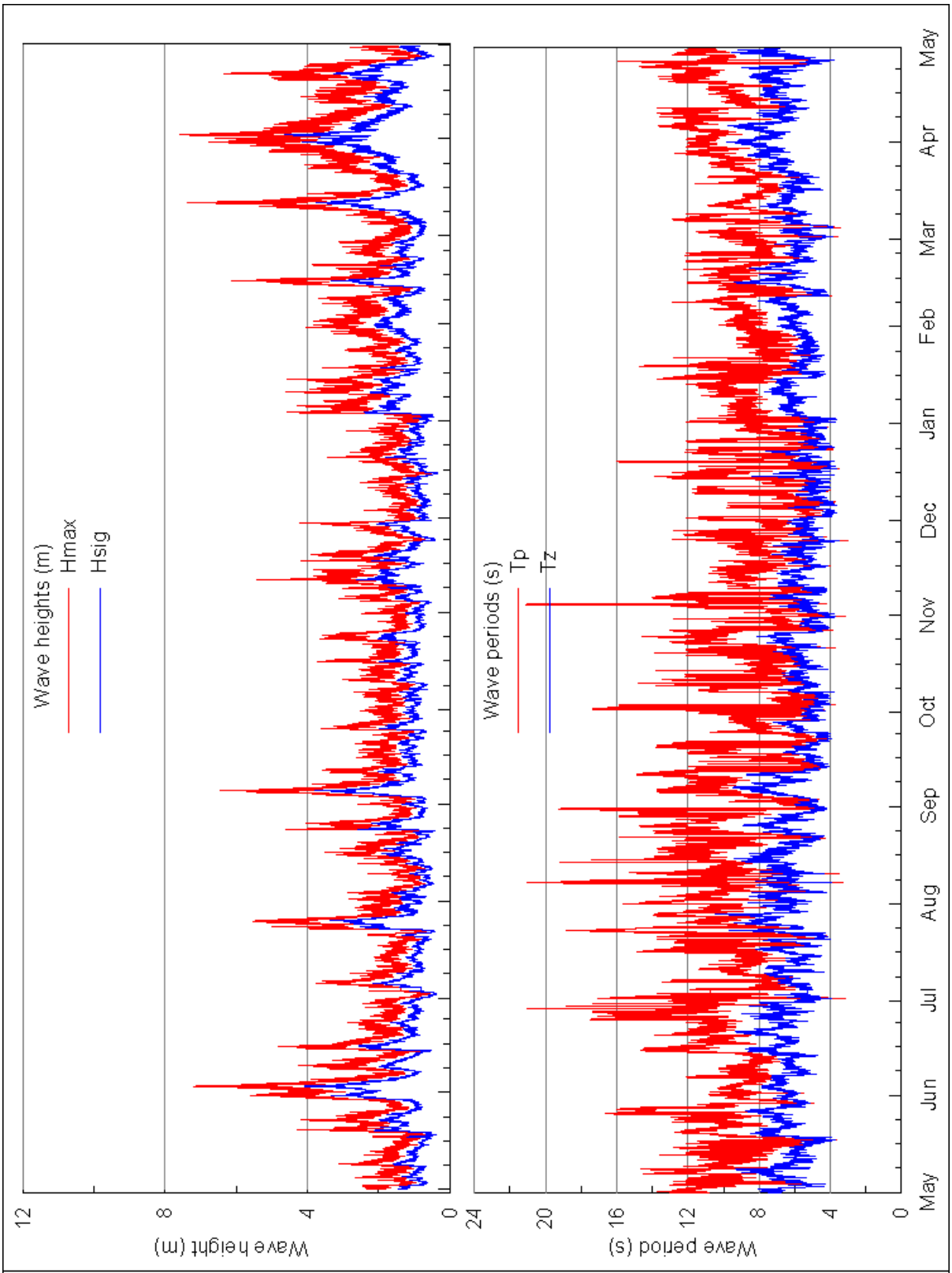
Figure 1.5



Tweed region—Daily wave recordings

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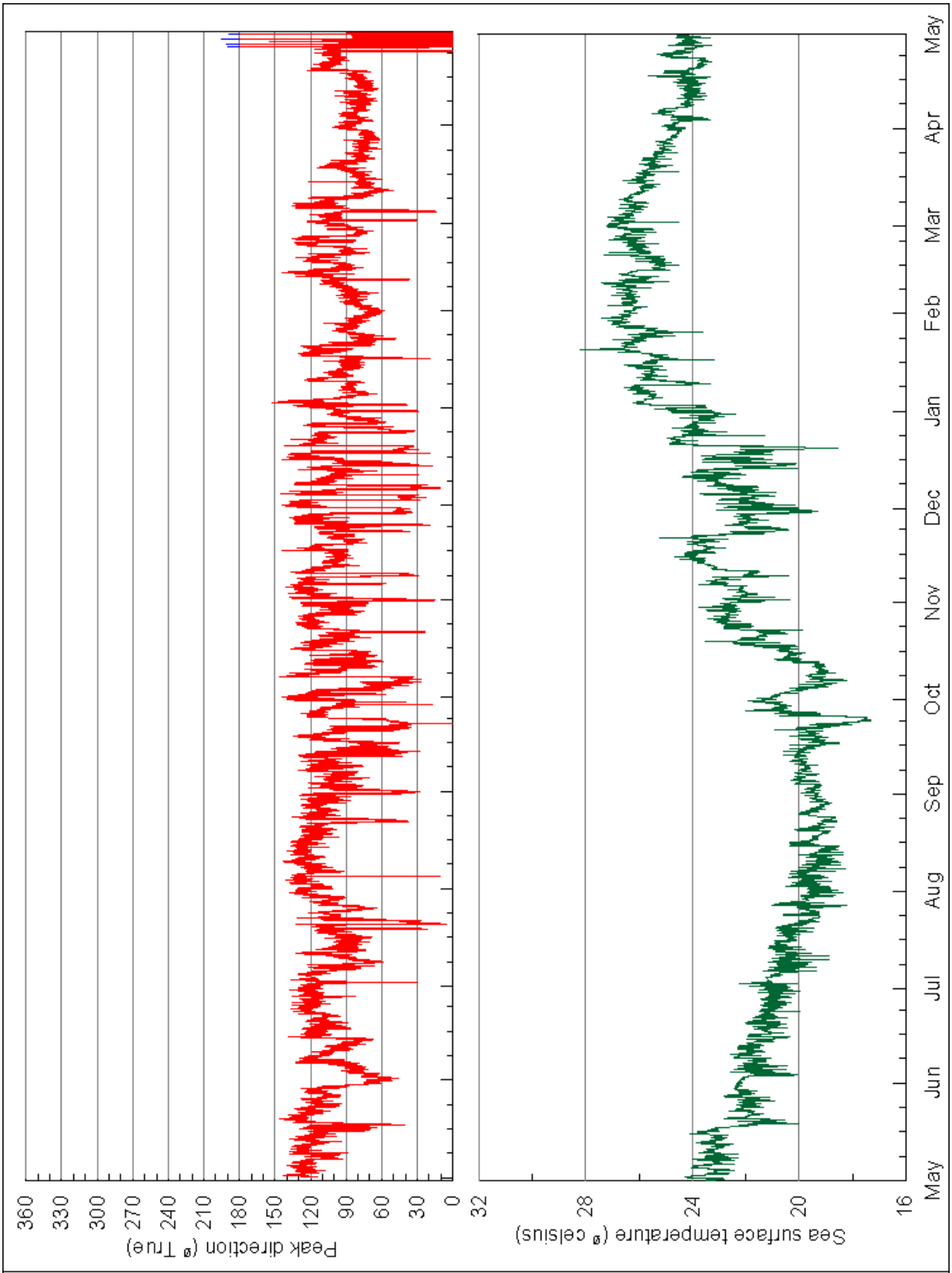
Figure 1.6



Tweed region—Sea surface temperature and peak wave directions

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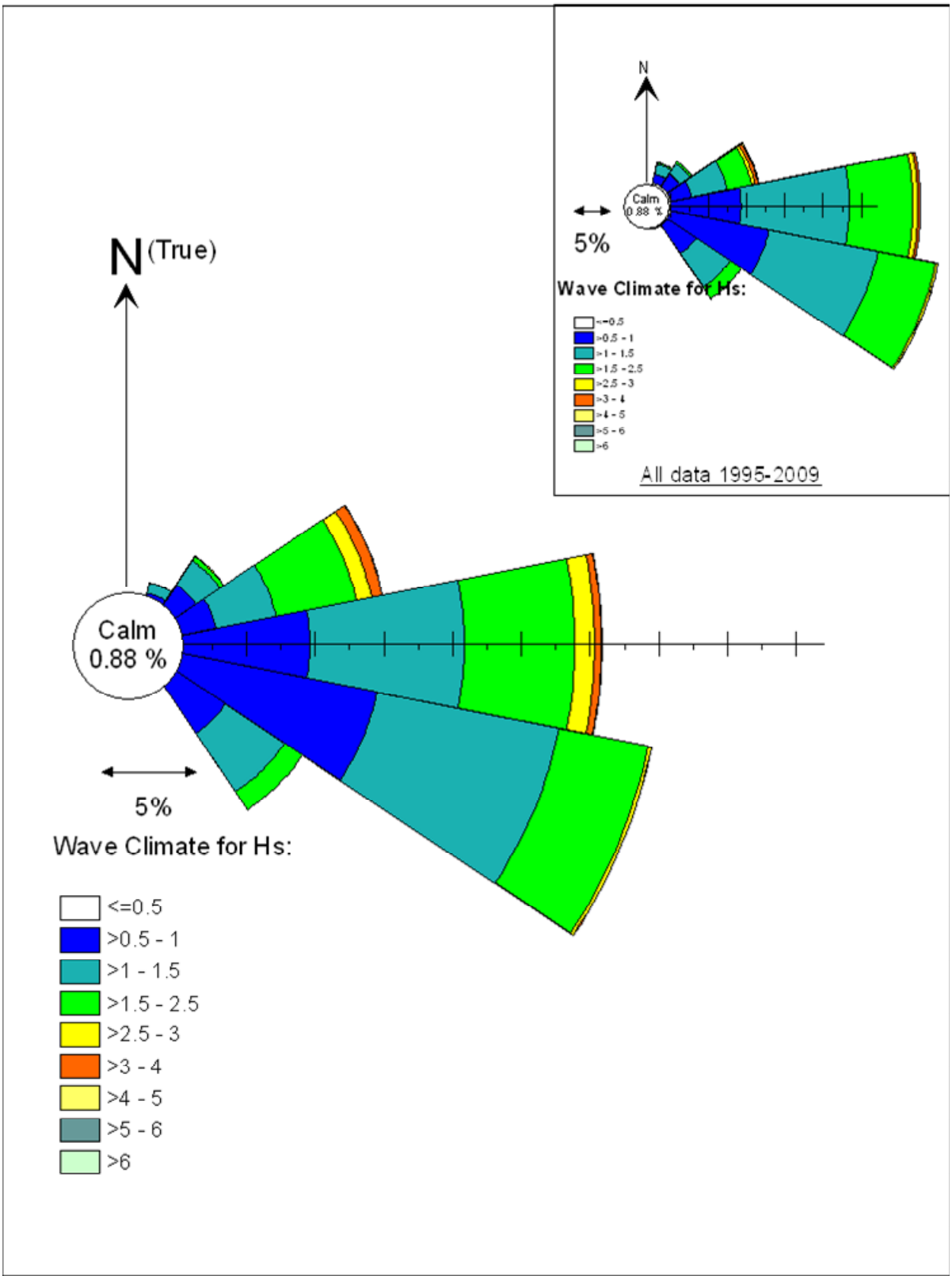
Figure 1.7



Tweed Heads—Directional Wave Rose

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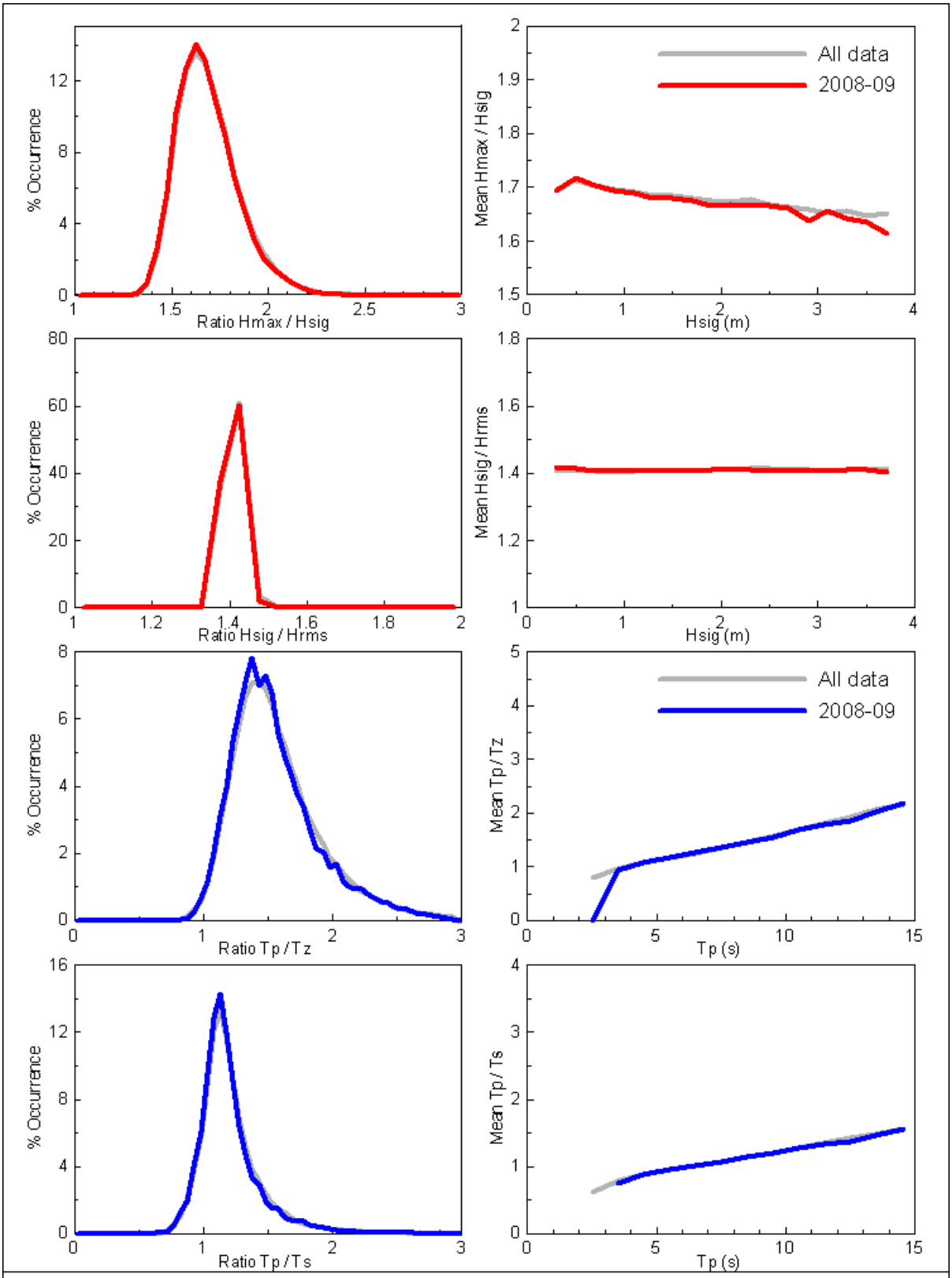
Figure 1.8



Tweed region—wave parameter relationships

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Figure 1.9

Brisbane

Wave recording station

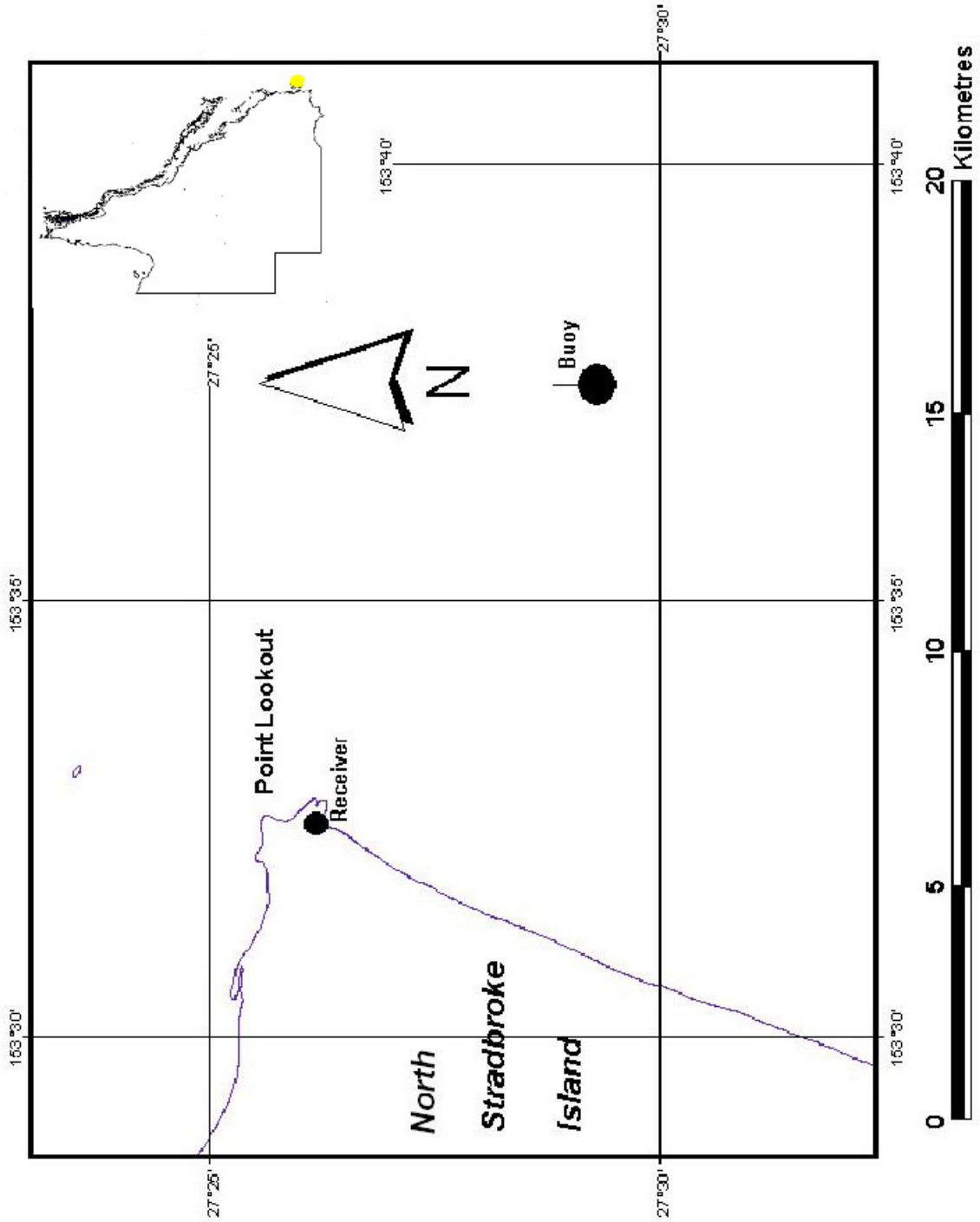
Details of wave recorder station

Maximum Possible Analysis Days (Last record–First record)	=	365.000
Total Days Used in Analysis	=	354.021
Gaps in Data from Selected Dates (Days)	=	10.979
Gaps in Data from Analysed Records (Days)	=	10.979
Number of Records Used in Analysis	=	16858

HAT at nearest standard port: Gold Coast Seaway, 1.89m

Table of highest ranked un-smoothed waves at Brisbane

Rank	Date (Hs)	Hs	Date (Hmax)	Hmax
1	17/03/1993 10:30	7.36	04/03/2006 09:00	16.75
2	04/03/2006 09:00	7.21	05/03/2004 17:30	14.31
3	05/03/2004 17:30	6.98	17/03/1993 10:30	13.09
4	02/05/1996 20:30	6.90	02/05/1996 20:30	12.83
5	15/02/1995 06:00	6.42	15/02/1995 06:00	12.17
6	23/08/2008 23:00	6.40	15/02/1996 19:30	12.09
7	31/12/2007 03:00	6.26	23/08/2008 23:00	11.53
8	15/02/1996 19:30	6.19	26/03/1998 08:00	11.49
9	25/04/1989 20:50	6.11	31/12/2007 03:00	11.06
10	26/03/1998 08:00	6.05	21/08/2007 23:00	10.86



Latitude	Longitude	Depth (m)	Deployed date	Removal date
27° 29.661'	153° 37.655'	70	27-May-08	4-Feb-09
27° 28.130'	153° 37.548'	70	4-Feb-09	Ongoing

Brisbane region—Locality plan

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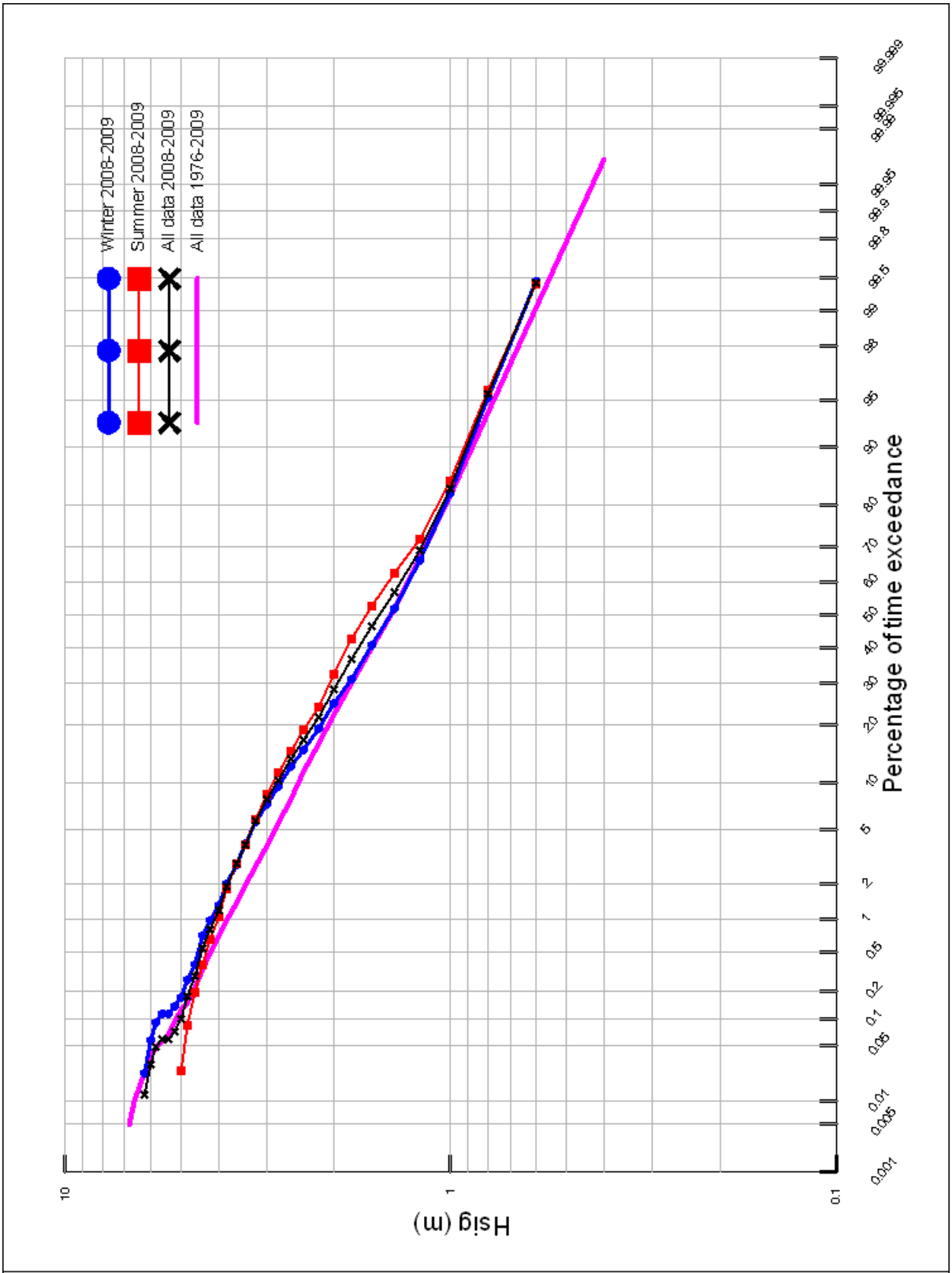
Figure 2.1



Brisbane region—Percentage (of time) exceedance of wave heights (Hsig) for all wave periods (Tp)

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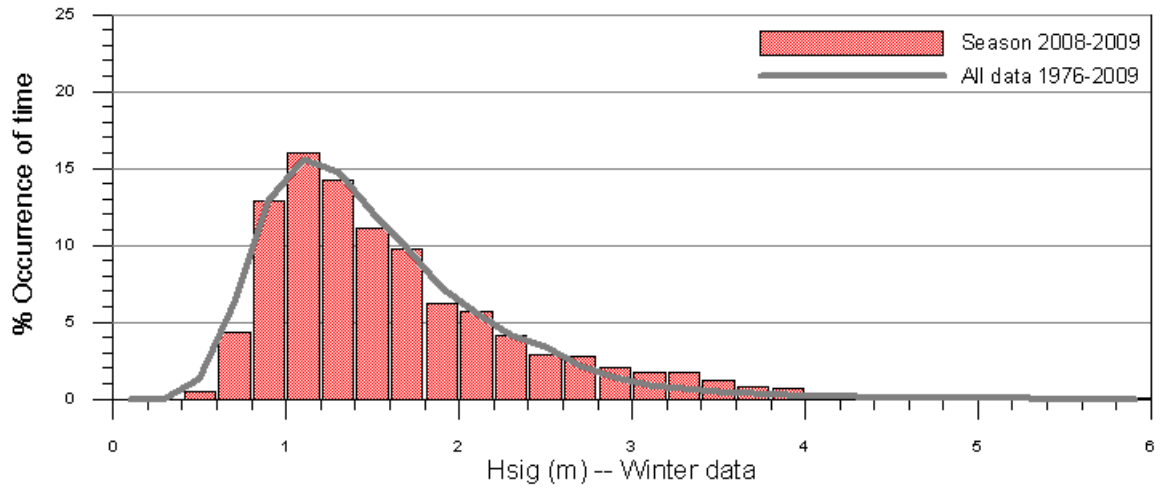
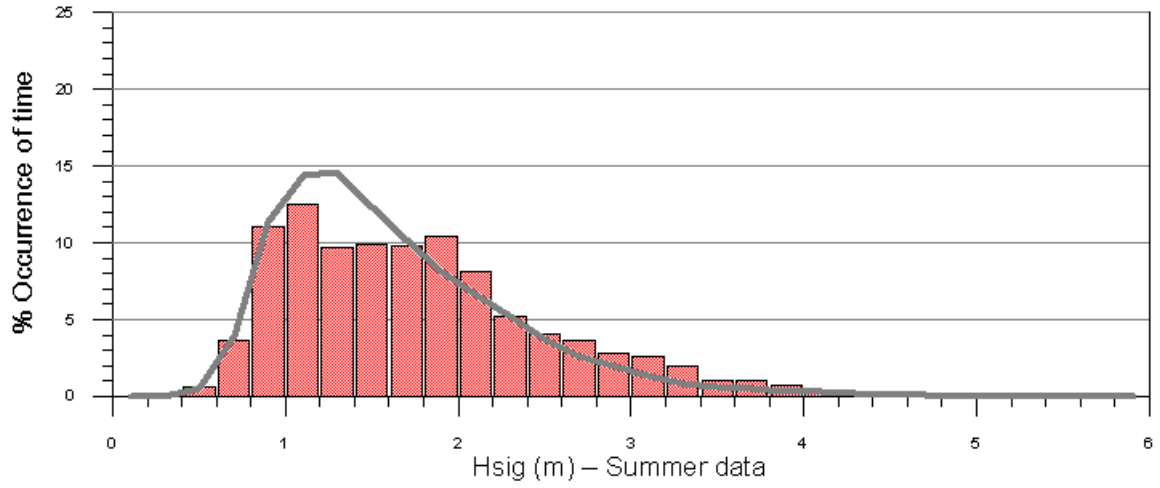
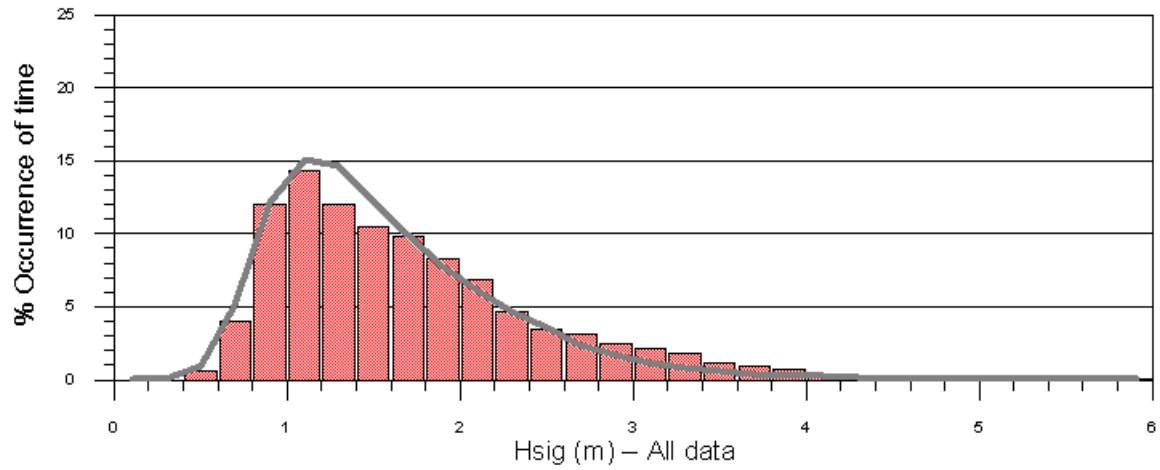
Figure 2.2







Brisbane region—Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

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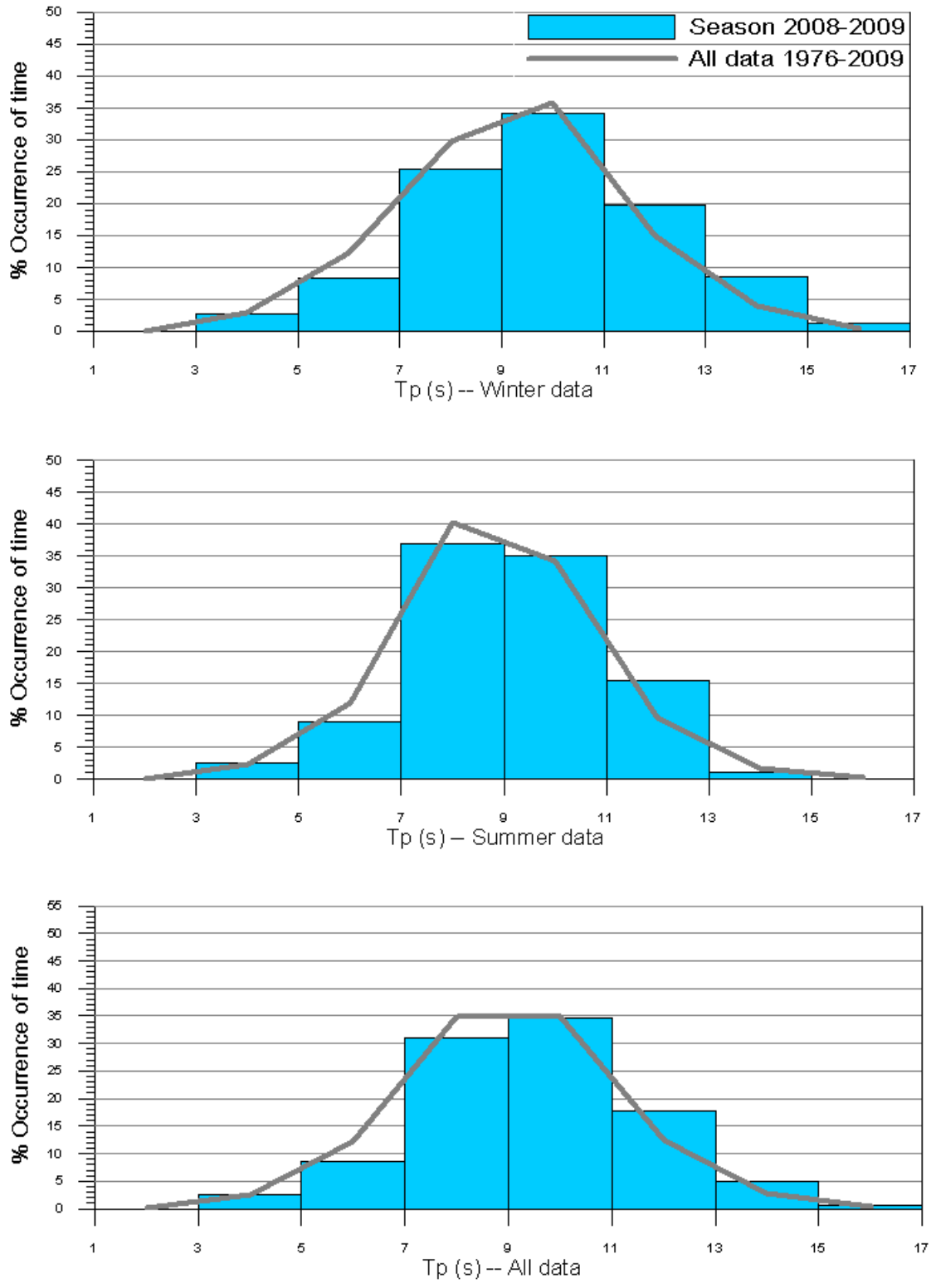
Figure 2.3



Brisbane region—Histogram percentage (of time) occurrence of wave periods (Tp) for all wave heights (Hsig)

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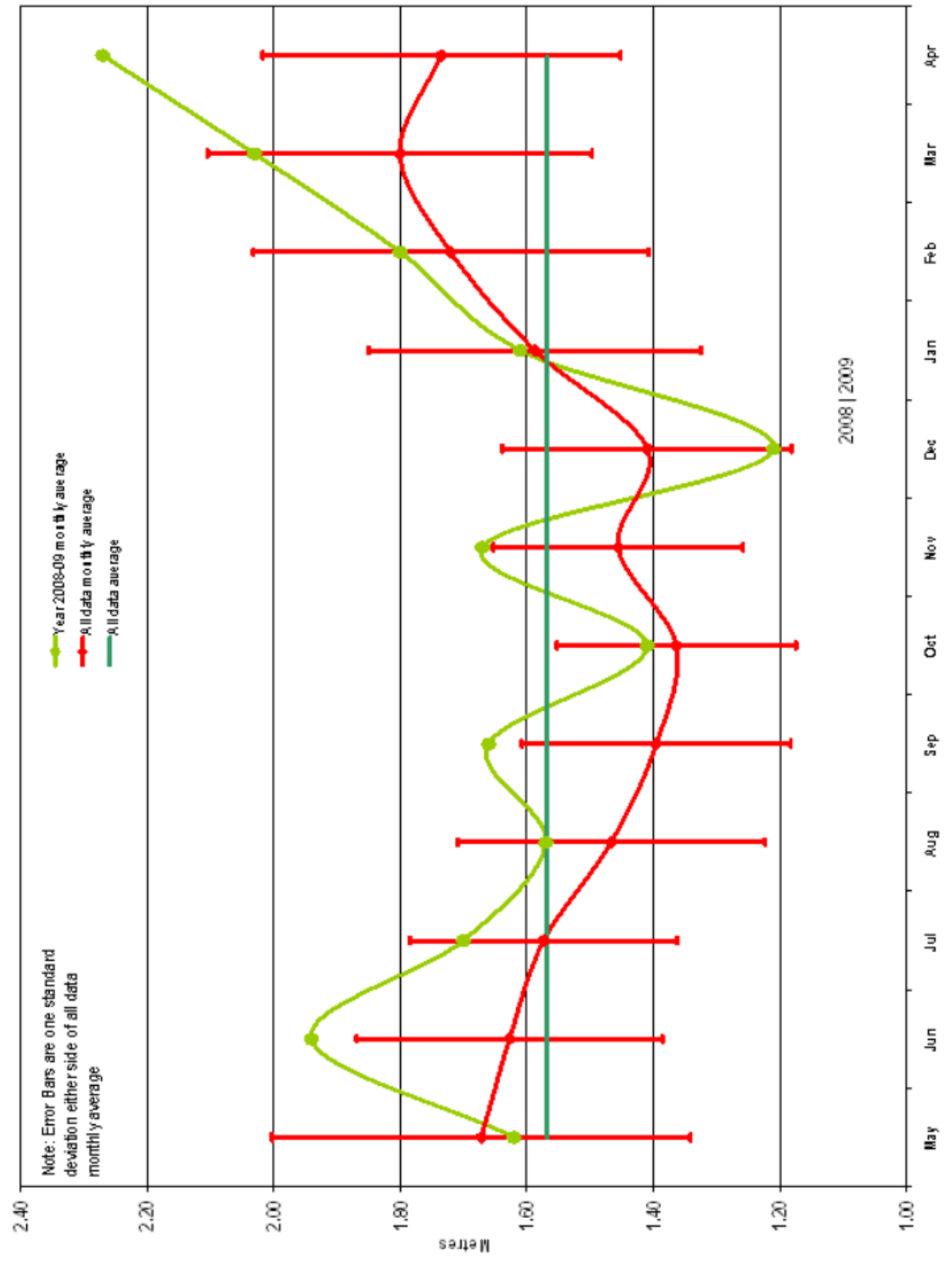
Figure 2.4



Brisbane region—Plot of monthly averages for seasonal year and for all data, for wave heights (Hsig)

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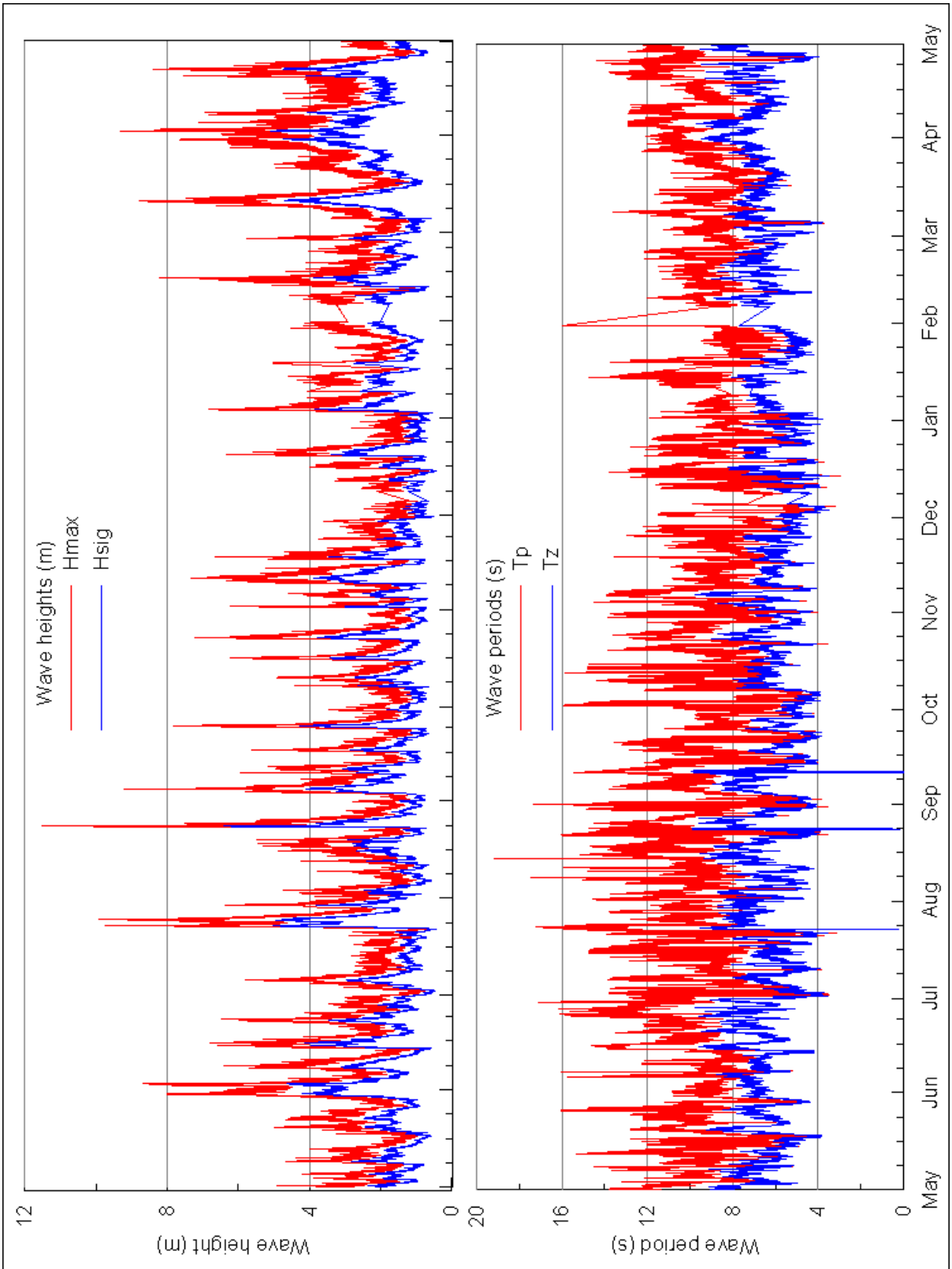
Figure 2.5



Brisbane region—Daily wave recordings

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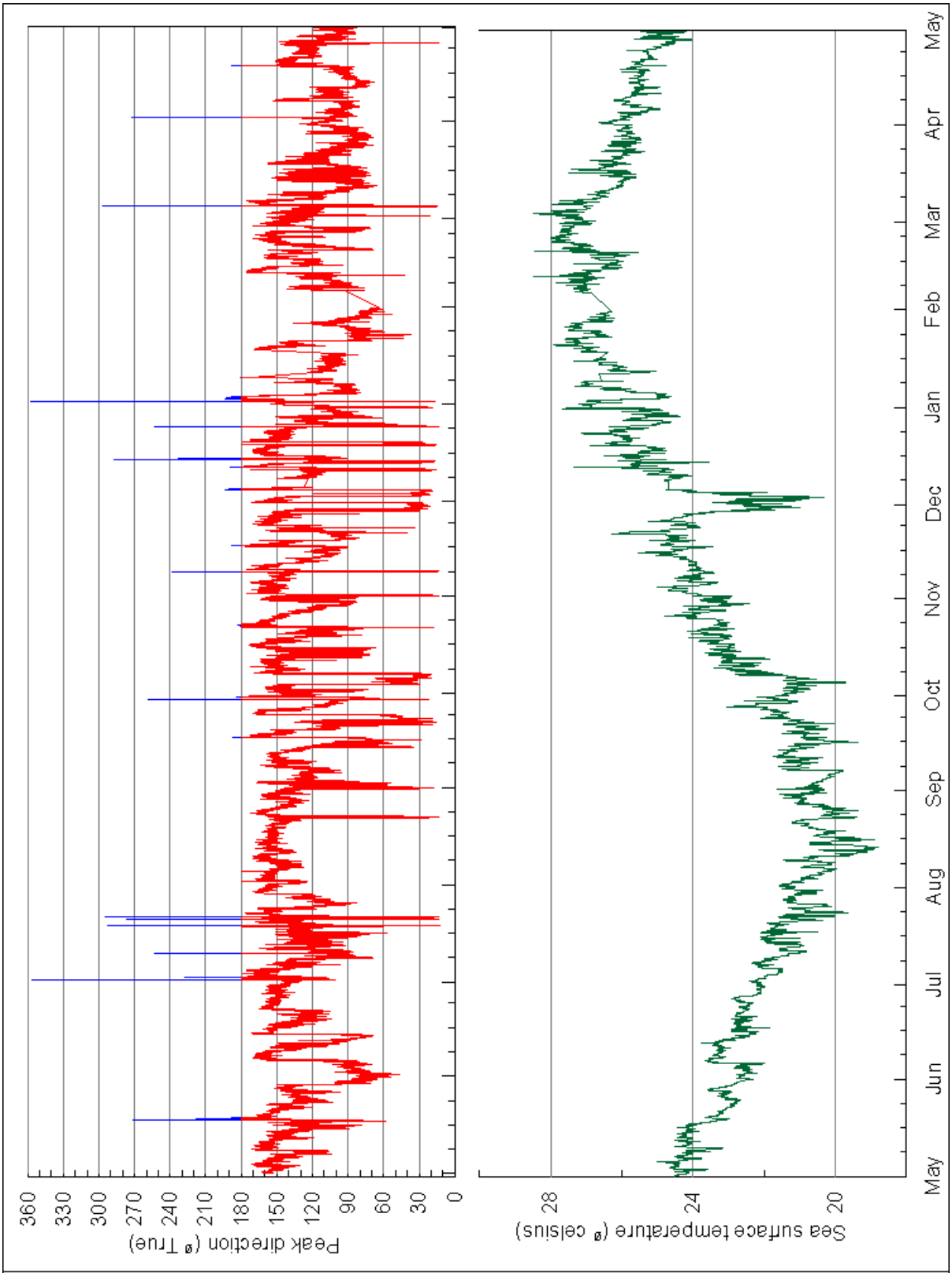
Figure 2.6



Brisbane region—Sea surface temperature and peak wave directions

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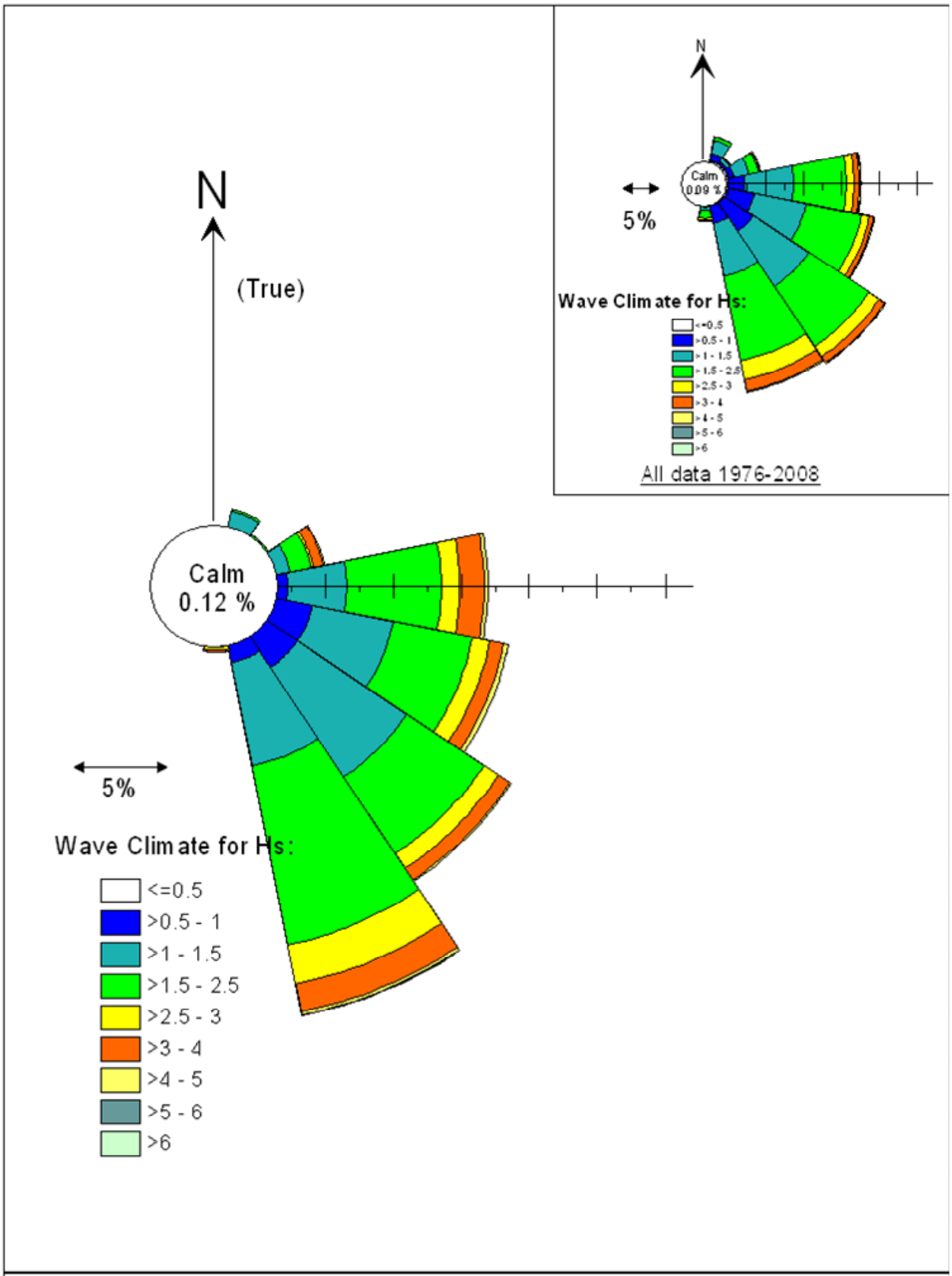
Figure 2.7



Brisbane—Directional Wave Rose

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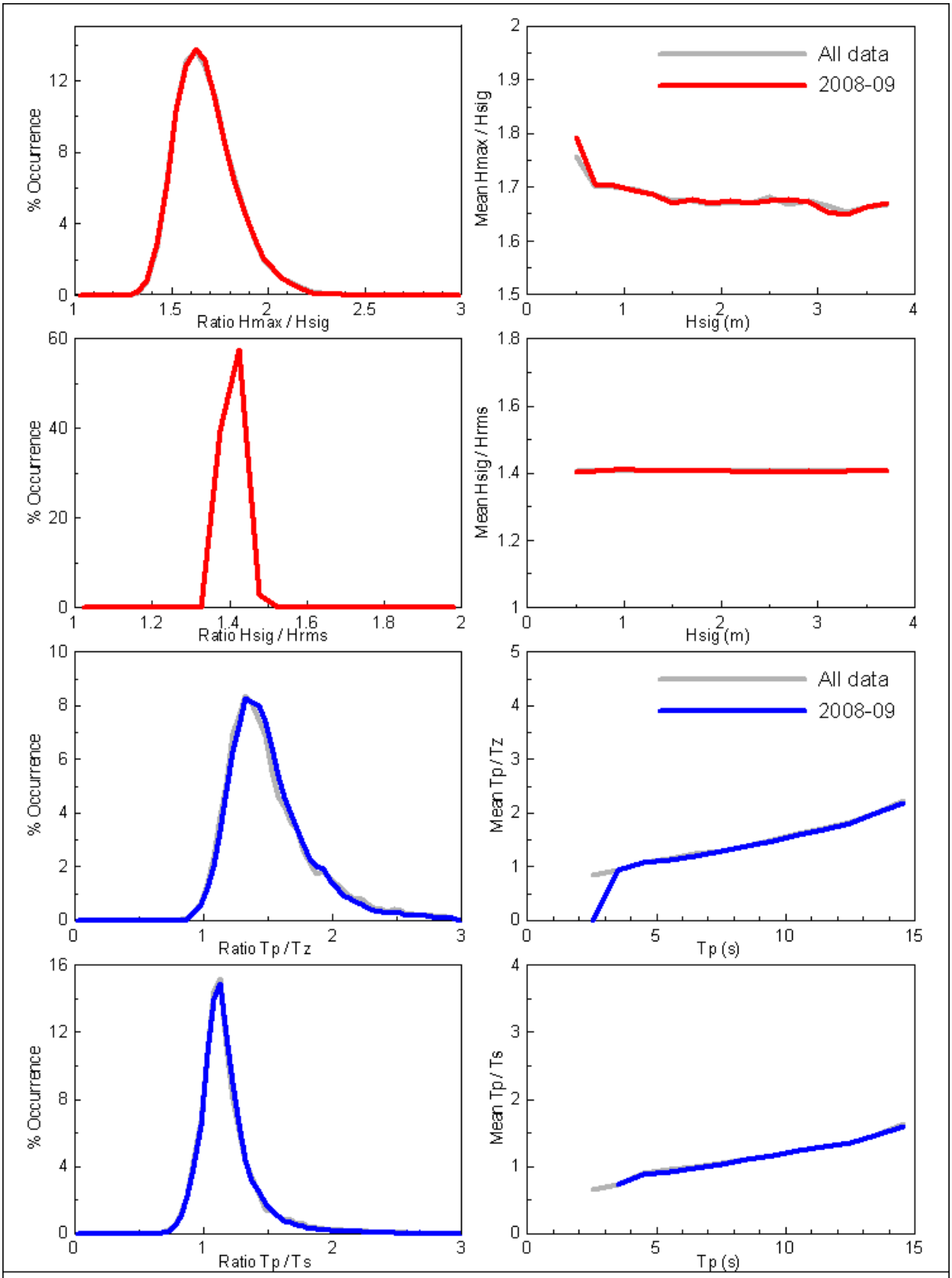
Figure 2.8



Brisbane region—wave parameter relationships

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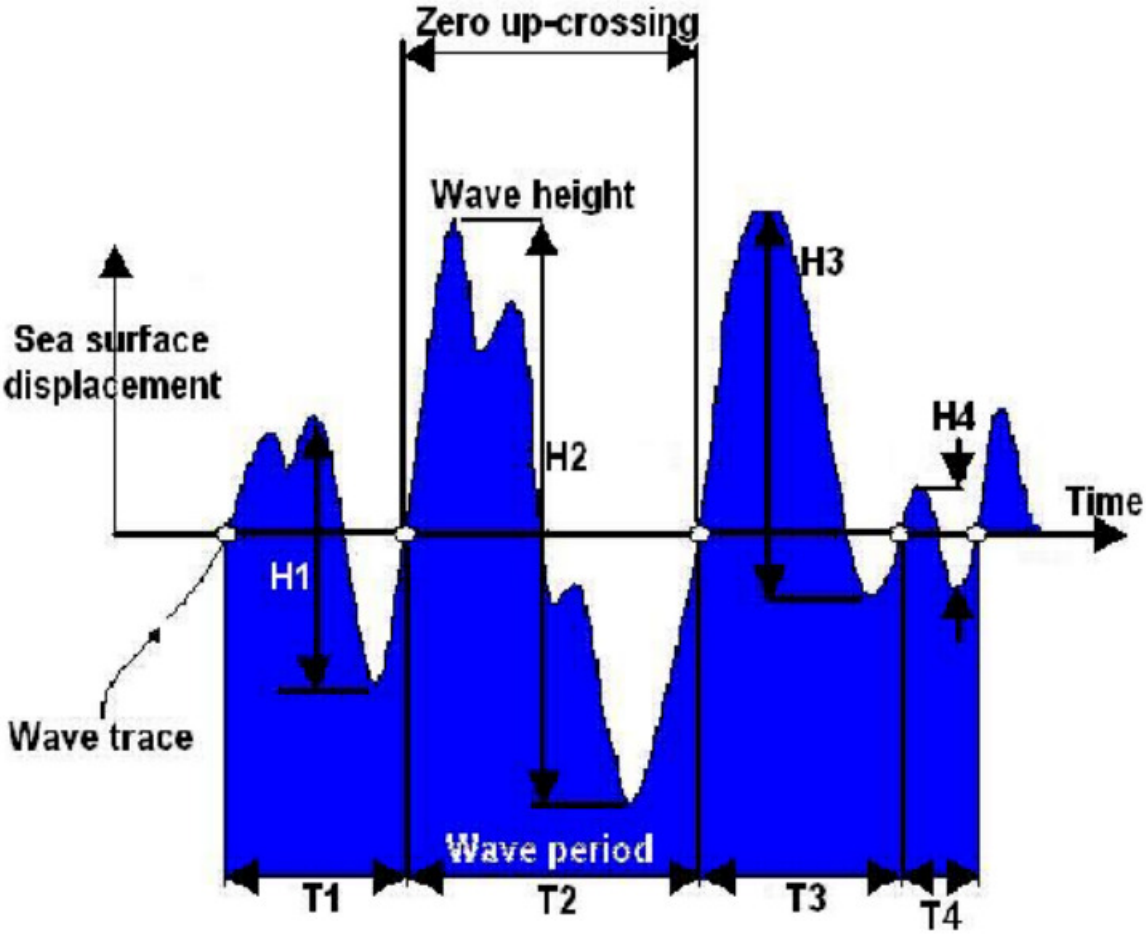
Figure 2.9

Zero crossing analysis

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

An explanation of wave parameters is presented in the Glossary.



Zero up-crossing analysis

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Figure C

Appendix A

Glossary of terms

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.
TH_{sig}	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.
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.
H10	Average of the highest 10 percent of all waves in a record
TH10	The period of the H10 waves
TH_{max}	Period of maximum height, zero up-crossing
Tz_{max}	The maximum zero crossing in a record
H_{m0}	Estimate of the significant wave height from frequency domain $4\sqrt{m_0}$
T_{03}	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)
HAT	HIGHEST ASTRONOMICAL TIDE is the highest water level which can be predicted to occur at a particular site under average weather conditions. This level won't be reached every year.
AHD	AUSTRALIAN HEIGHT DATUM is the reference level used by the Bureau of Meteorology in Storm Tide Warnings. AHD is very close to the average level of the sea over a long period (preferably 18.6 years), or the level of the sea in the absence of tides.
Wave setup	The increase in mean water level above the SWL towards the shoreline caused by wave ction in the surf zone. The amount of rise of the mean water level depends on wave height and beach slope such that setup increases with increasing wave height and increasing beach steepness. It can be very important during storm events as it results in a further increase in water level above the tide and surge levels.
Astronomical tide	Or more simply, the tide, is the periodic rise and fall of water along the coast because of gravitational attraction on the water by the moon and sun. When the moon, sun and earth are in line their combined attraction is strongest and the tide range is greater (spring tides). When the moon and sun are at right angles to each other (in relation to the earth) the effect of the attraction is somewhat reduced and the tide range is smaller (neap tides).
Predicted tide	The tide expected to occur under average meteorological conditions. Tide predictions are typically based on previous actual tide readings gathered over a long period (usually one year or more). The sun, moon and earth are not in the same relative position from year to year. Accordingly, the gravitational forces that generate the tides, and the tides themselves, are not the same each year.