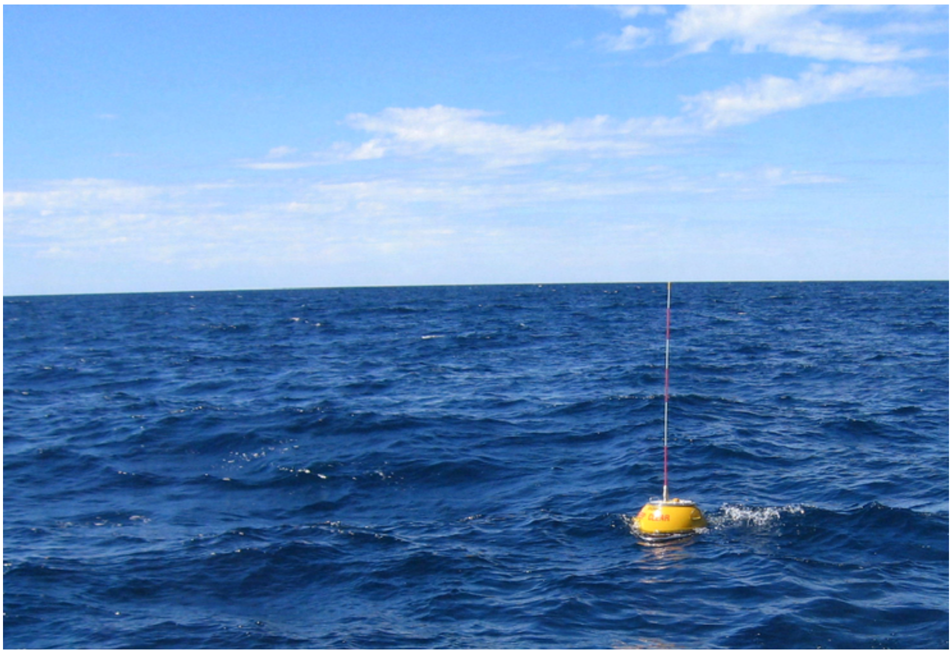
Government of **Western Australia**
Department for **Planning and Infrastructure**

Rottnest Wave Data Summary 1994 - 2008



Technical Report
Report No. 480
June 2009

Rottnest Wave Data Summary 1994 - 2008

DPI Report No. 480
June 2009

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Table Of Contents

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Symbols Used

H_s: Significant wave height

T_p: Peak period of the energy spectrum

T_m: Mean period of the energy spectrum

Glossary

Accelerometer: A device which measures the acceleration it experiences.

Calibration: Checking and adjusting the accuracy of the instrument by comparison with a standard.

Displacement: Excursions from the average position, not from the previous position.

Fast Fourier Transform (FFT): An algorithm used during spectral analysis to determine the Fourier coefficients directly from the time series.

Heave: The vertical (up and down) motion of a wave buoy; along the z-axis.

MATLAB: Software used for mathematical computer programming; including data analysis and plotting various forms of graphs.

Mean Period (T_m): Mean period of the energy spectrum, T_m=1/average frequency of the spectrum.

Measured or Observed Water Levels: The actual water level recorded at a given location. The combined effect of water level fluctuations from tides, storm surges, wind set-up, seiches, changes in mean sea level, continental shelf waves, the Leeuwin Current and ENSO is included.

Peak Period (T_p): Peak period of the energy spectrum, $T_p=1/f_p$ where f_p is the frequency of maximum spectral density.

Percentage Exeedance: The percentage of time that a given value is exceeded.

Percentage Occurrence: The percentage of time that a given value (or range of values) occurs.

Pitch: The motion of a wave buoy along its transverse axis (y-axis), the forward and aft ends rise and fall.

Predicted Tides: Computed tidal highs and lows at a given location resulting from the gravitation interactions between the earth and primarily the moon.

Quality Assurance: Processes to ensure the data collected will be of the best possible quality.

Quality Control: Processes to ensure the already collected data is of the best possible quality.

Receiver: A shore based device for recieving incoming wave signals.

Residual Water Levels: The actual water level recorded at a given location with the predicted tide for that location removed. The residual is the combined effect of water level fluctuations from storm surges, wind set-up, seiches, changes in mean sea level, continental shelf waves, the Leeuwin Current and ENSO.

Record Interval: The time between records (usually one hour but 30 minutes for some directional data).

Roll: The motion of a wave buoy along its longitudinal axis (x-axis), causes it to rock from side to side.

Sea Waves: Oceanic waves produced locally by wind blowing over the water surface. The characteristics of seas depend upon the length of the water body (fetch), the time wind has been blowing and the wind speed. Sea waves typically have short wavelengths and a disordered appearance. In the spectral wave data analysis carried out for the Perth coastal region sea waves are those that have a period less then 8s.

Significant Wave Height (H_s): Average height of the waves comprising the top 33 per cent of the waves recorded. In spectral analysis it is determined using the formula: $H_s = 4(m_o)^{1/2}$ where m_o is the zeroth spectral moment.

Spectral Analysis: A mathematical process that transforms the waveform into the frequency spectrum. For the wave height spectrum a Fast Fourier Transform is used by Tremarfon software to determine the wave height spectrum. For the wave direction spectrum the on-buoy processing uses north, west and vertical displacements to conduct a Fourier analysis yielding wave direction.

Swell Waves: Oceanic waves that are generated remotely and propagate long distances to arrive locally with a uniform and generally long wavelengths. For spectral wave data analysis for the Perth coastal region, swell waves are those that have a period greater then 8 seconds.

Wave Direction: The direction from which ocean waves approach a location.

Wave Height: The vertical distance between the trough and crest of a wave.

Wavelength (L): The length of one complete wave cycle; the horizontal distance between consecutive wave troughs or crests.

Wave Period (T): The time taken for one complete wavelength to pass a reference point, generally consecutive troughs or crests are used as the reference point.

Wave Buoy: A floating device used to measure water level variations caused by ocean waves.

1 Introduction

Wave data has been collected south-west of Rottnest by the Department for Planning and Infrastructure (DPI) since 1991, and is the longest wave data set managed by the DPI. The wave data was originally collected using non-directional wave buoys which measured wave heights and periods. For the first few years data was six-hourly with poor continuity and season losses. Hourly continuous data was recorded from February 1994. In 2004 directional wave buoys were deployed which additionally measured the wave direction. The directional wave buoy was deployed approximately two kilometres away from the non-directional wave buoy and the two instruments had a nine month overlap period of operation. This report discusses analysis of 15 years of non-directional data collected at Rottnest between 1994 and 2008 and five years of directional data collected between 2004 and 2008.

2 Wave Data Collection

The process of wave data collection involves data retrieval, data processing, quality assurance and quality control procedures. The individual steps and procedures conducted by the DPI at each stage of the data collection process are described in full below. An overview of the complete process is given in Figure 1.

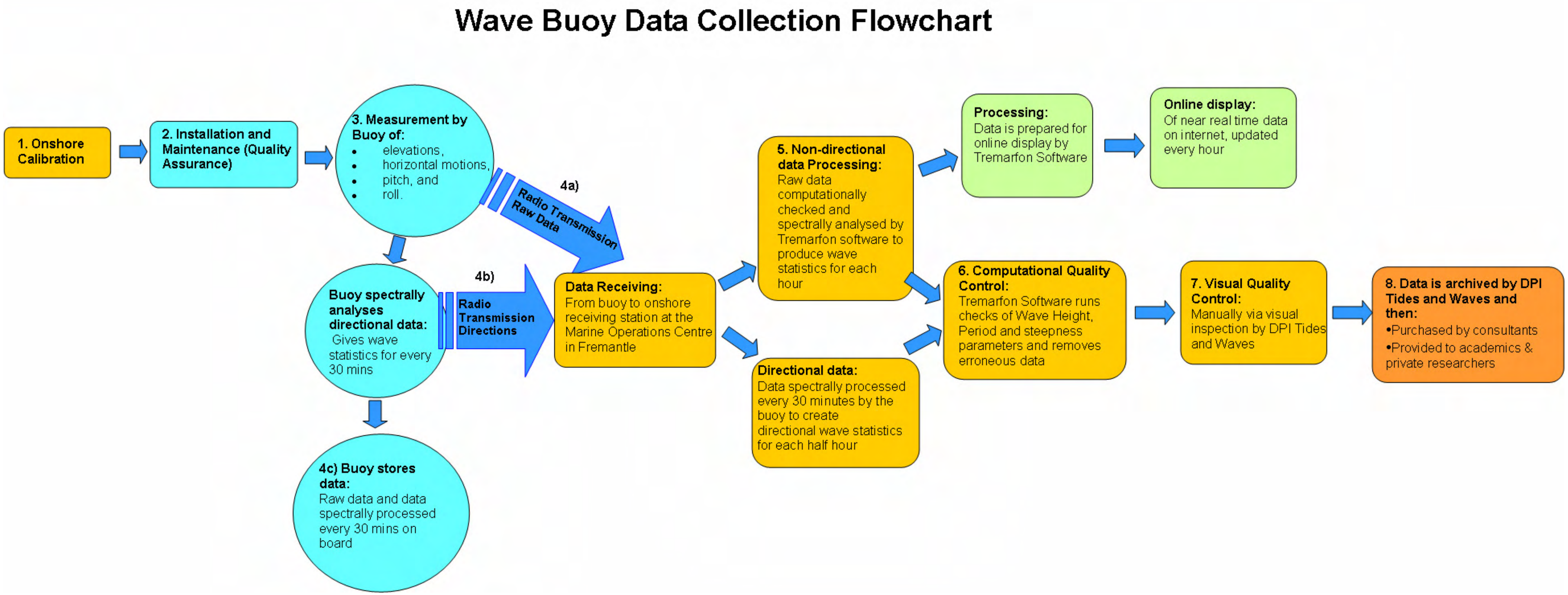

Figure 1. Flowchart showing the process of wave data collection within the DPI.

2.1 Wave Buoy Calibration

Wave buoys are calibrated pre and post deployment. The buoy is attached to an arm which rotates, simulating a two metre wave height. This arm rotates through a range of periods including 7-8, 10, 15 and 20 seconds. The use of this arm to calibrate a wave buoy is shown in Figure 2. The measured wave height and periods are compared to the simulated height and periods, and the differences between the two examined. From this examination calibration factors, if needed, are computed and applied to the data during computational data processing (see section 2.5).

Figure 2. Wave buoy calibration using the calibration arm at DPI's Marine Operations Centre to simulate a 2 m wave.

2.2 Installation

Wave buoys are deployed by the Tides and Waves section of the DPI. A deployed directional buoy similar to the Rottnest wave buoy is shown in Figure 3. The mooring layout for the directional wave buoy is shown in Figure 4. Mooring layouts are in accordance with the manufacturers recommendations, as correct mooring is essential for the accurate measurement of wave parameters. Most notably a rubber shock cord is included in the mooring arrangements because its flexibility allows the buoy to follow the wave motion.

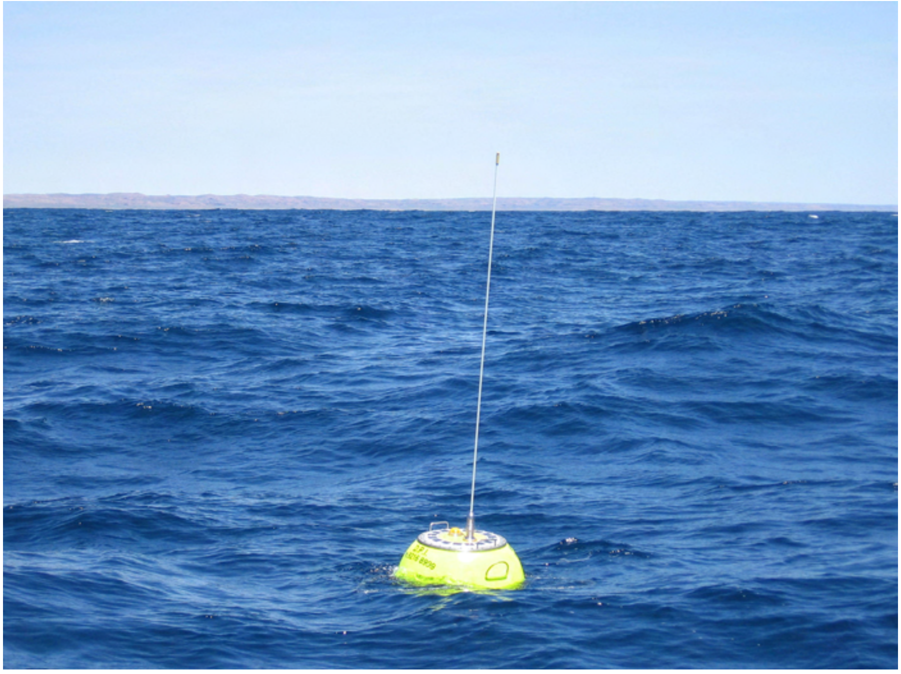

Figure 3. Directional wave buoy deployed at Exmouth, similar to the Rottnest wave buoy.

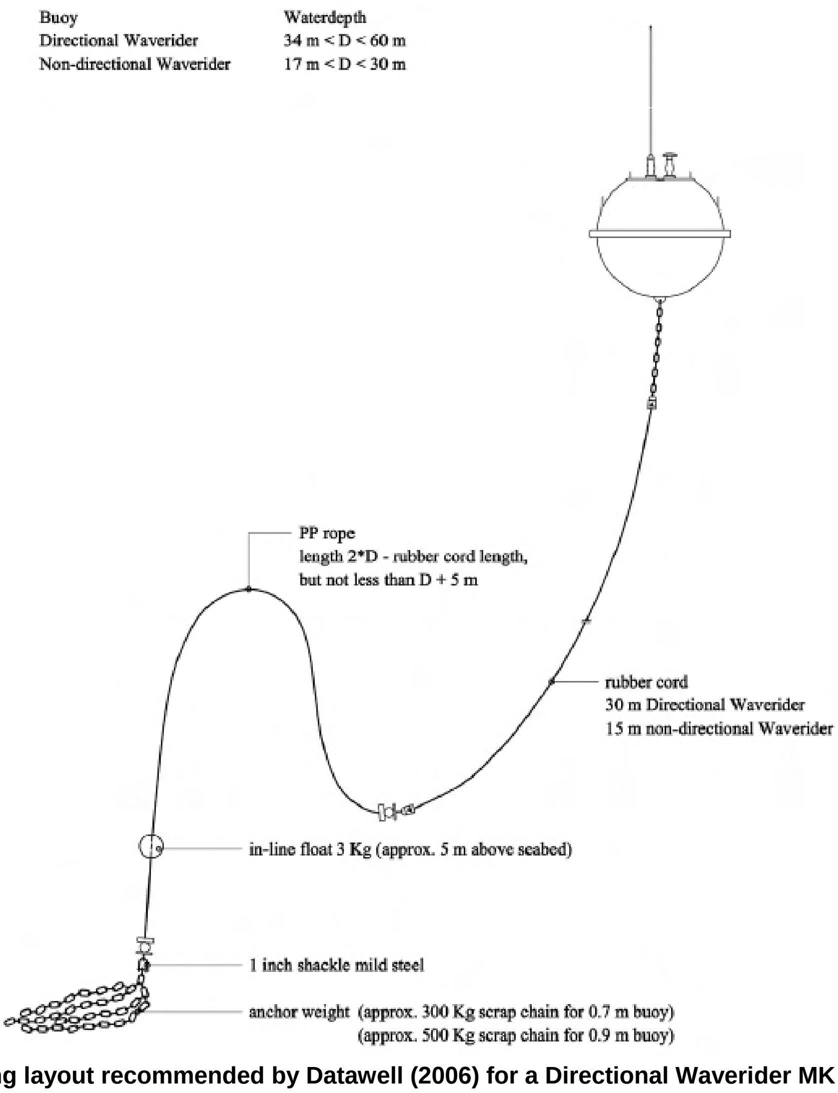

Figure 4. Mooring layout recommended by Datawell (2006) for a Directional Waverider MK III buoy in 34m to 60m water depth. The Rottnest wave buoy is deployed in 48m water depth.

2.2.1 Location and Deployment Dates

Deployment details are given in Table 1 and the location of the older non-directional buoy and newer directional buoy is shown in Figure 5. The distance between the mooring location of the older non-directional buoy location and the newer directional buoy location is approximately 2 kilometres.

Table 1. Deployment details for the Rottnest Waverider Buoy

	Non-Directional Buoy	Directional Buoy
Location Code	ROT33	RDW47
Position	32° 06' 41"S 115° 24' 07"E	32° 05' 39"S 115° 24' 28"E
Deployment depth(m)	48m	48m
Deployment date	25/07/1991 to 18/07/2005	14/09/2004 to date

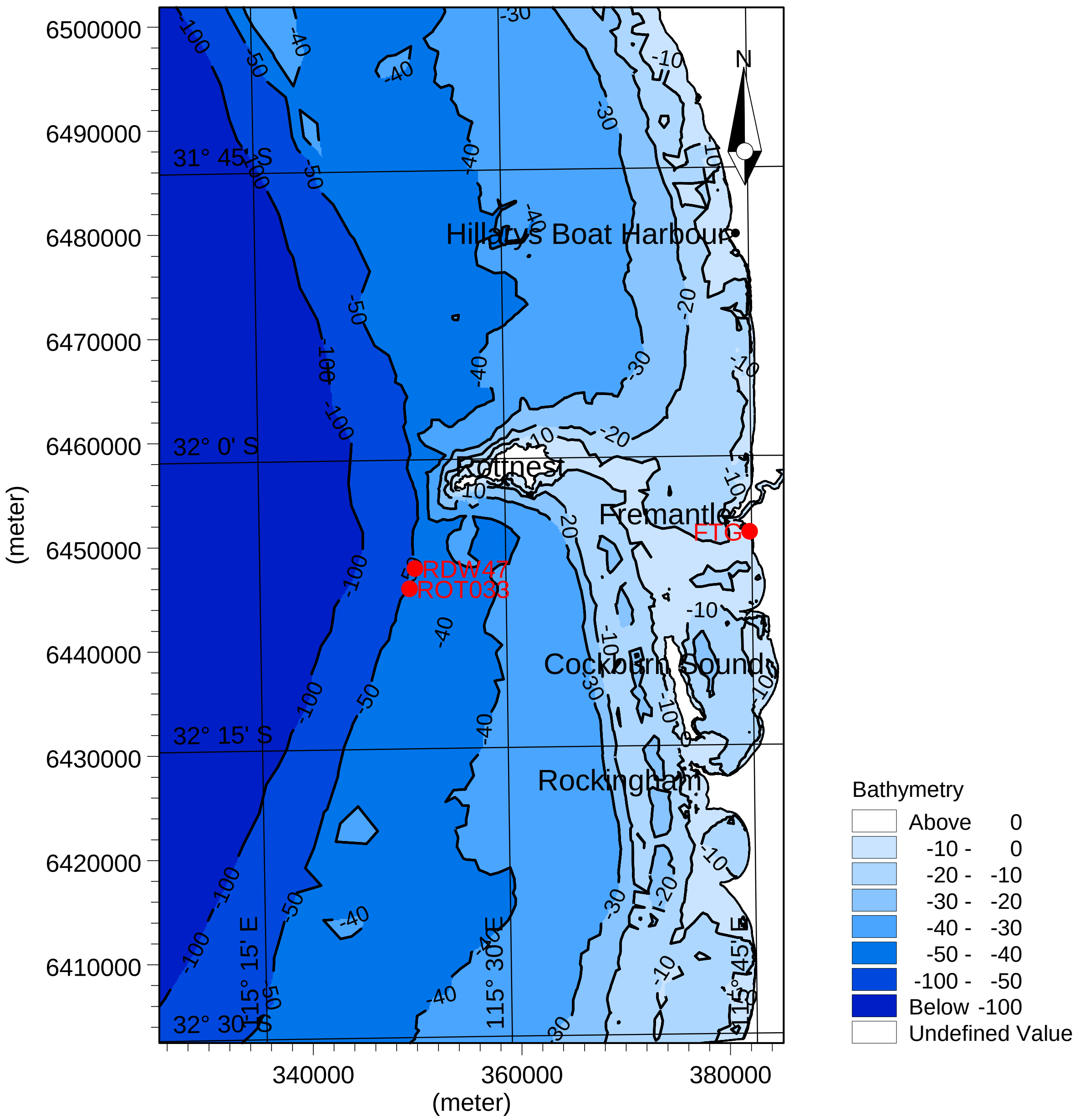

Figure 5. Location of the newer directional buoy is marked by the red point labelled RDW47, the location of the older non-direction buoy is marked by the red point labelled ROT033 and the Fremantle Tide Gauge is marked by the red point labelled FTG. Datum: Australian Height Datum (+0.756m above Chart Datum), unit: meters.

2.2.2 Instrument Details

Table 2 contains basic technical information for the non-directional and directional wave buoys deployed at Rottnest. The full Datawell technical specifications for the two models of wave buoys used are included in Appendix A.

Table 2. Basic instrumentation details for the non-directional and directional Waverider buoy deployed offshore Rottnest.

Instrument Type	Non-Directional	Directional
Instrument Make	Datawell	Datawell
Instrument Model	Waverider FL	Directional Waverider MK III
Diameter	0.7m diameter	0.7m diameter
Material	Cunifer 10	Cunifer 10
Additional information	Data collected on cassette tapes until 1997.1997 onwards, data collected digitally using a computer as logger	Onboard processor and storage. Onboard GPS receiver.
Receiver Make	Datawell	Datawell
Receiver Model	DIWAR Receiver	RX-C Receiver
Location Number	33	47

The interior of a non-directional wave buoy is shown below in Figure 6. Accelerometers mounted on a stabilised platform suspended in fluid are used to measure wave motion, see Figure 7. In general, the buoys also contain: radio aerials to transmit data to shore; internal data loggers; navigational warning lights; sea temperature sensors; battery cells; internal electronics; a Global Positioning System receiver; and more recent wave buoys also have solar panels, see Figure 8.

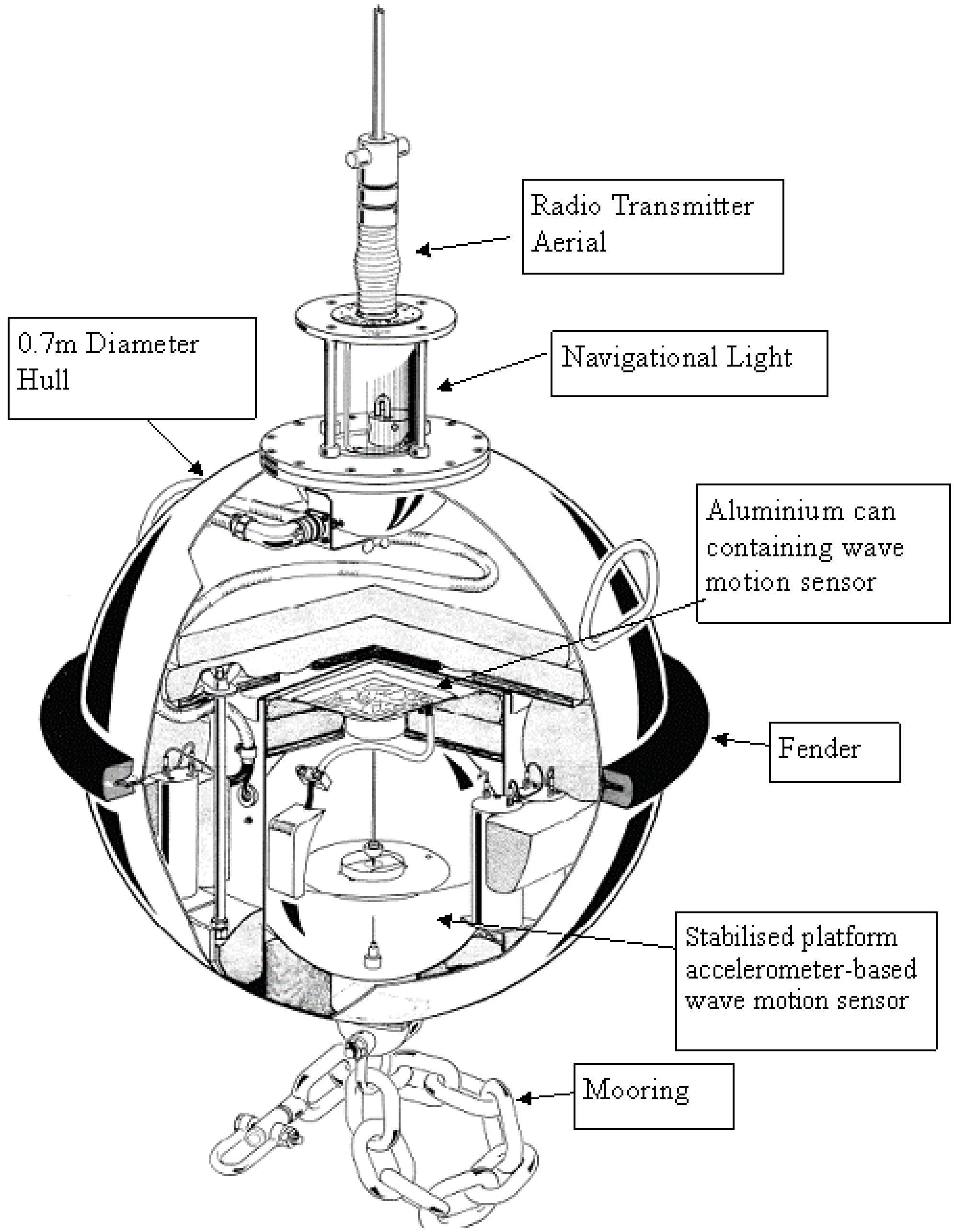

Figure 6. Equipment set-up of non-directional Waverider FL wave buoy, modified from Datawell (2007).

Figure 7. Datawell stabilised platform motion sensor. This is a fluid filled sphere allowing the motion sensor to be perfectly buoyant (Datawell 2008).

Figure 8. Instrumentation found on top of a directional wave buoy including solar panels and connections for the data transmitting antenna.

2.2.3 Maintenance

Routine maintenance of the Rottnest wave buoy has been conducted on board the service vessel every 12 months. This involves:

- removal of biofoul (see Figure 9);
- checking of instrumentation;
- servicing; and
- battery and mooring replacement.

With the recent departmental acquisition of a spare directional wave buoy the buoy is now swapped over every 12 months and maintenance is conducted on-shore at the Marine Operations Centre in Fremantle.

Figure 9.Typical biofoul found on a buoy after 12 months of deployment.

2.3 Buoy Recording

Raw elevations are measured by the wave buoy using a single accelerometer with its axis pointing in the vertical direction. These vertical accelerations are filtered and integrated twice to produce the elevations and thus the wave height.

Wave direction is determined by correlating the horizontal motion of the buoy with the vertical motion of the buoy. When the buoy is upright the horizontal motion of the buoy is measured by another two accelerometers. When the buoy is tilted the angles of pitch and roll are measured by the buoy and the horizontal motion measured by the two accelerometers is adjusted accordingly (Datawell 2006). The set-up of the sensors used for these measurements and the coordinate system is shown in Figure 10 and Figure 11.

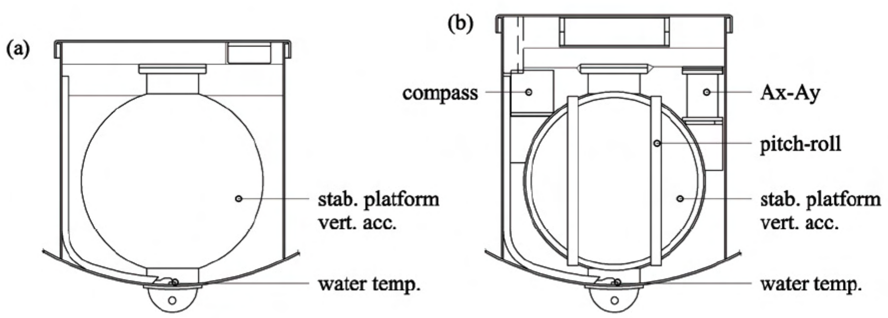

Figure 10. Contents of the aluminium can containing wave motion sensors for a) a non-directional wave buoy and b) a directional wave buoy (Datawell 2006)

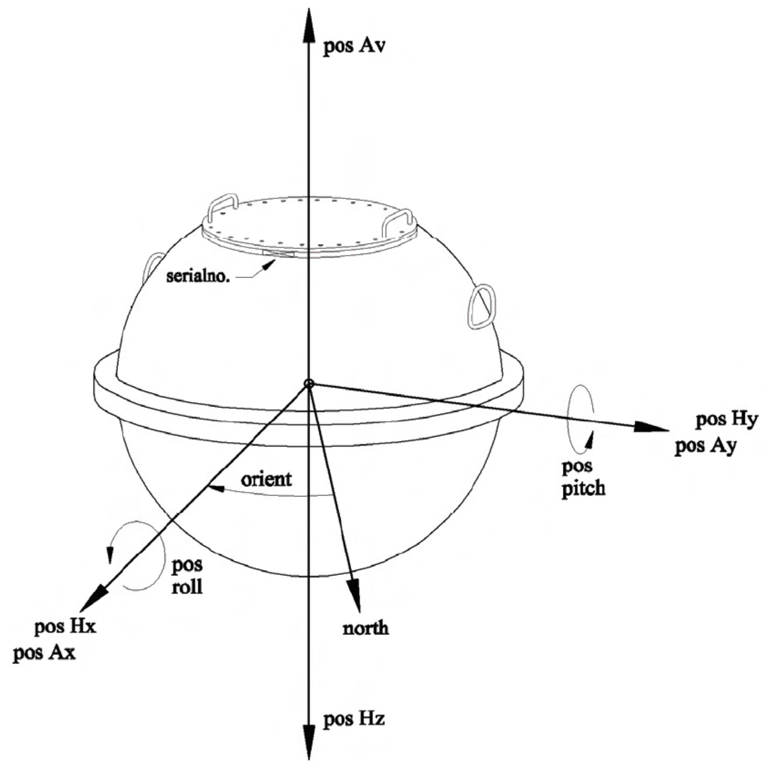

Figure 11. The directions of x, y, z and vertical axes that the accelerations, pitch and roll are measured relative to (Datawell 2006)

As indicated by Table 3 the older non-directional wave buoy generates the vertical displacement at a rate of 2.56 Hz and the newer directional wave buoy generates the vertical (z), west and north displacement at a rate of 1.28Hz.

Table 3. Sampling information for the two wave buoys deployed at Rottnest

	Non-Directional (1994 to 2005)	Directional (2004 to 2008)
Location Number	33	47
Sampling frequency	2.56Hz	1.28Hz
Sample length	Continuous	Continuous

2.4 Data Capture

A) Land logged raw data

The raw data from the older non-directional and newer directional wave buoy is transmitted to the shore receiving station at the Marine Operations Centre, Capo D'Orlando Drive, Fremantle. The raw elevations are monitored at the shore station. The access to real time wave data enables problems with the instrument to be identified. Measures are then taken to rectify the problem in a timely manner to ensure a good data recovery rate is obtained. This data is processed by software developed by Tremarfon Pty Ltd before it is made available for viewing on the internet in near-real time.

B) On-buoy processed directional data

The directional buoy transmits directional data to a shore receiving station that has been processed onboard through Fourier analysis of the raw data every 30 minutes. Datawell (2006) outlines the spectral analysis procedure and equations used. Wave direction data in half hour intervals is obtained from this buoy processed data.

C) On-buoy logged data
Raw displacements measured by the wave buoy and the on-buoy processed data are logged onboard the newer directional wave buoy and are downloaded during buoy maintenance.

Figure 12. Shore receiving station for the Rottnest wave buoy at the Marine Operations Centre.

2.5 Computational Data Processing

The raw elevations transmitted to the Marine Operations Centre are analysed by purpose built software developed by Tremarfon Pty Ltd. This software also applies the calibration factors determined from the wave buoy calibration. The raw elevations are analysed by the Tucker Draper method, Wave by Wave analysis and Fast Fourier Transform methods. The Tucker Draper and Wave by Wave analysis are used for quality control purposes only and the Fast Fourier Transform method is used to calculate the energy spectrum.

Non-directional data is spectrally analysed every 15 minutes to provide an energy spectrum and summary parameters. At the end of each hour the four energy spectra are averaged to produce the spectral statistics for the hour.

From the total wave statistics (combined sea and swell) this spectral analysis produces significant wave height (H_s), spectral peak period (T_p) and spectral mean period (T_m). Using a wave period split of 8 seconds the data is further broken down into sea and swell waves. The sea comprises waves with period below 8 seconds and the swell comprise waves with period greater than 8 seconds. This data is then analysed to produce swell significant wave height, swell peak period, swell mean period, sea significant wave height, sea peak period and sea mean period. Figure 13 is an example of a spectra with defined sea and swell wave peaks.

Directional data is taken from the 30 minute on-buoy processed data.

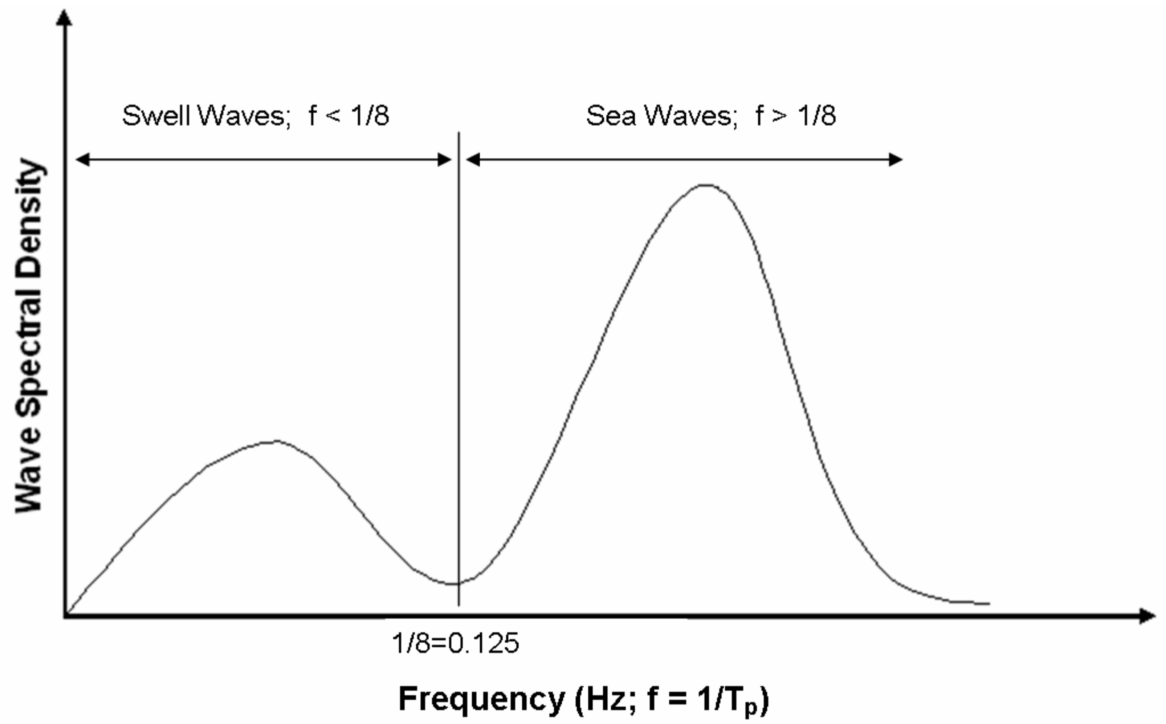

Figure 13. An example of a wave spectra showing a swell and sea wave peak as well as the 8 s period or 0.125 Hz frequency cut-off for sea and swell waves.

2.6 Computational Quality Control

Software developed by Tremarfon Pty Ltd conducts a number of automatic quality control checks on the non-directional and directional data files. The software includes checks for:

- data recording errors;
- spectral energy statistics; and
- limitations of wave height and period (includes checks of ratios, depth and steepness).

2.7 Visual Quality Control

After a calendar month of data has been collated and undergone computational quality control, the data undergoes visual quality control by the Tides and Waves section within the DPI. Firstly the data is plotted and visually inspected. Data from neighbouring wave buoys at Cape Naturaliste and Jurien Bay are compared and abnormal points or trends checked. Spikes are removed and significant wave height values are checked for validity. If it is not clear whether data is erroneous, the value is kept. Only values which are confidently assessed as being spurious are deleted.

The errors found in the visual quality analysis and the action taken are noted for future reference and traceability of data quality. Any major event or occurrence which affects the data capture is also noted.

2.8 Data Archiving

Once the data has been computationally and visually quality controlled it is archived by the DPI for internal use and external distribution to consultants and researchers.

2.9 Creation of a Uniform Data Set

The data that was used in this report underwent a further series of quality control to ensure it was suitable for the analyses conducted on it.

This was required because the current software developed by Tremarfon Pty Ltd does not analyse wave direction. Wave directions are obtained from the buoys onboard data processing, which produces a half hourly dataset, unlike the other statistics which are derived from the raw data to produce an hourly dataset.

To produce a data set with a uniform time interval, half-hourly directional data was merged with the hourly non-directional data set for 2005 to 2008. This process is outlined in Figure 14. Firstly the two peak period (T_p) values in each hour in the directional data set were compared with the one T_p value for the same hour from the non-directional data set. The direction with a corresponding T_p closest to the non-directional T_p was added to the non-directional data set. The two data sets were then compared to one another as each set of data had undergone a different quality control process. Where the non-directional data set had quality control data gaps the corresponding directional data was removed (with these actions recorded).

Due to the differences in processing of the data sets there were some problems due to discrepancies in the time stamping. Mostly this was related to the buoy processed data set having inconsistencies in the time interval between recordings. For example there may have been a 45 minute instead of a one hour time interval between two data records. To correct this the inconsistent time stamp was adjusted to the nearest hour with extra data removed or a blank row of data inserted where appropriate. A record of this time stamp adjustment has been kept.

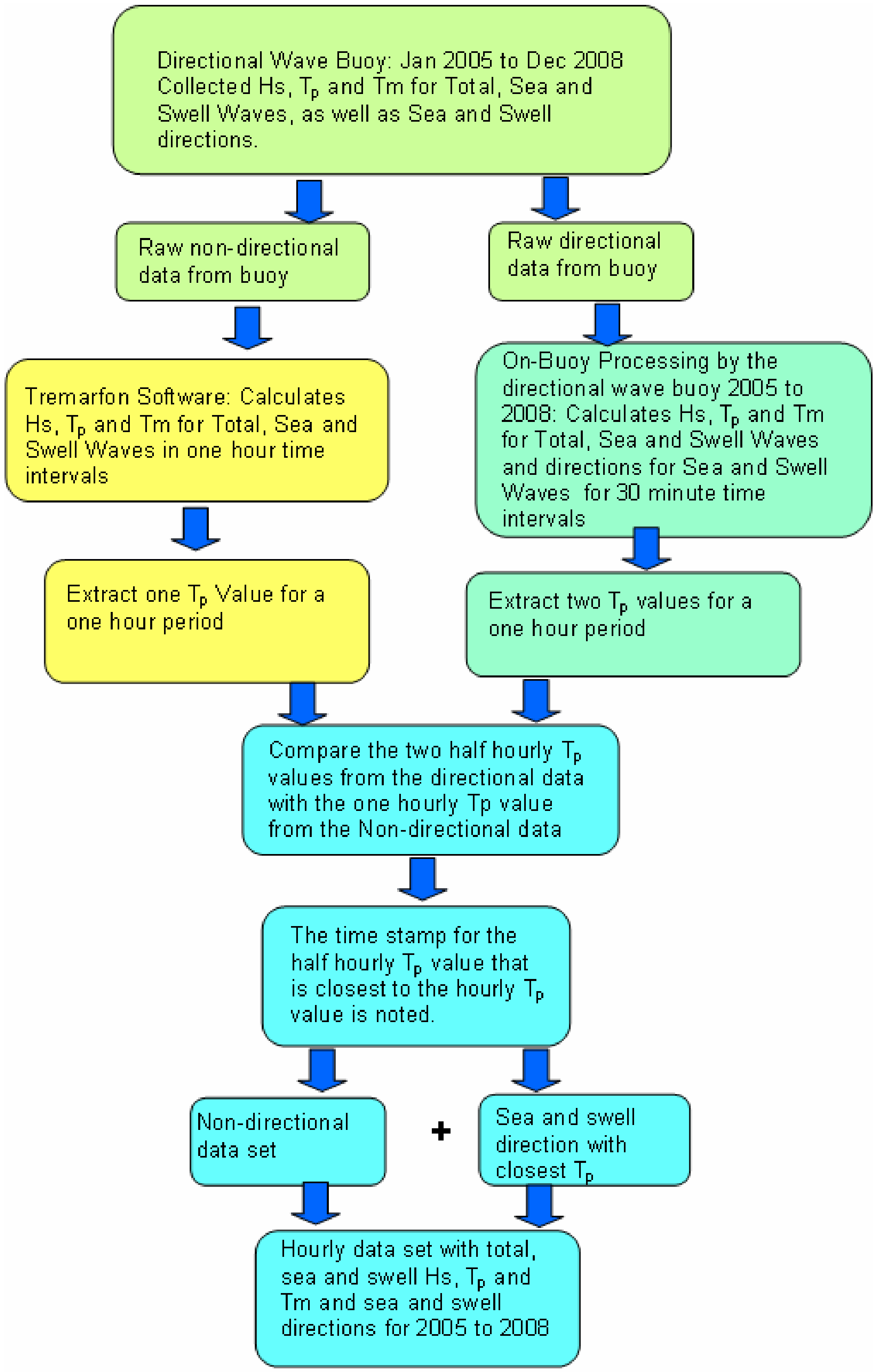

Figure 14. Flowchart outlining the process of combining directional and non-directional data to produce a directional, one hourly data set for 2005 to 2008.

2.10 Data Analysis

Once the data underwent the quality control and assurance processes outlined above, it was analysed using MATLAB to produce the plots in this report.

2.11 Data Recovery

Data recovery percentages for the last 15 years (1994 to 2008) of non-directional data and last five years (2005 to 2008) of directional data are listed in Table 4 and Table 5 below. These statistics are for the final data set used in the analyses in this report.

For the data analysis in this report non-directional data was used where possible because it has a higher rate of data recovery. The data recovery rate for the directional buoy is lower because of the additional quality control required to add the directional data to the non-directional data files.

The data recovery statistics below indicate that on average 95.4 per cent of non-directional data was recovered while 86.9 per cent of directional data was recovered. The recovery rate for directional data is generally lower because for the first few years of operation there was no spare directional wave buoy for deployment when equipment malfunction occurred. There are some time periods including January 2005, August 2005, September 2005 and June 2006 where equipment breakdown is responsible for the low recovery rate.

The percentage of recovered data for the directional wave buoy has increased from 73 per cent in 2005 to 98 per cent in 2008. The yearly recovery of non-directional data tends to be quite high and has been over 95 per cent for 11 of the 15 years of data collection.

Table 4. Monthly and yearly percentages of non-directional wave data capture

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1994	19.87	13.84	57.80	99.44	99.18	99.86	99.60	96.51	99.44	100.00	91.81	99.87	85.14
1995	99.46	99.85	90.19	98.89	99.60	99.72	99.33	94.49	100.00	99.33	99.72	100.00	98.36
1996	83.33	100.00	99.87	100.00	100.00	100.00	100.00	99.73	100.00	99.87	99.03	98.66	98.35
1997	99.88	100.00	99.87	99.58	100.00	99.44	99.87	99.87	100.00	99.73	99.86	100.00	99.84
1998	87.43	76.49	75.40	88.19	88.04	86.94	83.49	91.95	91.40	85.75	91.98	97.89	87.16
1999	99.06	100.00	99.33	99.58	99.06	97.36	93.95	97.45	99.17	80.38	99.44	97.72	96.83
2000	99.60	96.61	99.24	98.62	99.19	99.72	98.93	99.46	98.92	98.94	98.50	98.92	98.90
2001	98.14	97.03	99.60	99.18	96.25	95.57	96.30	99.35	97.09	90.79	91.14	97.04	96.46
2002	91.70	95.25	96.72	93.16	95.84	100.00	93.18	99.46	98.64	97.58	97.09	93.36	95.99
2003	99.60	99.55	97.20	99.45	99.34	99.58	95.58	93.03	97.92	94.81	92.79	93.31	96.82
2004	99.87	95.12	98.53	99.45	98.80	93.65	99.87	99.73	97.37	99.20	96.95	98.93	98.15
2005	52.76	97.17	100.00	99.72	99.06	99.72	99.60	75.67	47.50	97.04	99.72	99.73	88.94
2006	99.19	99.40	100.00	99.86	85.89	26.39	99.73	99.06	99.44	99.87	99.86	99.87	92.44
2007	99.46	99.40	99.87	97.92	99.06	95.28	98.66	98.79	99.72	99.60	99.86	100.00	98.97
2008	99.60	99.86	99.60	99.72	99.73	94.31	99.19	99.87	99.86	99.46	99.44	99.19	99.16
All Months	91.51	91.38	94.24	98.18	97.27	92.51	97.15	96.30	95.11	96.16	97.14	98.29	95.43

Table 5. Monthly and yearly percentages of directional wave data capture

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
2005	45.09	87.95	90.86	90.83	91.53	85.69	62.63	71.77	1.53	78.76	89.44	80.78	73.02
2006	39.11	83.48	87.23	93.19	76.21	23.33	81.99	86.83	93.06	94.49	92.78	97.18	79.08
2007	99.06	99.26	99.46	97.50	98.79	93.47	95.97	98.12	98.61	98.25	97.78	91.53	97.31
2008	99.19	96.12	99.19	98.06	99.46	93.61	98.12	98.92	97.22	98.92	99.44	98.25	98.06
All Months	70.62	91.74	94.19	94.90	91.50	73.96	84.68	88.91	72.60	92.57	94.86	91.90	86.87

3 Notes on Data Discrepancies

Over a nine month period from October 2004 to July 2005 wave data was recorded by both the older non-directional buoy and the newer directional buoy 2 kilometers away. Comparison of this wave data has revealed discrepancies in the recorded data files. Most of the data components collected by the different buoys were the same; with the significant wave height for sea, swell and total, peak period for sea, swell and total and mean period for swell correlating well. However, there are differences in the total mean period (Figure 15) and sea mean period (Figure 16).

Mean sea periods recorded by the non-directional buoy are consistently approximately 1 second longer than the directional buoy (Figure 15). The total mean period recorded by the non-directional buoy is also consistently longer then that recorded by the directional buoy by approximately 1 second (Figure 16).

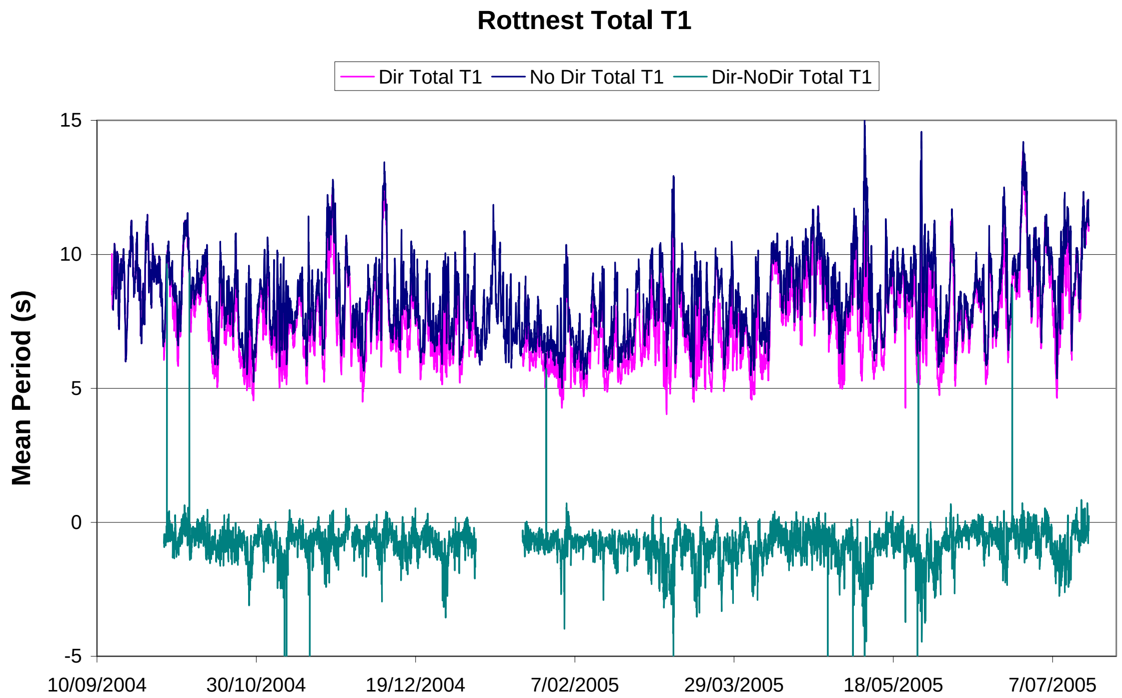

Figure 15. Plot of total mean period data from the non-directional and directional wave buoys, and the residual of directional total mean period subtracted from non-directional total mean period.

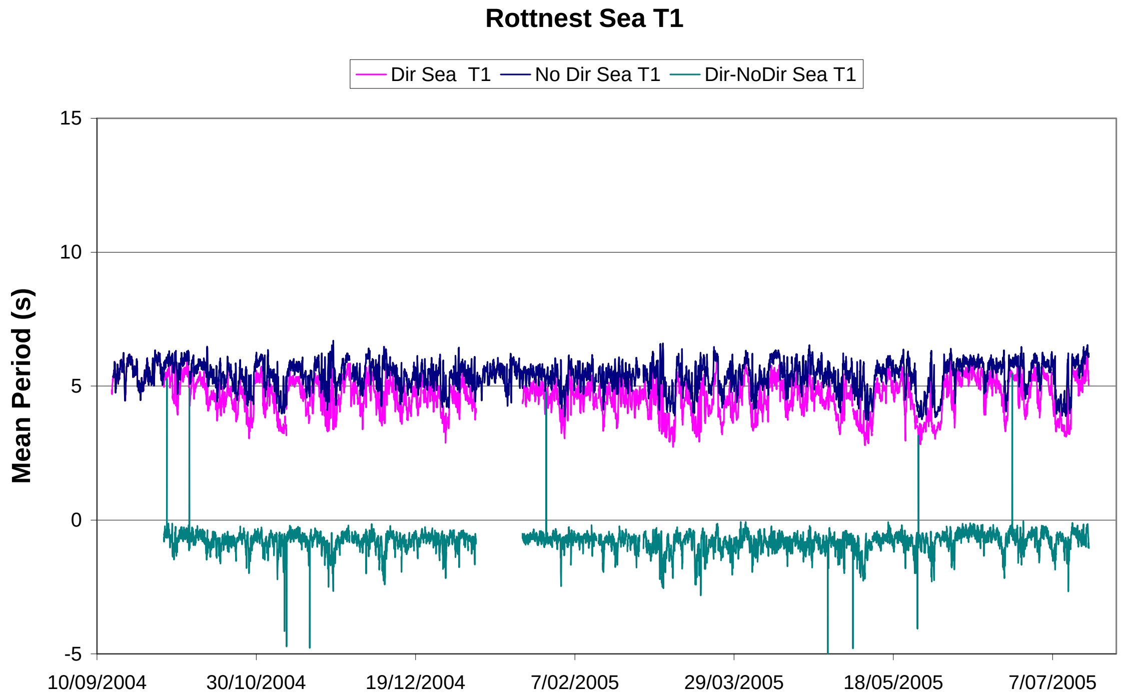

Figure 16. Plot of sea mean period data from the non-directional and directional wave buoys, and the residual of directional sea mean period subtracted from non-directional sea mean period.

Some research was carried out to identify similarities and differences between the non-directional and directional wave buoys. This research suggests that a difference in the frequency range of each buoy may be a cause of this discrepancy. Alternatively, physical differences between the two buoys may be a cause of this discrepancy. It is beyond the scope of this report to investigate the cause for the discrepancy further.

To simplify analysis, data from the non-directional wave buoy was used for the calendar years 1994 to 2004 and data from the directional wave buoy was used for the calendar years 2005 to 2008.

4 Wave and Water Level Time Series Plots

Yearly time series plots were produced to check data and as a first pass visual assessment of interesting events. For each year four subplots were produced, the first plotting total significant wave height and mean period, the second plotting swell significant wave height and mean period, the third plotting sea significant wave height and mean period. The fourth subplot has the corresponding water level measurements and residuals (measured water level minus the predicted water level) for the tide gauge located in Fremantle Fishing Boat Harbour (general location shown in Figure 5). These plots allow easy comparison of sea, swell and water level contributions for significant events.

Figure 17 contains the time series plot for 2008 while the full-time series for 1994 to 2008 is presented in Appendix B.

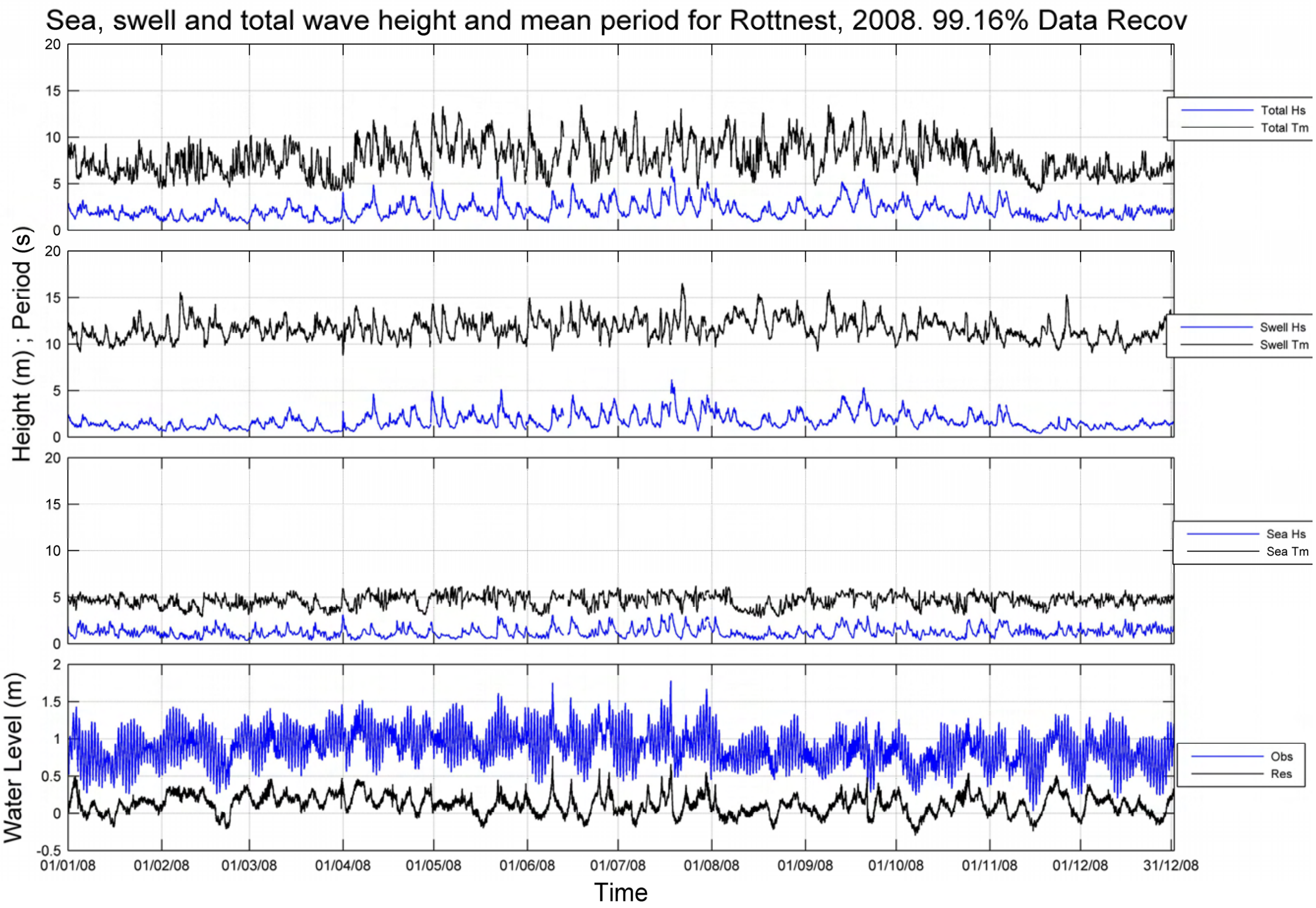

Figure 17. Time series plot of significant wave heights and mean period for total, swell and sea wave data along with observed and residual water levels for 2008.

5 Wave Height Distribution

All hourly total significant wave height data from 1994 to 2008 was binned to find the occurrence and exceedance distribution over the entire record length. This data was then used to produce a histogram and cumulative frequency plot as shown in Figure 18.

The wave height bins used were for significant wave heights from 0 metres to 10 metres with ranges of: 0 metres to 0.2 metres; followed by 0.4 metre bin intervals for 0.2 metres to 9.8 metres; and then 9.8 metres to 10.0 metres.

The yearly variation in wave height distribution was examined by plotting data from an individual year (i.e. 1994) against the full dataset (1994 - 2008). The monthly variation in wave height distribution was examined by plotting all data from a calendar month (i.e. all data from January months 1994 - 2008) with all data from all years (1994 - 2008). These plots are shown in Appendix C and Appendix D.

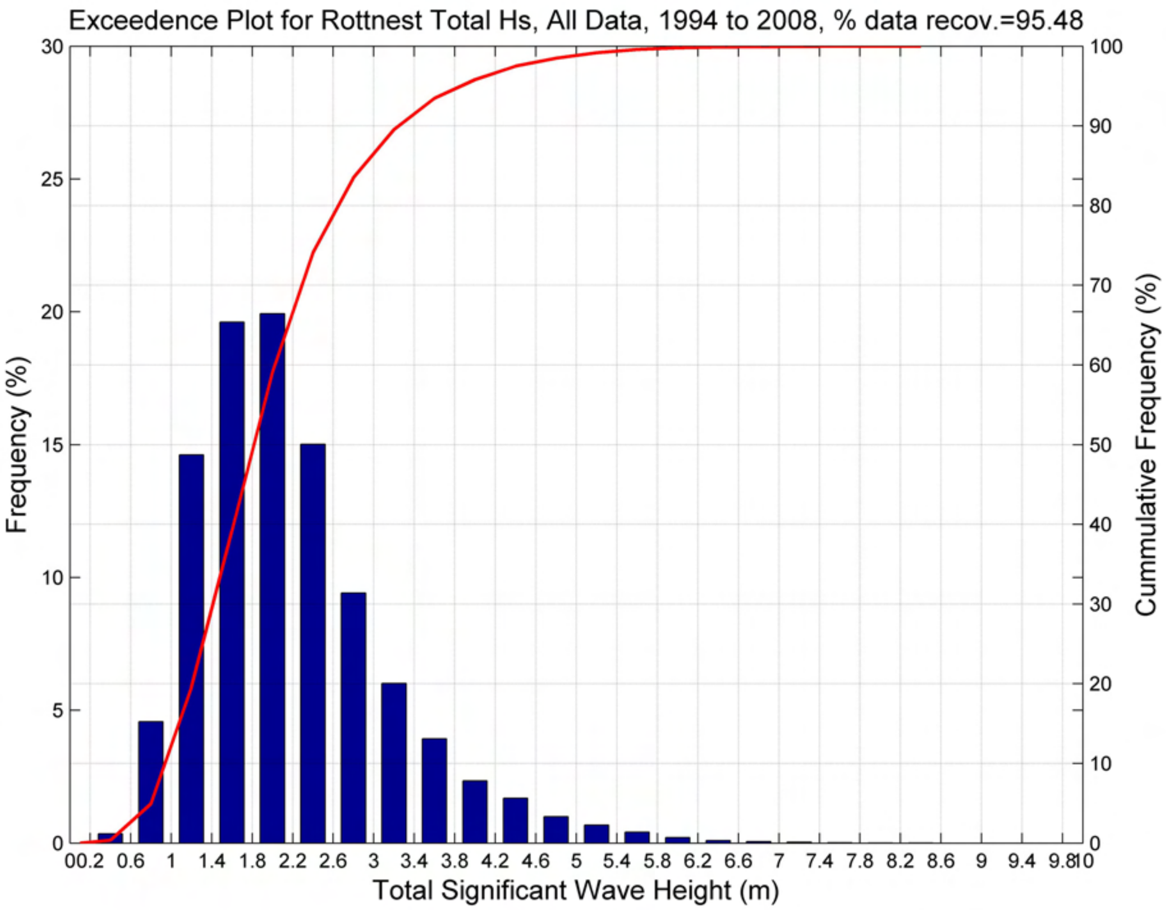

Figure 18. Total significant wave height (H_s) occurance and exceedence distribution for all 1994 to 2008 Rottnest wave data.

6 Wave Period Distribution

The distribution of all peak wave periods from 1994 - 2008 was examined through the preparation of histogram and cumulative frequency plots showing the occurrence and exceedance of the peak period (T_p) for total wave data, as shown in Figure 19. The peak period data was binned for 0 second to 30 second peak periods with bin ranges of 1 second.

The changes in yearly distributions were examined through the production of plots of peak period distributions for an individual year (i.e. 1994) compared against all data (1994 - 2008). Changes in the monthly distributions of peak periods was examined through the production of plots for all data from a month (i.e. all data from January months) compared against all data (1994 - 2008). These plots are shown in Appendix E and Appendix F.

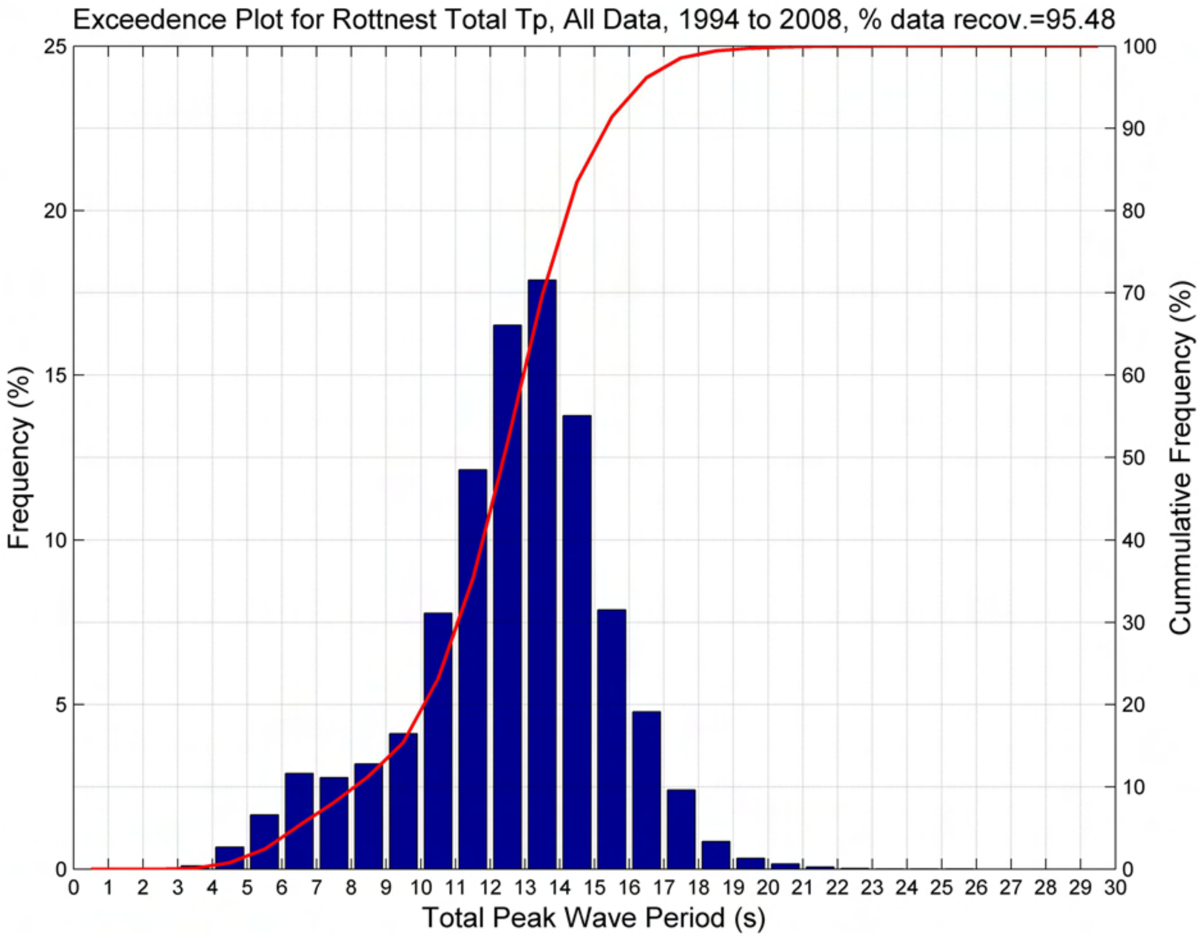

Figure 19. Peak period (T_p) occurrence and exceedance distribution for 1994 to 2008 Rottnest wave data.

7 Joint Wave Height and Period Distribution

To examine the joint occurrence of wave heights and periods a cross plot of the total significant wave height and the peak period was produced (Figure 20), as well as a cross plot of the total significant wave height and the mean period (Figure 22). Furthermore, density plots of the total significant wave height and the peak period (Figure 21), and the total significant wave height and the mean period (Figure 23) provide joint frequency of occurrence information. Figure 21 and Figure 23 show changes in the joint occurrence of wave height and period through the use of percentage occurrence colour contours. The bin intervals for wave height and period to produce Figure 21 and Figure 23 were made very small (0.25 metres and 0.25 seconds respectively) to ensure that small changes in the joint distribution of these parameters were shown. Thus the values of the percentage occurrences for wave height and period ranges in Figure 21 and Figure 23 are very low.

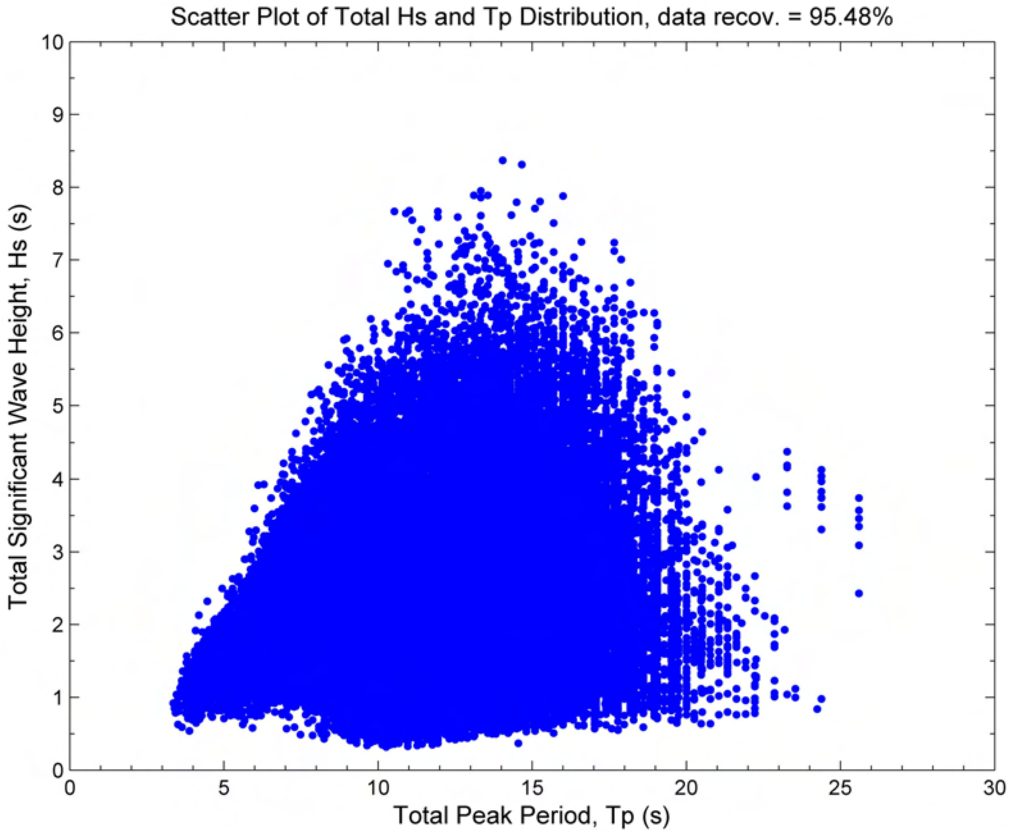

Figure 20. Cross plot of total significant wave height (H_s) versus total peak period (T_p) for Rottnest wave data, 1994 to 2008.

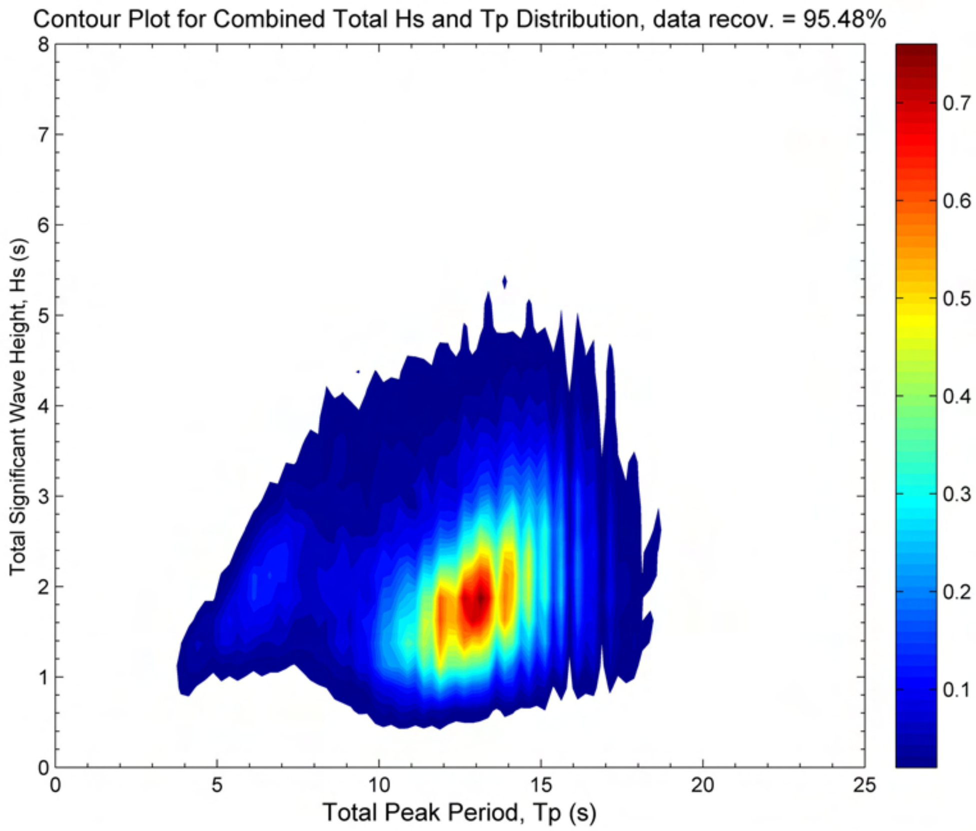

Figure 21. Density plot of percentage joint occurrences of total significant wave height (H_s) and total peak period (T_p) for Rottnest wave data, 1994 to 2008. Colourbar shows the percentage (%) of joint occurance.

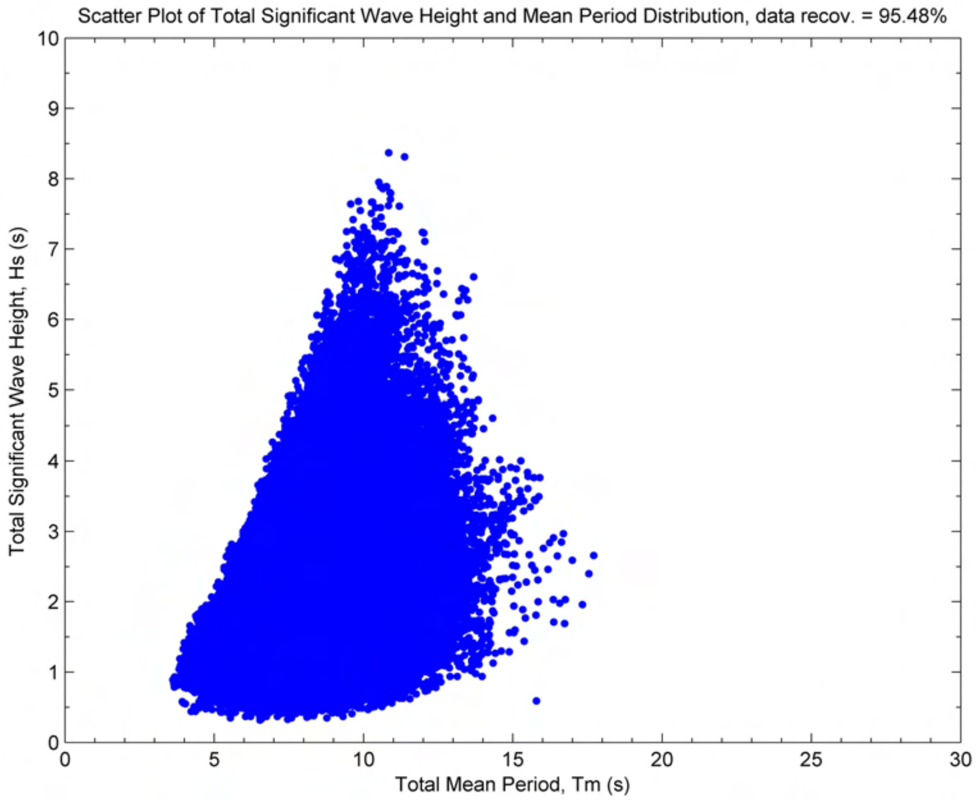

Figure 22. Cross plot of total significant wave height (H_s) versus total mean period (T_m) for Rottnest wave data, 1994 to 2008.

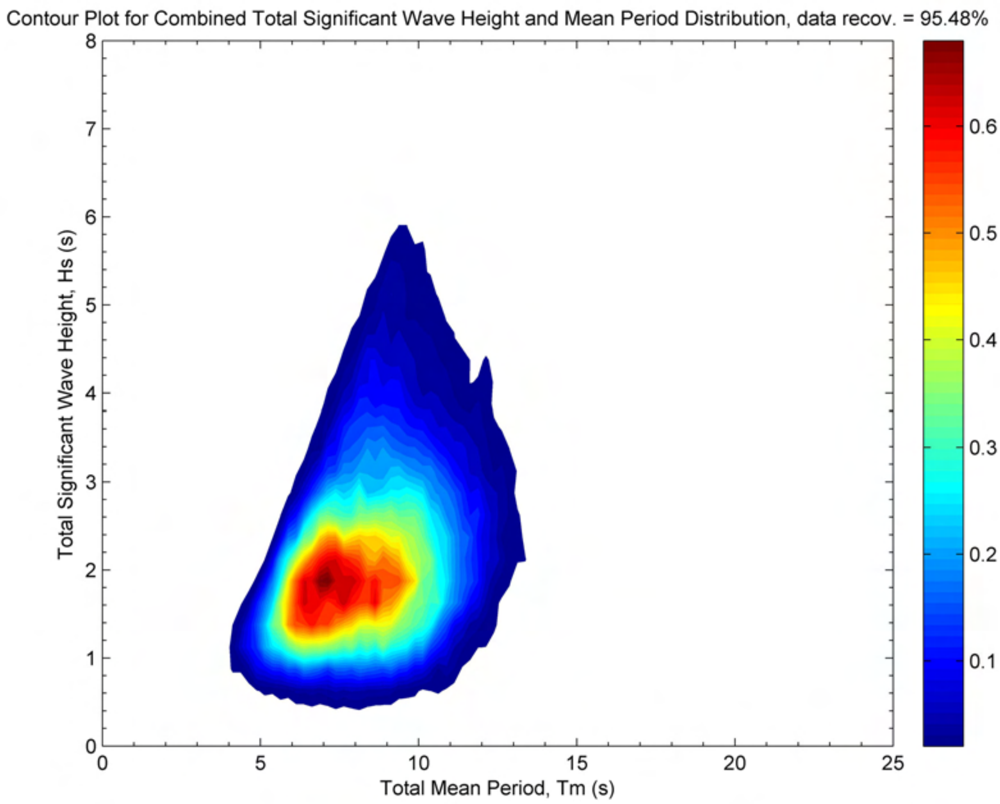

Figure 23. Density plot of percentage joint occurrences of total significant wave height (H_s) and total mean period (T_m) for Rottnest wave data, 1994 to 2008. Colourbar shows the percentage (%) of joint occurrence.

8 Wave Height Directional Analysis

To examine the relationship between wave height and direction, wave roses for all directional sea and swell wave data (2005 - 2008) were produced and are shown in Figure 24 and Figure 25. Additionally the monthly variation in the relationship between wave height and direction was investigated through the production of monthly wave roses (Appendix G) for sea and swell significant wave height. The wave height data was binned in 0.5 metre intervals from 0 metres to 6 metres and the direction data was binned in 10 degree intervals for all wave height and direction wave roses.

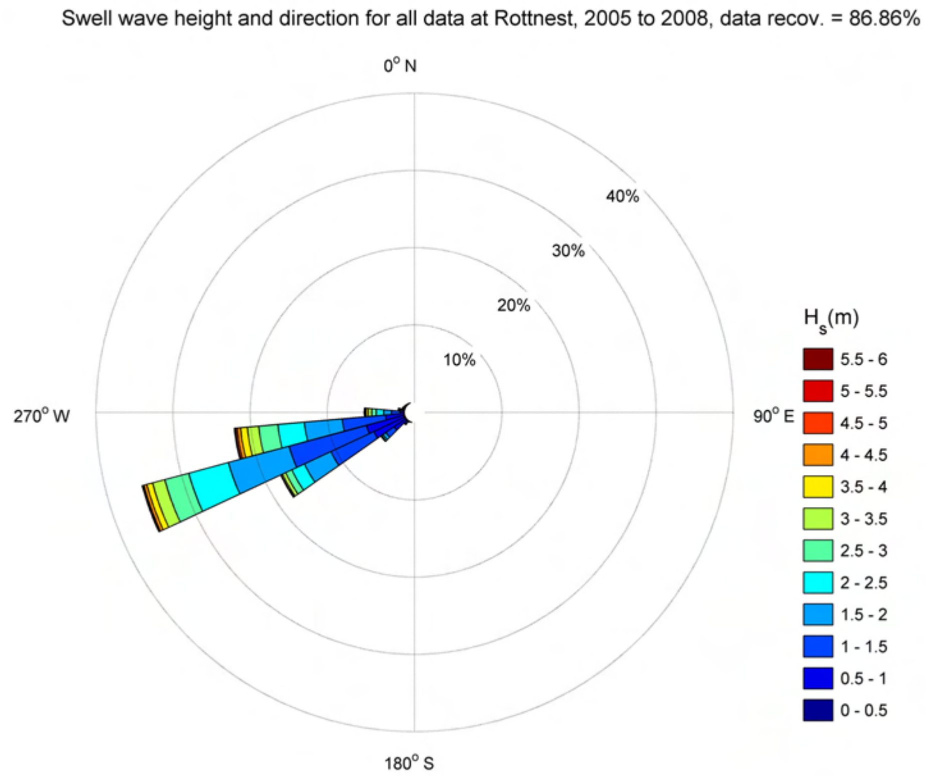

Figure 24. Wave rose for significant wave height and direction of swell waves recorded at Rottnest from 2005 to 2008.

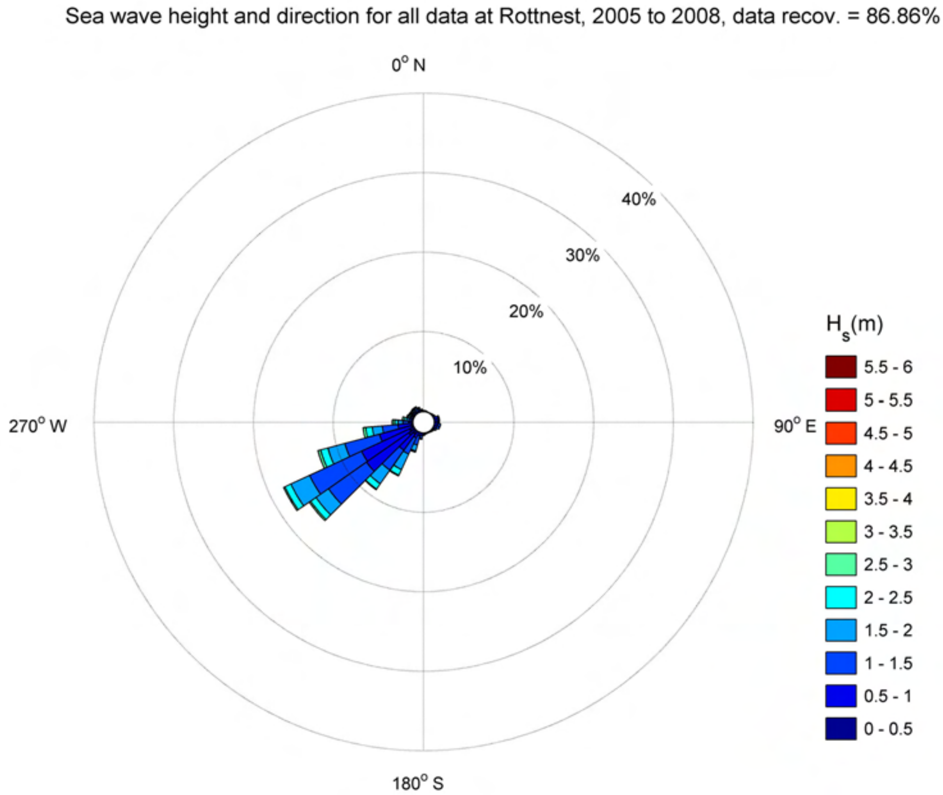

Figure 25. Wave rose of significant wave height and direction of sea waves recorded at Rottnest from 2005 to 2008.

9 Wave Period Directional Analysis

Wave roses were produced for sea and swell using mean wave period and direction data (2005 to 2008) to examine the relationship between mean wave period and direction (Figure 26 and Figure 27). Monthly variation of wave period with direction was examined through the production of monthly wave period and direction wave roses. Plots are shown in Appendix H. The direction data was binned in 10 degree intervals for all the mean wave period and direction wave roses. Swell mean wave period data was binned in two second intervals for periods of 8 seconds to 20 seconds and sea mean wave period data was binned in one second intervals for periods of 0 seconds to 8 seconds.

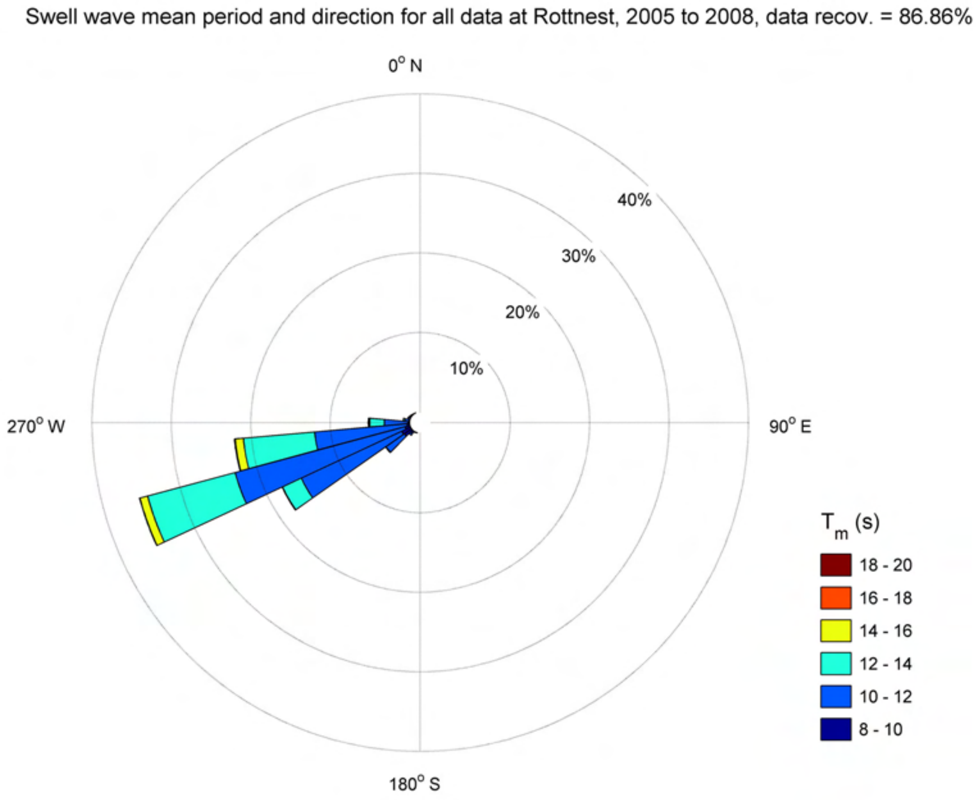

Figure 26. Wave rose of mean wave period and direction for swell wave data collected at Rottnest from 2005 to 2008.

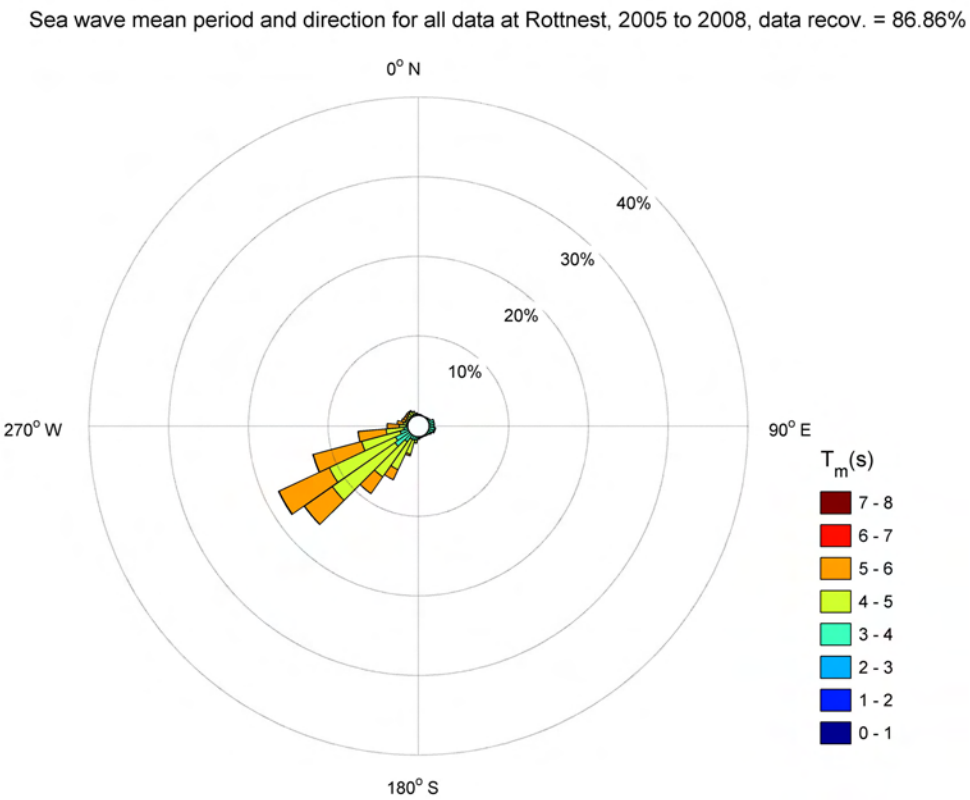

Figure 27. Wave rose showing mean wave periods and directions for sea waves collected at Rottnest from 2005 to 2008.

10 Conclusions

Non-directional wave heights and periods been collected at Rottnest for the last 15 years while sea and swell directions been collected for the last five years. The long term data set of wave heights and periods has allowed for an inspection of the distribution of wave heights and periods and their inter-annual and intra-annual variation. The additional collection of directional data has also allowed for an inspection of the inter-annual and intra-annual variation of wave height and period against wave direction.

11 References

Datawell 2006 *Datawell Waverider Reference Manual: WR-SG, DWR-MkIII, DWR-G*, Datawell BV, The Netherlands

Datawell 2007 *Waverider fl*, Datawell BV, The Netherlands

Datawell 2008 *Waverider SG*, Datawell BV, The Netherlands

Appendix A: Wave Buoy Technical Specifications

Directional Waverider MkIII

Datawell - Oceanographic Instruments

The Directional Waverider DWR-MkIII: Three years of continuous operation

The Directional Waverider hardly needs any introduction: it is the world's standard for measuring wave height and wave direction. Its success is due to the accurate and well-proven stabilized platform sensor, enabling wave height measurements by a single accelerometer. For the wave direction, direct pitch and roll measurements are performed needing no integration. In combination with horizontal accelerometers and a compass this forms the complete sensor unit, the heart of the instrument.

The highlights:

- **Measuring wave height and wave direction.**
- **HF link up to 50 km** over sea. By powering up the transmitter and using a directional receiving antenna the HF range can be stretched.
- **LED flash light** mounted at the top of the antenna increasing the buoy's visibility to passing ships.
- A **GPS receiver** for buoy positioning has now become a standard feature of the DWR-MkIII, and facilitates its retrieval.
- Standard integrated **data logger** based on the latest flash card technology.
- A **water temperature sensor** in the mooring eye providing sea surface temperature
- **High capacity primary cells** operating under all wave conditions and weather circumstances for up to three years without replacement.
- An accurate onboard **energy meter** monitors the actual energy consumption of the buoy, and reports a reliable estimate of the remaining operating life.

The DWR-MkIII comes standard with Datawell's HF link for ranges up to 50 Km over sea. For larger ranges the HF link can be combined or replaced with Iridium, Argos or Orbcomm satellite communication.

A GSM link is also available making the standard receiver redundant.
The MkIII can be supplied in a 70 cm hull offering easier handling and 1 year of continuous operation or a 90 cm hull for 3 years of continuous operation.

Optionals:

- **Iridium:** sending data via satellite over the Internet
- **Argos:** satellite link
- **Orbcomm:** satellite link (two-way)
- **GSM:** data through SMS or Internet
- **Hybrid Power System:** solar energy combined with primary cells for extending operational life by at least 100%
- **Hull painting:** yellow (no anti-fouling)
- **Radar reflectors** to increase visibility in busy waters

0.7 m, (Hull painting is optional, not standard)

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Directional Waverider MkIII

Datawell - Oceanographic Instruments

Specifications

Heave	Range	–20 m - +20 m
	Resolution	1 cm
	Scale accuracy (gain error)	< 0.5% of measured value after calibration < 1.0% of measured value after 3 year
	Period time	1.6 s - 30 s
Direction	Range	0° - 360°
	Resolution	1.5°
	Buoy heading error	0.4° - 2° (depending on latitude) typical 0.5°
	Reference	magnetic north
	Period time (free floating)	1.6 s - 30 s
Standard features	HF transmitter	frequency range 25.5 - 35.5 MHz (35.5 - 45.0 MHz on request) transmission range 50 Km (over sea)
	Data logger	type 1 Compact Flash Module, size 128 MB other sizes available
	Flash light antenna	4 LEDs, colour yellow (590 nm), pattern 5 flashes every 20 s standard length 195 cm
	GPS position	every 30 min, precision 10 m
	Water temperature	range –5 °C - +46 °C, resolution 0.05 °C, accuracy 0.2 °C
Options	Iridium/Argos/Orbcomm	satellite communication
	GSM	mobile communication
	Hybrid power system	solar panel combined with Boostcap capacitors
	Hull painting	Brantho Korrux “3 in 1”paint system (no anti-fouling)
	Radar reflectors	two reflectors mounted on hatchcover (retrofittable)
General	Hull diameter	0.7 m and 0.9 m (excluding fender)
	Material	stainless steel AISI316 or Cunifer10
	Weight	approx. 105 Kg (0.9m 225 Kg)
	Batteries	0.7 m diam. operational life 1 year, 1 section of 15 batteries 0.9 m diam. operational life 3 years, 3 sections of 15 batteries type Datacell RC20B (200 Wh black)
	Processing	32 bits
	Temperature range	operating –5 °C - +35 °C storage –5 °C - +40 °C (+ 55 °C short term, weeks only)
	Receiver	RX-C, RX-D or Warec (older Warecs may need modification)

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Waverider fl

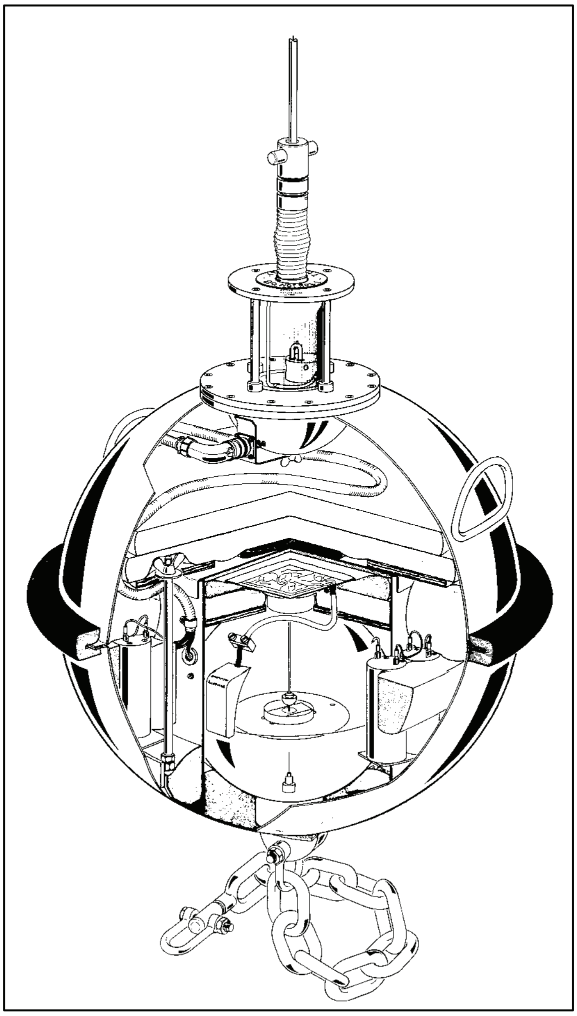
Datawell - Oceanographic Instruments

The Datawell Waverider, the first and most sold wave buoy ever

The quality and reliability of the Waverider does not need any advertising anymore. Over the years thousands of these buoys have been sold. Many of them operating over 15 years in the harsh sea environment.

Waves are measured by integrating the vertical acceleration. To avoid measurements of unwanted accelerations, the accelerometer is mounted on a stabilized platform having a natural period of 40 seconds. By this means the sensitive axis is kept within a few degrees of the vertical.

0.7 m



Though the suspension of the stabilized platform is fragile, the construction as a whole has proven to be very reliable. This reliability is accomplished by making the platform and the accelerometer neutrally buoyant in the sensor fluid. Many buoys have survived direct ship collisions, even propeller hits, without the sensor being damaged.

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Waverider fI

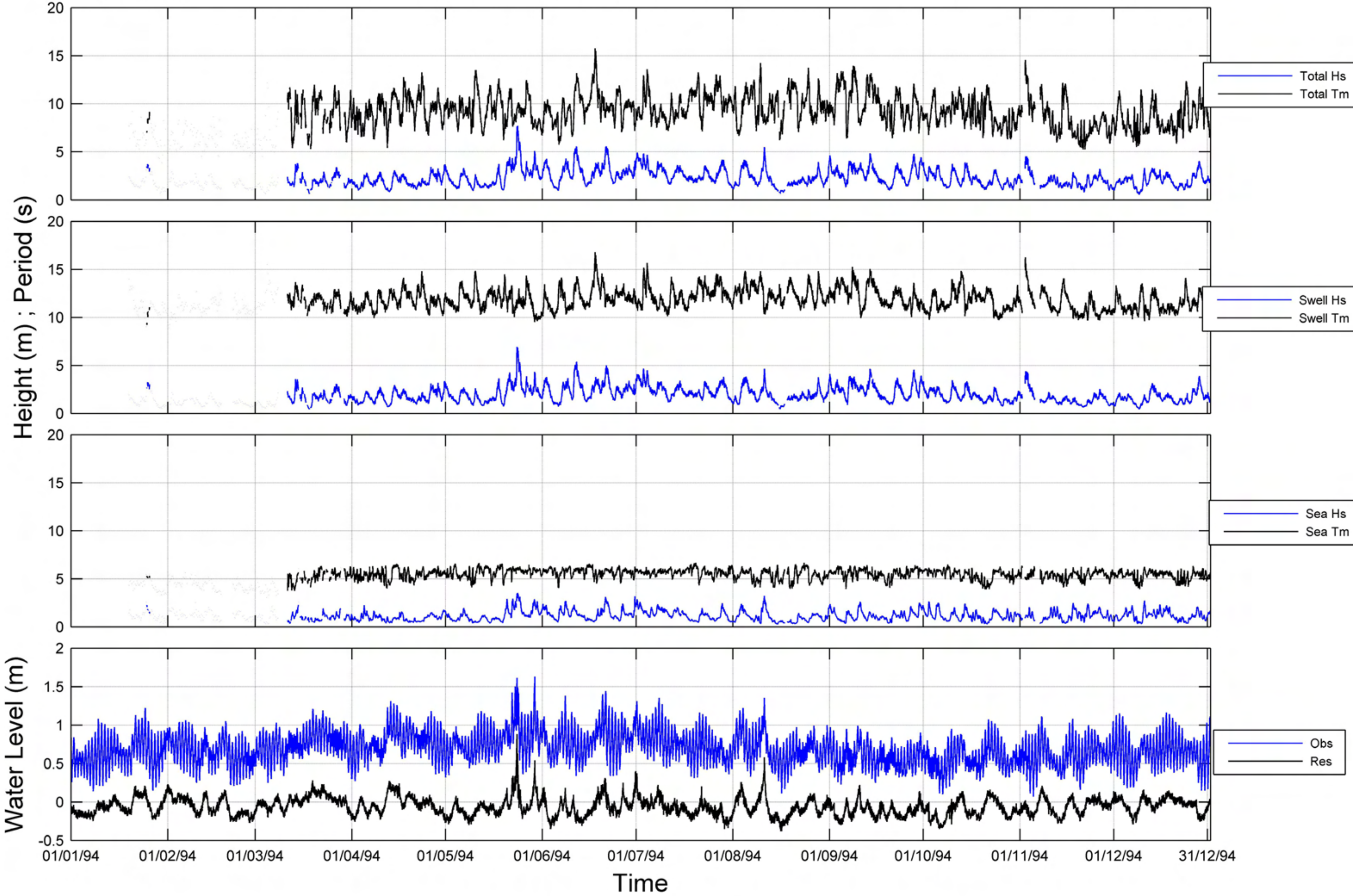
Datawell - Oceanographic Instruments

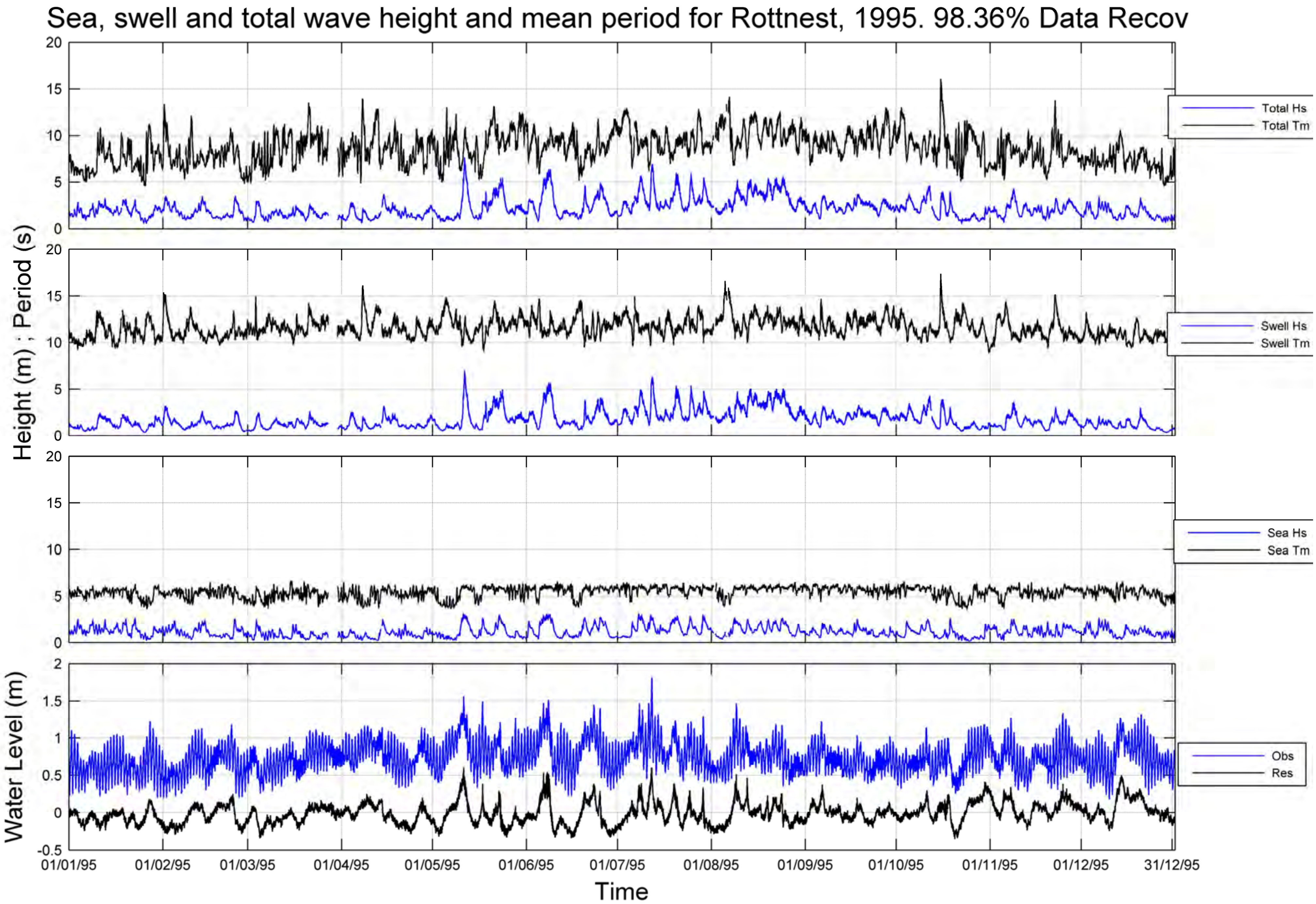
Specifications

Wave height	Range	−20 m - +20 m
	Noise	0.02 m peak - peak (bandwidth 1 Hz)
	Frequency range	0.065 Hz - 0.45 Hz (0.3 dB) (0.9 m diameter) 0.035 Hz - 0.55 Hz (3 dB) 0.065 Hz - 0.5 Hz (0.3 dB) (0.7 m diameter) 0.035 Hz - 0.65 Hz (3 dB)
Standard features	Flash light	Xenon tube, color yellow, pattern 5 flashes every 20 seconds, visibility range about 4 nautical miles
	HF transmitter	frequency range 26 MHz - 44 MHz transmission range 50 Km (over sea) radiated power 80 mW ±20 %
Options	Water temperature	range 0.7 ºC - +39.5 ºC, resolution 0.02 ºC, accuracy 0.2 ºC
	Hull painting	Brantho Korrux “3 in 1”paint system (no anti-fouling)
General	Hull diameter	0.9 m (0.7 m) (excluding fender)
	Weight	171 Kg (102 Kg)
	Material	3 mm (2 mm) AISI 316 stainless steel or Cunifer 10, Cunifer 10 does not suffer from pitting and fouling
	Mooring	standard, 15 m of 35 mm rubber cord (enables the Waverider to follow the wave orbital movement)
	Batteries	operational life 28 months (14 months), 26 (13) batteries, type Datacell RC25G (green)
	Receiver	DIWAR

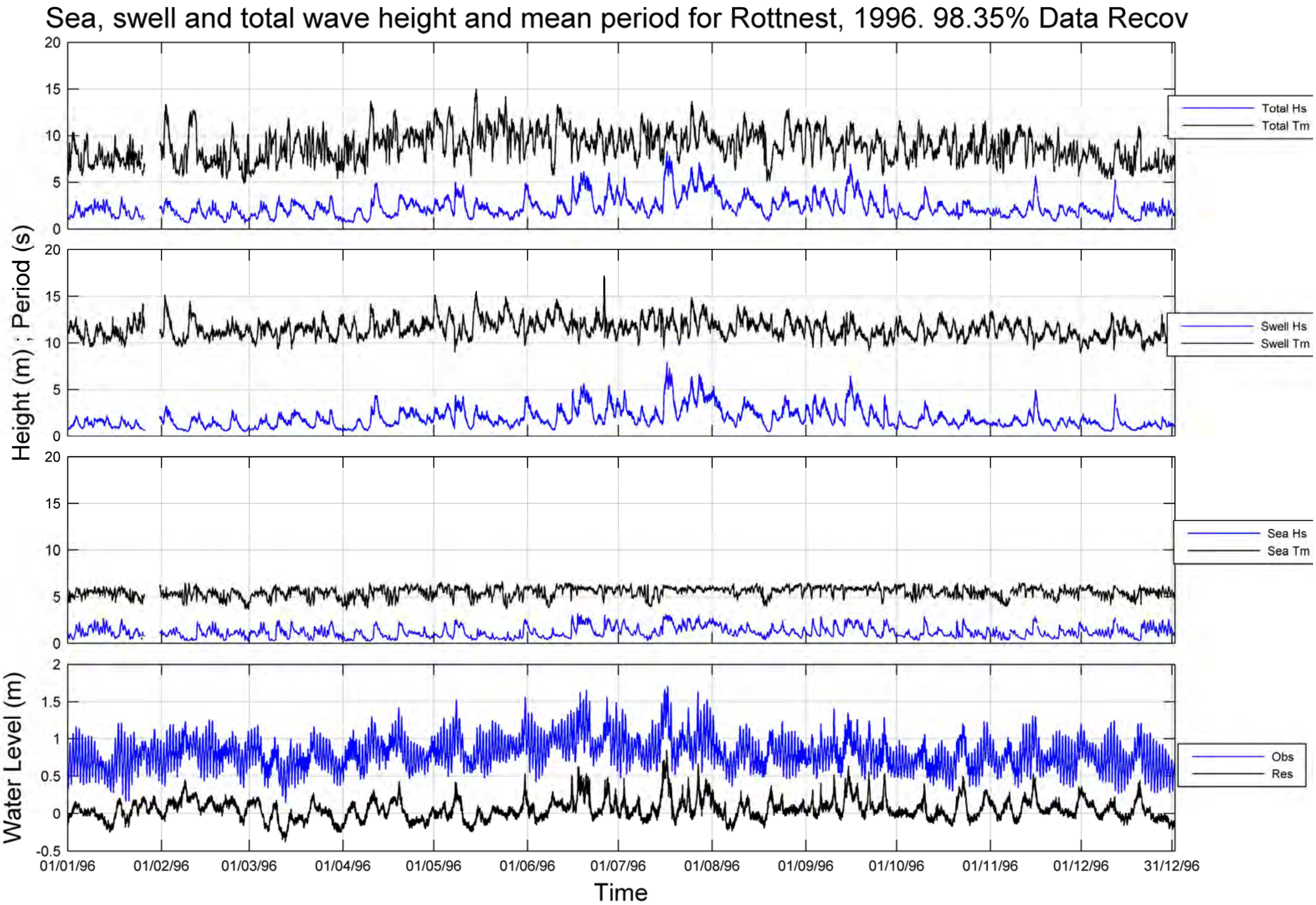
Appendix B: Yearly Timeseries Plots

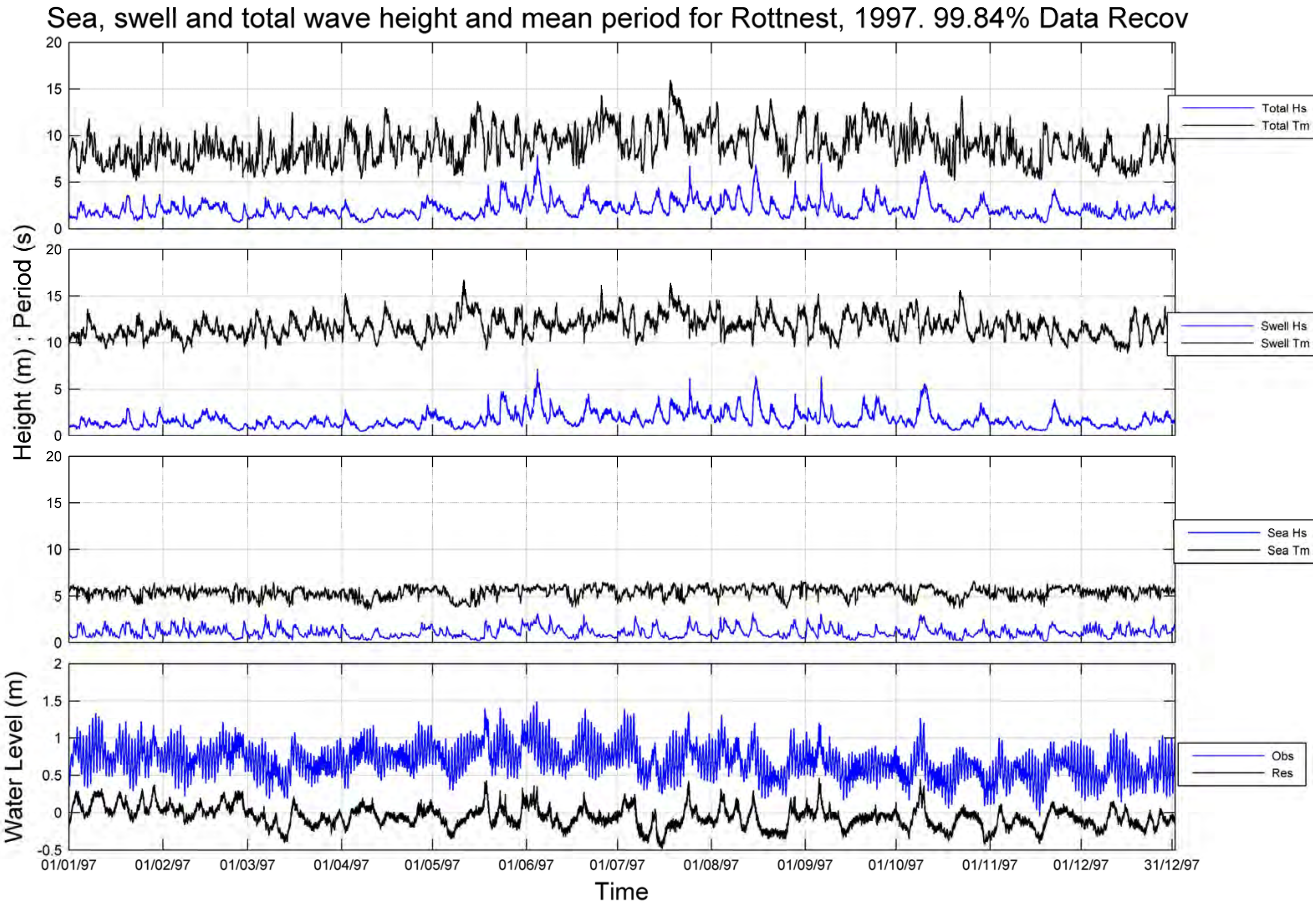
Sea, swell and total wave height and mean period for Rottnest, 1994. 85.14% Data Recov





Sea, swell and total wave height and mean period for Rottnest, 1995. 98.36% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/95
01/02/95
01/03/95
01/04/95
01/05/95
01/06/95
01/07/95
01/08/95
01/09/95
01/10/95
01/11/95
01/12/95
31/12/95
Time


Sea, swell and total wave height and mean period for Rottnest, 1996. 98.35% Data Recov
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Obs
Res
Height (m) ; Period (s)
Water Level (m)
Time
01/01/96
01/02/96
01/03/96
01/04/96
01/05/96
01/06/96
01/07/96
01/08/96
01/09/96
01/10/96
01/11/96
01/12/96
31/12/96



Sea, swell and total wave height and mean period for Rottnest, 1997. 99.84% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/97
01/02/97
01/03/97
01/04/97
01/05/97
01/06/97
01/07/97
01/08/97
01/09/97
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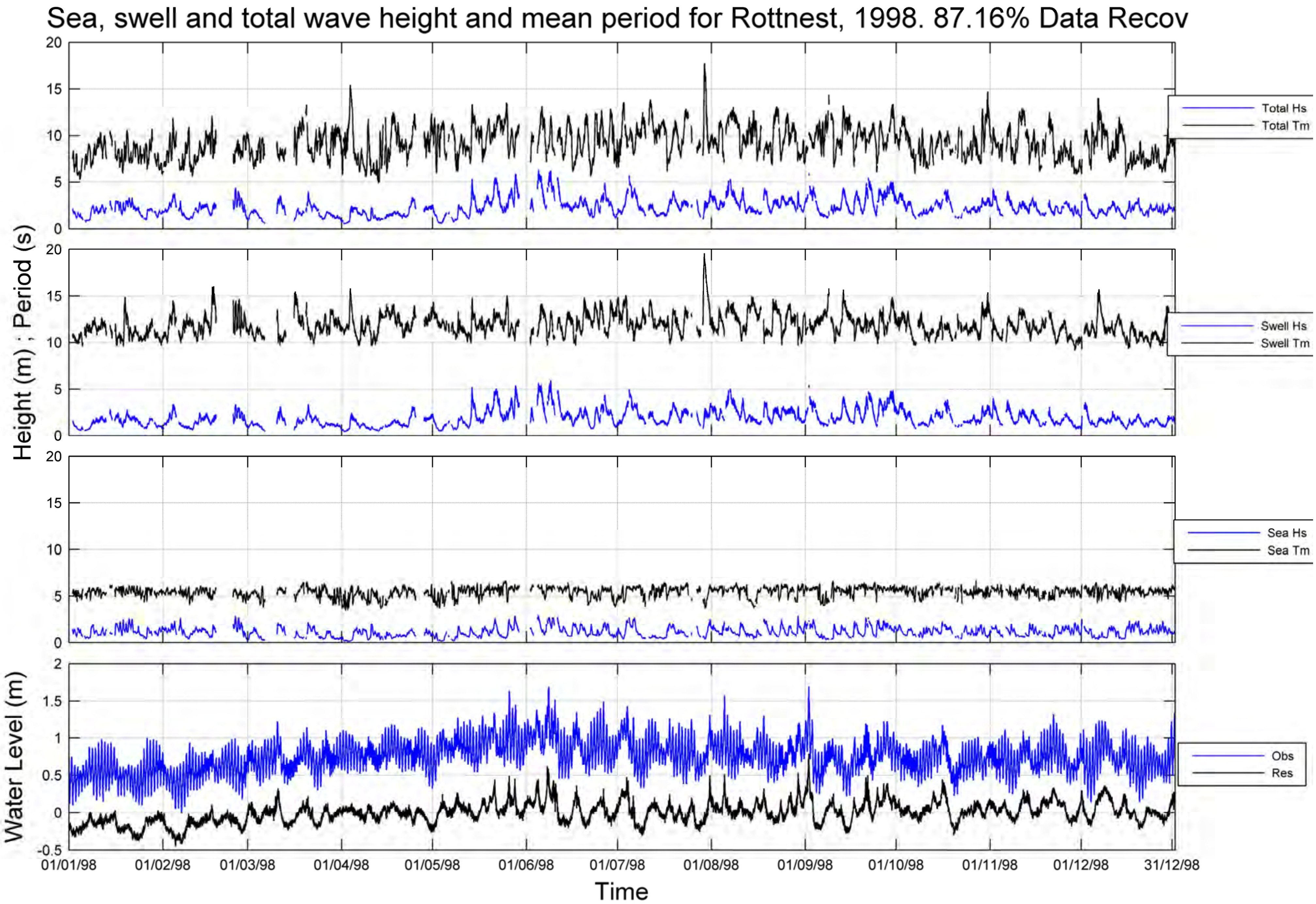
01/12/97
31/12/97
Time


Sea, swell and total wave height and mean period for Rottnest, 1998. 87.16% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/98
01/02/98
01/03/98
01/04/98
01/05/98
01/06/98
01/07/98
01/08/98
01/09/98
01/10/98
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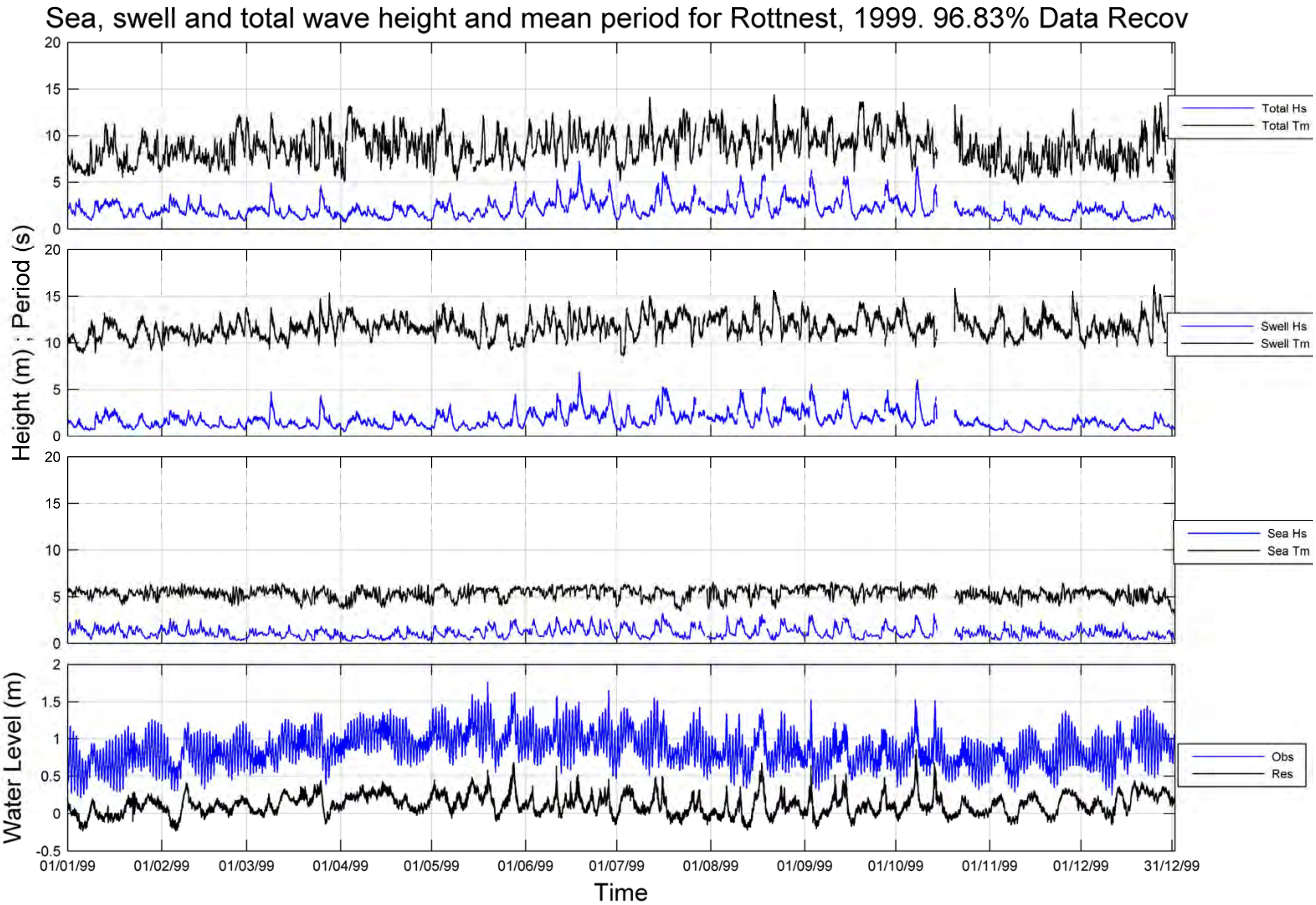
01/12/98
31/12/98
Time



Sea, swell and total wave height and mean period for Rottnest, 1999. 96.83% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/99
01/02/99
01/03/99
01/04/99
01/05/99
01/06/99
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01/08/99
01/09/99
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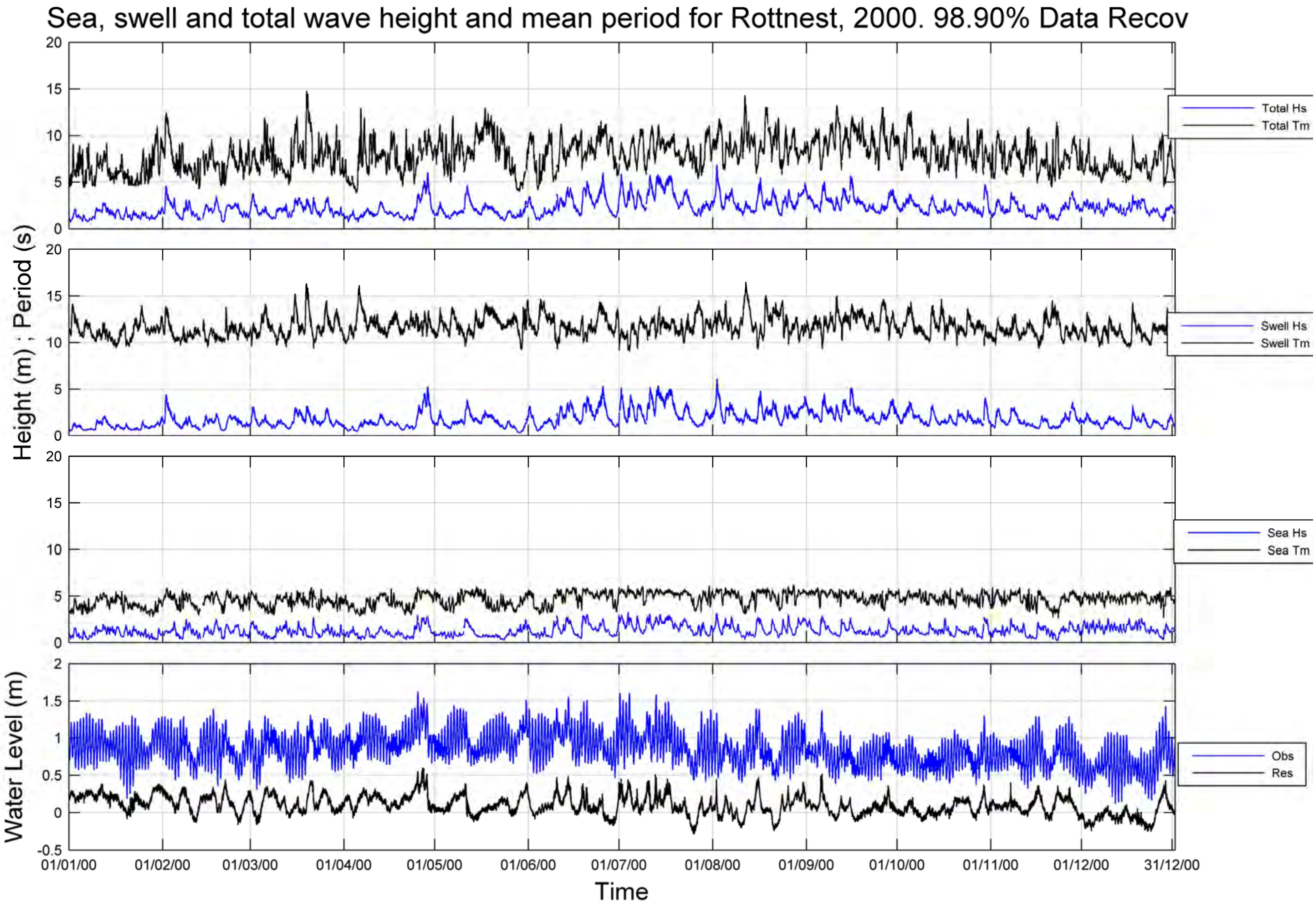
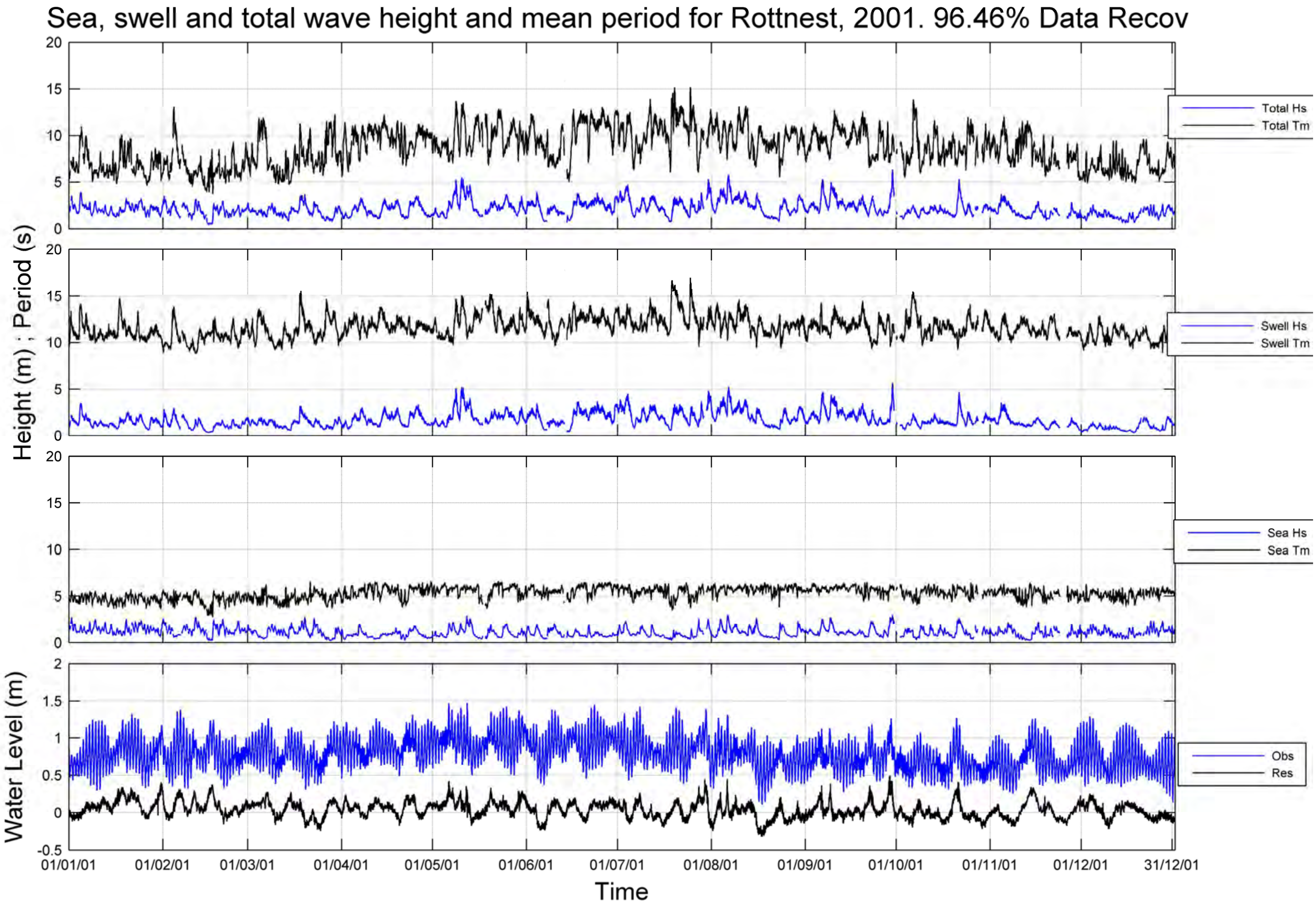
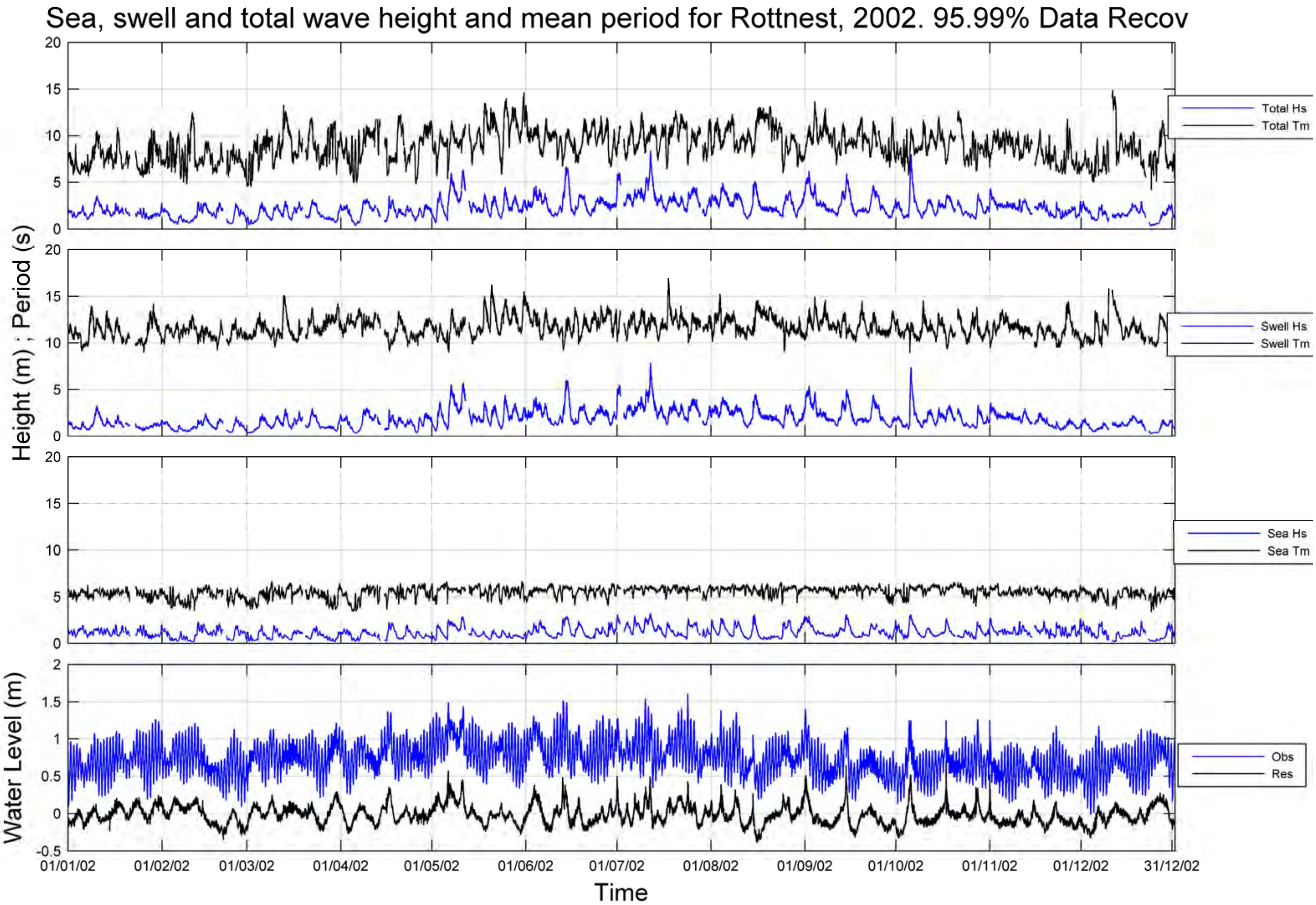
01/11/99
01/12/99
31/12/99
Time

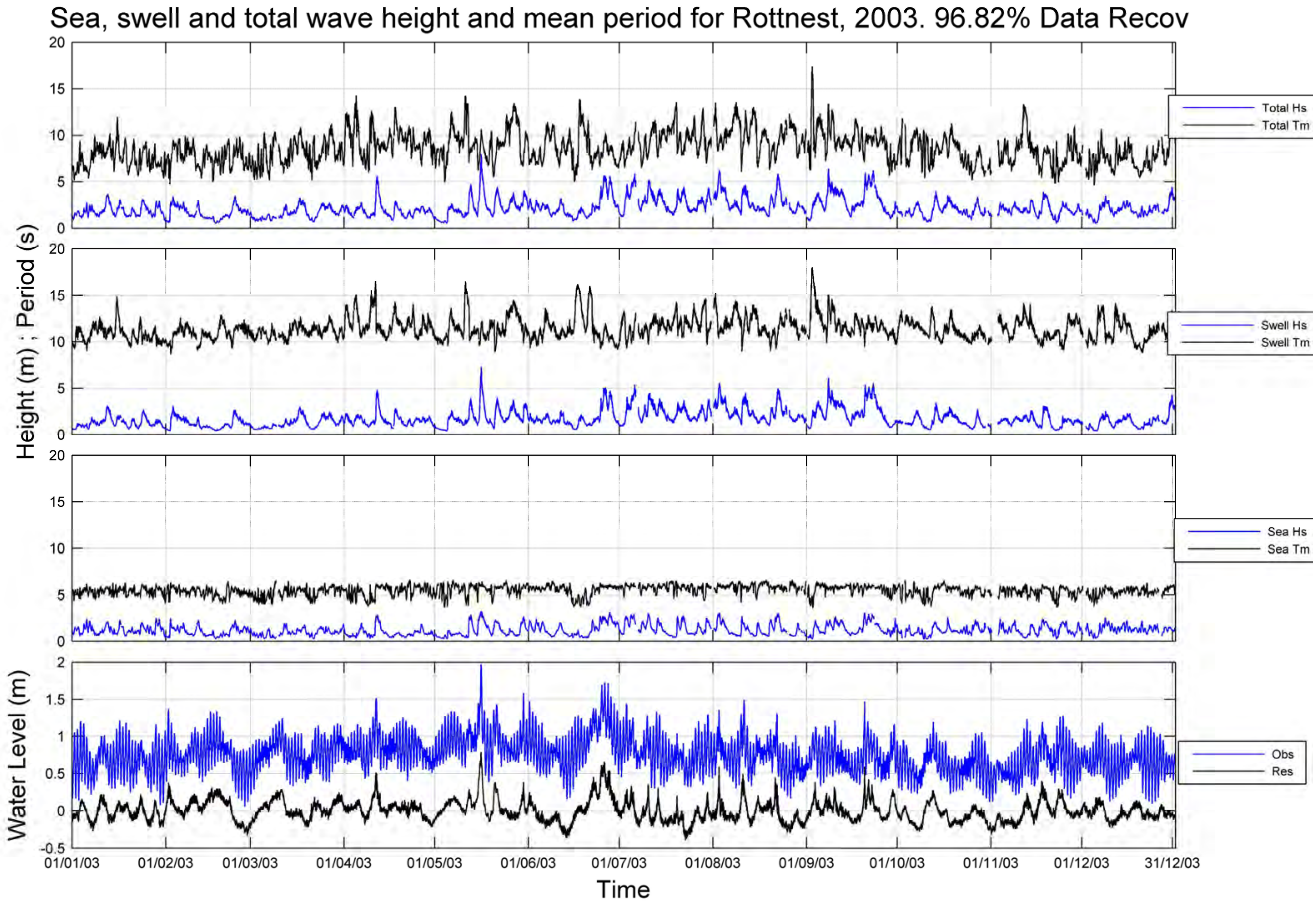


Sea, swell and total wave height and mean period for Rottnest, 2000. 98.90% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/00
01/02/00
01/03/00
01/04/00
01/05/00
01/06/00
01/07/00
01/08/00
01/09/00
01/10/00
01/11/00
01/12/00
31/12/00
Time

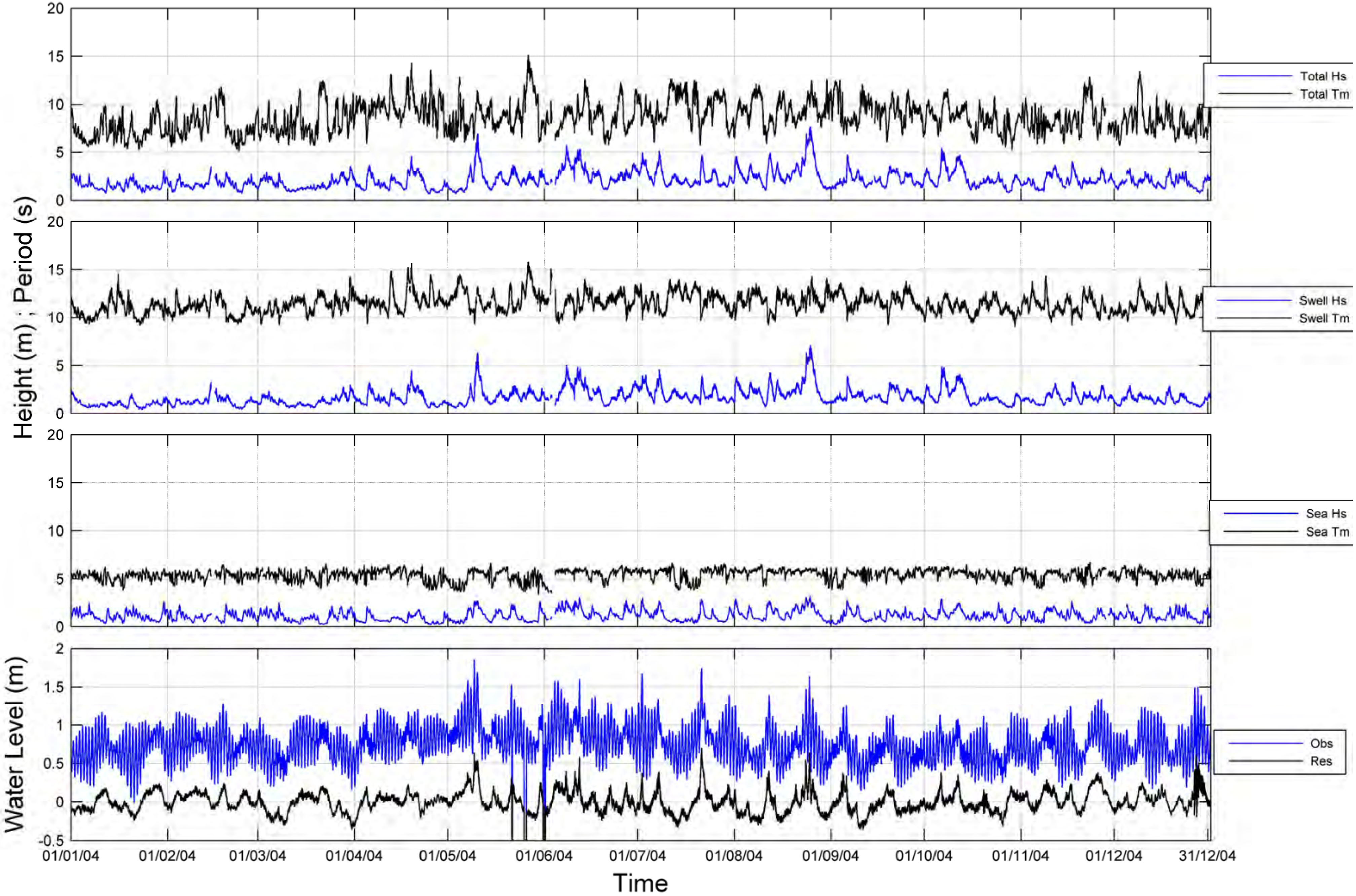


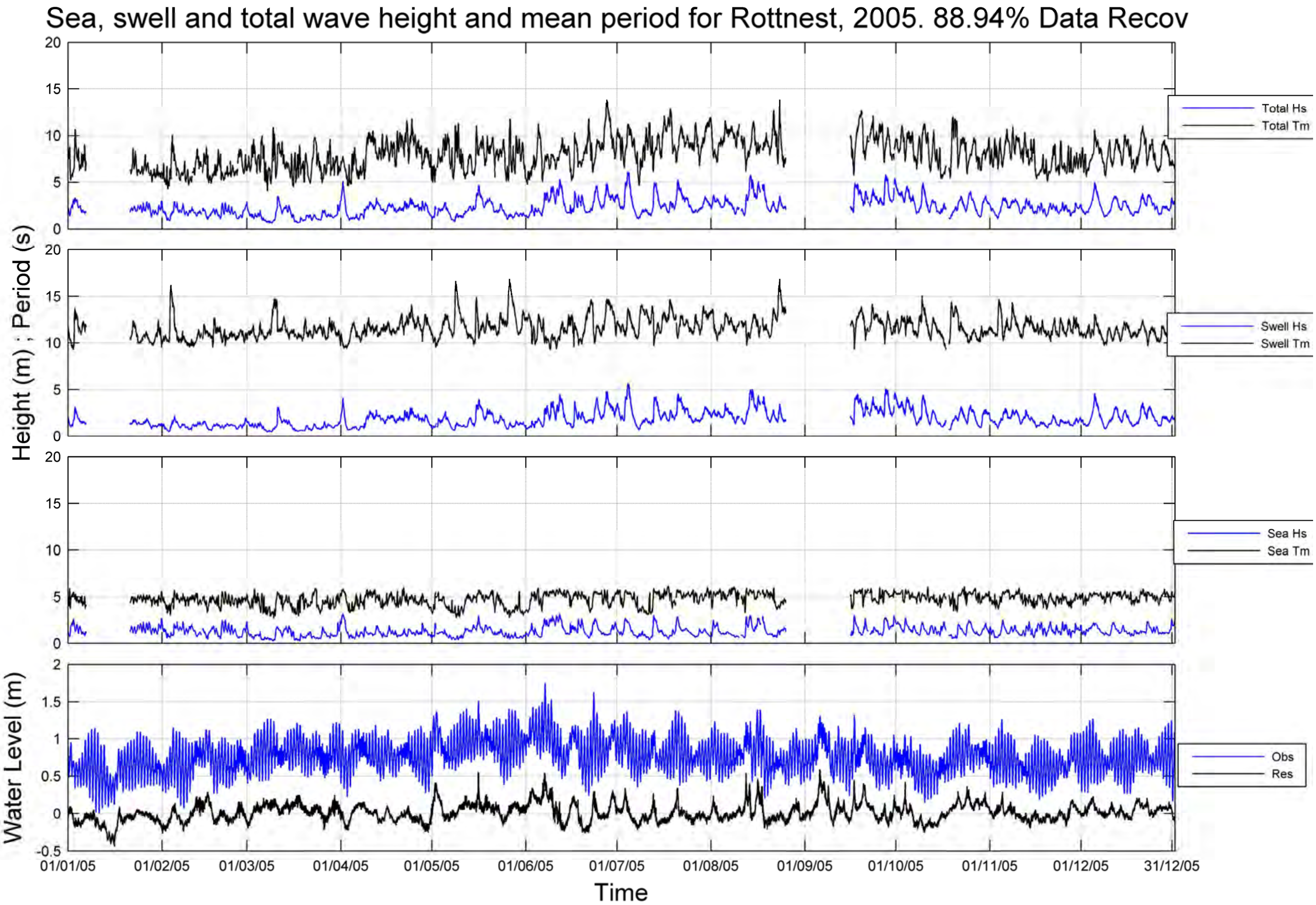
Sea, swell and total wave height and mean period for Rottnest, 2001. 96.46% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/01
01/02/01
01/03/01
01/04/01
01/05/01
01/06/01
01/07/01
01/08/01
01/09/01
01/10/01
01/11/01
01/12/01
31/12/01
Time


Sea, swell and total wave height and mean period for Rottnest, 2002. 95.99% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/02
01/02/02
01/03/02
01/04/02
01/05/02
01/06/02
01/07/02
01/08/02
01/09/02
01/10/02
01/11/02
01/12/02
31/12/02
Time


Sea, swell and total wave height and mean period for Rottnest, 2003. 96.82% Data Recov
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Obs
Res
Height (m) ; Period (s)
Water Level (m)
Time
01/01/03
01/02/03
01/03/03
01/04/03
01/05/03
01/06/03
01/07/03
01/08/03
01/09/03
01/10/03
01/11/03
01/12/03
31/12/03

Sea, swell and total wave height and mean period for Rottnest, 2004. 98.15% Data Recov





Sea, swell and total wave height and mean period for Rottnest, 2005. 88.94% Data Recov
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Obs
Res
Height (m) ; Period (s)
Water Level (m)
Time
01/01/05
01/02/05
01/03/05
01/04/05
01/05/05
01/06/05
01/07/05
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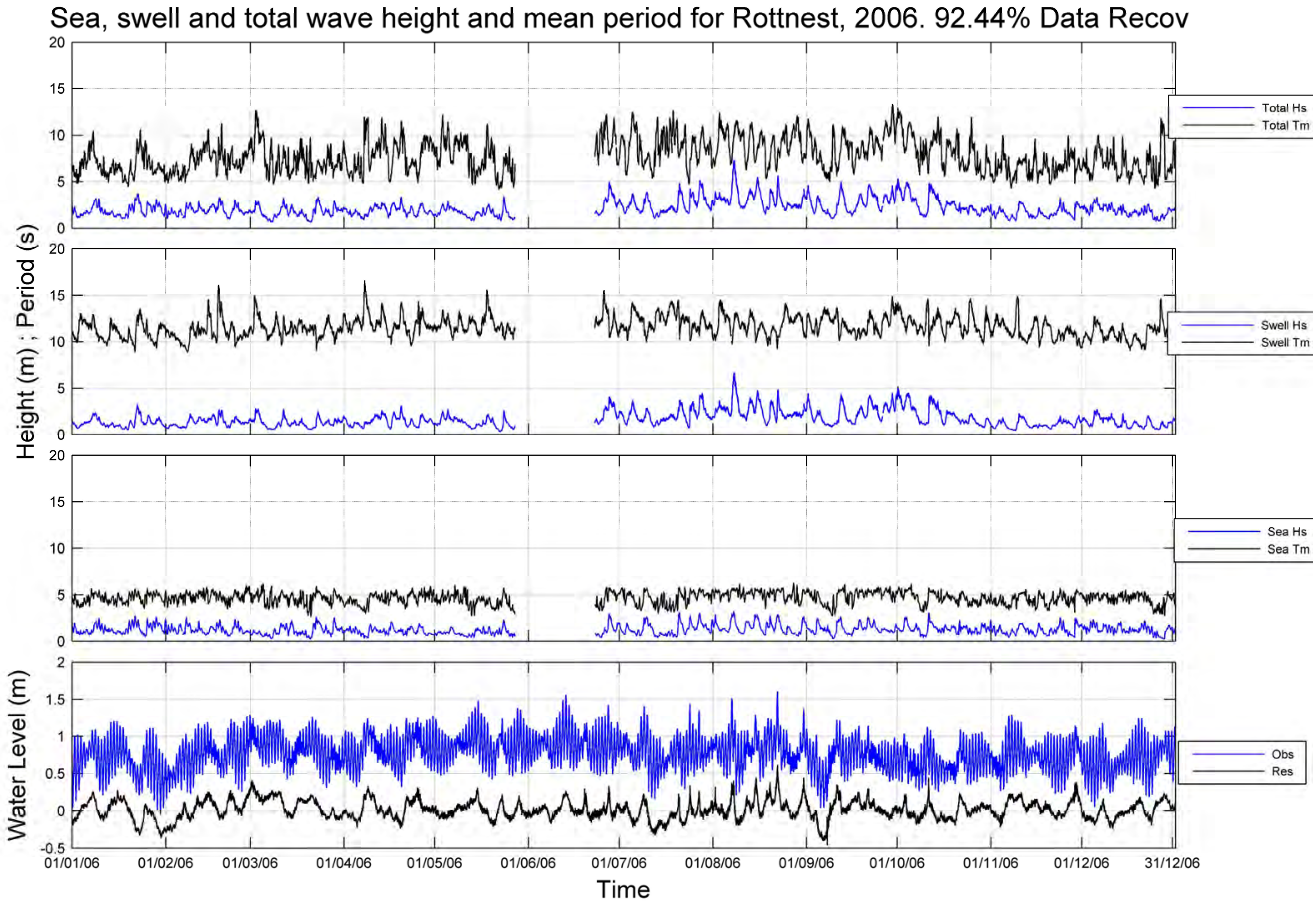
01/09/05
01/10/05
01/11/05
01/12/05
31/12/05


Sea, swell and total wave height and mean period for Rottnest, 2006. 92.44% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/06
01/02/06
01/03/06
01/04/06
01/05/06
01/06/06
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01/08/06
01/09/06
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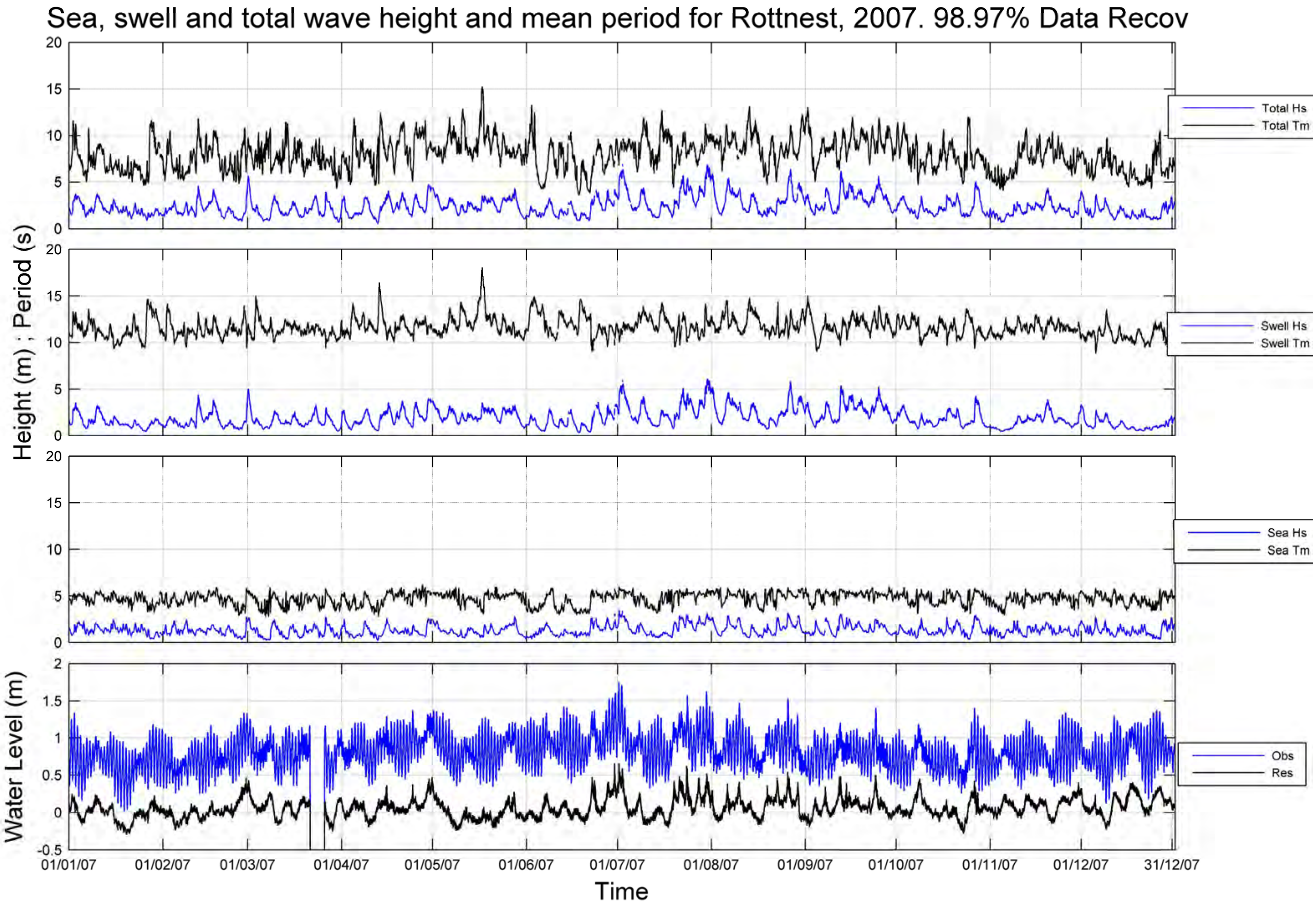
01/11/06
01/12/06
31/12/06
Time


Sea, swell and total wave height and mean period for Rottnest, 2007. 98.97% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/07
01/02/07
01/03/07
01/04/07
01/05/07
01/06/07
01/07/07
01/08/07
01/09/07
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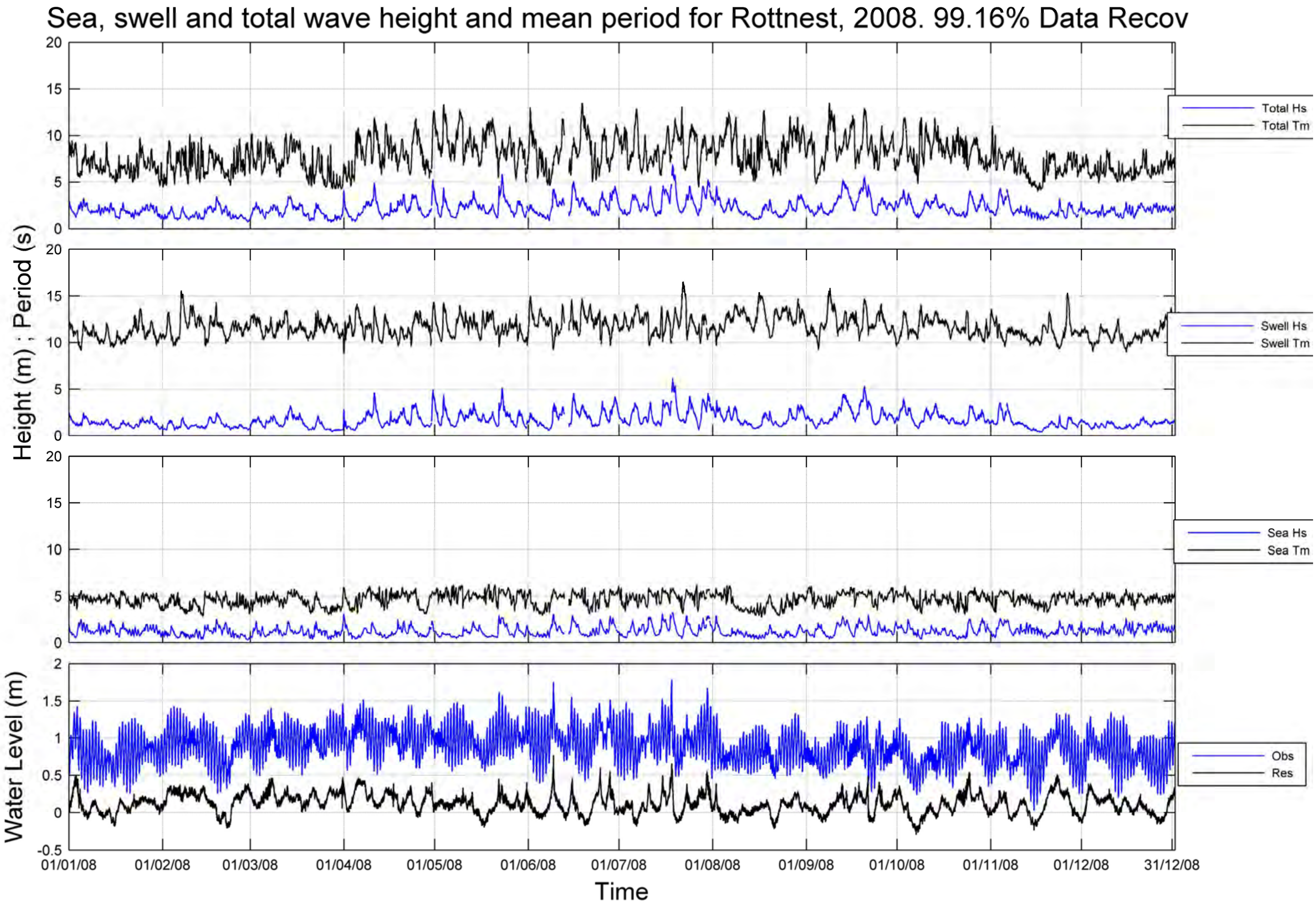
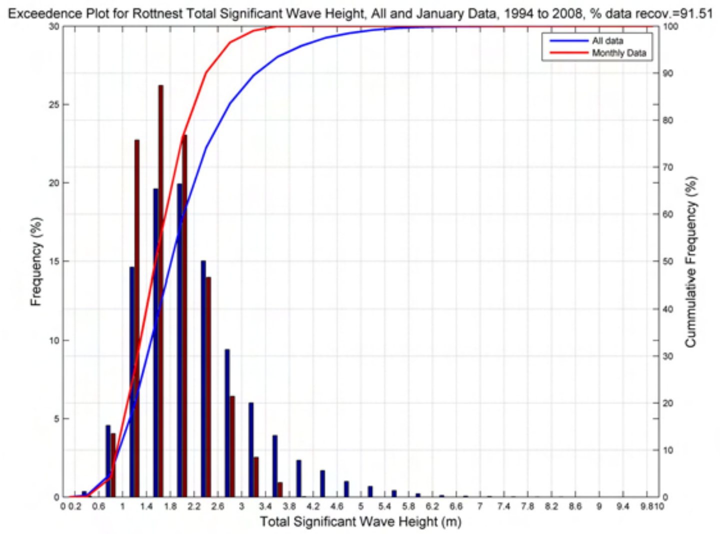
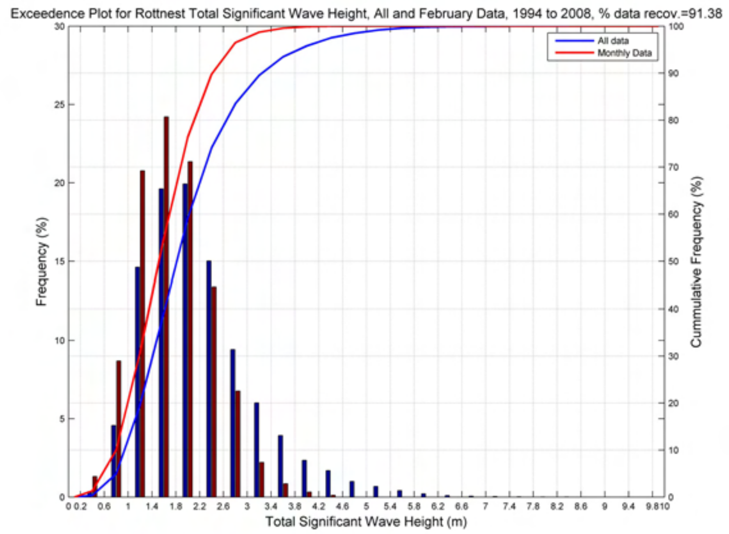
01/12/07
31/12/07
Time

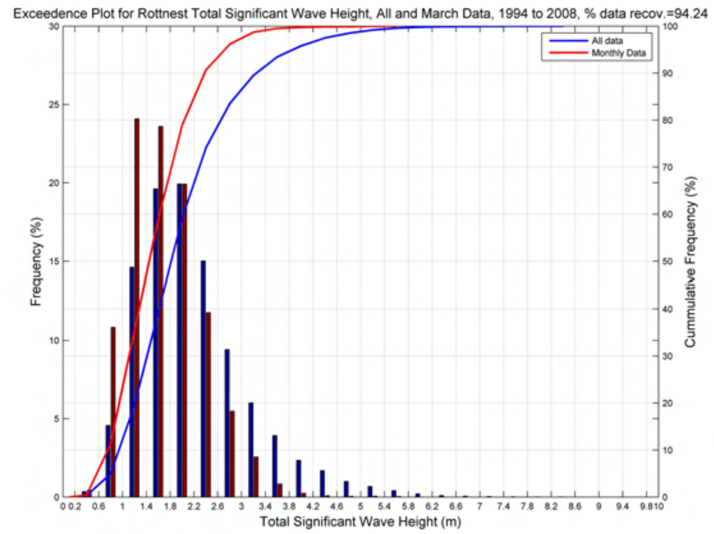


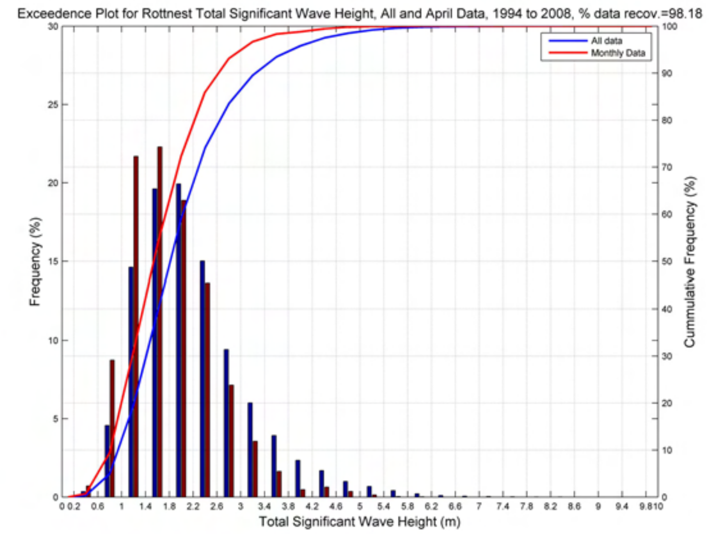
Sea, swell and total wave height and mean period for Rottnest, 2008. 99.16% Data Recov
Height (m) ; Period (s)
Total Hs
Total Tm
Swell Hs
Swell Tm
Sea Hs
Sea Tm
Water Level (m)
Obs
Res
01/01/08
01/02/08
01/03/08
01/04/08
01/05/08
01/06/08
01/07/08
01/08/08
01/09/08
01/10/08
01/11/08
01/12/08
31/12/08
Time

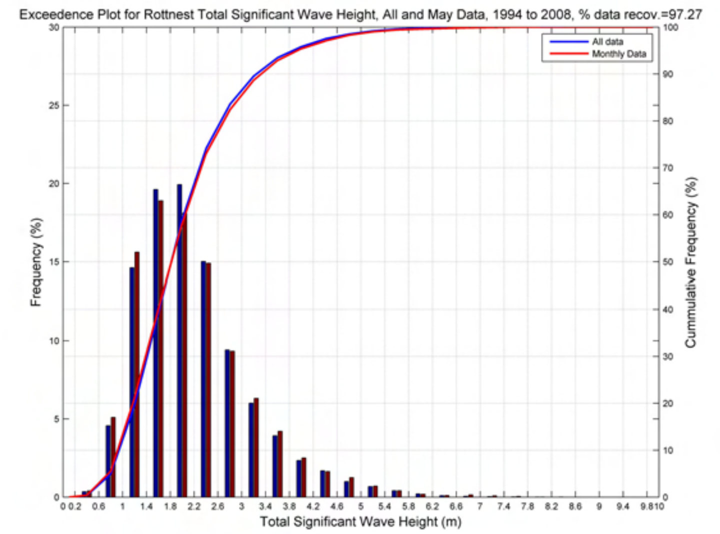
Appendix C: Monthly Variations of H_s Distributions

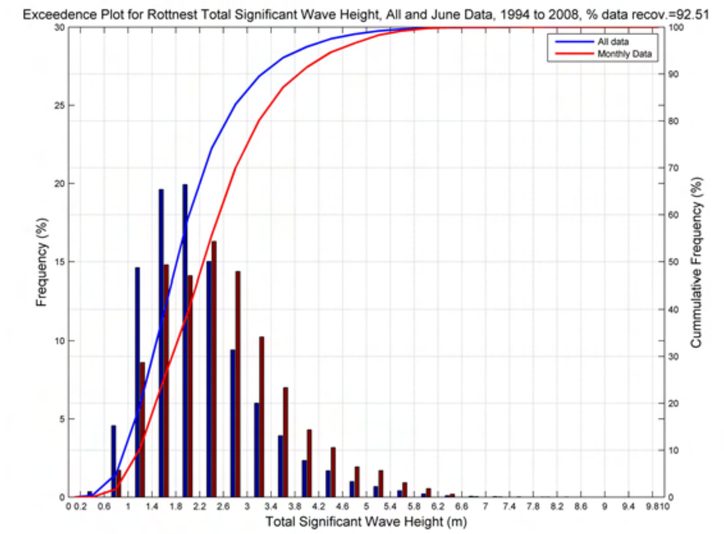

Exceedence Plot for Rottnest Total Significant Wave Height, All and January Data, 1994 to 2008, % data recov.=91.51
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

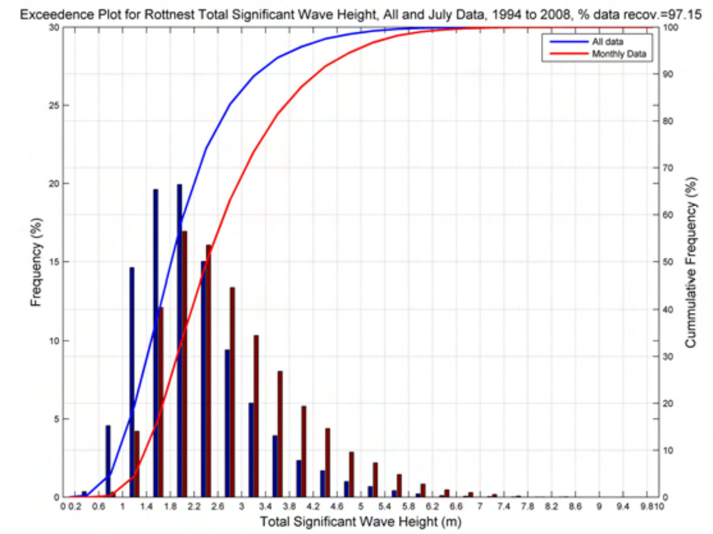

Exceedence Plot for Rottnest Total Significant Wave Height, All and February Data, 1994 to 2008, % data recov.=91.38
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

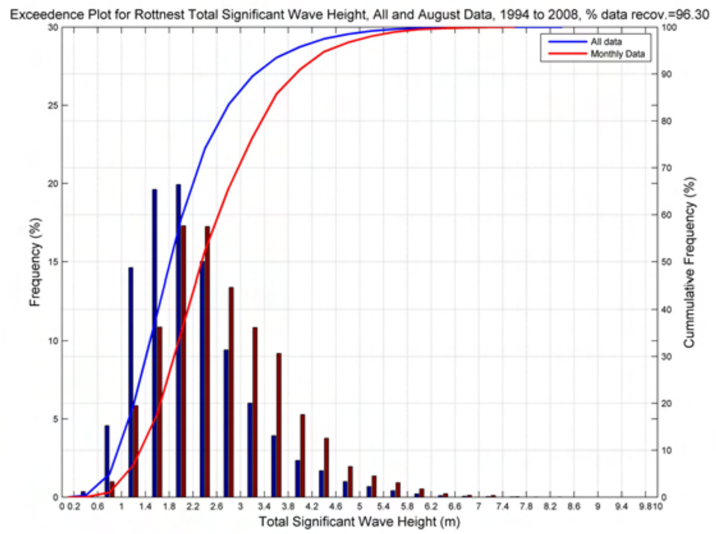

Exceedence Plot for Rottnest Total Significant Wave Height, All and March Data, 1994 to 2008, % data recov.=94.24
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

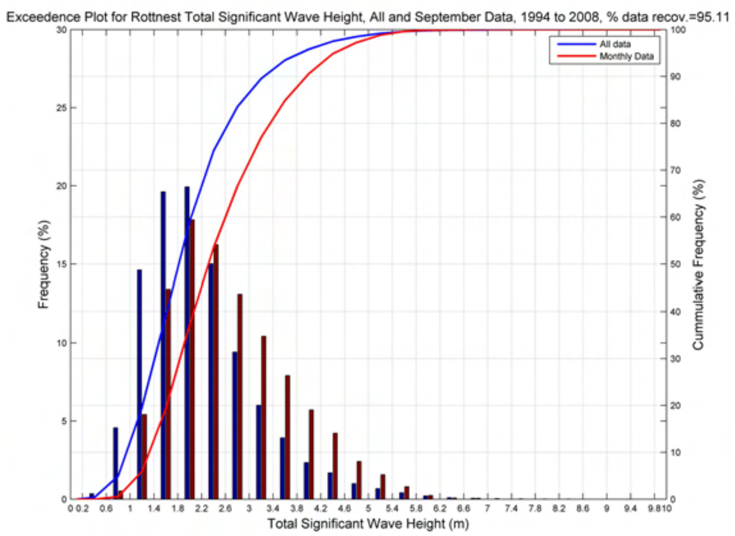

Exceedence Plot for Rottnest Total Significant Wave Height, All and April Data, 1994 to 2008, % data recov.=98.18
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

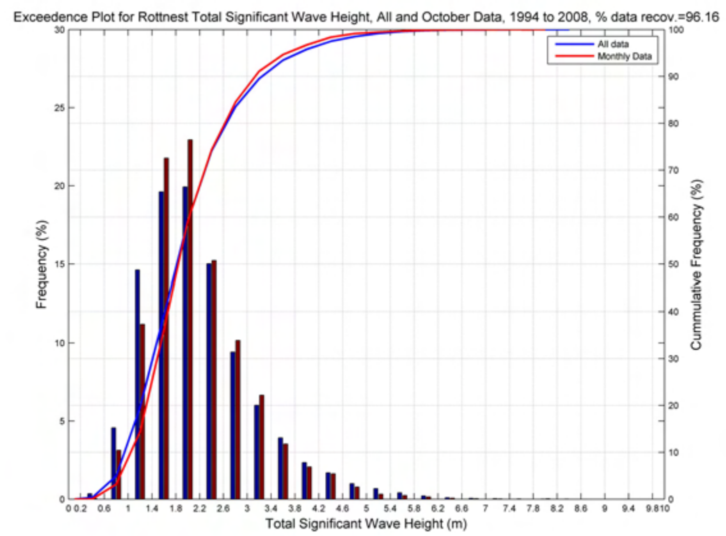

Exceedence Plot for Rottnest Total Significant Wave Height, All and May Data, 1994 to 2008, % data recov.=97.27
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

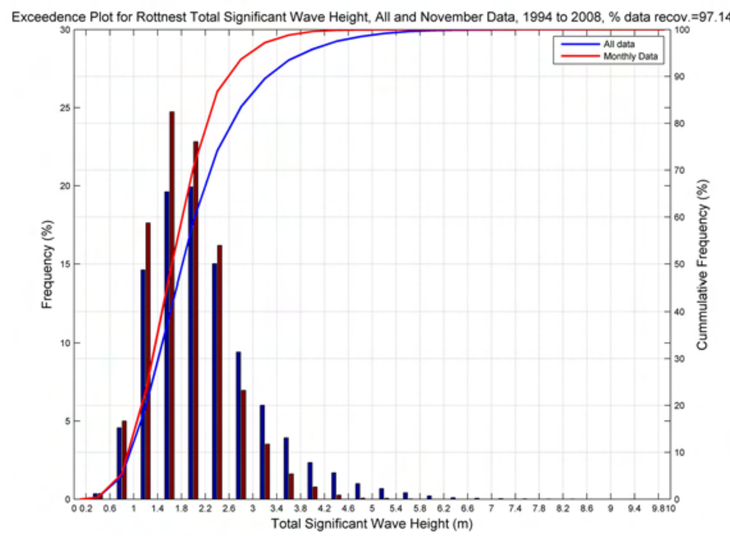

Exceedence Plot for Rottnest Total Significant Wave Height, All and June Data, 1994 to 2008, % data recov.=92.51
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

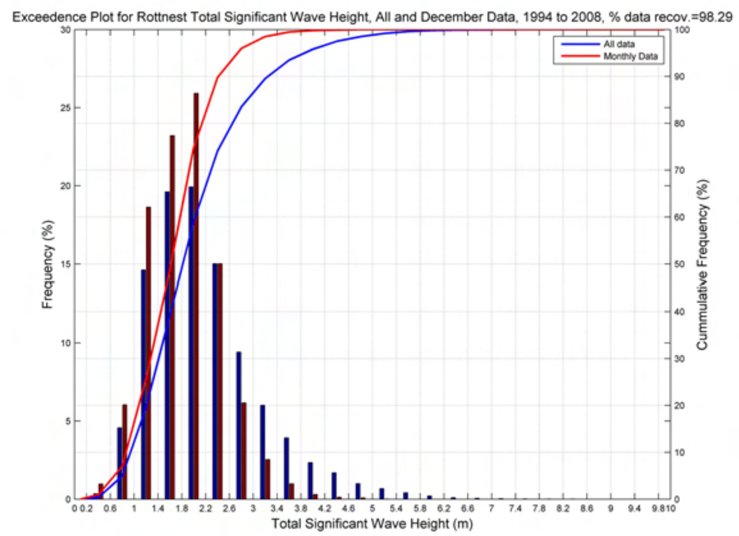

Exceedence Plot for Rottnest Total Significant Wave Height, All and July Data, 1994 to 2008, % data recov.=97.15
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)


Exceedence Plot for Rottnest Total Significant Wave Height, All and August Data, 1994 to 2008, % data recov.=96.30
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

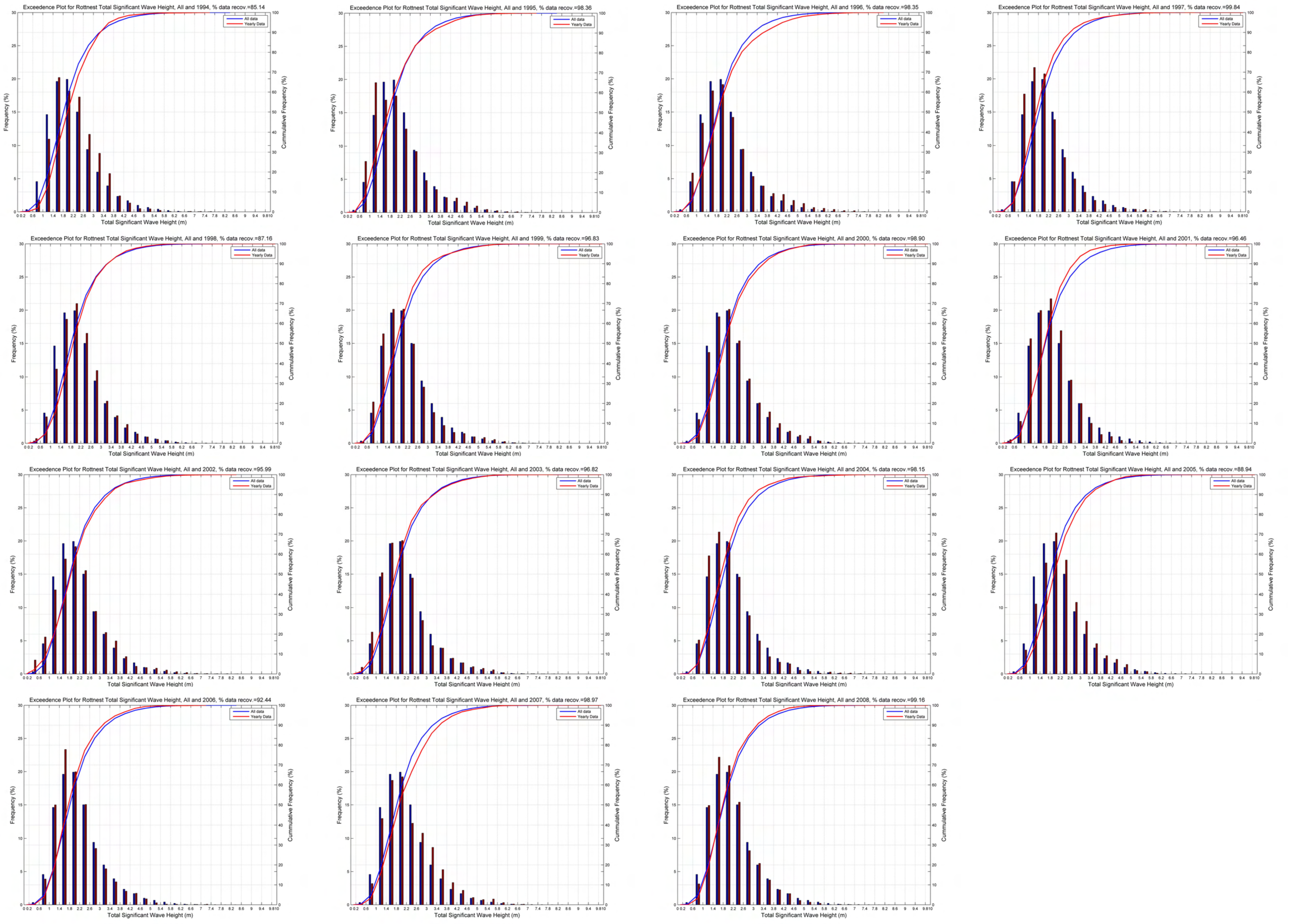

Exceedence Plot for Rottnest Total Significant Wave Height, All and September Data, 1994 to 2008, % data recov.=95.11
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)


Exceedence Plot for Rottnest Total Significant Wave Height, All and October Data, 1994 to 2008, % data recov.=96.16
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)


Exceedence Plot for Rottnest Total Significant Wave Height, All and November Data, 1994 to 2008, % data recov.=97.14
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

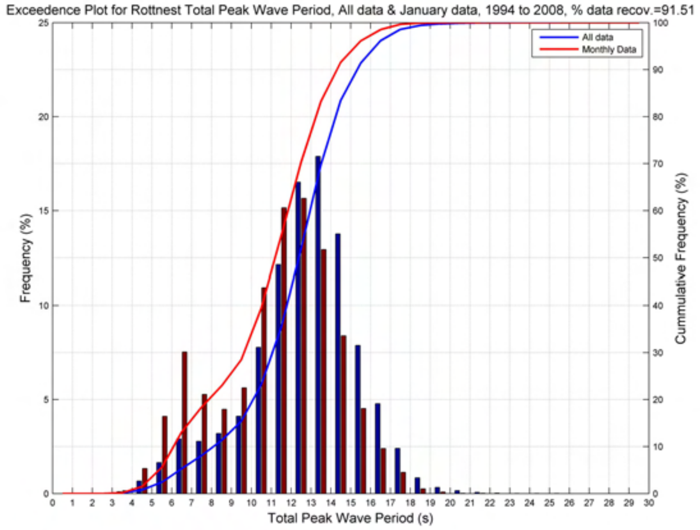

Exceedence Plot for Rottnest Total Significant Wave Height, All and December Data, 1994 to 2008, % data recov.=98.29
All data
Monthly Data
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)

Appendix D: Yearly Variations of H_s Distributions

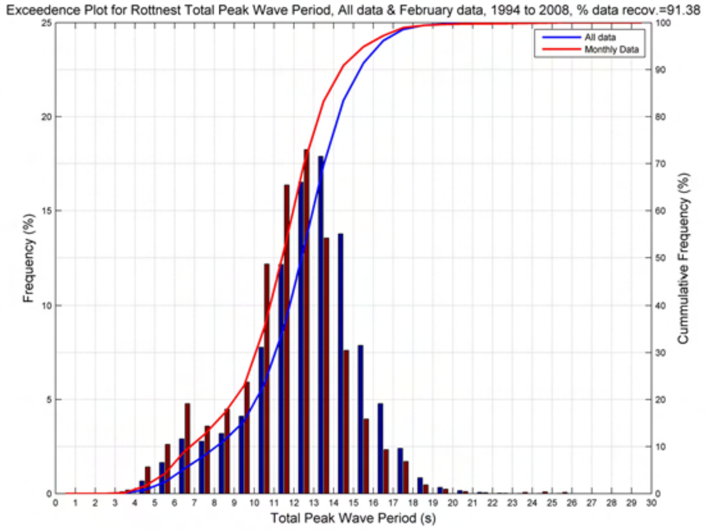

Exceedence Plot for Rottnest Total Significant Wave Height, All and 1994, % data recov.=85.14
Exceedence Plot for Rottnest Total Significant Wave Height, All and 1995, % data recov.=98.36
Exceedence Plot for Rottnest Total Significant Wave Height, All and 1996, % data recov.=98.35
Exceedence Plot for Rottnest Total Significant Wave Height, All and 1997, % data recov.=99.84
Exceedence Plot for Rottnest Total Significant Wave Height, All and 1998, % data recov.=87.16
Exceedence Plot for Rottnest Total Significant Wave Height, All and 1999, % data recov.=96.83
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2000, % data recov.=98.90
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2001, % data recov.=96.46
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2002, % data recov.=95.99
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2003, % data recov.=96.82
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2004, % data recov.=98.15
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2005, % data recov.=88.94
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2006, % data recov.=92.44
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2007, % data recov.=98.97
Exceedence Plot for Rottnest Total Significant Wave Height, All and 2008, % data recov.=99.16
Frequency (%)
Cummulative Frequency (%)
Total Significant Wave Height (m)
All data
Yearly Data

Appendix E: Monthly Variations of T_p Distributions

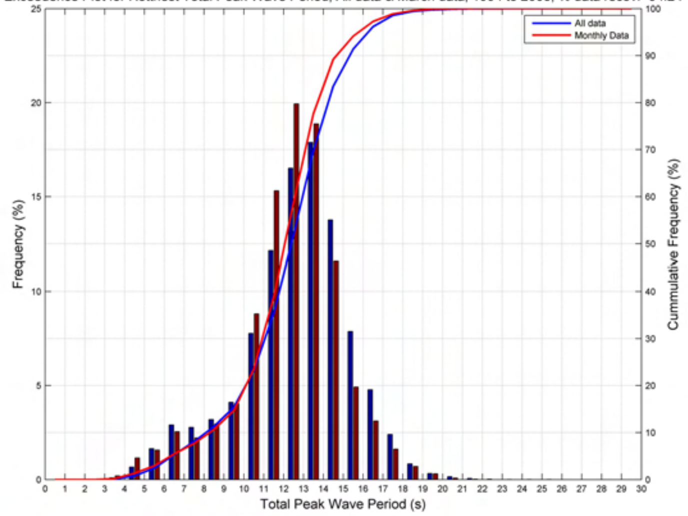
Exceedence Plot for Rottnest Total Peak Wave Period, All data & January data, 1994 to 2008, % data recov.=91.51



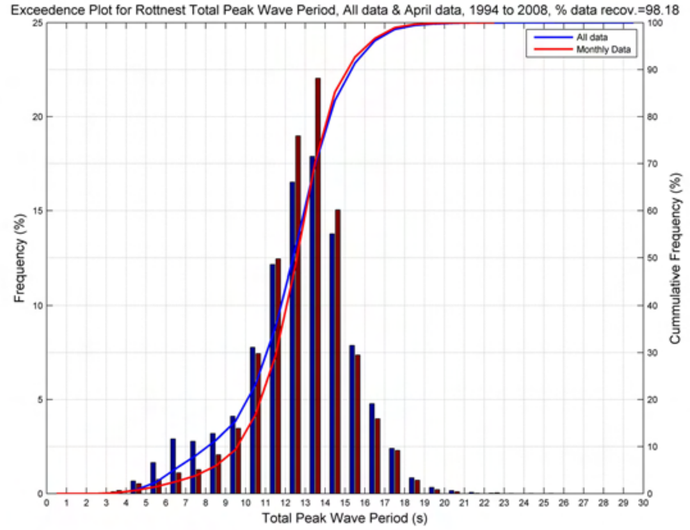
Exceedence Plot for Rottnest Total Peak Wave Period, All data & February data, 1994 to 2008, % data recov.=91.38



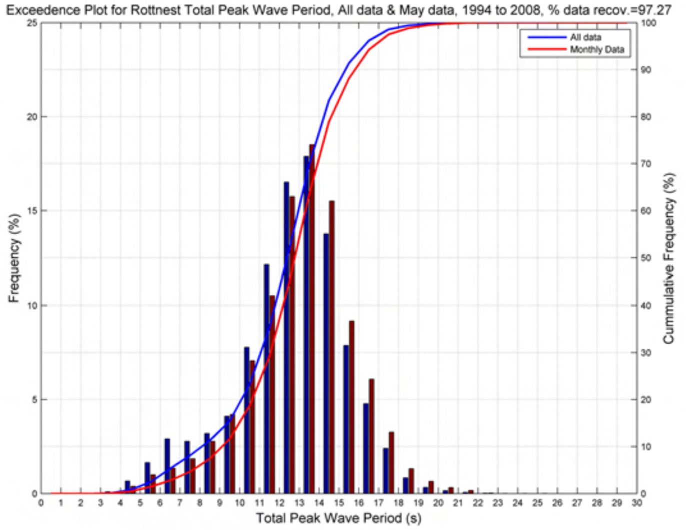
Exceedence Plot for Rottnest Total Peak Wave Period, All data & March data, 1994 to 2008, % data recov.=94.24



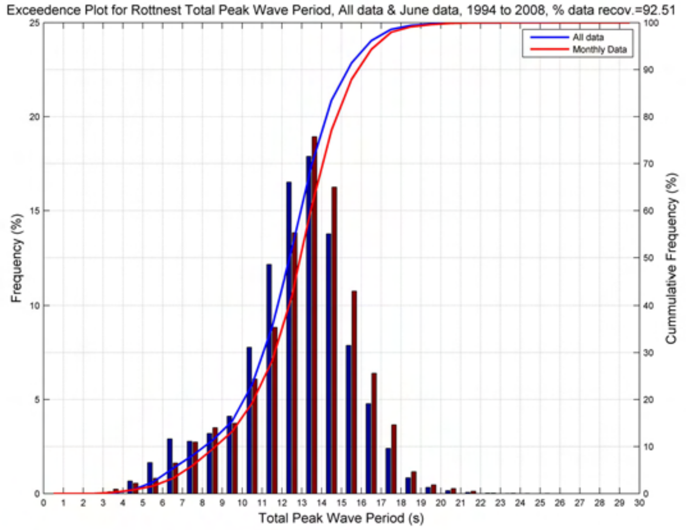
Exceedence Plot for Rottnest Total Peak Wave Period, All data & April data, 1994 to 2008, % data recov.=98.18



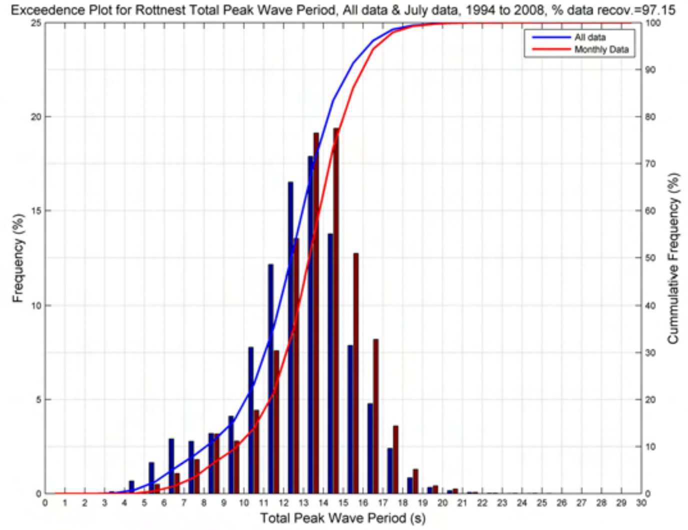
Exceedence Plot for Rottnest Total Peak Wave Period, All data & May data, 1994 to 2008, % data recov.=97.27



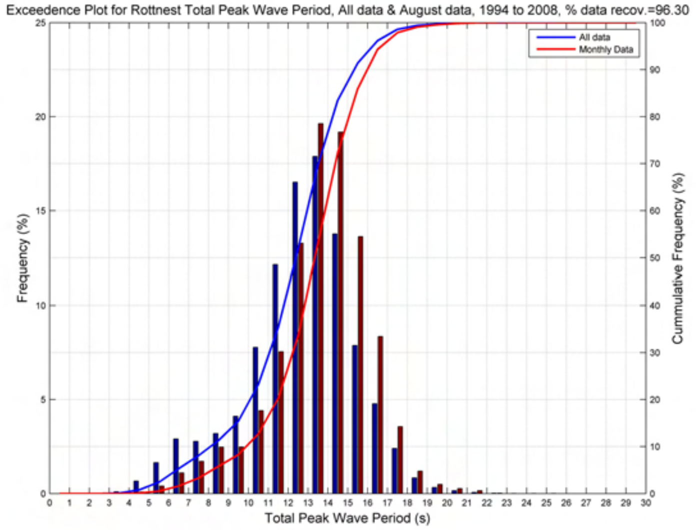
Exceedence Plot for Rottnest Total Peak Wave Period, All data & June data, 1994 to 2008, % data recov.=92.51



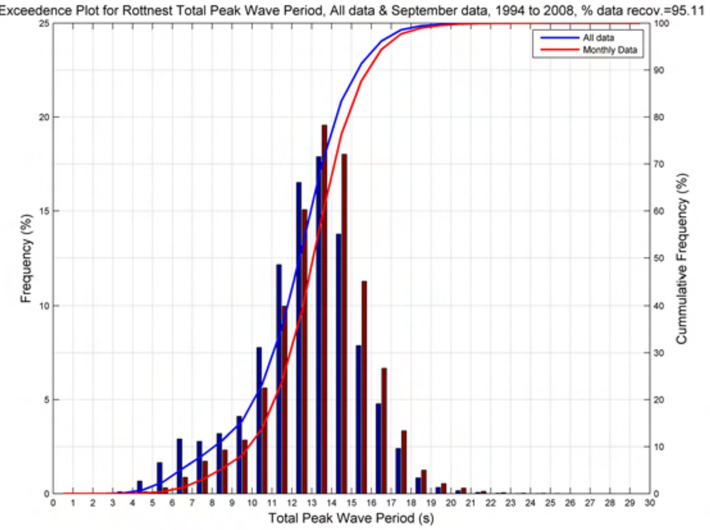
Exceedence Plot for Rottnest Total Peak Wave Period, All data & July data, 1994 to 2008, % data recov.=97.15



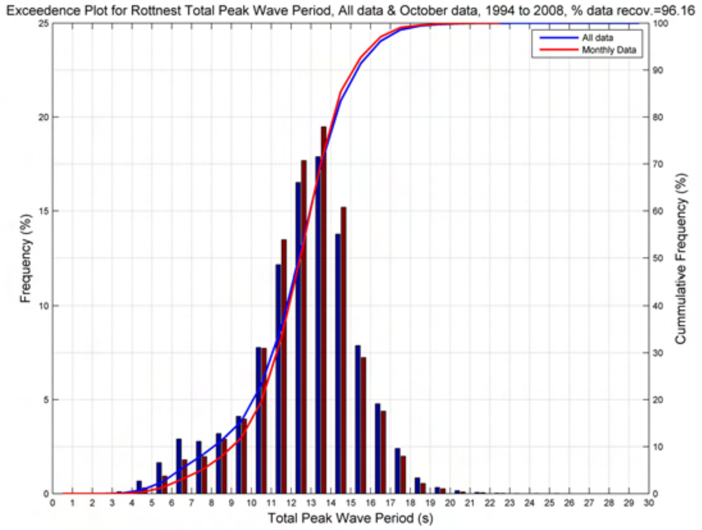
Exceedence Plot for Rottnest Total Peak Wave Period, All data & August data, 1994 to 2008, % data recov.=96.30



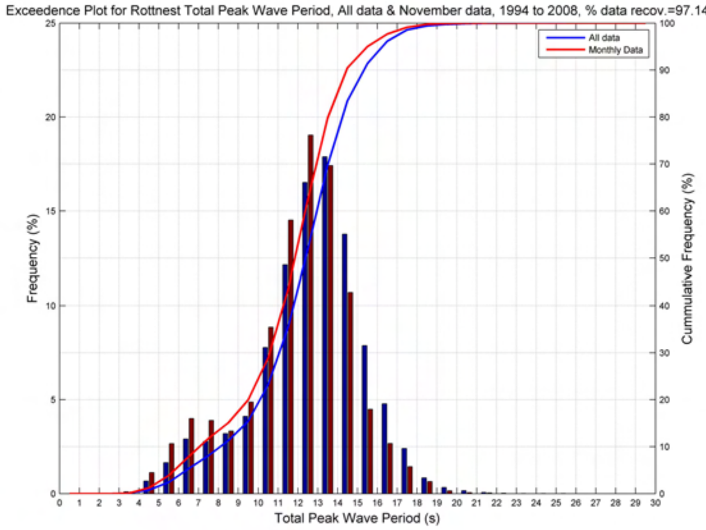
Exceedence Plot for Rottnest Total Peak Wave Period, All data & September data, 1994 to 2008, % data recov.=95.11



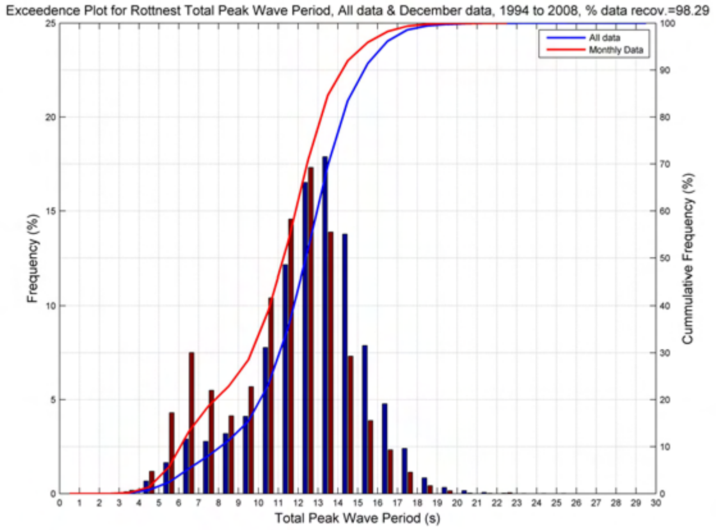
Exceedence Plot for Rottnest Total Peak Wave Period, All data & October data, 1994 to 2008, % data recov.=96.16



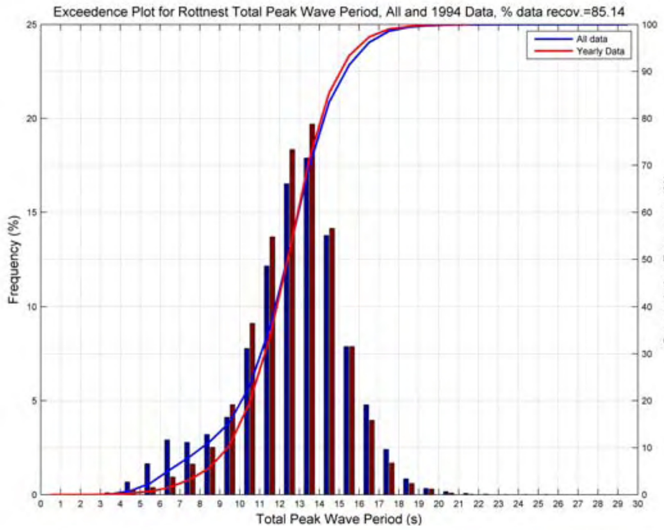
Exceedence Plot for Rottnest Total Peak Wave Period, All data & November data, 1994 to 2008, % data recov.=97.14

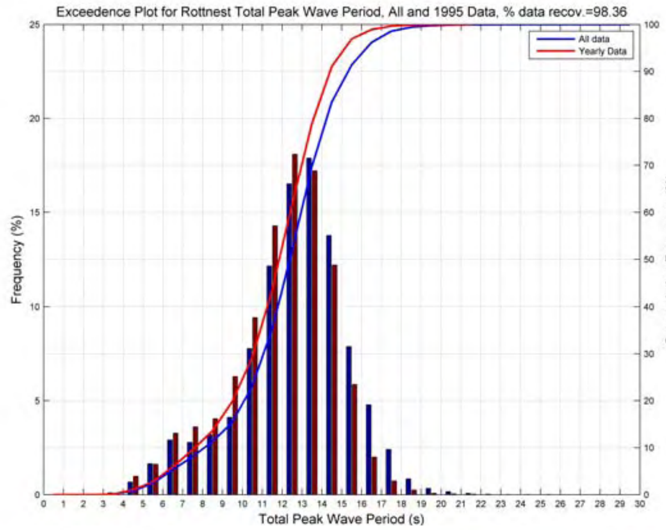


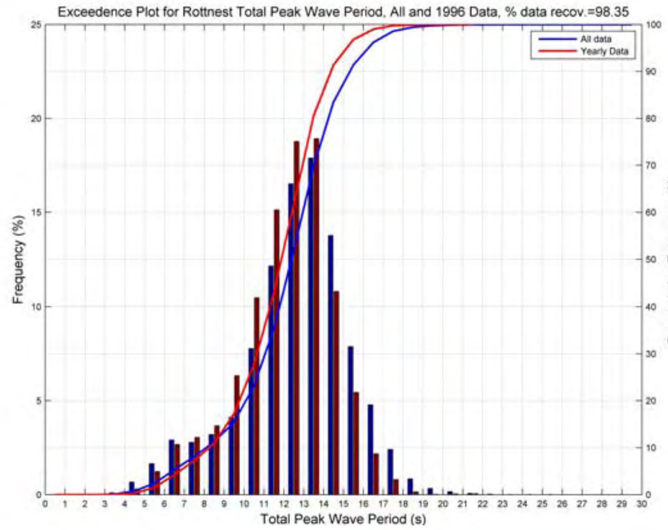
Exceedence Plot for Rottnest Total Peak Wave Period, All data & December data, 1994 to 2008, % data recov.=98.29

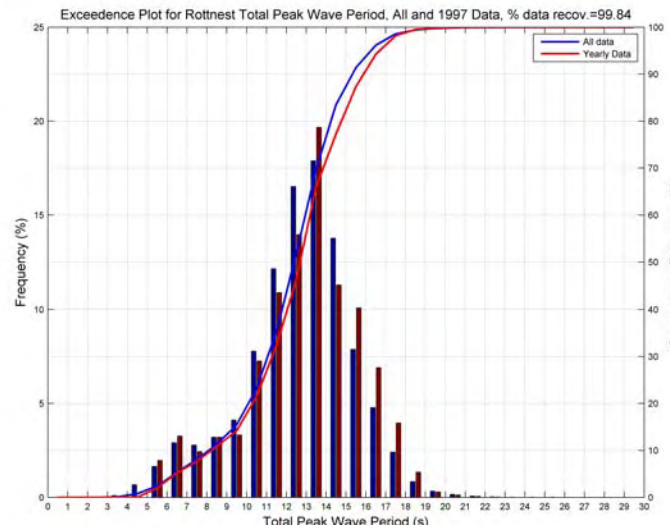


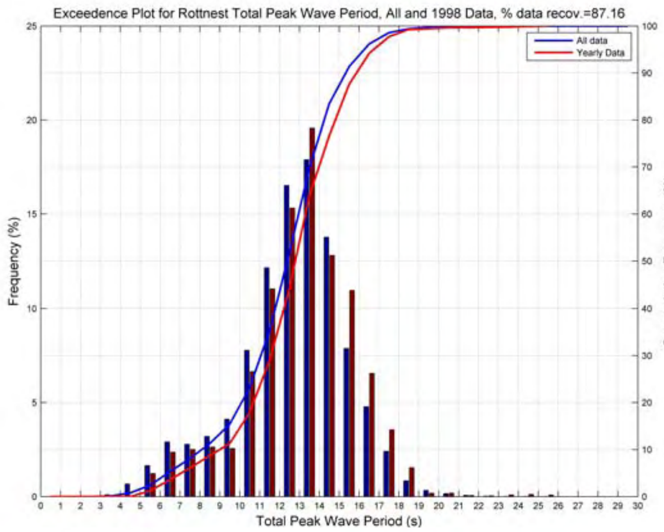
Appendix F: Yearly Variations of T_p Distributions

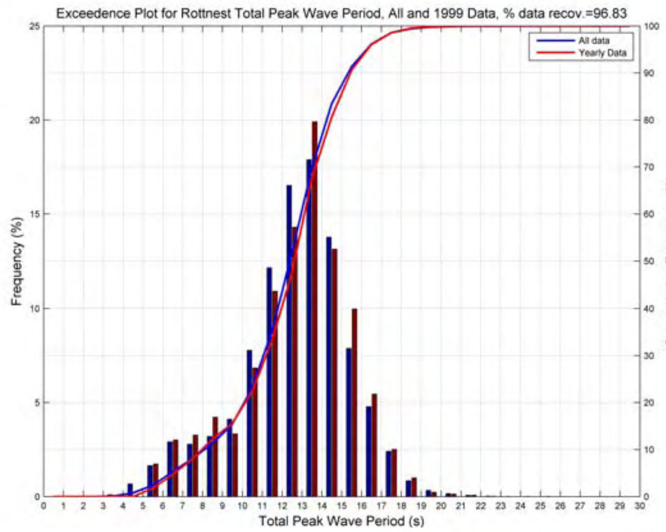

Exceedence Plot for Rottnest Total Peak Wave Period, All and 1994 Data, % data recov.=85.14
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

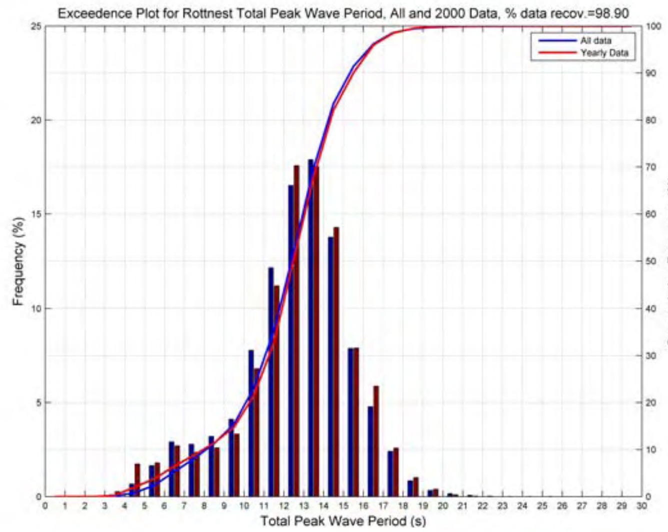

Exceedence Plot for Rottnest Total Peak Wave Period, All and 1995 Data, % data recov.=98.36
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

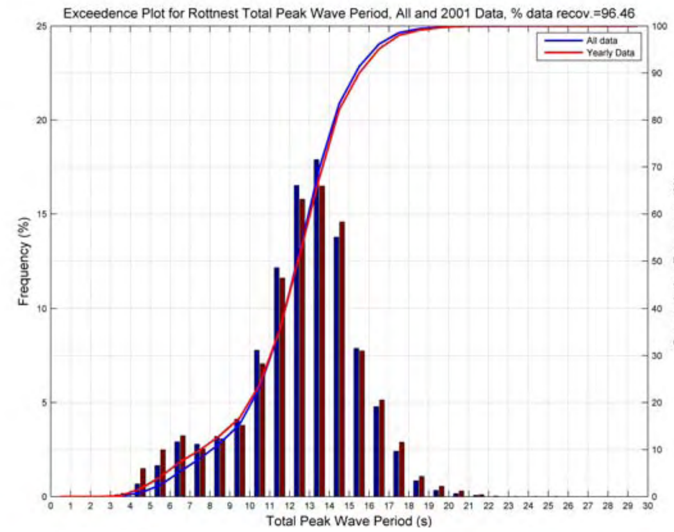

Exceedence Plot for Rottnest Total Peak Wave Period, All and 1996 Data, % data recov.=98.35
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

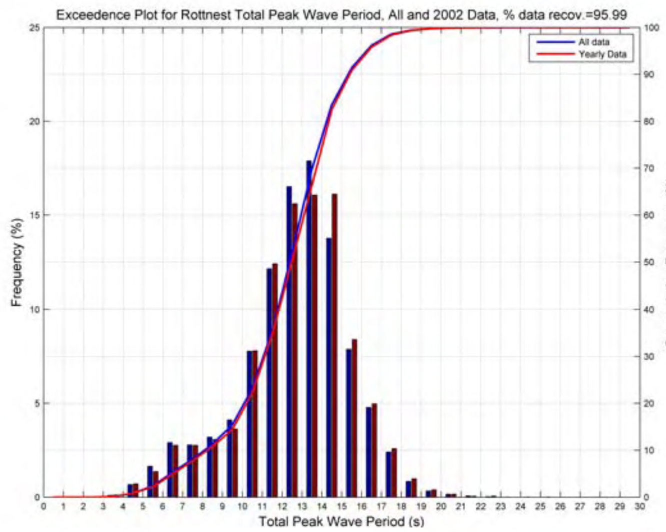

Exceedence Plot for Rottnest Total Peak Wave Period, All and 1997 Data, % data recov.=99.84
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

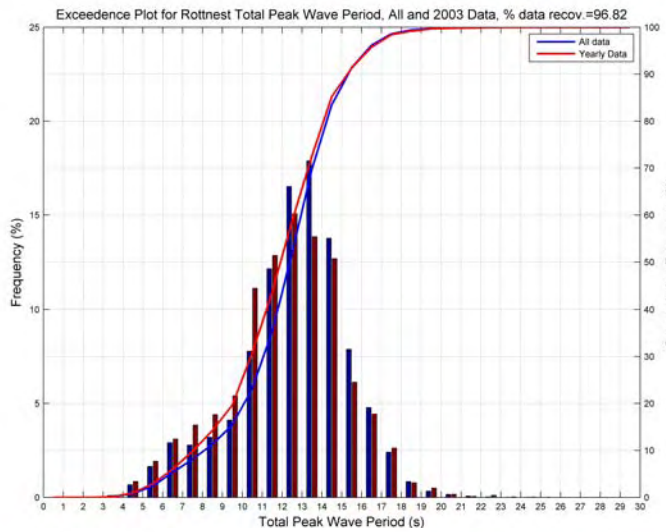

Exceedence Plot for Rottnest Total Peak Wave Period, All and 1998 Data, % data recov.=87.16
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

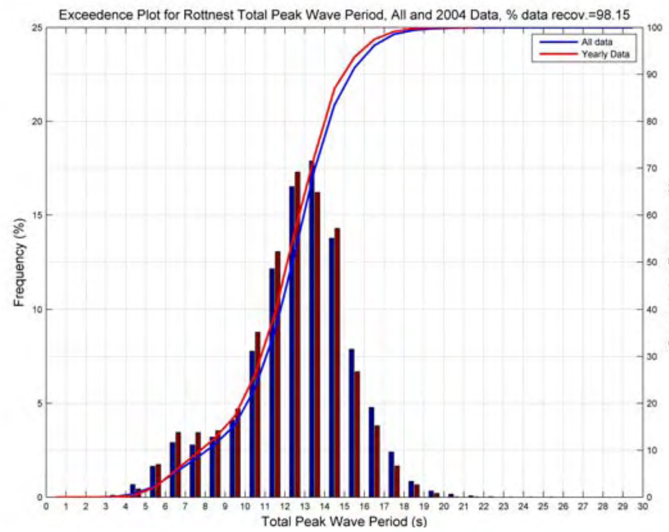

Exceedence Plot for Rottnest Total Peak Wave Period, All and 1999 Data, % data recov.=96.83
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

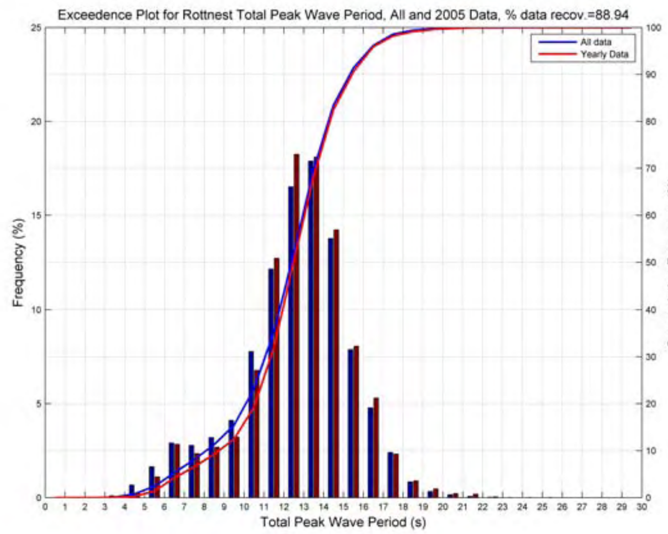

Exceedence Plot for Rottnest Total Peak Wave Period, All and 2000 Data, % data recov.=98.90
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

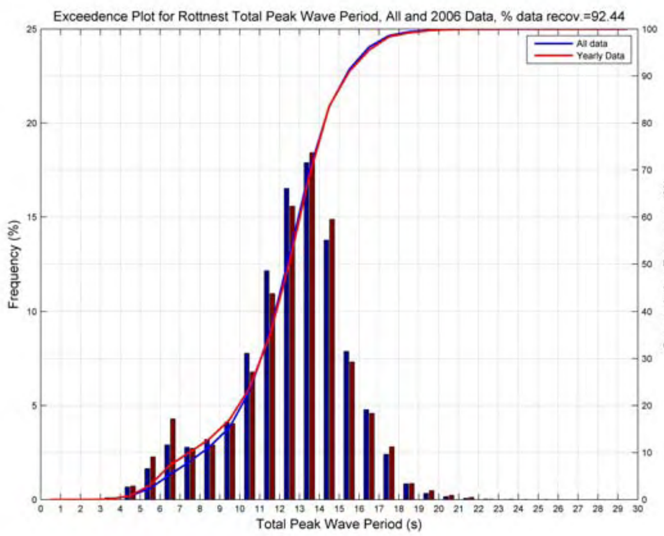

Exceedence Plot for Rottnest Total Peak Wave Period, All and 2001 Data, % data recov.=96.46
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

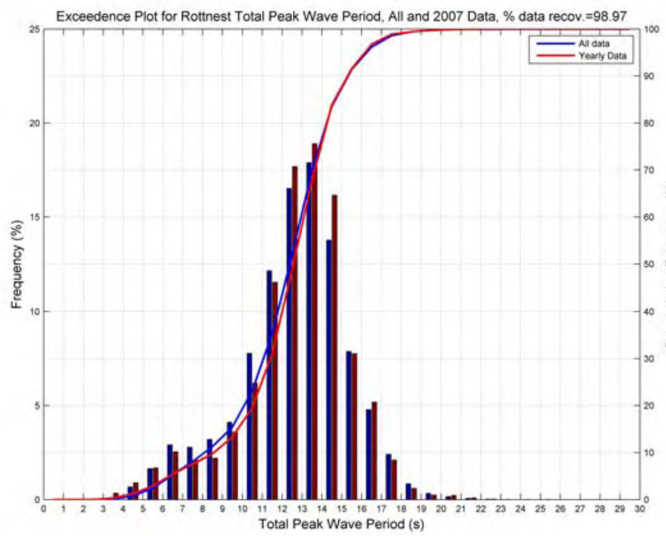

Exceedence Plot for Rottnest Total Peak Wave Period, All and 2002 Data, % data recov.=95.99
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

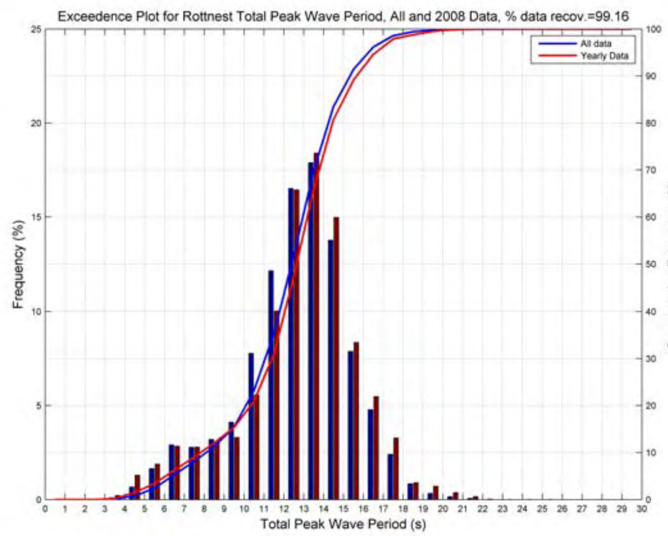

Exceedence Plot for Rottnest Total Peak Wave Period, All and 2003 Data, % data recov.=96.82
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)


Exceedence Plot for Rottnest Total Peak Wave Period, All and 2004 Data, % data recov.=98.15
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)


Exceedence Plot for Rottnest Total Peak Wave Period, All and 2005 Data, % data recov.=88.94
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

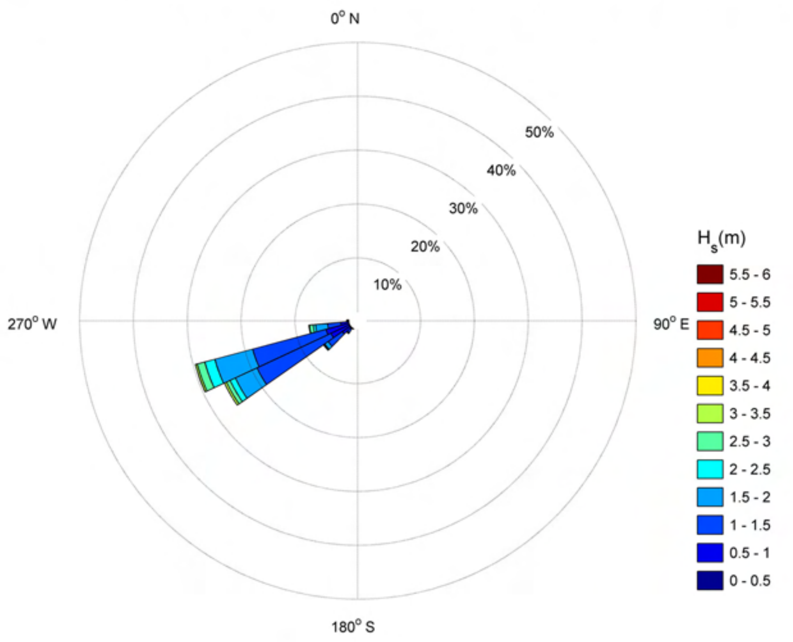

Exceedence Plot for Rottnest Total Peak Wave Period, All and 2006 Data, % data recov.=92.44
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)


Exceedence Plot for Rottnest Total Peak Wave Period, All and 2007 Data, % data recov.=98.97
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

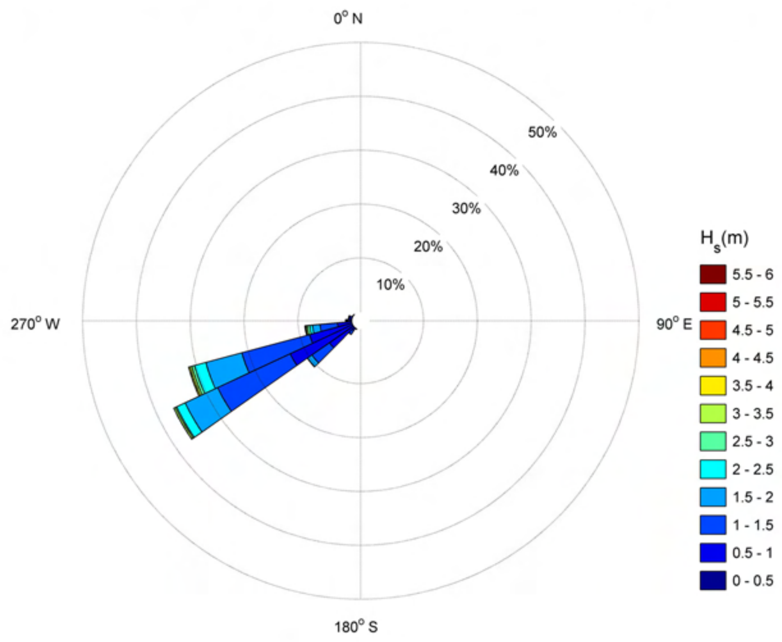

Exceedence Plot for Rottnest Total Peak Wave Period, All and 2008 Data, % data recov.=99.16
All data
Yearly Data
Frequency (%)
Cummulative Frequency (%)
Total Peak Wave Period (s)

Appendix G: Monthly Variations of H_s Wave Roses

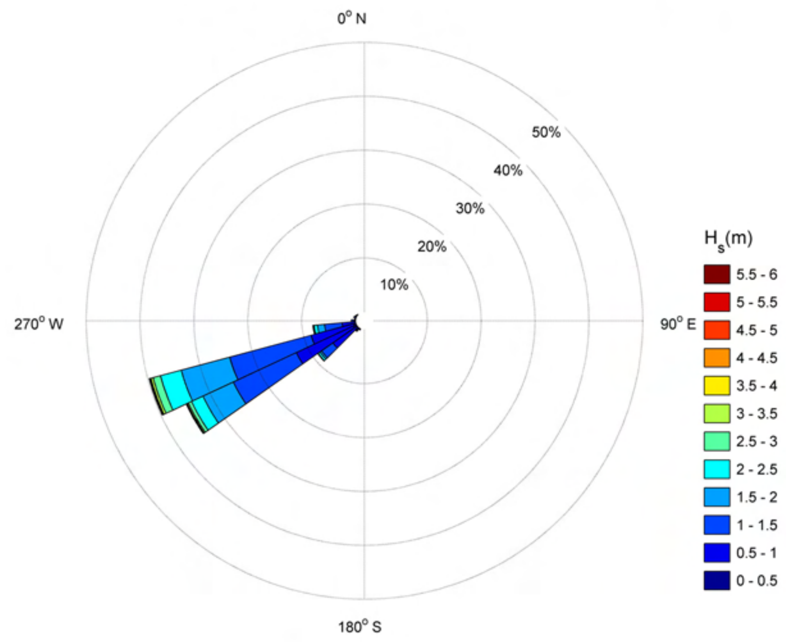
Swell wave height and direction for January at Rottnest, 2005 to 2008, data recov. = 70.62%



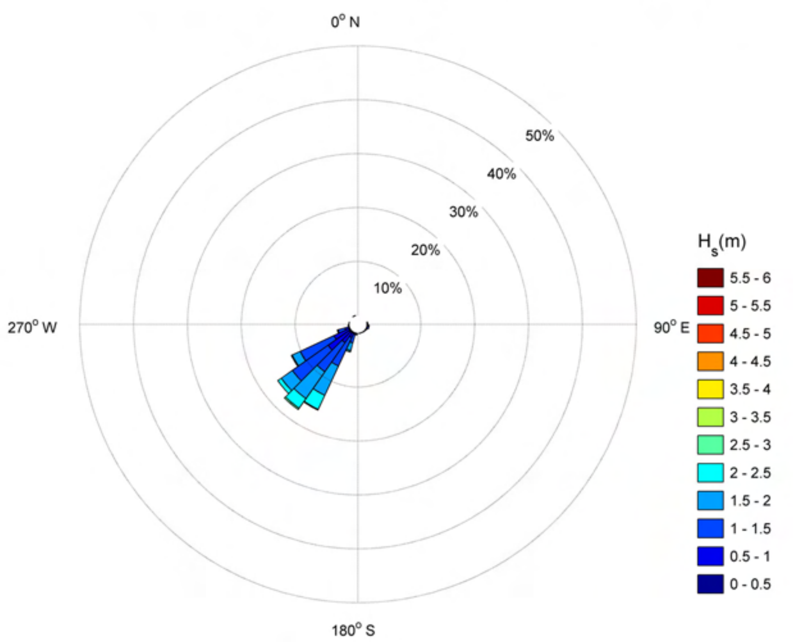
Swell wave height and direction for February at Rottnest, 2005 to 2008, data recov. = 91.74%



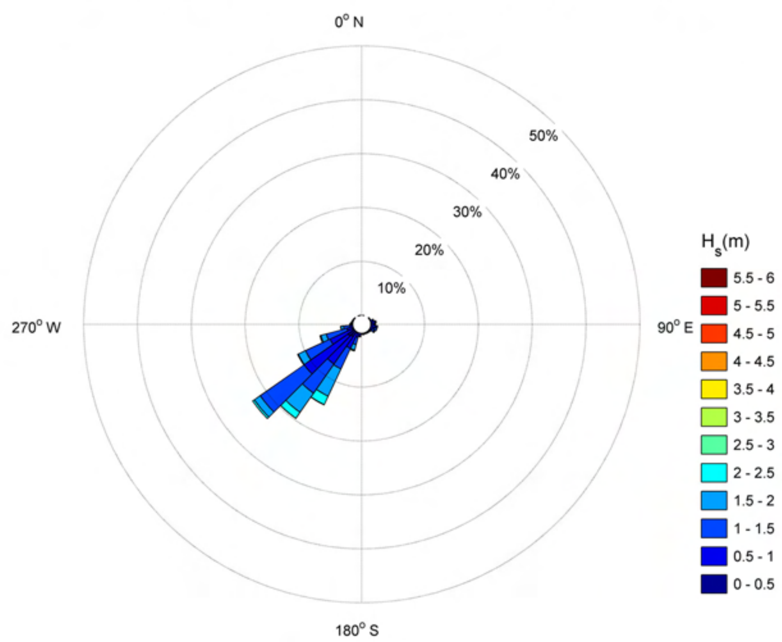
Swell wave height and direction for March at Rottnest, 2005 to 2008, data recov. = 94.19%



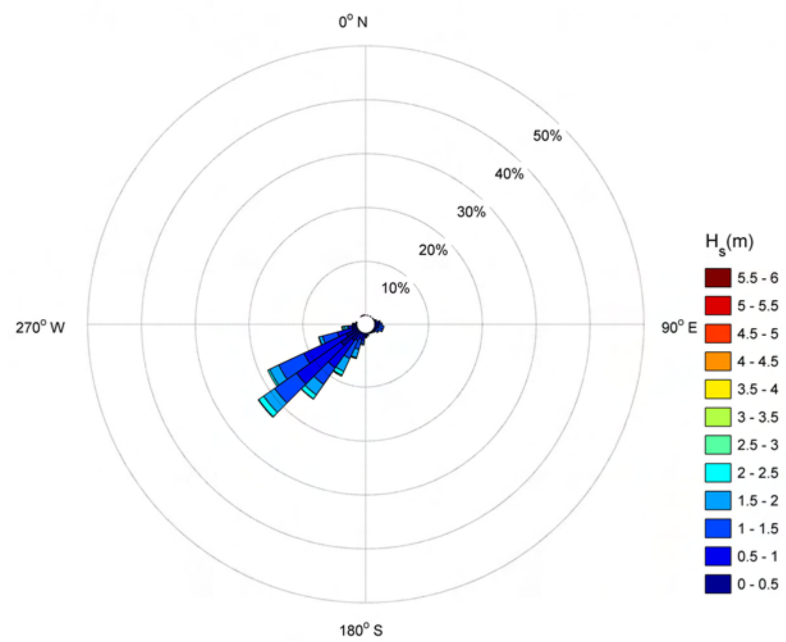
Sea wave height and direction for January at Rottnest, 2005 to 2008, data recov. = 70.62%



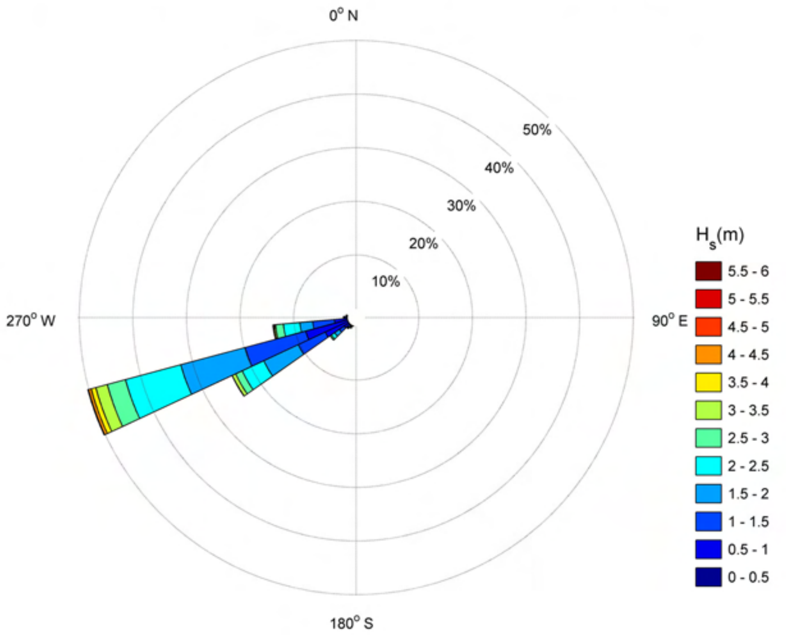
Sea wave height and direction for February at Rottnest, 2005 to 2008, data recov. = 91.74%



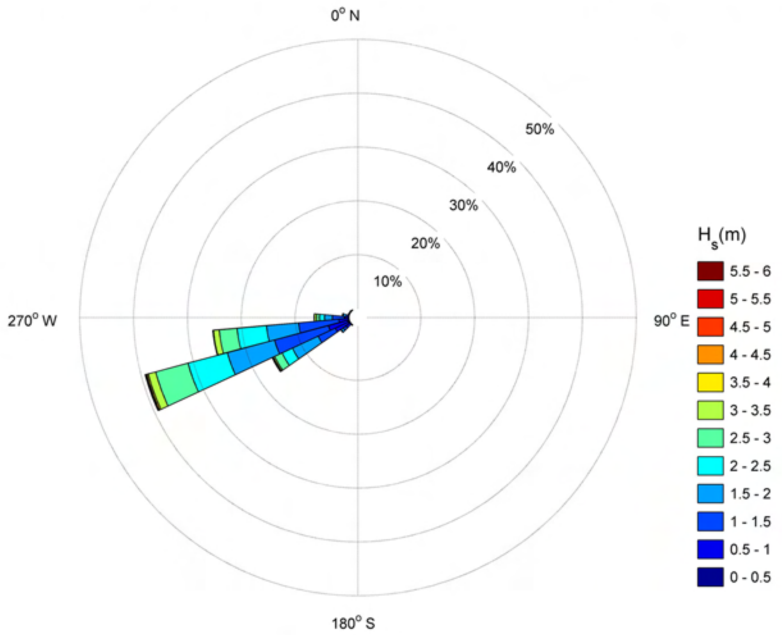
Sea wave height and direction for March at Rottnest, 2005 to 2008, data recov. = 94.19%



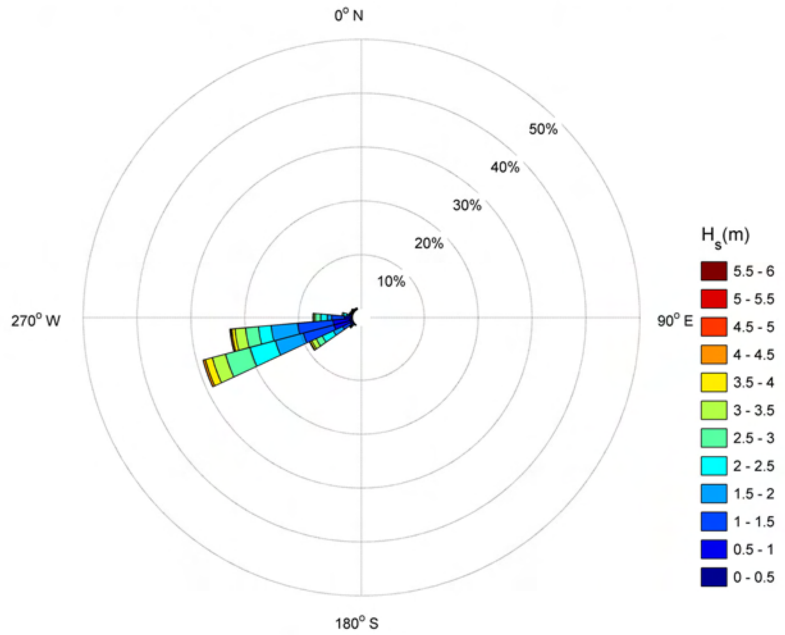
Swell wave height and direction for April at Rottnest, 2005 to 2008, data recov. = 94.90%



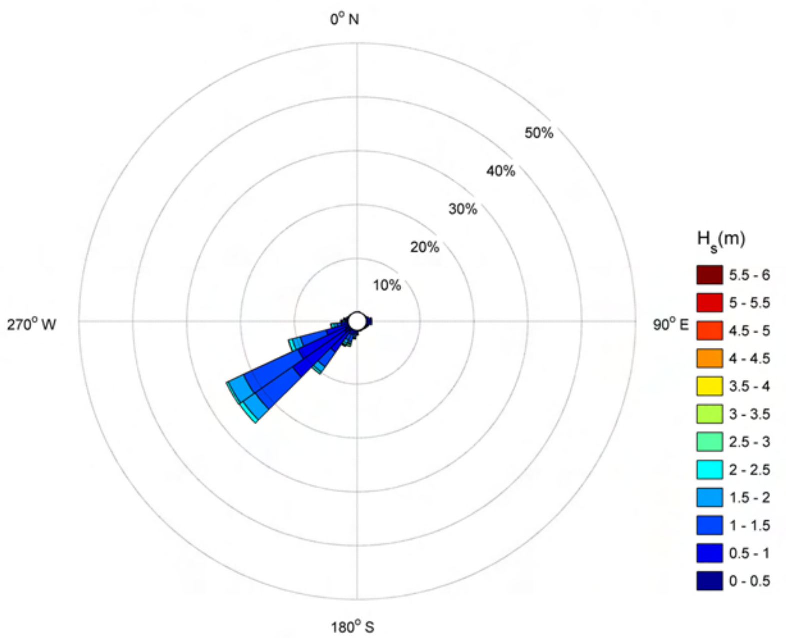
Swell wave height and direction for May at Rottnest, 2005 to 2008, data recov. = 91.50%



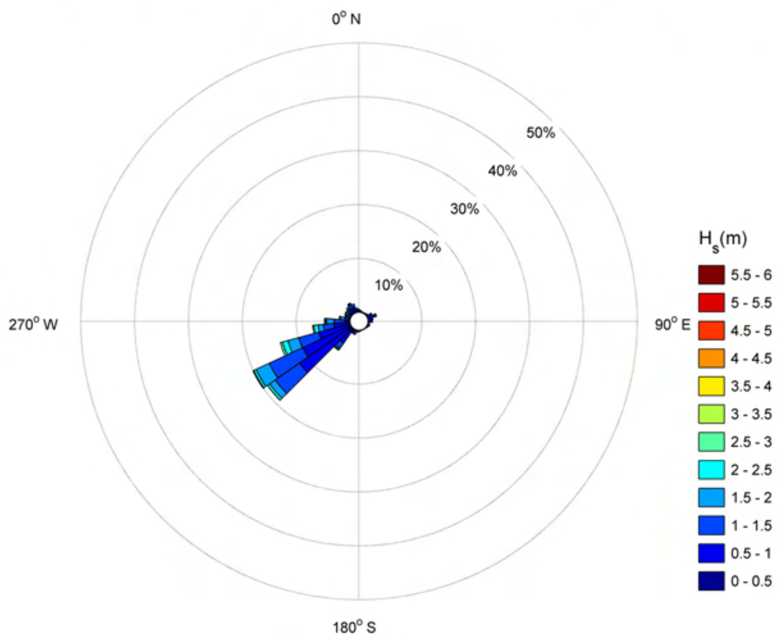
Swell wave height and direction for June at Rottnest, 2005 to 2008, data recov. = 73.96%



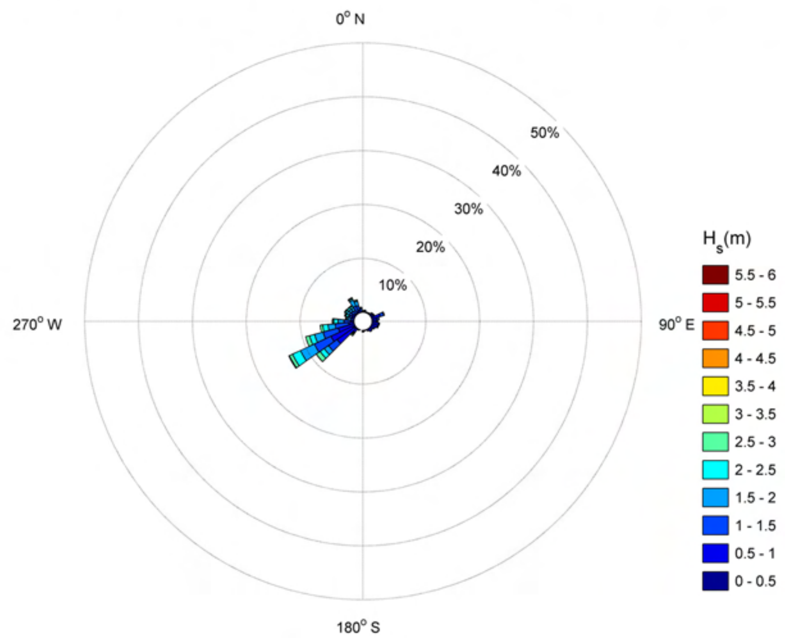
Sea wave height and direction for April at Rottnest, 2005 to 2008, data recov. = 94.90%



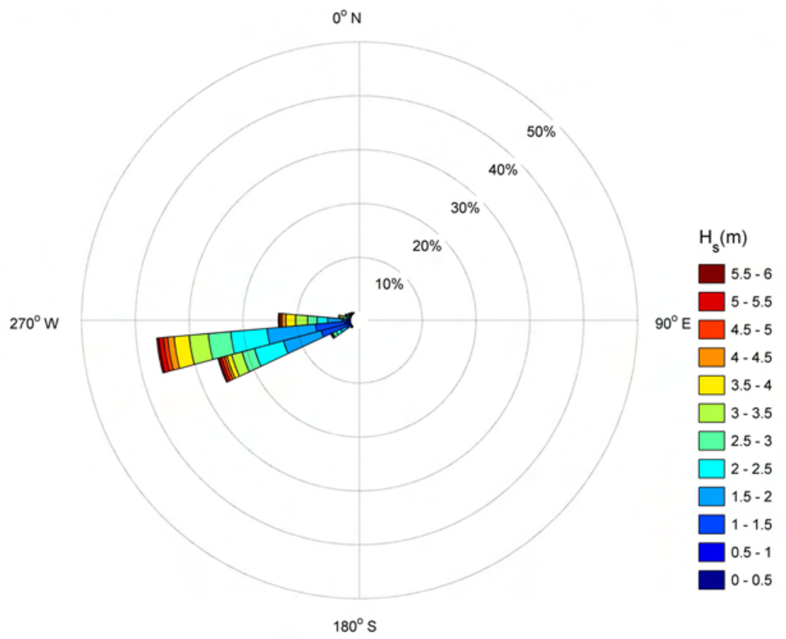
Sea wave height and direction for May at Rottnest, 2005 to 2008, data recov. = 91.50%



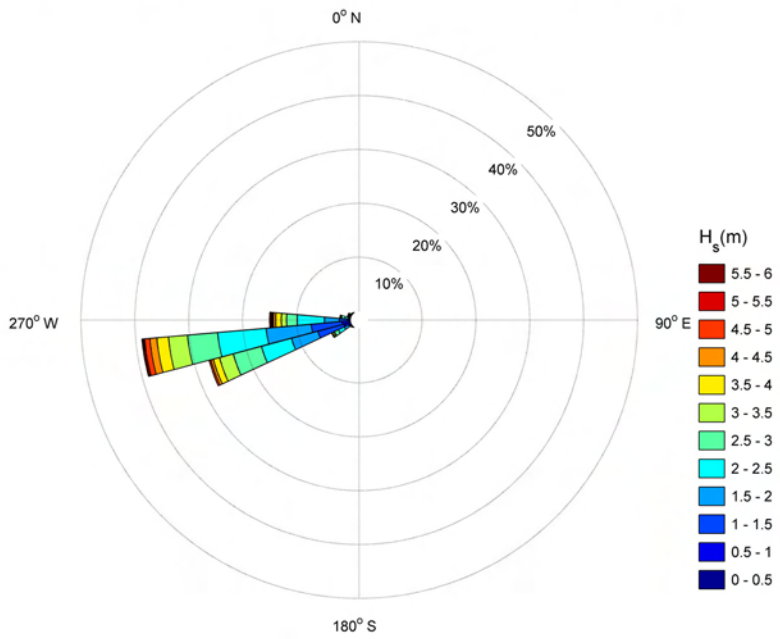
Sea wave height and direction for June at Rottnest, 2005 to 2008, data recov. = 73.96%



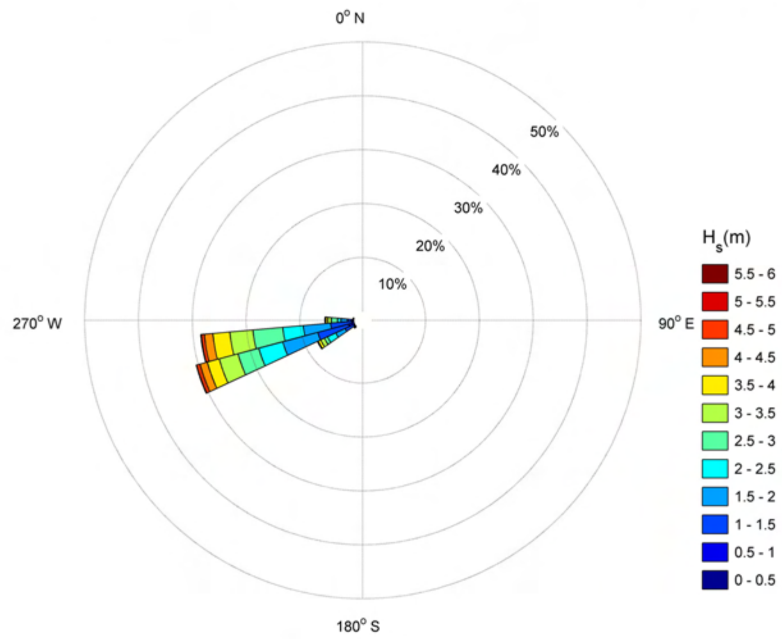
Swell wave height and direction for July at Rottnest, 2005 to 2008, data recov. = 84.68%



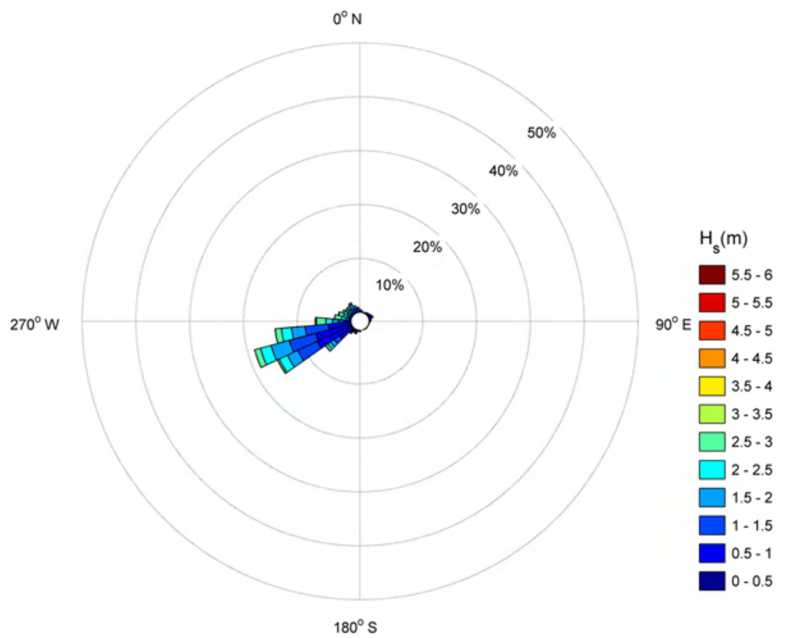
Swell wave height and direction for August at Rottnest, 2005 to 2008, data recov. = 88.91%



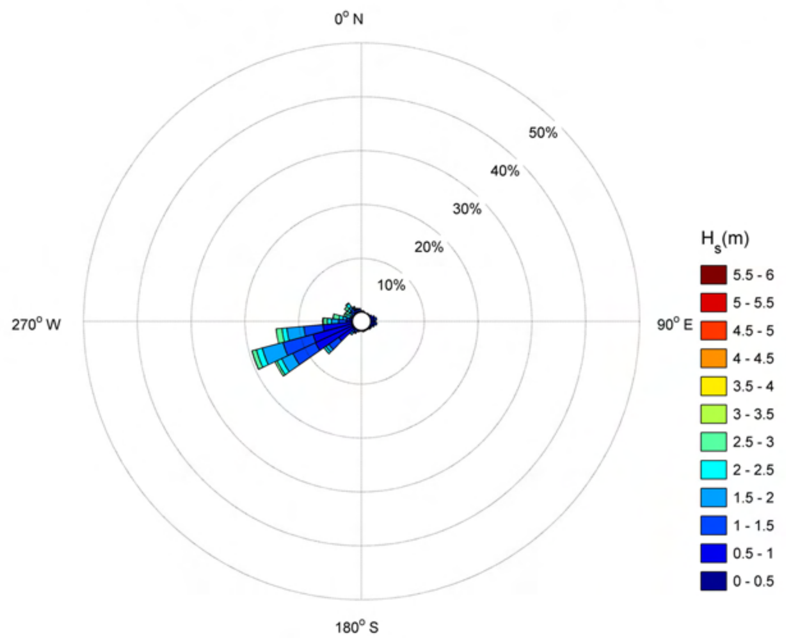
Swell wave height and direction for September at Rottnest, 2005 to 2008, data recov. = 72.60%



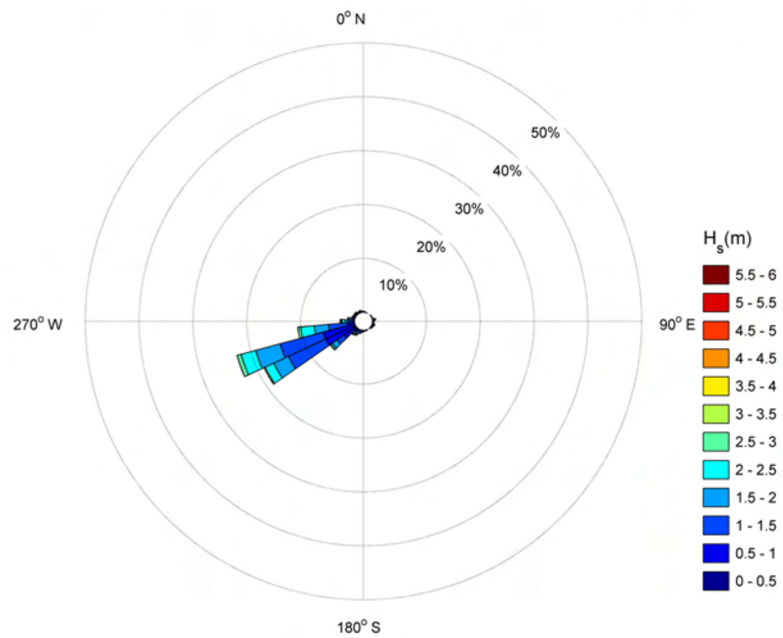
Sea wave height and direction for July at Rottnest, 2005 to 2008, data recov. = 84.68%



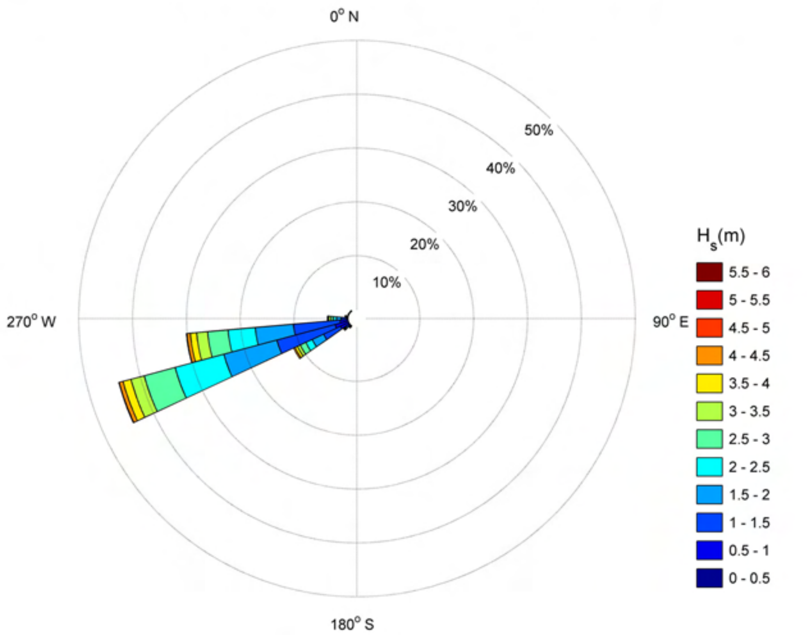
Sea wave height and direction for August at Rottnest, 2005 to 2008, data recov. = 88.91%



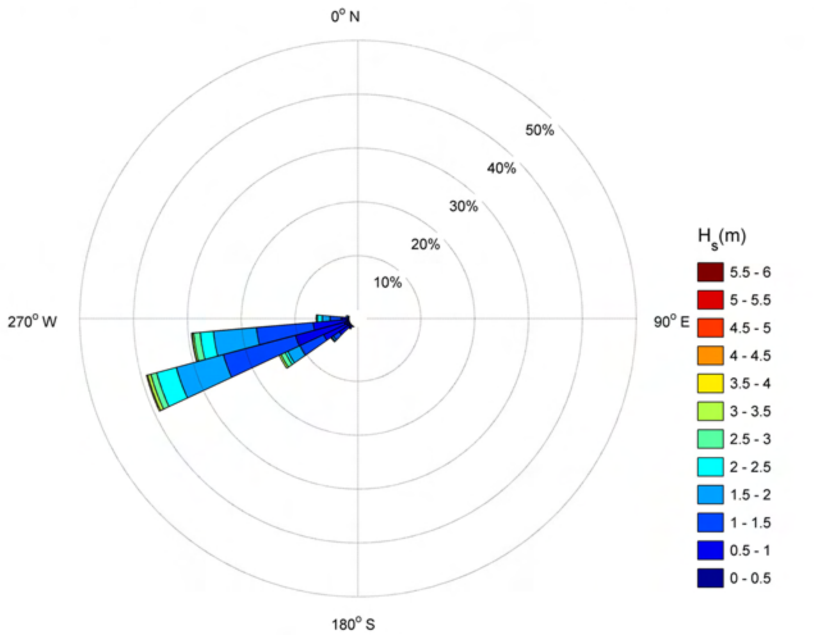
Sea wave height and direction for September at Rottnest, 2005 to 2008, data recov. = 72.60%



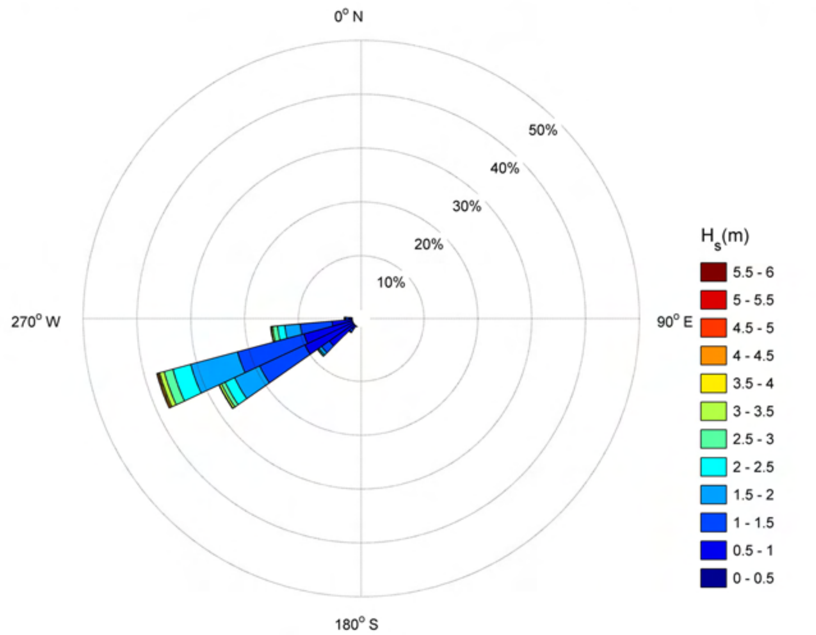
Swell wave height and direction for October at Rottnest, 2005 to 2008, data recov. = 92.57%



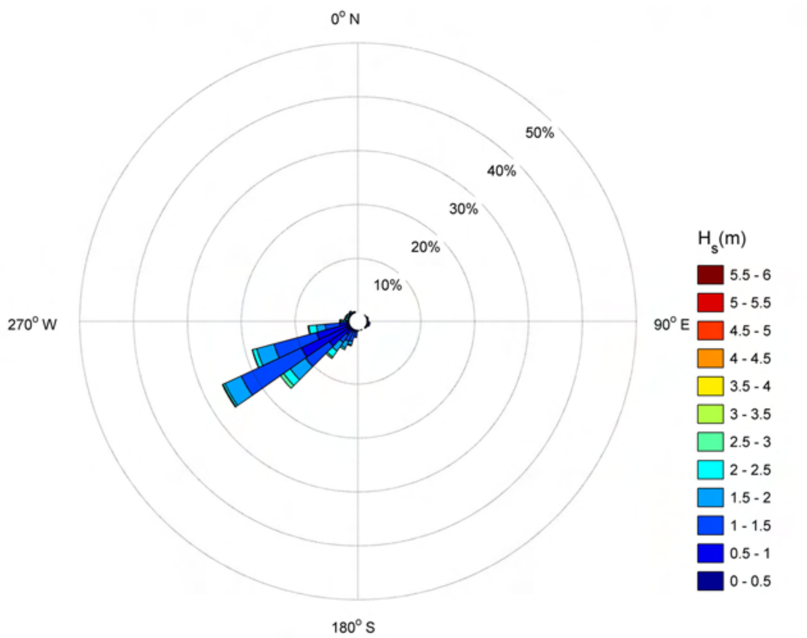
Swell wave height and direction for November at Rottnest, 2005 to 2008, data recov. = 94.86%



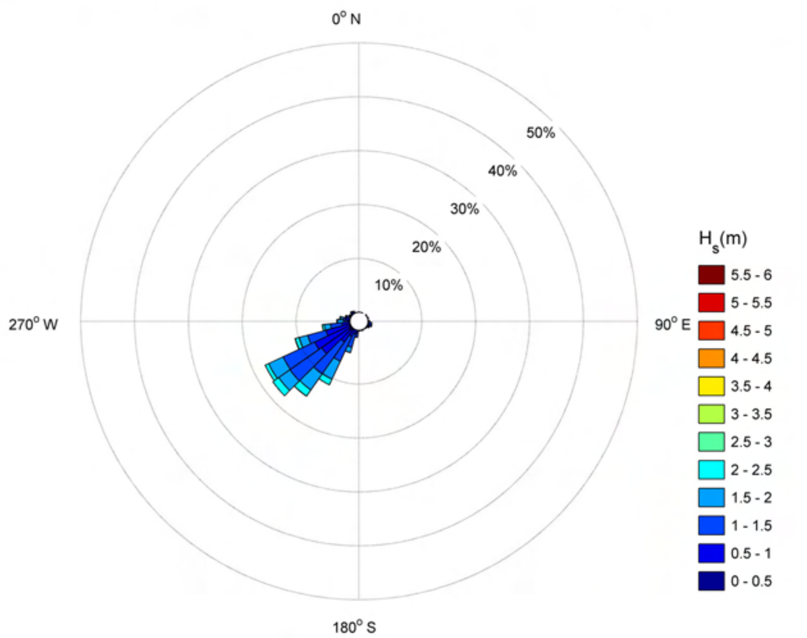
Swell wave height and direction for December at Rottnest, 2005 to 2008, data recov. = 91.90%



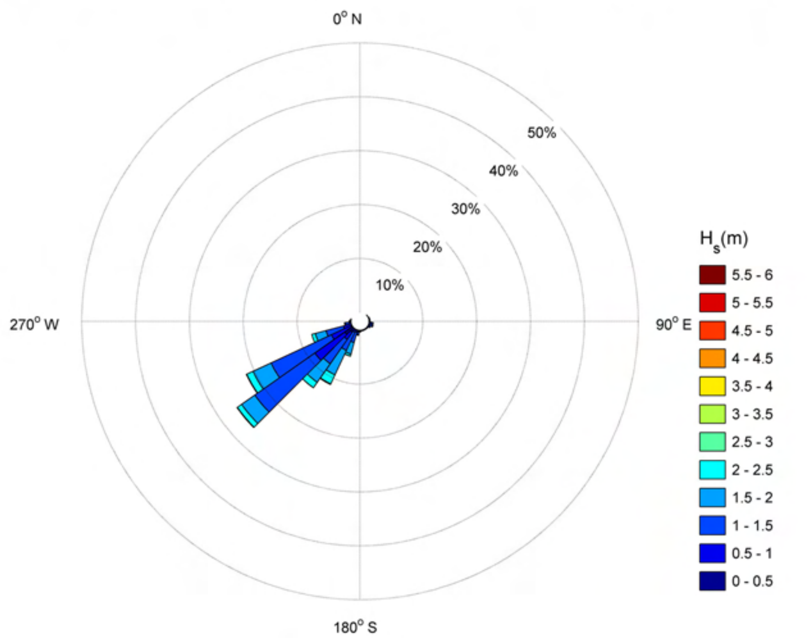
Sea wave height and direction for October at Rottnest, 2005 to 2008, data recov. = 92.57%



Sea wave height and direction for November at Rottnest, 2005 to 2008, data recov. = 94.86%

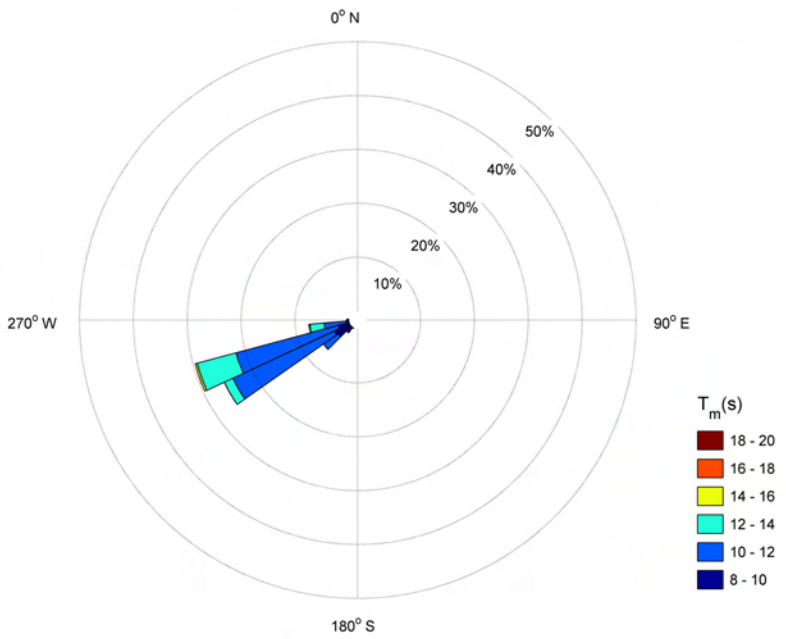


Sea wave height and direction for December at Rottnest, 2005 to 2008, data recov. = 91.90%

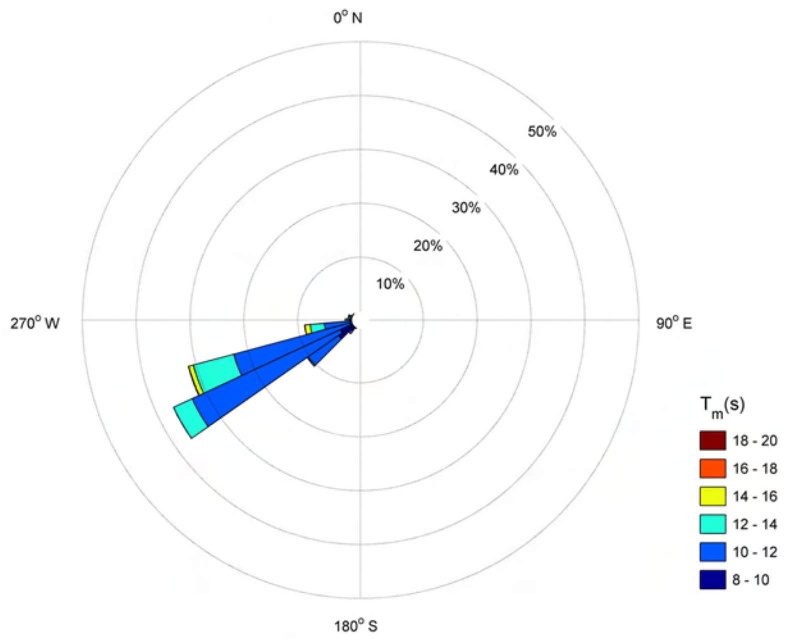


Appendix H: Monthly Variations of T_m Wave Roses

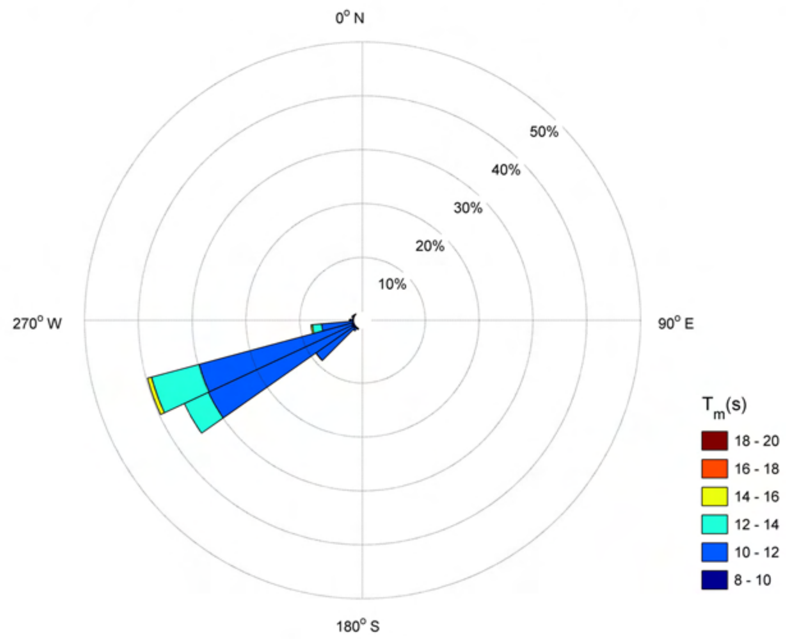
Swell wave mean period and direction for January at Rottnest, 2005 to 2008, data recov. = 70.62%



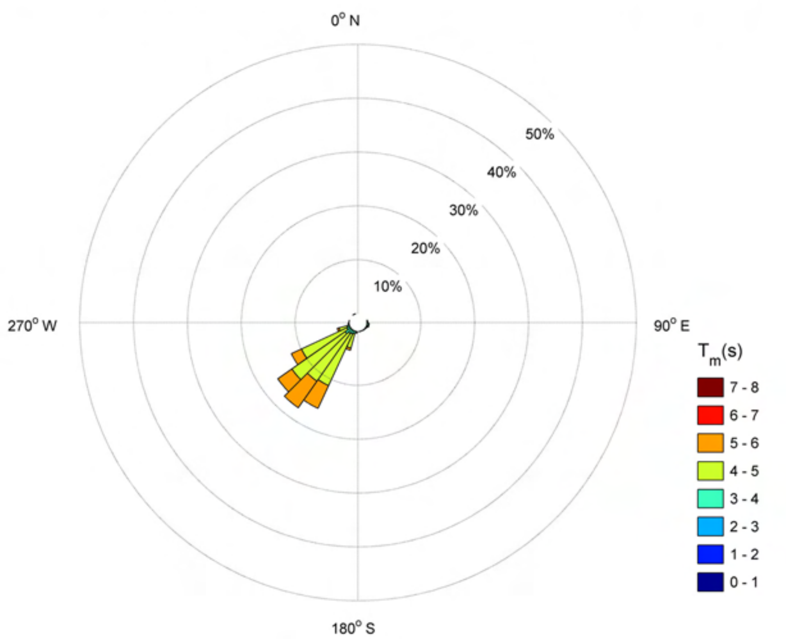
Swell wave mean period and direction for February at Rottnest, 2005 to 2008, data recov. = 91.74%



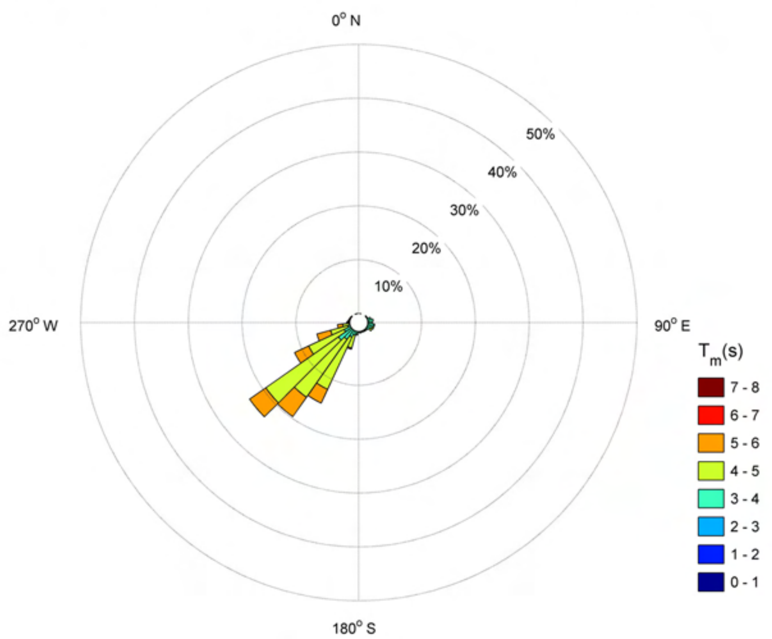
Swell wave mean period and direction for March at Rottnest, 2005 to 2008, data recov. = 94.19%



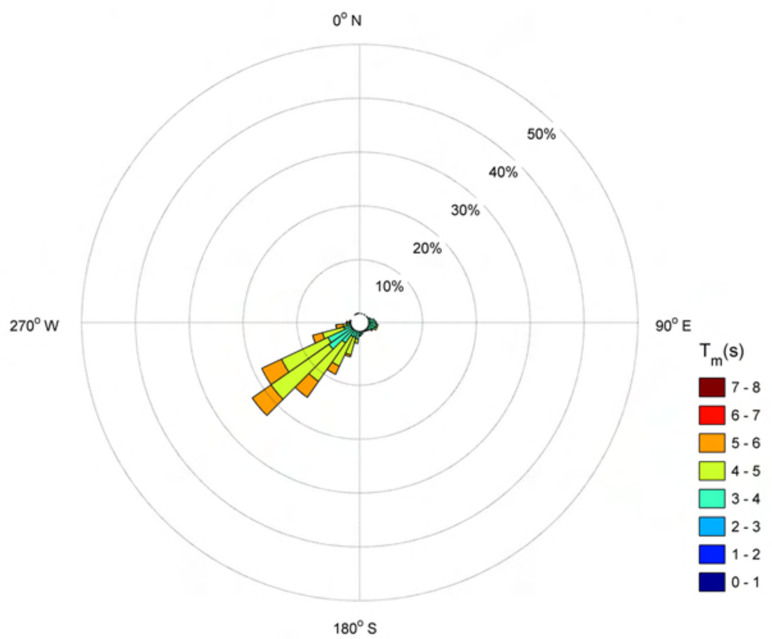
Sea wave mean period and direction for January at Rottnest, 2005 to 2008, data recov. = 70.62%



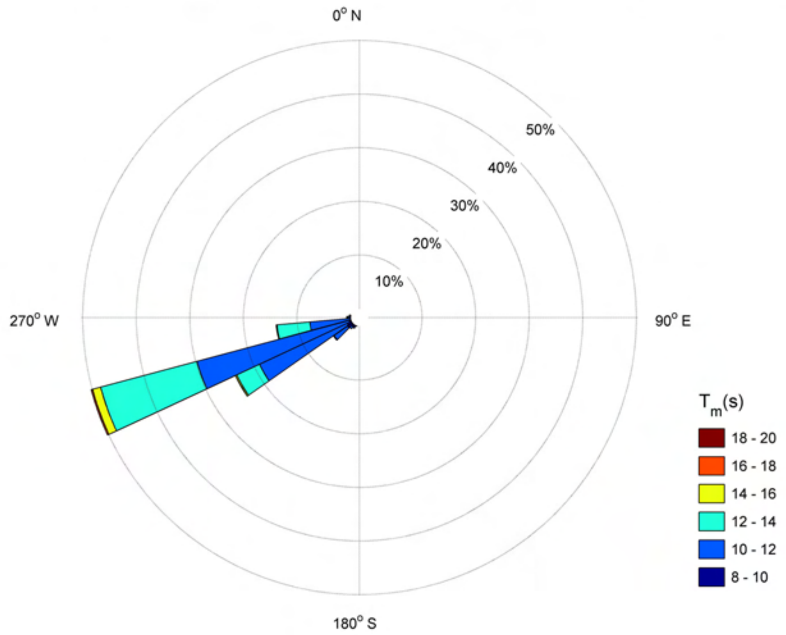
Sea wave mean period and direction for February at Rottnest, 2005 to 2008, data recov. = 91.74%



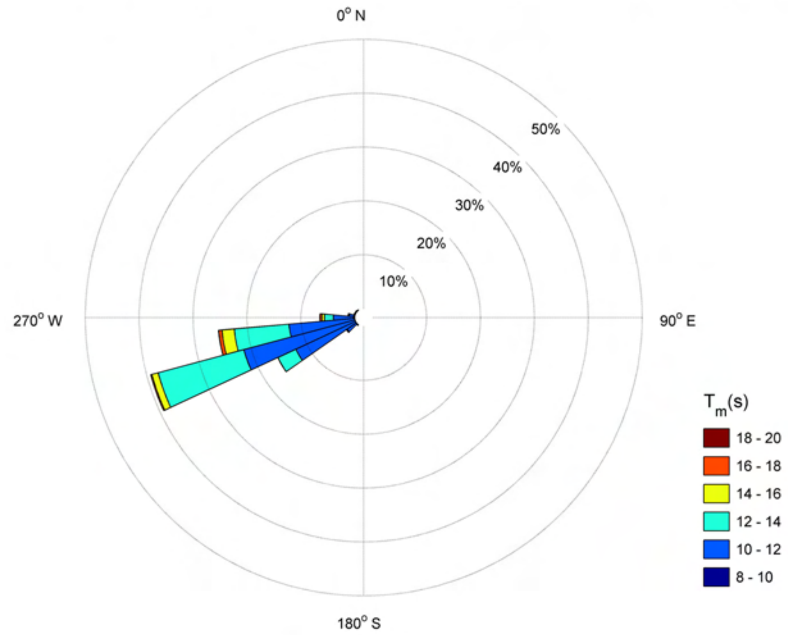
Sea wave mean period and direction for March at Rottnest, 2005 to 2008, data recov. = 94.19%



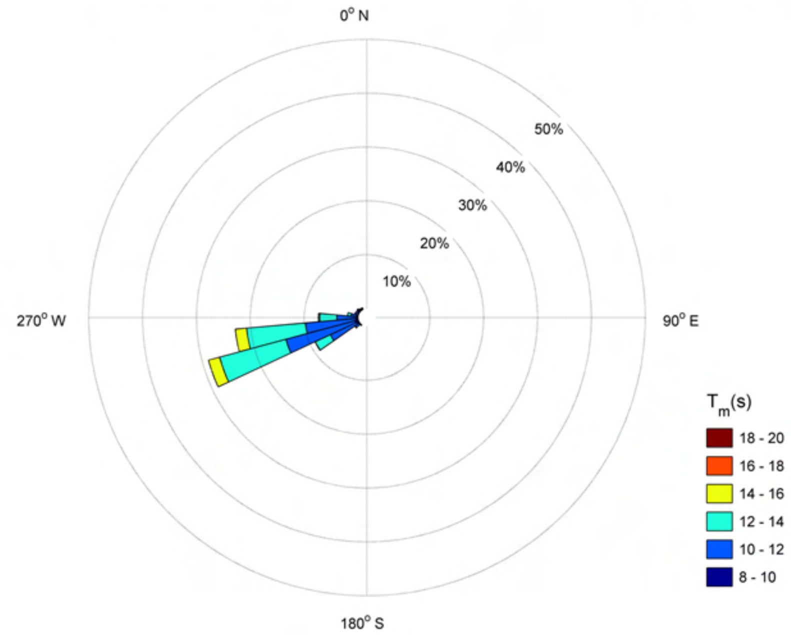
Swell wave mean period and direction for April at Rottnest, 2005 to 2008, data recov. = 94.90%



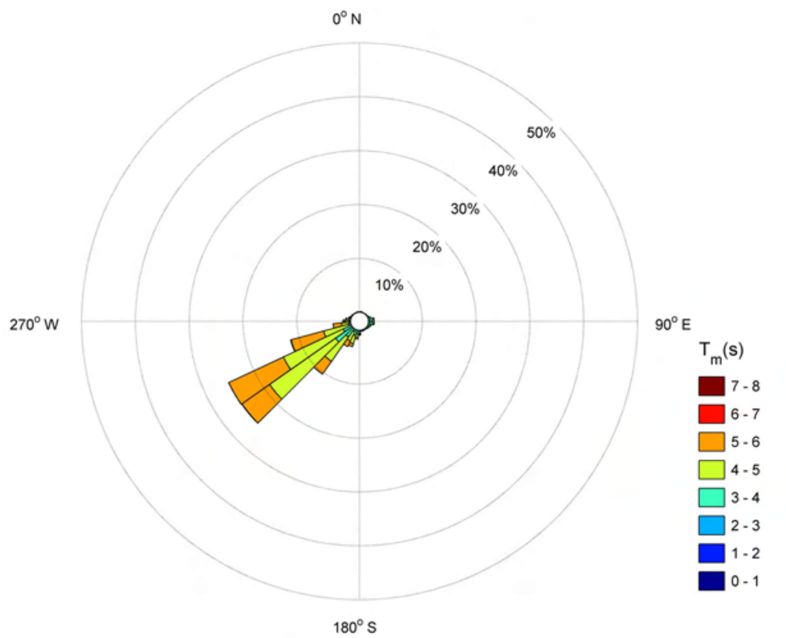
Swell wave mean period and direction for May at Rottnest, 2005 to 2008, data recov. = 91.50%



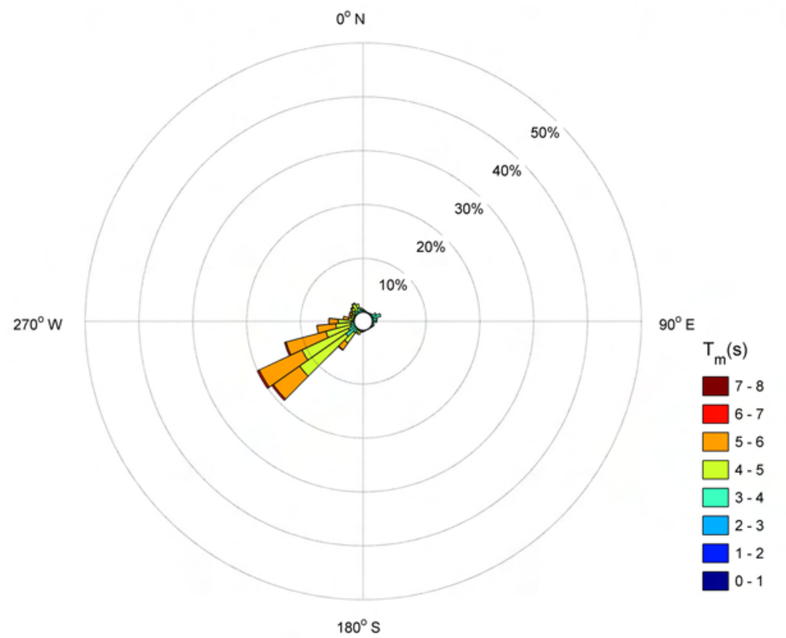
Swell wave mean period and direction for June at Rottnest, 2005 to 2008, data recov. = 73.96%



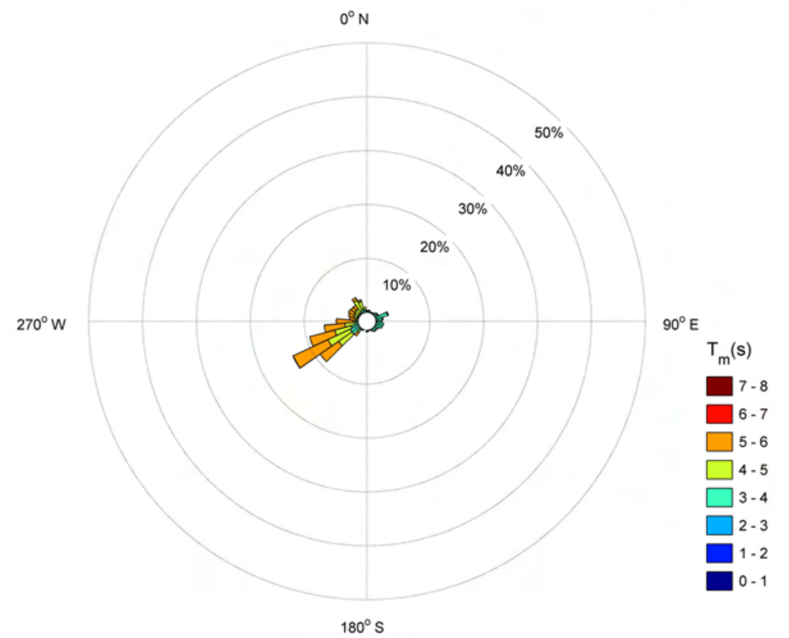
Sea wave mean period and direction for April at Rottnest, 2005 to 2008, data recov. = 94.90%



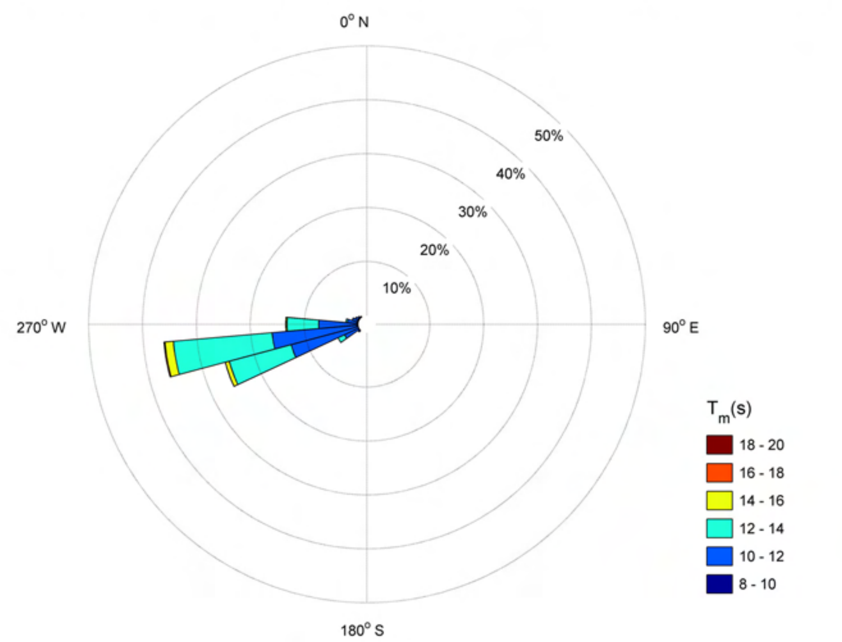
Sea wave mean period and direction for May at Rottnest, 2005 to 2008, data recov. = 91.50%



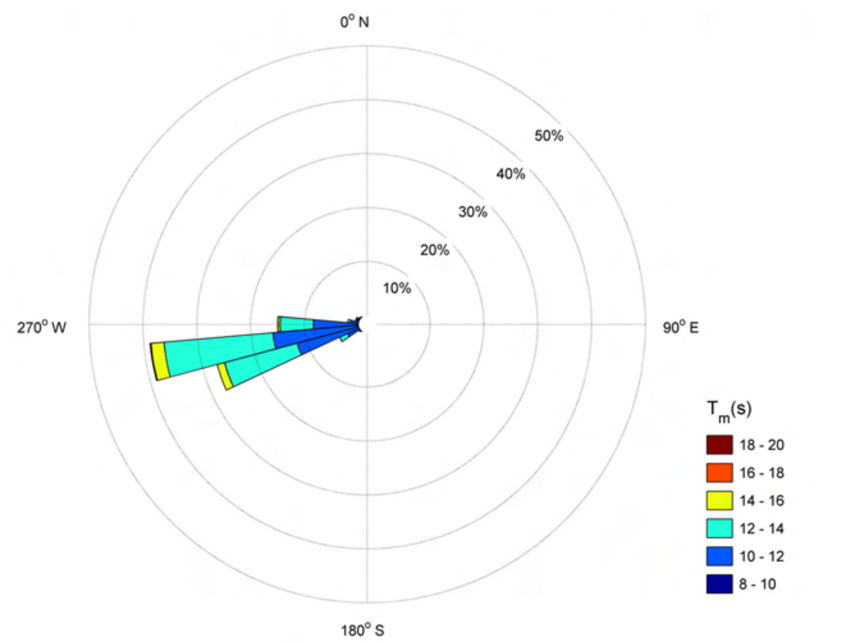
Sea wave mean period and direction for June at Rottnest, 2005 to 2008, data recov. = 73.96%



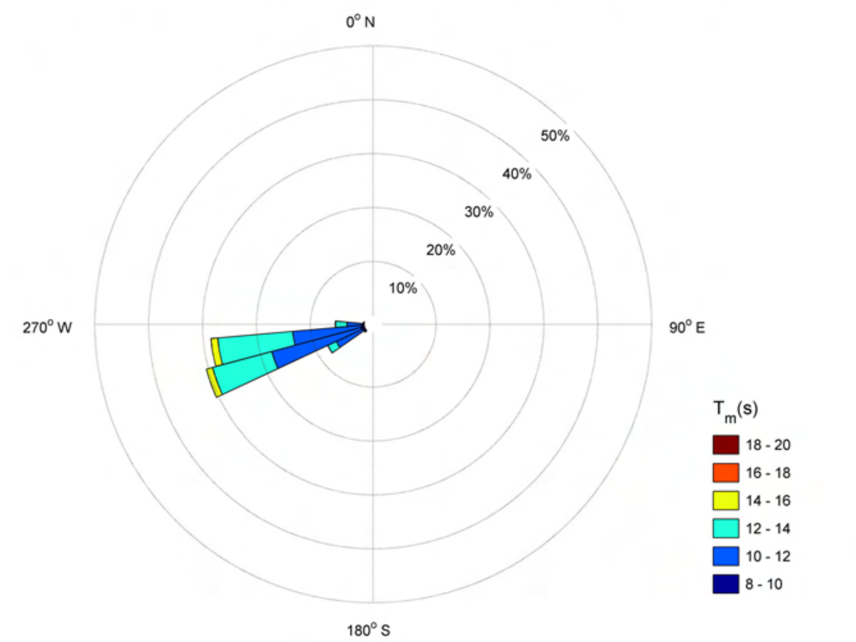
Swell wave mean period and direction for July at Rottnest, 2005 to 2008, data recov. = 84.68%



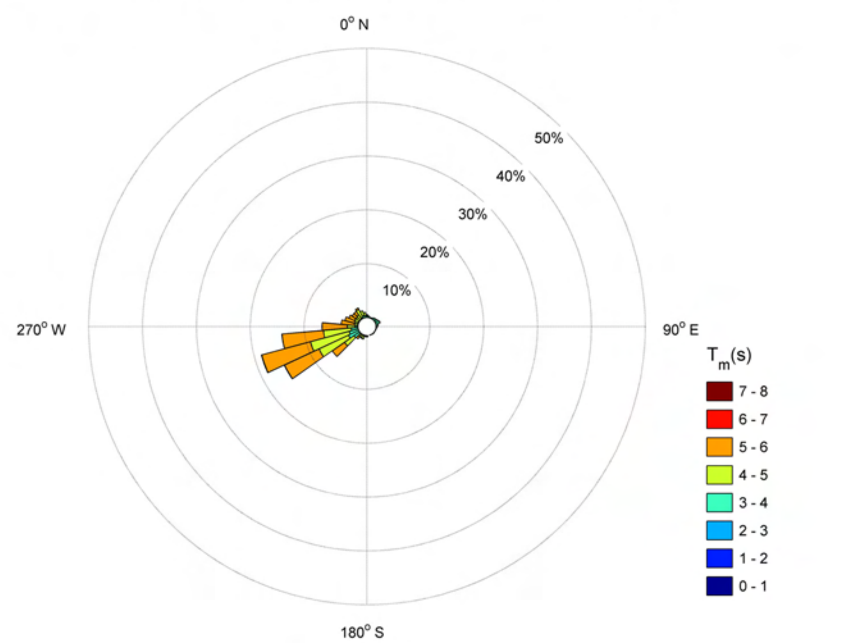
Swell wave mean period and direction for August at Rottnest, 2005 to 2008, data recov. = 88.91%



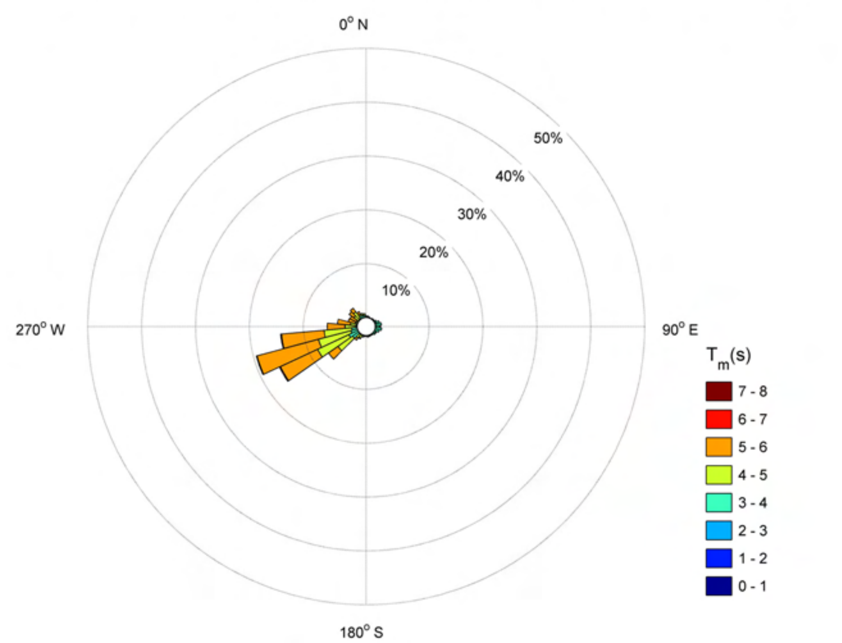
Swell wave mean period and direction for September at Rottnest, 2005 to 2008, data recov. = 72.60%



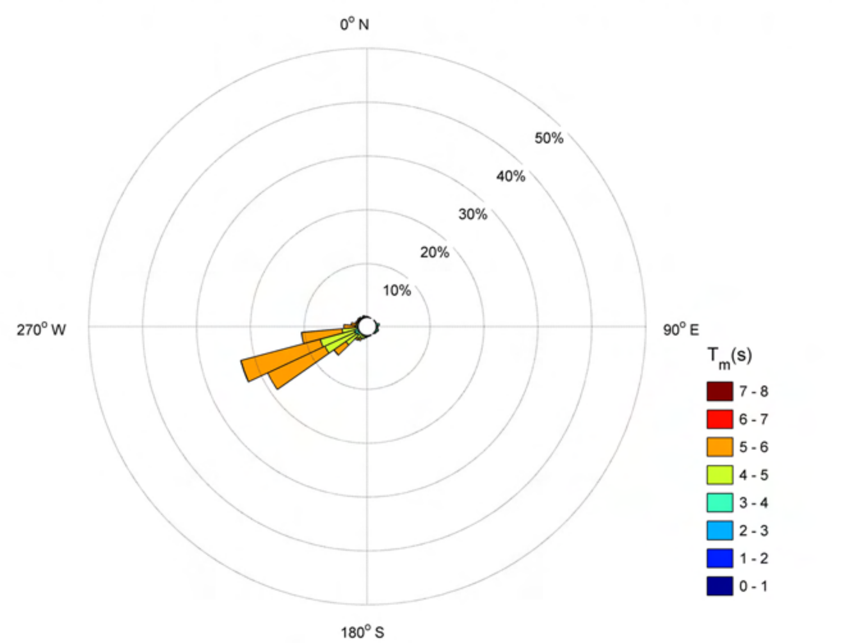
Sea wave mean period and direction for July at Rottnest, 2005 to 2008, data recov. = 84.68%



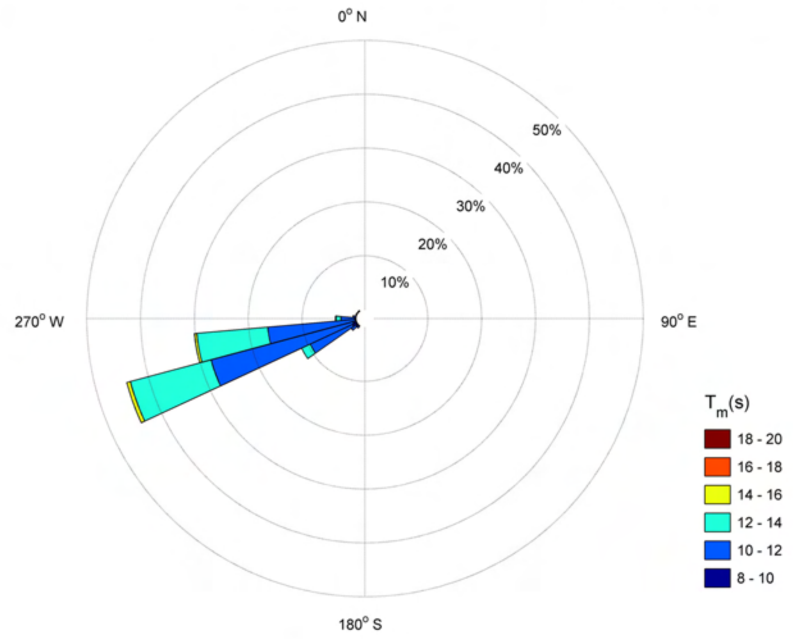
Sea wave mean period and direction for August at Rottnest, 2005 to 2008, data recov. = 88.91%



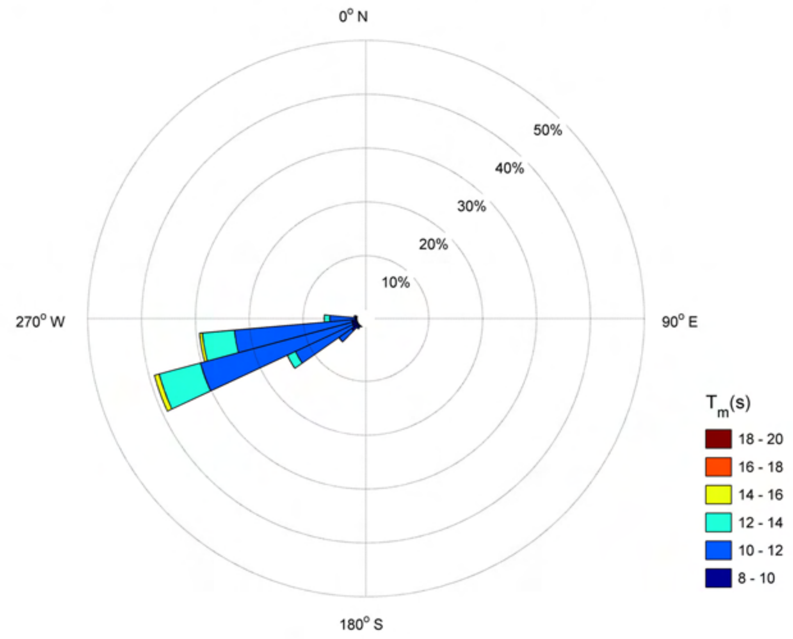
Sea wave mean period and direction for September at Rottnest, 2005 to 2008, data recov. = 72.60%



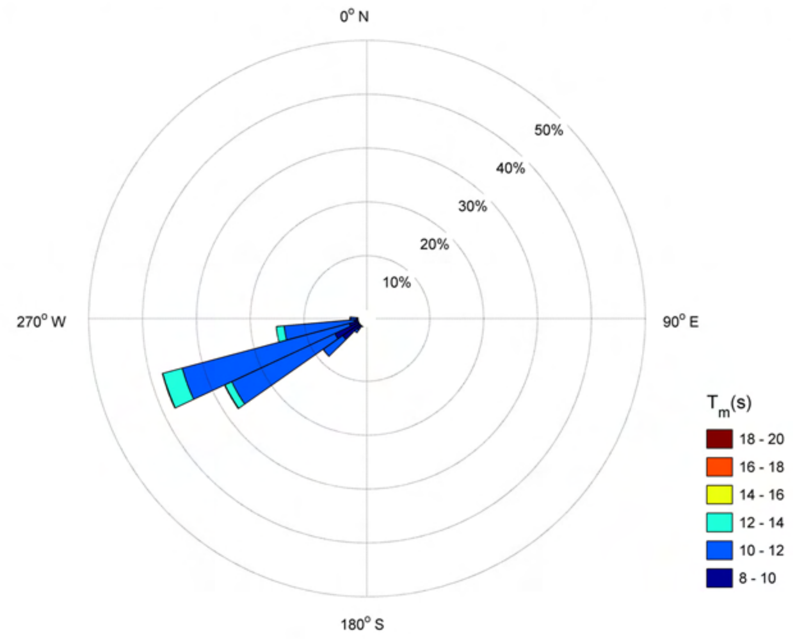
Swell wave mean period and direction for October at Rottnest, 2005 to 2008, data recov. = 92.57%



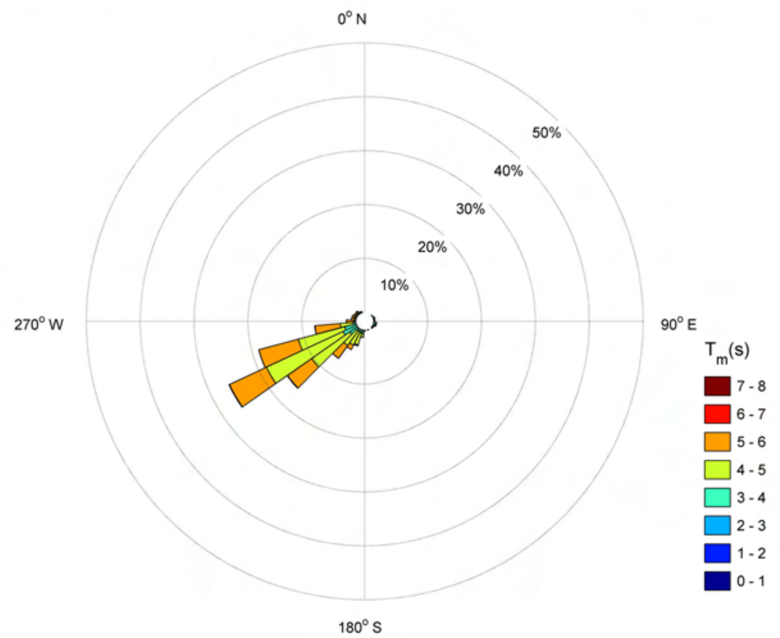
Swell wave mean period and direction for November at Rottnest, 2005 to 2008, data recov. = 94.86%



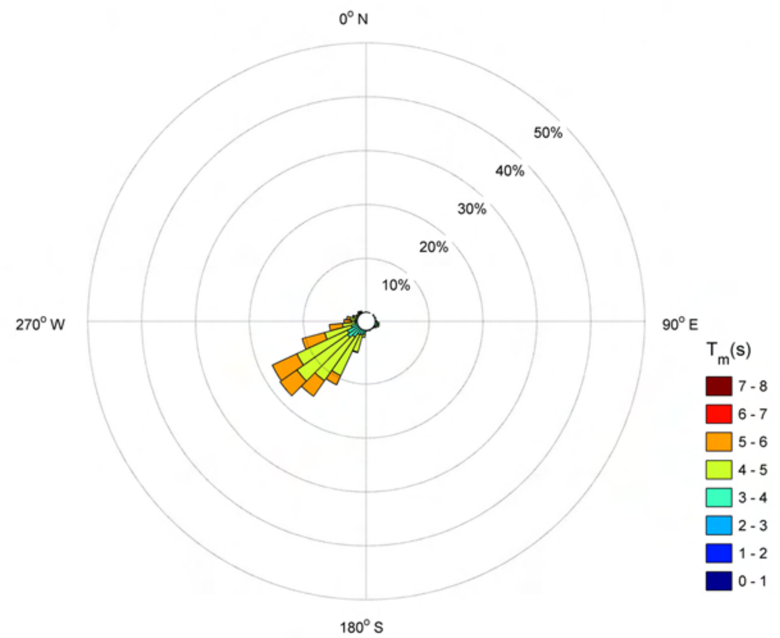
Swell wave mean period and direction for December at Rottnest, 2005 to 2008, data recov. = 91.90%



Sea wave mean period and direction for October at Rottnest, 2005 to 2008, data recov. = 92.57%



Sea wave mean period and direction for November at Rottnest, 2005 to 2008, data recov. = 94.86%



Sea wave mean period and direction for December at Rottnest, 2005 to 2008, data recov. = 91.90%