Altimetry Comparison, Backward Wave Refraction and Extreme Wave Analysis of NCEP Data: Cape Point to Richards Bay

by

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Declaration

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Abstract

Offshore wave climate along the south and east coast of South Africa has been investigated in this thesis. The design waves are needed to understand the offshore wave climate and necessary for the design of structures in this region. The wave condition data was produced by the WAVEWATCH III numerical model, i.e. NCEP data. The ultimate aim of the study was to derive extreme wave estimates off the South African coastline and assess its accuracy through comparison of various datasets. Comparisons of Satellite Altimetry data with NCEP and wave buoy data at two locations along the south coast (Cape Point and FA-Platform) was performed. Thereafter, wave conditions, obtained from 'backward' refracting nearshore data to the offshore NCEP locations, were performed in an attempt to validate NCEP data for East London and Richards Bay. Two approaches were conducted in order to backward refract, namely; Snell's Law (serving as a first estimate) and SWAN (fully describing the wave processes). The SWAN approach achieved offshore conditions by running a numerical model of various input conditions and creating a lookup table or matrix by means of an interpolation function using those general input conditions and output results. The methodology is important as neither the SWAN outputs nor the NCEP data could be regarded as 'ground truth'. An Extreme Wave Analysis was performed for the offshore NCEP data at six locations along the south and east coast of South Africa. An Exponential, Gumbel and 3-parameter Weibull distribution was conducted, where it was found that the latter was a best fit for the South African waters. An objective and conservative automated Peaks-over-Threshold (POT) value technique was used and wave heights for 1 in 1, 5, 10, 30, 50 and 100 year return periods with associated directions were obtained. Lastly, an analysis of the different distributions as well as percent exceedance graphs of the peak period per site was performed and compared.

Keywords: WAVEWATCH III, Satellite Altimetry, Backward refraction, Comparison, Extreme wave analysis.

Opsomming

Diepsee golfklimaat langs die suid- en ooskus van Suid-Afrika is ondersoek. Meer spesifiek, golftoestande wat geproduseer word deur die WAVE-WATCH III numeriese model (NCEP data). Die ontwerpgolwe is nodig om die diepsee golfklimaat te verstaan en vir die ontwerp van strukture in hierdie streek. Hierdie studie het daarop gemik om Satelliet Altemetrie data met NCEP en golfboei data op twee plekke langs die suidkus (Kaappunt en FA-Platform) te vergelyk. Daarna is golftoestande verkry van 'terugwaartse' refraksie vlakwaterdata en uitgevoer na die diepsee NCEP-liggings in 'n poging om NCEP-data vir Oos-Londen en Richardsbaai te verifieer. Twee benaderings is gebruik om die terugwaartse refraksie te bereken, naamlik; Snell se Wet (dien as eerste skatting) en SWAN (volledige beskrywing van die golfprosesse). Die metodologie is belangrik aangesien beide die SWAN-resultate en die NCEP-data nie as 'grondwaarheid' beskou kan word nie. Uiterste golfanalises vir die diepsee NCEP-data is op ses plekke langs die suid- en ooskus van Suid-Afrika uitgevoer. Golfhoogte vir 1 in 1, 5, 10, 30, 50 en 100 jaar terugkeerperiodes en die geassosieerde rigtings is bepaal. Dit is verkry deur 'n 3-parameter Weibull-verspreiding toe te pas op die data deur middel van die "Peaks-over-Threshold" (POT) metode. Ten slotte is 'n analise op die verkeie verspreidings uitgevoer. Die persentasie-oorskrydings grafieke van die spitsperiode per bestemming is ook uitgevoer en vergelyk.

Sleutelwoorde: WAVEWATCH III, Satelliet Altimetrie, terugwaartse refraksie, vergelyking, uiterste golf analise.

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J. K. Barnes

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Nomenclature

Variables

c	Celerity in tansitional water	[m/s]
c_g	Group velocity for tansitional water	[m/s]
c_0	Celerity in deep water	[m/s]
c_{g0}	Group velocity for deep water	[m/s]
d	Water depth	[m]
Dir	Wave direction in transitional water	[°]
Dir_0	Wave direction in deep water	[°]
E_1	Experimental quantity 1	[ ]
E_2	Experimental quantity 2	[ ]
g	Gravitational acceleration (9.81 m/s^2)	[m/s^2]
H_s	Significant wave height in transitional water	[m]
H_{s0}	Significant wave height in deep water	[m]
k	Wavenumber	[rad/m]
K_s	Shoalling coefficient	[ ]
K_r	Refraction coefficient	[ ]
L	Wave length in transitional water	[m]
L_0	Wave length in deep water	[m]
m	Number of data values within a dataset	[ ]
n	Constant	[ ]
si	Scatter index	[ ]
T	Return period	[years]
T_p	Peak wave period	[s]
W	Willmott index	[ ]
x_i	Predicted values	[ ]
x'_i	Difference between observed and observed average	[ ]
$\bar{x}$	Average of observed values	[ ]
y_i	Observed values	[ ]
y'_i	Difference between estimated and observed average	[ ]
$\%Diff$	Percentage difference error	[%]
$RMSE$	Root Mean Square Error	[ ]

Note: The significant wave height can be calculated from a time series (H_s), a spectrum (H_{m0}), or from the radar altimeter fitted to the satellite (swh_ku). In this document the significant wave height has been referred to as (H_s), unless otherwise stated.

Greek Variables

α	Angle from the wave front to the depth contour	[°]
ϕ	Angle Perpendicular to Coastline	[°]
θ	Nearshore angle between wave ray and ϕ	[°]
θ_0	Offshore angle between wave ray and ϕ	[°]
φ	constant for Gumbel distribution	[ ]
β	constant for Gumbel distribution	[ ]
μ	mode for Gumbel distribution	[ ]
σ^2	Variance for Gumbel distribution	[ ]
τ	Euler-Mascheroni constant (0.5772)	[ ]
γ	Weibull 3 location parameter	[ ]
η	Weibull 3 scale parameter	[ ]
ξ	Weibull 3 shape parameter	[ ]

Abbreviations

ADCP: Acoustic Doppler Current Profiler
cdf: Cumulative Density Function
CNES: Centre National d'Etudes Spatiales
CSIR: Council for Scientific and Industrial Research
DOSO: Direction of Swell Orthogonals
EUMETSAT: European Meteorological Satellite Organisation
GDR: "final" Geophysical Data Record
IGDR: Interim Geophysical Data Record
INES: Inverted Echo-Sounder
MMAB: Marine Modeling and Analysis Branch
NASA: National Aeronautics and Space Administration
NCEP: National Centers for Environmental Prediction
netCDF: Network Common Data Form
NIO: National Institute of Oceanography
NOAA: National Oceanic and Atmospheric Administration
OGDR: Operational Geophysical Data Record
OSTM: Ocean Surface Topography Mission
POT: Peaks Over Threshold
SANHO: Hydrographic Office of the South African Navy
SWAN: Simulating WAves Nearshore
TNPA: Transnet National Port Authority
VOS: Voluntary Observing Ships

Chapter 1

Introduction

1.1 Research Background

The South African coastline stretches more than 2 500 kilometers from the Namibian border on the Atlantic (western) Coast around the tip of Africa and to the Mozambican border (eastern) on the Indian Ocean. Ports that lie along this coastline are major contributors to the import and export industry. Figure 1.1 presents the locations of the nine major ports along the South African coastline that have a significant impact on the country's economy. Beaches, also providing an economic benefit, span the coastline and add value to the tourism sector.

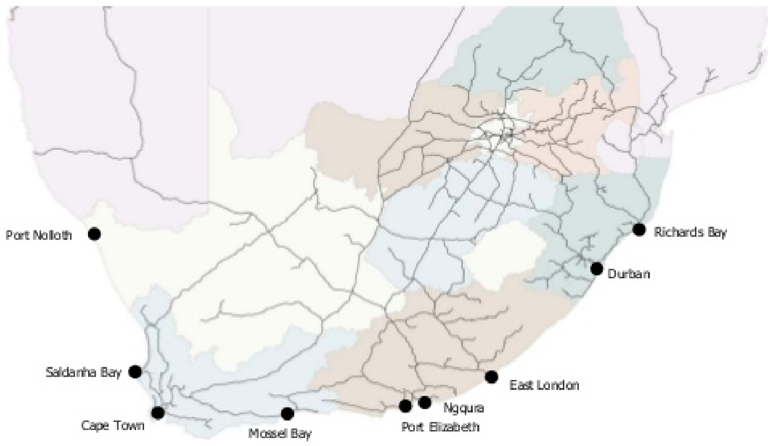


Figure 1.1: South African Port System

Structural changes, such as port expansion to facilitate import-export trading in the nearshore or offshore platforms for drilling or data collection, have an impact on the marine environment. It is the responsibility of engineers to work with nature in order to mitigate any negative effects as far as possible. In doing so, the integrity and design life of such structures should not be compromised, which is accomplished by understanding the natural hydrodynamic processes at the site of interest. The implications of processes (for instance currents, sediment transport, and wave impact) are to be considered during the design process. A broad oceanographic knowledge together with adequate data at specific local sites compliment a coastal engineer's technical skills in providing the best possible structural solution for the problem or development at hand.

1.2 Problem Description

The purpose of this section is to outline the main aim and objectives of the thesis together with the layout of the document. The problem description was formulated as: *"There has not been a focus on the offshore wave climate data validation around the south and east coast of South Africa and determining design waves for this region."*

1.3 Aims and Objective

The CSIR (Council for Scientific and Industrial Research) have been collecting wave records from 1970 by means of wave measuring buoys. The buoys record high resolution wave data, although it has the disadvantage of only obtaining single point wave data. A minimal number of wave buoys have been deployed along the South African coast, mainly outside the major ports. Due to both of the above mentioned disadvantages, the measuring buoys do not obtain a good coverage and therefore do not fully represent the wave climate along the South African coastline. The use of numerical models and satellite data are able to achieve this 'complete picture' although the measured data is necessary for calibration purposes. These techniques provide a greater understanding of the nearshore areas that the measuring wave buoys are unable to fully describe. An added benefit is that these techniques also provide an understanding for the offshore regions.

The scope of this thesis focuses on the offshore region; therefore, offshore data records of more than 20 years were used in this study. This data is produced by a numerical model (WAVEWATCH III) and managed by the Marine Modeling and Analysis Branch (MMAB) of the Environmental Modeling Center at the National Centers for Environmental Prediction (NCEP). Although this model has been validated for certain regions around the globe, the challenge lies in validating the offshore data (NCEP data) along the south and east coast of Southern Africa. The aim of this research involves validating and conducting an extreme wave analysis for offshore wave data along the south and east coast of Southern Africa. The analysis is to provide extreme wave heights per direction sector and to suggest an associated range of peak periods, which can be calculated using a formula. This will be accomplished by satellite altimetry comparisons to NCEP data along the south coast and two different backward refraction validation approaches for the east coast, thereafter, conducting an extreme wave analysis on the offshore NCEP wave data.

Backward refraction is a process whereby the natural wave process of refraction and shoaling from offshore to nearshore is reversed by means of mathematical calculations. The result is offshore wave conditions obtained from the known nearshore wave conditions in order to compare to NCEP data. The first approach makes use of Snell's Law and provides a first estimate of the offshore wave conditions, although the parallel bathymetric contours do not represent what is found in nature at the particular sites along the east coast. The method is then improved in the second approach by making use of SWAN (Simulating WAves Nearshore), which is a numerical model able to better resolve the wave processes from the offshore to nearshore. Thereafter, an interpolation function is created between the nearshore and offshore model locations in order to interpolate from known nearshore to offshore wave conditions and compare to NCEP data for validation purposes.

1.4 Research Questions

The fulfillment of the present research is to be achieved through the focus of the following research topics and respective questions. Breaking up the research into these components, creates a systematic approach in answering the research problem.

Validate NCEP significant wave height using Altimetry data: Investigate the accuracy of altimetry data and compare it with NCEP and wave buoy data to find the correlation.

Backward refract using Snell's Law and compare to NCEP data: Conduct a simplistic Snell's Law approach obtaining offshore wave conditions. Compare and consider the reliability of these results to NCEP data at two sites along the east coast.

Backward refract using a SWAN and Interpolation and compare to NCEP data: Conduct a numerical SWAN model that describes a more detailed wave propagation. Use these results in order to create an interpolation function between nearshore and offshore wave conditions for comparison to NCEP data at the same two sites along the east coast.

Extreme wave analysis on NCEP data: Depending on the reliability of the results from the backward refraction techniques, adjustment of the NCEP data in preparation for the extreme wave analysis would be required. Calculate the extreme wave height and periods with associated directions for specific return periods using different distributions. Determine the best offshore wave climate distribution technique for the south and east coast of South Africa.

1.5 Thesis Layout

This document has been constructed in relation to the research questions as described in section 1.4. Chapter 2 introduces the history of data collection along the South African coastline, including the development of the instrumentation. Each subsequent chapter includes short literature reviews before the methodology and results section. Chapter 3 is concerned with the satellite altimetry data and comparisons at two locations on the south coast. Chapter 4 focuses on two locations on the east coast and methods to validate the NCEP data by means of backward refraction. Two different approaches are described for each location. Thereafter, Chapter 5 provides the extreme wave analysis for six offshore locations along the south and east of South Africa, including the four previously mentioned locations. Finally, Chapters 6 and 7 conclude the findings and formulate recommendations or future works to compliment this study.

Chapter 2

Wave Data Along the South African Coastline

2.1 General

It is important to accurately record wave parameters so as to fully understand the nearshore wave climate around the South African coastline. Storing the data in a format that is accessible and can be used across different platforms for post processing is necessary for coastal design applications. In this section, a description of the historical development and technological advances with regards to obtaining wave data around the South African coast is given from as early as 1944 to the current day. Nearshore wave buoy data has been collected over many years, however, obtaining offshore records by means of a wave buoy has its challenges. These challenges include a more robust mooring system capable of extending into the deeper waters and withstanding extreme sea conditions. Only locations including Slangkop, FA-Platform, and weather ships that were in commission many years ago obtained this data, (Rossouw, 1989). However, advances in computer processing power as well as the development and refinement of accurate numerical schemes allow coastal engineers to rely more heavily on numerical model tools and their outputs. In industry, these tools reduce the cost and time necessary to deploy and obtain accurate data records by means of wave buoy measurements.

2.2 Agulhas Current

The Agulhas Current is one of the largest western boundary currents, flowing along the east coast of Africa between 27°S and 40°S (Gordon, 1985). The current transports a large volume of water poleward, with the latest year-long current meter measurement estimate by Bryden *et al.* (2003) at 69.7 ± 4.3 Sverdrups (Sv, millions m^3/s).

The contributing sources to the development of the Agulhas Current comprise of the Mozambique Channel eddies (de Ruijter *et al.*, 2002) and the East Madagascar Current as well as the recirculation of the southwest Indian Ocean sub-gyre (Stramma and Lutjeharms, 1997). Figure 2.1 presents the conceptual portrayal of the Agulhas current, including the contributing eddies in the north and the return current back into the Indian Ocean basin.

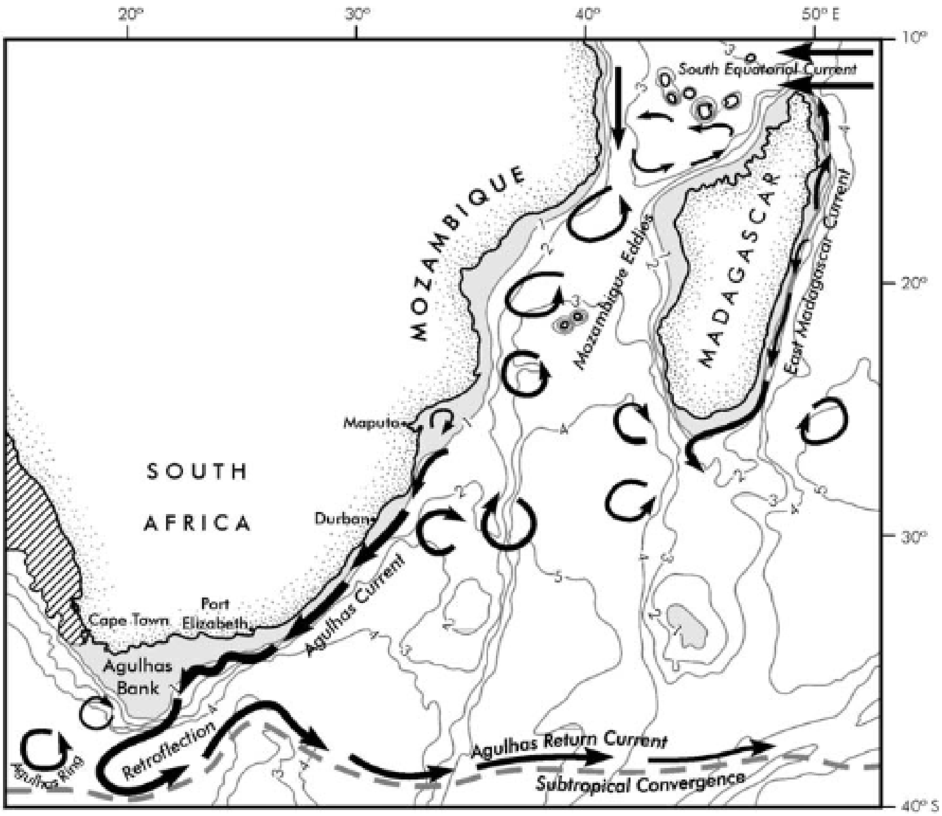


Figure 2.1: A conceptual portrayal of the flow patterns in the greater Agulhas Current, (Lutjeharms, 2007)

The Current only fully develops somewhere north of Durban and follows the continental shelf poleward between Maputo and Port Elizabeth. The shelf is narrow and steep, stabilising the current and preventing wide meanderings which can be found along other boundary currents, such as the Gulf Stream and the Kuroshio. The Natal Bight, between Richards Bay and Durban, is the only region along this section of the shelf that is significantly wider causing a solitary meander. This is known as the Natal Pulse and has the ability to grow rapidly, resulting in a seaward shift of up to 200km from its usual location. This causes a number of major disruptions to the flow regime, comprising early shedding of Agulhas rings further downstream and upstream retroflections near Port Elizabeth. The landward edge of the Agulhas Current changes noticeably when it reaches the Agulhas bank. Long warm plumes form due to extensive meandering across its average path in this region. The wave-current interactions are complex and therefore, imperfectly understood (Lutjeharms, 2006). It was also found that the Agulhas current enhances the significant wave height during certain wind and wave conditions opposing the direction of the current (Grundlingh, 1994).

The modeling of this current is omitted from both the Snell's Law and SWAN approach due to its complex nature and highly variable conditions. Although the modeling implementation of this current was not in the scope of this thesis, it is important to note the existence, location and affects.

2.3 South African Weather Patterns

The meteorology and weather patterns surrounding South Africa are major contributors to the sea state. Detailed descriptions of the weather patterns that affect South Africa have been documented in various publications (Watts, 2004; Tyson and Preston-Whyte, 2000). Wahl (2016) provides a brief description of the typical meteorological features that impact the South African wave climate, which is important to understand as this causes extreme events.

The Hadley cell is a large-scale atmospheric convection cell which is heated air that rises at the equator and descends in the region of 30°S. This descending air, moving in an anti-clockwise rotation around the center, causes two semi-permanent high pressure systems, namely; the South Indian High and the South Atlantic High (MacHutchon, 2006). The Ferrel westerlies, situated south of the Hadley cell, spiral eastwards around the globe. The low pressure systems of the South Atlantic is created by the distributed air in the Ferrel westerlies. Thereafter, these depressions move from west to east. The main source of large waves affecting the South African region is due to the path of these low pressure systems with associated cold fronts (Rossouw, 1989).

These depressions move over the southern tip of Africa at intervals of between 3 and 5 days during the winter months. In summer, however, this occurs less frequently as the entire system shifts southward. Figure 2.2 represents the general synoptic patterns over Southern Africa for the summer and winter months (van Wyk *et al.*, 2011). This implies that high waves can be expected more frequently along the coast of South Africa during winter but this does not mean that high waves do not occur during the summer months. Furthermore as cold fronts move past the south west and south coast, the wind directions usually swing from NW through SW to SE. This often results in wave conditions which are duration limited and therefore not fully developed. These factors, combined with the change in coastline direction on the east coast, have the effect that lower wave heights can be found east of Port Elizabeth. These wave heights are influenced by much smaller systems such as coastal lows. The presence of the South Indian High weather system tends to deflect the cold fronts away from the coast in this region (Rossouw, 1989). Notably, extreme events are usually caused by cut-off lows, which is a phenomenon described by the low pressure system being restricted from passing the high pressure system.

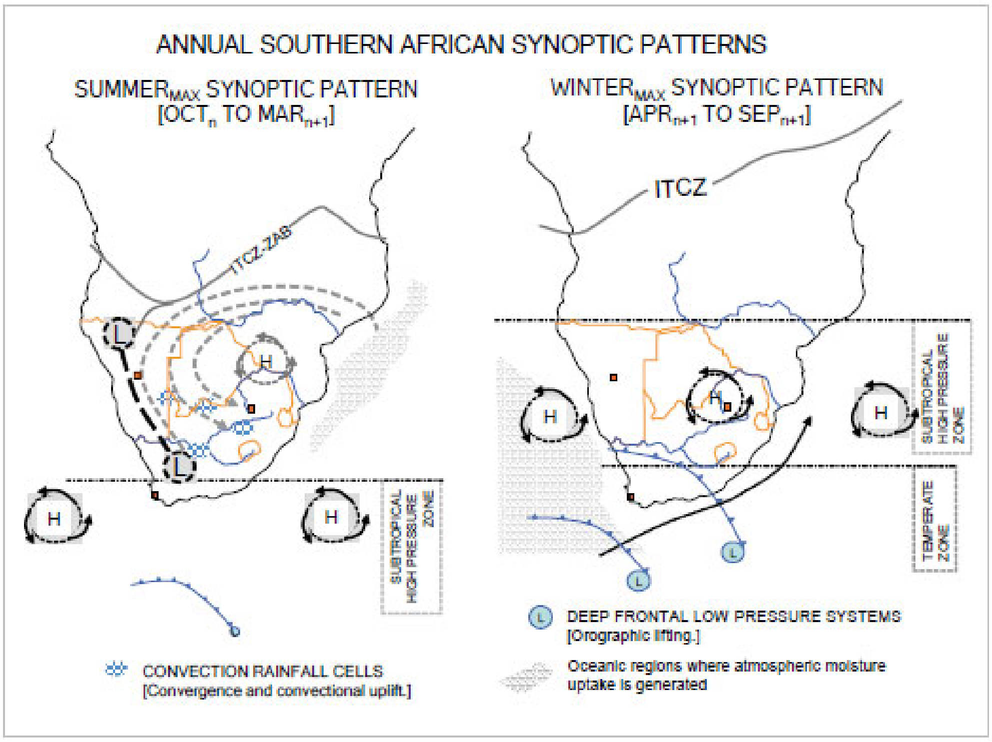


Figure 2.2: South African Synoptic Patterns, (van Wyk *et al.*, 2011)

Another contributing weather system causing high waves along the eastern extremity of the South African coast is the presence of tropical cyclones. These cyclones are smaller but more intense and unpredictable compared to the cold front systems. They are localised systems with large low pressures and form over tropical and subtropical oceans. It involves a process whereby lower atmospheric layers are brought into thermodynamic equilibrium with the warm tropical waters, therefore lowering the pressure and adding energy to the atmosphere. Organised convection patterns and cyclonic wind circulation around the low pressure develops and forms the tropical cyclone.

They originate and move within 7 tropical cyclone "basins" worldwide 4 above and 3 below the equator. Figure 2.3 shows the global cyclone tracks from 1848 to 2013, illustrating that only the northern Natal coast is susceptible to these systems. Rossouw (1999) found that the tropical cyclones should occur at least once every hundred years at coastal locations with latitudes between 2.5 °S and 32.5 °S and therefore should be accounted for in the design conditions. However, this is not in the scope of this thesis. Thereafter, van Niekerk (2016) determined the storm surge levels expected to be produced by tropical cyclones and the best significant wave heights estimates for specific return periods at four locations along the east coast. This was investigated by applying extreme wind speeds determined by Fearon (2014) to third-generation numerical models at Durban, Maputo, Beira and Pemba.

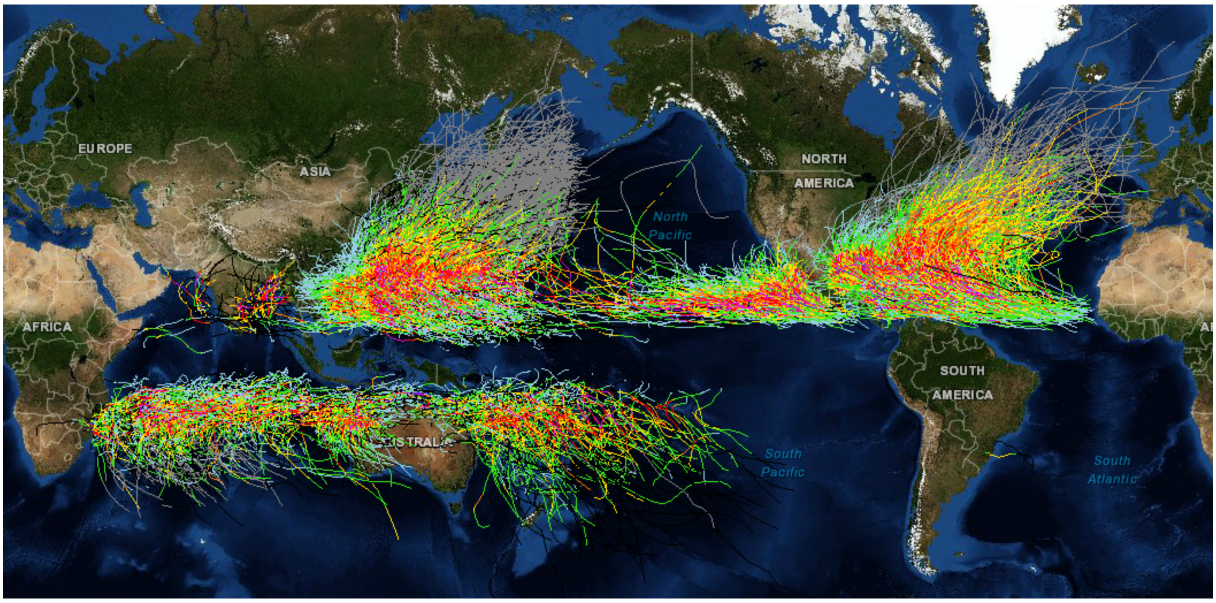


Figure 2.3: Global Cyclone Tracks 1848-2013. Warmer colours indicate stronger winds, (Shultz *et al.*, 2014)

2.4 History of Wave Data Collection

This section gives a background of the instrumentation used to collect data in previous years and thus provides insight into the development and current status of equipment deployed along the South African coast.

Work completed by Rossouw (1984, 1989) explains the different instruments and their contributions to collecting data along the South African coast. This section provides a chronological description of the development of wave recording equipment in this region. Before the development of instrumentation, wave records were collected visually from lighthouses, other stations on land or by voluntary observing ships (VOS) from as early as 1944. The observed wave height, period and direction were made by an experienced observer at six-hourly intervals. It must be noted that the reliability of such records depends on the skill and experience of individual observers (CSIR, 1969). VOS data was stored by the German and Dutch weather bureaus for the west and east of 20°E meridian respectively. This data does not form part of this study because the accuracy of this data is questionable. In addition, there are more accurate technologies that have been developed and are discussed in more detail later in this section.

The clinometer followed the VOS method for obtaining wave parameters and greatly improved the accuracy. The instrument contained a telescope with a graded lens which made it possible to determine the nearshore wave directions. The instrument was usually situated at a high vantage point, allowing the wave height and period to be determined by observing a moored buoy. This instrument was used from 1961 until 1974 (CSIR *et al.*, 1973).

In order to improve the accuracy of the clinometer, experiments with different instrumentation was conducted. First an Inverted Echo-Sounder (INES) was tested in Cape Town and Durban, but was abandoned due to difficulties with maintenance and laying of the cable in the surf zone. A self-contained Inverted Echo-Sounder was also tested, but suffered from leakages and internal defects. The batteries and recording paper had to be changed every four to six weeks and the instrument was normally set to take 15 minute records at six hourly intervals (CSIR, 1969). These instruments became obsolete due to their inherent defects and difficulties without producing useful results.

Thereafter, the National Institute of Oceanography (NIO) shipborne wave recorders were fitted to the hull of research ships; Benguela, Thomas B. Davie, Africana II, Meiring Naudé and the survey ship (SAS Natal) between 1964 and 1969 (van der Borch van Verwolde, 2004). The instrument measured the wave weight and period by means of accelerometers and pressure recorders producing an analogue trace of the water surface. The wave direction was determined visually by means of the ship's compass. A NIO recorder was also fitted to a South Africa weather ship, the F. H. Hughes, stationed at 40°S and 10°E during September 1969 to March 1974 (Rossouw, 1989).

In 1968, Datawell developed an accelerometer buoy called the Waverider that incorporated basic principles of the gravity stabilising long period motion sensors. It was first installed in 1969 off the coast of Mossel Bay in a water depth of 100m. It proved to be superior to any previously used recorders. During the period 1971 to 1973, the number of Waverider stations increased from one to seven. The wave data was recoded on paper rolls in analogue form, carried out for 20 minutes every six hours. In February 1976, the first digital recorder was installed at Slangkop. However, these buoys occasionally lost radio connection during severe storm events and failed to measure wave direction (Rossouw, 1989). This lead to the development of the Direction of Swell Orthogonals (DOSO) which made up for the shortcoming by recording regular wave direction. It was placed in relatively shallow water on the sea bottom where it sensed the orbital motions of waves. The devise produced useful data at a few sites such as Koeberg and Gansbaai (Rossouw, 1989).

Since then, Datawell have updated the Waverider buoy system and the CSIR currently has deployed instruments according to Table 2.1 around the South African coastline, see Appendix A for the specifications of the current Datawell instruments (Datawell BV, 2017). These buoys do not store any of the data, but rather measure for roughly 30 minutes The average wave parameters are then calculated on-board and sent to a base station via radio link. These files are in a very compact form, CSIR's 'in-house' programs decipher and reformat them for display and loading onto the database (which itself belongs to CSIR). The loading is still done manually on a monthly basis.

2.5 Measured Data used in this Study

The data that has been used for this study includes wave buoy data obtained from measuring instruments in the nearshore region. Refer to Table 2.1 for a full description of the locations, instrument types, limitations, start and end dates, including the number of records for the wave buoys along the South African coastline. It should be noted that the limitations represent the wave parameters that the specific instrument did not capture and not the discontinuity of data recordings over time. The stations used for the satellite altimetry comparison include Cape Point and the FA-Platform because the distances of the wave buoys are more than 5km from the land, which is where the satellite produces accurate significant wave height data. These locations are therefore offshore and the wave buoys are in deep water.

Although this data belongs to Transnet National Port Authority (TNPA), it has been stored processed at the CSIR. The longer the wave records, the more confidence engineers have in the design wave heights calculated for specific locations around the coast. The CSIR is also responsible for deploying and maintaining the buoys for research and other projects. Some instruments have on-board processing so that coastal engineers can use the data in this processed format for design. This is not always the case as the data is sometimes not in the correct format or parameters have been omitted due to storage space or specific parameters are not preprogrammed within the buoy. In this case, the CSIR has developed in-house processes to analyse the data and produce the parameters that are necessary for specific studies. Theft and damage of the buoys have been areas of concern in the past, with buoys being bumped or stolen as ships pass. Maintenance also proves to be difficult to monitor regularly. The measured wave buoy data form a vital part in understanding the oceans around South Africa and in designing and planning for nearshore and offshore structures.

It is important to note that all data recorded by the Datawell buoys prior November 1989 was 6-hourly data, thereafter producing wave records on a 3-hourly basis. The MAREX system that was used on the FA-Platform was a vertical radar system that monitors the water level on a small area (a footprint of a few square metres). The sensor is about 20m above the mean water level and did not include wave direction (only Hs and Tz). This system was supplemented a number of years ago by a horizontal radar system (WaMoS from OceanWaves in Germany). The system itself scans the sea surface around the Platform (360 deg and includes wave direction). The virtual buoy system at Port Elizabeth works from an original numerical model that was set up for the region and calibrated. Subsequently, an interpolation function is used on a continuous basis to hindcast the wave parameters at the virtual buoy location. The Waverider data for Cape Point and Marex/WaMos data for the FA-Platform was used in Chapter 3 for comparisons to NCEP significant wave heights along the south coast. The wave buoy data at East London and Richards Bay was used in Chapter 4 in order to backward refract from nearshore to offshore wave conditions as well as for comparison purposes.

There is a large volume of measured wave buoy data with variable quality. Data obtained from either: Waverider/Wavemonitor; 3D Directional Buoy; Directional Waverider; Marex; or a Virtual Buoy, will further be referred to as wave buoy data, although these are not all strictly buoys.

Table 2.1: Measuring Wave Buoy Data Information

Location Name	**Longitude (DD.ddddd)**	**Latitude (DD.ddddd)**	**Water Depth(m)**	**Station Code**	**Instrument Type**	**Limitation**	**No. Records**	**Record Start Date (dd/mm/yyyy)**	**Record End Date (dd/mm/yyyy)**
Slangkop	18.17666	34.12666	170	SL01	Waverider	No Dir	50715	03/02/1976	12/06/1993
Cape Point	18.28667	34.20400	70	CP01	Waverider	None	66672	07/06/1994	Current(28/02/2017)
FA-Platform	22.17000	34.97000	113	FB01	Marex	No Tp & Dir	44104	06/06/1996	10/07/2011
Mossel Bay	22.15350	34.12467	24	MB02	Waverider	No Dir	28568	22/05/2007	Current(28/02/2017)
Port Elizabeth	25.66400	33.94600	14	PE	WAVEWATCH III	None	13842	30/01/1997	Current(28/02/2017)
Ngqura	25.71666	33.83333	21	NG01	DWR	None	17504	05/03/2011	Current(28/02/2017)
East London	27.93083	33.03800	27	OL01	Waverider	No Dir	23518	22/04/1992	17/05/2000
East London	27.93083	33.03800	27	OL01	3D Buoy	None	18275	19/11/1997	20/02/2004
East London	27.93083	33.03800	27	OL01	DWR	None	42136	29/09/2002	Current(28/02/2017)
Cooper Light	30.99833	29.98447	42	CL01	Waverider	No Dir	28048	11/08/1992	31/10/2001
Durban ADCP	31.06750	29.86250	15	DB04	ADCP	None	12696	25/01/2002	02/10/2006
Durban Bluff	31.07067	29.88400	30	DB08	DWR	None	27824	23/08/2007	Current(28/02/2017)
Richards Bay	32.10400	28.82650	22	RB01	Waverider	No Dir	59976	14/09/1979	23/03/2000
Richards Bay	32.10400	28.82650	22	RB01	3D Buoy	None	15615	11/06/1997	14/10/2002
Richards Bay	32.10400	28.82650	22	RB01	DWR	None	32024	08/11/2002	23/10/2013
Richards Bay	32.10400	28.82650	22	RB01	DWR Mk4	None	56662	31/10/2013	Current(28/02/2017)

2.6 NCEP Data used in this Study

It is important to understand how the offshore wave data is obtained in order to conduct an extreme wave analysis for the offshore regions of South Africa. The NOAA WAVE-WATCH III operational wave model suite consists of a set of five wave models. This study, however, made use of the data obtained from the global NWW3 model. There is work currently underway to develop a regional model but until then the model is run four times a day: 00:00, 06:00, 12:00, and 18:00, producing wave parameters and used by coastal engineers for project applications. Model outputs at a resolution of roughly 1°x1° produce a rather broad coverage globally. The significant wave height, peak period and direction was used for this study, though it should be noted that spectral offshore data has recently been made available to the scientific community.

The model does have its limitations, such as how it resolves diffraction and the degree to which it is able to solve wave-current interactions. The global model data that is used by South African coastal engineers does not include the Agulhas Current as an input into the model. However, the model framework includes wave-current interactions. The implementation of these interactions has only been tested in idealized test cases. Only limited tests in realistic conditions have been performed. This would then need to be investigated and implemented in a regional model as this is particularly important along the east coast of South Africa, where the Agulhas current flows south, producing eddies within this region.

WAVEWATCH III (Tolman, 1997, 1999, 2000) is a third generation wave model developed at NOAA/NCEP from the WAM model (WAMDIG, 1988; Komen *et al.*, 1994). It is a further development of the WAVEWATCH and WAVEWATCH II models. WAVEWATCH was developed at Delft University of Technology (Tolman, 1989), where WAVEWATCH II was developed at NASA (Tolman, 1992). WAVEWATCH III, however, differs from its predecessors in many important aspects, namely; the model structure, physical parametrisation, numerical methods, and the governing equations. Furthermore, WAVEWATCH III is evolving from a wave model into a wave modeling framework that allows variations in numerical approaches and the development of additional physical wave modeling parameters. WAVEWATCH III solves the random phase spectral action density balance equation for wavenumber direction spectra. The equation makes the implicit assumption that the properties of the medium and wave field vary on space and time scale, which are greater than the variation scale of a single wave. The WAVEWATCH III uses operational NCEP products as input to drive the model. The six locations along the coast for which the extreme wave analysis was determined have been plotted in Figure 2.4.

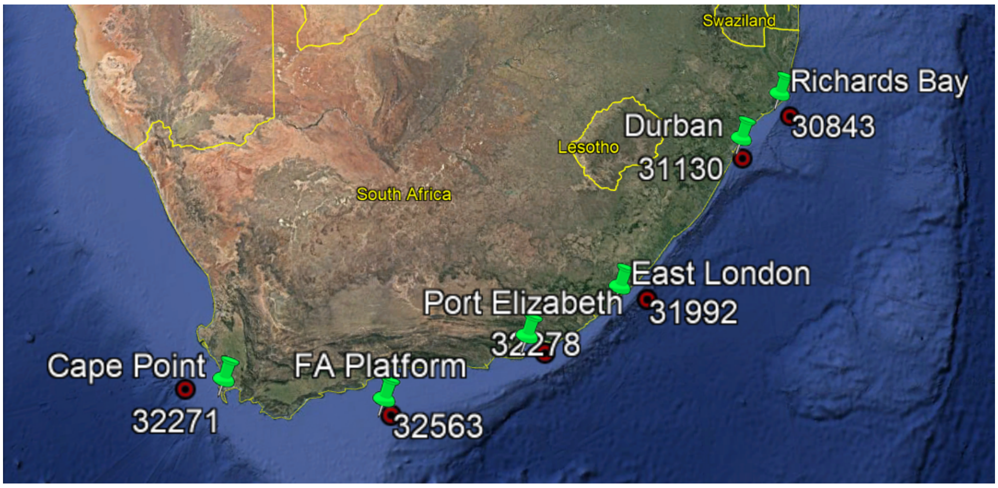


Figure 2.4: South African Measuring Wave Buoys and Nearest NCEP Locations

The locations, average depths and distances between the wave buoys along the coast and the nearest NCEP locations have been tabulated, see Table 2.2. Satellite altimetry comparisons for Cape Point and FA-Platform were conducted. Cape Point was selected as the weather systems move from west to east and hence, the wave conditions between the NCEP location and the wave buoy should be similar. Additionally, the Cape Point wave buoy is in relatively deep water which means that the waves are not affected by bottom effects. The choice for FA-Platform was due to the NCEP and wave buoy locations that are both offshore and in close proximity to one another. East London and Richards Bay were used for the backward refraction approaches due to the large geographical distance between their respective wave buoy and NCEP location as well as the shallow water associated with the wave buoys in the nearshore along the east coast.

Table 2.2: Measuring Wave Buoy and NCEP Location Information

Location Name	**Longitude**	**Latitude**	**Water Depth (m)**	**Nearest NCEP Location**	**Longitude**	**Latitude**	**Water Depth (m)**	**Location Distances (km)**
Slangkop	18°10’35.98"	34°07’35.98"	170	32271	17°30’00.00"	34°00’00.00"	627	64
Cape Point	18°17’12.01"	34°12’14.40"	70	32271	17°30’00.00"	34°00’00.00"	627	76
FA-Platform	22°10’12.00"	34°58’12.00"	113	32563	22°30’00.00"	35°00’00.00"	130	30
Mossel Bay	22°09’12.60"	34°07’28.81"	24	32563	22°30’00.00"	35°00’00.00"	130	102
Port Elizabeth	25°39’50.40"	33°56’45.60"	14	32278	26°15’00.00"	34°00’00.00"	109	54
Ngqura	25°42’59.98"	33°49’59.99"	21	32278	26°15’00.00"	34°00’00.00"	109	53
East London	27°55’50.99"	33°02’16.80"	27	31992	28°45’00.00"	33°00’00.00"	2082	76
Durban	31°04’14.41"	29°53’02.40"	30	31130	31°15’00.00"	30°00’00.00"	441	21
Richards Bay	32°06’14.40"	28°49’35.40"	22	30843	32°30’00.00"	29°00’00.00"	1300	43

2.7 Discussion

The weather systems (moving over the southern tip of Africa, bringing with them the cold fronts that influence and cause storms) are important to understand as this results in large waves necessary to conduct the extreme wave analysis. Studies have made use of previous work on tropical cyclones and the wind speeds at specific return periods for estimates of significant wave heights and storm surge levels. However, the inclusion of cyclone effects is not in the scope of this study. The Agulhas Current is a complex system and not yet fully understood. The physical processes have not been successfully described within numerical models i.e. WAVEWATCH III and therefore are not included or modelled within this study.

The single point measuring instrumentation used along the South African coastline that is deployed and managed by the CSIR have been further referred to as wave bouys in this document. The wave parameters obtained from these instruments were used for comparison purposes. WAVEWATCH III, a numerical model solving the random phase spectral action density balance equation, produces outputs i.e. NCEP data, which was used as offshore data. Validation and extreme wave analysis of this data is to be performed in the chapters to follow.

For validation purposes, a direct comparison of two sites along the south coast of South Africa, i.e. Cape Point and FA-Platform, was conducted using satellite altimetry data. An indirect comparison of two sites along the east coast of South Africa, i.e. East London and Richards Bay, was conducted using two backward refraction approaches. The method of Snell's Law was used as a first estimate but the more complex approach used SWAN and an interpolation function. Both the satellite data and backward refracted data were compared to the offshore NCEP data in order to validate the data before conducting the extreme wave analysis.

Chapter 3

Altimetry Comparison

3.1 General

The applications of coastal engineers are usually concerned with the nearshore wave climate and dominant conditions. This is due to design work concerned with port development and mitigation measures within the port channel or basins in order to ensure safe handling of cargo and vessels. Traditionally, this information was obtained at a local site by measurements from wave recording buoys and depending on the application and data available, Acoustic Doppler Current Profilers (ADCP's) and pressure sensors have also become common practice. Then for design purposes, the wave climates were tested using either physical or numerical model studies. Numerical model predictions have become an ever growing tool for analysing and conceptualising wave dynamics for coastal engineers over the last couple of decades. Although there is still much to learn, the technological and computer processing improvements have given way to a new perspective and understanding during the analysis process.

The complexity of fluid dynamics, more specifically waves, will remain the work of mathematicians and engineers providing design solutions, mitigation measures and other coastal developments for years to come. There are institutes dedicated to exploring wave processes and reducing processing power and time in order to create a robust and user friendly numerical model. One such model is the WAVEWATCH III model. This is a global model and therefore is forced mainly by wind data obtained from weather stations situated around the world and fed into the model. Results obtained from the WAVEWATCH III model are known to South African coastal engineers as 'NCEP points' and are then used in different numerical model packages to fully describe the nearshore conditions at a site of interest, depending on the specific application. These points are outputted at a grid resolution of roughly 1° by 1° from 1997, but has since been refined to 0.5° by 0.5° grid outputs (Chawla and Tolman, 2007). Refer to chapter 2 for a full description of the WAVEWATCH III model. It is important to note that coastal engineers in industry trust the outputs produced by these models only once it was calibrated. Originally, the way in which models had been calibrated (and still today) was by comparing the model data to wave buoy measurements. Another, more modern and exciting approach is to make use of satellites. Satellite data covers almost the entire ocean which is a significant advantage over single-point data from wave buoys. The data obtained from the satellite (Jason-2), once calibrated, could be used to either verify numerical models or more generally to understand wave climates in remote areas where no wave records are available. Section 3.2 provides a full description of the Jason-2 satellite, also known as the Ocean Surface Topography Mission or OSTM that was used in this study in order to verify the NCEP data.

3.2 Jason-2 Satellite

Jason-2/OSTM was a follow-on satellite mission that took over and continued from the TOPEX/Poseidon (1992-2005) and Jason-1 (2001-2013) missions. The TOPEX/Poseidon and Jason-1 missions were conducted under a co-operation between the United States National Aeronautics and Space Administration (NASA) and the French Space Agency, "Centre National d'Etudes Spatiales" (CNES). Two additional partners were introduced for the OSTM/Jason-2 mission in order to facilitate the transition towards a fully operational altimetry mission by satisfying data reliability and timeliness. These partners were the National Oceanic and Atmospheric Administration (NOAA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). The satellite manuals for TOPEX/Poseidon, Jason-1 and Jason-2 supply a detailed description of the satellites with respect to their specifications and capabilities (Merged TOPEX/POSEIDON Products, 1996; Jason-1 Products Handbook, 2016; OSTM/Jason-2 Products Handbook, 2017). Jason-2 was launched on 20 June 2008 and remained on its nominal orbit gathering data until October 2016. After this 8 year service, i.e. cycle 303, the Jason-2 satellite changed to the interleaved orbit that was used during 2002-2005 by Topex and during 2009-2012 by Jason-1. Jason-3 was launched in January 2016, serving as a key element of the constellation of altimetry satellites by continuing long-term operational oceanography observations. The system has been upgraded with a number of enhancements, ensuring that the satellite achieves the mission outcomes (Jason-3 Products Handbook, 2017).

The reason for the Jason-2/OSTM mission was:

- Ensuring the Ocean Science community maintains a continuity of high quality measurements.
- Satisfying the data timeliness and reliability requirements of the satellite observations used for operational applications in industry or by the scientific community, i.e. forecasting applications.

The major aspects of the Jason-2/OSTM mission include:

- A satellite obtaining altimetry records of wave heights above the sea surface.
- A stabilization and positioning system ensuring accurate precision along its orbit.
- A distribution and data analysis system used for processing, verifying and making the satellite data available to the scientific community.
- A Principal Investigator Program generating a feedback platform for scientific studies and operational applications focussed on the satellite observations.

This study made use of the 8 years of altimetry data obtained from Jason-2 which had an altitude of 1336 km and repeat cycle of 9.9156 days. The Jason-2/OSTM level 2 products consists of an Operational Geophysical Data Record (OGDR) that is produced within 3-5 hours of the satellite overflight. It has the lowest quality and the most intermittent data but useful for time critical applications. The Interim Geophysical Data Record (IGDR) is produced within 1-2 days of overflight. The orbital quality is far better. The science quality "final" Geophysical Data Record (GDR) is produced with a 60 day time lag. All files are available in NetCDF format (Lillibridge *et al.*, 2011). The netCDF data archive was obtained from NOAA.

The two-frequency solid-state altimeter is derived from the two-frequency Poseidon-2 altimeter. This sensor has a measuring range that accounts for and corrects ionospheric influences. It operates at 13.575 GHz (Ku-band) and 5.3 GHz (C-band). There is a high level of quality monitoring ensuring that the data made available to the research community has been corrected. These corrections are reported for both the Ku and C band ranges separately. These ranges must be corrected because of the atmospheric path delay through which the radar pulse passes. The Ku-band range is used for most applications and subsequently used in this study as it has a higher resolution. The aim of the altimeter sensor was to achieve an accuracy within 5% or 0.25m of the true significant wave height which is sufficient for engineering applications. Refer to Equation 3.1 defining the corrected range. The range includes orbital corrections and the sea state bias correction is calculated empirically as a function of significant wave height and wind speed at ten meters above mean sea level. The wet troposphere correction is caused by clouds and rain (variable). The dry troposphere correction is caused by oxygen molecules and the ionospheric correction is caused by the presence of free electrons in the ionosphere.

$$\begin{aligned}\text{Corrected Range} = {} & \text{Range} + \text{Wet Troposphere} + \\ & \text{Dry Troposphere} + \text{Ionosphere} + \\ & \text{Sea State Bias}\end{aligned} \tag{3.1}$$

3.3 Method

The data is freely available and the data is organised by cycle (a full repeat 10 days for Jason-2). The pass information is situated within the cycle folders for Jason. There are tools assisting the research community to select, filter and visualise the data such as the pass locater. This tool was used for determining the Jason-2 pass numbers nearest Cape Point and the FA-Platform measuring instruments for comparison purposes. Refer to Figure 3.1 for the Jason-2 passes over Southern Africa.

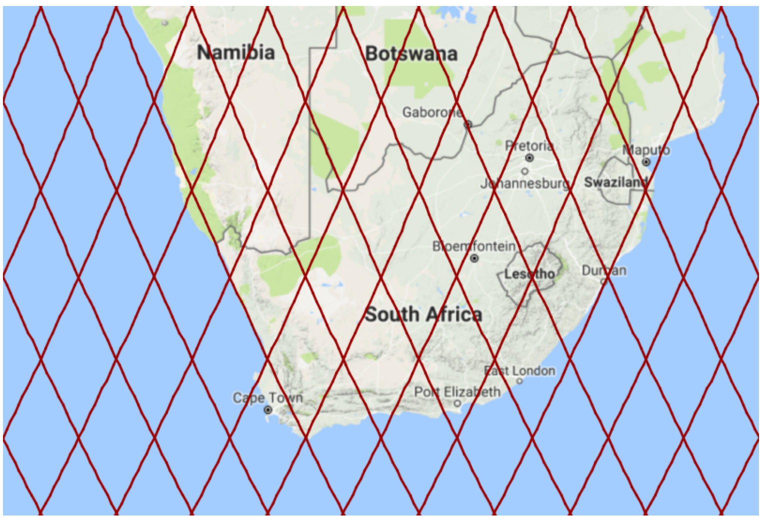


Figure 3.1: Jason 2 Tacks over Southern Africa

The complete GDR for Jason-2 is archived and accessed from a tape library system called CLASS from NOAA. The data is in netCDF file format which is a convenient file format as it is self-describing, meaning that software packages can directly read the data and determine its structure, the variable names and essential metadata such as the units. This self-describing aspect of netCDF file format means that the information needed to ensure accurate work (reduce the incidence of errors) is available with the data itself. In addition, programs such as MATLAB can examine a netCDF file and generate the code needed to read, plot and analyse the file (NOAA, 2017).

Jason-2 data is relatively limited, having a mission lifetime of roughly 8 years and only producing a data point at a specific location every 10 days. For this reason, an intersection point where 2 passes overlap was chosen, making the sample dataset double in size as data could be extracted every 5 days instead of 10 days. The Google Earth image in Figure 3.2 represents the ascending and descending passes that overlap, showing the intersection locations nearest the measuring buoys and NCEP locations. There is a considerable distance of 102km from the intersection location of pass 046 and 209 and the NCEP location (32271), and 138km to the Cape Point wave buoy. However, a direct comparison is still possible as the dominant weather creates waves approaching from the SW direction. These waves are fully developed because of the vast fetch over which they travel and there is no influence of wave diffraction due to land masses. This means that the waves will not be transformed by the time they arrive at the NCEP and wave buoy locations. For this reason no spatial interpolation of the satellite, wave buoy or NCEP data was performed.

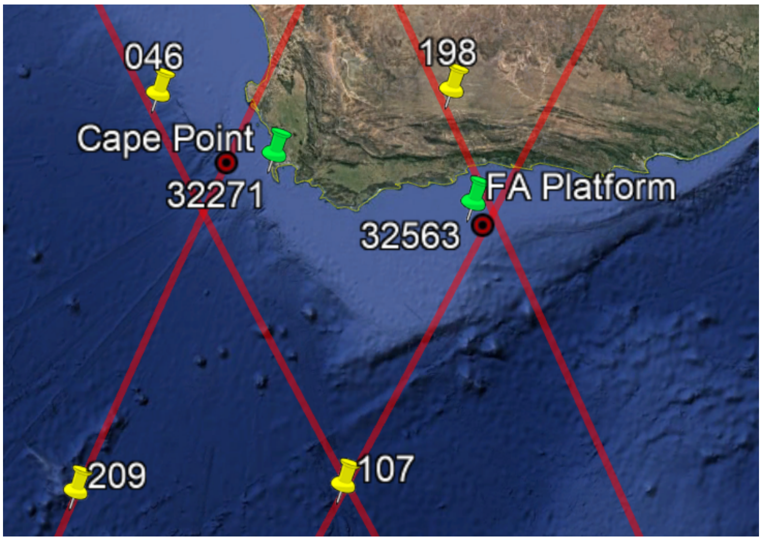


Figure 3.2: NCEP and Measuring Buoy Locations Relative to Satellite Passes for Cape Point and FA-Platform

Another tool used to visualise the data within the netCDF file is called ‘Brat’. This tool allows the user to view the significant wave height variable and the associated variables, including latitudes and longitudes as well as the date-time association. The longitude is positive to the east, ranging from -180°to 180°. The latitude is positive to the North, ranging from -66°to 66°. Figure 3.3 shows the tracks of all cycles for pass 107 and 198 on a global map.

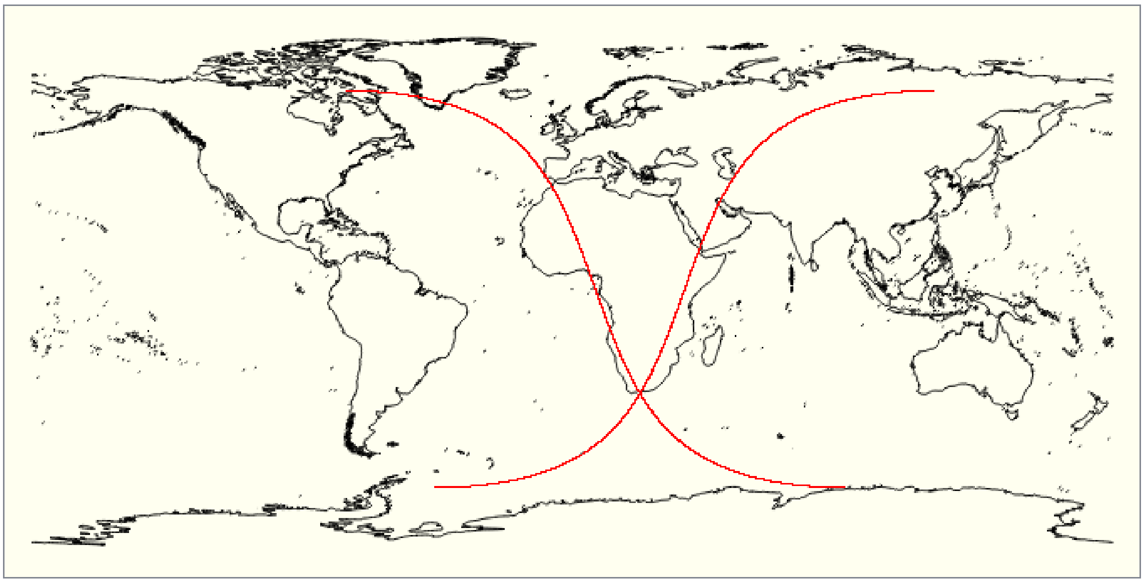


Figure 3.3: Jason 2 Swath path of pass 107 and 198

Figure 3.4 and 3.5 represent the significant wave height along these passes in 2D and 3D respectively with regards to the spatial stamp associated with the captured data. Together with the spatial stamp, there is an associated time stamp to each significant wave height. The time convention of the data captured, i.e. significant wave height, was converted from a numerical value with units in seconds since 01/01/2000 to the Gregorian calendar's convention for date and time.

By using the point of intersection, represented by red circles in the figures, it made it possible to extract data every 5 days instead of every 10 days. The significant wave height and associated time stamp was extracted according to a latitude value of -34.826° for the intersection of pass 107 and 198 and -34.822° for pass 046 and 209. An example of this location is clearly presented in the 2D figure and just before the data peaks, becomes unstable as the satellite moves over the land in the 3D figure. What is interesting to note is that the significant wave heights increase for more southerly latitudes, which is known to be caused by the roaring forties - strong westerly winds generally between the latitudes of 40 and 50 degrees (NOAA, 2018). Although only the cycles for pass 107 and 198 are presented, a similar pattern should be expected for pass 046 and 209. The significant wave heights were extracted from the wave buoy and NCEP data at time stamps that correlated with the time stamps of the altimeter data captured for the latitudes chosen, refer to Appendix B.

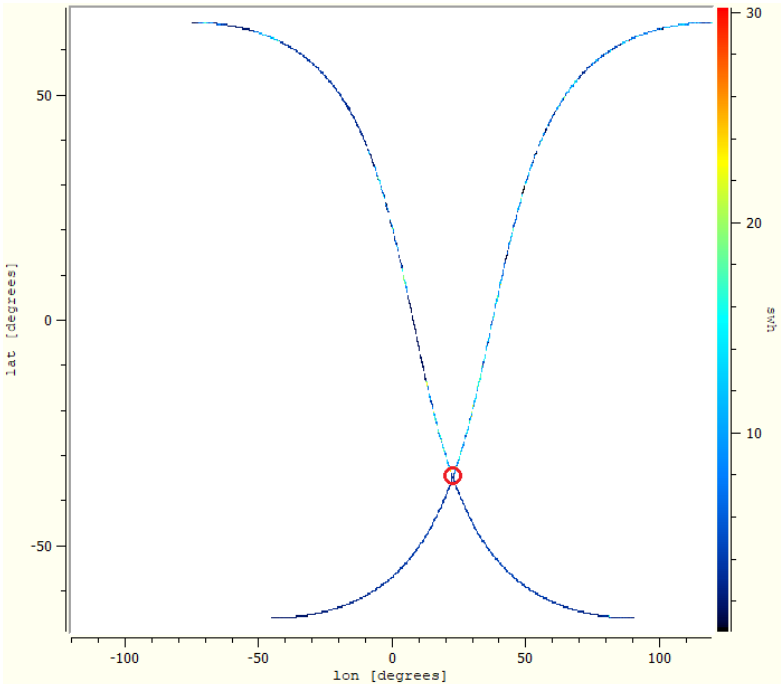


Figure 3.4: 2D View of Significant Wave Height per Spatial Stamp of all the cycles for pass 107 and 198

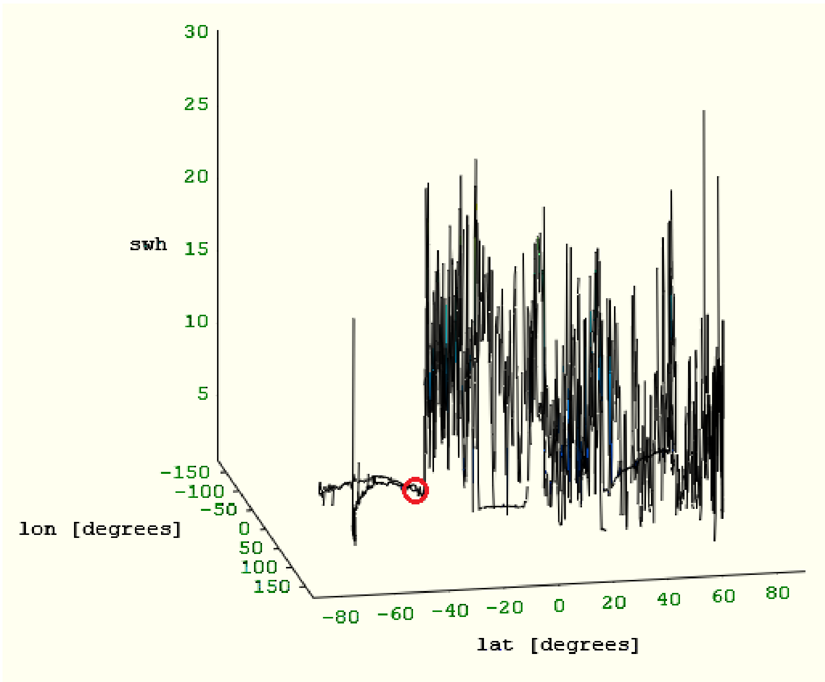


Figure 3.5: 3D View of Significant Wave Height per Spatial Stamp of all the cycles for pass 107 and 198

Firstly, Statistical analysis was performed on the altimeter-and-NCEP, altimeter-and-wave buoy, as well as the wave buoy-and-NCEP data. The bias between the two data sets (bias), the root mean square error (RMSE) (Chai and Draxler, 2014), the slope of the best fit line passing through the origin (slope), the scatter index (si) and the Willmott index of agreement (W) (Liberti *et al.*, 2013) was determined. Table 3.1 through to 3.6 provide the statistical results for the analysis which include the indices describing the performance. For the NCEP and altimetry comparison, a given series of m NCEP values y_i corresponds to altimetry values x_i. Whereas for the wave buoy and altimetry comparison, a given series of m altimetry values y_i corresponds to wave buoy values x_i. Similarly for completeness, a comparison between wave buoy values x_i and NCEP values y_i was undertaken. The indices are defined as follows:

$$bias = \frac{1}{m}\sum_{i=1}^{m}(y_i - x_i) \tag{3.2}$$

$$rmse = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(y_i - x_i)^2} \tag{3.3}$$

$$slope = \frac{\sum_{i=1}^{m} x_i y_i}{\sum_{i=1}^{m} x_i x_i} \tag{3.4}$$

$$si = \frac{rmse}{\frac{1}{m}\sum_{i=1}^{m} y_i} \tag{3.5}$$

$$W = 1 - \left[\sum_{i=1}^{m}(y_i - x_i)^2 / \sum_{i=1}^{m}(|y_i'| + |x_i'|)^2\right] \tag{3.6}$$

Where $y_i' = y_i - \bar{x}$, $x_i' = x_i - \bar{x}$ and $\bar{x}$ is the average of the observed values. This Willmott index is bound between 0 and 1, where 1 implies a perfect match between the observed and predicted.

Secondly, a two sample t-test was conducted in order to determine whether or not the significant wave height means of the comparison data samples differ within a 5% significance level.

Lastly, the average significant wave heights per season for the same comparison data samples was undertaken, not only to see the seasonal variation over the years but also the variation between data samples. The reason was to identify fluctuations or a relative consistency of average seasonal significant wave heights for the data over the entire time period for which the data is available.

3.4 Results

This section focuses on presenting the findings for the above described methodology. The statistical tables and comparison density plots for Altimetry-and-NCEP, Altimetry-and-Wave Buoy and NCEP-and-Wave Buoy were discussed, followed by the two sample t-test. Subsequently, the average significant seasonal wave heights were tabulated and plotted.

The Jason-2 mission started in 2008 and ended in 2016, capturing data every 5 days at intersection locations which limits the data to less than 600 data values. Tables 3.1 to 3.4 present the statistical analysis for the total period for the comparisons of the wave buoy and NCEP data with the altimetry data. It was important to then do statistical analysis for each full year (2009 to 2015) that it was in the nominal orbit in order to confirm the consistency and reliability of the data. Extracting the yearly statistics for the NCEP and Wave Buoy Comparison was not critical as the large quantity data samples ensure reliable results, refer to Tables 3.5 and 3.6. The comparisons show good agreement and are discussed in more detail by describing the plots and statistical results in the tables below.

Density scatter plots were drawn up for an Altimetry-and-NCEP, Altimetry-and-Wave Buoy and NCEP-and-Wave Buoy comparisons for both Cape Point and FA-Platform, refer to Figures 3.6 to 3.11. The colour scale ranging from blue to yellow with respective zero to one values represent the density qualitatively with respect to the entire data sample. The scatter plot was coloured by density, in other words, the yellow points resemble the most dense or highest concentration of data points at a particular value with respect to all other data points. Similarly, the blue represents the most sparse and distant data points with respect to all other data points. It can be seen that the highest occurrence is focused around the 1 to 1 line, implying that there are not many data points that occur at large distances from the perfect correlation line. The 1 to 1 line representing a perfect correlation as well as the fitted trend line of the data through zero was plotted as a red solid line and dotted line respectively. The trend line was plotted through the origin as the assumption is that when the observed data is zero so should the predicted data. The slope of this line is also in the statistical analysis tables associated with each plot. The slopes vary around 1 for all comparisons, implying the trend is towards a good correlation between data samples, although this should be considered in conjunction with RMSE, si and the Willmott index.

Below is a detailed description of these comparisons, making sense of the results for the south coast, i.e. Cape Point and FA-Platform.

3.4.1 Altimetry and NCEP Comparison

Referring to Tables 3.1 and 3.2 and Figures 3.6 and 3.7 for altimetry and NCEP Comparison results for Cape Point and FA-Platform respectively. The Cape Point comparison has a larger overall scatter index than the FA-Platform comparison, which can also be seen in the figures. The best fit line is closer to the perfect match due to the symmetry around the one to one line and illustrated with a trend-line equation for Cape Point of $H_{s(NCEP)} = 0.967H_{s(Alt)}$ compared to $H_{s(NCEP)} = 1.080H_{s(Alt)}$ for FA-Platform. This implies that on average the NCEP significant wave height is slightly lower than the altimetry significant wave height recordings for Cape Point and the opposite is true for FA-Platform. The Cape Point bias of -0.061m and RMSE of 0.601m compared to FA-Platforms bias of 0.225m and RMSE of 0.532m also confirms these findings. The Willmott index of agreement for both sites being larger than 0.9 proves that there is good agreement between these two data samples.

Table 3.1: Cape Point Statistics for Jason-2 (pass 046 & 209) and NCEP (32271) Significant Wave Height Comparison

Period	**Samples**	**Bias (m)**	**RMSE (m)**	**Slope**	**si**	**W**
Total	588	-0.061	0.601	0.967	0.200	0.911
2009	72	-0.031	0.644	0.986	0.210	0.908
2010	73	0.048	0.615	1.003	0.203	0.878
2011	72	-0.032	0.617	0.982	0.204	0.909
2012	73	0.008	0.507	0.994	0.162	0.936
2013	68	-0.055	0.570	0.968	0.187	0.946
2014	72	0.061	0.502	1.015	0.166	0.938
2015	73	-0.259	0.655	0.896	0.227	0.872

Table 3.2: FA-Platform Statistics for Jason-2 (pass 107 & 198) and NCEP (32563) Significant Wave Height Comparison

Period	**Samples**	**Bias (m)**	**RMSE (m)**	**Slope**	**si**	**W**
Total	596	0.255	0.532	1.080	0.174	0.924
2009	72	0.301	0.538	1.092	0.174	0.910
2010	74	0.372	0.610	1.121	0.191	0.897
2011	73	0.248	0.451	1.072	0.146	0.955
2012	74	0.281	0.486	1.083	0.154	0.937
2013	69	0.321	0.665	1.095	0.206	0.921
2014	73	0.320	0.557	1.104	0.172	0.924
2015	74	0.118	0.421	1.030	0.154	0.901

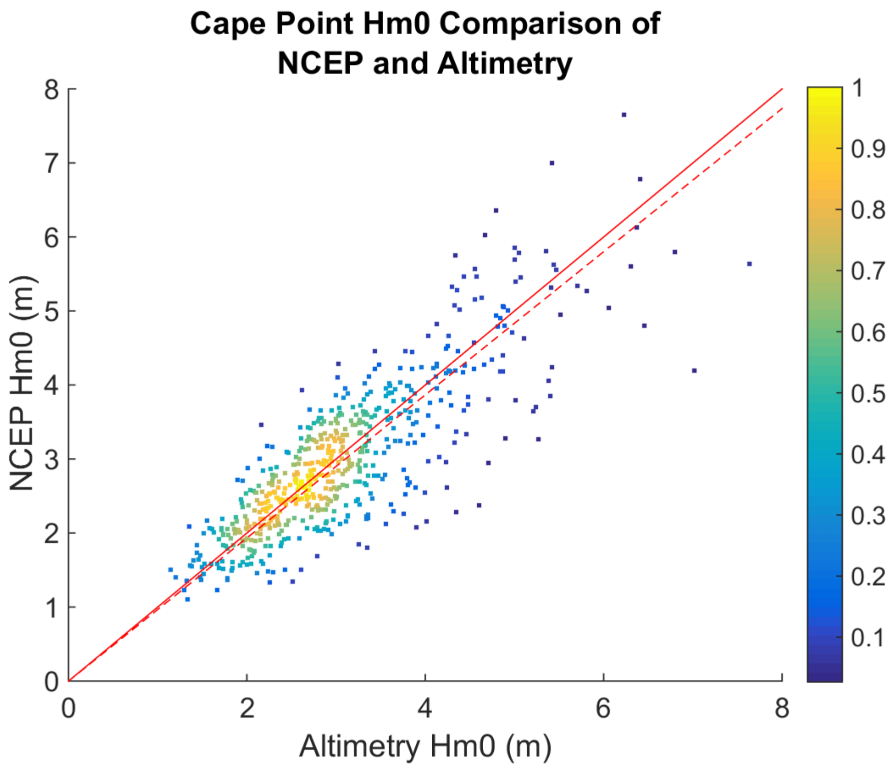


Figure 3.6: Cape Point Density Scatter Plots of NCEP to Altimetry

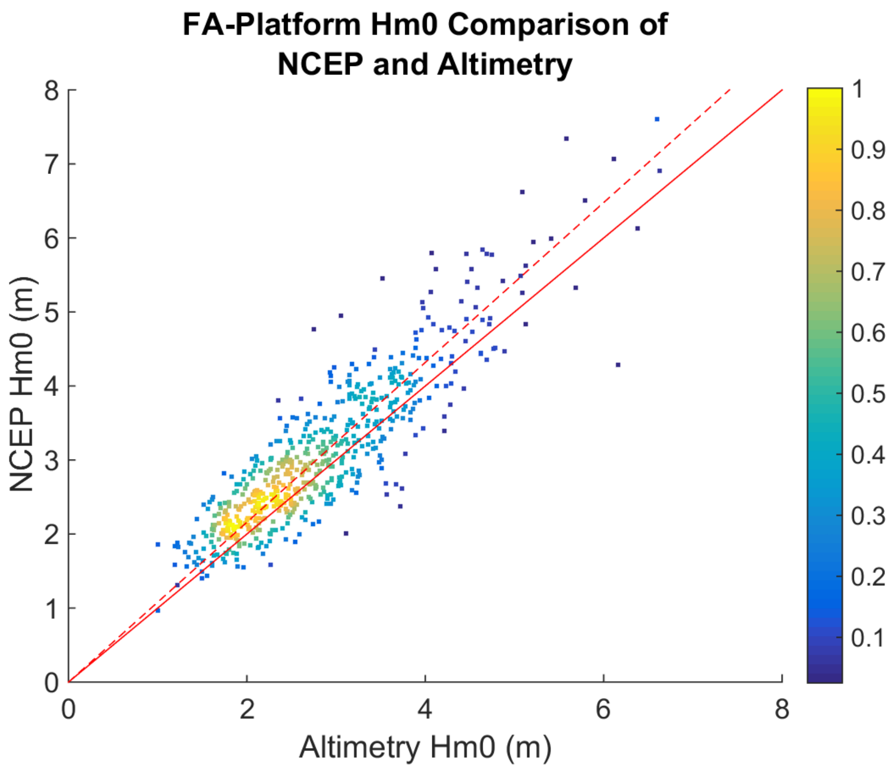


Figure 3.7: FA-Platform Density Scatter Plots of NCEP to Altimetry

3.4.2 Altimetry and Wave Buoy Comparison

Referring to Tables 3.3 and 3.4 and Figures 3.8 and 3.9 for altimetry and wave buoy Comparison results for Cape Point and FA-Platform respectively. Again, the overall scatter index of Cape Point is larger than FA-Platform, also seen in the figures. The best fit line is further from the perfect match, illustrated with a trend-line equation for Cape Point of $H_{s(Alt)} = 1.168H_{s(WaveBuoy)}$ compared to $H_{s(Alt)} = 1.007H_{s(WaveBuoy)}$ for FA-Platform. The main reason for the difference could be attributed to a more southerly satellite intersection location than the Waverider location with more adverse wave climate. The wave buoy is closer to the shore and seems to have been effected by 'bottom effects', therefore decreasing the wave heights at this location. This was illustrated with a larger bias of 0.549m and RMSE value of 0.824m for Cape Point, whereas as bias of 0.091m and RMSE value of 0.521m was found for FA-Platform. The Willmott index of agreement for Cape Point still shows a good agreement, although only a value of 0.832 was calculated, which is due to the reason described above. FA-Platform, again, proves to be a good agreement with a Willmott index larger than 0.9.

Table 3.3: Cape Point Statistics for Jason-2 (pass 046 & 209) and Measured Buoy Significant Wave Height Comparison

Period	**Samples**	**Bias (m)**	**RMSE (m)**	**Slope**	**si**	**W**
Total	588	0.549	0.824	1.168	0.271	0.832
2009	72	0.609	0.900	1.193	0.290	0.810
2010	73	0.437	0.671	1.168	0.225	0.844
2011	72	0.609	0.803	1.214	0.263	0.842
2012	73	0.469	0.702	1.168	0.225	0.862
2013	68	0.479	0.689	1.149	0.223	0.923
2014	72	0.491	0.732	1.130	0.248	0.882
2015	73	0.698	1.089	1.259	0.347	0.667

Table 3.4: FA-Platform Statistics for Jason-2 (pass 107 & 198) and Measured Buoy Significant Wave Height Comparison

Period	**Samples**	**Bias (m)**	**RMSE (m)**	**Slope**	**si**	**W**
Total	596	0.091	0.521	1.007	0.187	0.905
2009	72	0.150	0.344	1.052	0.123	0.957
2010	74	0.106	0.358	1.035	0.127	0.952
2011	73	0.102	0.261	1.065	0.092	0.971
2012	74	-0.048	0.461	0.956	0.161	0.919
2013	69	0.044	0.711	0.982	0.245	0.876
2014	73	0.149	0.705	0.998	0.241	0.863
2015	74	0.171	0.651	1.010	0.252	0.794

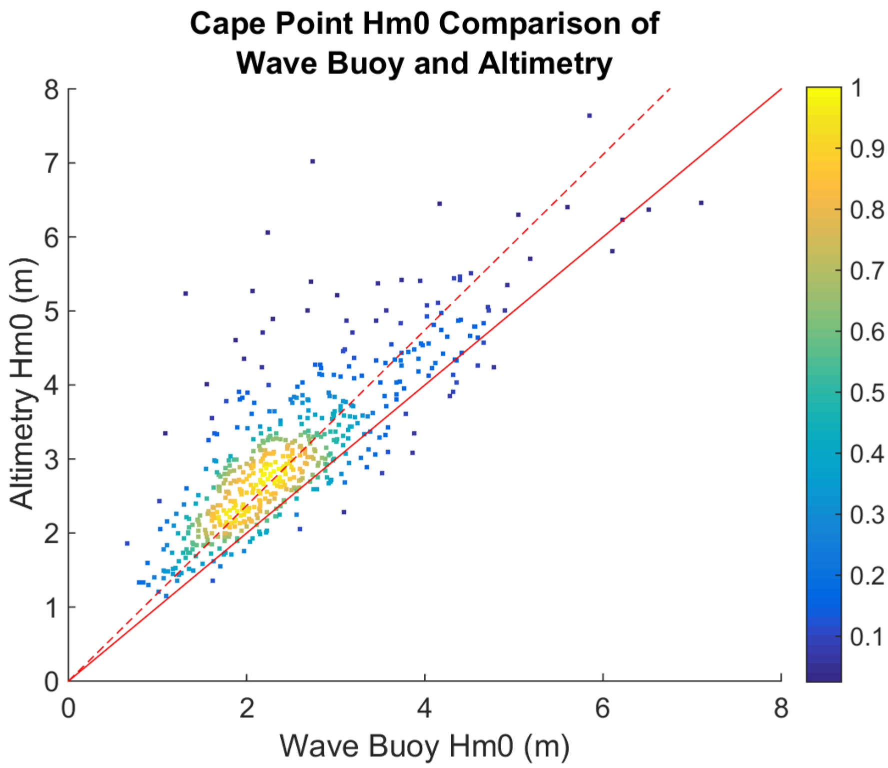


Figure 3.8: Cape Point Density Scatter Plots of Measured to Altimetry

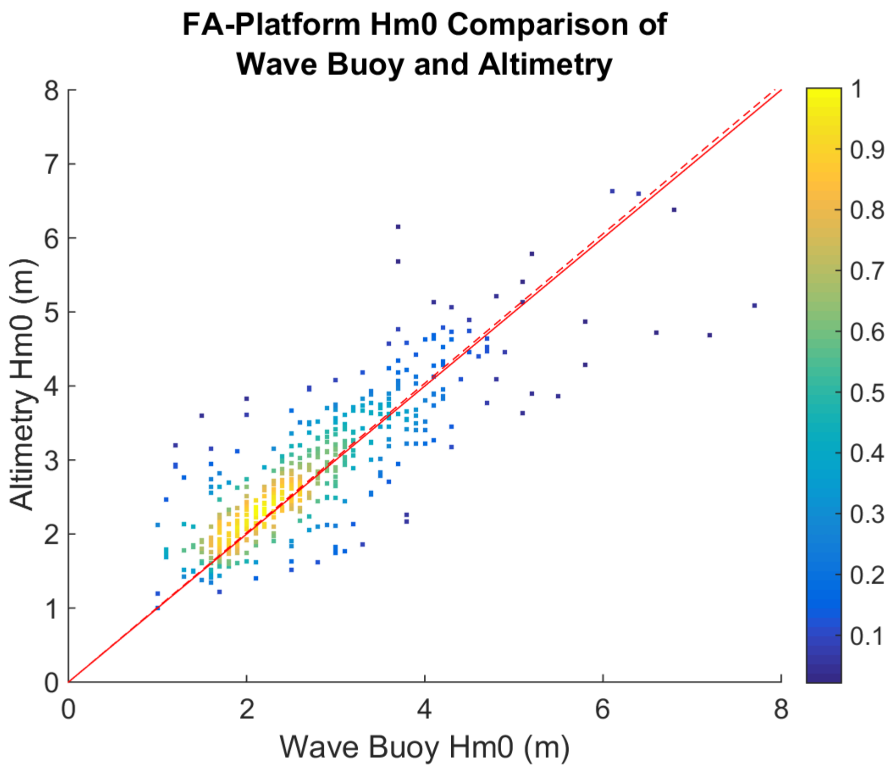


Figure 3.9: FA-Platform Density Scatter Plots of Measured to Altimetry

3.4.3 NCEP and Wave Buoy Comparison

Figures 3.10 and 3.11 are density scatter plots of the significant wave height recorded from the wave buoys as well as NCEP outputs at Cape Point and FA-Platform. These plots show a very good correlation between the NCEP and wave buoy significant wave heights, although the NCEP reading tends to be larger for the corresponding wave buoy reading. Tables 3.5 and 3.6 show the correlation statistics. Again, statistical consistency was found as the number of data samples provides confidence in the statistical results obtained. Cape Point had 45 656 data records while FA-Platform had 42 032 data records.

Here, the scatter spread is relatively narrow with a scatter index in the order of 0.2 for Cape Point and 0.17 for FA-Platform. The best fit line is further from the perfect match illustrated with a trend-line equation for Cape Point of $H_{s(NCEP)} = 1.145H_{s(WaveBuoy)}$ compared to $H_{s(NCEP)} = 1.065H_{s(WaveBuoy)}$ for FA-Platform. The same reason of distance between the recording locations and 'bottom effects' hold for Cape Point but this time between NCEP location and the wave buoy location, resulting in a larger NCEP significant wave height recording than the associated wave buoy recording. This is illustrated with a larger bias of 0.416m and RMSE value of 0.609m for Cape Point, whereas a bias of 0.208m and RMSE value of 0.512m was found for FA-Platform. On average, it can be said that the NCEP significant wave height is slightly larger than the wave buoy recordings for the FA-Platform based on the trend-line. The Willmott index of agreement for both sites being larger than 0.9 proves that there is good agreement between these two datasets.

Table 3.5: Cape Point Statistics for Measured Buoy and NCEP Significant Wave Height Comparison

Period	**Samples**	**Bias (m)**	**RMSE (m)**	**Slope**	**si**	**W**
Total	58 457	0.406	0.604	1.147	0.209	0.905

Table 3.6: FA-Platform Statistics for Measured Buoy and NCEP Significant Wave Height Comparison

Period	**Samples**	**Bias (m)**	**RMSE (m)**	**Slope**	**si**	**W**
Total	58 457	0.201	0.506	1.061	0.171	0.924

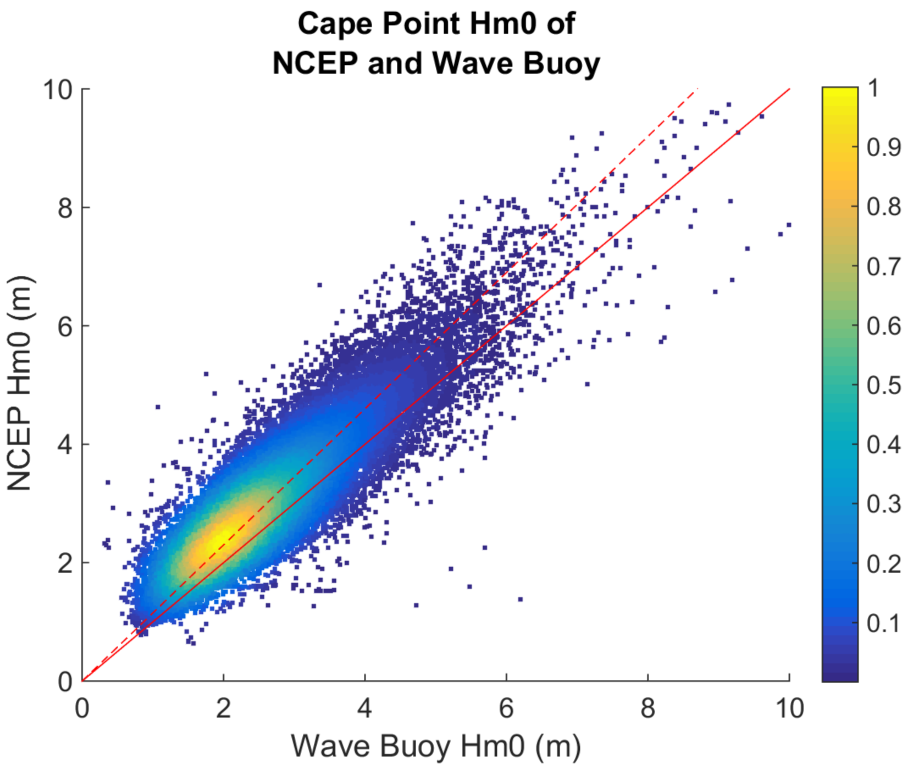


Figure 3.10: Cape Point Density Scatter Plots of Measured to NCEP

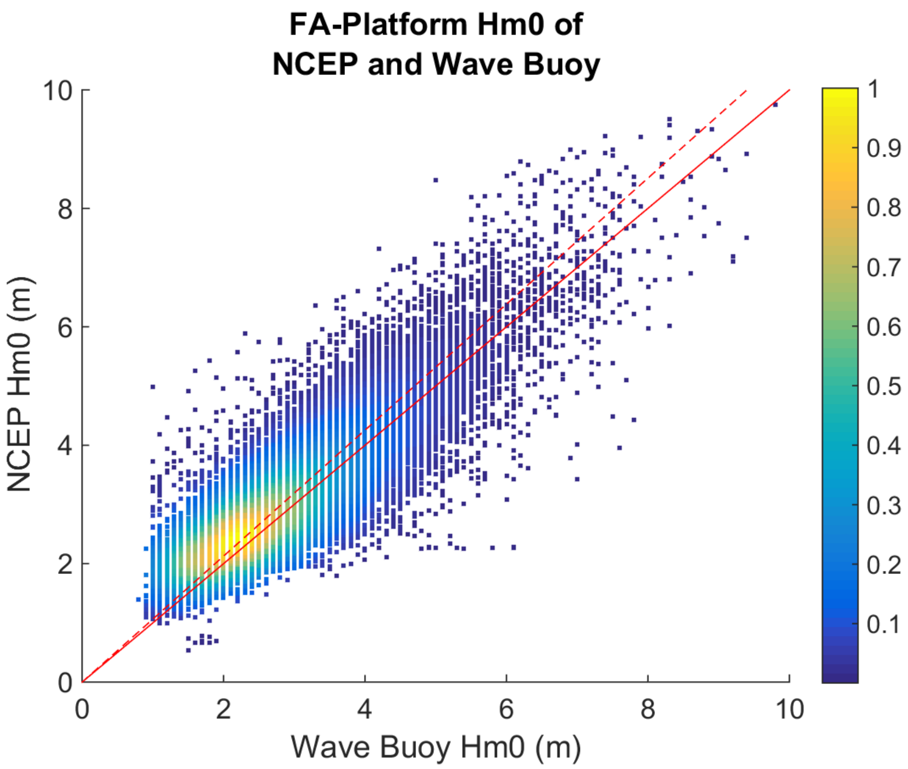


Figure 3.11: FA-Platform Density Scatter Plots of Measured to NCEP

Thereafter, a two sample t-test was conducted that compares two independent data samples, refer to Equation 3.7 (Cressie and Whitford, 1986).

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{{s_x}^2}{n} + \frac{{s_y}^2}{m}}} \tag{3.7}$$

Where $\bar{x}$ and $\bar{y}$ are the sample means, s_x and s_y are the sample standard deviations, and n and m are the sample sizes excluding any values that are "Not a Number" within the dataset. A large number of samples (>30) allowed the assumption of a normal distribution (Ghasemi and Zahediasl, 2012). In order to determine whether or not the means are the same, the tentative assumption (null hypothesis) is that no difference exists between the mean of each dataset with a 5% significance level, where the alternative hypothesis assumes the opposite is true, refer to Equation 3.8 and 3.9.

$$h_o : \mu_1 - \mu_2 = 0 \tag{3.8}$$

$$h_a : \mu_1 - \mu_2 \neq 0 \tag{3.9}$$

Table 3.7 presents the results of the two sample t-test and whether or not the null hypothesis was rejected or not for a 95% confidence in the means of the data samples.

Table 3.7: Two Sample t-test Results

Data	Locations	Sample size	Mean	St. dev	h	P-value	Ho: Rejected
Altimetry and NCEP	Cape Point	585	3.06	1.03	0	0.31	No
			3.00	1.05			
	FA-Platform	594	2.80	0.94	1	-	Yes
			3.05	1.02			
Altimetry and Wave Buoy	Cape Point	554	3.07	1.04	1	-	Yes
			2.49	0.98			
	FA-Platform	474	2.83	0.94	0	0.07	No
			2.72	1.02			
Wave Buoy and NCEP	Cape Point	58 457	2.46	0.97	1	-	Yes
			2.89	1.043			
	FA-Platform	58 457	2.72	1.02	1	-	Yes
			2.96	1.02			

It can be seen that the data samples for each site location were of the same size. The associated mean and standard deviations of these data samples were presented. The hypothesis test result (h) indicates rejection (h=1) or failure to reject (h=0) the null hypothesis at the 5% significance level. A P-value was returned only for cases where a failure to reject the null hypothesis was determined. This value is a scalar ranging between 0 and 1. It is the probability of observing a test statistic as extreme as, or more extreme than, the observed value under the null hypothesis. In other words, small values of p cast doubt on the validity of the null hypothesis.

The sample results offer sufficient evidence that the significant wave height means of Cape Point's Altimetry-and-NCEP and FA-Platforms Altimetry-and-Wave Buoy do not differ with 5% significance level, where the other data samples did.

Finally, a comparison of average significant wave heights per season was undertaken. This was conducted over the same time frame from 2008 to 2016 for satellite, wave buoy and NCEP data, refer to Tables 3.8 and 3.9. The data samples start in June of 2008 as this was the first altimetry data obtained from Jason-2. The other missing values within the table are only for the FA-Platform during the spring of 2011 and summer of 2012, which is over the time when the instrument was switched from the Marex Radar Wave Monitor to the WaMoS II Wave Radar System. It can be seen that the average significant wave heights for the winter season was larger than the other seasons.

This was then graphed for illustration purposes, see Figures 3.12 and 3.13. It can be seen that there is a clear increase in average significant wave heights over the winter months compared to the summer months, especially during the year 2013. It is important to note that the average significant wave heights per year and season remain relatively consistent for each data sample. The comparison covers a number of years and a good correlation was found and this, therefore, should be representative of what occurs each season.

Table 3.8: Seasonal Comparison for Cape Point

	Average Hs per Season and Data Sample											
	Summer (Dec of prev. year - Feb)			**Autumn (Mar - May)**			**Winter (Jun - Aug)**			**Spring (Sep - Nov)**		
Year	**Altimetry**	**Wave Buoy**	**NCEP**	**Altimetry**	**Wave Buoy**	**NCEP**	**Altimetry**	**Wave Buoy**	**NCEP**	**Altimetry**	**Wave Buoy**	**NCEP**
2008	-	-	-	-	-	-	3.16	2.63	3.28	3.00	2.67	3.06
2009	2.72	2.12	2.85	3.16	2.67	3.10	3.30	2.75	3.49	3.30	2.42	2.93
2010	2.71	2.24	2.69	3.02	2.67	3.31	3.04	2.61	3.13	3.05	2.32	2.90
2011	2.69	2.04	2.77	3.22	2.43	2.86	3.09	2.59	3.43	3.14	2.56	2.97
2012	2.93	2.62	3.08	2.95	2.43	3.00	3.74	3.19	3.77	3.12	2.45	2.96
2013	2.51	2.15	2.68	2.56	2.13	2.57	4.05	3.38	3.83	2.84	2.52	2.75
2014	2.90	2.18	2.77	2.97	2.44	2.96	3.17	2.74	3.44	2.80	2.16	2.70
2015	3.15	2.72	2.96	2.90	2.29	2.85	3.30	2.80	3.22	3.31	2.55	2.80
2016	3.54	1.92	2.59	2.87	2.26	2.45	3.54	2.81	3.03	3.23	1.92	2.36
Ave	2.89	2.25	2.80	2.96	2.42	2.89	3.38	2.83	3.40	3.09	2.40	2.83

Table 3.9: Seasonal Comparison for FA-Platform

	Average Hs per Season and Data Sample											
	Summer (Dec of prev. year - Feb)			**Autumn (Mar - May)**			**Winter (Jun - Aug)**			**Spring (Sep - Nov)**		
Year	**Altimetry**	**Wave Buoy**	**NCEP**	**Altimetry**	**Wave Buoy**	**NCEP**	**Altimetry**	**Wave Buoy**	**NCEP**	**Altimetry**	**Wave Buoy**	**NCEP**
2008	-	-	-	-	-	-	2.91	2.94	3.48	2.77	2.72	3.03
2009	2.62	2.39	2.87	2.71	2.47	3.04	2.77	2.80	3.17	3.13	3.11	3.20
2010	3.06	2.87	3.42	2.71	2.63	3.18	2.98	2.74	3.26	2.70	2.57	3.05
2011	2.47	2.31	2.79	2.67	2.53	2.88	3.14	3.14	3.17	3.07	-	3.51
2012	2.34	-	2.72	2.75	2.59	3.11	3.17	3.36	3.43	3.25	3.31	3.40
2013	2.40	2.40	2.73	2.47	2.51	2.81	3.76	3.49	4.16	3.01	2.96	3.16
2014	2.36	2.62	2.77	2.70	2.48	3.01	3.44	3.43	3.91	2.84	2.55	2.93
2015	2.79	2.69	3.09	2.36	2.02	2.64	3.14	3.09	3.08	2.59	2.26	2.51
2016	2.11	2.12	2.27	2.56	2.52	2.35	2.60	3.03	2.78	3.27	2.60	2.79
Ave	2.52	2.48	2.83	2.62	2.47	2.88	3.10	3.11	3.38	2.96	2.76	3.06

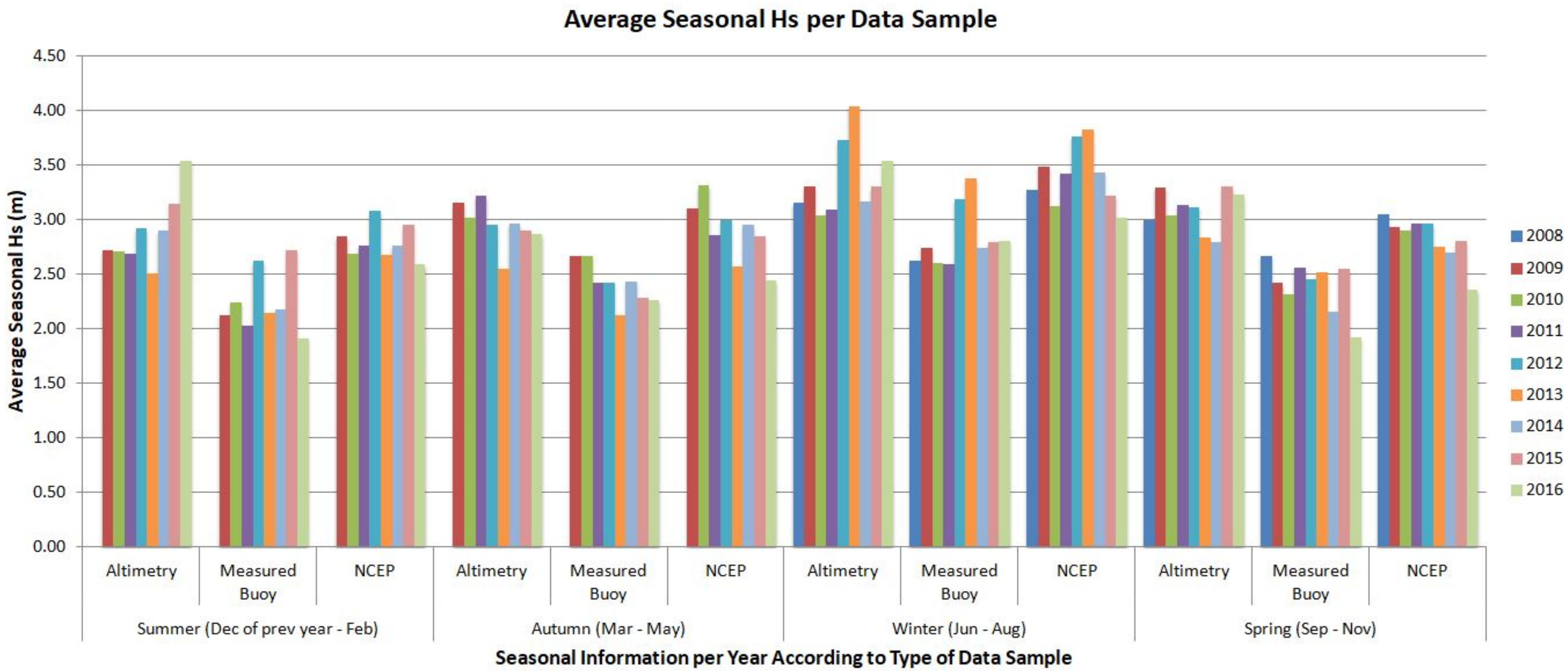


Figure 3.12: Average Seasonal Comparison for Cape Point

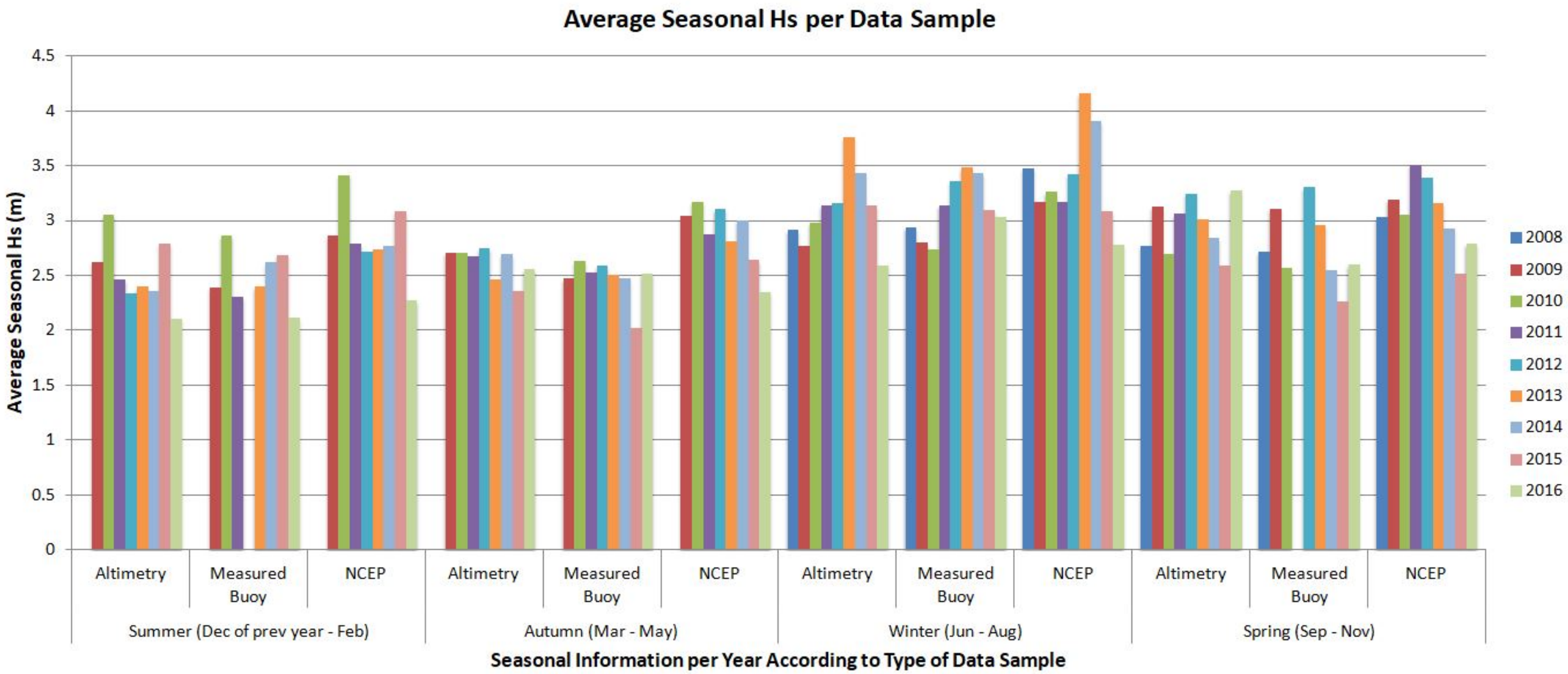


Figure 3.13: Average Seasonal Comparison for FA=Platform

3.5 Discussion

Both sites (Cape Point and FA-Platform) are located south of South Africa. All three datasets are in relatively close geographical proximity for FA-Platform. Cape Point's datasets were not in close proximity, though waves were not transformed over the spatial difference and subsequently allowed for the type of comparison to be undertaken.

After the direct comparison of altimetry, NCEP and wave buoy data was clear that there was a good correlation between the data sets. However, the two sample t-test revealed that only the means of the Altimetry-and-NCEP data sample for Cape Point and the Altimetry-and-Wave Buoy data sample for FA-Platform were within the 5% significance level. The seasonal comparison between data samples showed consistency and thus reliable data.

This lead to the discovery that satellite altimetry data from OSTM/Jason-2 could be used as a reliable and accurate source of significant wave height data for the south coast. This then poses the question of how the altimetry data would compare up the east coast as it could be used as a source of significant wave height data along this coast. Pass intersection locations should preferably be used for comparison purposes in order to maximize the sample size of wave height data, i.e. twice as many data values than any other position on the satellite pass.

For the east coast the geographical proximity of the datasets are relatively far from each other and so a closer look at the accuracy of the altimetry data along this coast could form part of further research. For this study, a different comparison approach was taken for the east coast site locations (East London and Richards Bay), which includes a backward refraction to the offshore locations and this is explained in more detail in Section 4.

Chapter 4

Backward Wave Refraction

4.1 General

The distance between the offshore Jason-2 pass intersection locations and the nearshore wave buoys are too large for the South African east coast site locations. Implying that waves are transformed from the offshore to nearshore, i.e. a reduction of wave energy as a result of wave refraction and wave dissipation. Therefore, the direct comparison of satellite altimetry data to NCEP was not possible and another approach was needed.

An indirect approach for the east coast was then considered that transforms the nearshore wave conditions to an offshore location near an NCEP location through backward refraction. Essentially, this effort attempts to calculate the offshore wave conditions by reversing the refraction process that occurs naturally in the coastal regions. The offshore wave conditions are then compared to the NCEP data using a direct comparison. Two approaches were used in order to transform the wave conditions backward from nearshore to offshore.

The first approach was by making use of a simplistic Snell's Law method. The aim here was to achieve a first estimate of the offshore wave conditions focusing on the methodology and success of backward refraction using this method. The second approach was more complex which included the use of a numerical model called SWAN and interpolation functions. The results from both approaches were compared to the NCEP wave conditions. These approaches were undertaken for two sites along the east coast of South Africa, namely East London and Richards Bay. East London has the only commercial river port on the South African coastline and lies at the mouth of the Buffalo River, 950km east of Cape Town and 460km south of Durban on the eastern seaboard. The port of Richards Bay lies 160km north-east of Durban and was established in 1976 primarily to handle coal exports. Wave buoys have been deployed outside these ports and certain characteristics need to be known in order to apply the backward refraction. These parameters include the angle perpendicular to the coastline and the average water depth at the location of the wave buoy at each site. East London and Richards Bay have a perpendicular angle orientated at roughly 140° and 135° from true North as well as water depths of 27m and 22m respectively. The calculations and results are described further in the following sections.

4.2 Snell's Law Approach

It should be stressed that this approach served as a first estimate due to the simplistic assumption that the bathymetric contours are parallel to the shoreline which is unrealistic.

The waves traveling towards the shoreline from deep water into the transitional region are influenced by the seabed. This experience results in a reduction of wave celerity and wavelength, thus altering the direction of the wave crests through a process known as refraction, and altering the wave height through a process known as shoaling. Waves approaching shallower water lead to wave energy dissipation by bottom friction and finally, wave breaking. The following analysis is not strictly applicable to this region because the wave fronts steepen and are no longer described by the Airy waveform. However, it is common practice to apply refraction analysis up to the so-called breaker line. In general, this is justified on the grounds that the inherent inaccuracies are small compared to the initial predictions for deep-water waves, and are within acceptable engineering tolerances.

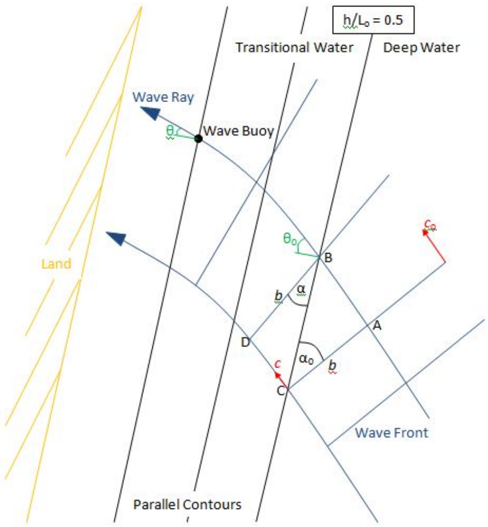


Figure 4.1: Combined refraction and shoaling

Refer to Figure 4.1, the subscript o refers to deep water conditions. The wave length in deep water is denoted as L_0, and L for transitional water. From the figure, it is illustrated that the celerity (c_0) in deep water is faster than in transitional water (c), thereby rotating the wave front AC to BD. By letting the angle α represent the angle from the wave front to the depth contour, then $\sin\alpha = L/BC$ and $\sin\alpha_0 = L_0/BC$. By combining these equations and eliminating BC presents Snell's Law in Equation 4.1 (Lopez-Ruiz *et al.*, 2015):

$$\frac{\sin\alpha}{\sin\alpha_0} = \frac{L}{L_0} = \frac{c}{c_0} = \tanh(kd) \tag{4.1}$$

4.2.1 Method

The approach described below reverses the natural process of waves refracting and shoaling as they travel towards the shoreline. The wave conditions at the wave buoy location are known in the form of a time series and the offshore wave conditions are determined. This is achieved by making use of backward refracting the waves using Snell's Law. The only parameter that remains constant for an individual wave train from deep water to transitional water is the wave period (T_p), whereas wave height and direction change.

Equations 4.2 to 4.4 were used in order to calculate the deep water group velocities, where Equations 4.5 to 4.8 were used to calculate the transitional water group velocities:

For deep water:

$$L_0 = \frac{gT_p^2}{2\pi} \tag{4.2}$$

$$c_0 = \frac{L_0}{T_p} \tag{4.3}$$

$$c_{g0} = 0.5c_0 \tag{4.4}$$

For transitional water:

$$L = \frac{gT_p^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \tag{4.5}$$

$$c = \frac{gT_p}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \tag{4.6}$$

$$n = \frac{1}{2}\left[1 + \frac{\frac{4\pi d}{L}}{\sinh\left(\frac{4\pi d}{L}\right)}\right] \tag{4.7}$$

$$c_g = nc \tag{4.8}$$

These parameters were then used for determining the shoaling coefficient, Equation 4.9.

Shoaling Coefficient:

$$K_s = \sqrt{\frac{c_{g0}}{C_g}} \tag{4.9}$$

Equation 4.10 was then calculated. If ϕ represents the angle perpendicular to coastline, then θ represents the angle between the direction of the wave ray and ϕ at the location of the wave buoy. Similarly, θ_0 represents a similar angle, but at the offshore location.

Refraction coefficient:

$$K_r = \sqrt{\frac{\cos\theta}{\cos\theta_0}} \tag{4.10}$$

After the above mentioned coefficients had been determined the wave height transformation from transitional water to deep water was possible, Equation 4.11.

Wave height transformation:

$$H_{s0} = H_s \frac{1}{K_s} \frac{1}{K_r} \tag{4.11}$$

The directional transformation is calculated using Equation 4.12. The addition of θ_0 is for when the direction angle measured at the wave buoy is greater than ϕ and subtracted when it is less.

Wave direction transformation:

$$Dir_0 = \phi \pm \theta_0 \tag{4.12}$$

4.2.2 Results

Backward refraction using Snell's Law was applied to the time series of wave conditions at the wave buoy location for East London and Richards Bay, resulting in a time series at the offshore location. Then compared directly to the NCEP data and the analysis, results are presented in Table 4.1 and 4.2.

Table 4.1: East London Statistics for Backward Refracted and NCEP (31992) Wave Condition Comparison

	Wave Height (m)	**Wave Period (s)**	**Wave Direction(°)**
Average BR	2.24	11.20	181.78
Average NCEP	2.55	10.74	177.56
Difference	0.32	0.46	4.21
St. dev. BR	1.03	2.36	37.44
St. dev. NCEP	0.84	2.52	58.37
Difference	0.19	0.16	20.93

Table 4.2: Richards Bay Statistics for Backward Refracted and NCEP (30843) Wave Conditions Comparison

	Wave Height (m)	**Wave Period (s)**	**Wave Direction(°)**
Average BR	1.78	10.90	143.03
Average NCEP	2.14	9.73	149.90
Difference	0.35	1.16	6.87
St. dev. BR	0.66	2.68	36.12
St. dev. NCEP	0.73	2.77	56.44
Difference	0.08	0.10	20.32

The abbreviation 'BR' in the tables, and where mentioned otherwise in this document, stands for the 'Backward Refracted' wave conditions that were obtained. The statistics for East London and Richards Bay were determined using 3-hourly data from 1997 to 2017 and 1997 to 2013 respectively, implying 58 457 samples for East London and 48 888 for Richards Bay.

The overall averages and standard deviations were determined for each dataset. For East London a difference of 0.32m, 0.46s and 4.21° was found between the backward refracted and NCEP averaged wave height, period and direction values with an associated 0.19m, 0.16s and 20.93° difference between the respective standard deviation. For Richards Bay, a difference of 0.35m, 1.16s and 6.87° was found between the backward refracted and NCEP averaged wave height, period and direction values with an associated 0.08m, 0.10s and 20.32° difference between the respective standard deviations. The findings present adequate wave height and period values for NCEP, although a relatively large standard deviation and difference discrepancy was found with regards to the directional distribution and so has been investigated further.

The percent difference error is applied when comparing two experimental quantities, E_1 and E_2, neither of which can be considered a 'true' value. In this case, the backward refracted data was obtained from Snell's Law and the NCEP data was obtained from the WAVEWATCH III numerical model. Consequently, these quantities are not considered 'ground truth'. The percent difference is the absolute value of the difference over the mean as a percentage, seen in Equation 4.13.

$$\%Diff = \frac{|E_1 - E_2|}{\frac{1}{2}(E_1 + E_2)}100 \tag{4.13}$$

Calculated for each time step for East London, the average percent difference for wave height and period was 22.78% and 16.47% respectively. Similarly, 23.85% and 20.33% was determined for Richards Bay. Qualitatively, these percent difference errors represented the order of magnitude that these 'experimental value' datasets were different from each other. The percent difference could not be used in order to calculate the directional error due to the large variation in directions, and so another technique was used. The histograms in Figures 4.2 and 4.3 compare the backward refracted directions to NCEP directions binned in 10 degree sectors. For a quantitative look at the error, the root mean square error (RMSE) was determined for wave height, period and direction. In this case, the backward refracted data was used as the 'true' values and the NCEP as the estimated values. The RMSE for East London was calculated to be 1.39m for significant wave height, 2.39s for period and 47.65° direction. Richards Bay obtained RMSE values of 0.63m, 2.84s and 47.82° for wave height, period and direction respectively.

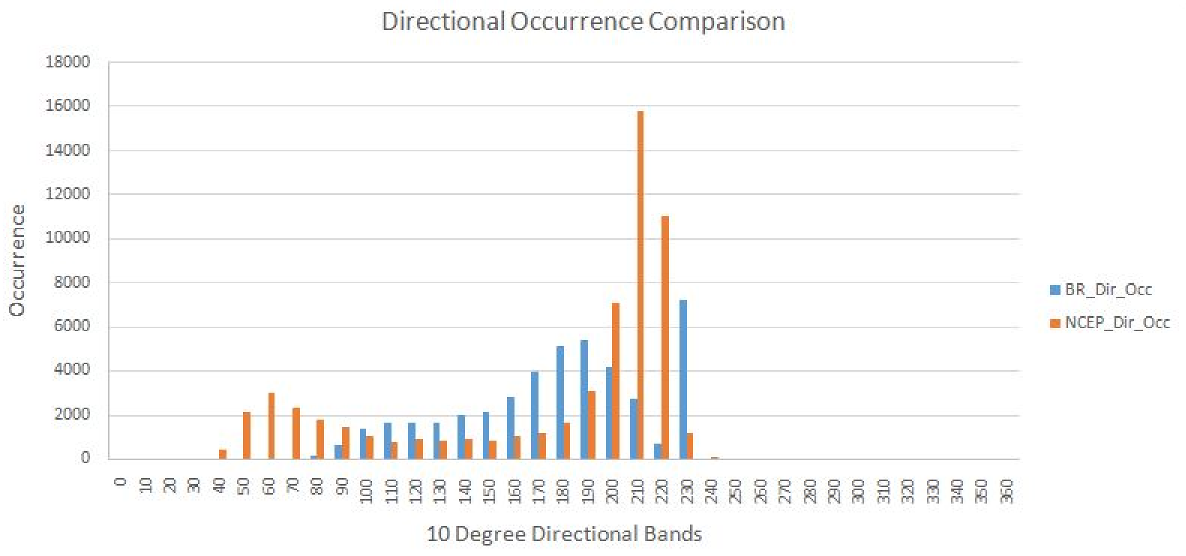


Figure 4.2: East London Directional Distribution Analysis between Backward Refracted and NCEP data

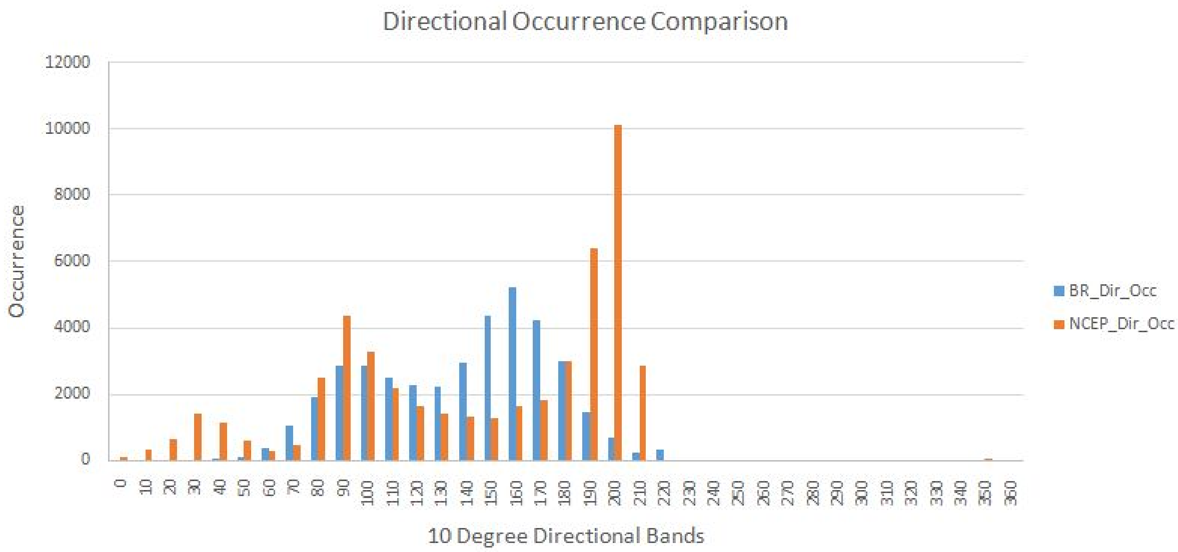
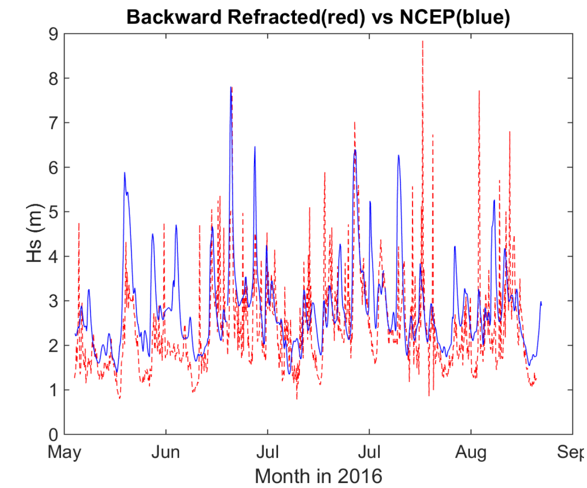


Figure 4.3: Richards Bay Directional Distribution Analysis between Backward Refracted and NCEP data

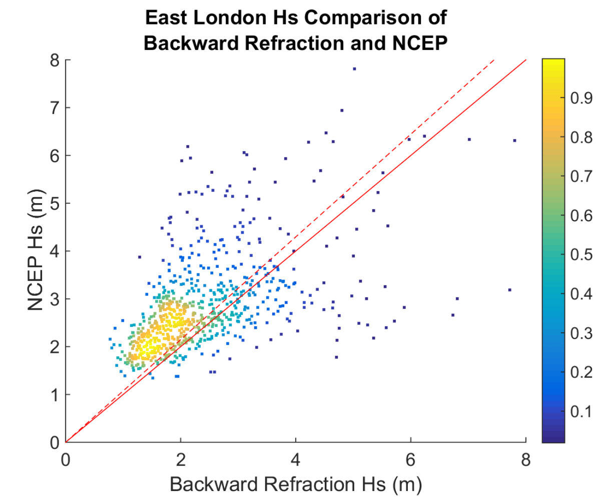
The reasons as to why there could be inaccuracies in directional distribution of the NCEP data include the grid resolution and bathymetry detail among others over this complex region. It is important to note that the Agulhas current is not modeled within the WAVEWATCH III model and can therefore not accurately represent the wave current interactions in this region. The peak directional offset seen for East London based on this directional distribution comparison is in the order of 30°. The backward refracted directional occurrence peak was found to be within the 190° bin, whereas the NCEP peak was found to be within the 210° bin. Richards Bay shows a peak directional offset in the region of 40°, where the backward refracted directional occurrence peak was found to be within the 160° bin and the NCEP peak was found to be within the 200° bin. An arbitrary three month winter period from June to August in 2016 for East London and 2013 for Richards Bay was chosen to plot wave condition comparisons. The reason for choosing the winter months was in order to compare and correctly represent the larger waves. Three months were chosen due to the feasibility of computational implications of running 726 input conditions, making up a 3 month period in intervals of 3-hours for the SWAN approach and therefore, reaching consistency.

Figure 4.4 and 4.5 show the respective time series comparisons for wave height, period and direction and associated density scatter plots. These graphs confirm the percent error differences that were calculated. Although these comparisons were coarse, it was still comparable keeping in mind that neither the backward refracted nor the NCEP datasets were considered 'ground truth'. Here the method is important as a first estimate as it could be said that the errors occur within Snell's approach or the NCEP data output. This was unclear at that stage and hence the SWAN approach that makes use of a calibrated numerical model (able of better describing the wave processes) was used to improve the Snell's Law methodology. For the sake of completeness, the SWAN models that were created for the SWAN approach was used to compare the nearshore wave conditions for the

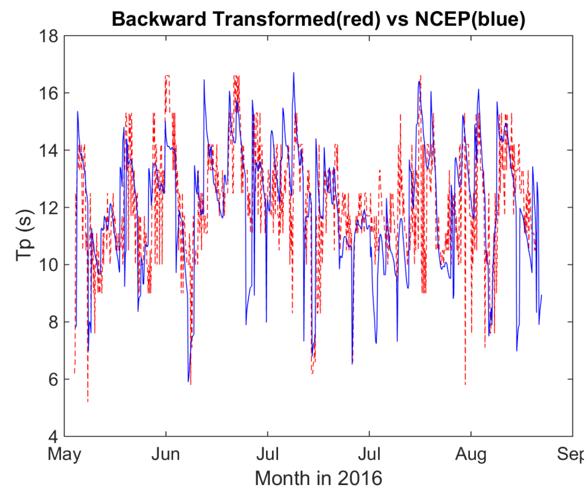
Snell's Law approach by obtaining results at the wave buoy location. The wave conditions of the wave buoy were compared to the model results for the 3 month period, producing the comparison graphs found in Appendix C in Figures C.1 and C.2. The model wave period was truncated at 9 seconds and there was some minor discrepancy in the wave direction. Richards Bay shows agreement in terms of wave period, while the wave height and direction were underestimated.



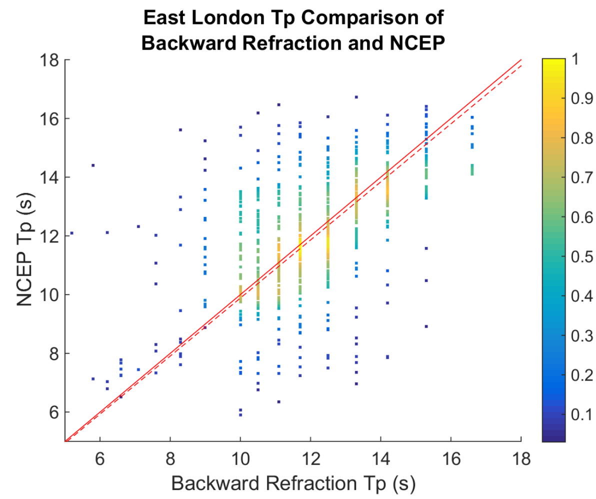
(a) Hs Time Series



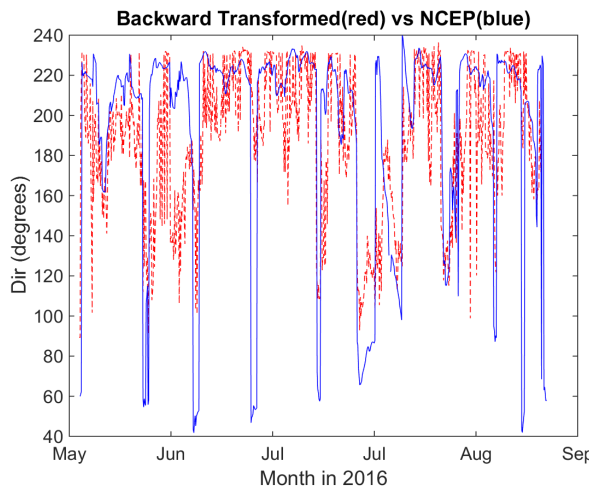
(b) Hs Density Scatter Plot



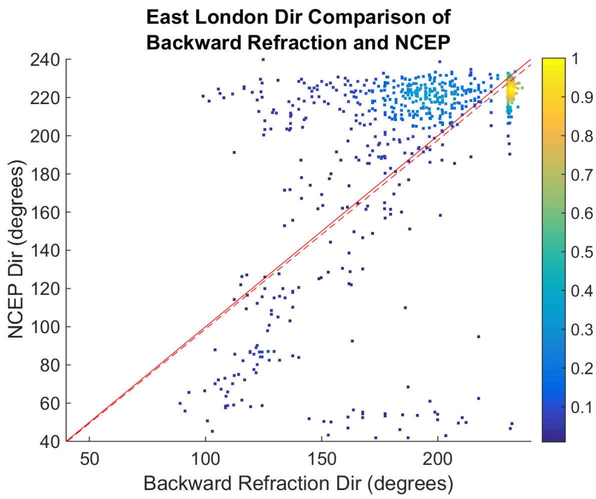
(c) Tp Time Series



(d) Tp Density Scatter Plot

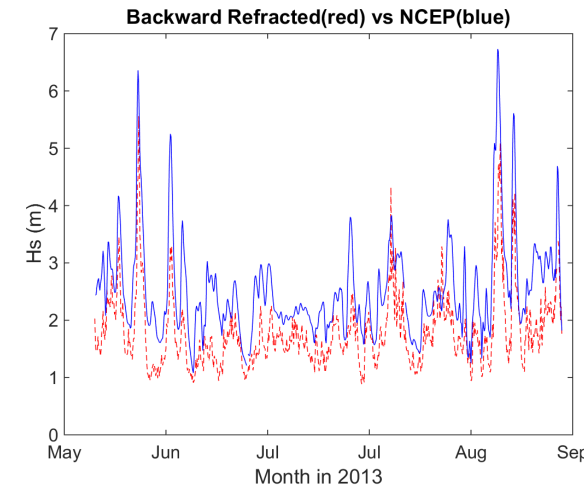


(e) Dir Time Series

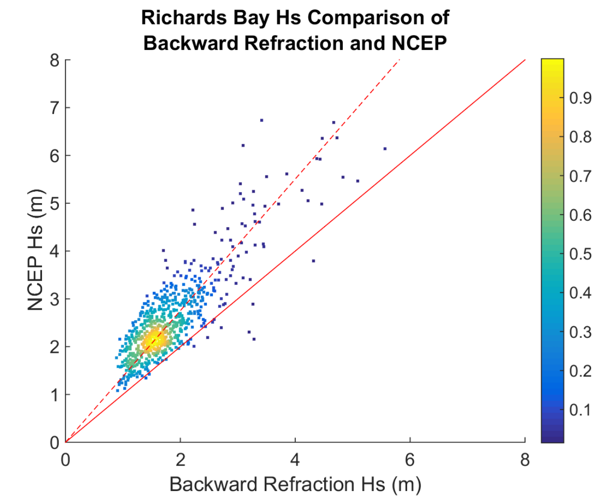


(f) Dir Density Scatter Plot

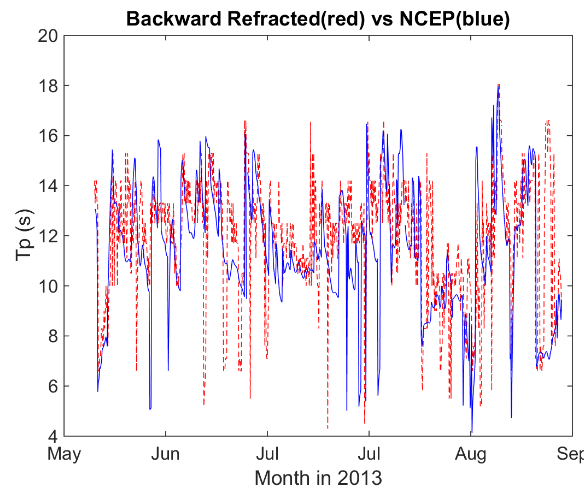
Figure 4.4: East London Backward Refracted Compared to NCEP Wave Conditions for June to August 2016 for Snell's Law Approach



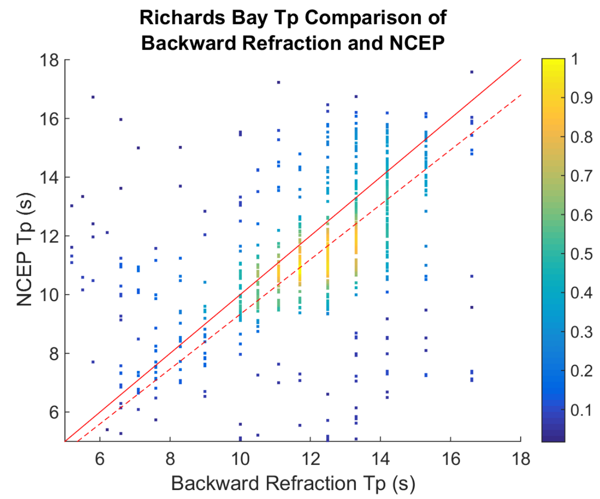
(a) Hs Time Series



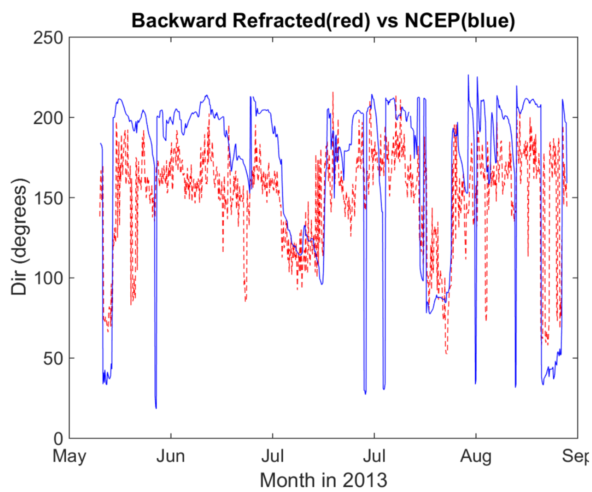
(b) Hs Density Scatter Plot



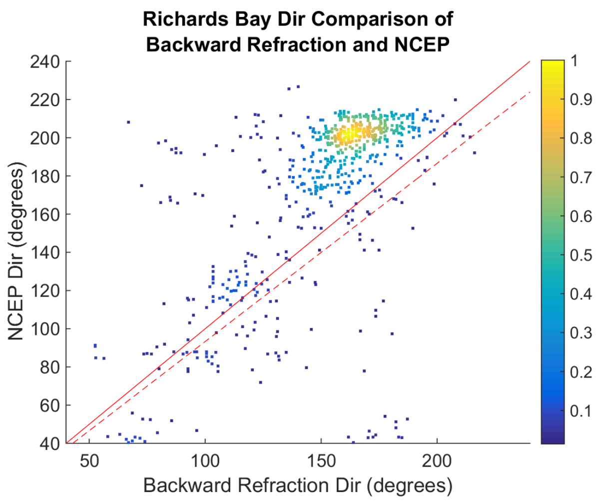
(c) Tp Time Series



(d) Tp Density Scatter Plot



(e) Dir Time Series



(f) Dir Density Scatter Plot

Figure 4.5: Richards Bay Backward Refracted Compared to NCEP Wave Conditions for June to August 2013 for Snell's Law Approach

4.3 SWAN Approach

The following approach was used to improve the analysis of NCEP data reliability along the east coast of South Africa. It also allows an understanding of the simplistic assumptions made in Snell's Law, presented in the previous section.

The complexity of this approach made use of a numerical model (SWAN) in order to better describes the hydrodynamic processes and wave propagation within the study area, i.e. East London and Richards Bay. This approach achieves this by solving the wave action balance equation within the shallow wave model and thereafter an interpolation function is generated using MATLAB that relates the nearshore and offshore wave conditions. This enables offshore wave conditions to be generated from the nearshore wave buoy for comparison to NCEP data.

SWAN was developed by Delft University of Technology and is an advanced spectral wind-wave model and extension of the deep water third-generation wave models. It computes random, short-crested waves in coastal regions, based on an Eulerian formulation (a way of looking at fluid motion that focuses on a fixed frame of reference in space through which the fluid flows as time passes) of the discrete spectral balance of action density (SWAN Scientific and Technical Documentation, 1993). It solves this based on sources and sinks without any experimental or observed restrictions for the evolution of wave growth (Holthuijsen, 2007). The model accounts for wave propagation, generation and dissipation over arbitrary bathymetry profiles which was one of Snell's law's major limitations. The model has been implemented and validated as the results agree well with analytical solutions, laboratory and field observations. It is driven by wave parameters and/or wind fields applied as input conditions along the boundaries of the model domain. Other models make use of explicit propagation schemes in geographical and spectral space, where SWAN makes use of an implicit scheme, implying more robust and economic computations in shallow water and suitable in coastal regions (Booij *et al.*, 1999).

4.3.1 Method

The model setup for East London and Richards Bay is described below. Referring to Figures 4.6 and 4.7, two model-grids were used to setup each model. The land boundaries for each site as well as the wave buoy locations and NCEP locations denoted as red SWAN markers were included. The bathymetry information, which consisted of depth data samples and associated locations, were mainly based on the standard South African Navy (SAN) bathymetry charts produced by the Hydrographic Office of the South African Navy (SANHO).

These models had been previously setup by the CSIR for a project conducted for the Department of Environmental Affairs. This project was conducted for a country-wide refraction exercise, where this study was concerned with two local sites. For this reason, the coarse grids were refined from a 1km resolution to a 500m resolution and a nested 500m grid to a nested 100m grid resolution.

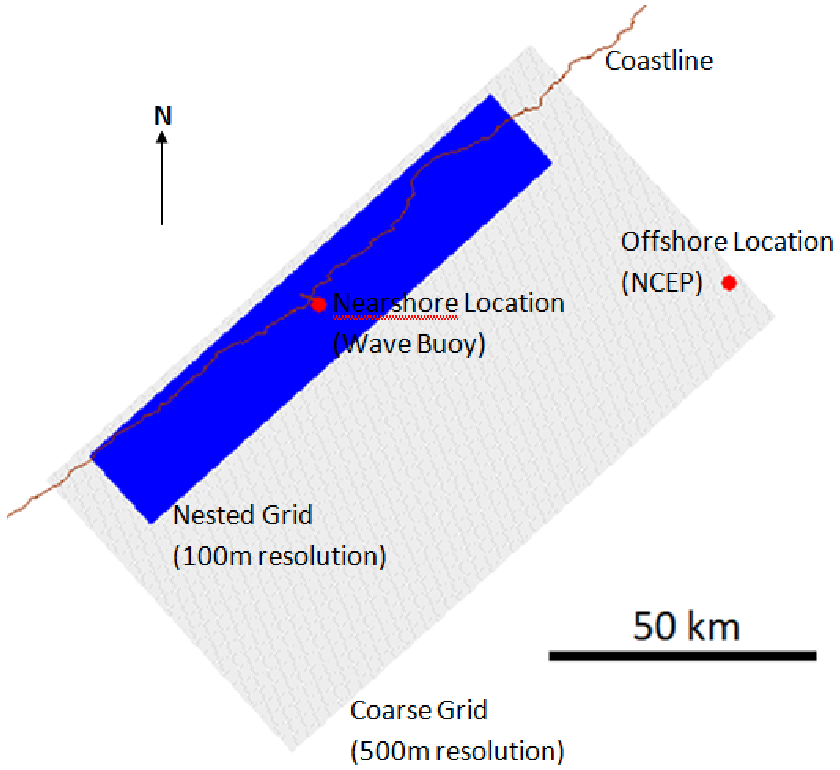


Figure 4.6: East London Model Domain Including Grids and Output Locations

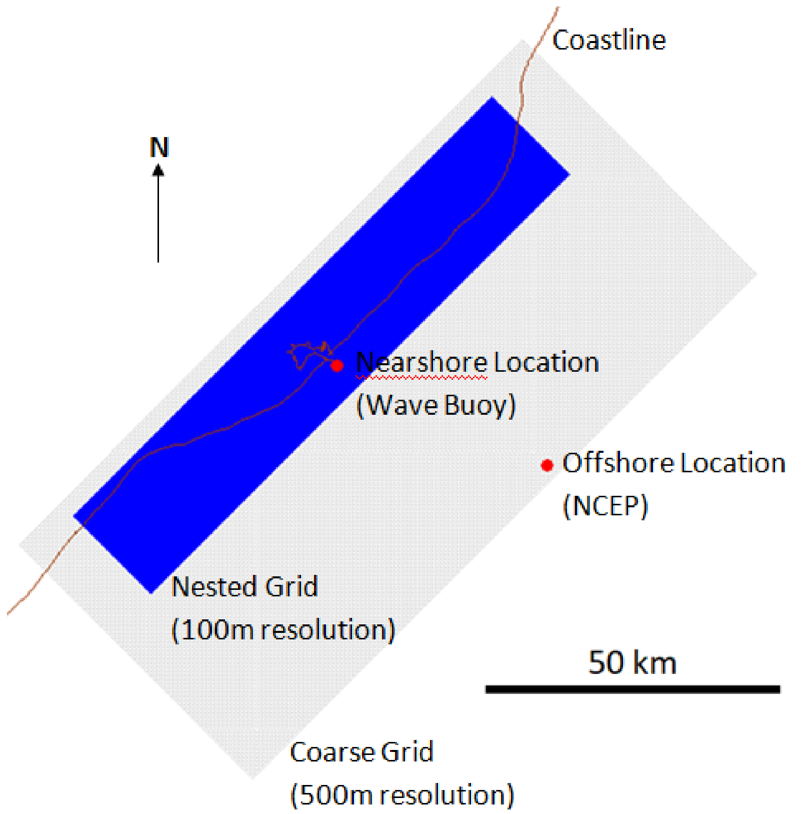


Figure 4.7: Richards Bay Model Domain Including Grids and Output Locations

The more refined models had been validated in this study for wave height, period and direction for each site, see Figures D.1 to D.3 and D.4 to D.6 in Appendix D. The offshore conditions, therefore SWAN input conditions, applied to the boundaries of each model domain was made up of discrete wave heights, periods and directions. Firstly, the wave heights ranging from 1m to 11m, with increments of 2m. The periods of between 6s and 20s, with increments of 2s. Lastly, a direction spectrum between 45°and 236.25°with increments of 11.25°and a wave spreading of 25°. This made up a total of 864 general wave conditions that forced the model. The wave roses and occurrence tables at the NCEP locations for East London and Richards Bay that were used as a guide to draw up the input conditions can be found in Appendix E.

The SWAN model was run in batch mode and the reason for the wide range of wave conditions was to ensure interpolation coefficients between the nearshore and offshore locations. The results at the two SWAN locations per site were used in order to create an interpolant that fits a surface of the form V = F(X) to the scattered data in (X, V). X is a matrix of size mpts-by-ndim, mpts in this case was the length of the 3-hourly intervals over the duration that the wave buoy has been recording and ndim was the three wave parameters. The column vector V defines the values at X, where the length of V equals mpts and is the ratio of nearshore data to offshore data for wave height and period and equal to the nearshore data for wave direction (Terblanche, 2017). In other words, the interpolation function can be visualised a 3D matrix of size: wave height, wave period and wave direction. Providing the code with the nearshore conditions, the matrix or interpolation function was able to output the offshore conditions for the specific nearshore parameters given. This then allowed a direct comparison to NCEP data.

4.3.2 Results

The SWAN results for certain conditions are presented in Figures 4.8 to 4.11 for East London and Figures 4.12 to 4.15 for Richards Bay. The conditions represented were based on dominant NCEP conditions, refer to Appendix E. A base case of 225°(SW), 12s and 3m wave input conditions is shown as well as another dominant direction occurring in spring and summer of 67.5°(ENE) for East London. The base case with a period of 16s and wave height of 7m is also shown separately. This is similar for Richards Bay but with dominant directions of 202.5°(SSW) and 90°(E). The figures include a significant wave height colour bar between 0m and 7m as well as the peak direction vectors displayed on the 500m grid and the more resolved 100m grid. Offshore, the waves propagate in the same direction as the waves forcing the model, only to reduce in height and refract towards the shore once the waves were impacted by bottom effects.

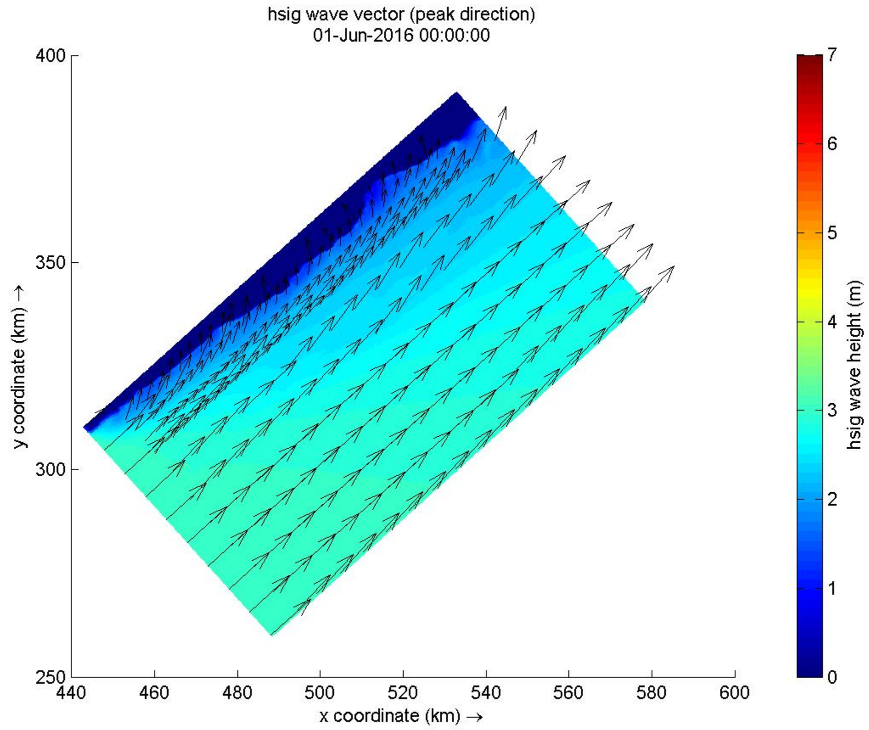


Figure 4.8: East London SWAN Outputs for Input Condition: 225°, 12s, 3m

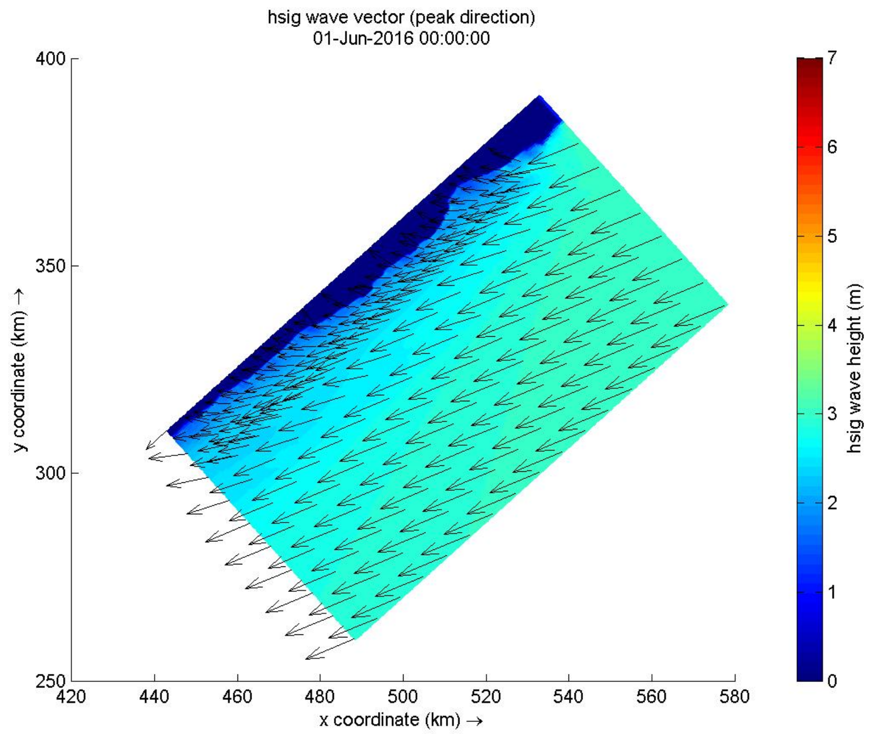


Figure 4.9: East London SWAN Outputs for Input Condition: 67.5°, 12s, 3m

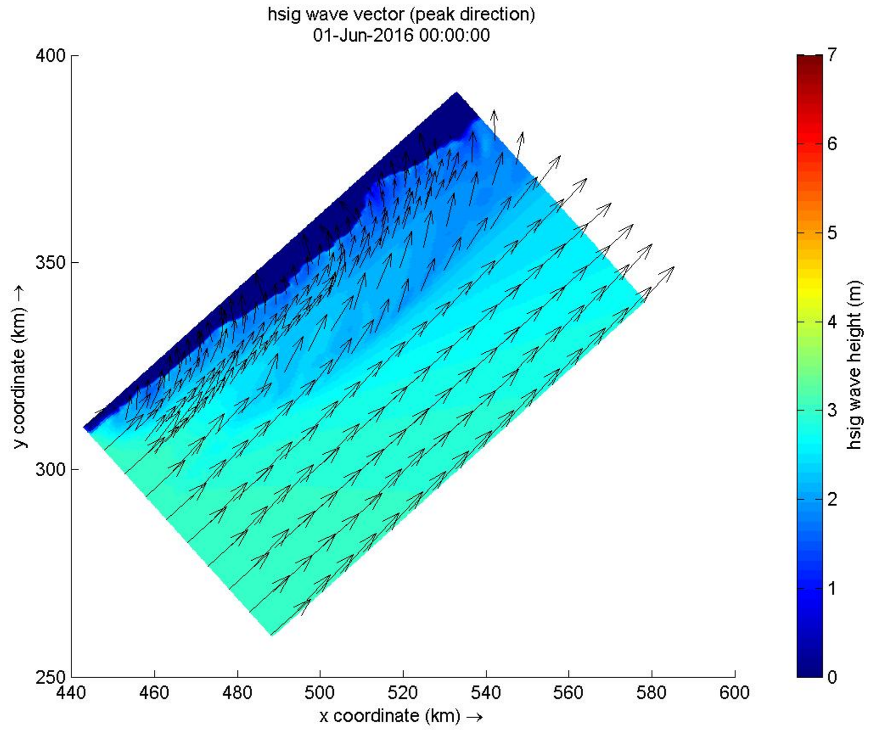


Figure 4.10: East London SWAN Outputs for Input Condition: 225°, 16s, 3m

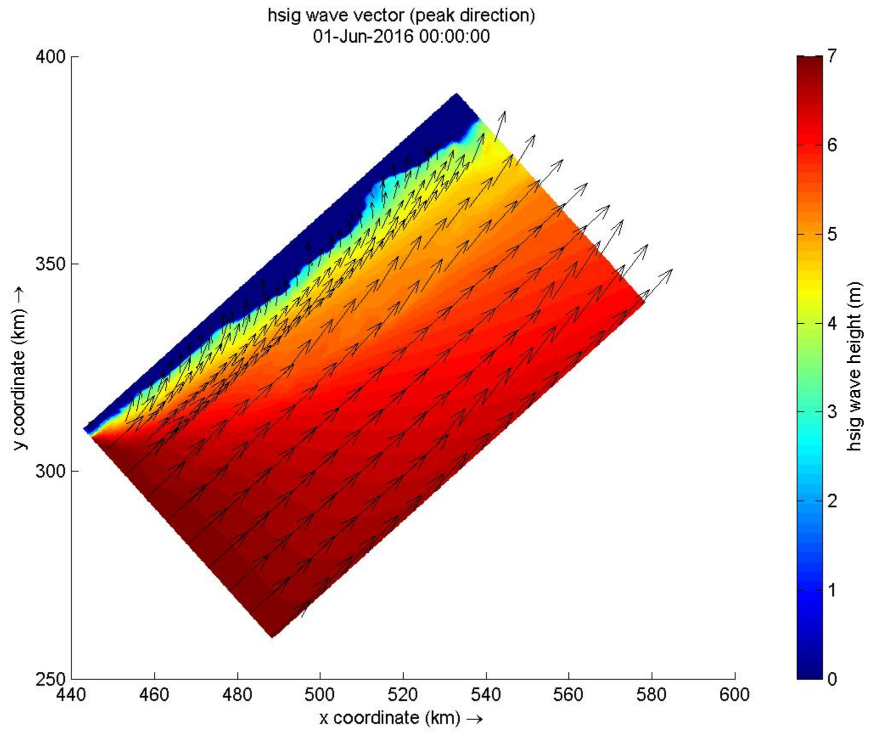


Figure 4.11: East London SWAN Outputs for Input Condition: 225°, 12s, 7m

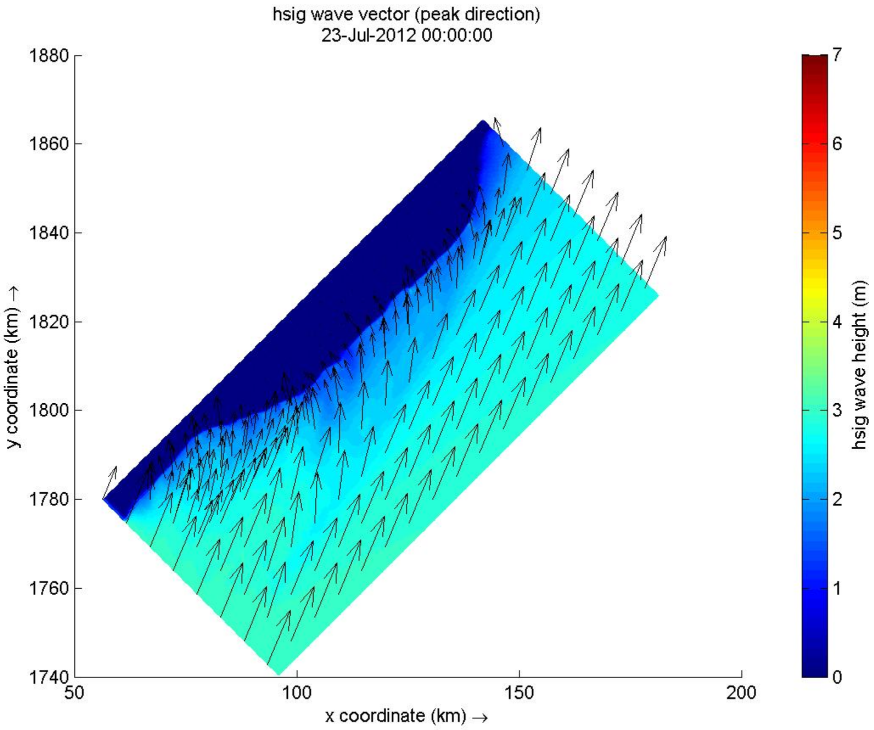


Figure 4.12: Richards Bay SWAN Outputs for Input Condition: 202.5°, 12s, 3m

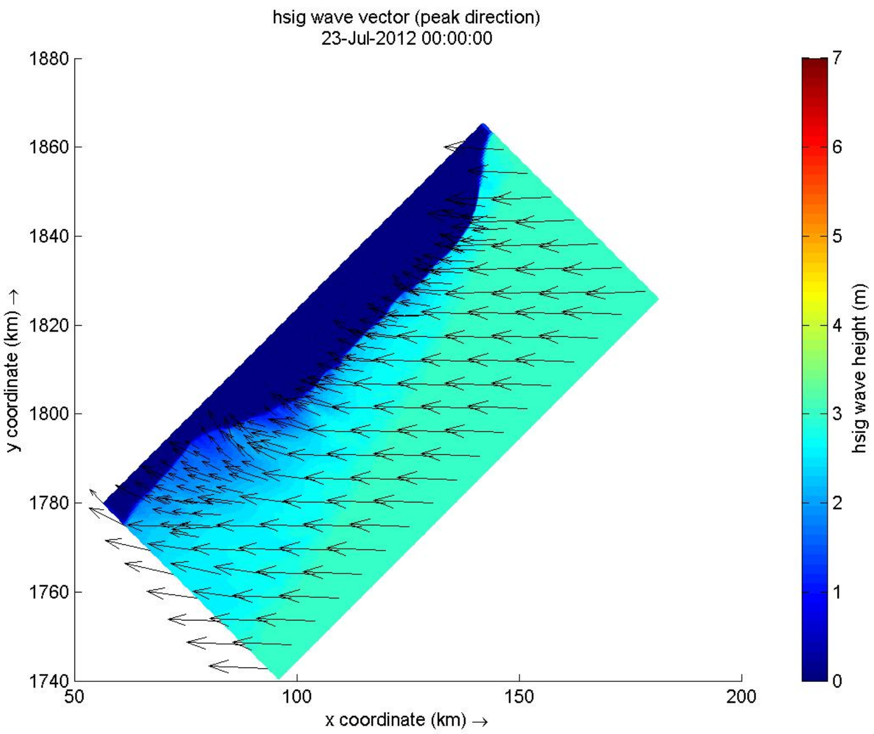


Figure 4.13: Richards Bay SWAN Outputs for Input Condition: 90°, 12s, 3m

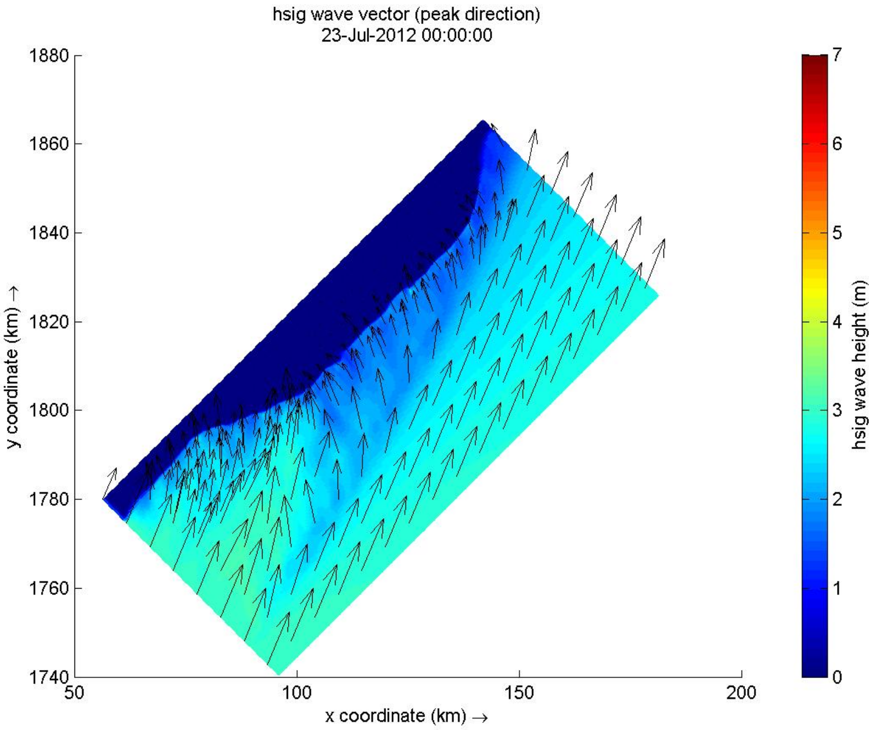


Figure 4.14: Richards Bay SWAN Outputs for Input Condition: 202.5°, 16s, 3m

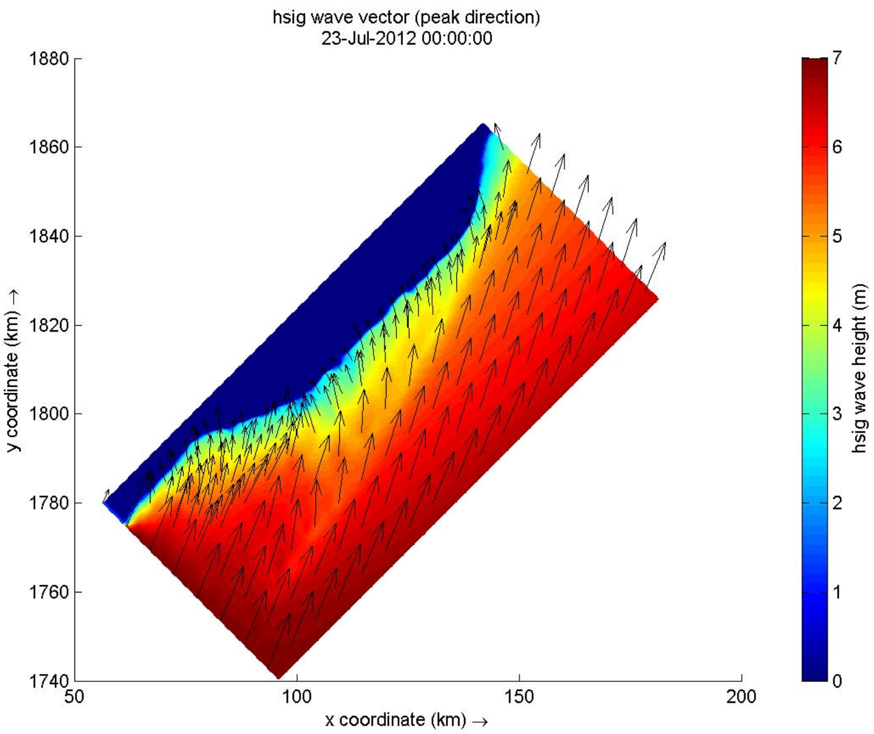


Figure 4.15: Richards Bay SWAN Outputs for Input Condition: 202.5°, 12s, 7m

Using the SWAN results for both locations and the interpolation function created in MATLAB, a time series (3 hourly) was generated of the offshore wave conditions at the SWAN NCEP location. A comparison between the data obtained from the SWAN NCEP location and data supplied by NCEP served as an improvement in the backward refracted method approach. The comparison results, however, do not resemble a more accurate offshore wave climate over the 3 month period, Refer to Table 4.3 and 4.4. The average difference in and standard deviation difference seem to be the same order of magnitude found when Snell's Law was used. Only with slight improvements for East London's average and standard deviation differences of wave height and standard deviation difference of directional distribution. Richards Bay also slightly improved the average difference of wave period and standard deviation difference of directional distribution.

Table 4.3: East London Statistics for Offshore SWAN Location and NCEP (31992) Wave Condition Comparison

	Wave Height (m)	**Wave Period (s)**	**Wave Direction(°)**
Average Offshore Location	2.29	11.21	179.44
Average NCEP	2.55	10.74	177.56
Difference	0.26	0.47	1.87
St. dev. Offshore Location	0.84	2.11	35.71
St. dev. NCEP	0.84	2.52	58.37
Difference	0.00	0.42	22.67

Table 4.4: Richards Bay Statistics for Offshore SWAN Location and NCEP (31992) Wave Condition Comparison

	Wave Height (m)	**Wave Period (s)**	**Wave Direction(°)**
Average Offshore Location	2.90	10.69	158.02
Average NCEP	2.14	9.73	149.90
Difference	0.66	0.95	8.12
St. dev. Offshore Location	1.21	2.13	56.03
St. dev. NCEP	0.73	2.77	56.44
Difference	0.31	0.65	0.41

The results for East London produced percent difference errors for wave height and period of 23.19% and 15.87% respectively. Similarly, 32.80% and 19.19% was determined for Richards Bay. The RMSE values for East London were 0.75m for significant wave height, 2.30s for period and 46.61° for direction and 2.03m for significant wave height, 2.62s for period and 55.45° for direction for Richards Bay. Again, a histogram of the occurrence of data points within the 10 degree bins has been shown in Figures 4.16 and 4.17, improving the directional distribution using this method compared to using Snell's Law. The reason is that the shape of the histogram and more specifically the peaks more closely represent the NCEP directional distribution.

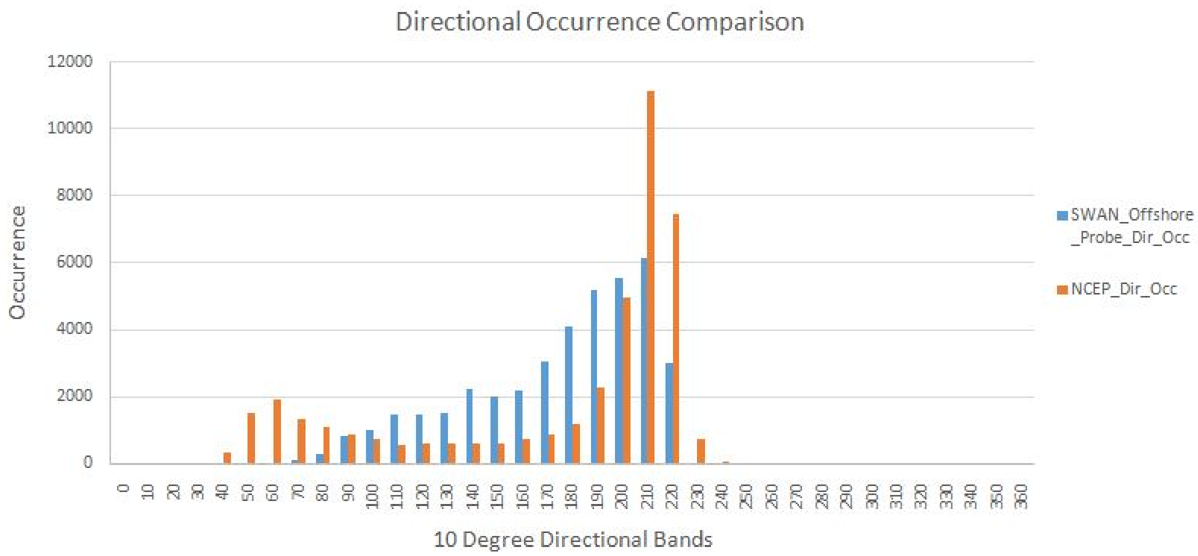


Figure 4.16: East London Directional Distribution Analysis between SWAN Offshore Location and NCEP data

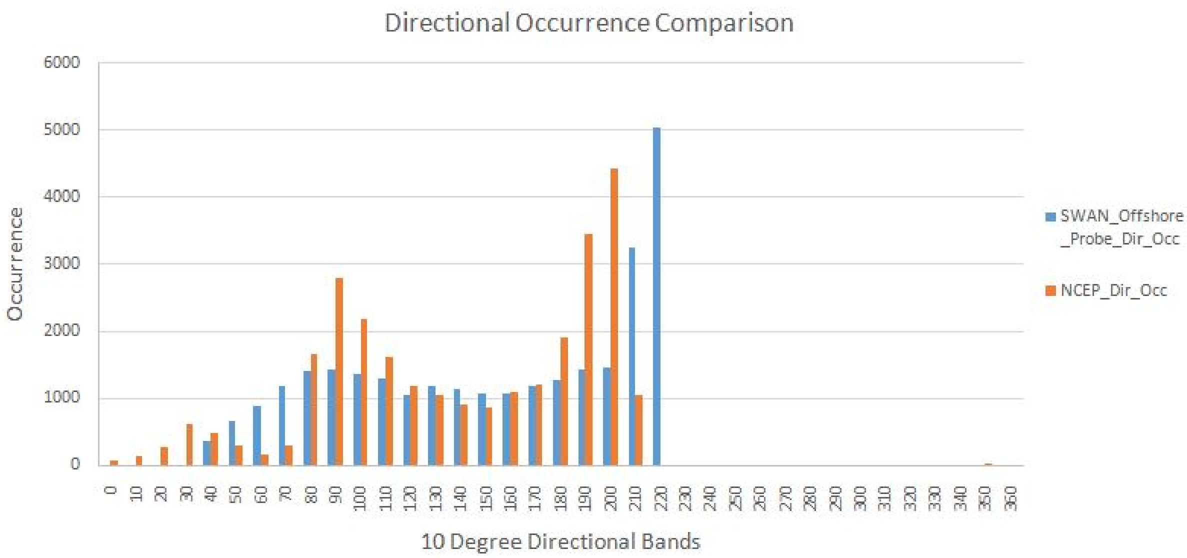
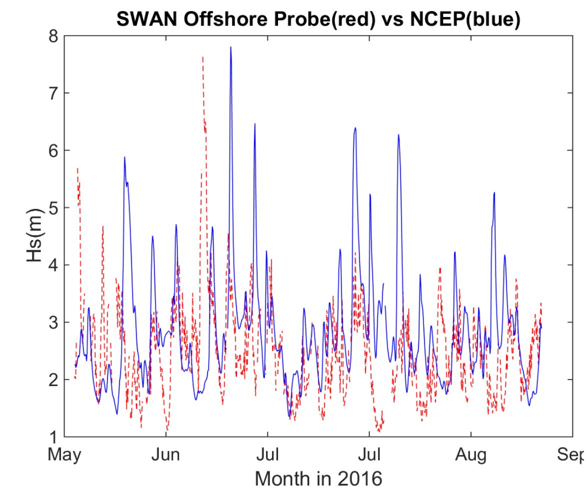
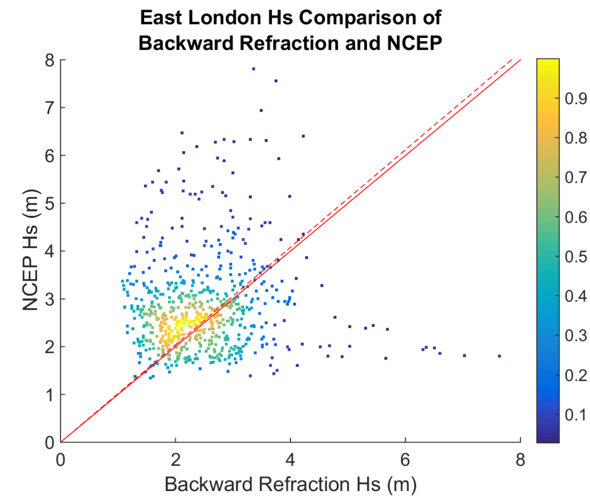


Figure 4.17: Richards Bay Directional Distribution Analysis between SWAN Offshore Location and NCEP data

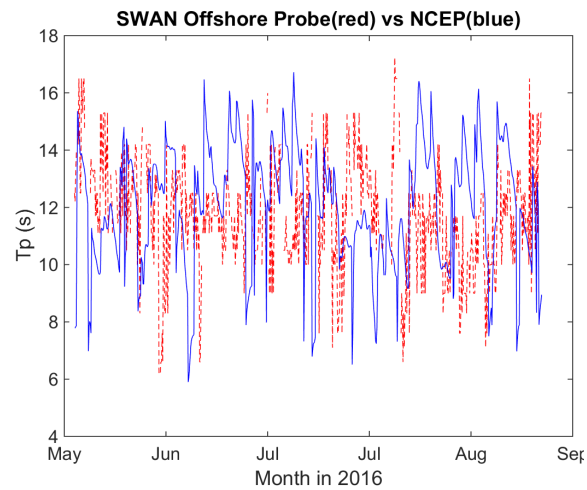
Once again, the three month time series, i.e. winter of 2016, for the offshore SWAN outputs (red) and the offshore NCEP locations (blue) were plotted. This was conducted for wave height, period and direction with the associated density scatter plots for East London and Richards Bay respectively, refer to Figures 4.18 and 4.19.



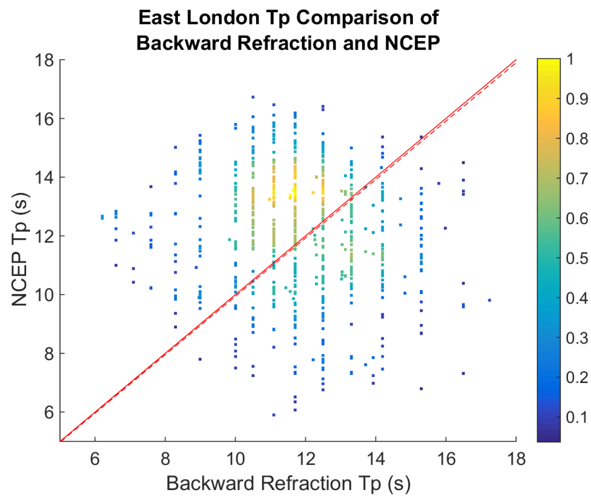
(a) Hs Time Series



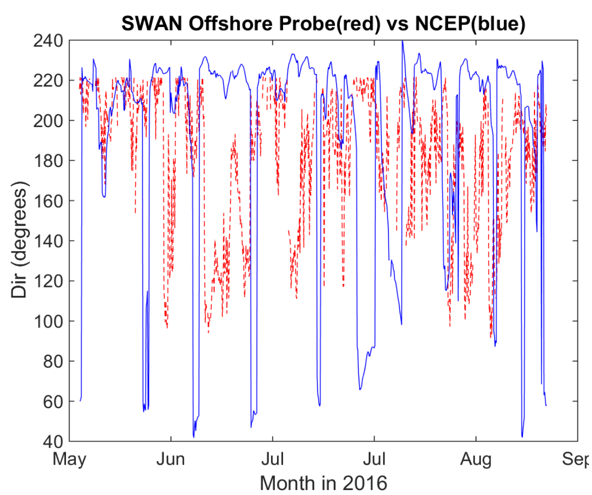
(b) Hs Density Scatter Plot



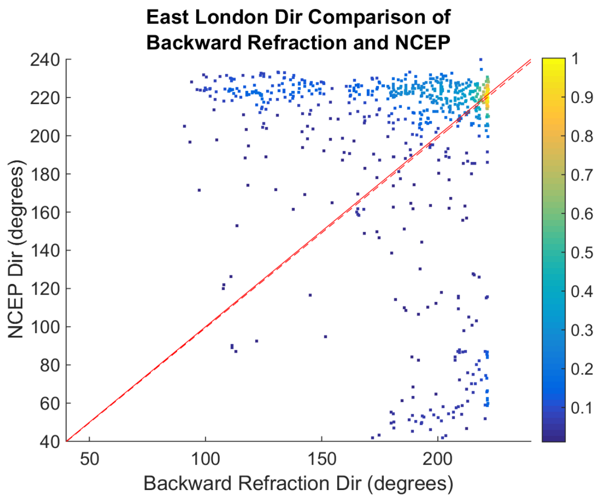
(c) Tp Time Series



(d) Tp Density Scatter Plot

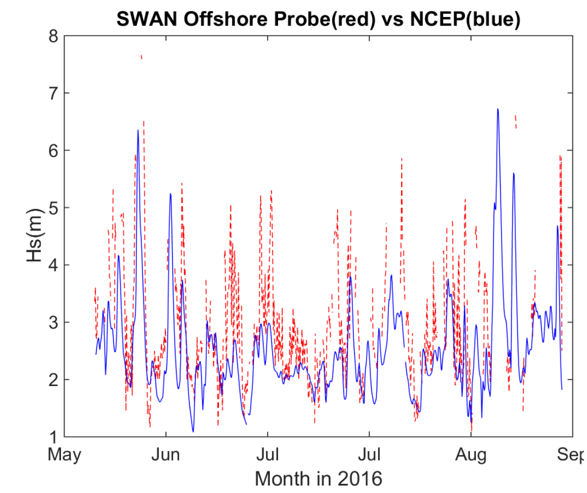


(e) Dir Time Series

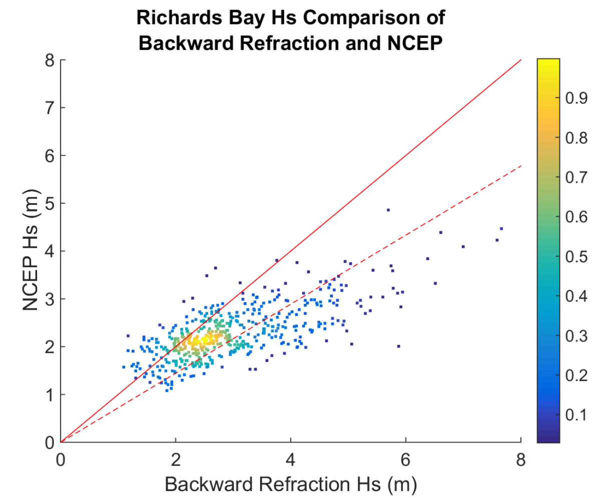


(f) Dir Density Scatter Plot

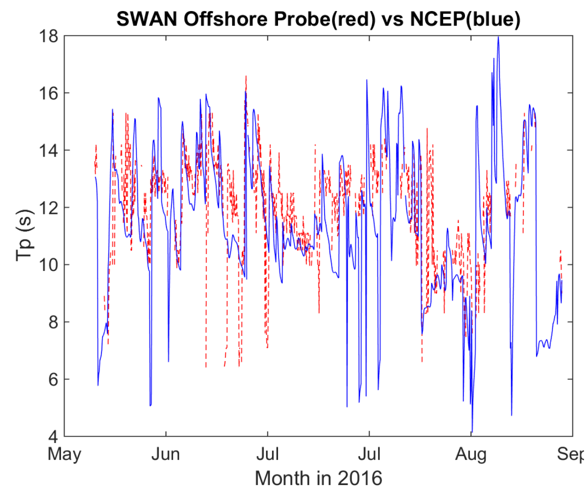
Figure 4.18: East London SWAN Offshore Location and NCEP Wave Condition Comparison for SWAN Approach



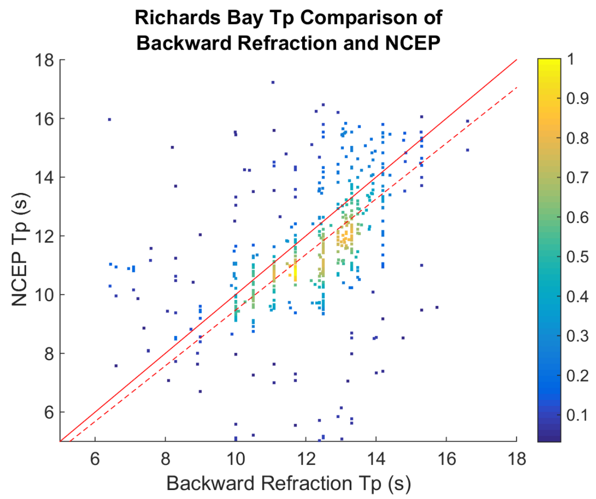
(a) Hs Time Series



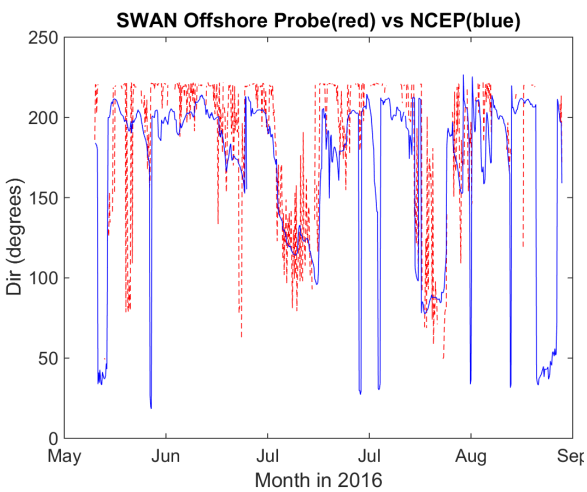
(b) Hs Density Scatter Plot



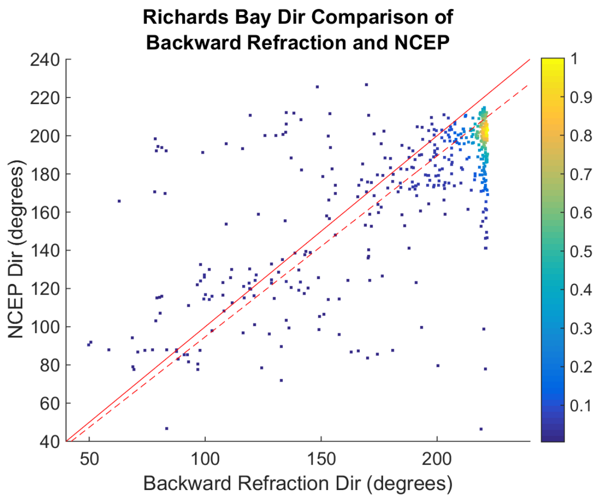
(c) Tp Time Series



(d) Tp Density Scatter Plot



(e) Dir Time Series



(f) Dir Density Scatter Plot

Figure 4.19: Richards Bay SWAN Offshore Location and NCEP Wave Condition Comparison for SWAN Approach

The density scatter plots of East London and Richards Bay wave height comparison was plotted from 0m to 8m in order to incorporate all the conditions. Firstly, it can be seen that for East London, there was a large scatter cloud though the trend line closely matched the 1 to 1 line. For Richards Bay the opposite is true, in that, the scatter is relatively narrow, but the trend line deviates from the 1 to 1 line. This shows that there was a larger backward refracted value determined for the associated NCEP value. The density scatter plots for period and direction were plotted in order to clearly indicate the dominant results found over the 3 month period. This implies that the period was plotted from 5s to 18s and the direction between 40° and 240°. Secondly and similar to the wave height, it was found that there is a large scatter for East London, while the trend line closely represents the 1 to 1 line and for Richards Bay the scatter is narrower, while on average the backward refracted periods are larger than the associated NCEP periods. Lastly, the wave direction plots show that for East London, although the trend line closely resembles the 1 to 1 line, it seems to indicate that for the majority of cases the backward refracted directions under estimate the NCEP predictions and the opposite is true for Richards Bay.

There were a number of anomalies or large variations extracted from the backward refracted data sample. This implies that even though the SWAN model better describes the wave processes, there are situations where the incorrect wave conditions are extracted from the look-up table and could be corrected for by means of a 'ground truth'.

4.3.3 Sensitivity Tests

In order to assess the accuracy of the SWAN model and lookup table, a sensitivity test was conducted. This was completed for East London, where Richards Bay could be expected to show similar results. It involved choosing a nearshore parameter to test by varying it according to the accuracy of the wave buoy and then comparing the other two associated offshore wave parameters.

The East London nearshore peak period values exceeded 30%(12.10s), 50%(11. 20s) and 70%(9.80s) of the time, see Figure 5.30, with 1 second variations either side were selected for the test. The nearshore mean significant wave height (1.76m) and dominant direction (180°) together with these periods made up the nearshore wave parameters. The associated offshore significant wave height and direction values for were plotted, refer to Figures 4.20 to 4.25. The largest deviation for offshore significant wave height and direction was calculated as a percentage difference from what was determined for the 12.10s, 11.20s and 9.80s peak periods. The percent values were 4.64%, 3.48% and 4.50% for significant wave height, see Figures 4.20 to 4.22. Values of 2.50%, 2.27% and 2.22% were calculated for wave direction, see Figures 4.23 to 4.25.

A similar effort was conducted for the wave direction parameter, where a variation of 10° was used either side of dominant wave directions. The percent difference values were 21.30%, 5.18% and 1.55% for significant wave height, see Figures 4.26 to 4.28. Values of 0% was found for peak period as there was no change, see Figures 4.29 to 4.31. These findings provide proof of the accuracy of the lookup table and therefore, confidence in the method.

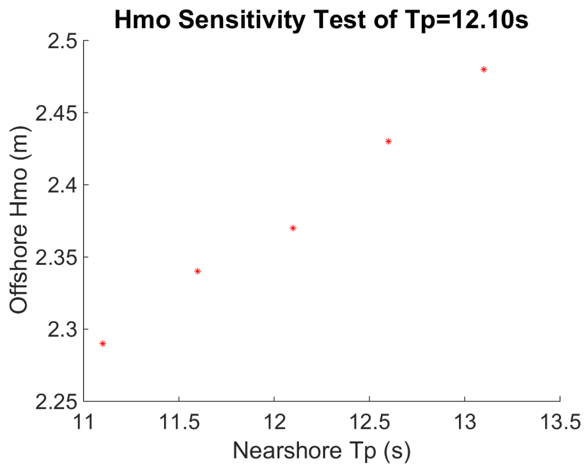


Figure 4.20: Hmo Sensitivity Test for Tp=12.10s

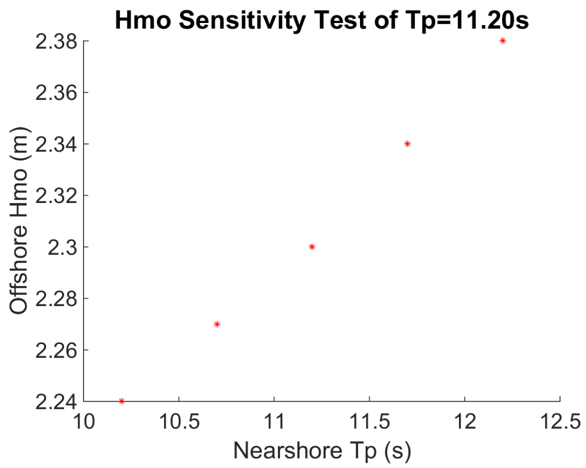


Figure 4.21: Hmo Sensitivity Test for Tp=11.20s

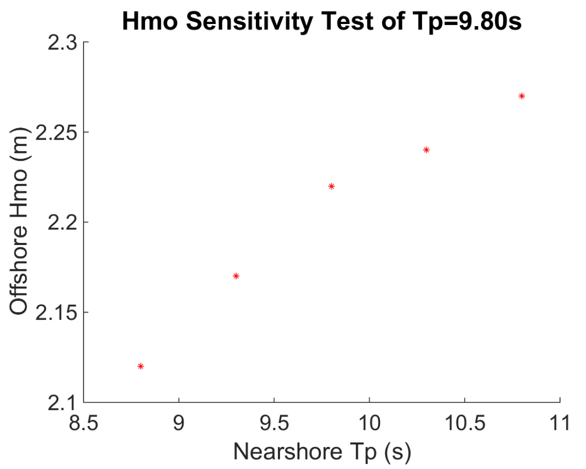


Figure 4.22: Hmo Sensitivity Test for Tp=9.80s

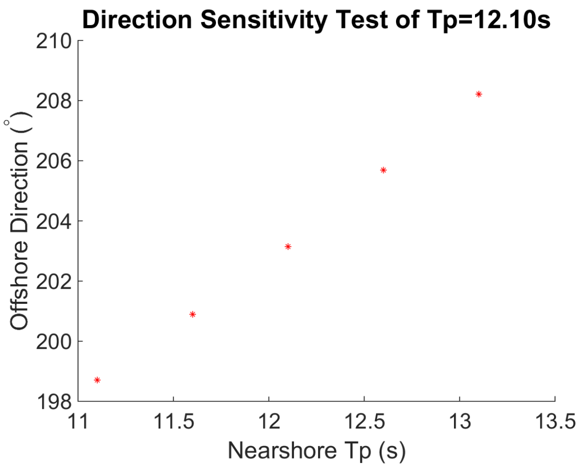


Figure 4.23: Direction Sensitivity Test for Tp=12.10s

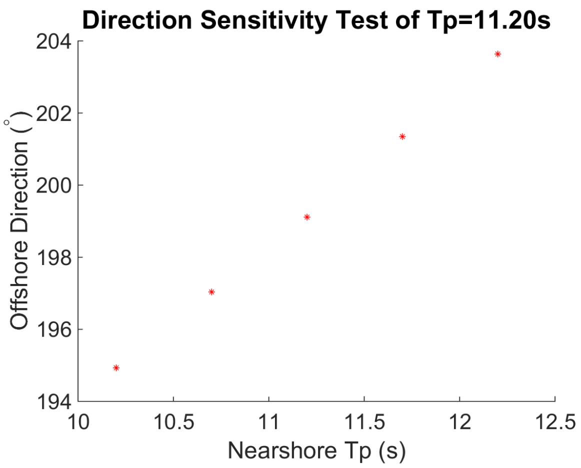


Figure 4.24: Direction Sensitivity Test for Tp=11.20s

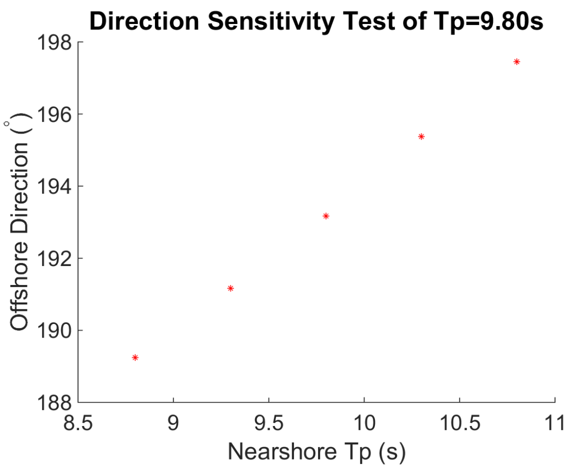


Figure 4.25: Direction Sensitivity Test for Tp=9.80s

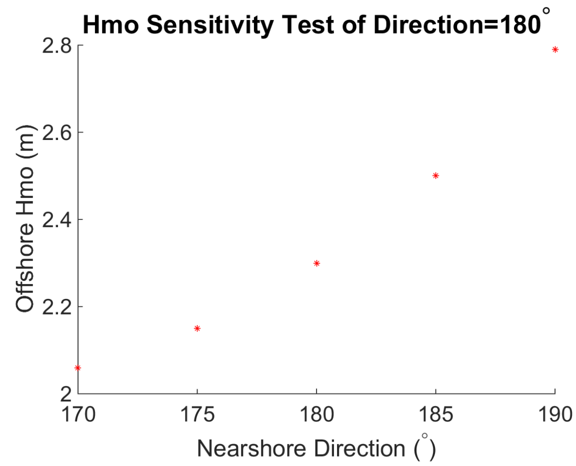


Figure 4.26: Hmo Sensitivity Test for Direction=180°

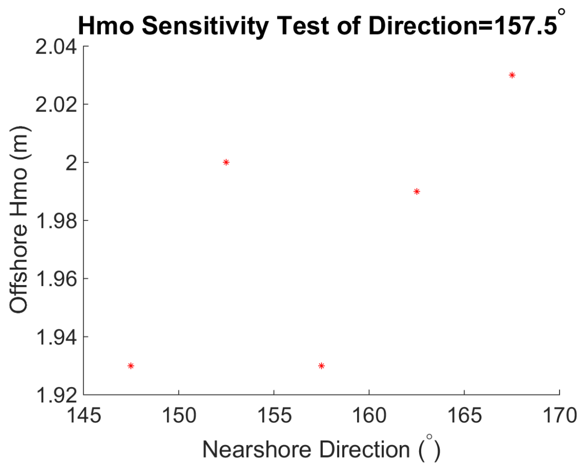


Figure 4.27: Hmo Sensitivity Test for Direction=157.5°

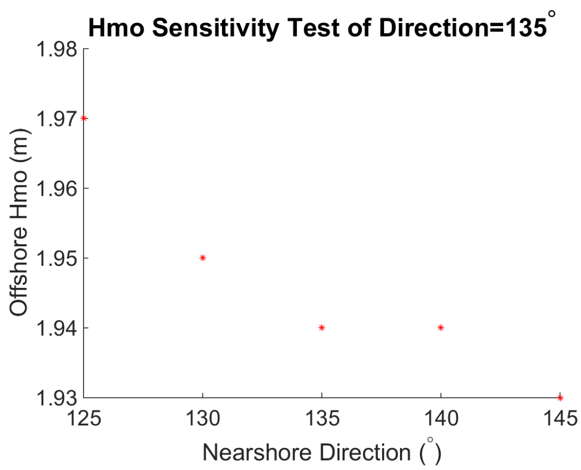


Figure 4.28: Hmo Sensitivity Test for Direction=135°

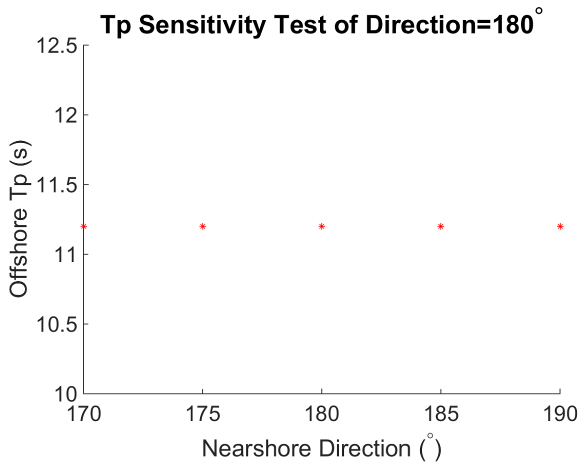


Figure 4.29: Tp Sensitivity Test for Direction=180°

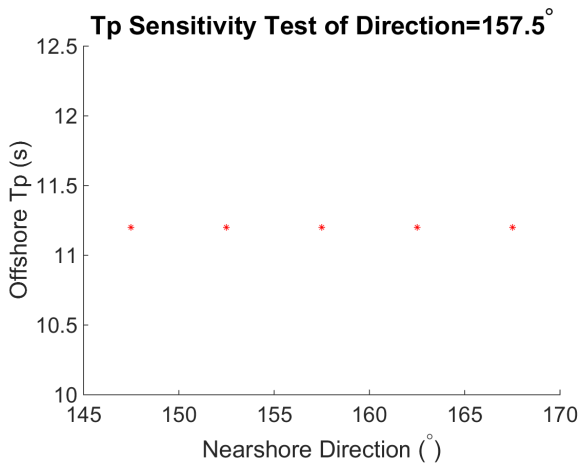


Figure 4.30: Tp Sensitivity Test for Direction=157.5°

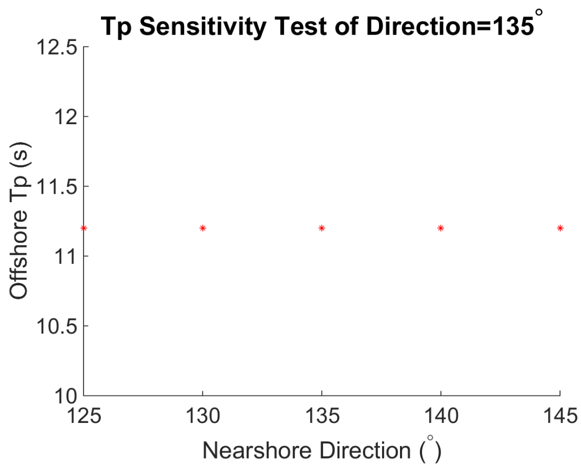


Figure 4.31: Tp Sensitivity Test for Direction=135°

4.4 Discussion

A first estimate of the offshore wave conditions at the NCEP locations were determined using the Snell's Law approach. This approach made use of the unrealistic assumption that the bathymetric contours are parallel. This had the benefit of relatively simplistic numerical calculations for backward refraction, but the limitation to correctly resolve the hydrodynamic processes. The SWAN approach, however, attempted to incorporate all hydrodynamic processes where possible using a SWAN numerical model to solve the mathematical transformations of the waves. This approach made use of generating a matrix in which the nearshore wave parameters could be used to determine the offshore parameters by means of interpolation.

The Snell Law approach resulted in percent difference errors for East London of 22.78% and 16.47% for wave height and period respectively. RMSE values were found to be 1.39m, 2.39s and 47.65° for wave height, period and direction respectively. The SWAN approach resulted in percent difference errors of 23.19% and 15.87% for wave height and period respectively. RMSE values of 0.75m, 2.30s and 46.61° were determined.

The Snell's Law approach at Richards Bay generated percent difference errors of 23.85% and 20.33% for wave height and period respectively. RMSE values of 0.63m, 2.84s and 47.82°. The SWAN approach resulted in percent difference errors of 32.80% and 19.19% for wave height and period respectively. RMSE values of 2.03m, 2.62s and 55.45° were calculated.

The results from the Snell's Law and SWAN approach show that the percent difference errors and RMSE values have a similar magnitude. It was however found that the SWAN approach slightly improved the results for East London, but not for Richards Bay. Therefore along this region of the South African coastline, it is recommended to implement either approach for determining the offshore wave height and period, but not direction. A complex and refined SWAN model together with the interpolation function should be used to better describe the directional distribution.

The fact that neither the backward refracted nor the NCEP data is considered 'ground truth', made the validation, i.e. any adjustment to NCEP wave conditions unjustified. The important aspect then remains in the methodologies used within each backward refracted approach. Furthermore, a deployment of a wave buoy at the offshore location for each site would enhance the findings of this study by not only comparison of the approaches to 'ground truth', but also complete the validation process enabling adjustments to NCEP data. Due to time and resource constraints, this was not possible for this study.

Chapter 5

Extreme Wave Analysis

5.1 General

The estimation of extreme or design wave heights is important for coastal engineers when designing structures in nearshore coastal regions for mitigation measures or development of the coastal infrastructure. This is accomplished by fitting appropriate distributions to measured nearshore measured data. While ADCP, pressure sensors and other instrumentation can be used, wave buoy data has the largest dataset and is thus used to conduct the analysis. Rossouw (1989) used the method of moments to fit a two-parameter Extreme I (Fisher-Tippet I or Gumbel) probability distribution to wave buoy data that consisted of winter months. This method is referred to as the Gumbel distribution in the following section. The mean and standard deviation of the wave height made up the two parameters used for this method. In later years, estimating extreme wave heights off the south coast of South Africa using satellite data was investigated (Rossouw and Rossouw, 1999). The mean wave height of the Slangkop wave buoy and the Geosat data compared well, although the standard deviation was poorly estimated by the satellite. A larger dataset would overcome this issue, but this did not exist at that time (Kapp, 1997). Again, it was found that the Gumbel method was applicable for this data. Rossouw and Rossouw (2000) was another study concerned with extreme wave analysis by means of satellite (Topex/Poseidon) data where the Gumbel distribution was applied (Carter and Challenor, 1983).

A few aspects are important to consider for the Gumbel distribution. By using the total sample of data, the condition of statistical independence between individual data values is violated (Goda, 1989). However, the effect of using the total sample of data for the South African coastline was found to be negligible. Stable estimates are provided in regions where storms are of similar origin and occur regularly. In South Africa, waves from the winter months are usually generated by similar weather systems. Resulting in relatively constant wave heights and standard deviations which constitutes an identical dataset. It is therefore important that the storms are responsible for the extreme events (Rossouw and Rossouw, 1997). The method does not apply in cyclonic or semi-protected regions, such as bays or areas with mostly calm conditions with occasional severe storms.

Although the Gumbel method had been used along the South African coastline in the past, Stander (2015) recommends the Weibull 3-parameter distribution fit using the Peaks-over-Threshold (POT) method as recommended by IAHR (International Association for Hydro-Environment Engineering and Research) (Mathiesen *et al.*, 1994). This method ensures independent and identical data by using the highest wave recorded between the up and down crossing of a chosen threshold. This method is expected to be superior in cases where there is a danger of using non identical data, such as areas where cyclones or mixed systems occur, i.e. the northern Natal coast. The 3-parameter Weibull distribution is also a good fit to most data (Rossouw and Medina, 1996). This method has been used in a nearshore analysis for the South African Department of Environmental Affairs (Theron *et al.*, 2014).

5.2 Method

The offshore extreme wave conditions are important for offshore structure design and shipping. The only offshore data along the east coast of South Africa is either from satellites or NCEP. Chapter 3 and 4 dealt with approaches capable of validating NCEP data but due to inadequate results, there was no adjustment made to the NCEP data. It remained unchanged for the purpose of the extreme value analysis. This section includes plots of cumulative density functions (cdf) of the Exponential, Gumbel as well as the Weibull 3-parameter distribution in order to conduct a diagnostic test, i.e. visual comparison, of the best fit. From this test, the most applicable distribution would be further explored, refer to Equation 5.1 and 5.2 for the cumulative density functions for the Gumbel (Gumbel, 2004) and Weibull 3-parameter (Cousineau, 2008) distributions respectively.

$$Q(p) = \mu - \beta \ln(-\ln(p)) \tag{5.1}$$

where:

$$\sigma^2 = \beta^2 \frac{\pi^2}{6}$$

$$\varphi = \mu - \beta\tau$$

and:
- σ^2 is the variance
- μ is the mode
- τ is the Euler-Mascheroni constant (0.5772).

$$F(t) = 1 - \exp^{-\left(\frac{t-\gamma}{\eta}\right)^{\xi}} \tag{5.2}$$

where:

$$f(t) \geq 0, \; t \geq 0 \; or \; \gamma, \; \xi > 0, \; \eta > 0, \; -\infty < \gamma < \infty$$

and:
- ξ is the shape parameter, also known as the Weibull slope.
- η is the scale parameter.
- γ is the location parameter.

The POT method includes the largest storms and therefore, emphasis is placed on the upper tail of the data. The use of three parameters in the Weibull 3-parameter distribution allows the fit to follow the data deviations at the upper tail. It was fitted to the significant wave height values produced by the WAVEWATCH III model at 3-hour time intervals over a period of 20 years using the POT method (Goda *et al.*, 2001; Holthuijsen, 2007) as well as no POT method for comparison purposes.

The estimations were performed using a procedure whereby user defined POT values were chosen and an optimum threshold level was selected for each dataset (Thompson *et al.*, 2009). The procedure for finding a suitable threshold is to identify suitable values of equally spaced candidate thresholds (i.e. 100 candidate values ranging from the median up to the 98% quantile or the 100th data value in descending order if fewer than 100 values exceed the 98% quantile value). Pearson's Chi-square Test is then applied in order to establish whether or not the observed differences are consistent with a normal distribution with mean 0. If the null hypothesis of normality is not rejected for that specific candidate threshold then that is considered a suitable threshold. This procedure is repeated until the Pearson's normality test indicates that the differences are consistent with a normal distribution with mean 0. This was found to be an adequate method for the extreme value analysis (Theron *et al.*, 2014). A comparison of the user defined POT values and the AutoPOT method described above were compared for the 1 in 100 year wave heights determined for a Weibull 3-parameter distribution, see Figure 5.1. The advantage of the automated selection technique is that this is an objective approach and not subject to the user's idea of an appropriate threshold value. It was thus the technique chosen for the Weibull 3-parameter distribution.

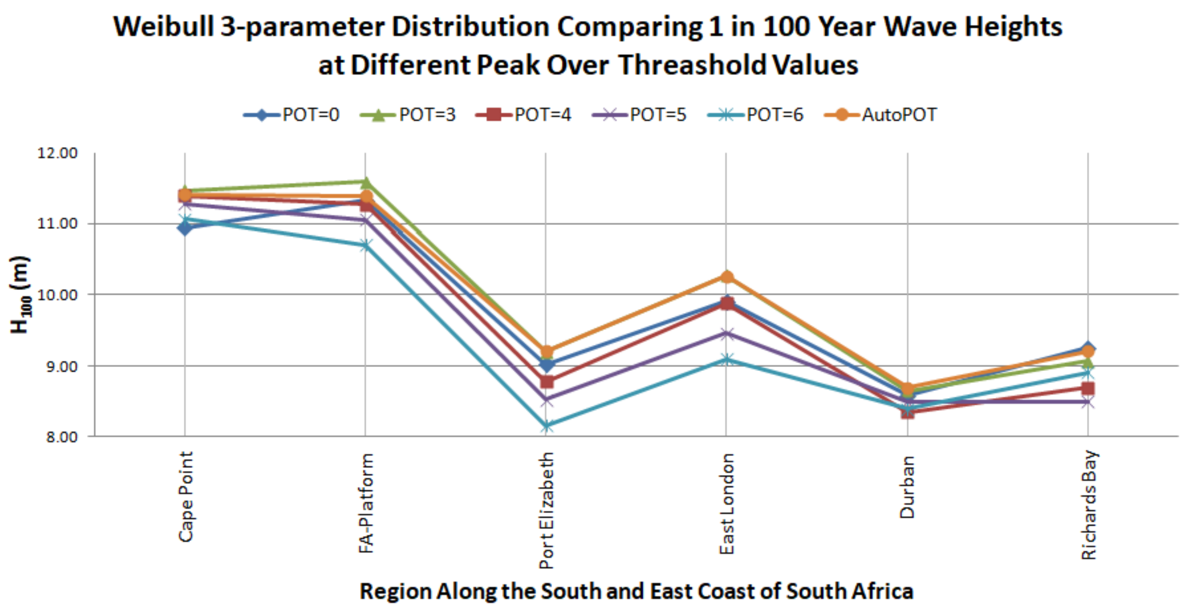


Figure 5.1: POT Value Comparison for 1 in 100 Year Wave Heights Determined From a Weibull 3-parameter Distribution

Taking a closer look at the POT comparison for Cape Point, Figure 5.2. It can be seen that this technique is not only an objective approach as the user does not define the POT value subjectively, but also a conservative approach by obtaining the second highest 1 in 100 year extreme value significant wave height of 11.42m.

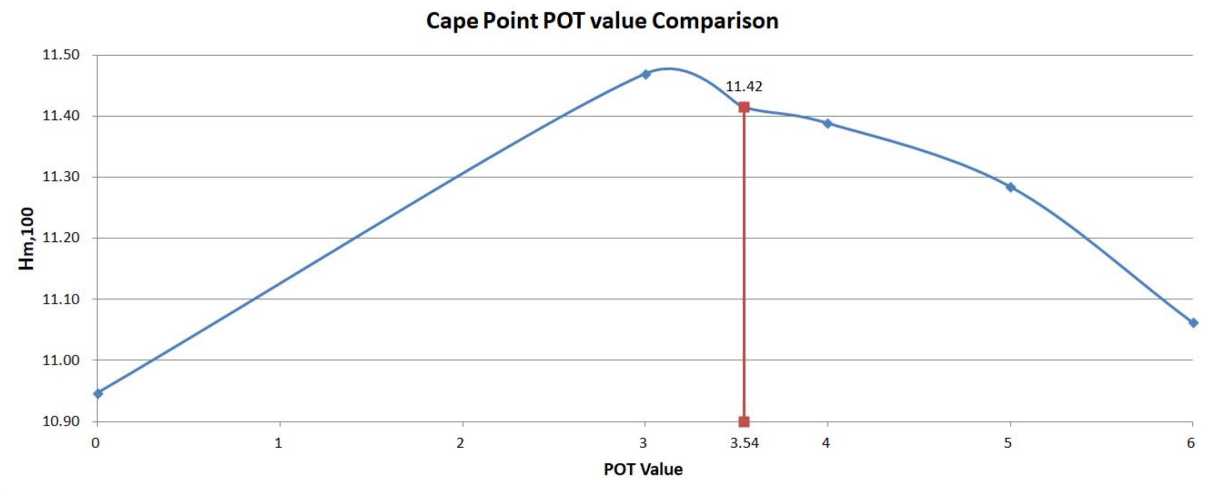


Figure 5.2: Cape Point POT Comparison

In addition to the above figures, it is interesting to note the number of events per year associated with the chosen POT values that can also be used as a realistic check to actual number of significant events, refer to Table 5.1. The site locations have been abbreviated: Cape Point (CP); FA-Platform (FA); Port Elizabeth (PE); East London (EL); Durban (D); Richards Bay (RB) and these abbreviations have been used later in this section. The automated POT selection technique chose values with associated events per year in the order of 40, which is realistic along the South African Coastline.

Table 5.1: Peak Over Threshold Comparison

	Weibull 3-parameter Distribution											
	AutoPOT		**POT=0**		**POT=3**		**POT=4**		**POT=5**		**POT=6**	
Site	$\mathbf{H}_{100}$	$\frac{\text{Events}}{\text{year}}$	$\mathbf{H}_{100}$	$\frac{\text{Events}}{\text{year}}$	$\mathbf{H}_{100}$	$\frac{\text{Events}}{\text{year}}$	$\mathbf{H}_{100}$	$\frac{\text{Events}}{\text{year}}$	$\mathbf{H}_{100}$	$\frac{\text{Events}}{\text{year}}$	$\mathbf{H}_{100}$	$\frac{\text{Events}}{\text{year}}$
CP	11.42	46.64	10.95	99.27	11.47	68.18	11.39	34.89	11.29	15.35	11.06	6.05
FA	11.39	49.29	11.32	98.22	11.59	69.88	11.27	35.59	11.05	17.40	10.70	6.95
PE	9.21	49.14	9.02	97.82	9.20	48.54	8.78	18.05	8.52	6.50	8.16	1.60
EL	10.26	49.29	9.91	98.27	10.28	53.59	9.88	21.09	9.46	7.75	9.10	2.55
D	8.70	32.64	8.59	96.37	8.65	29.44	8.35	9.70	8.50	3.00	8.40	0.60
RB	9.21	42.54	9.26	96.52	9.07	32.74	8.70	12.25	8.49	4.20	8.91	1.35

Rossouw and Rossouw (1999) presented five methods from previous studies for determining the wave period associated with the extreme or design wave heights. It was found that a four second variation from the most likely wave period best described the range of wave periods associated with the extreme wave height for the South African context. This represented the 95% confidence bands (defined by the normal distribution) but generated a wide range of periods. A more suitable and narrower range was determined using the method by Det Norske Veritas DNV (1977) and given by Equation 5.3.

$$3.6\sqrt{H_s} < T_p < 5.5\sqrt{H_s} \tag{5.3}$$

5.3 Results

The Exponential, Gumbel, Weibull 3-parameter with no POT value and Weibull 3-parameter with an automatically generated POT value was plotted. This was conducted for six locations along the south and east coast. The six locations were NCEP locations in the region of: Cape Point (32271), FA-Platform (32563), Port Elizabeth (32278), East London (31992), Durban (31130) and Richards Bay (30843). The location and associated NCEP numbers are expressed in parenthesis below each figure. For all plots, the data was represented in blue while the fitted distribution were represented in red. The black dotted lines represent the extreme wave heights associated with specific return periods.

The cdf plots for the Exponential distribution are presented in Figures 5.3 to 5.8. The black dotted line represents the 1 in 100 year return period with associated design wave height values. The equation for the distribution line and the coefficient of determination (R^2) has been displayed in the top right hand corner of each graph. The x-axis represents the probability of exceedance on a logarithmic scale, where the y-axis presents the significant wave height in meters. It can be seen that this distribution better represents the data for Cape Point, Durban and Richards Bay compared to the other locations.

The gumbel distributions are presented in Figures 5.9 to 5.14. Here, together with the 1 in 100 year return period, the 1 in 1, 5, 10, 30 and 50 were also included. The x-axis was plotted on a double logarithmic scale and the y-axis remained the significant wave height in meters. Although the point of interest is not the lower tail, this distribution poorly describes this end of the data. The upper tail underestimated the extreme wave heights for the six locations.

The Weibull 3-parameter distribution has an x-axis plotted on a logarithmic scale and y-axis measuring the significant wave height. Stander (2015) suggests fitting a Weibull 3-parameter distribution to significant wave heights in order to determine the design waves for the South African coastline. The distribution using a POT value of 0 was plotted for completeness, refer to Figures 5.15 to 5.20. Section 5.2 recommended using the autoPOT technique and has been plotted for all six locations, refer to Figures 5.21 to 5.26. The Weibull 3-parameter distribution recommended by Stander (2015) as well as the objective and conservative autoPOT technique had the best fit to the data samples when analysed by eye and was therefore explored further.

It was found that deviations of the data at the upper tail are both above and below the fitted distribution. The results for Figure 5.21 and 5.22 tend to follow the data closely and was hence considered an accurate estimate for extreme wave height. Due to the emphasis placed on the upper tail, slightly lower design wave heights were estimated when the data deviates downward at the upper tail, which was the case for Figures 5.23 to 5.26. The reason for the jump in the last data points in Figures 5.25 and 5.26 could be due to extreme events caused by cut off lows or cyclonic influences along the northern Natal region. The inclusion of cyclone events influencing the design wave heights was not in the scope of this thesis, though, this should not be neglected in the design process and therefore should be investigated further.

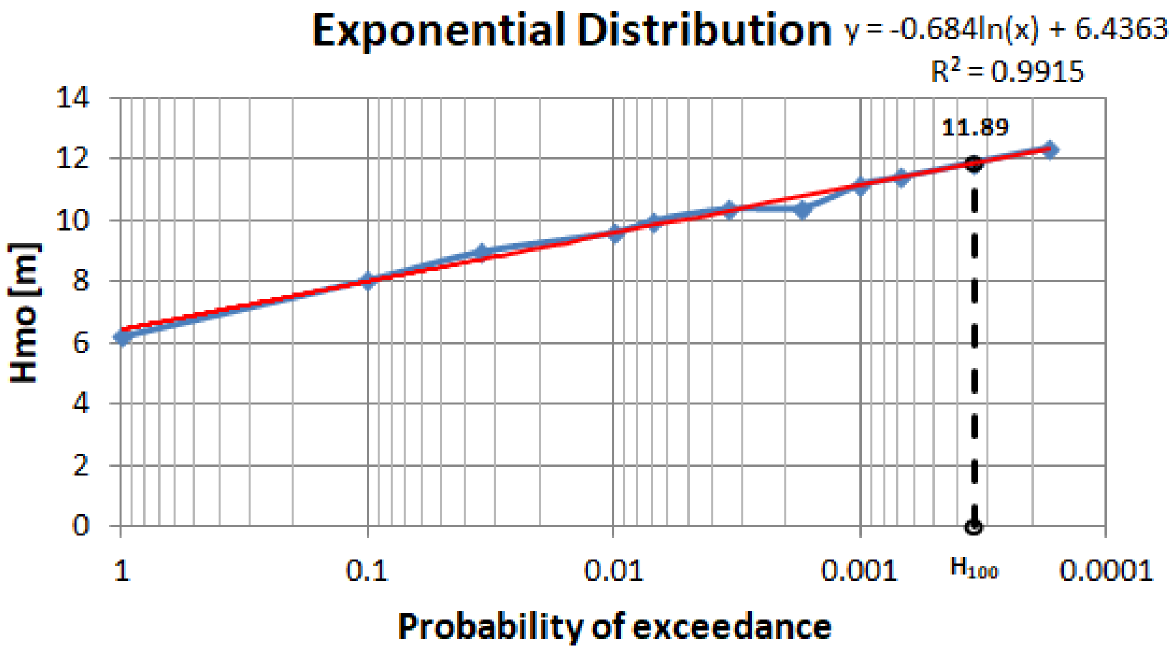


Figure 5.3: Extreme Wave Analysis using Exponential Distribution for Cape Point (NCEP 32271)

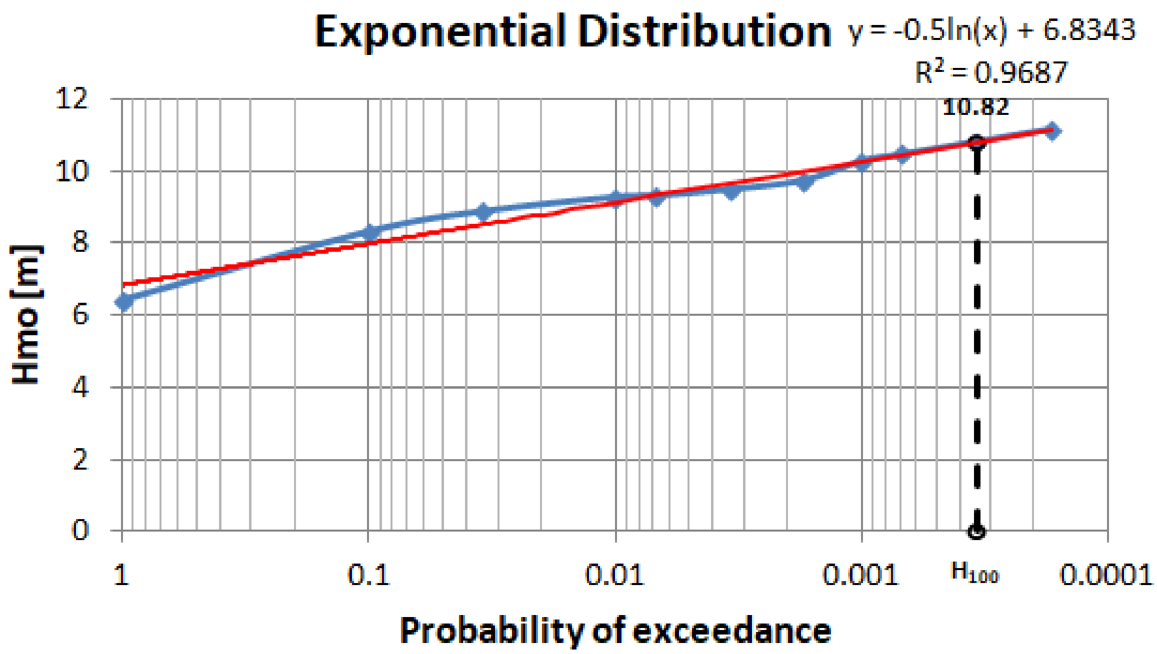


Figure 5.4: Extreme Wave Analysis using Exponential Distribution for FA-Platform (NCEP 32563)

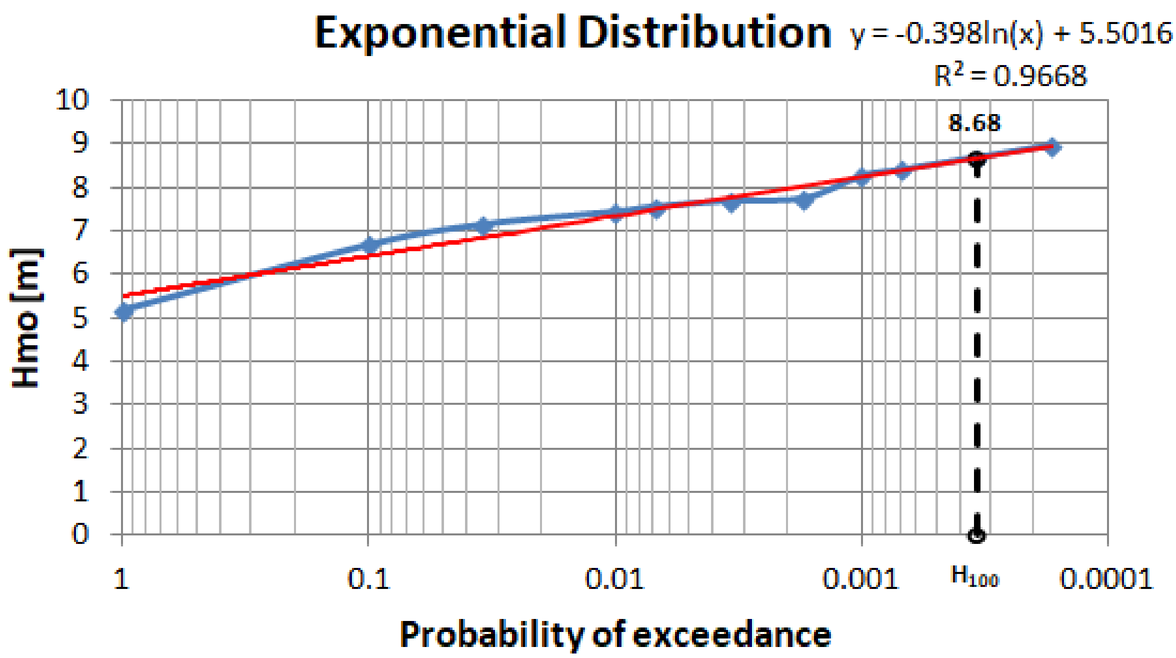


Figure 5.5: Extreme Wave Analysis using Exponential Distribution for Port Elizabeth (NCEP 32278)

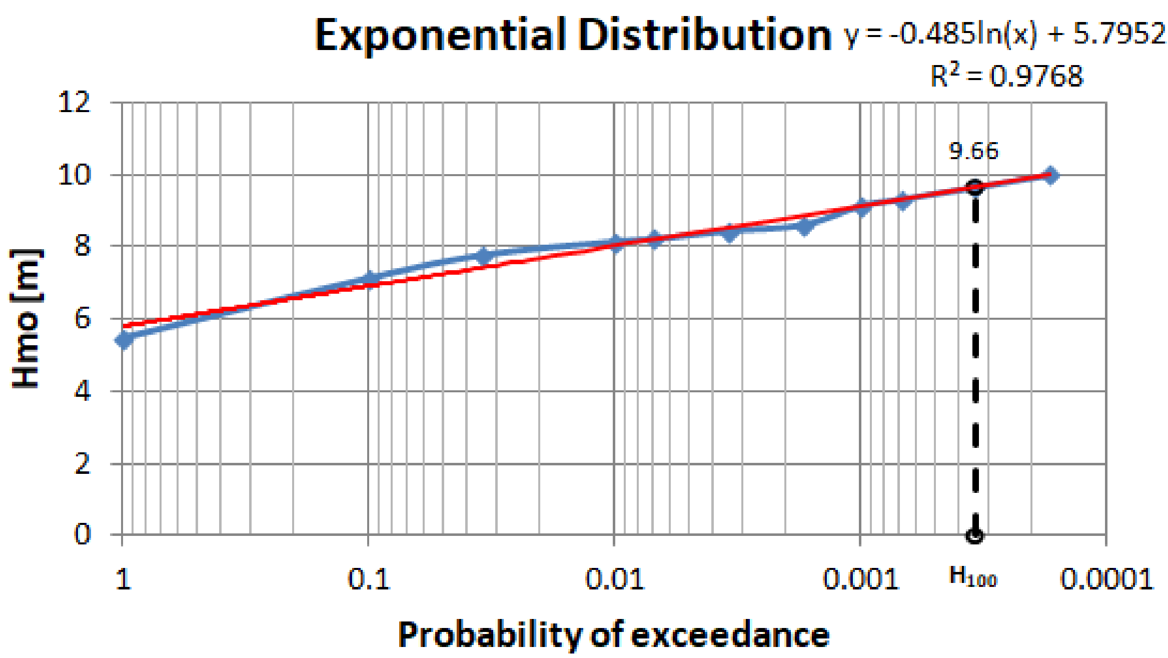


Figure 5.6: Extreme Wave Analysis using Exponential Distribution for East London (NCEP 31992)

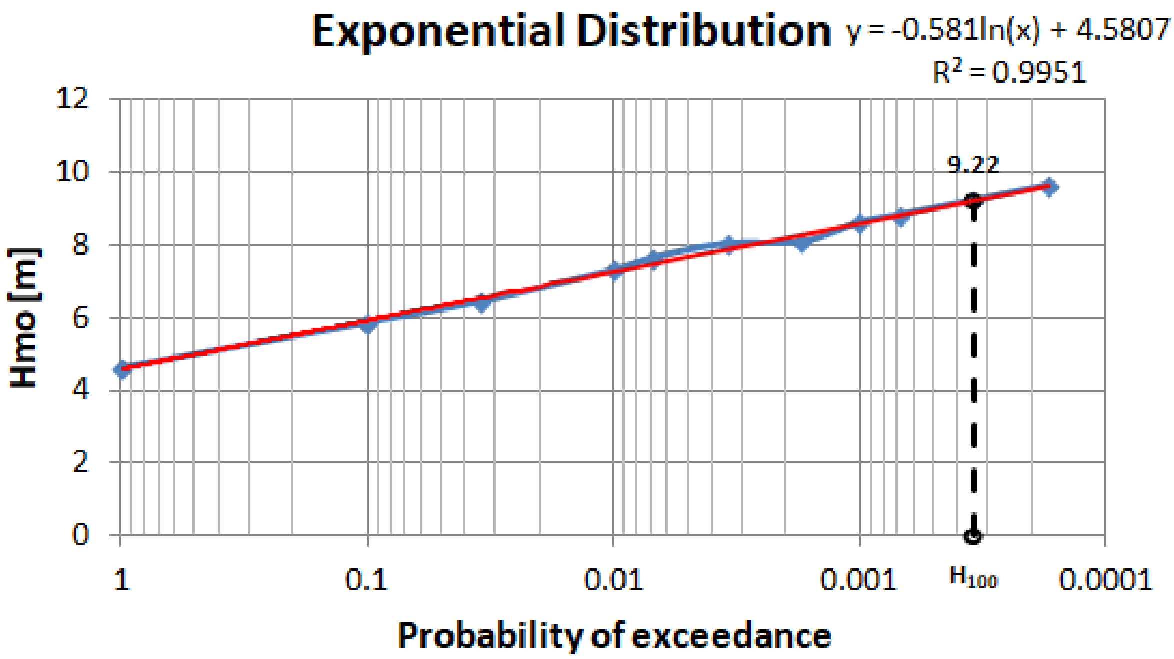


Figure 5.7: Extreme Wave Analysis using Exponential Distribution for Durban (NCEP 31130)

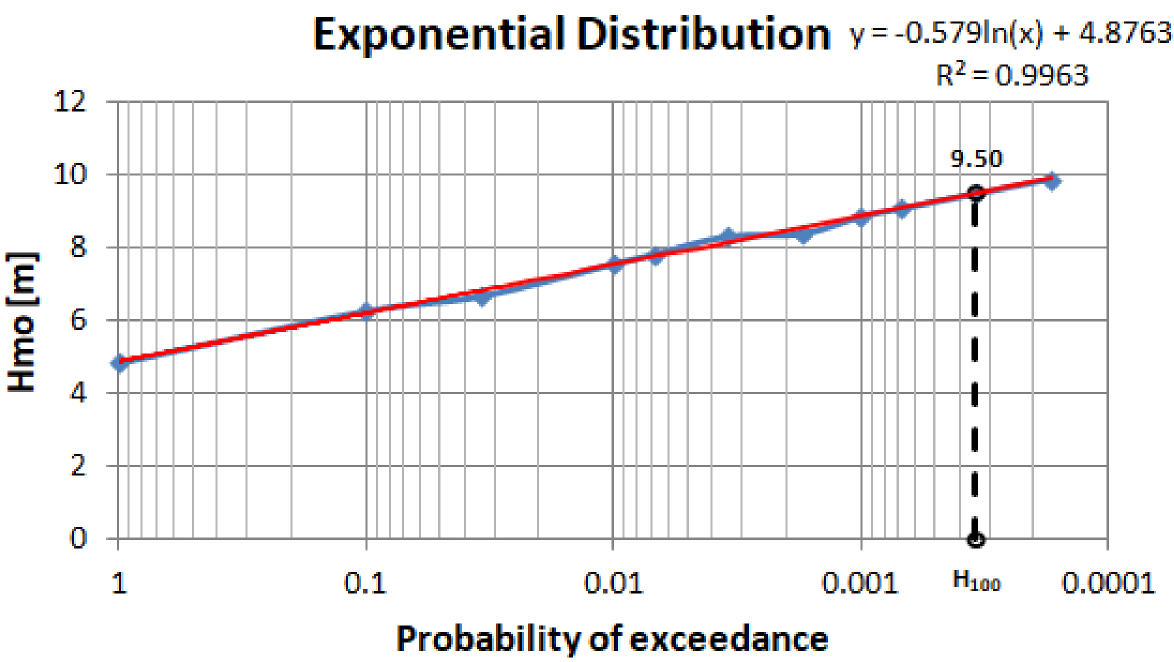


Figure 5.8: Extreme Wave Analysis using Exponential Distribution for Richards Bay (NCEP 30843)

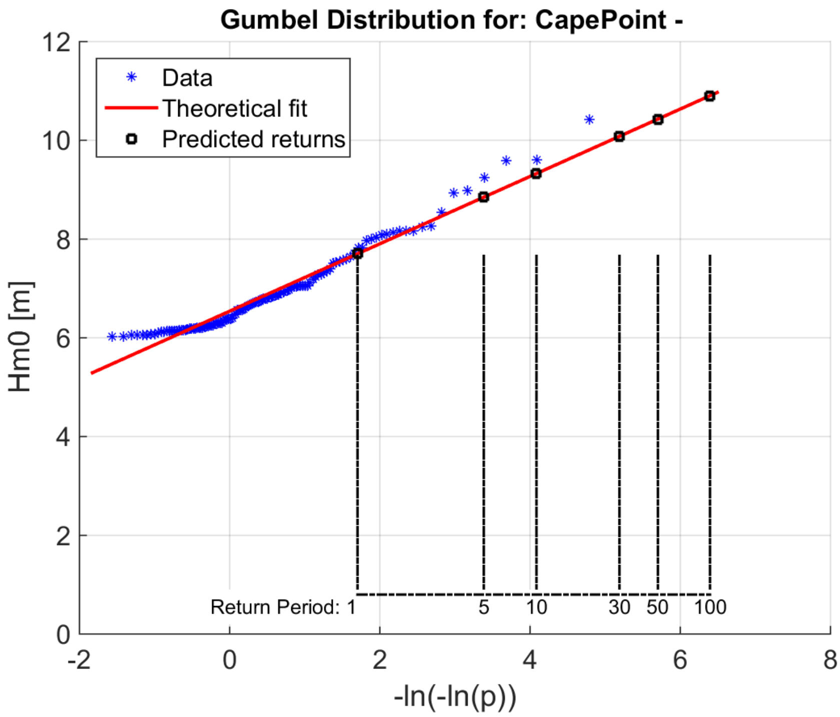


Figure 5.9: Extreme Wave Analysis using Gumbel Distribution for Cape Point (NCEP 32271)

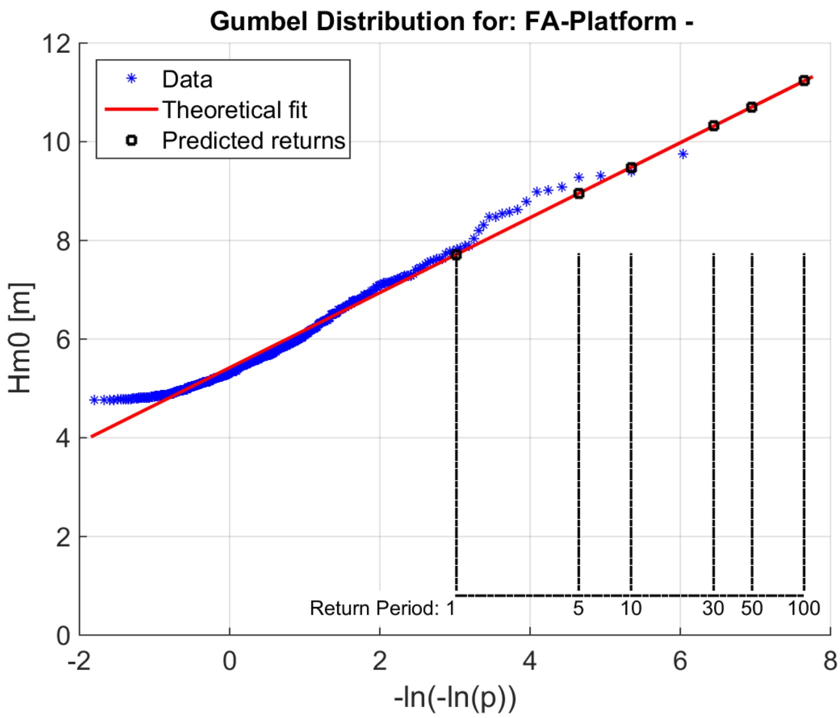


Figure 5.10: Extreme Wave Analysis using Gumbel Distribution for FA-Platform (NCEP 32563)

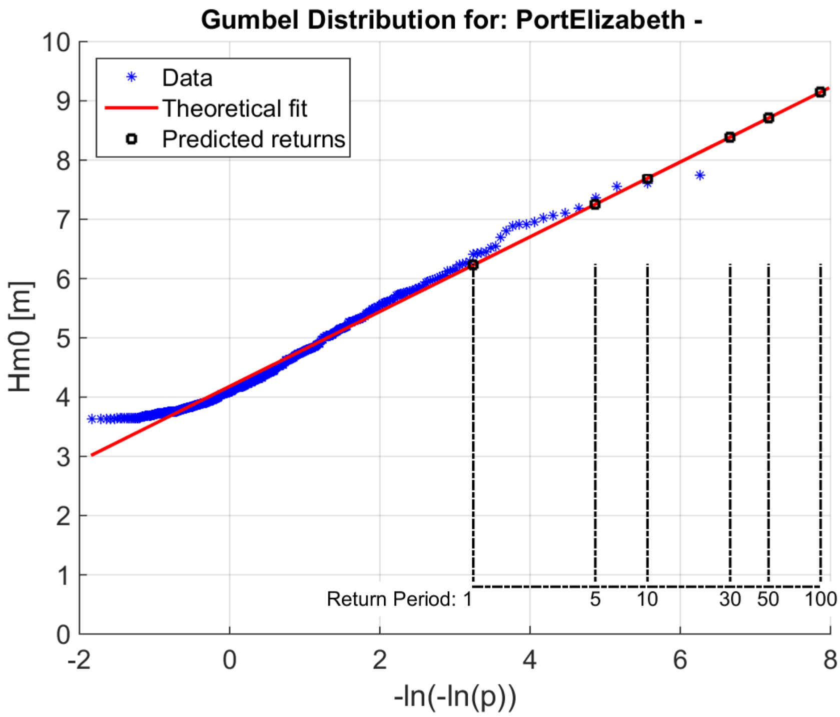


Figure 5.11: Extreme Wave Analysis using Gumbel Distribution for Port Elizabeth (NCEP 32278)

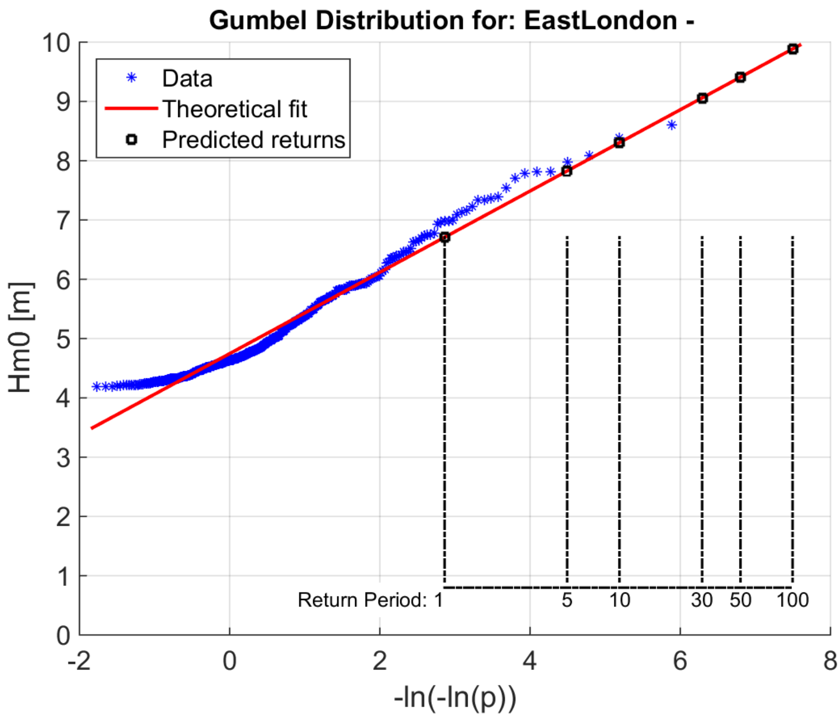


Figure 5.12: Extreme Wave Analysis using Gumbel Distribution for East London (NCEP 31992)

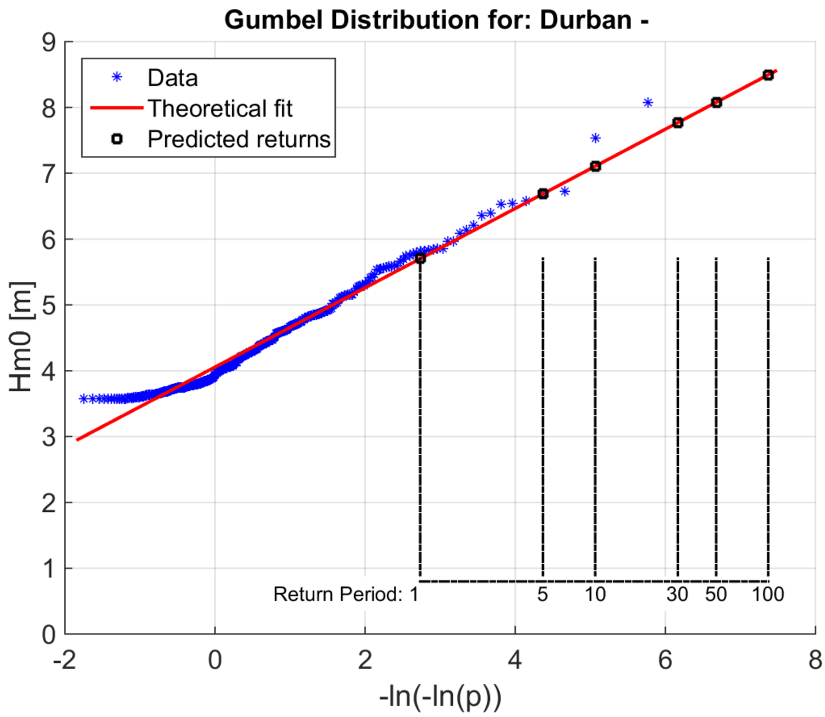


Figure 5.13: Extreme Wave Analysis using Gumbel Distribution for Durban (NCEP 31130)

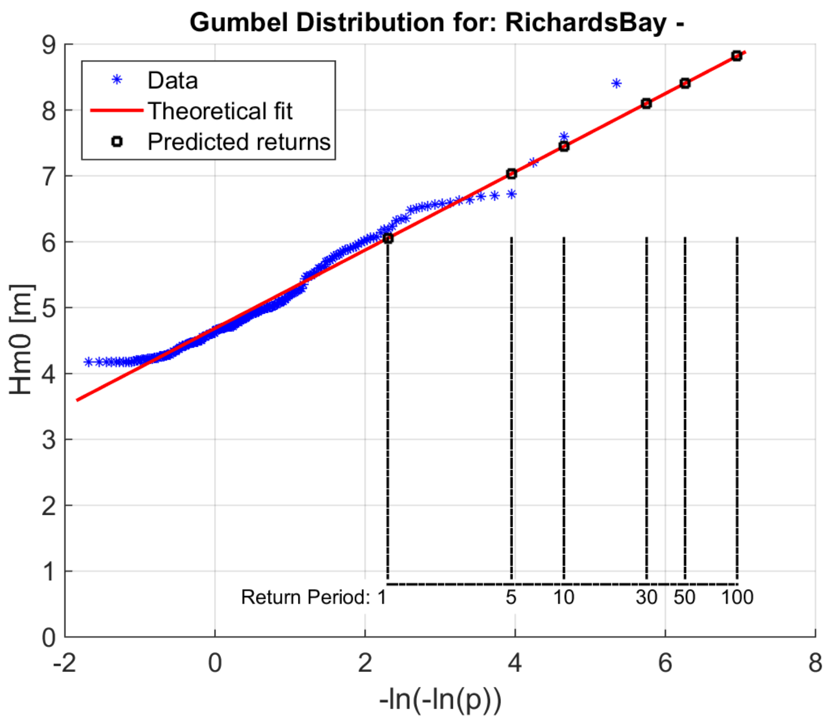


Figure 5.14: Extreme Wave Analysis using Gumbel Distribution for Richards Bay (NCEP 30843)

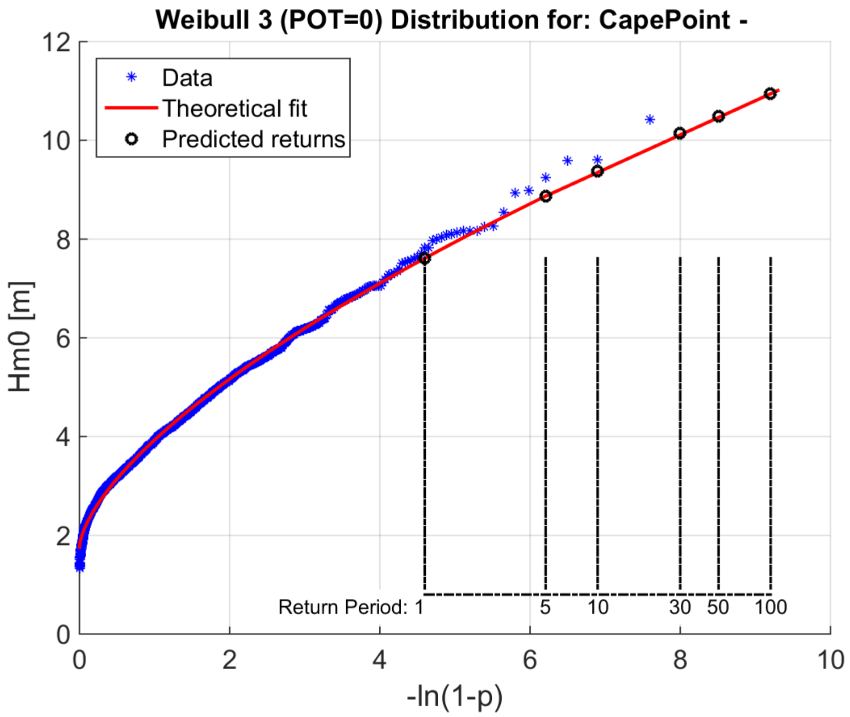


Figure 5.15: Extreme Wave Analysis using a 3 parameter Weibull (POT=0) Distribution for Cape Point (NCEP 32271)

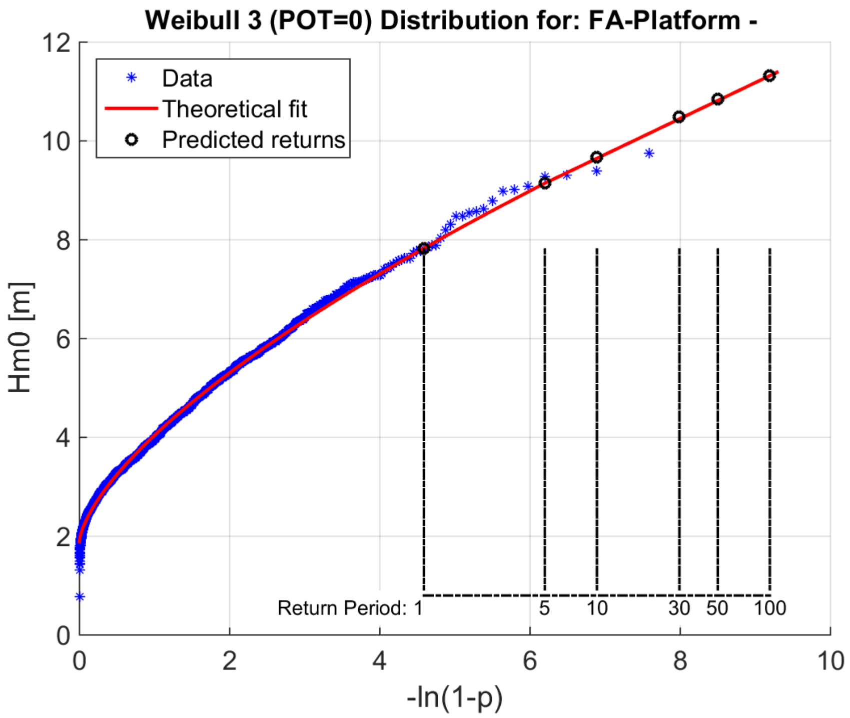


Figure 5.16: Extreme Wave Analysis using a 3 parameter Weibull (POT=0) Distribution for FA-Platform (NCEP 32563)

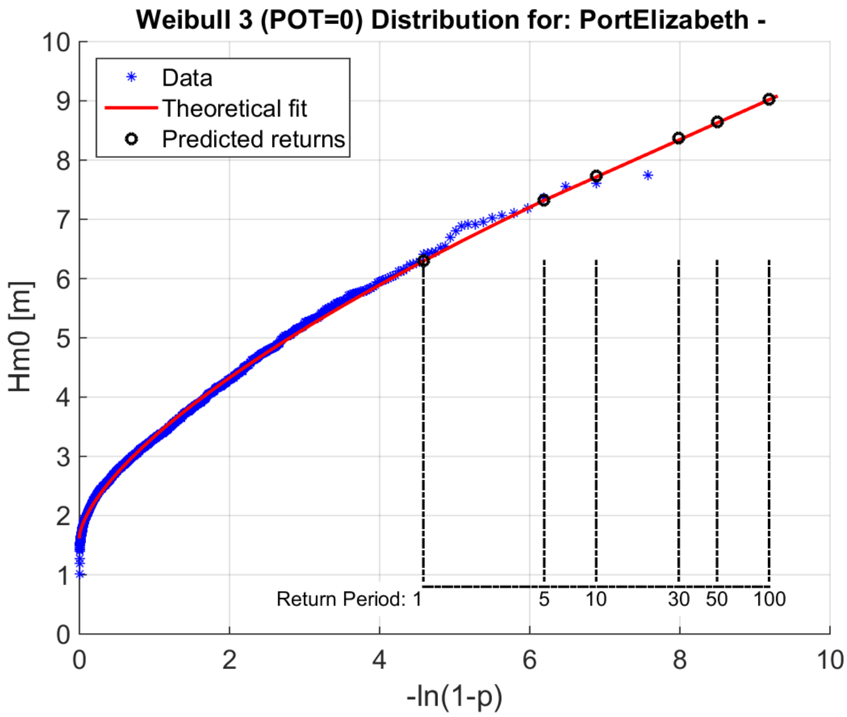


Figure 5.17: Extreme Wave Analysis using a 3 parameter Weibull (POT=0) Distribution for Port Elizabeth (NCEP 32278)

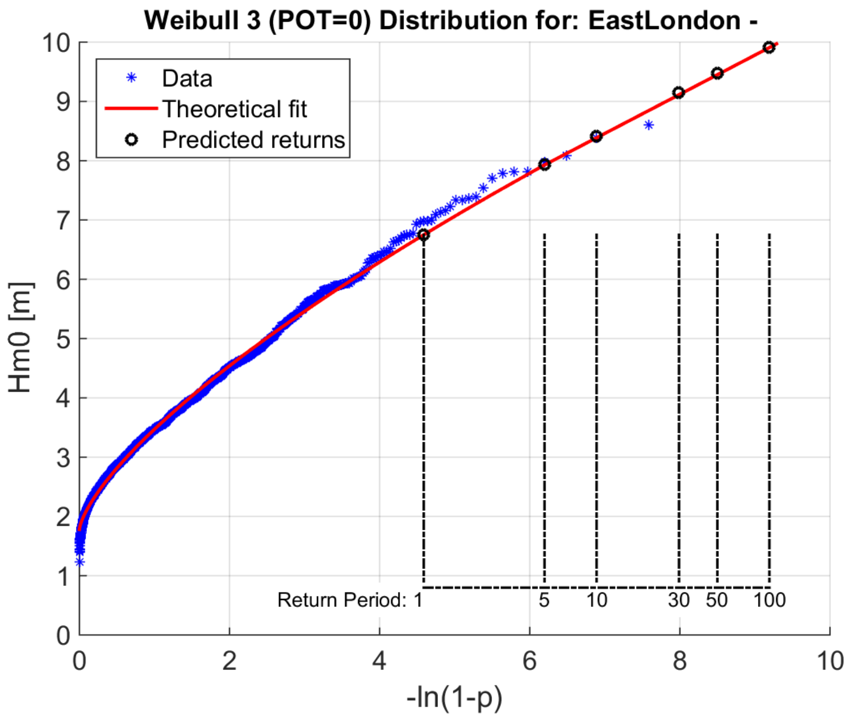


Figure 5.18: Extreme Wave Analysis using a 3 parameter Weibull (POT=0) Distribution for East London (NCEP 31992)

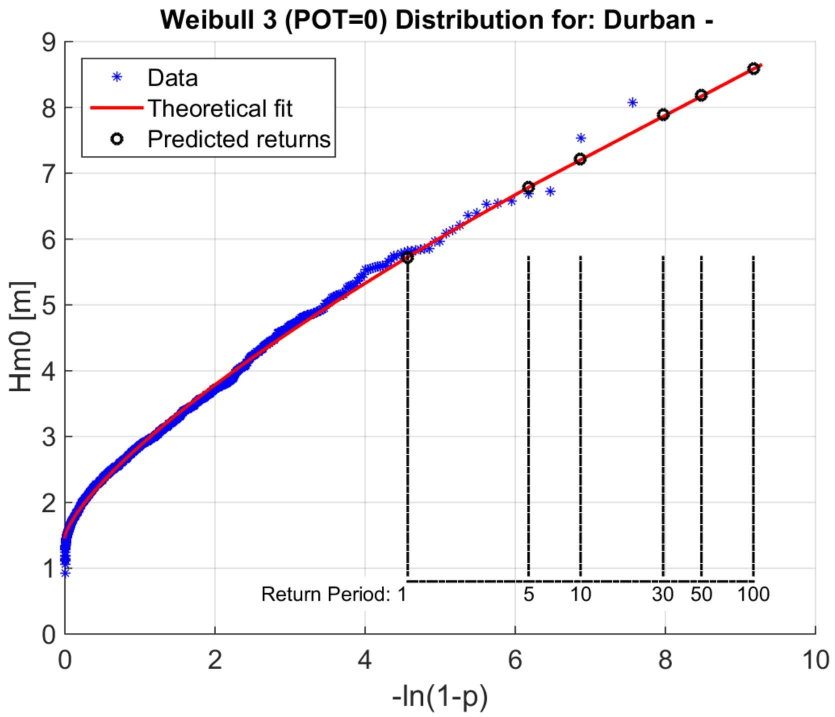


Figure 5.19: Extreme Wave Analysis using a 3 parameter Weibull (POT=0) Distribution for Durban (NCEP 31130)

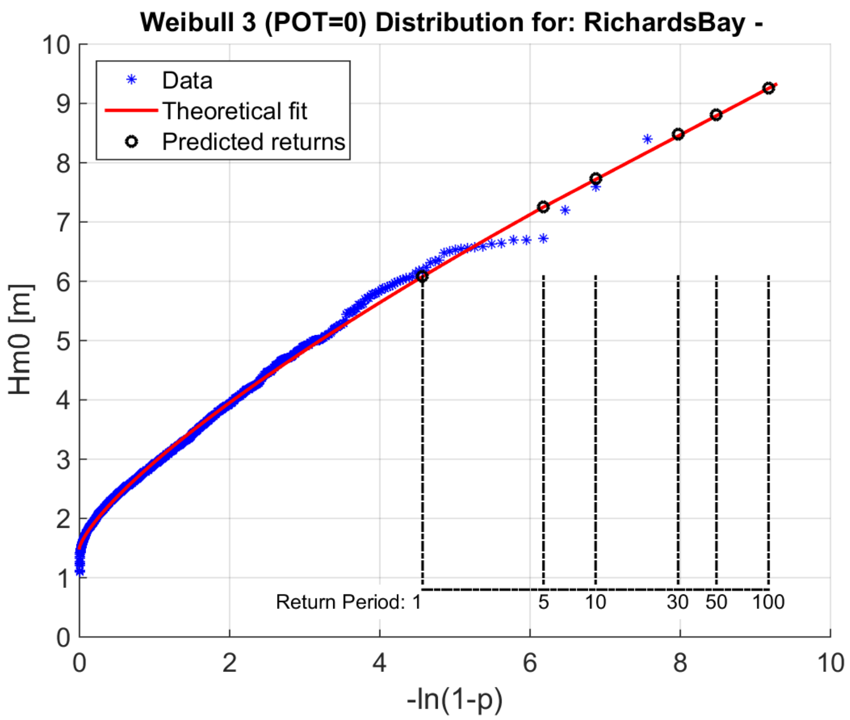


Figure 5.20: Extreme Wave Analysis using a 3 parameter Weibull (POT=0) Distribution for Richards Bay (NCEP 30843)

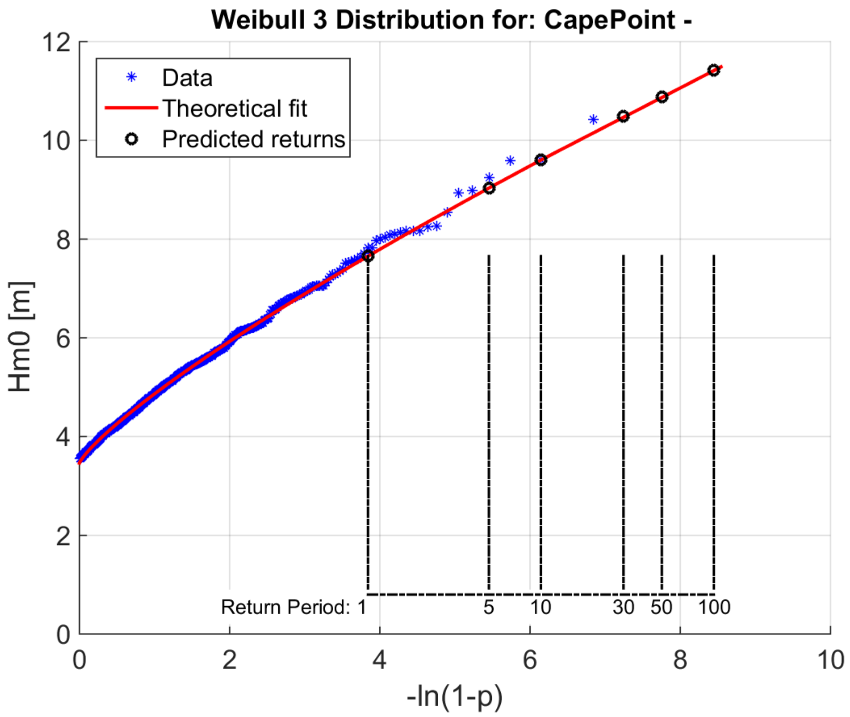


Figure 5.21: Extreme Wave Analysis using a 3 parameter Weibull (autoPOT) Distribution for Cape Point (NCEP 32271)

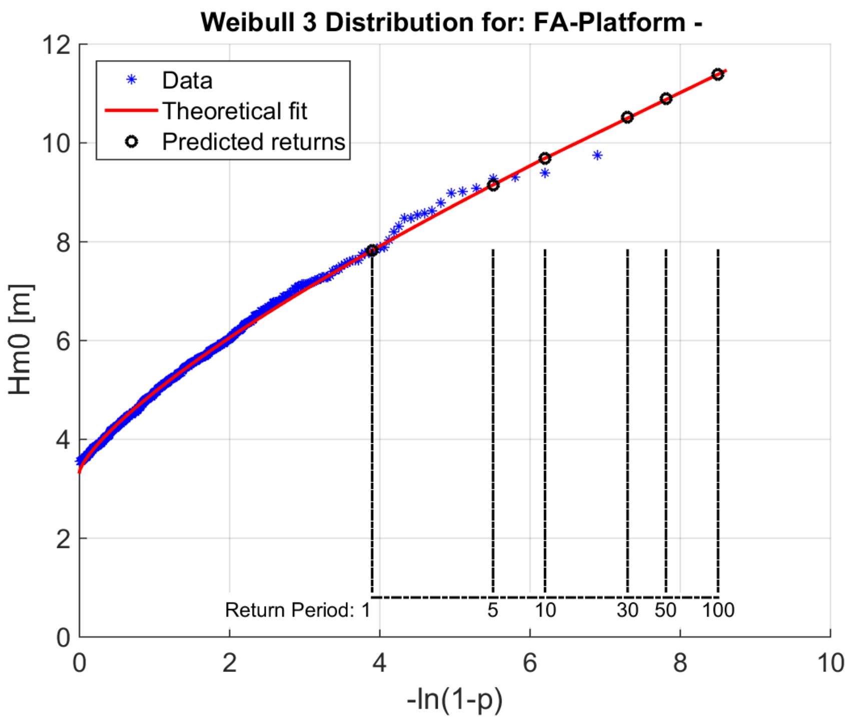


Figure 5.22: Extreme Wave Analysis using a 3 parameter Weibull (autoPOT) Distribution for FA-Platform (NCEP 32563)

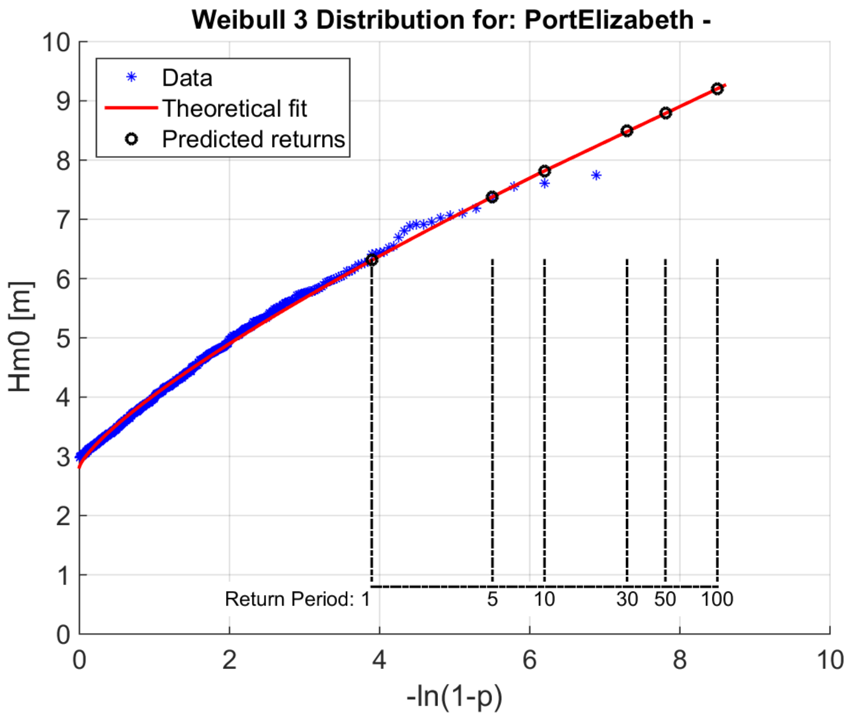


Figure 5.23: Extreme Wave Analysis using a 3 parameter Weibull (autoPOT) Distribution for Port Elizabeth (NCEP 32278)

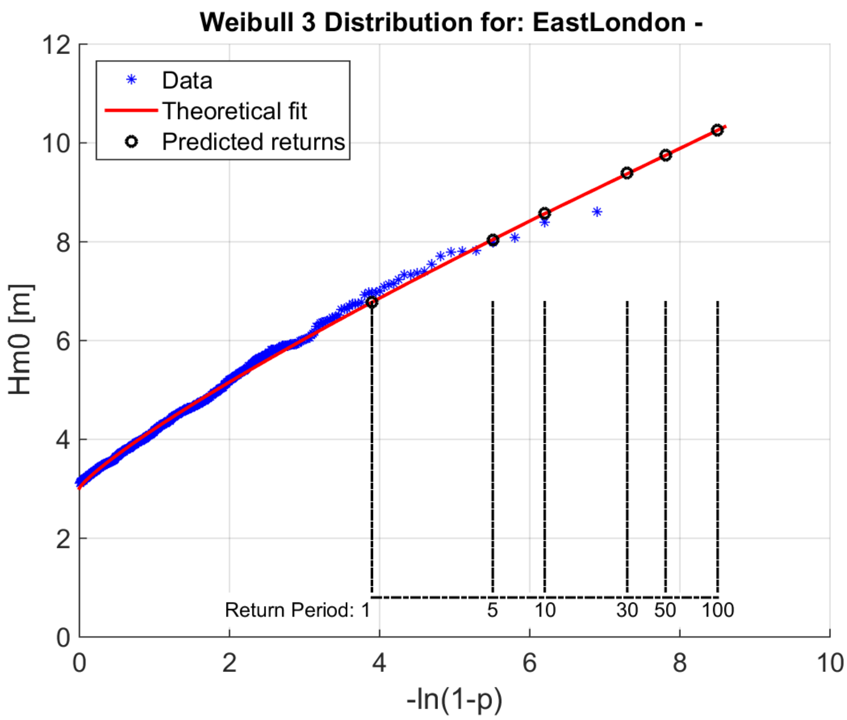


Figure 5.24: Extreme Wave Analysis using a 3 parameter Weibull (autoPOT) Distribution for East London (NCEP 31992)

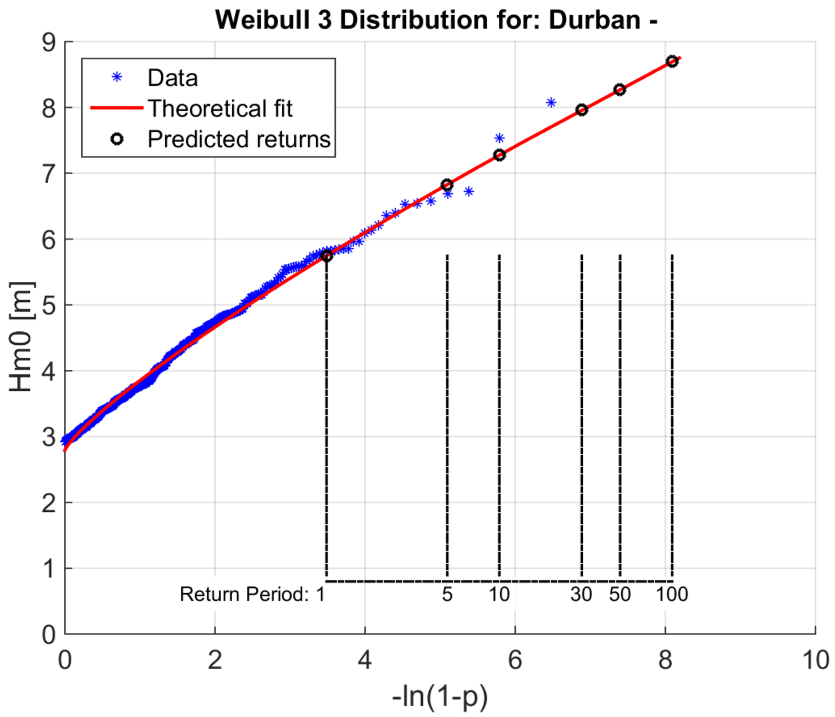


Figure 5.25: Extreme Wave Analysis using a 3 parameter Weibull (autoPOT) Distribution for Durban (NCEP 31130)

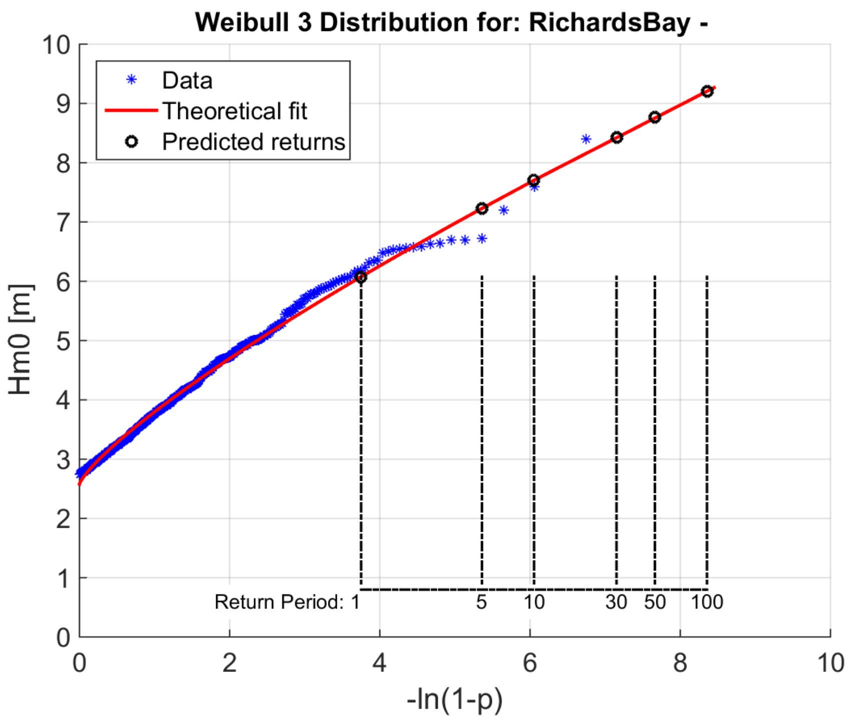


Figure 5.26: Extreme Wave Analysis using a 3 parameter Weibull (autoPOT) Distribution for Richards Bay (NCEP 30843)

Figure 5.27 presents the comparison of the results obtained from different distributions for the 1 in 100 year extreme wave heights along the south and east coast. The graph shows the comparison plots of the Weibull 3-parameter with the automated POT value selection technique, the Gumbel and Exponential applied to offshore NCEP data together with the Gumbel applied to nearshore wave buoy data by Rossouw (1989). The nearshore 1 in 100 year extreme wave heights were not determined for Port Elizabeth and Durban. A recent study has been conducted for the Durban region (Stretch and Corbella, 2012), but the 1 in 100 year return period was not determined.

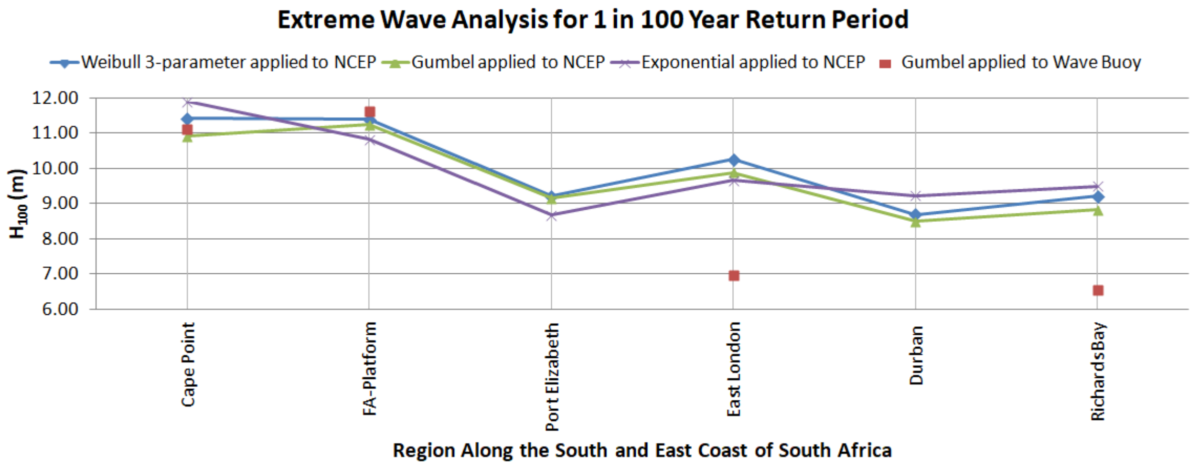


Figure 5.27: Extreme Wave Analysis Results Compared to Previous Findings

There was a good correlation between the methods at the southern locations, i.e. Cape Point/Slangkop and FA-Platform. The reason was because the locations of the wave buoy and NCEP points were in close proximity to one another and similar wave records were obtained for the wave buoy and the NCEP data, shown in Chapter 3. There was a 47% and 41% decrease in the 1 in 100 year extreme wave events at East London and Richards Bay respectively between the Weibull 3-parameter applied to NCEP data and Gumbel applied to wave buoy data by Rossouw (1989). This can be attributed to the fact that this study made use of offshore data, where Rossouw (1989) used nearshore data, i.e. reduced wave heights.

The Exponential, Gumbel and Weibull 3 parameter distribution give similar results for the 1 in 100 year design wave heights. The exponential seems to either over or under predict the 1 in 100 year design wave heights depending on location. This is not the preferred distribution due to this inconsistency. The Gumbel distribution underestimates the 1 in 100 year design wave heights, where the Weibull 3-parameter distribution is more conservative. Thus, it is the recommended distribution for determining the design wave height for offshore locations along the South African coastline.

The chosen distribution, i.e. Weibull 3-parameter, was analyzed further and thus, all the variables and results have been tabulated in Table 5.2. The three parameters (β, η, γ) are presented, the POT value and the extreme wave heights for the corresponding return periods (T). This has all been completed and tabulated within directional sectors for the six NCEP locations.

Table 5.2: Weibull 3-parameter Distribution Results for Extreme Analysis

Sites	Dir	Events	η	ξ	γ	POT	Return Period					
							1	5	10	30	50	100
CP	All	933	1.40	1.23	3.46	3.54	7.65	9.03	9.60	10.48	10.88	11.42
	SE	48	0.63	1.27	3.47	3.54	4.04	4.77	5.04	5.46	5.64	5.88
	S	62	1.00	1.16	3.55	3.54	4.67	5.94	6.45	7.23	7.58	8.05
	SW	754	1.45	1.25	3.48	3.54	7.56	8.95	9.53	10.42	10.82	11.36
	W	64	1.89	1.47	3.28	3.54	5.37	7.06	7.68	8.58	8.98	9.50
	NW	5	1.68	3.20	3.07	3.54	4.10	4.12	4.70	5.16	5.31	5.49
FA	All	986	1.61	1.33	3.34	3.55	7.82	9.15	9.69	10.52	10.89	11.39
	E	74	0.47	0.85	3.59	3.55	4.24	4.77	5.74	6.54	6.92	7.44
	SE	21	0.54	0.81	3.52	3.55	3.53	4.53	5.08	6.02	6.49	7.15
	S	64	1.64	1.81	3.09	3.55	4.88	5.98	6.36	6.90	7.13	7.42
	SW	76	1.77	1.40	3.34	3.55	7.81	9.15	9.69	10.51	10.88	11.36
	W	59	1.28	1.39	3.45	3.55	4.80	6.05	6.52	7.20	7.51	7.90
PE	All	983	1.22	1.29	2.82	2.98	6.31	7.38	7.82	8.49	8.80	9.21
	E	97	0.36	0.70	3.05	2.98	3.73	4.93	5.55	6.62	7.16	7.93
	SE	35	1.08	1.47	2.77	2.98	3.50	4.60	4.98	5.51	5.76	6.06
	S	243	1.21	1.31	2.81	2.98	5.23	6.35	6.79	7.47	7.77	8.17
	SW	606	1.35	1.38	2.80	2.98	6.09	7.15	7.58	8.23	8.52	8.91
EL	All	986	1.20	1.19	3.01	3.11	6.78	8.04	8.57	9.39	9.76	10.26
	NE	99	0.37	0.86	3.26	3.11	3.91	4.71	5.08	5.69	5.98	6.38
	E	62	0.76	1.07	3.02	3.11	3.87	4.97	5.42	6.13	6.46	6.90
	SE	27	0.16	0.45	3.73	3.11	3.75	4.41	5.09	6.71	7.70	9.32
	S	91	1.17	1.27	2.93	3.11	4.56	5.82	6.31	7.06	7.39	7.83
	SW	707	1.40	1.30	2.97	3.11	6.68	7.91	8.41	9.18	9.53	9.99
D	All	653	1.06	1.22	2.79	2.93	5.75	6.83	7.28	7.96	8.28	8.70
	NE	49	0.55	1.28	2.88	2.93	3.39	4.01	4.25	4.60	4.76	4.97
	E	36	0.48	0.90	2.97	2.93	3.24	4.11	4.52	5.18	5.49	5.93
	SE	29	0.57	0.85	2.99	2.93	3.17	4.26	4.80	5.70	6.14	6.74
	S	29	0.91	1.07	2.87	2.93	5.17	6.45	6.99	7.83	8.22	8.75
	SW	248	1.52	1.62	2.60	2.93	5.28	6.24	6.60	7.14	7.38	7.69
RB	All	851	1.22	1.25	2.58	2.74	6.08	7.23	7.70	8.43	8.76	9.21
	NE	33	0.69	2.96	2.45	2.74	2.99	3.33	3.42	3.54	3.59	3.64
	E	47	0.56	0.88	2.76	2.74	3.22	4.32	4.83	5.68	6.08	6.64
	SE	40	0.50	0.85	2.92	2.74	3.25	4.25	4.73	5.53	5.91	6.45
	S	413	1.01	1.07	2.67	2.74	5.50	6.88	7.47	8.38	8.81	9.38
	SW	318	1.78	1.74	2.37	2.74	5.55	6.51	6.88	7.41	7.65	7.95

Figure 5.28 presents the peak period range for the 1 in 100 year extreme waves which was determined by applying Equation 5.3 for all six site locations. It was interesting that peak periods obtained for stations with lower extreme wave heights were similar to those stations where larger waves were recorded. This is due to the fact that generally the same weather conditions are responsible for the extreme wave events, see Section 2.3.

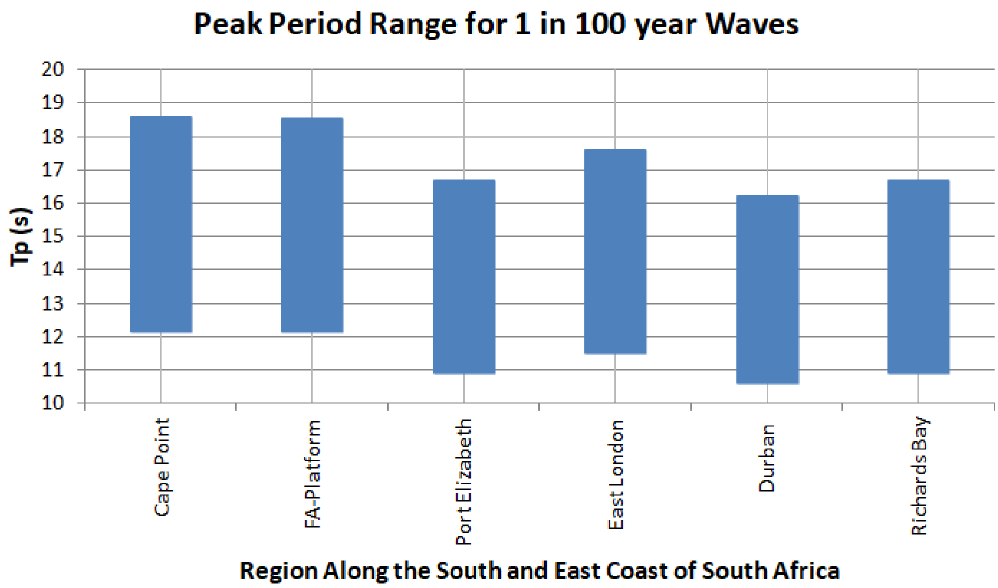


Figure 5.28: Peak Period Range Comparisons Along the South African Coastline of 1 in 100 Year Extreme Wave Events

Figure 5.29 has been created from Table 5.2, presenting the most dominant wave directions from which extreme waves are generated. This is not to say that most of the storm events occur from this direction, refer to Durban in Table 5.2.

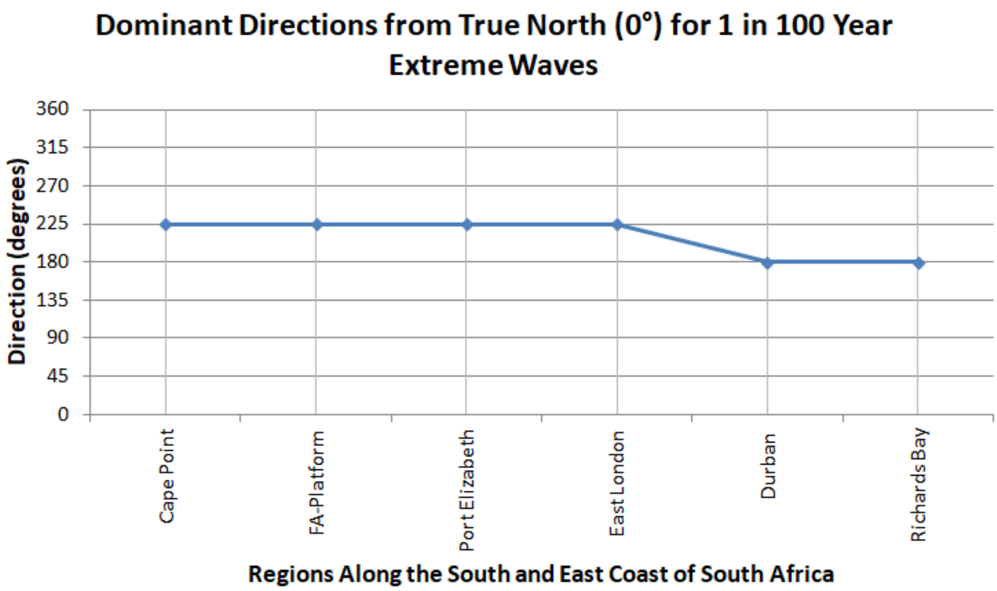


Figure 5.29: Dominant Direction Comparisons Along the South African Coastline of 1 in 100 Year Extreme Wave Events

An analysis of the peak wave periods was conducted, whereby the exceedance curves were plotted for the six locations for nearshore wave buoy data as well as the offshore NCEP data, see Figures 5.30 and 5.31.

The wave buoy exceedance curves for all locations along the south and east coast show that 100% of the time waves exceed 4s periods, besides in the case of Port Elizabeth. Port Elizabeth is not a Datawell buoy instrument but rather a virtual buoy. This means that these readings are generated from an interpolation from the NCEP location to the nearshore location with a possibility of induced errors and hence, the irregular shape. Periods of 10, 11 and 12 seconds occur more often at Cape Point compared to the other locations, where Durban seems to have lower occurrence of specific periods than any other location. All the locations seems to have near zero occurrences of periods greater than 16 seconds while for some sites this does occur occasionally.

The NCEP exceedance curves are smooth as it was produced by numerical model outputs from WAVEWATCH III, where the wave buoy exceedance curves are produced from actual measurements obtained from the instruments. This plot makes intuitive sense as there is a larger occurrence of specific periods, ranging between 4 and 16 seconds, as one moves from the east to the south of South Africa. Again, there are occurrences of period below 4 seconds and above 16 seconds for the locations, although not very many.

Figures 5.32 (a) to (f) represent a direct peak wave period exceedance curve comparisons of the offshore NCEP data and the nearshore wave buoy data. It should be noted that the similarity between the wave buoy (red) and NCEP (blue) curves are due to the period remaining constant for an individual wave train from deep water to transitional water. It can be seen that the curves follow the same exceedance trends for Cape Point, East London and Durban. East London shows that lower exceedance values were found for NCEP data at the higher and lower period values than for the wave buoy data. For the FA-Platform, the wave buoy data shows lower exceedance values between 7 and 13 seconds than the NCEP data. Port Elizabeth shows a lower exceedance for the wave buoy periods than the NCEP data and the opposite was found for Richards Bay.

In general, it can be seen that larger periods occur along the south coast compared to the east coast. Additionally, it can be seen that the wave periods remain fairly constant as the wave propagates from offshore to nearshore.

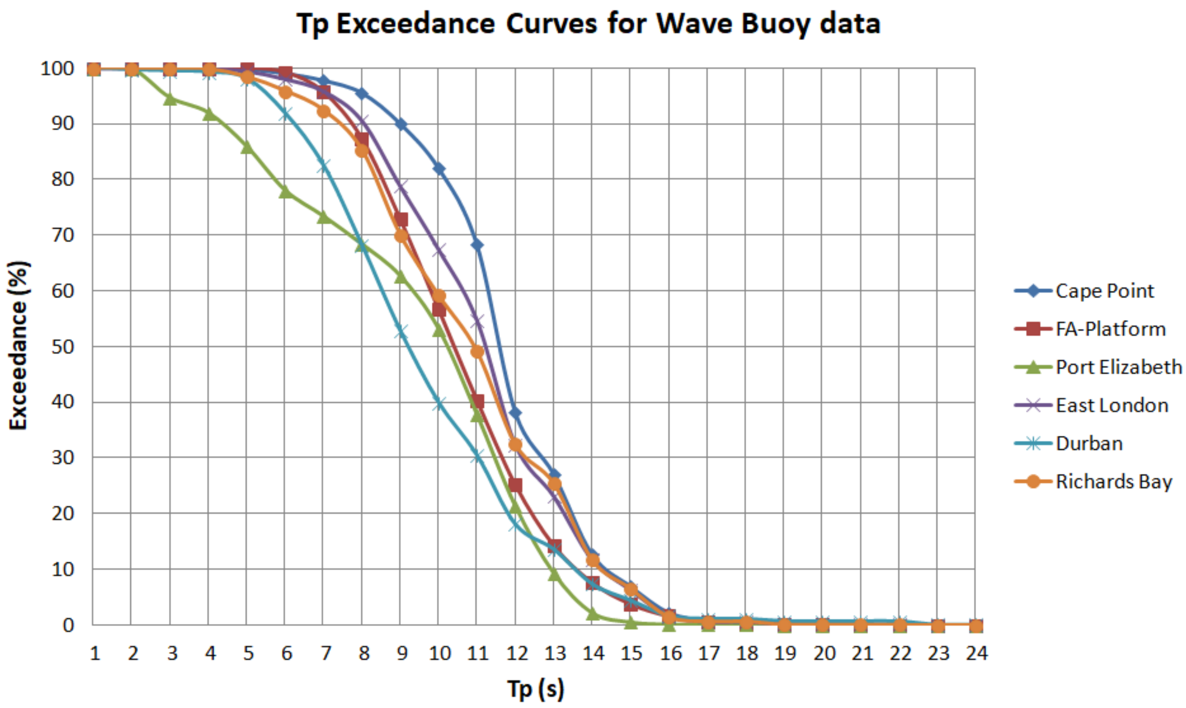


Figure 5.30: Wave Buoy Tp Exceedance Curves

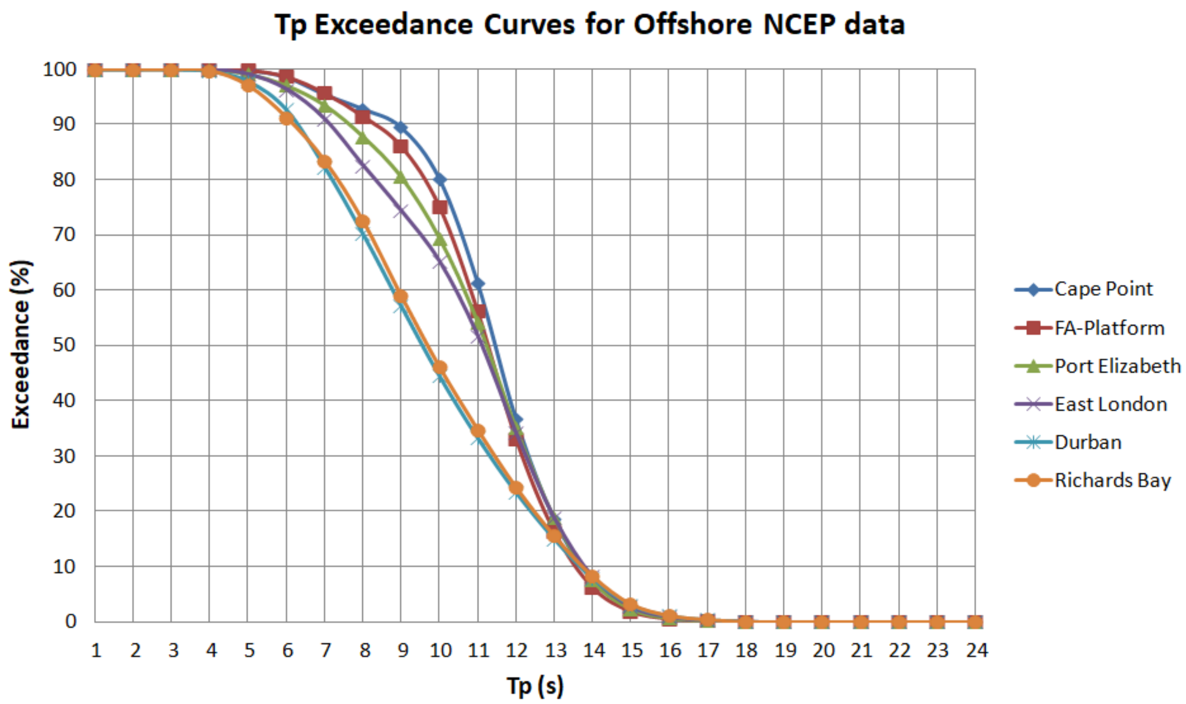
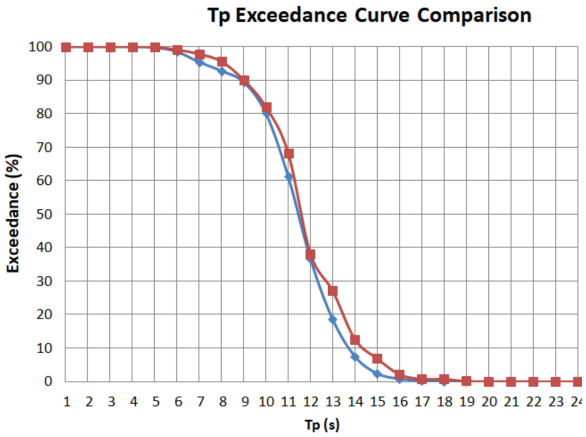
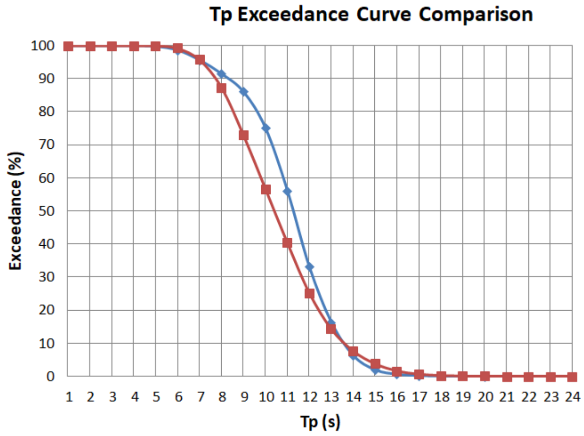


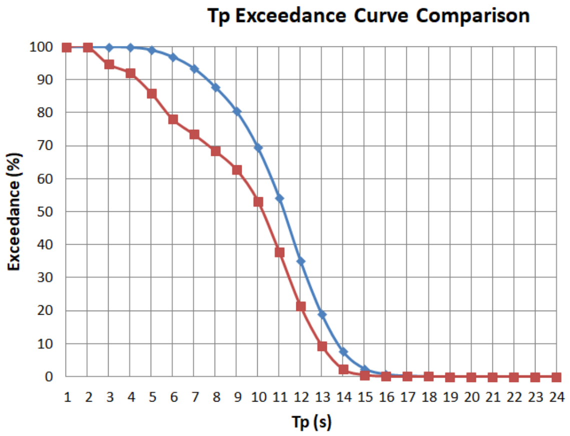
Figure 5.31: NCEP Tp Exceedance Curves



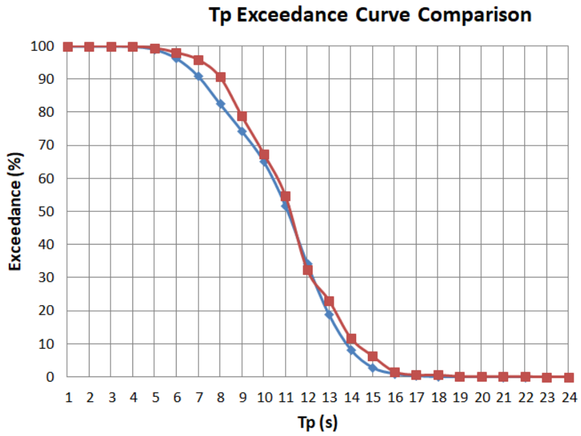
(a) Cape Point



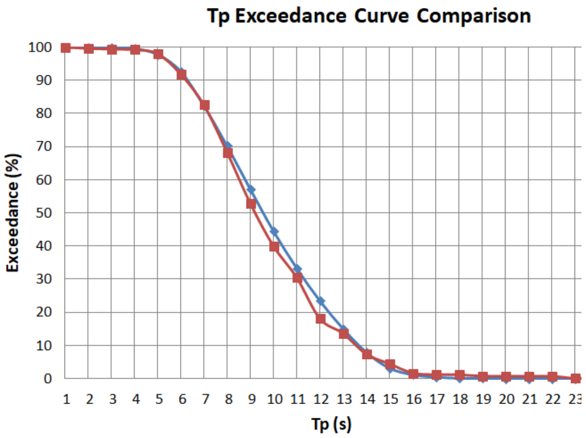
(b) FA-Platform



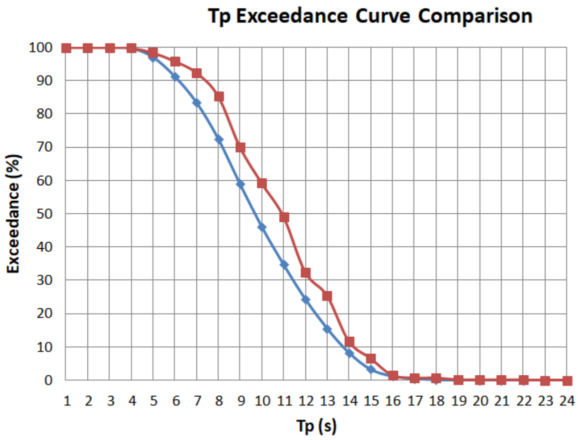
(c) Port Elizabeth



(d) East London



(e) Durban



(f) Richards Bay

Figure 5.32: Tp Exceedance Curve Comparisons for wave buoy (red) and NCEP(blue) locations along the South African Coastline

5.4 Discussion

The Exponential, Gumbel and Weibull 3-parameter cumulative density functions were applied to six offshore NCEP locations along South Africa and individually plotted. The extreme wave heights determined for 1 in 100 year return period obtained in this study and those obtained by Rossouw (1989) were also graphed on a comparison plot for the locations on the south and east coast of South Africa, refer to Figure 5.27. The Weibull 3-parameter, was said to best fit the data by means of a visual test and work conducted by Stander (2015). Important to note was that the effect of cyclones was not included in the determination of design waves as it was not in the scope of this thesis. However, this allows for further investigation and studies, more specifically for the Mozambican channel.

This distribution made use of the Peaks-over-Threshold (POT) method to predict the design waves for specific return periods and direction sectors (Mathiesen *et al.*, 1994). The sampling method, i.e POT, ensured that identical and independent data was obtained. The estimations were performed using a procedure whereby the optimum threshold level was selected for each dataset (Thompson *et al.*, 2009). This had the benefit of not only being a conservative approach but also an objective one. This was shown in graphs whereby different POT values were compared, refer to Figures 5.1 and 5.2. The results of Figures 5.21 to 5.26 were tabulated in Table 5.2 per direction sector. The 1 in 100 year offshore extreme wave heights were found to be: 11.42m for Cape Point (NCEP 32271); 11.39m for FA-Platform (NCEP 32563); 9.21m for Port Elizabeth (NCEP 32278); 10.26m for East London (NCEP 31992); 8.70m for Durban (NCEP 31130); and 9.21m for Richards Bay (NCEP 30843).

The associated period range was obtainable by applying Equation 5.3 and it was found that all sites had roughly a 6 second range between 10 and 19 seconds. It is interesting that even the stations with lower extreme wave heights obtained similar peak period ranges, refer to Figure 5.28.

The peak period exceedance curves were plotted, refer to Figures 5.30, 5.31 and 5.32. It was found that there are larger periods occurring along the south coast compared to the east coast. In addition to this the wave periods remain fairly constant as the wave propagates from offshore to nearshore.

Chapter 6

Conclusion

To conclude the work undertaken for the fulfillment of this Master's thesis, the following section provides the outcomes reached in order to answer the research questions described in Section 1.4.

The NCEP significant wave height was validated using altimetry data. This was accomplished for Cape Point and the FA-Platform off the south coast of South Africa. It was found that the corrected satellite altimetry data by NOAA for Jason-2/OSTM was accurate. The direct comparison of this data correlated well with the wave buoy and NCEP data at Cape Point and FA-Platform. This implied that the wave buoy and NCEP data would also correlate well for those locations, which was shown. This resulted in the idea that satellite altimetry data could be used for research purposes and calibration of numerical models along the South African coastline instead of consultants relying entirely on wave buoy measurements provided by the CSIR or self-deployment. There is room for more work in this area in order to gain confidence in the data.

An altimeter comparison was not possible along the east coast as pass intersections, wave buoy and NCEP locations were not in close proximity of one another. Therefore, a backward refraction was performed in order to obtain offshore conditions to compare to NCEP data. The first approach used Snell's Law, providing a first estimate of the offshore wave conditions. Thereafter, a SWAN and interpolation approach aimed at improving the first approach. The questions of generating the two different approaches and analysing the comparison results was still answered, however, focus should be drawn to the methodology of the approaches more specifically the second one. This was because neither the backward refracted nor the NCEP data could be considered 'ground truth' and therefore, no adjustment was made to the NCEP data during the extreme wave analysis.

An extreme wave analysis was conducted for six locations along the south and east coast of South Africa. The Exponential, Gumbel as well as the Weibull 3-parameter distributions were determined, however the latter (using the automated POT selector technique) obtained a better fit by visual observation and was therefore analysed further. The extreme wave heights were determined for different direction sectors for the NCEP data at these locations, refer to Table 5.2. From these results, the associated range of wave periods could also be determined using Equation 5.3. A comparison of the 1 in 100 year extreme wave heights for the different distributions was graphed with the nearshore results from Rossouw (1989), refer to Figure 5.27. It was found that the Exponential distribution was not recommended due to the inconsistency of either over or under predicting the extreme wave heights. The Gumbel distribution was under conservative and thus the Weibull 3-parameter distribution forecasted was the recommended distribution for south and east offshore regions along the South Africa coastline.

Peak period exceedance curves were plotted showing that larger wave periods occur more often on the south coast than the east coast and the wave periods remain fairly similar as the wave propagates from offshore to nearshore.

Lastly, it should be noted that the effect of the Agulhas current was not included within the modeling procedure. The extent and severity of the current should be included, although the variability of the current makes this a challenging task to completely represent what happens in nature. The effect of cyclones were also outside the scope of this study but should be looked at separately and in a further study.

This therefore links the title of this study to the research questions and finally the work undergone. This study achieved the primary objective of conducting an extreme wave analysis for offshore NCEP data for the south and east coast of South Africa. In doing so, validation of NCEP significant wave heights along the south coast using satellite data and providing a method for east coast validation by means of backward refraction.

Chapter 7

Recommendations

This section provides recommendations derived from the conclusions made. The most important aspects include the continuation of the work introduced or work that could aid in solidifying the backward refraction methods described.

The first recommendation would be to make use of the newly available spectral data from NOAA and to further analyse this data (similar to what Rossouw (1989) had done in the past) as it better describes the ocean and wave characteristics, rather than just the three wave parameters used in this study.

Another further recommendation would be to continue direct comparisons of satellite altimetry to NCEP and wave buoy significant wave heights even if intersection locations are not able to be used, i.e. smaller datasets. This would be useful information in order to see the extent to which this data could be used.

It is clear that the WAVEWATCH III model provides a very powerful numerical modeling tool for coastal engineers to use. The complexities along the east coast, including the Agulhas current and associated processes such as eddies, plumes and retroflections make it challenging to resolve wave processes and therefore has the potential to cause inaccuracies to NCEP data along this region. A numerical model that successfully includes the Agulhas current and complexities should be explored, (by either improving the WAVEWATCH III model or creating an entirely new model) therefore, improving knowledge in this area. This would provide more confidence for coastal engineers using the data provided by NCEP. Along with the inclusion of the Agulhas current, the wave-current interactions are also of concern. The current flows down the coast while the dominant wave direction is up the coast, causing rogue waves in some instances. This affects shipping in this area as it is a shipping passage linking the northern and southern hemispheres.

A further study could include the refinement of the SWAN and interpolation approach. This could be achieved by deploying an offshore wave buoy at the NCEP location. This would allow not only a calibration of the backward refraction approach and methodology, but also a direct comparison with NCEP data which would prove to be invaluable along the east coast of South Africa. In this way, the necessary adjustments could be made to the NCEP data. Additionally, more reliable offshore wave data would further improve the understanding of nearshore wave conditions as it is used to drive numerical models.

The last recommendation is to further investigate the extent to which cyclone events within the Mozambican channel affect the northern Natal coast in order to determine the extreme wave heights and compare to the wave heights determined in this study.

Appendices

Appendix A

Datawell Buoy Specifications

Waverider SG

Datawell - Oceanographic Instruments

Second generation non-directional wave height measuring buoy

The second generation Waverider SG (WR-SG) is a real-time non-directional wave height measuring buoy. Wave height is measured with a resolution of 1 cm using the well-proven Datawell stabilized platform sensor. The stabilized platform ensures that the buoy accurately tracks the vertical component of the orbital wave motion. In the WR-SG, the platform mounting of the sensor has been reinforced, significantly increasing the robustness of the buoy.

The WR-SG is the successor to the Waverider FI. Whereas the Waverider FI used analog techniques to process the wave data, the Waverider SG digitizes the wave signal at an early stage. Combined with the same processing hardware as the directional DWR-MkIII and DWR-G buoys, many features and options are now standard which were not possible on the previous model:

- Standard integrated **datalogger**. Flash cards up to 2 GByte store all measured data.
- Standard **GPS position** monitoring. Position monitoring allows for drift alarm possibility and easy retrieval of a buoy adrift.
- A **LED flashlight** mounted at the top of the antenna. The high mounted flashing light increases visibility significantly.
- A **water temperature sensor** in the mooring eye providing sea surface temperature

The buoy can be equipped with the Datawell HF link. This link suffices for ranges up to 50 Km. If larger transmitting ranges are desired, the HF link can be combined or replaced with Iridium satellite communication.
To acquire, store and analyze the received data, Datawell offers the W@ves21 and SeaSaw21 software package, which fully supports the WR-SG. See our brochures for more information.
The WR-SG is available in either a 0.7 m hull diameter (WR-SG7) or in a 0.9 m hull diameter (WR-SG9). An attractive yellow hull coating is available as an option.

Optional features:

- **HF link:** 25.5 MHz-35.5 MHz
- **Iridium:** global, two-way satellite link
- **Iridium SBD:** global, two-way satellite link
- **Power switch:** on/off
- **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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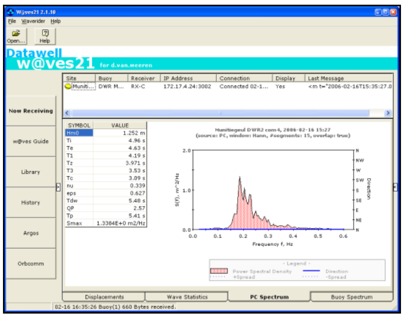
Waverider SG

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 years
	Period time	1 s - 30 s
Standard features	Datalogger	Compact Flash Module, size 1Gb
	LED Flashlight	4 LEDs, colour yellow (590 nm), pattern 5 flashes every 20 s standard length 35 cm
	GPS position	New position every 30 min, precision 10 m
	Water temperature	Range –5 °C - +46 °C, resolution 0.05 °C, accuracy 0.2 °C
Options	HF Datawell HF link	Frequency range 25.5 - 35.5 MHz (35.5 - 45 MHz on request) Transmission range 50 Km over sea, user replaceable. For use with Datawell RX-C or RX-D receivers.
	Iridium	Satellite communication
	Power switch	Data files are closed and secured
	Hull painting	Brantho Korrux “3 in 1”paint system (no anti-fouling)
	Radar reflectors	Two reflectors mounted on hatchcover (retrofittable)
	Hull diameter	0.7 m and 0.9 m (excluding fender)
General	Material	Stainless steel AISI316 or Cunifer10
	Weight	Approx. 95 Kg (150 Kg)
	Batteries	0.7 m diam. operational life 1.3 year, 1 section of 13 batteries 0.9 m diam. operational life 2.6 years,2 sections of 13 batteries type Datacell RC25G (250 Wh green)
	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)

The Datawell stabilized platform sensor



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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 proprietary well-proven and accurate Datawell 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.

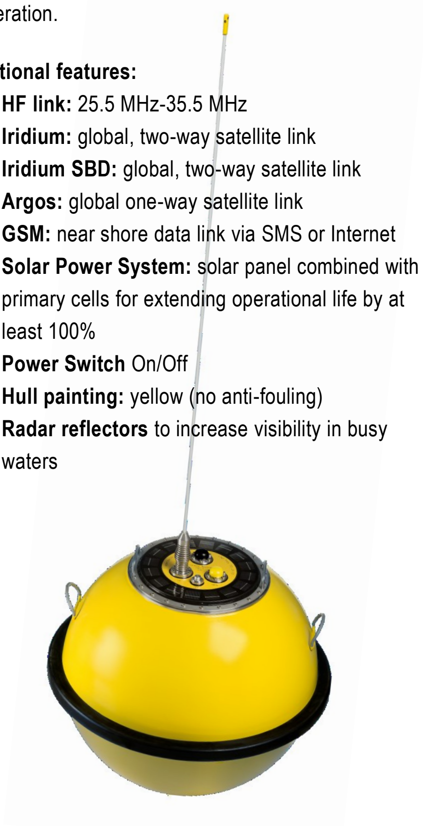
The highlights:

- **Real time** measurement of wave height with half-hourly heave and directional spectra updates.
- **HF link up to 50 km** over sea**.** The proprietary Datawell HF link module is easy replaceable if a different transmission frequency is required.
- **LED flashlight** integrated in the top of the antenna increasing the buoy's visibility.
- **GPS receiver** for buoy positioning has now become a standard feature of the DWR-MkIII, and facilitates its retrieval.
- **Integrated datalogger** based on the latest flash card technology.
- A **water temperature sensor** in the mooring eye providing sea surface temperature
- **High capacity primary cells** operating reliably and safely under all wave conditions and weather circumstances for **up to three years** without replacement.
- Built-in **energy meter** reports an accurate estimation of the remaining operating life.
- **Intelligent Test Box** enables sequential discharge of individual battery strings

The DWR-MkIII comes standard with the Datawell 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. For near shore applications, a GSM link is also available. The MkIII can be supplied in a 70 cm hull offering easier handling and 1.2 years of continuous operation or a 90 cm hull for 3.5 years of continuous operation.

Optional features:

- **HF link:** 25.5 MHz-35.5 MHz
- **Iridium:** global, two-way satellite link
- **Iridium SBD:** global, two-way satellite link
- **Argos:** global one-way satellite link
- **GSM:** near shore data link via SMS or Internet
- **Solar Power System:** solar panel combined with primary cells for extending operational life by at least 100%
- **Power Switch** On/Off
- **Hull painting:** yellow (no anti-fouling)
- **Radar reflectors** to increase visibility in busy waters



DWR-MkIII with optional solar panels, power switch and painted hull

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Directional Waverider MkIII

Datawell - Oceanographic Instruments

Specifications

Resolution and Accuracy	Heave	Range: –20 m - +20 m, resolution: 0.01m Accuracy: < 0.5% of measured value after calibration < 1.0% of measured value after 3 year Period: 1.6 s - 30 s
	Direction	Range: 0° - 360°, resolution 1.4° (1 binary degree) Heading error: 0.4° - 2° (depending on latitude) typical 0.5° Period: 1.6 s - 30 s (free floating)
	Water temperature	Range: –5 °C - +46 °C, resolution: 0.05 °C Accuracy: < 0.1 °C (sensor accuracy)
Sensor and Processing	Type	Datawell stabilized platform sensor, performing heave and direct pitch and roll measurements combined with a 3D fluxgate compass and X/Y accelerometers.
	Sampling	8-channel, 14bit @ 3.84Hz
	Processing	32 bits microprocessor system
Standard features	Integrated datalogger	Compact flash module 1Gb
	LED Flashlight	Antenna with integrated LED flasher, colour yellow (590 nm), pattern 5 flashes every 20 s, standard length 35 cm
	GPS position	12 channel, fix every 30 min, precision <5 m
	Intelligent Test Box	Enables sequential discharge of individual battery strings
Optional features	Datawell HF link	Frequency range 25.5 - 35.5 MHz (35.5 - 45.0 MHz on request) Transmission range 50 Km over sea, user replaceable. For use with Datawell RX-C or RX-D receivers.
	Iridium / Argos	Satellite communication
	GSM	Mobile communication
	Solar power system	Solar panel combined with Boostcap capacitors
	Power Switch	Data files are closed and secured
	Hull painting	Brantho Korrux "3 in 1"paint system (no anti-fouling)
	Radar reflectors	Two reflectors mounted on hatchcover (retrofittable)
	Hull diameter	0.7 m and 0.9 m (excluding fender)
General	Material	Stainless steel AISI316 or Cunifer10
	Weight	Approx. 109 Kg 0.7m AISI316, 113Kg 0.7m Cunifer10
		Approx. 216 Kg 0.9m AISI316, 225Kg 0.9m Cunifer10
	Batteries	0.7 m diam. operational life 1.2 years, 1 section of 15 batteries 0.9 m diam. operational life 3.5 years, 3 sections of 15 batteries Type: Datacell RC24B (200 Wh black)
	Temperature range	Operating: –5 °C - +35 °C Storage: –5 °C - +40 °C (+ 55 °C short term, weeks only)

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Appendix B

Tabulated Altimetry, Wave Buoy and NCEP Data

Cape Point								
Altimetry Data			Measured Buoy Data			NCEP data		
Date	Time	Hs	Date	Time	Hs	Date	Time	Hs
2008/07/13	20:09	1.63	2008/07/13	21:00	1.24	2008/07/13	21:00	2.01
2008/07/20	04:28	2.71	2008/07/20	03:00	2.36	2008/07/20	03:00	3.42
2008/07/23	18:08	2.26	2008/07/23	18:00	NaN	2008/07/23	18:00	2.87
2008/07/30	02:27	3.11	2008/07/30	03:00	2.77	2008/07/30	03:00	2.84
2008/08/02	16:06	3.29	2008/08/02	15:00	2.25	2008/08/02	15:00	3.10
2008/08/09	00:25	5.47	2008/08/09	00:00	4.39	2008/08/09	00:00	5.56
2008/08/12	14:05	2.94	2008/08/12	15:00	2.45	2008/08/12	15:00	3.31
2008/08/18	22:24	3.78	2008/08/18	21:00	1.77	2008/08/18	21:00	2.52
2008/08/22	12:03	2.36	2008/08/22	12:00	2.09	2008/08/22	12:00	2.46
2008/08/28	20:22	4.03	2008/08/28	21:00	4.36	2008/08/28	21:00	4.66
2008/09/01	10:02	9.01	2008/09/01	09:00	7.55	2008/09/01	09:00	7.43
2008/09/07	18:21	4.97	2008/09/07	18:00	4.19	2008/09/07	18:00	4.71
2008/09/11	08:01	3.05	2008/09/11	09:00	2.92	2008/09/11	09:00	3.62
2008/09/17	16:19	1.93	2008/09/17	15:00	2.07	2008/09/17	15:00	2.46
2008/09/21	05:59	2.14	2008/09/21	06:00	1.77	2008/09/21	06:00	2.40
2008/09/27	14:18	3.19	2008/09/27	15:00	3.08	2008/09/27	15:00	3.70
2008/10/07	12:17	2.79	2008/10/07	12:00	1.69	2008/10/07	12:00	1.69
2008/10/11	01:56	2.19	2008/10/11	03:00	2.03	2008/10/11	03:00	2.19
2008/10/17	10:15	2.34	2008/10/17	09:00	1.63	2008/10/17	09:00	2.23
2008/10/20	23:55	3.09	2008/10/20	21:00	3.86	2008/10/20	21:00	3.83
2008/10/27	08:14	2.95	2008/10/27	09:00	2.81	2008/10/27	09:00	3.10
2008/10/30	21:53	1.87	2008/10/30	21:00	1.39	2008/10/30	21:00	2.02
2008/11/06	06:12	1.60	2008/11/06	06:00	0.89	2008/11/06	06:00	1.58
2008/11/09	19:52	2.71	2008/11/09	21:00	2.31	2008/11/09	21:00	2.94
2008/11/16	04:11	1.82	2008/11/16	03:00	NaN	2008/11/16	03:00	1.93
2008/11/19	17:50	2.82	2008/11/19	18:00	NaN	2008/11/19	18:00	3.66
2008/11/26	02:09	1.72	2008/11/26	03:00	1.83	2008/11/26	03:00	2.04
2008/11/29	15:49	3.86	2008/11/29	15:00	2.63	2008/11/29	15:00	3.47
2008/12/06	00:08	1.90	2008/12/06	00:00	1.90	2008/12/06	00:00	2.72
2008/12/09	13:47	2.18	2008/12/09	12:00	1.88	2008/12/09	12:00	2.84
2008/12/15	22:06	2.43	2008/12/15	21:00	2.15	2008/12/15	21:00	2.60
2008/12/19	11:46	1.96	2008/12/19	12:00	1.80	2008/12/19	12:00	2.71
2008/12/29	09:44	3.34	2008/12/29	09:00	1.64	2008/12/29	09:00	2.23
2009/01/04	18:03	2.62	2009/01/04	18:00	1.63	2009/01/04	18:00	2.47
2009/01/08	07:43	2.11	2009/01/08	06:00	1.39	2009/01/08	06:00	1.46
2009/01/14	16:02	3.08	2009/01/14	15:00	3.11	2009/01/14	15:00	3.32
2009/01/18	05:41	3.30	2009/01/18	06:00	2.75	2009/01/18	06:00	3.65
2009/01/24	14:00	1.58	2009/01/24	15:00	1.51	2009/01/24	15:00	2.07
2009/01/28	03:40	4.87	2009/01/28	03:00	3.45	2009/01/28	03:00	5.07
2009/02/03	11:59	4.04	2009/02/03	12:00	3.50	2009/02/03	12:00	4.04
2009/02/07	01:38	3.44	2009/02/07	00:00	2.15	2009/02/07	00:00	3.59
2009/02/13	09:57	1.44	2009/02/13	09:00	1.24	2009/02/13	09:00	1.73
2009/02/16	23:37	2.67	2009/02/16	21:00	1.82	2009/02/16	21:00	2.58
2009/02/23	07:56	3.98	2009/02/23	09:00	2.57	2009/02/23	09:00	3.32
2009/02/26	21:36	1.35	2009/02/26	21:00	1.62	2009/02/26	21:00	2.09
2009/03/05	05:54	4.23	2009/03/05	06:00	2.84	2009/03/05	06:00	2.96
2009/03/08	19:34	4.27	2009/03/08	18:00	2.83	2009/03/08	18:00	3.90

2009/03/15	03:53	3.31	2009/03/15	03:00	2.84	2009/03/15	03:00	3.50
2009/03/18	17:33	3.32	2009/03/18	18:00	2.27	2009/03/18	18:00	3.18
2009/03/25	01:52	2.17	2009/03/25	03:00	2.23	2009/03/25	03:00	2.56
2009/03/28	15:31	2.44	2009/03/28	15:00	1.87	2009/03/28	15:00	2.39
2009/04/03	23:50	2.02	2009/04/03	21:00	NaN	2009/04/03	21:00	2.09
2009/04/07	13:30	2.94	2009/04/07	12:00	2.67	2009/04/07	12:00	3.48
2009/04/13	21:49	2.67	2009/04/13	21:00	2.19	2009/04/13	21:00	2.51
2009/04/17	11:28	2.84	2009/04/17	12:00	2.42	2009/04/17	12:00	2.93
2009/04/23	19:47	2.38	2009/04/23	18:00	1.68	2009/04/23	18:00	1.83
2009/04/27	09:27	2.03	2009/04/27	09:00	1.46	2009/04/27	09:00	1.78
2009/05/03	17:46	2.89	2009/05/03	18:00	2.50	2009/05/03	18:00	2.97
2009/05/07	07:25	2.17	2009/05/07	06:00	2.05	2009/05/07	06:00	2.40
2009/05/13	15:44	4.71	2009/05/13	15:00	3.19	2009/05/13	15:00	3.81
2009/05/17	05:24	6.46	2009/05/17	06:00	7.10	2009/05/17	06:00	8.09
2009/05/23	13:43	1.96	2009/05/23	12:00	1.55	2009/05/23	12:00	1.89
2009/05/27	03:22	4.04	2009/05/27	03:00	3.68	2009/05/27	03:00	3.59
2009/06/06	01:21	3.90	2009/06/06	00:00	2.92	2009/06/06	00:00	3.50
2009/06/12	09:40	2.88	2009/06/12	09:00	2.06	2009/06/12	09:00	2.32
2009/06/15	23:19	4.87	2009/06/15	21:00	3.12	2009/06/15	21:00	4.18
2009/06/22	07:38	2.94	2009/06/22	06:00	2.00	2009/06/22	06:00	3.01
2009/06/25	21:18	5.01	2009/06/25	21:00	4.90	2009/06/25	21:00	5.85
2009/07/02	05:37	2.81	2009/07/02	06:00	2.08	2009/07/02	06:00	2.79
2009/07/05	19:16	1.80	2009/07/05	18:00	1.70	2009/07/05	18:00	1.97
2009/07/12	03:35	2.62	2009/07/12	03:00	2.38	2009/07/12	03:00	2.68
2009/07/15	17:15	2.80	2009/07/15	18:00	2.44	2009/07/15	18:00	3.15
2009/07/22	01:34	3.06	2009/07/22	00:00	3.44	2009/07/22	00:00	3.60
2009/07/25	15:13	2.77	2009/07/25	15:00	2.03	2009/07/25	15:00	2.73
2009/07/31	23:32	2.65	2009/07/31	21:00	2.43	2009/07/31	21:00	3.13
2009/08/04	13:12	3.49	2009/08/04	12:00	3.24	2009/08/04	12:00	4.27
2009/08/10	21:31	5.42	2009/08/10	21:00	4.39	2009/08/10	21:00	7.00
2009/08/14	11:10	2.31	2009/08/14	12:00	1.81	2009/08/14	12:00	2.21
2009/08/20	19:29	3.88	2009/08/20	18:00	3.68	2009/08/20	18:00	3.88
2009/08/24	09:09	2.66	2009/08/24	09:00	2.05	2009/08/24	09:00	2.64
2009/08/30	17:28	3.60	2009/08/30	18:00	2.77	2009/08/30	18:00	3.90
2009/09/03	07:07	3.81	2009/09/03	06:00	3.68	2009/09/03	06:00	3.55
2009/09/09	15:26	3.00	2009/09/09	15:00	2.98	2009/09/09	15:00	3.86
2009/09/13	05:06	2.58	2009/09/13	06:00	2.50	2009/09/13	06:00	2.64
2009/09/19	13:25	2.85	2009/09/19	12:00	2.52	2009/09/19	12:00	2.95
2009/09/23	03:05	3.56	2009/09/23	03:00	1.61	2009/09/23	03:00	2.12
2009/09/29	11:23	4.13	2009/09/29	12:00	2.98	2009/09/29	12:00	3.95
2009/10/03	01:03	2.76	2009/10/03	00:00	1.71	2009/10/03	00:00	2.06
2009/10/12	23:02	2.78	2009/10/12	21:00	2.27	2009/10/12	21:00	2.35
2009/10/19	07:21	3.35	2009/10/19	06:00	NaN	2009/10/19	06:00	2.25
2009/10/22	21:00	4.02	2009/10/22	21:00	1.55	2009/10/22	21:00	2.16
2009/10/29	05:19	2.38	2009/10/29	06:00	1.96	2009/10/29	06:00	2.45
2009/11/01	18:59	2.56	2009/11/01	18:00	1.77	2009/11/01	18:00	3.03
2009/11/08	03:18	4.30	2009/11/08	03:00	4.12	2009/11/08	03:00	5.33
2009/11/11	16:57	4.43	2009/11/11	18:00	4.20	2009/11/11	18:00	4.17
2009/11/18	01:16	5.27	2009/11/18	00:00	2.07	2009/11/18	00:00	3.27
2009/11/21	14:56	1.49	2009/11/21	15:00	1.07	2009/11/21	15:00	1.37
2009/11/27	23:15	2.80	2009/11/27	21:00	1.75	2009/11/27	21:00	2.34

2009/12/01	12:54	3.42	2009/12/01	12:00	2.01	2009/12/01	12:00	2.91
2009/12/07	21:13	2.43	2009/12/07	21:00	1.02	2009/12/07	21:00	1.51
2009/12/11	10:53	1.74	2009/12/11	12:00	1.34	2009/12/11	12:00	1.97
2009/12/17	19:12	2.28	2009/12/17	18:00	3.09	2009/12/17	18:00	2.65
2009/12/21	08:51	1.88	2009/12/21	09:00	2.04	2009/12/21	09:00	2.22
2009/12/27	17:10	2.61	2009/12/27	18:00	2.53	2009/12/27	18:00	3.28
2009/12/31	06:50	2.32	2009/12/31	06:00	1.95	2009/12/31	06:00	2.77
2010/01/06	15:09	2.34	2010/01/06	15:00	1.86	2010/01/06	15:00	2.17
2010/01/10	04:48	2.67	2010/01/10	03:00	2.31	2010/01/10	03:00	2.45
2010/01/16	13:07	3.62	2010/01/16	12:00	3.42	2010/01/16	12:00	3.90
2010/01/20	02:47	2.70	2010/01/20	03:00	2.59	2010/01/20	03:00	3.67
2010/01/26	11:06	4.24	2010/01/26	12:00	2.17	2010/01/26	12:00	2.61
2010/01/30	00:45	2.70	2010/01/30	00:00	1.89	2010/01/30	00:00	2.49
2010/02/05	09:04	2.59	2010/02/05	09:00	2.75	2010/02/05	09:00	3.01
2010/02/08	22:44	2.33	2010/02/08	21:00	2.14	2010/02/08	21:00	2.48
2010/02/15	07:03	2.84	2010/02/15	06:00	2.63	2010/02/15	06:00	3.27
2010/02/18	20:42	2.25	2010/02/18	21:00	1.97	2010/02/18	21:00	2.12
2010/02/25	05:01	3.55	2010/02/25	06:00	2.68	2010/02/25	06:00	2.79
2010/02/28	18:41	3.02	2010/02/28	18:00	NaN	2010/02/28	18:00	2.84
2010/03/07	03:00	2.84	2010/03/07	03:00	NaN	2010/03/07	03:00	2.79
2010/03/10	16:40	2.31	2010/03/10	15:00	1.99	2010/03/10	15:00	2.55
2010/03/17	00:58	3.04	2010/03/17	00:00	2.41	2010/03/17	00:00	3.69
2010/03/20	14:38	2.00	2010/03/20	15:00	1.61	2010/03/20	15:00	1.93
2010/03/26	22:57	2.10	2010/03/26	21:00	1.76	2010/03/26	21:00	2.55
2010/03/30	12:37	2.82	2010/03/30	12:00	2.62	2010/03/30	12:00	3.32
2010/04/05	20:55	2.70	2010/04/05	21:00	2.71	2010/04/05	21:00	3.30
2010/04/09	10:35	5.11	2010/04/09	09:00	4.15	2010/04/09	09:00	4.63
2010/04/15	18:54	3.22	2010/04/15	18:00	2.71	2010/04/15	18:00	3.46
2010/04/19	08:34	2.34	2010/04/19	09:00	2.03	2010/04/19	09:00	2.48
2010/04/25	16:53	1.74	2010/04/25	18:00	1.16	2010/04/25	18:00	1.98
2010/04/29	06:32	3.05	2010/04/29	06:00	2.20	2010/04/29	06:00	3.23
2010/05/05	14:51	2.87	2010/05/05	15:00	2.60	2010/05/05	15:00	3.35
2010/05/09	04:31	4.81	2010/05/09	03:00	4.10	2010/05/09	03:00	4.79
2010/05/15	12:50	4.64	2010/05/15	12:00	4.59	2010/05/15	12:00	5.18
2010/05/19	02:29	2.86	2010/05/19	03:00	NaN	2010/05/19	03:00	2.98
2010/05/25	10:48	2.60	2010/05/25	09:00	2.54	2010/05/25	09:00	3.43
2010/05/29	00:28	3.32	2010/05/29	00:00	3.56	2010/05/29	00:00	4.02
2010/06/04	08:47	2.20	2010/06/04	09:00	1.63	2010/06/04	09:00	2.11
2010/06/07	22:26	2.72	2010/06/07	21:00	2.61	2010/06/07	21:00	2.69
2010/06/14	06:45	4.34	2010/06/14	06:00	4.34	2010/06/14	06:00	5.75
2010/06/17	20:25	2.08	2010/06/17	21:00	1.81	2010/06/17	21:00	2.57
2010/06/24	04:44	4.44	2010/06/24	03:00	3.81	2010/06/24	03:00	4.26
2010/06/27	18:23	2.91	2010/06/27	18:00	1.81	2010/06/27	18:00	2.04
2010/07/04	02:42	2.42	2010/07/04	03:00	2.25	2010/07/04	03:00	2.54
2010/07/07	16:22	3.71	2010/07/07	15:00	3.05	2010/07/07	15:00	3.61
2010/07/14	00:41	3.79	2010/07/14	00:00	2.69	2010/07/14	00:00	3.99
2010/07/17	14:20	3.81	2010/07/17	15:00	NaN	2010/07/17	15:00	3.99
2010/07/23	22:39	2.94	2010/07/23	21:00	2.88	2010/07/23	21:00	2.43
2010/07/27	12:19	3.78	2010/07/27	12:00	3.08	2010/07/27	12:00	4.46
2010/08/02	20:38	2.15	2010/08/02	21:00	1.97	2010/08/02	21:00	2.19
2010/08/06	10:17	2.88	2010/08/06	09:00	2.41	2010/08/06	09:00	2.78

2010/08/12	18:36	1.48	2010/08/12	18:00	1.09	2010/08/12	18:00	1.70
2010/08/16	08:16	2.57	2010/08/16	09:00	2.56	2010/08/16	09:00	2.80
2010/08/22	16:35	3.43	2010/08/22	15:00	3.59	2010/08/22	15:00	4.22
2010/08/26	06:14	3.13	2010/08/26	06:00	2.76	2010/08/26	06:00	2.23
2010/09/01	14:33	3.65	2010/09/01	15:00	2.26	2010/09/01	15:00	2.29
2010/09/05	04:13	2.18	2010/09/05	03:00	1.45	2010/09/05	03:00	1.59
2010/09/11	12:32	3.03	2010/09/11	12:00	NaN	2010/09/11	12:00	4.29
2010/09/15	02:11	2.02	2010/09/15	03:00	2.14	2010/09/15	03:00	2.38
2010/09/21	10:30	2.97	2010/09/21	09:00	2.48	2010/09/21	09:00	3.28
2010/09/25	00:10	2.69	2010/09/25	00:00	2.94	2010/09/25	00:00	3.14
2010/10/01	08:29	2.21	2010/10/01	09:00	2.12	2010/10/01	09:00	2.41
2010/10/04	22:09	4.61	2010/10/04	21:00	1.88	2010/10/04	21:00	2.38
2010/10/11	06:27	6.40	2010/10/11	06:00	5.60	2010/10/11	06:00	6.78
2010/10/14	20:07	3.88	2010/10/14	21:00	NaN	2010/10/14	21:00	3.22
2010/10/21	04:26	3.57	2010/10/21	03:00	2.60	2010/10/21	03:00	3.27
2010/10/24	18:06	3.00	2010/10/24	18:00	1.89	2010/10/24	18:00	2.47
2010/10/31	02:24	2.87	2010/10/31	03:00	NaN	2010/10/31	03:00	2.92
2010/11/03	16:04	2.87	2010/11/03	15:00	1.54	2010/11/03	15:00	2.06
2010/11/10	00:23	2.23	2010/11/10	00:00	2.33	2010/11/10	00:00	3.18
2010/11/13	14:03	3.26	2010/11/13	15:00	NaN	2010/11/13	15:00	2.98
2010/11/19	22:22	1.20	2010/11/19	21:00	1.01	2010/11/19	21:00	1.40
2010/11/23	12:01	2.54	2010/11/23	12:00	2.15	2010/11/23	12:00	2.72
2010/11/29	20:20	2.70	2010/11/29	21:00	2.41	2010/11/29	21:00	2.39
2010/12/03	10:00	3.26	2010/12/03	09:00	2.44	2010/12/03	09:00	2.69
2010/12/09	18:19	2.21	2010/12/09	18:00	1.68	2010/12/09	18:00	2.33
2010/12/13	07:58	2.72	2010/12/13	09:00	1.91	2010/12/13	09:00	2.78
2010/12/19	16:17	2.14	2010/12/19	15:00	1.92	2010/12/19	15:00	3.00
2010/12/23	05:57	2.79	2010/12/23	06:00	1.79	2010/12/23	06:00	2.08
2010/12/29	14:16	2.84	2010/12/29	15:00	2.30	2010/12/29	15:00	3.47
2011/01/02	03:55	2.00	2011/01/02	03:00	1.34	2011/01/02	03:00	2.05
2011/01/08	12:14	1.79	2011/01/08	12:00	NaN	2011/01/08	12:00	1.79
2011/01/12	01:54	2.92	2011/01/12	03:00	2.05	2011/01/12	03:00	3.12
2011/01/18	10:13	2.97	2011/01/18	09:00	2.08	2011/01/18	09:00	3.11
2011/01/21	23:52	3.01	2011/01/21	21:00	2.18	2011/01/21	21:00	3.35
2011/01/28	08:11	3.56	2011/01/28	09:00	3.22	2011/01/28	09:00	3.95
2011/01/31	21:51	2.84	2011/01/31	21:00	2.16	2011/01/31	21:00	3.55
2011/02/07	06:10	1.95	2011/02/07	06:00	1.46	2011/02/07	06:00	1.61
2011/02/10	19:49	2.61	2011/02/10	18:00	1.33	2011/02/10	18:00	1.50
2011/02/17	04:08	4.28	2011/02/17	03:00	2.77	2011/02/17	03:00	4.18
2011/02/20	17:48	2.30	2011/02/20	18:00	1.74	2011/02/20	18:00	2.56
2011/02/27	02:07	2.29	2011/02/27	03:00	2.23	2011/02/27	03:00	2.71
2011/03/02	15:46	1.94	2011/03/02	15:00	1.75	2011/03/02	15:00	2.41
2011/03/09	00:05	1.66	2011/03/09	00:00	1.32	2011/03/09	00:00	1.58
2011/03/12	13:45	3.44	2011/03/12	12:00	3.16	2011/03/12	12:00	3.09
2011/03/18	22:04	3.89	2011/03/18	21:00	2.01	2011/03/18	21:00	2.61
2011/03/22	11:43	2.39	2011/03/22	12:00	1.30	2011/03/22	12:00	1.87
2011/03/28	20:02	3.36	2011/03/28	21:00	2.66	2011/03/28	21:00	2.78
2011/04/01	09:42	3.12	2011/04/01	09:00	2.16	2011/04/01	09:00	3.32
2011/04/07	18:01	5.21	2011/04/07	18:00	3.02	2011/04/07	18:00	3.64
2011/04/11	07:40	2.42	2011/04/11	06:00	1.86	2011/04/11	06:00	1.92
2011/04/17	15:59	3.11	2011/04/17	15:00	2.08	2011/04/17	15:00	2.37

2011/04/21	05:39	6.37	2011/04/21	06:00	6.51	2011/04/21	06:00	6.13
2011/04/27	13:58	5.41	2011/04/27	15:00	3.95	2011/04/27	15:00	5.32
2011/05/01	03:38	2.99	2011/05/01	03:00	1.86	2011/05/01	03:00	2.50
2011/05/07	11:56	4.12	2011/05/07	12:00	3.05	2011/05/07	12:00	4.11
2011/05/11	01:36	3.22	2011/05/11	00:00	2.19	2011/05/11	00:00	2.43
2011/05/17	09:55	1.48	2011/05/17	09:00	1.12	2011/05/17	09:00	1.40
2011/05/20	23:35	1.15	2011/05/20	21:00	1.10	2011/05/20	21:00	1.50
2011/05/27	07:54	2.74	2011/05/27	09:00	2.63	2011/05/27	09:00	2.52
2011/06/09	19:32	2.53	2011/06/09	18:00	1.80	2011/06/09	18:00	2.20
2011/06/16	03:51	4.67	2011/06/16	03:00	4.51	2011/06/16	03:00	6.03
2011/06/19	17:30	4.56	2011/06/19	18:00	3.96	2011/06/19	18:00	5.57
2011/06/26	01:49	3.24	2011/06/26	00:00	2.54	2011/06/26	00:00	2.92
2011/06/29	15:29	4.56	2011/06/29	15:00	4.04	2011/06/29	15:00	5.16
2011/07/05	23:48	2.16	2011/07/05	21:00	1.70	2011/07/05	21:00	2.10
2011/07/09	13:27	2.51	2011/07/09	12:00	1.46	2011/07/09	12:00	1.34
2011/07/15	21:46	2.01	2011/07/15	21:00	2.22	2011/07/15	21:00	2.88
2011/07/19	11:26	1.84	2011/07/19	12:00	1.61	2011/07/19	12:00	1.61
2011/07/25	19:45	3.64	2011/07/25	18:00	2.31	2011/07/25	18:00	3.42
2011/07/29	09:24	3.03	2011/07/29	09:00	2.73	2011/07/29	09:00	3.59
2011/08/04	17:43	4.84	2011/08/04	18:00	3.73	2011/08/04	18:00	4.90
2011/08/08	07:23	2.46	2011/08/08	06:00	2.56	2011/08/08	06:00	3.09
2011/08/14	15:42	3.01	2011/08/14	15:00	2.85	2011/08/14	15:00	4.10
2011/08/18	05:21	2.16	2011/08/18	06:00	2.06	2011/08/18	06:00	3.46
2011/08/24	13:40	2.21	2011/08/24	12:00	1.69	2011/08/24	12:00	2.50
2011/08/28	03:20	3.10	2011/08/28	03:00	2.30	2011/08/28	03:00	3.41
2011/09/03	11:39	4.58	2011/09/03	12:00	4.66	2011/09/03	12:00	5.46
2011/09/07	01:18	2.37	2011/09/07	00:00	1.71	2011/09/07	00:00	2.29
2011/09/13	09:37	3.32	2011/09/13	09:00	3.08	2011/09/13	09:00	3.60
2011/09/16	23:17	2.38	2011/09/16	21:00	1.88	2011/09/16	21:00	2.42
2011/09/23	07:36	4.15	2011/09/23	06:00	2.82	2011/09/23	06:00	3.03
2011/09/26	21:15	2.80	2011/09/26	21:00	NaN	2011/09/26	21:00	2.03
2011/10/03	05:34	2.91	2011/10/03	06:00	2.20	2011/10/03	06:00	2.46
2011/10/06	19:14	2.25	2011/10/06	18:00	2.37	2011/10/06	18:00	2.67
2011/10/13	03:33	3.90	2011/10/13	03:00	1.91	2011/10/13	03:00	2.08
2011/10/16	17:12	3.12	2011/10/16	18:00	2.21	2011/10/16	18:00	3.08
2011/10/23	01:31	2.95	2011/10/23	00:00	2.66	2011/10/23	00:00	3.06
2011/10/26	15:11	2.59	2011/10/26	15:00	1.69	2011/10/26	15:00	1.93
2011/11/01	23:30	3.28	2011/11/01	21:00	2.33	2011/11/01	21:00	3.10
2011/11/05	13:09	5.51	2011/11/05	12:00	4.52	2011/11/05	12:00	4.95
2011/11/11	21:28	2.57	2011/11/11	21:00	1.94	2011/11/11	21:00	2.58
2011/11/15	11:08	2.21	2011/11/15	12:00	1.81	2011/11/15	12:00	2.33
2011/11/21	19:27	3.35	2011/11/21	18:00	3.88	2011/11/21	18:00	3.60
2011/11/25	09:07	2.29	2011/11/25	09:00	1.90	2011/11/25	09:00	2.79
2011/12/01	17:25	3.04	2011/12/01	18:00	2.48	2011/12/01	18:00	3.28
2011/12/05	07:05	2.45	2011/12/05	06:00	2.14	2011/12/05	06:00	2.11
2011/12/11	15:24	3.33	2011/12/11	15:00	NaN	2011/12/11	15:00	2.91
2011/12/15	05:04	3.62	2011/12/15	06:00	2.97	2011/12/15	06:00	3.55
2011/12/21	13:23	2.93	2011/12/21	12:00	2.90	2011/12/21	12:00	3.18
2011/12/25	03:02	2.48	2011/12/25	03:00	1.76	2011/12/25	03:00	2.65
2011/12/31	11:21	2.79	2011/12/31	12:00	2.27	2011/12/31	12:00	3.51
2012/01/04	01:01	4.24	2012/01/04	00:00	4.77	2012/01/04	00:00	4.49

2012/01/10	09:20	2.72	2012/01/10	09:00	2.95	2012/01/10	09:00	3.27
2012/01/13	22:59	2.69	2012/01/13	21:00	3.10	2012/01/13	21:00	3.43
2012/01/20	07:18	2.73	2012/01/20	06:00	2.00	2012/01/20	06:00	2.32
2012/01/23	20:58	3.02	2012/01/23	21:00	2.68	2012/01/23	21:00	2.96
2012/01/30	05:17	1.89	2012/01/30	06:00	1.75	2012/01/30	06:00	2.16
2012/02/02	18:56	3.66	2012/02/02	18:00	3.05	2012/02/02	18:00	3.94
2012/02/09	03:15	2.33	2012/02/09	03:00	2.33	2012/02/09	03:00	2.89
2012/02/12	16:55	2.56	2012/02/12	18:00	2.23	2012/02/12	18:00	2.68
2012/02/19	01:14	2.66	2012/02/19	00:00	NaN	2012/02/19	00:00	2.93
2012/02/22	14:53	3.58	2012/02/22	15:00	3.16	2012/02/22	15:00	3.53
2012/02/28	23:12	2.91	2012/02/28	21:00	2.08	2012/02/28	21:00	2.79
2012/03/03	12:52	2.71	2012/03/03	12:00	1.86	2012/03/03	12:00	2.65
2012/03/09	21:11	1.55	2012/03/09	21:00	1.71	2012/03/09	21:00	2.17
2012/03/13	10:50	2.82	2012/03/13	09:00	1.96	2012/03/13	09:00	2.50
2012/03/19	19:09	2.68	2012/03/19	18:00	2.18	2012/03/19	18:00	2.77
2012/03/23	08:49	2.53	2012/03/23	09:00	2.32	2012/03/23	09:00	2.79
2012/03/29	17:08	2.91	2012/03/29	18:00	2.42	2012/03/29	18:00	3.27
2012/04/02	06:47	1.72	2012/04/02	06:00	1.60	2012/04/02	06:00	2.19
2012/04/08	15:06	5.35	2012/04/08	15:00	4.93	2012/04/08	15:00	5.81
2012/04/12	04:46	3.76	2012/04/12	03:00	2.09	2012/04/12	03:00	2.26
2012/04/18	13:05	3.34	2012/04/18	12:00	NaN	2012/04/18	12:00	3.33
2012/04/22	02:44	3.33	2012/04/22	03:00	2.80	2012/04/22	03:00	3.63
2012/04/28	11:03	2.26	2012/04/28	12:00	1.61	2012/04/28	12:00	2.17
2012/05/02	00:43	3.05	2012/05/02	00:00	2.60	2012/05/02	00:00	3.11
2012/05/08	09:02	2.26	2012/05/08	09:00	1.56	2012/05/08	09:00	2.07
2012/05/11	22:41	2.42	2012/05/11	21:00	2.43	2012/05/11	21:00	2.41
2012/05/18	07:00	4.93	2012/05/18	06:00	4.02	2012/05/18	06:00	5.01
2012/05/21	20:40	3.07	2012/05/21	21:00	2.51	2012/05/21	21:00	3.17
2012/05/28	04:59	2.06	2012/05/28	06:00	NaN	2012/05/28	06:00	1.69
2012/05/31	18:39	3.38	2012/05/31	18:00	2.69	2012/05/31	18:00	3.91
2012/06/07	02:57	5.42	2012/06/07	03:00	3.74	2012/06/07	03:00	4.24
2012/06/10	16:37	2.91	2012/06/10	15:00	NaN	2012/06/10	15:00	3.09
2012/06/17	00:56	2.80	2012/06/17	00:00	2.20	2012/06/17	00:00	2.31
2012/06/20	14:36	3.37	2012/06/20	15:00	3.00	2012/06/20	15:00	3.44
2012/06/26	22:55	4.36	2012/06/26	21:00	3.93	2012/06/26	21:00	5.28
2012/06/30	12:34	4.38	2012/06/30	12:00	NaN	2012/06/30	12:00	5.02
2012/07/06	20:53	5.01	2012/07/06	21:00	3.57	2012/07/06	21:00	5.69
2012/07/10	10:33	4.26	2012/07/10	09:00	3.74	2012/07/10	09:00	4.66
2012/07/16	18:52	3.01	2012/07/16	18:00	2.06	2012/07/16	18:00	2.59
2012/07/20	08:31	2.84	2012/07/20	09:00	2.88	2012/07/20	09:00	3.18
2012/07/26	16:50	3.29	2012/07/26	15:00	3.49	2012/07/26	15:00	3.15
2012/07/30	06:30	2.95	2012/07/30	06:00	NaN	2012/07/30	06:00	1.99
2012/08/05	14:49	3.12	2012/08/05	15:00	2.51	2012/08/05	15:00	3.32
2012/08/09	04:28	2.11	2012/08/09	03:00	1.47	2012/08/09	03:00	2.00
2012/08/15	12:47	5.01	2012/08/15	12:00	4.72	2012/08/15	12:00	5.40
2012/08/19	02:27	3.91	2012/08/19	03:00	4.32	2012/08/19	03:00	3.66
2012/08/25	10:46	4.88	2012/08/25	09:00	NaN	2012/08/25	09:00	5.05
2012/08/29	00:25	3.65	2012/08/29	00:00	2.99	2012/08/29	00:00	3.78
2012/09/04	08:44	3.18	2012/09/04	09:00	2.61	2012/09/04	09:00	2.93
2012/09/07	22:24	1.67	2012/09/07	21:00	1.32	2012/09/07	21:00	1.23
2012/09/14	06:43	2.95	2012/09/14	06:00	2.32	2012/09/14	06:00	2.97

2012/09/17	20:22	1.96	2012/09/17	21:00	1.55	2012/09/17	21:00	2.35
2012/09/24	04:41	4.33	2012/09/24	03:00	4.36	2012/09/24	03:00	4.19
2012/09/27	18:21	6.45	2012/09/27	18:00	4.17	2012/09/27	18:00	4.80
2012/10/04	02:40	2.70	2012/10/04	03:00	2.37	2012/10/04	03:00	2.72
2012/10/07	16:19	3.56	2012/10/07	15:00	2.85	2012/10/07	15:00	3.85
2012/10/14	00:38	3.35	2012/10/14	00:00	2.79	2012/10/14	00:00	3.87
2012/10/17	14:18	2.72	2012/10/17	15:00	1.76	2012/10/17	15:00	2.84
2012/10/23	22:37	3.76	2012/10/23	21:00	2.63	2012/10/23	21:00	2.86
2012/10/27	12:16	3.54	2012/10/27	12:00	2.96	2012/10/27	12:00	3.09
2012/11/02	20:35	3.35	2012/11/02	21:00	1.09	2012/11/02	21:00	1.80
2012/11/06	10:15	1.33	2012/11/06	09:00	0.79	2012/11/06	09:00	1.36
2012/11/12	18:34	2.35	2012/11/12	18:00	1.95	2012/11/12	18:00	2.61
2012/11/16	08:13	2.59	2012/11/16	09:00	2.79	2012/11/16	09:00	3.11
2012/11/22	16:32	3.00	2012/11/22	15:00	2.88	2012/11/22	15:00	3.52
2012/11/26	06:12	3.37	2012/11/26	06:00	2.94	2012/11/26	06:00	3.25
2012/12/02	14:31	2.08	2012/12/02	15:00	1.35	2012/12/02	15:00	1.73
2012/12/06	04:11	3.14	2012/12/06	03:00	2.46	2012/12/06	03:00	2.99
2012/12/12	12:29	3.16	2012/12/12	12:00	2.60	2012/12/12	12:00	2.90
2012/12/16	02:09	2.13	2012/12/16	03:00	1.83	2012/12/16	03:00	2.64
2012/12/22	10:28	1.30	2012/12/22	09:00	0.90	2012/12/22	09:00	1.23
2012/12/26	00:08	1.73	2012/12/26	00:00	1.36	2012/12/26	00:00	1.62
2013/01/01	08:27	3.44	2013/01/01	09:00	3.18	2013/01/01	09:00	4.46
2013/01/04	22:06	3.13	2013/01/04	21:00	3.37	2013/01/04	21:00	3.88
2013/01/11	06:25	2.75	2013/01/11	06:00	2.53	2013/01/11	06:00	3.26
2013/01/14	20:05	2.44	2013/01/14	21:00	2.42	2013/01/14	21:00	3.10
2013/01/21	04:24	2.35	2013/01/21	03:00	1.62	2013/01/21	03:00	2.14
2013/01/24	18:03	2.00	2013/01/24	18:00	1.75	2013/01/24	18:00	2.17
2013/01/31	02:22	2.00	2013/01/31	03:00	1.54	2013/01/31	03:00	2.53
2013/02/03	16:02	3.19	2013/02/03	15:00	2.47	2013/02/03	15:00	3.46
2013/02/10	00:21	1.83	2013/02/10	00:00	1.44	2013/02/10	00:00	1.49
2013/02/13	14:00	1.73	2013/02/13	15:00	1.29	2013/02/13	15:00	1.84
2013/02/19	22:19	4.23	2013/02/19	21:00	4.08	2013/02/19	21:00	4.16
2013/02/23	11:59	2.60	2013/02/23	12:00	2.45	2013/02/23	12:00	2.64
2013/03/01	20:18	2.58	2013/03/01	21:00	2.13	2013/03/01	21:00	2.94
2013/03/05	09:57	1.85	2013/03/05	09:00	1.40	2013/03/05	09:00	1.84
2013/03/11	18:16	3.34	2013/03/11	18:00	1.67	2013/03/11	18:00	2.19
2013/03/15	07:56	2.88	2013/03/15	09:00	1.76	2013/03/15	09:00	2.14
2013/03/21	16:15	2.27	2013/03/21	15:00	1.77	2013/03/21	15:00	2.36
2013/04/10	12:12	3.37	2013/04/10	12:00	3.39	2013/04/10	12:00	4.12
2013/04/14	01:51	2.29	2013/04/14	03:00	1.57	2013/04/14	03:00	1.47
2013/04/20	10:10	2.67	2013/04/20	09:00	NaN	2013/04/20	09:00	2.36
2013/04/23	23:50	1.46	2013/04/23	21:00	1.27	2013/04/23	21:00	1.64
2013/04/30	08:09	1.90	2013/04/30	09:00	1.56	2013/04/30	09:00	2.04
2013/05/03	21:48	3.85	2013/05/03	21:00	4.28	2013/05/03	21:00	4.45
2013/05/10	06:07	2.68	2013/05/10	06:00	2.92	2013/05/10	06:00	3.25
2013/05/13	19:47	1.61	2013/05/13	18:00	1.63	2013/05/13	18:00	2.06
2013/05/20	04:06	3.04	2013/05/20	03:00	2.47	2013/05/20	03:00	2.61
2013/05/23	17:45	1.40	2013/05/23	18:00	0.96	2013/05/23	18:00	1.63
2013/05/30	02:04	3.72	2013/05/30	03:00	3.20	2013/05/30	03:00	4.03
2013/06/02	15:44	4.79	2013/06/02	15:00	4.56	2013/06/02	15:00	6.36
2013/06/09	00:03	4.66	2013/06/09	00:00	4.25	2013/06/09	00:00	4.28

2013/06/12	13:43	2.00	2013/06/12	12:00	1.76	2013/06/12	12:00	2.13
2013/06/18	22:01	2.56	2013/06/18	21:00	1.79	2013/06/18	21:00	2.50
2013/06/22	11:41	5.81	2013/06/22	12:00	6.10	2013/06/22	12:00	5.27
2013/06/28	20:00	2.23	2013/06/28	21:00	1.61	2013/06/28	21:00	2.34
2013/07/02	09:40	3.34	2013/07/02	09:00	2.87	2013/07/02	09:00	3.47
2013/07/08	17:59	4.05	2013/07/08	18:00	3.72	2013/07/08	18:00	3.76
2013/07/12	07:38	3.47	2013/07/12	06:00	2.62	2013/07/12	06:00	2.78
2013/07/18	15:57	3.52	2013/07/18	15:00	2.38	2013/07/18	15:00	2.73
2013/07/22	05:37	2.63	2013/07/22	06:00	1.69	2013/07/22	06:00	2.17
2013/07/28	13:56	4.89	2013/07/28	15:00	4.40	2013/07/28	15:00	4.80
2013/08/01	03:35	2.75	2013/08/01	03:00	2.37	2013/08/01	03:00	2.85
2013/08/07	11:54	5.44	2013/08/07	12:00	4.33	2013/08/07	12:00	5.62
2013/08/11	01:34	2.43	2013/08/11	00:00	1.82	2013/08/11	00:00	2.11
2013/08/17	09:53	7.64	2013/08/17	09:00	5.85	2013/08/17	09:00	5.64
2013/08/20	23:32	3.34	2013/08/20	21:00	2.33	2013/08/20	21:00	2.65
2013/08/27	07:51	6.30	2013/08/27	09:00	5.05	2013/08/27	09:00	5.60
2013/08/30	21:31	5.05	2013/08/30	21:00	4.71	2013/08/30	21:00	5.79
2013/09/16	03:48	5.71	2013/09/16	03:00	5.18	2013/09/16	03:00	5.34
2013/09/19	17:28	4.79	2013/09/19	18:00	4.57	2013/09/19	18:00	4.94
2013/09/26	01:47	2.52	2013/09/26	00:00	2.28	2013/09/26	00:00	2.47
2013/09/29	15:26	3.72	2013/09/29	15:00	3.57	2013/09/29	15:00	4.23
2013/10/05	23:45	2.25	2013/10/05	21:00	2.11	2013/10/05	21:00	2.52
2013/10/09	13:25	2.04	2013/10/09	12:00	1.53	2013/10/09	12:00	1.91
2013/10/15	21:44	1.86	2013/10/15	21:00	1.56	2013/10/15	21:00	2.06
2013/10/19	11:23	2.94	2013/10/19	12:00	2.22	2013/10/19	12:00	2.59
2013/10/25	19:42	2.15	2013/10/25	18:00	1.87	2013/10/25	18:00	2.05
2013/10/29	09:22	1.78	2013/10/29	09:00	1.33	2013/10/29	09:00	1.39
2013/11/04	17:41	2.01	2013/11/04	18:00	1.34	2013/11/04	18:00	1.66
2013/11/08	07:20	2.05	2013/11/08	06:00	2.60	2013/11/08	06:00	1.59
2013/11/14	15:39	1.73	2013/11/14	15:00	1.76	2013/11/14	15:00	1.52
2013/11/18	05:19	3.72	2013/11/18	06:00	3.18	2013/11/18	06:00	3.24
2013/11/28	03:17	3.31	2013/11/28	03:00	2.69	2013/11/28	03:00	3.81
2013/12/04	11:36	2.96	2013/12/04	12:00	2.32	2013/12/04	12:00	2.70
2013/12/08	01:16	4.90	2013/12/08	00:00	2.29	2013/12/08	00:00	3.28
2013/12/14	09:35	1.95	2013/12/14	09:00	1.68	2013/12/14	09:00	1.82
2013/12/17	23:15	2.62	2013/12/17	21:00	1.70	2013/12/17	21:00	2.69
2013/12/24	07:33	3.25	2013/12/24	06:00	2.98	2013/12/24	06:00	3.48
2013/12/27	21:13	2.78	2013/12/27	21:00	2.18	2013/12/27	21:00	2.38
2014/01/03	05:32	2.31	2014/01/03	06:00	1.99	2014/01/03	06:00	2.10
2014/01/06	19:12	3.83	2014/01/06	18:00	2.56	2014/01/06	18:00	3.63
2014/01/13	03:31	3.00	2014/01/13	03:00	2.75	2014/01/13	03:00	3.54
2014/01/16	17:10	2.08	2014/01/16	18:00	1.64	2014/01/16	18:00	2.31
2014/01/23	01:29	1.98	2014/01/23	00:00	1.81	2014/01/23	00:00	2.23
2014/01/26	15:09	1.69	2014/01/26	15:00	1.43	2014/01/26	15:00	1.92
2014/02/01	23:28	2.27	2014/02/01	21:00	1.63	2014/02/01	21:00	1.82
2014/02/05	13:07	3.85	2014/02/05	12:00	3.55	2014/02/05	12:00	3.93
2014/02/11	21:26	3.27	2014/02/11	21:00	2.29	2014/02/11	21:00	2.88
2014/02/15	11:06	3.07	2014/02/15	12:00	2.29	2014/02/15	12:00	2.80
2014/02/21	19:25	3.18	2014/02/21	18:00	2.14	2014/02/21	18:00	2.92
2014/02/25	09:04	3.27	2014/02/25	09:00	2.08	2014/02/25	09:00	3.36
2014/03/03	17:23	3.77	2014/03/03	18:00	3.11	2014/03/03	18:00	3.66

2014/03/07	07:03	3.02	2014/03/07	06:00	3.28	2014/03/07	06:00	3.48
2014/03/13	15:22	3.17	2014/03/13	15:00	2.46	2014/03/13	15:00	3.52
2014/03/17	05:01	1.53	2014/03/17	06:00	1.20	2014/03/17	06:00	1.59
2014/03/23	13:20	2.29	2014/03/23	12:00	2.15	2014/03/23	12:00	3.16
2014/03/27	03:00	2.64	2014/03/27	03:00	2.34	2014/03/27	03:00	2.61
2014/04/02	11:19	4.25	2014/04/02	12:00	3.15	2014/04/02	12:00	4.53
2014/04/06	00:58	4.71	2014/04/06	00:00	2.18	2014/04/06	00:00	2.95
2014/04/12	09:17	NaN	2014/04/12	09:00	NaN	2014/04/12	09:00	1.40
2014/04/15	22:57	2.86	2014/04/15	21:00	2.36	2014/04/15	21:00	3.51
2014/04/22	07:16	2.61	2014/04/22	06:00	2.08	2014/04/22	06:00	2.70
2014/04/25	20:55	1.36	2014/04/25	21:00	1.22	2014/04/25	21:00	1.56
2014/05/02	05:14	1.52	2014/05/02	06:00	1.17	2014/05/02	06:00	1.45
2014/05/05	18:54	4.55	2014/05/05	18:00	3.62	2014/05/05	18:00	4.57
2014/05/12	03:13	2.18	2014/05/12	03:00	1.87	2014/05/12	03:00	2.32
2014/05/15	16:52	2.88	2014/05/15	18:00	2.22	2014/05/15	18:00	2.60
2014/05/22	01:11	1.93	2014/05/22	00:00	1.90	2014/05/22	00:00	2.01
2014/05/25	14:51	4.13	2014/05/25	15:00	4.32	2014/05/25	15:00	4.29
2014/05/31	23:10	4.13	2014/05/31	21:00	3.29	2014/05/31	21:00	4.25
2014/06/04	12:50	6.23	2014/06/04	12:00	6.22	2014/06/04	12:00	7.65
2014/06/10	21:08	3.84	2014/06/10	21:00	2.99	2014/06/10	21:00	3.78
2014/06/14	10:48	2.99	2014/06/14	09:00	2.97	2014/06/14	09:00	3.25
2014/06/20	19:07	3.57	2014/06/20	18:00	3.36	2014/06/20	18:00	3.65
2014/06/24	08:47	2.03	2014/06/24	09:00	2.23	2014/06/24	09:00	2.58
2014/06/30	17:05	2.53	2014/06/30	18:00	2.30	2014/06/30	18:00	2.92
2014/07/04	06:45	4.33	2014/07/04	06:00	3.45	2014/07/04	06:00	5.08
2014/07/10	15:04	3.07	2014/07/10	15:00	2.22	2014/07/10	15:00	3.01
2014/07/14	04:44	2.95	2014/07/14	03:00	2.48	2014/07/14	03:00	3.09
2014/07/20	13:03	3.61	2014/07/20	12:00	3.79	2014/07/20	12:00	3.99
2014/07/24	02:42	1.72	2014/07/24	03:00	1.74	2014/07/24	03:00	2.07
2014/07/30	11:01	2.55	2014/07/30	12:00	2.07	2014/07/30	12:00	2.40
2014/08/03	00:41	3.42	2014/08/03	00:00	1.90	2014/08/03	00:00	2.77
2014/08/09	09:00	2.05	2014/08/09	09:00	1.03	2014/08/09	09:00	1.77
2014/08/12	22:39	2.17	2014/08/12	21:00	1.61	2014/08/12	21:00	1.62
2014/08/19	06:58	2.62	2014/08/19	06:00	2.39	2014/08/19	06:00	3.93
2014/08/22	20:38	2.97	2014/08/22	21:00	2.16	2014/08/22	21:00	2.82
2014/08/29	04:57	4.43	2014/08/29	06:00	4.41	2014/08/29	06:00	5.46
2014/09/01	18:36	2.15	2014/09/01	18:00	1.46	2014/09/01	18:00	1.91
2014/09/08	02:55	2.73	2014/09/08	03:00	2.48	2014/09/08	03:00	2.95
2014/09/11	16:35	2.65	2014/09/11	15:00	2.10	2014/09/11	15:00	2.61
2014/09/18	00:54	3.48	2014/09/18	00:00	2.38	2014/09/18	00:00	3.69
2014/09/21	14:33	2.69	2014/09/21	15:00	1.96	2014/09/21	15:00	2.58
2014/09/27	22:52	3.23	2014/09/27	21:00	3.01	2014/09/27	21:00	3.60
2014/10/01	12:32	2.03	2014/10/01	12:00	1.94	2014/10/01	12:00	2.09
2014/10/07	20:51	2.08	2014/10/07	21:00	2.00	2014/10/07	21:00	2.12
2014/10/11	10:30	2.84	2014/10/11	09:00	2.43	2014/10/11	09:00	3.15
2014/10/17	18:49	2.98	2014/10/17	18:00	1.80	2014/10/17	18:00	2.29
2014/10/21	08:29	3.61	2014/10/21	09:00	2.06	2014/10/21	09:00	2.39
2014/10/27	16:48	1.84	2014/10/27	15:00	1.11	2014/10/27	15:00	1.53
2014/10/31	06:27	3.28	2014/10/31	06:00	3.14	2014/10/31	06:00	3.73
2014/11/06	14:46	2.56	2014/11/06	15:00	1.93	2014/11/06	15:00	2.82
2014/11/10	04:26	4.29	2014/11/10	03:00	3.56	2014/11/10	03:00	3.72

2014/11/16	12:45	3.07	2014/11/16	12:00	2.66	2014/11/16	12:00	3.24
2014/11/20	02:24	2.57	2014/11/20	03:00	1.70	2014/11/20	03:00	2.46
2014/11/26	10:43	2.26	2014/11/26	09:00	1.21	2014/11/26	09:00	1.70
2014/12/06	08:42	3.46	2014/12/06	09:00	3.04	2014/12/06	09:00	3.67
2014/12/09	22:21	2.24	2014/12/09	21:00	1.93	2014/12/09	21:00	2.43
2014/12/16	06:40	2.81	2014/12/16	06:00	3.52	2014/12/16	06:00	3.55
2014/12/26	04:39	6.80	2014/12/26	03:00	8.23	2014/12/26	03:00	5.80
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2015/01/08	16:17	3.07	2015/01/08	15:00	2.26	2015/01/08	15:00	3.26
2015/01/15	00:36	3.25	2015/01/15	00:00	2.18	2015/01/15	00:00	2.45
2015/01/24	22:35	2.75	2015/01/24	21:00	2.90	2015/01/24	21:00	2.48
2015/01/28	12:14	3.40	2015/01/28	12:00	3.14	2015/01/28	12:00	3.56
2015/02/03	20:33	3.15	2015/02/03	21:00	2.89	2015/02/03	21:00	2.93
2015/02/07	10:13	1.93	2015/02/07	09:00	1.30	2015/02/07	09:00	1.56
2015/02/13	18:32	3.00	2015/02/13	18:00	2.52	2015/02/13	18:00	3.38
2015/02/17	08:11	3.26	2015/02/17	09:00	1.57	2015/02/17	09:00	1.85
2015/02/23	16:30	3.26	2015/02/23	15:00	2.24	2015/02/23	15:00	2.83
2015/02/27	06:10	1.83	2015/02/27	06:00	1.52	2015/02/27	06:00	2.12
2015/03/05	14:29	2.43	2015/03/05	15:00	2.26	2015/03/05	15:00	2.81
2015/03/09	04:08	3.10	2015/03/09	03:00	3.59	2015/03/09	03:00	3.95
2015/03/15	12:27	1.39	2015/03/15	12:00	1.07	2015/03/15	12:00	1.55
2015/03/19	02:07	2.28	2015/03/19	03:00	1.67	2015/03/19	03:00	2.20
2015/03/25	10:26	1.78	2015/03/25	09:00	1.39	2015/03/25	09:00	2.05
2015/03/29	00:05	2.37	2015/03/29	00:00	2.15	2015/03/29	00:00	2.69
2015/04/04	08:24	2.78	2015/04/04	09:00	2.74	2015/04/04	09:00	3.23
2015/04/07	22:04	2.98	2015/04/07	21:00	1.64	2015/04/07	21:00	2.61
2015/04/14	06:23	3.66	2015/04/14	06:00	2.69	2015/04/14	06:00	3.25
2015/04/17	20:02	3.80	2015/04/17	21:00	1.92	2015/04/17	21:00	2.74
2015/04/24	04:21	2.83	2015/04/24	03:00	1.81	2015/04/24	03:00	2.32
2015/04/27	18:01	2.25	2015/04/27	18:00	2.56	2015/04/27	18:00	2.53
2015/05/04	02:20	2.84	2015/05/04	03:00	1.86	2015/05/04	03:00	2.47
2015/05/07	15:59	5.40	2015/05/07	15:00	2.72	2015/05/07	15:00	3.85
2015/05/14	00:18	3.35	2015/05/14	00:00	2.16	2015/05/14	00:00	3.11
2015/05/17	13:58	2.80	2015/05/17	15:00	3.06	2015/05/17	15:00	2.96
2015/05/23	22:17	3.59	2015/05/23	21:00	3.30	2015/05/23	21:00	3.89
2015/05/27	11:56	2.61	2015/05/27	12:00	2.59	2015/05/27	12:00	3.15
2015/06/02	20:15	5.01	2015/06/02	21:00	2.68	2015/06/02	21:00	3.79
2015/06/06	09:55	2.20	2015/06/06	09:00	1.35	2015/06/06	09:00	2.32
2015/06/12	18:14	2.15	2015/06/12	18:00	1.98	2015/06/12	18:00	2.28
2015/06/16	07:54	5.07	2015/06/16	09:00	4.02	2015/06/16	09:00	5.45
2015/06/22	16:12	2.95	2015/06/22	15:00	3.15	2015/06/22	15:00	3.66
2015/06/26	05:52	2.52	2015/06/26	06:00	1.94	2015/06/26	06:00	2.92
2015/07/02	14:11	2.41	2015/07/02	15:00	2.15	2015/07/02	15:00	2.44
2015/07/06	03:51	2.11	2015/07/06	03:00	2.11	2015/07/06	03:00	2.55
2015/07/12	12:10	4.13	2015/07/12	12:00	4.04	2015/07/12	12:00	4.82
2015/07/16	01:49	1.52	2015/07/16	00:00	1.35	2015/07/16	00:00	2.00
2015/07/22	10:08	4.09	2015/07/22	09:00	3.21	2015/07/22	09:00	4.23
2015/07/25	23:48	2.75	2015/07/25	21:00	2.80	2015/07/25	21:00	3.49
2015/08/01	08:07	3.39	2015/08/01	09:00	NaN	2015/08/01	09:00	2.54
2015/08/04	21:46	4.84	2015/08/04	21:00	4.66	2015/08/04	21:00	4.18

2015/08/11	06:05	2.36	2015/08/11	06:00	2.38	2015/08/11	06:00	2.11
2015/08/14	19:45	4.44	2015/08/14	18:00	3.74	2015/08/14	18:00	3.66
2015/08/21	04:04	3.36	2015/08/21	03:00	NaN	2015/08/21	03:00	2.20
2015/08/24	17:43	3.11	2015/08/24	18:00	NaN	2015/08/24	18:00	2.16
2015/08/31	02:02	4.37	2015/08/31	03:00	3.21	2015/08/31	03:00	4.46
2015/09/03	15:42	3.04	2015/09/03	15:00	1.82	2015/09/03	15:00	2.12
2015/09/10	00:01	5.38	2015/09/10	00:00	3.47	2015/09/10	00:00	4.06
2015/09/13	13:40	4.00	2015/09/13	12:00	2.25	2015/09/13	12:00	2.55
2015/09/19	21:59	2.83	2015/09/19	21:00	1.67	2015/09/19	21:00	2.03
2015/09/23	11:39	2.90	2015/09/23	12:00	2.08	2015/09/23	12:00	2.39
2015/09/29	19:58	4.48	2015/09/29	21:00	3.10	2015/09/29	21:00	3.84
2015/10/03	09:37	3.27	2015/10/03	09:00	3.02	2015/10/03	09:00	3.35
2015/10/09	17:56	3.32	2015/10/09	18:00	2.61	2015/10/09	18:00	2.67
2015/10/13	07:36	3.13	2015/10/13	06:00	2.63	2015/10/13	06:00	2.87
2015/10/19	15:55	3.13	2015/10/19	15:00	2.66	2015/10/19	15:00	2.64
2015/10/23	05:34	4.14	2015/10/23	06:00	2.85	2015/10/23	06:00	3.44
2015/10/29	13:53	2.30	2015/10/29	15:00	2.02	2015/10/29	15:00	2.75
2015/11/02	03:33	3.26	2015/11/02	03:00	2.38	2015/11/02	03:00	2.39
2015/11/08	11:52	1.49	2015/11/08	12:00	1.40	2015/11/08	12:00	1.54
2015/11/12	01:31	3.22	2015/11/12	00:00	2.51	2015/11/12	00:00	2.69
2015/11/18	09:50	2.47	2015/11/18	09:00	2.31	2015/11/18	09:00	2.46
2015/11/21	23:30	4.26	2015/11/21	21:00	4.59	2015/11/21	21:00	4.19
2015/11/28	07:49	3.01	2015/11/28	06:00	NaN	2015/11/28	06:00	2.49
2015/12/01	21:29	1.34	2015/12/01	21:00	0.84	2015/12/01	21:00	1.10
2015/12/08	05:47	1.98	2015/12/08	06:00	NaN	2015/12/08	06:00	1.91
2015/12/11	19:27	2.97	2015/12/11	18:00	1.66	2015/12/11	18:00	2.18
2015/12/18	03:46	2.37	2015/12/18	03:00	NaN	2015/12/18	03:00	1.99
2015/12/21	17:26	6.06	2015/12/21	18:00	2.24	2015/12/21	18:00	5.04
2015/12/28	01:44	5.24	2015/12/28	00:00	1.32	2015/12/28	00:00	3.70
2015/12/31	15:24	1.86	2015/12/31	15:00	0.66	2015/12/31	15:00	2.00
2016/01/06	23:43	3.84	2016/01/06	21:00	2.53	2016/01/06	21:00	3.32
2016/01/10	13:23	3.27	2016/01/10	12:00	2.70	2016/01/10	12:00	3.53
2016/01/16	21:42	3.76	2016/01/16	21:00	2.51	2016/01/16	21:00	3.80
2016/01/20	11:21	2.92	2016/01/20	12:00	2.27	2016/01/20	12:00	2.91
2016/01/26	19:37	13.54	2016/01/26	18:00	1.76	2016/01/26	18:00	1.53
2016/01/30	09:20	2.59	2016/01/30	09:00	1.92	2016/01/30	09:00	2.46
2016/02/05	17:39	2.00	2016/02/05	18:00	1.23	2016/02/05	18:00	1.57
2016/02/09	07:18	3.13	2016/02/09	06:00	2.15	2016/02/09	06:00	2.24
2016/02/15	15:37	2.46	2016/02/15	15:00	2.21	2016/02/15	15:00	2.17
2016/02/19	05:17	1.69	2016/02/19	06:00	1.43	2016/02/19	06:00	1.53
2016/02/25	13:36	2.72	2016/02/25	12:00	2.15	2016/02/25	12:00	2.22
2016/02/29	03:15	3.59	2016/02/29	03:00	2.98	2016/02/29	03:00	4.02
2016/03/06	11:34	2.24	2016/03/06	12:00	NaN	2016/03/06	12:00	1.48
2016/03/10	01:14	2.08	2016/03/10	00:00	1.87	2016/03/10	00:00	1.76
2016/03/16	09:33	3.81	2016/03/16	09:00	2.68	2016/03/16	09:00	3.21
2016/03/19	23:12	4.46	2016/03/19	21:00	3.08	2016/03/19	21:00	3.34
2016/03/26	07:31	2.39	2016/03/26	06:00	1.43	2016/03/26	06:00	2.03
2016/03/29	21:11	3.86	2016/03/29	21:00	2.93	2016/03/29	21:00	4.22
2016/04/05	05:30	1.99	2016/04/05	06:00	2.15	2016/04/05	06:00	2.07
2016/04/08	19:09	2.15	2016/04/08	18:00	1.11	2016/04/08	18:00	1.99
2016/04/15	03:28	2.22	2016/04/15	03:00	2.32	2016/04/15	03:00	2.30

2016/04/18	17:08	2.67	2016/04/18	18:00	1.74	2016/04/18	18:00	2.07
2016/04/25	01:27	2.73	2016/04/25	00:00	2.24	2016/04/25	00:00	2.79
2016/04/28	15:06	4.87	2016/04/28	15:00	4.38	2016/04/28	15:00	4.40
2016/05/04	23:25	2.21	2016/05/04	21:00	1.33	2016/05/04	21:00	1.82
2016/05/08	13:05	4.35	2016/05/08	12:00	1.97	2016/05/08	12:00	2.28
2016/05/14	21:24	1.44	2016/05/14	21:00	1.17	2016/05/14	21:00	1.84
2016/05/18	11:03	2.26	2016/05/18	12:00	1.77	2016/05/18	12:00	1.33
2016/05/24	19:22	2.89	2016/05/24	18:00	3.35	2016/05/24	18:00	2.48
2016/05/28	09:02	3.08	2016/05/28	09:00	2.94	2016/05/28	09:00	2.65
2016/06/03	17:21	1.76	2016/06/03	18:00	1.97	2016/06/03	18:00	1.82
2016/06/07	07:01	2.24	2016/06/07	06:00	1.48	2016/06/07	06:00	1.93
2016/06/13	15:19	1.78	2016/06/13	15:00	1.07	2016/06/13	15:00	1.37
2016/06/17	04:59	4.33	2016/06/17	06:00	3.73	2016/06/17	06:00	3.22
2016/06/23	13:18	2.10	2016/06/23	12:00	1.18	2016/06/23	12:00	1.89
2016/06/27	02:58	3.96	2016/06/27	03:00	3.77	2016/06/27	03:00	4.24
2016/07/03	11:17	2.91	2016/07/03	12:00	2.80	2016/07/03	12:00	2.70
2016/07/07	00:56	4.18	2016/07/07	00:00	3.93	2016/07/07	00:00	3.79
2016/07/13	09:15	2.68	2016/07/13	09:00	2.16	2016/07/13	09:00	2.78
2016/07/16	22:55	3.80	2016/07/16	21:00	2.49	2016/07/16	21:00	2.65
2016/07/23	07:14	3.59	2016/07/23	06:00	3.09	2016/07/23	06:00	3.16
2016/07/26	20:53	7.02	2016/07/26	21:00	2.74	2016/07/26	21:00	4.19
2016/08/02	05:12	2.89	2016/08/02	06:00	1.92	2016/08/02	06:00	2.16
2016/08/05	18:52	4.35	2016/08/05	18:00	3.66	2016/08/05	18:00	3.37
2016/08/12	03:11	2.55	2016/08/12	03:00	2.00	2016/08/12	03:00	2.73
2016/08/15	16:50	4.48	2016/08/15	15:00	3.88	2016/08/15	15:00	3.74
2016/08/22	01:09	4.75	2016/08/22	00:00	4.19	2016/08/22	00:00	4.34
2016/08/25	14:49	3.33	2016/08/25	15:00	3.32	2016/08/25	15:00	3.19
2016/08/31	23:08	4.54	2016/08/31	21:00	3.98	2016/08/31	21:00	4.22
2016/09/04	12:47	3.82	2016/09/04	12:00	1.95	2016/09/04	12:00	2.68
2016/09/10	21:06	3.41	2016/09/10	21:00	2.26	2016/09/10	21:00	2.47
2016/09/14	10:46	2.47	2016/09/14	09:00	1.55	2016/09/14	09:00	1.93

FA-Platform								
Altimetry Data			Measured Buoy Data			NCEP data		
Date	Time	Hs	Date	Time	Hs	Date	Time	Hs
2008/07/16	04:54	4.46	2008/07/16	06:00	4.50	2008/07/16	06:00	5.79
2008/07/19	18:34	1.49	2008/07/19	18:00	1.60	2008/07/19	18:00	1.49
2008/07/26	02:53	3.52	2008/07/26	03:00	4.00	2008/07/26	03:00	5.45
2008/07/29	16:33	2.28	2008/07/29	15:00	2.20	2008/07/29	15:00	3.03
2008/08/05	00:51	2.32	2008/08/05	00:00	2.40	2008/08/05	00:00	2.50
2008/08/08	14:31	3.42	2008/08/08	15:00	3.30	2008/08/08	15:00	4.39
2008/08/14	22:50	3.20	2008/08/14	21:00	2.60	2008/08/14	21:00	3.04
2008/08/18	12:30	3.21	2008/08/18	12:00	3.00	2008/08/18	12:00	3.23
2008/08/24	20:49	3.62	2008/08/24	21:00	3.70	2008/08/24	21:00	3.77
2008/08/28	10:28	1.62	2008/08/28	09:00	2.10	2008/08/28	09:00	2.12
2008/09/03	18:47	5.41	2008/09/03	18:00	5.10	2008/09/03	18:00	5.99
2008/09/07	08:27	2.22	2008/09/07	09:00	2.10	2008/09/07	09:00	1.84
2008/09/13	16:46	1.74	2008/09/13	15:00	1.80	2008/09/13	15:00	2.05
2008/09/17	06:25	2.86	2008/09/17	06:00	3.00	2008/09/17	06:00	3.25
2008/09/23	14:44	2.64	2008/09/23	15:00	2.20	2008/09/23	15:00	2.88
2008/09/27	04:24	4.19	2008/09/27	03:00	3.70	2008/09/27	03:00	4.75
2008/10/03	12:43	3.86	2008/10/03	12:00	4.20	2008/10/03	12:00	4.41
2008/10/07	02:22	3.49	2008/10/07	03:00	3.90	2008/10/07	03:00	3.06
2008/10/13	10:41	2.67	2008/10/13	09:00	2.60	2008/10/13	09:00	2.90
2008/10/17	00:21	1.80	2008/10/17	00:00	1.90	2008/10/17	00:00	2.18
2008/10/23	08:40	NaN	2008/10/23	09:00	2.90	2008/10/23	09:00	3.51
2008/10/26	22:19	2.15	2008/10/26	21:00	2.10	2008/10/26	21:00	2.57
2008/11/02	06:38	1.92	2008/11/02	06:01	1.70	2008/11/02	06:00	2.33
2008/11/05	20:18	2.52	2008/11/05	21:00	2.20	2008/11/05	21:00	2.30
2008/11/12	04:37	3.65	2008/11/12	03:00	3.40	2008/11/12	03:00	3.66
2008/11/15	18:16	1.44	2008/11/15	18:00	1.70	2008/11/15	18:00	2.20
2008/11/22	02:35	2.31	2008/11/22	03:00	2.30	2008/11/22	03:00	2.51
2008/11/25	16:15	2.30	2008/11/25	15:00	2.20	2008/11/25	15:00	2.17
2008/12/02	00:34	3.48	2008/12/02	00:00	2.70	2008/12/02	00:00	2.97
2008/12/05	14:13	1.63	2008/12/05	15:00	1.50	2008/12/05	15:00	2.10
2008/12/11	22:32	1.50	2008/12/11	21:00	1.40	2008/12/11	21:00	1.40
2008/12/15	12:12	2.63	2008/12/15	12:00	2.00	2008/12/15	12:00	2.70
2008/12/21	20:31	3.52	2008/12/21	21:00	2.80	2008/12/21	21:00	3.31
2008/12/25	10:10	4.09	2008/12/25	09:00	4.40	2008/12/25	09:00	4.27
2008/12/31	18:29	2.51	2008/12/31	18:00	2.30	2008/12/31	18:00	2.98
2009/01/04	08:09	2.51	2009/01/04	09:00	2.00	2009/01/04	09:00	2.40
2009/01/10	16:28	2.27	2009/01/10	15:00	1.80	2009/01/10	15:00	2.00
2009/01/14	06:07	2.13	2009/01/14	06:00	2.10	2009/01/14	06:00	2.15
2009/01/20	14:26	2.41	2009/01/20	15:00	2.30	2009/01/20	15:00	2.95
2009/01/24	04:06	1.62	2009/01/24	03:00	1.70	2009/01/24	03:00	2.47
2009/01/30	12:25	2.10	2009/01/30	12:00	2.10	2009/01/30	12:00	2.58
2009/02/03	02:05	3.89	2009/02/03	03:00	3.40	2009/02/03	03:00	4.06
2009/02/09	10:24	2.36	2009/02/09	09:00	2.10	2009/02/09	09:00	2.96
2009/02/13	00:03	2.57	2009/02/13	00:00	2.60	2009/02/13	00:00	2.61
2009/02/19	08:22	2.37	2009/02/19	09:00	2.40	2009/02/19	09:00	3.56
2009/02/22	22:02	3.62	2009/02/22	21:00	3.50	2009/02/22	21:00	4.16
2009/03/01	06:21	3.30	2009/03/01	06:00	2.80	2009/03/01	06:00	3.62

2009/03/04	20:00	3.04	2009/03/04	21:00	3.10	2009/03/04	21:00	3.99
2009/03/11	04:19	2.00	2009/03/11	03:00	1.80	2009/03/11	03:00	2.19
2009/03/14	17:59	2.35	2009/03/14	18:00	2.60	2009/03/14	18:00	3.80
2009/03/21	02:18	2.63	2009/03/21	03:00	1.90	2009/03/21	03:00	2.84
2009/03/24	15:57	2.69	2009/03/24	15:00	2.30	2009/03/24	15:00	2.87
2009/03/31	00:16	2.32	2009/03/31	00:00	2.10	2009/03/31	00:00	2.58
2009/04/03	13:56	2.44	2009/04/03	15:00	2.50	2009/04/03	15:00	3.39
2009/04/09	22:15	3.25	2009/04/09	21:00	3.10	2009/04/09	21:00	3.27
2009/04/13	11:54	2.95	2009/04/13	12:00	2.60	2009/04/13	12:00	2.75
2009/04/19	20:13	2.93	2009/04/19	21:00	2.90	2009/04/19	21:00	4.18
2009/04/23	09:53	2.01	2009/04/23	09:00	2.30	2009/04/23	09:00	2.12
2009/04/29	18:12	1.61	2009/04/29	18:00	1.60	2009/04/29	18:00	1.98
2009/05/03	07:51	2.97	2009/05/03	09:00	2.90	2009/05/03	09:00	3.06
2009/05/09	16:10	2.13	2009/05/09	15:00	1.80	2009/05/09	15:00	2.21
2009/05/13	05:50	2.10	2009/05/13	06:00	1.90	2009/05/13	06:00	2.18
2009/05/19	14:09	3.62	2009/05/19	15:00	3.10	2009/05/19	15:00	4.39
2009/05/23	03:48	2.43	2009/05/23	03:00	2.00	2009/05/23	03:00	1.93
2009/05/29	12:07	4.76	2009/05/29	12:00	3.70	2009/05/29	12:00	4.50
2009/06/02	01:47	2.51	2009/06/02	00:00	2.50	2009/06/02	00:00	3.16
2009/06/08	10:06	2.72	2009/06/08	09:00	2.60	2009/06/08	09:00	2.96
2009/06/11	23:45	3.67	2009/06/11	21:00	2.50	2009/06/11	21:00	2.67
2009/06/18	08:04	3.90	2009/06/18	09:00	3.60	2009/06/18	09:00	4.63
2009/06/21	21:44	1.76	2009/06/21	21:00	1.50	2009/06/21	21:00	2.16
2009/06/28	06:03	3.40	2009/06/28	06:00	3.90	2009/06/28	06:00	3.78
2009/07/01	19:42	1.69	2009/07/01	18:00	1.70	2009/07/01	18:00	2.15
2009/07/08	04:01	2.86	2009/07/08	03:00	2.50	2009/07/08	03:00	2.98
2009/07/11	17:41	2.27	2009/07/11	18:00	NaN	2009/07/11	18:00	3.01
2009/07/18	02:00	1.55	2009/07/18	03:00	NaN	2009/07/18	03:00	1.97
2009/07/21	15:40	2.22	2009/07/21	15:00	NaN	2009/07/21	15:00	2.83
2009/07/27	23:58	2.04	2009/07/27	21:00	1.90	2009/07/27	21:00	1.85
2009/07/31	13:38	1.71	2009/07/31	12:00	1.70	2009/07/31	12:00	2.01
2009/08/06	21:57	4.41	2009/08/06	21:00	4.60	2009/08/06	21:00	5.15
2009/08/10	11:37	2.69	2009/08/10	12:00	2.60	2009/08/10	12:00	3.24
2009/08/16	19:55	3.68	2009/08/16	21:00	3.90	2009/08/16	21:00	3.82
2009/08/20	09:35	3.45	2009/08/20	09:00	3.50	2009/08/20	09:00	3.68
2009/08/26	17:54	4.12	2009/08/26	18:00	3.90	2009/08/26	18:00	5.58
2009/08/30	07:34	2.00	2009/08/30	06:00	1.90	2009/08/30	06:00	2.67
2009/09/05	15:53	3.89	2009/09/05	15:00	4.10	2009/09/05	15:00	4.51
2009/09/09	05:32	4.63	2009/09/09	06:00	4.30	2009/09/09	06:00	4.45
2009/09/15	13:51	3.88	2009/09/15	15:00	4.10	2009/09/15	15:00	3.77
2009/09/19	03:31	4.27	2009/09/19	03:00	4.10	2009/09/19	03:00	4.79
2009/09/25	11:50	1.61	2009/09/25	12:00	1.50	2009/09/25	12:00	1.57
2009/09/29	01:29	3.73	2009/09/29	00:00	4.10	2009/09/29	00:00	4.11
2009/10/05	09:48	1.41	2009/10/05	09:00	1.60	2009/10/05	09:00	1.62
2009/10/15	07:47	2.31	2009/10/15	06:00	2.60	2009/10/15	06:00	2.52
2009/10/18	21:26	1.93	2009/10/18	21:00	2.00	2009/10/18	21:00	2.37
2009/10/25	05:45	1.43	2009/10/25	06:00	1.30	2009/10/25	06:00	1.76
2009/10/28	19:25	3.35	2009/10/28	17:58	3.00	2009/10/28	18:00	3.08
2009/11/04	03:44	3.35	2009/11/04	03:00	3.00	2009/11/04	03:00	3.46
2009/11/07	17:23	2.97	2009/11/07	18:00	3.10	2009/11/07	18:00	2.47
2009/11/14	01:42	4.79	2009/11/14	00:00	4.20	2009/11/14	00:00	4.51

2009/11/17	15:22	4.34	2009/11/17	15:01	3.70	2009/11/17	15:00	4.19
2009/11/23	23:41	3.07	2009/11/23	21:00	NaN	2009/11/23	21:00	2.78
2009/11/27	13:20	2.21	2009/11/27	12:00	NaN	2009/11/27	12:00	2.36
2009/12/03	21:39	1.52	2009/12/03	21:00	1.30	2009/12/03	21:00	2.02
2009/12/07	11:19	2.68	2009/12/07	12:00	2.80	2009/12/07	12:00	3.08
2009/12/13	19:38	3.13	2009/12/13	18:00	2.80	2009/12/13	18:00	3.22
2009/12/17	09:17	2.10	2009/12/17	09:00	1.70	2009/12/17	09:00	2.36
2009/12/23	17:36	2.69	2009/12/23	18:00	2.90	2009/12/23	18:00	3.62
2009/12/27	07:16	3.70	2009/12/27	06:00	2.90	2009/12/27	06:00	4.02
2010/01/02	15:35	2.88	2010/01/02	15:00	2.40	2010/01/02	15:00	3.12
2010/01/06	05:14	2.86	2010/01/06	06:00	2.90	2010/01/06	06:00	2.63
2010/01/12	13:33	3.64	2010/01/12	12:00	5.10	2010/01/12	12:00	4.11
2010/01/16	03:13	4.62	2010/01/16	03:00	4.00	2010/01/16	03:00	4.44
2010/01/22	11:32	2.29	2010/01/22	12:00	2.30	2010/01/22	12:00	2.71
2010/01/26	01:12	3.67	2010/01/26	00:00	3.30	2010/01/26	00:00	4.07
2010/02/01	09:30	4.24	2010/02/01	09:00	3.60	2010/02/01	09:00	4.00
2010/02/04	23:10	3.83	2010/02/04	21:00	3.30	2010/02/04	21:00	4.16
2010/02/11	07:29	3.05	2010/02/11	06:00	2.40	2010/02/11	06:00	4.95
2010/02/14	21:09	3.18	2010/02/14	21:00	3.10	2010/02/14	21:00	3.50
2010/02/21	05:28	2.22	2010/02/21	06:00	2.30	2010/02/21	06:00	2.82
2010/02/24	19:07	2.72	2010/02/24	18:00	2.50	2010/02/24	18:00	2.68
2010/03/03	03:26	2.95	2010/03/03	03:00	3.70	2010/03/03	03:00	3.54
2010/03/06	17:06	1.85	2010/03/06	18:00	1.40	2010/03/06	18:00	1.75
2010/03/13	01:25	2.13	2010/03/13	00:00	2.20	2010/03/13	00:00	2.42
2010/03/16	15:04	1.79	2010/03/16	15:00	1.80	2010/03/16	15:00	2.05
2010/03/22	23:23	2.20	2010/03/22	21:00	1.70	2010/03/22	21:00	2.21
2010/03/26	13:03	1.93	2010/03/26	12:00	1.70	2010/03/26	12:00	2.10
2010/04/01	21:22	1.98	2010/04/01	21:00	1.80	2010/04/01	21:00	2.62
2010/04/05	11:01	3.28	2010/04/05	12:00	3.60	2010/04/05	12:00	3.93
2010/04/11	19:20	2.68	2010/04/11	18:00	2.60	2010/04/11	18:00	3.15
2010/04/15	09:00	2.34	2010/04/15	09:00	2.40	2010/04/15	09:00	2.51
2010/04/21	17:19	2.52	2010/04/21	18:00	2.70	2010/04/21	18:00	3.58
2010/04/25	06:58	2.51	2010/04/25	06:00	2.50	2010/04/25	06:00	2.39
2010/05/01	15:17	2.75	2010/05/01	15:00	2.80	2010/05/01	15:00	4.77
2010/05/05	04:57	2.94	2010/05/05	06:00	2.70	2010/05/05	06:00	4.14
2010/05/11	13:16	4.47	2010/05/11	12:00	4.70	2010/05/11	12:00	5.41
2010/05/15	02:55	4.73	2010/05/15	03:00	4.30	2010/05/15	03:00	4.92
2010/05/21	11:14	2.65	2010/05/21	12:00	2.50	2010/05/21	12:00	2.30
2010/05/25	00:54	2.86	2010/05/25	00:00	2.30	2010/05/25	00:00	3.13
2010/05/31	09:13	2.91	2010/05/31	09:00	2.60	2010/05/31	09:00	3.42
2010/06/03	22:52	1.92	2010/06/03	21:00	2.00	2010/06/03	21:00	1.84
2010/06/10	07:11	1.91	2010/06/10	06:00	2.30	2010/06/10	06:00	2.34
2010/06/13	20:51	3.38	2010/06/13	21:00	3.20	2010/06/13	21:00	4.02
2010/06/20	05:10	1.86	2010/06/20	06:00	1.70	2010/06/20	06:00	2.05
2010/06/23	18:49	1.78	2010/06/23	18:00	1.80	2010/06/23	18:00	2.26
2010/06/30	03:08	3.97	2010/06/30	03:00	3.70	2010/06/30	03:00	5.05
2010/07/03	16:48	2.66	2010/07/03	15:00	2.50	2010/07/03	15:00	2.69
2010/07/10	01:07	3.76	2010/07/10	00:00	3.60	2010/07/10	00:00	3.68
2010/07/13	14:46	1.85	2010/07/13	15:00	1.90	2010/07/13	15:00	2.10
2010/07/19	23:05	2.61	2010/07/19	21:00	2.20	2010/07/19	21:00	2.48
2010/07/23	12:45	2.82	2010/07/23	12:00	2.50	2010/07/23	12:00	3.76

2010/07/29	21:04	3.57	2010/07/29	21:00	3.60	2010/07/29	21:00	3.86
2010/08/02	10:43	2.28	2010/08/02	09:00	2.10	2010/08/02	09:00	2.45
2010/08/08	19:02	5.79	2010/08/08	18:00	5.20	2010/08/08	18:00	6.51
2010/08/12	08:42	1.89	2010/08/12	09:00	NaN	2010/08/12	09:00	1.73
2010/08/18	17:01	4.05	2010/08/18	18:00	NaN	2010/08/18	18:00	3.84
2010/08/22	06:41	3.44	2010/08/22	06:00	NaN	2010/08/22	06:00	4.49
2010/08/28	14:59	4.22	2010/08/28	15:00	NaN	2010/08/28	15:00	3.59
2010/09/01	04:39	2.44	2010/09/01	03:00	3.10	2010/09/01	03:00	3.46
2010/09/07	12:58	3.11	2010/09/07	12:00	2.90	2010/09/07	12:00	3.28
2010/09/11	02:38	3.67	2010/09/11	03:00	3.20	2010/09/11	03:00	3.78
2010/09/17	10:57	4.69	2010/09/17	12:00	4.10	2010/09/17	12:00	4.36
2010/09/21	00:36	2.26	2010/09/21	00:00	1.70	2010/09/21	00:00	1.90
2010/09/27	08:55	3.74	2010/09/27	09:00	3.60	2010/09/27	09:00	4.31
2010/09/30	22:35	3.19	2010/09/30	21:00	2.50	2010/09/30	21:00	2.81
2010/10/07	06:54	2.60	2010/10/07	06:00	2.20	2010/10/07	06:00	2.97
2010/10/10	20:33	4.06	2010/10/10	21:00	3.70	2010/10/10	21:00	5.27
2010/10/17	04:52	2.12	2010/10/17	06:00	2.20	2010/10/17	06:00	2.05
2010/10/20	18:32	1.87	2010/10/20	18:00	1.90	2010/10/20	18:00	1.94
2010/10/27	02:51	1.75	2010/10/27	03:00	1.90	2010/10/27	03:00	2.20
2010/10/30	16:30	2.74	2010/10/30	15:00	2.60	2010/10/30	15:00	3.28
2010/11/06	00:49	2.10	2010/11/06	00:00	2.20	2010/11/06	00:00	2.92
2010/11/09	14:29	2.30	2010/11/09	15:00	2.20	2010/11/09	15:00	2.76
2010/11/15	22:48	2.13	2010/11/15	21:00	2.20	2010/11/15	21:00	2.31
2010/11/19	12:27	1.76	2010/11/19	12:00	1.80	2010/11/19	12:00	2.29
2010/11/25	20:46	2.49	2010/11/25	21:00	2.70	2010/11/25	21:00	3.23
2010/11/29	10:26	2.27	2010/11/29	09:00	2.20	2010/11/29	09:00	2.88
2010/12/05	18:45	3.15	2010/12/05	18:00	3.00	2010/12/05	18:00	4.01
2010/12/09	08:24	1.85	2010/12/09	09:00	1.80	2010/12/09	09:00	2.08
2010/12/15	16:43	2.66	2010/12/15	15:00	2.40	2010/12/15	15:00	2.93
2010/12/19	06:23	1.63	2010/12/19	06:00	1.80	2010/12/19	06:00	2.05
2010/12/25	14:42	1.75	2010/12/25	15:00	2.00	2010/12/25	15:00	2.42
2010/12/29	04:21	2.09	2010/12/29	03:00	2.00	2010/12/29	03:00	2.57
2011/01/04	12:40	3.22	2011/01/04	12:00	3.10	2011/01/04	12:00	3.83
2011/01/08	02:20	1.56	2011/01/08	03:00	1.80	2011/01/08	03:00	2.34
2011/01/14	10:39	2.65	2011/01/14	09:00	2.40	2011/01/14	09:00	2.88
2011/01/18	00:18	3.83	2011/01/18	00:00	4.20	2011/01/18	00:00	3.94
2011/01/24	08:37	2.42	2011/01/24	09:00	2.20	2011/01/24	09:00	2.42
2011/01/27	22:17	3.36	2011/01/27	21:00	2.50	2011/01/27	21:00	3.21
2011/02/03	06:36	3.31	2011/02/03	06:00	2.90	2011/02/03	06:00	3.95
2011/02/06	20:15	2.75	2011/02/06	21:00	1.60	2011/02/06	21:00	2.13
2011/02/13	04:34	1.51	2011/02/13	03:00	1.40	2011/02/13	03:00	1.64
2011/02/16	18:14	2.10	2011/02/16	18:00	1.90	2011/02/16	18:00	2.30
2011/02/23	02:33	2.80	2011/02/23	03:00	2.80	2011/02/23	03:00	3.18
2011/02/26	16:12	1.80	2011/02/26	15:00	1.70	2011/02/26	15:00	2.37
2011/03/05	00:31	1.91	2011/03/05	00:00	1.50	2011/03/05	00:00	1.87
2011/03/08	14:11	1.52	2011/03/08	15:00	1.60	2011/03/08	15:00	1.80
2011/03/14	22:30	4.46	2011/03/14	21:00	4.90	2011/03/14	21:00	4.90
2011/03/18	12:10	1.80	2011/03/18	12:00	1.70	2011/03/18	12:00	2.43
2011/03/24	20:28	2.13	2011/03/24	21:00	1.90	2011/03/24	21:00	2.31
2011/03/28	10:08	3.02	2011/03/28	09:00	3.10	2011/03/28	09:00	3.20
2011/04/03	18:27	2.56	2011/04/03	18:00	2.30	2011/04/03	18:00	2.87

2011/04/07	08:07	4.21	2011/04/07	09:00	3.80	2011/04/07	09:00	3.39
2011/04/13	16:26	1.82	2011/04/13	15:00	1.40	2011/04/13	15:00	1.95
2011/04/17	06:05	2.77	2011/04/17	06:00	2.60	2011/04/17	06:00	3.37
2011/04/23	14:24	1.62	2011/04/23	15:00	1.80	2011/04/23	15:00	2.50
2011/04/27	04:04	6.63	2011/04/27	03:00	6.10	2011/04/27	03:00	6.91
2011/05/03	12:23	2.07	2011/05/03	12:00	2.00	2011/05/03	12:00	2.54
2011/05/07	02:02	3.83	2011/05/07	03:00	3.60	2011/05/07	03:00	3.65
2011/05/13	10:21	1.44	2011/05/13	09:00	1.60	2011/05/13	09:00	1.59
2011/05/17	00:01	2.02	2011/05/17	00:00	1.70	2011/05/17	00:00	2.07
2011/05/23	08:20	1.91	2011/05/23	09:01	1.80	2011/05/23	09:00	1.86
2011/05/26	21:59	2.41	2011/05/26	21:00	2.20	2011/05/26	21:00	2.66
2011/06/02	06:18	4.04	2011/06/02	06:00	3.90	2011/06/02	06:00	4.93
2011/06/12	04:17	3.77	2011/06/12	03:00	3.40	2011/06/12	03:00	3.08
2011/06/15	17:56	3.07	2011/06/15	18:00	2.80	2011/06/15	18:00	2.99
2011/06/22	02:15	2.54	2011/06/22	03:00	2.40	2011/06/22	03:00	1.89
2011/06/25	15:55	4.53	2011/06/25	15:00	4.20	2011/06/25	15:00	4.73
2011/07/02	00:14	3.75	2011/07/02	00:00	3.00	2011/07/02	00:00	3.57
2011/07/05	13:53	2.44	2011/07/05	15:00	2.30	2011/07/05	15:00	2.49
2011/07/11	22:12	1.00	NaN	NaN	NaN	2011/07/11	21:00	0.97
2011/07/15	11:52	2.34	NaN	NaN	NaN	2011/07/15	12:00	2.87
2011/07/21	20:11	2.19	NaN	NaN	NaN	2011/07/21	21:00	2.35
2011/07/25	09:50	3.79	NaN	NaN	NaN	2011/07/25	09:00	4.04
2011/07/31	18:09	4.28	NaN	NaN	NaN	2011/07/31	18:00	3.75
2011/08/04	07:49	2.53	NaN	NaN	NaN	2011/08/04	06:00	2.34
2011/08/10	16:08	3.35	NaN	NaN	NaN	2011/08/10	15:00	3.33
2011/08/14	05:47	5.09	NaN	NaN	NaN	2011/08/14	06:00	5.26
2011/08/20	14:06	2.46	NaN	NaN	NaN	2011/08/20	15:00	2.87
2011/08/24	03:46	3.43	NaN	NaN	NaN	2011/08/24	03:00	3.49
2011/08/30	12:05	1.93	NaN	NaN	NaN	2011/08/30	12:00	2.16
2011/09/03	01:44	6.12	NaN	NaN	NaN	2011/09/03	00:00	7.07
2011/09/09	10:03	2.48	NaN	NaN	NaN	2011/09/09	09:00	3.27
2011/09/12	23:43	2.95	NaN	NaN	NaN	2011/09/12	21:00	3.38
2011/09/19	08:02	4.30	NaN	NaN	NaN	2011/09/19	09:00	4.40
2011/09/22	21:41	2.40	NaN	NaN	NaN	2011/09/22	21:00	3.00
2011/09/29	06:00	2.97	NaN	NaN	NaN	2011/09/29	06:00	3.30
2011/10/02	19:40	2.48	NaN	NaN	NaN	2011/10/02	18:00	2.67
2011/10/09	03:59	3.00	NaN	NaN	NaN	2011/10/09	03:00	3.33
2011/10/12	17:39	3.73	NaN	NaN	NaN	2011/10/12	18:00	4.13
2011/10/19	01:57	2.71	NaN	NaN	NaN	2011/10/19	03:00	3.52
2011/10/22	15:37	1.69	NaN	NaN	NaN	2011/10/22	15:00	2.27
2011/10/28	23:56	2.50	NaN	NaN	NaN	2011/10/28	21:00	2.90
2011/11/01	13:36	3.64	NaN	NaN	NaN	2011/11/01	12:00	4.18
2011/11/07	21:55	1.90	NaN	NaN	NaN	2011/11/07	21:00	2.10
2011/11/11	11:34	2.87	NaN	NaN	NaN	2011/11/11	12:00	3.08
2011/11/17	19:53	2.94	NaN	NaN	NaN	2011/11/17	21:00	2.91
2011/11/21	09:33	3.18	NaN	NaN	NaN	2011/11/21	09:00	3.90
2011/11/27	17:52	3.41	NaN	NaN	NaN	2011/11/27	18:00	3.83
2011/12/01	07:31	2.18	NaN	NaN	NaN	2011/12/01	06:00	2.45
2011/12/07	15:50	3.49	NaN	NaN	NaN	2011/12/07	15:00	4.12
2011/12/11	05:30	2.46	NaN	NaN	NaN	2011/12/11	06:00	3.10
2011/12/17	13:49	1.88	NaN	NaN	NaN	2011/12/17	12:00	2.38

2011/12/21	03:28	3.04	NaN	NaN	NaN	2011/12/21	03:00	2.76
2011/12/27	11:47	1.22	NaN	NaN	NaN	2011/12/27	12:00	1.88
2011/12/31	01:27	1.64	NaN	NaN	NaN	2011/12/31	00:00	2.12
2012/01/06	09:46	1.88	NaN	NaN	NaN	2012/01/06	09:00	2.24
2012/01/09	23:25	2.04	NaN	NaN	NaN	2012/01/09	21:00	2.22
2012/01/16	07:44	2.84	NaN	NaN	NaN	2012/01/16	06:00	3.41
2012/01/19	21:24	1.97	NaN	NaN	NaN	2012/01/19	21:00	2.41
2012/01/26	05:43	2.15	NaN	NaN	NaN	2012/01/26	06:00	2.29
2012/01/29	19:22	2.21	NaN	NaN	NaN	2012/01/29	18:00	2.73
2012/02/05	03:41	1.93	NaN	NaN	NaN	2012/02/05	03:00	2.67
2012/02/08	17:21	2.03	NaN	NaN	NaN	2012/02/08	18:00	2.81
2012/02/15	01:40	3.33	NaN	NaN	NaN	2012/02/15	00:00	3.85
2012/02/18	15:19	2.65	NaN	NaN	NaN	2012/02/18	15:00	3.10
2012/02/24	23:38	3.23	NaN	NaN	NaN	2012/02/24	21:00	2.70
2012/02/28	13:18	2.32	NaN	NaN	NaN	2012/02/28	12:00	2.46
2012/03/05	21:37	3.25	NaN	NaN	NaN	2012/03/05	21:00	4.02
2012/03/09	11:16	2.08	NaN	NaN	NaN	2012/03/09	12:00	2.52
2012/03/15	19:35	1.78	NaN	NaN	NaN	2012/03/15	18:00	2.04
2012/03/19	09:15	2.98	NaN	NaN	NaN	2012/03/19	09:00	4.25
2012/03/25	17:34	2.53	NaN	NaN	NaN	2012/03/25	18:00	2.40
2012/03/29	07:14	1.83	NaN	NaN	NaN	2012/03/29	06:00	2.77
2012/04/04	15:32	2.77	NaN	NaN	NaN	2012/04/04	15:00	3.58
2012/04/08	05:12	5.07	2012/04/08	05:10	4.30	2012/04/08	06:00	5.49
2012/04/14	13:31	1.86	2012/04/14	02:50	3.30	2012/04/14	12:00	1.97
2012/04/18	03:11	3.20	2012/04/18	03:10	1.20	2012/04/18	03:00	3.32
2012/04/24	11:29	2.05	2012/04/24	11:30	2.70	2012/04/24	12:00	3.02
2012/04/28	01:09	1.73	2012/04/28	01:10	1.70	2012/04/28	00:00	1.67
2012/05/04	09:28	3.61	2012/05/04	09:30	3.60	2012/05/04	09:00	4.12
2012/05/07	23:08	2.90	2012/05/07	23:10	2.20	2012/05/07	21:00	2.41
2012/05/14	07:27	2.66	2012/05/14	10:50	2.60	2012/05/14	06:00	3.42
2012/05/17	21:06	4.45	2012/05/17	21:10	NaN	2012/05/17	21:00	4.61
2012/05/24	05:25	2.46	2012/05/24	05:20	2.10	2012/05/24	06:00	2.31
2012/05/27	19:05	2.29	2012/05/27	19:00	2.20	2012/05/27	18:00	2.06
2012/06/03	03:24	2.20	2012/06/03	03:20	1.70	2012/06/03	03:00	2.48
2012/06/06	17:03	4.64	2012/06/06	17:00	4.70	2012/06/06	18:00	4.89
2012/06/13	01:22	4.87	2012/06/13	01:20	5.80	2012/06/13	00:00	5.42
2012/06/16	15:02	2.38	2012/06/16	15:00	2.50	2012/06/16	15:00	2.44
2012/06/22	23:21	2.50	2012/06/22	23:20	2.90	2012/06/22	21:00	2.96
2012/06/26	13:00	2.32	2012/06/26	13:00	2.40	2012/06/26	12:00	2.06
2012/07/02	21:19	3.36	2012/07/02	21:20	NaN	2012/07/02	21:00	3.53
2012/07/06	10:59	3.00	2012/07/06	10:50	3.40	2012/07/06	12:00	3.09
2012/07/12	19:18	3.93	2012/07/12	19:20	3.40	2012/07/12	18:00	4.38
2012/07/16	08:57	3.29	2012/07/16	08:50	2.80	2012/07/16	09:00	3.76
2012/07/22	17:16	4.29	2012/07/22	17:20	4.20	2012/07/22	18:00	4.03
2012/07/26	06:56	2.46	2012/07/26	06:50	NaN	2012/07/26	06:00	2.15
2012/08/01	15:15	3.81	2012/08/02	15:40	NaN	2012/08/01	15:00	4.05
2012/08/05	04:54	2.45	2012/08/05	04:50	2.80	2012/08/05	06:00	3.04
2012/08/11	13:13	3.96	2012/08/11	13:10	4.20	2012/08/11	12:00	4.75
2012/08/15	02:53	3.01	2012/08/15	02:50	3.50	2012/08/15	03:00	3.78
2012/08/21	11:12	3.15	2012/08/21	11:10	2.80	2012/08/21	12:00	3.83
2012/08/25	00:51	2.27	2012/08/25	00:50	NaN	2012/08/25	00:00	1.59

2012/08/31	09:10	2.25	2012/08/31	09:10	NaN	2012/08/31	09:00	2.86
2012/09/03	22:50	3.75	2012/09/03	22:50	3.50	2012/09/03	21:00	4.45
2012/09/10	07:09	4.10	2012/09/10	07:10	4.80	2012/09/10	06:00	4.83
2012/09/13	20:48	2.49	2012/09/13	20:50	2.50	2012/09/13	21:00	3.01
2012/09/20	05:07	2.45	2012/09/20	05:10	2.60	2012/09/20	06:00	2.30
2012/09/23	18:47	6.38	2012/09/23	18:50	6.80	2012/09/23	18:00	6.13
2012/09/30	03:06	3.25	2012/09/30	03:10	3.40	2012/09/30	03:00	3.45
2012/10/03	16:45	3.38	2012/10/03	16:40	2.90	2012/10/03	15:00	3.71
2012/10/10	01:04	2.77	2012/10/10	01:00	3.00	2012/10/10	00:00	2.61
2012/10/13	14:44	3.48	2012/10/13	14:40	3.10	2012/10/13	15:00	3.43
2012/10/19	23:03	4.89	2012/10/19	23:00	4.50	2012/10/19	21:00	4.47
2012/10/23	12:42	2.30	2012/10/23	12:40	2.20	2012/10/23	12:00	2.37
2012/10/29	21:01	2.88	2012/10/29	21:00	2.90	2012/10/29	21:00	3.56
2012/11/02	10:41	3.22	2012/11/02	10:40	3.80	2012/11/02	09:00	3.12
2012/11/08	19:00	2.18	2012/11/08	19:00	2.00	2012/11/08	18:00	2.55
2012/11/12	08:40	2.47	2012/11/12	08:40	2.30	2012/11/12	09:00	2.61
2012/11/18	16:59	2.54	2012/11/18	16:50	3.40	2012/11/18	18:00	2.60
2012/11/22	06:38	4.13	2012/11/22	06:40	4.10	2012/11/22	06:00	4.00
2012/11/28	14:57	1.88	2012/11/28	14:50	1.70	2012/11/28	15:00	1.95
2012/12/02	04:37	2.15	2012/12/02	04:40	NaN	2012/12/02	03:00	2.06
2012/12/08	12:56	1.36	2012/12/07	22:00	NaN	2012/12/08	12:00	1.88
2012/12/12	02:35	1.74	2012/12/07	22:00	NaN	2012/12/12	03:00	2.00
2012/12/18	10:54	1.52	2012/12/24	05:30	2.50	2012/12/18	12:00	2.40
2012/12/22	00:34	1.63	2012/12/24	05:30	2.50	2012/12/22	00:00	1.83
2012/12/28	08:53	3.40	2012/12/28	08:50	4.00	2012/12/28	09:00	4.03
2012/12/31	22:32	3.77	2012/12/31	22:30	4.70	2012/12/31	21:00	3.72
2013/01/07	06:51	3.12	2013/01/07	06:50	NaN	2013/01/07	06:00	3.40
2013/01/10	20:31	4.43	2013/01/10	20:30	3.90	2013/01/10	21:00	3.97
2013/01/17	04:50	2.57	2013/01/17	04:50	2.40	2013/01/17	03:00	2.57
2013/01/20	18:29	1.60	2013/01/20	18:30	1.80	2013/01/20	18:00	1.89
2013/01/27	02:48	2.28	2013/01/27	02:50	2.10	2013/01/27	03:00	2.53
2013/01/30	16:28	1.64	2013/01/30	16:30	1.70	2013/01/30	15:00	2.25
2013/02/06	00:47	2.01	2013/02/06	00:50	2.10	2013/02/06	00:00	2.22
2013/02/09	14:26	1.69	2013/02/09	14:30	1.10	2013/02/09	15:00	2.41
2013/02/15	22:45	2.64	2013/02/13	15:40	1.60	2013/02/15	21:00	3.33
2013/02/19	12:25	3.15	2013/02/13	15:40	1.60	2013/02/19	12:00	4.15
2013/02/25	20:44	2.56	2013/02/13	15:40	1.60	2013/02/25	21:00	2.58
2013/03/01	10:23	2.83	2013/03/01	10:20	3.50	2013/03/01	09:00	3.10
2013/03/07	18:42	3.63	2013/03/07	18:40	3.60	2013/03/07	18:00	4.05
2013/03/11	08:22	2.89	2013/03/11	08:10	3.20	2013/03/11	09:00	2.99
2013/03/17	16:41	1.59	2013/03/17	16:40	NaN	2013/03/17	15:00	2.43
2013/03/21	06:20	1.63	2013/03/21	06:20	2.00	2013/03/21	06:00	1.71
2013/04/06	12:38	2.49	2013/04/06	12:40	3.00	2013/04/06	12:00	2.97
2013/04/10	02:17	3.97	2013/04/10	02:20	3.70	2013/04/10	03:00	5.13
2013/04/16	10:36	1.35	2013/04/16	16:40	1.60	2013/04/16	09:00	1.69
2013/04/20	00:16	2.48	2013/04/19	07:40	NaN	2013/04/20	00:00	2.98
2013/04/26	08:35	1.69	2013/04/25	21:40	1.70	2013/04/26	09:00	1.93
2013/04/29	22:15	2.22	2013/04/25	21:40	1.70	2013/04/29	21:00	2.49
2013/05/06	06:33	2.87	2013/05/06	06:30	2.70	2013/05/06	06:00	2.57
2013/05/09	20:13	3.95	2013/05/09	20:10	2.70	2013/05/09	21:00	4.09
2013/05/16	04:32	2.55	2013/05/16	04:30	2.40	2013/05/16	03:00	2.55

2013/05/19	18:12	1.97	2013/05/19	18:10	1.90	2013/05/19	18:00	1.87
2013/05/26	02:31	1.74	2013/05/26	02:30	1.10	2013/05/26	03:00	2.22
2013/05/29	16:10	2.10	2013/05/29	16:10	2.80	2013/05/29	15:00	3.05
2013/06/05	00:29	5.21	2013/06/05	00:30	4.80	2013/06/05	00:00	5.94
2013/06/08	14:09	5.13	2013/06/08	14:10	5.10	2013/06/08	15:00	4.84
2013/06/14	22:28	5.58	2013/06/14	22:30	NaN	2013/06/14	21:00	7.34
2013/06/18	12:07	2.24	2013/06/18	12:10	2.70	2013/06/18	12:00	2.66
2013/06/24	20:26	2.14	2013/06/24	20:30	1.90	2013/06/24	21:00	2.34
2013/06/28	10:06	2.94	2013/06/28	15:30	1.20	2013/06/28	09:00	2.53
2013/07/04	18:25	3.37	2013/07/04	18:20	3.20	2013/07/04	18:00	3.69
2013/07/08	08:04	2.86	2013/07/08	08:00	3.00	2013/07/08	09:00	3.38
2013/07/14	16:23	3.94	2013/07/12	17:20	NaN	2013/07/14	15:00	3.81
2013/07/18	06:03	6.16	2013/07/19	05:50	3.70	2013/07/18	06:00	4.29
2013/07/24	14:22	3.74	2013/07/24	14:20	3.30	2013/07/24	15:00	4.31
2013/07/28	04:01	4.64	2013/07/28	04:00	4.10	2013/07/28	03:00	5.84
2013/08/03	12:20	2.45	2013/08/03	12:20	2.50	2013/08/03	12:00	2.84
2013/08/07	02:00	3.13	2013/08/06	09:30	NaN	2013/08/07	03:00	4.06
2013/08/13	10:19	2.94	2013/08/13	06:30	3.10	2013/08/13	09:00	4.06
2013/08/16	23:58	4.69	2013/08/17	10:00	7.20	2013/08/16	21:00	5.79
2013/08/23	08:17	3.60	2013/08/23	08:20	3.90	2013/08/23	09:00	4.23
2013/08/26	21:57	2.92	2013/08/26	21:50	2.60	2013/08/26	21:00	3.01
2013/09/02	06:16	2.65	2013/09/02	06:20	3.00	2013/09/02	06:00	2.19
2013/09/15	17:54	6.60	2013/09/15	17:50	6.40	2013/09/15	18:00	7.61
2013/09/22	02:13	3.46	2013/09/19	12:00	4.30	2013/09/22	03:00	3.82
2013/09/25	15:52	2.60	2013/09/25	15:50	2.60	2013/09/25	15:00	3.24
2013/10/02	00:11	1.22	2013/10/02	12:10	1.70	2013/10/02	00:00	1.31
2013/10/05	13:51	2.37	2013/10/05	13:50	NaN	2013/10/05	15:00	3.26
2013/10/11	22:10	3.89	2013/10/12	13:50	NaN	2013/10/11	21:00	4.72
2013/10/15	11:49	2.33	2013/10/15	19:30	2.00	2013/10/15	12:00	2.40
2013/10/21	20:08	2.52	2013/10/21	20:10	NaN	2013/10/21	21:00	2.75
2013/10/25	09:48	2.58	2013/10/24	07:10	NaN	2013/10/25	09:00	2.57
2013/10/31	18:07	3.12	2013/10/31	18:10	2.90	2013/10/31	18:00	2.01
2013/11/04	07:46	2.09	2013/11/04	07:50	2.10	2013/11/04	06:00	2.44
2013/11/10	16:05	3.72	2013/11/10	16:00	3.20	2013/11/10	15:00	2.38
2013/11/14	05:45	1.89	2013/11/14	05:40	1.60	2013/11/14	06:00	1.56
2013/11/20	14:04	3.37	2013/11/20	14:00	2.70	2013/11/20	15:00	4.30
2013/11/24	03:44	3.68	2013/11/22	13:50	3.00	2013/11/24	03:00	3.59
2013/11/30	12:03	3.16	2013/11/22	13:50	3.00	2013/11/30	12:00	3.54
2013/12/04	01:42	2.12	2013/11/22	13:50	3.00	2013/12/04	00:00	2.99
2013/12/10	10:01	1.82	2013/11/22	13:50	3.00	2013/12/10	09:00	2.00
2013/12/13	23:41	1.77	2013/11/22	13:50	3.00	2013/12/13	21:00	1.95
2013/12/20	08:00	1.81	2013/11/22	13:50	3.00	2013/12/20	09:00	2.17
2013/12/23	21:39	1.75	2013/11/22	13:50	3.00	2013/12/23	21:00	2.82
2013/12/30	05:58	2.71	2013/11/22	13:50	3.00	2013/12/30	06:00	2.96
2014/01/02	19:38	1.77	2014/01/06	11:20	3.10	2014/01/02	18:00	2.32
2014/01/09	03:57	2.33	2014/01/09	03:50	2.10	2014/01/09	03:00	3.26
2014/01/12	17:36	2.61	2014/01/12	17:40	2.30	2014/01/12	18:00	3.83
2014/01/19	01:55	1.89	2014/01/19	01:50	1.80	2014/01/19	03:00	2.58
2014/01/22	15:35	1.84	2014/01/22	15:30	2.10	2014/01/22	15:00	2.12
2014/01/28	23:54	3.51	2014/01/28	23:50	NaN	2014/01/28	21:00	3.53
2014/02/01	13:33	2.47	2014/02/01	13:30	2.30	2014/02/01	12:00	2.52

2014/02/07	21:52	1.89	2014/02/04	10:00	1.50	2014/02/07	21:00	2.67
2014/02/11	11:32	3.05	2014/02/13	14:50	NaN	2014/02/11	12:00	2.66
2014/02/17	19:51	3.14	2014/02/17	19:50	3.20	2014/02/17	21:00	3.12
2014/02/21	09:30	3.26	2014/02/21	09:30	3.20	2014/02/21	09:00	2.86
2014/02/27	17:49	2.68	2014/02/27	17:50	2.30	2014/02/27	18:00	3.48
2014/03/03	07:29	3.23	2014/03/03	07:30	3.40	2014/03/03	06:00	3.99
2014/03/09	15:48	3.13	2014/03/09	15:50	2.70	2014/03/09	15:00	3.47
2014/03/13	05:27	3.18	2014/03/13	05:30	4.30	2014/03/13	06:00	4.30
2014/03/19	13:46	4.33	2014/03/19	13:50	4.20	2014/03/19	12:00	4.74
2014/03/23	03:26	2.47	2014/03/23	03:30	1.10	2014/03/23	03:00	2.81
2014/03/29	11:45	1.86	2014/03/29	11:40	1.80	2014/03/29	12:00	2.56
2014/04/02	01:24	3.15	2014/04/02	01:20	2.30	2014/04/02	00:00	4.07
2014/04/08	09:43	1.80	2014/04/08	09:40	1.10	2014/04/08	09:00	2.10
2014/04/11	23:23	1.19	2014/04/11	23:20	NaN	2014/04/11	21:00	1.58
2014/04/18	07:42	2.70	2014/04/18	07:40	NaN	2014/04/18	06:00	2.50
2014/04/21	21:21	2.78	2014/04/21	21:20	2.60	2014/04/21	21:00	2.81
2014/04/28	05:40	2.02	2014/04/28	05:40	1.90	2014/04/28	06:00	2.45
2014/05/01	19:20	1.98	2014/05/03	07:50	1.90	2014/05/01	18:00	2.15
2014/05/08	03:39	2.57	2014/05/08	03:40	2.40	2014/05/08	03:00	2.40
2014/05/11	17:19	3.42	2014/05/11	10:40	NaN	2014/05/11	18:00	3.15
2014/05/18	01:37	2.90	2014/05/18	01:40	3.00	2014/05/18	00:00	3.17
2014/05/21	15:17	3.61	2014/05/21	15:20	2.00	2014/05/21	15:00	3.42
2014/05/27	23:36	2.49	2014/05/27	23:40	NaN	2014/05/27	21:00	2.47
2014/05/31	13:16	2.44	2014/05/28	13:10	NaN	2014/05/31	12:00	2.98
2014/06/06	21:35	3.07	2014/06/06	21:30	3.00	2014/06/06	21:00	3.04
2014/06/10	11:14	4.57	2014/06/10	11:10	3.60	2014/06/10	12:00	5.06
2014/06/16	19:33	3.80	2014/06/16	19:30	4.00	2014/06/16	18:00	3.91
2014/06/20	09:13	5.13	2014/06/20	09:10	4.10	2014/06/20	09:00	5.62
2014/06/26	17:32	4.58	2014/06/26	17:30	3.80	2014/06/26	18:00	5.33
2014/06/30	07:11	4.29	2014/06/30	07:10	5.80	2014/06/30	06:00	4.31
2014/07/06	15:30	2.98	2014/07/06	15:30	2.40	2014/07/06	15:00	3.59
2014/07/10	05:10	3.41	2014/07/10	20:20	3.10	2014/07/10	06:00	3.83
2014/07/16	13:29	1.67	2014/07/16	13:30	1.60	2014/07/16	12:00	1.72
2014/07/20	03:08	4.52	2014/07/20	03:10	4.70	2014/07/20	03:00	5.58
2014/07/26	11:27	4.08	2014/07/28	03:50	3.00	2014/07/26	12:00	5.80
2014/07/30	01:07	2.31	2014/07/30	01:10	NaN	2014/07/30	00:00	2.49
2014/08/05	09:26	2.44	2014/08/05	09:30	2.30	2014/08/05	09:00	2.81
2014/08/08	23:05	2.14	2014/08/08	23:00	2.00	2014/08/08	21:00	1.83
2014/08/15	07:24	2.12	2014/08/15	07:20	1.70	2014/08/15	06:00	2.39
2014/08/18	21:04	2.08	2014/08/18	21:00	2.10	2014/08/18	21:00	2.86
2014/08/25	05:23	3.61	2014/08/27	03:50	NaN	2014/08/25	06:00	3.55
2014/08/28	19:02	5.08	2014/08/28	12:40	7.70	2014/08/28	18:00	6.62
2014/09/04	03:21	1.96	2014/09/04	03:20	NaN	2014/09/04	03:00	1.55
2014/09/07	17:01	3.42	2014/09/07	17:00	3.80	2014/09/07	18:00	3.91
2014/09/14	01:20	3.83	2014/09/14	01:20	2.00	2014/09/14	00:00	3.54
2014/09/17	14:59	3.04	2014/09/17	14:50	2.80	2014/09/17	15:00	2.72
2014/09/23	23:18	1.90	2014/09/23	23:20	1.60	2014/09/23	21:00	1.92
2014/09/27	12:58	4.02	2014/09/27	12:50	3.70	2014/09/27	12:00	4.38
2014/10/03	21:17	2.36	2014/10/03	21:20	2.00	2014/10/03	21:00	2.32
2014/10/07	10:56	2.04	2014/10/07	10:50	1.90	2014/10/07	12:00	2.43
2014/10/13	19:15	2.14	2014/10/13	19:10	1.90	2014/10/13	18:00	2.53

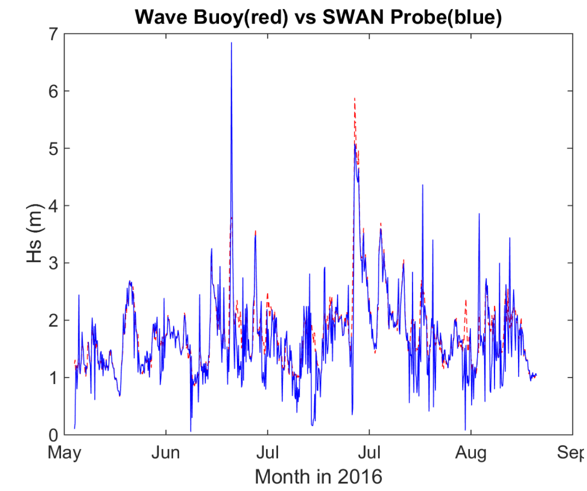
2014/10/17	08:55	3.41	2014/10/17	08:50	3.00	2014/10/17	09:00	3.24
2014/10/23	17:14	2.02	2014/10/23	17:10	2.10	2014/10/23	18:00	2.47
2014/10/27	06:53	2.79	2014/10/27	06:50	3.50	2014/10/27	06:00	2.93
2014/11/02	15:12	2.27	2014/11/02	14:00	2.00	2014/11/02	15:00	3.02
2014/11/06	04:52	2.18	2014/11/06	04:50	1.90	2014/11/06	06:00	2.20
2014/11/12	13:11	2.38	2014/11/13	08:30	2.50	2014/11/12	12:00	2.39
2014/11/16	02:51	5.68	2014/11/16	02:50	3.70	2014/11/16	03:00	5.33
2014/11/22	11:09	2.64	2014/11/21	20:00	1.70	2014/11/22	12:00	2.60
2014/11/26	00:49	3.07	2014/11/26	00:50	3.20	2014/11/26	00:00	3.26
2014/12/02	09:08	2.33	2014/12/02	09:10	1.80	2014/12/02	09:00	2.63
2014/12/05	22:48	3.15	2014/12/04	17:10	NaN	2014/12/05	21:00	3.89
2014/12/12	07:07	2.07	2014/12/14	19:50	NaN	2014/12/12	06:00	2.75
2014/12/15	20:46	3.86	2014/12/15	20:50	5.50	2014/12/15	21:00	3.69
2014/12/22	05:05	2.99	2014/12/22	05:00	2.40	2014/12/22	06:00	3.28
2014/12/25	18:45	4.74	2014/12/25	18:40	4.50	2014/12/25	18:00	5.77
2015/01/01	03:04	2.34	2015/01/01	03:00	2.50	2015/01/01	03:00	2.58
2015/01/04	16:43	2.86	2015/01/04	16:40	2.30	2015/01/04	15:00	3.21
2015/01/11	01:02	2.81	2015/01/11	01:00	NaN	2015/01/11	00:00	2.17
2015/01/14	14:42	3.60	2015/01/11	14:10	1.50	2015/01/14	15:00	3.71
2015/01/20	23:01	2.82	2015/01/20	23:00	2.40	2015/01/20	21:00	2.85
2015/01/24	12:40	2.56	2015/01/24	12:40	3.40	2015/01/24	12:00	3.04
2015/01/30	20:59	1.80	2015/01/28	09:50	NaN	2015/01/30	21:00	2.12
2015/02/03	10:39	2.15	2015/02/03	10:40	1.70	2015/02/03	09:00	2.85
2015/02/09	18:58	1.96	2015/02/09	18:50	1.60	2015/02/09	18:00	2.54
2015/02/13	08:37	2.31	2015/02/13	08:40	NaN	2015/02/13	09:00	2.64
2015/02/19	16:56	3.05	2015/02/19	16:50	NaN	2015/02/19	18:00	3.22
2015/02/23	06:36	2.90	2015/02/23	06:40	2.70	2015/02/23	06:00	2.69
2015/03/01	14:55	1.61	2015/03/02	20:10	2.80	2015/03/01	15:00	2.07
2015/03/05	04:34	2.10	2015/03/05	04:30	1.60	2015/03/05	03:00	2.09
2015/03/11	12:53	2.36	2015/03/11	12:50	1.90	2015/03/11	12:00	2.70
2015/03/15	02:33	2.10	2015/03/15	02:30	1.40	2015/03/15	03:00	2.22
2015/03/21	10:52	1.90	2015/03/21	10:50	2.50	2015/03/21	12:00	2.18
2015/03/25	00:31	2.13	2015/03/25	18:20	1.30	2015/03/25	00:00	2.49
2015/03/31	08:50	2.11	2015/03/31	08:50	2.20	2015/03/31	09:00	2.56
2015/04/03	22:30	2.44	2015/04/03	22:30	NaN	2015/04/03	21:00	2.54
2015/04/10	06:49	2.34	2015/04/10	06:50	2.20	2015/04/10	06:00	2.46
2015/04/13	20:28	1.23	2015/04/13	20:30	NaN	2015/04/13	21:00	1.82
2015/04/20	04:47	1.19	2015/04/20	04:50	1.00	2015/04/20	03:00	1.84
2015/04/23	18:27	2.34	2015/04/23	18:30	2.20	2015/04/23	18:00	2.77
2015/04/30	02:46	4.18	2015/04/30	02:50	3.30	2015/04/30	03:00	4.37
2015/05/03	16:26	2.45	2015/05/03	16:30	NaN	2015/05/03	15:00	3.11
2015/05/10	00:44	2.62	2015/05/10	00:40	NaN	2015/05/10	00:00	2.80
2015/05/13	14:24	2.78	2015/05/13	14:20	2.60	2015/05/13	15:00	2.64
2015/05/19	22:43	2.77	2015/05/19	22:40	1.30	2015/05/19	21:00	2.66
2015/05/23	12:23	2.40	2015/05/23	16:10	2.00	2015/05/23	12:00	2.91
2015/05/29	20:42	3.87	2015/05/26	15:50	NaN	2015/05/29	21:00	4.01
2015/06/02	10:21	4.72	2015/06/04	14:20	6.60	2015/06/02	09:00	4.83
2015/06/08	18:40	NaN	2015/06/08	18:40	NaN	2015/06/08	18:00	1.66
2015/06/12	08:20	2.73	2015/06/12	08:20	2.40	2015/06/12	09:00	2.43
2015/06/18	16:39	3.50	2015/06/18	16:40	2.60	2015/06/18	15:00	3.26
2015/06/22	06:18	3.26	2015/06/22	06:20	4.10	2015/06/22	06:00	3.85

2015/06/28	14:37	3.63	2015/06/28	14:40	3.40	2015/06/28	15:00	3.53
2015/07/02	04:17	1.78	2015/07/02	04:20	1.30	2015/07/02	03:00	2.08
2015/07/08	12:36	2.72	2015/07/08	12:40	2.30	2015/07/08	12:00	2.48
2015/07/12	02:15	3.07	2015/07/12	02:10	2.50	2015/07/12	03:00	3.79
2015/07/18	10:34	3.51	2015/07/18	10:30	3.00	2015/07/18	09:00	3.84
2015/07/22	00:14	3.70	2015/07/22	00:10	3.50	2015/07/22	00:00	4.19
2015/07/28	08:33	2.26	2015/07/22	19:30	3.80	2015/07/28	09:00	3.21
2015/07/31	22:12	3.66	2015/07/22	19:30	3.80	2015/07/31	21:00	4.24
2015/08/07	06:31	2.95	2015/08/07	06:30	1.60	2015/08/07	06:00	2.73
2015/08/10	20:11	3.55	2015/08/10	20:10	3.80	2015/08/10	21:00	2.68
2015/08/17	04:30	3.45	2015/08/17	04:30	3.60	2015/08/17	03:00	3.17
2015/08/20	18:09	3.23	2015/08/20	18:10	3.90	2015/08/20	18:00	2.56
2015/08/27	02:28	2.12	2015/08/27	02:30	1.00	2015/08/27	03:00	1.81
2015/08/30	16:08	2.62	2015/08/30	16:10	2.50	2015/08/30	15:00	2.23
2015/09/06	00:27	1.84	2015/09/06	00:30	2.50	2015/09/06	00:00	1.97
2015/09/09	14:06	3.51	2015/09/09	14:10	2.70	2015/09/09	15:00	3.00
2015/09/15	22:25	2.75	2015/09/15	22:20	2.00	2015/09/15	21:00	2.98
2015/09/19	12:05	2.26	2015/09/19	12:00	1.90	2015/09/19	12:00	2.01
2015/09/25	20:24	2.22	2015/09/25	20:20	NaN	2015/09/25	21:00	2.38
2015/09/29	10:03	2.59	2015/09/29	10:00	2.20	2015/09/29	09:00	2.00
2015/10/05	18:22	3.25	2015/10/05	18:20	2.90	2015/10/05	18:00	2.77
2015/10/09	08:02	2.92	2015/10/09	08:00	1.20	2015/10/09	09:00	2.93
2015/10/15	16:21	3.18	2015/10/15	16:20	2.50	2015/10/15	15:00	2.59
2015/10/19	06:00	2.84	2015/10/19	06:00	2.80	2015/10/19	06:00	2.95
2015/10/25	14:19	2.44	2015/10/25	14:20	2.00	2015/10/25	15:00	2.34
2015/10/29	03:59	1.38	2015/10/29	03:50	1.50	2015/10/29	03:00	1.87
2015/11/04	12:18	2.48	2015/11/04	12:20	2.40	2015/11/04	12:00	2.82
2015/11/08	01:58	1.75	2015/11/08	01:50	1.60	2015/11/08	03:00	1.62
2015/11/14	10:16	3.19	2015/11/14	10:20	3.60	2015/11/14	09:00	3.51
2015/11/17	23:56	3.06	2015/11/17	23:50	2.70	2015/11/17	21:00	2.96
2015/11/24	08:15	2.91	2015/11/24	08:10	NaN	2015/11/24	09:00	2.52
2015/11/27	21:55	2.06	2015/11/27	21:50	1.70	2015/11/27	21:00	2.02
2015/12/04	06:14	1.87	2015/12/04	06:10	1.70	2015/12/04	06:00	2.09
2015/12/07	19:53	1.31	2015/12/07	19:50	NaN	2015/12/07	21:00	1.76
2015/12/14	04:12	2.18	2015/12/14	04:10	2.60	2015/12/14	03:00	1.73
2015/12/17	17:52	2.49	2015/12/17	17:50	2.30	2015/12/17	18:00	2.26
2015/12/24	02:11	2.56	2015/12/24	02:10	2.70	2015/12/24	03:00	3.57
2015/12/27	15:50	1.97	2015/12/27	15:50	2.30	2015/12/27	15:00	2.84
2016/01/03	00:09	1.56	2016/01/03	00:10	1.70	2016/01/03	00:00	1.44
2016/01/06	13:49	1.90	2016/01/06	01:00	2.10	2016/01/06	12:00	1.99
2016/01/12	22:08	1.40	2016/01/06	01:00	2.10	2016/01/12	21:00	1.96
2016/01/16	11:47	2.70	2016/01/19	03:00	1.80	2016/01/16	12:00	2.67
2016/01/22	20:06	1.00	2016/01/22	20:10	1.00	2016/01/22	21:00	1.86
2016/01/26	09:46	2.53	2016/01/26	09:50	2.60	2016/01/26	09:00	2.42
2016/02/01	18:05	2.07	2016/02/01	18:00	1.70	2016/02/01	18:00	2.32
2016/02/05	07:44	2.13	2016/02/06	06:40	3.20	2016/02/05	06:00	2.40
2016/02/11	16:03	2.10	2016/02/14	10:50	2.30	2016/02/11	15:00	1.94
2016/02/15	05:43	2.96	2016/02/15	05:40	2.50	2016/02/15	06:00	2.91
2016/02/21	14:02	2.82	2016/02/26	05:10	1.70	2016/02/21	15:00	2.54
2016/02/25	03:41	2.46	2016/02/26	05:10	1.70	2016/02/25	03:00	2.23
2016/03/02	12:00	2.90	2016/03/02	12:00	2.70	2016/03/02	12:00	2.48

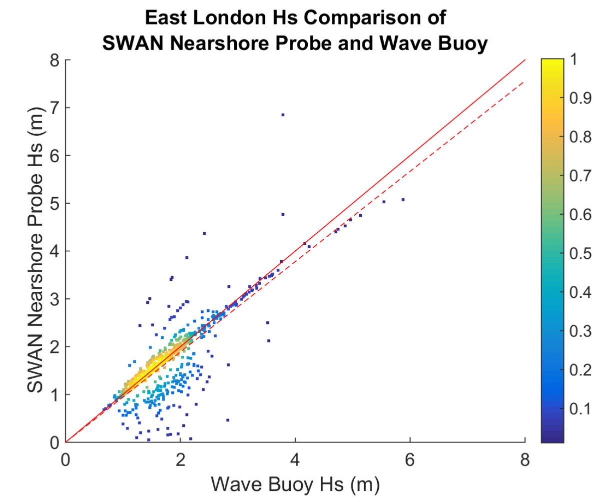
2016/03/06	01:40	1.61	2016/03/07	06:40	1.90	2016/03/06	00:00	1.61
2016/03/12	09:59	3.54	2016/03/12	09:50	3.80	2016/03/12	09:00	3.29
2016/03/15	23:38	2.70	2016/03/15	14:30	2.40	2016/03/15	21:00	2.70
2016/03/22	07:57	3.12	2016/03/25	11:10	1.90	2016/03/22	09:00	2.83
2016/03/25	21:37	2.03	2016/03/25	18:50	NaN	2016/03/25	21:00	2.09
2016/04/01	05:56	3.02	2016/04/01	05:50	2.60	2016/04/01	06:00	2.65
2016/04/04	19:35	2.94	2016/04/04	19:30	NaN	2016/04/04	18:00	2.41
2016/04/11	03:54	1.77	2016/04/11	03:50	NaN	2016/04/11	03:00	1.73
2016/04/14	17:34	1.77	2016/04/13	20:00	NaN	2016/04/14	18:00	2.15
2016/04/21	01:53	1.96	2016/04/20	10:00	NaN	2016/04/21	03:00	2.74
2016/04/24	15:32	2.49	2016/04/24	15:30	2.90	2016/04/24	15:00	2.26
2016/04/30	23:51	3.26	2016/04/30	23:50	3.20	2016/04/30	21:00	2.80
2016/05/04	13:31	2.16	2016/05/04	13:30	1.90	2016/05/04	12:00	1.88
2016/05/10	21:50	1.85	2016/05/10	21:50	1.60	2016/05/10	21:00	2.10
2016/05/14	11:30	1.77	2016/05/14	11:30	1.90	2016/05/14	12:00	1.75
2016/05/20	19:49	3.57	2016/05/20	19:50	3.00	2016/05/20	18:00	2.53
2016/05/24	09:28	3.74	2016/05/24	09:30	3.00	2016/05/24	09:00	2.61
2016/05/30	17:47	2.40	2016/05/30	16:00	NaN	2016/05/30	18:00	2.08
2016/06/03	07:27	1.71	2016/06/02	04:20	NaN	2016/06/03	06:00	2.35
2016/06/09	15:46	2.17	2016/06/12	05:00	3.80	2016/06/09	15:00	2.96
2016/06/13	05:25	1.89	2016/06/12	23:50	NaN	2016/06/13	06:00	1.65
2016/06/19	13:44	3.98	2016/06/19	13:40	2.70	2016/06/19	12:00	3.43
2016/06/23	03:24	1.32	2016/06/22	18:30	NaN	2016/06/23	03:00	1.56
2016/06/29	11:43	2.94	2016/06/28	16:20	NaN	2016/06/29	12:00	3.24
2016/07/03	01:22	3.89	2016/07/03	01:20	5.20	2016/07/03	00:00	3.34
2016/07/09	09:41	3.29	2016/07/07	13:50	NaN	2016/07/09	09:00	3.19
2016/07/12	23:21	2.50	2016/07/12	23:20	2.30	2016/07/12	21:00	2.41
2016/07/19	07:40	3.21	2016/07/19	07:40	3.00	2016/07/19	06:00	3.86
2016/07/22	21:19	3.45	2016/07/21	08:30	3.10	2016/07/22	21:00	3.52
2016/07/29	05:38	2.74	2016/07/29	05:40	2.50	2016/07/29	06:00	2.71
2016/08/01	19:18	2.12	2016/08/01	19:20	2.90	2016/08/01	18:00	2.59
2016/08/08	03:37	3.18	2016/08/08	03:40	3.10	2016/08/08	03:00	2.88
2016/08/11	17:16	1.46	2016/08/11	17:20	NaN	2016/08/11	18:00	1.68
2016/08/18	01:35	1.77	2016/08/18	01:30	1.70	2016/08/18	00:00	2.20
2016/08/21	15:15	3.23	2016/08/22	10:20	4.00	2016/08/21	15:00	4.23
2016/08/27	23:34	1.80	2016/08/27	23:30	1.50	2016/08/27	21:00	1.79
2016/08/31	13:13	2.71	2016/08/31	13:10	3.60	2016/08/31	12:00	3.32
2016/09/10	11:12	3.51	2016/09/10	11:10	2.60	2016/09/10	12:00	2.89
2016/09/20	09:10	3.04	2016/09/19	13:30	NaN	2016/09/20	09:00	2.69

Appendix C

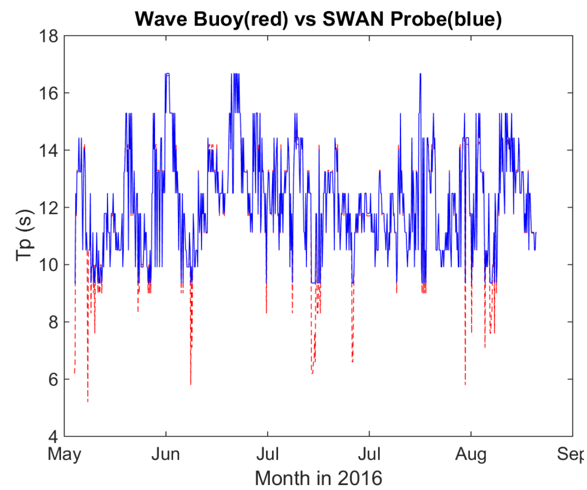
SWAN Probe and Wave Buoy Comparison



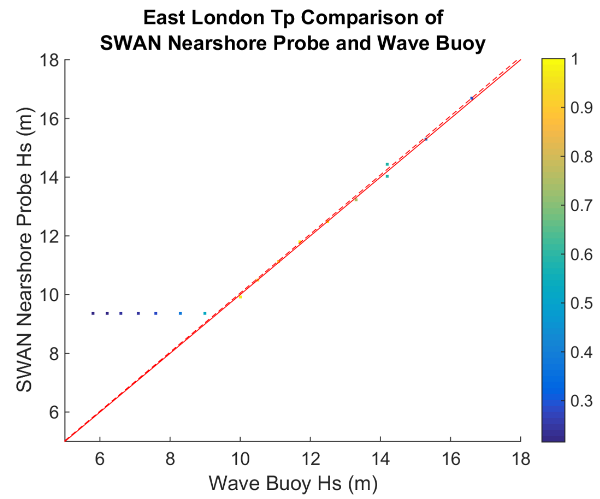
(a) Hs Time Series



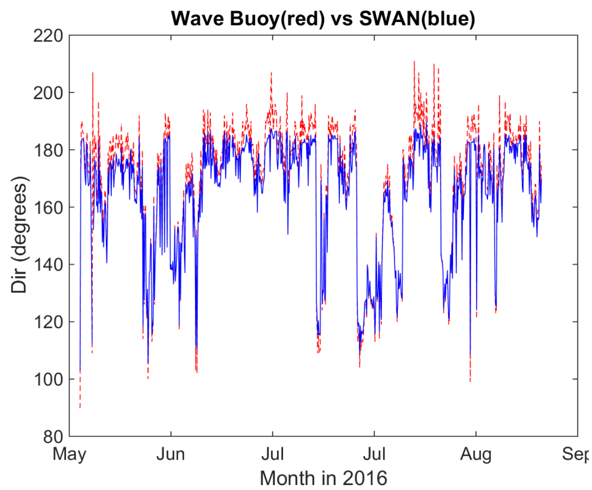
(b) Hs Density Scatter Plot



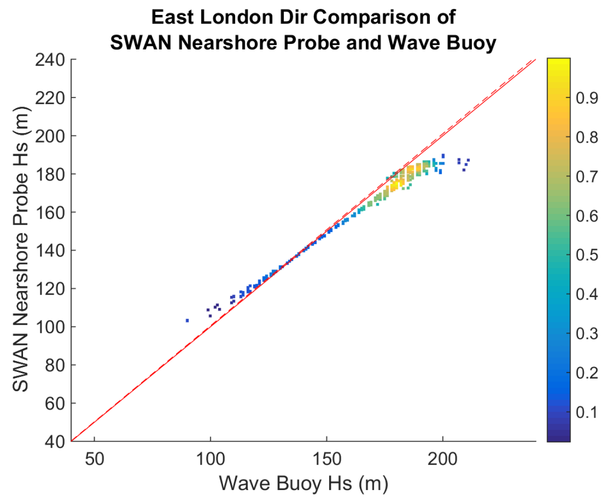
(c) Tp Time Series



(d) Tp Density Scatter Plot

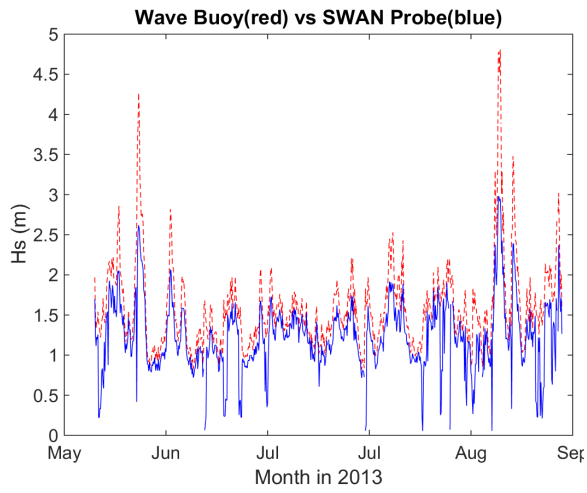


(e) Dir Time Series

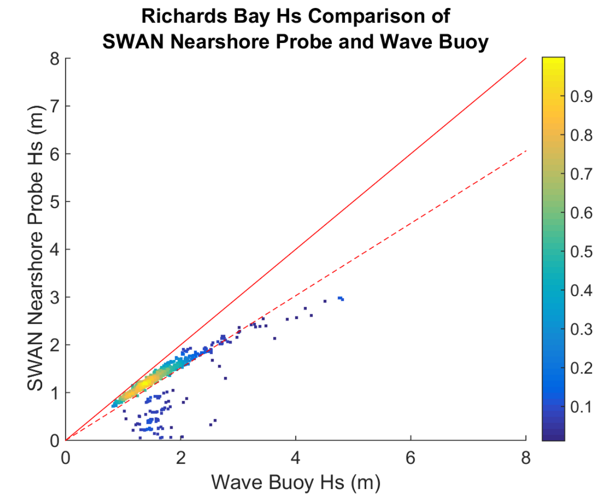


(f) Dir Density Scatter Plot

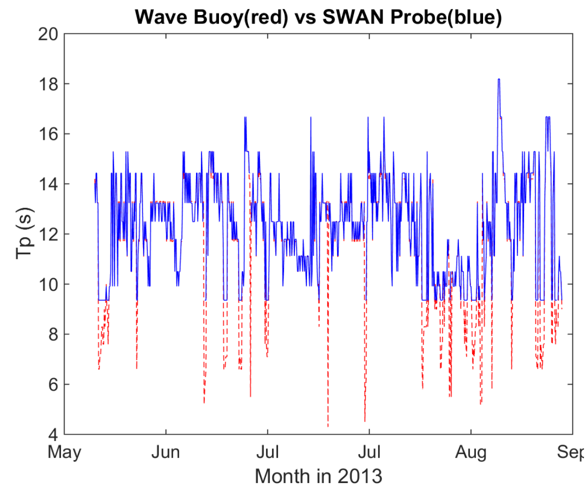
Figure C.1: East London SWAN Probe and Wave Buoy Comparing Wave Conditions for June to August 2016



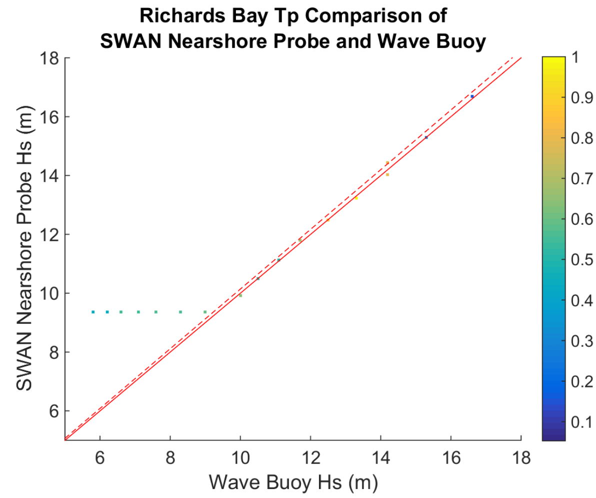
(a) Hs Time Series



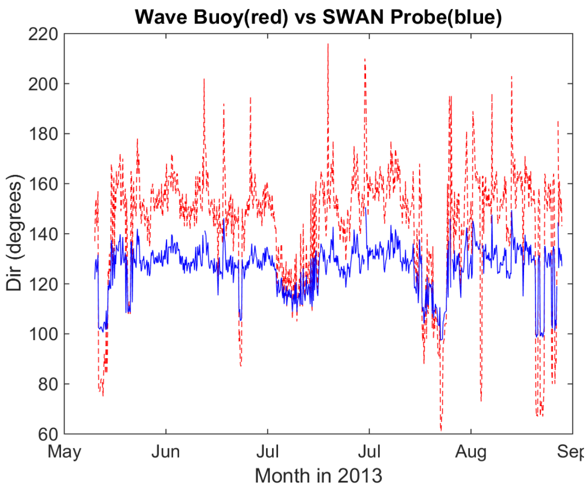
(b) Hs Density Scatter Plot



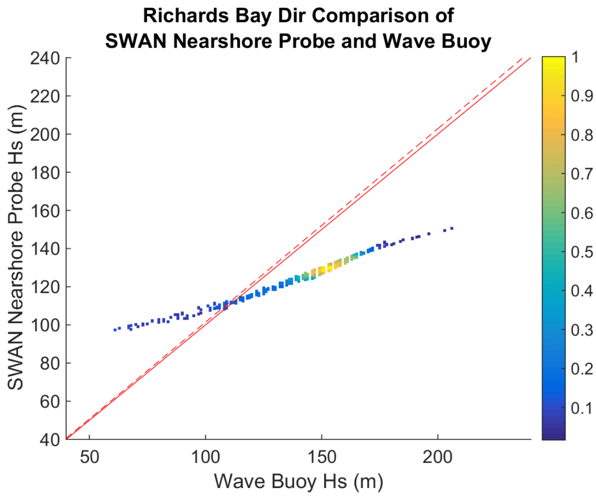
(c) Tp Time Series



(d) Tp Density Scatter Plot



(e) Dir Time Series



(f) Dir Density Scatter Plot

Figure C.2: Richards Bay SWAN Probe and Wave Buoy Comparing Wave Conditions for June to August 2013

Appendix D

SWAN Validation Time Series Graphs for East London and Richards Bay

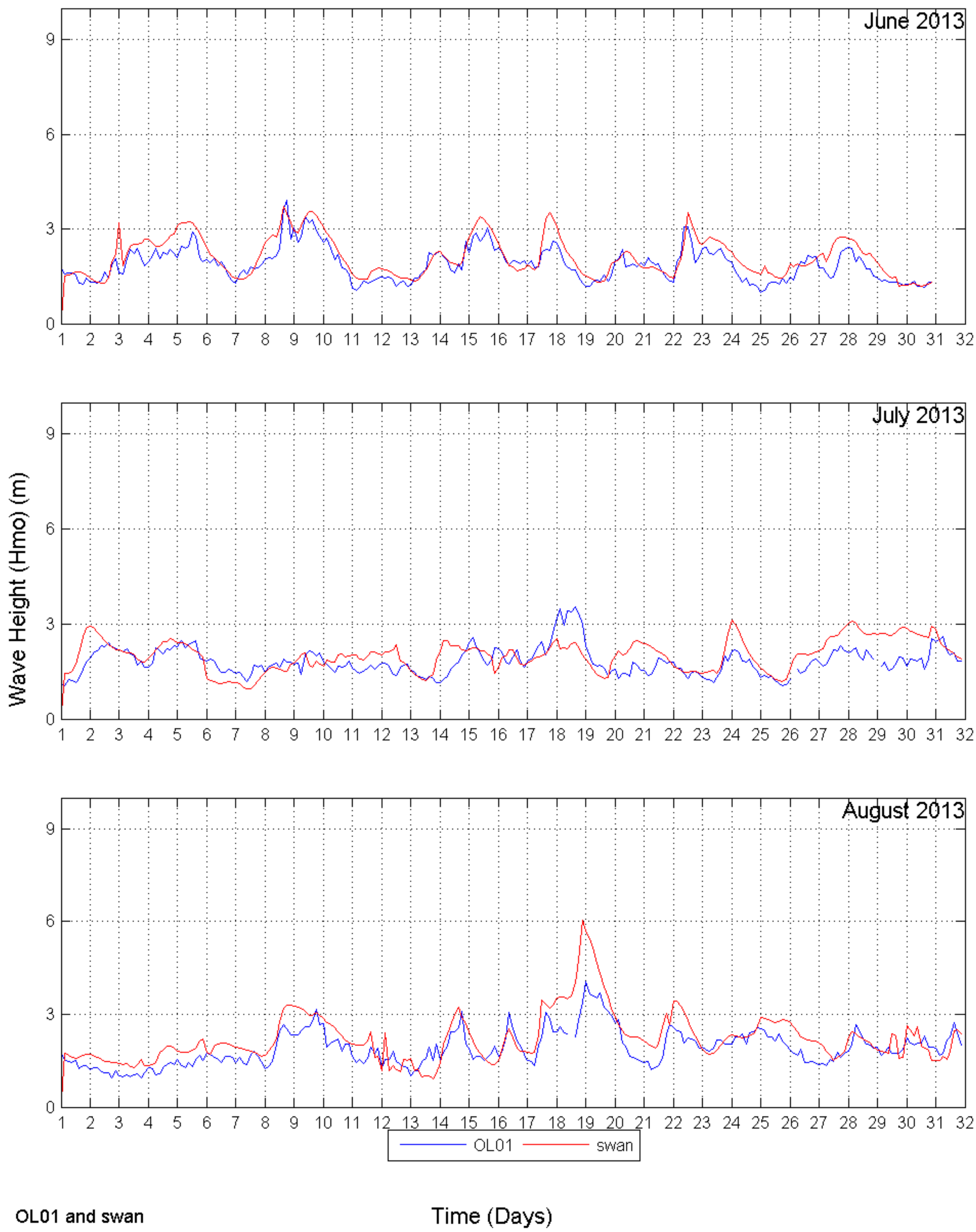


Figure D.1: Wave height Validation Time-Series Graph for East London Buoy (EL01) in Blue and the Simulated Data (SWAN) in Red during the months of June to August 2013

Figure D.2: Peak Period Validation Time-Series Graph for East London Buoy (EL01) in Blue and the Simulated Data (SWAN) in Red during the months of June to August 2013

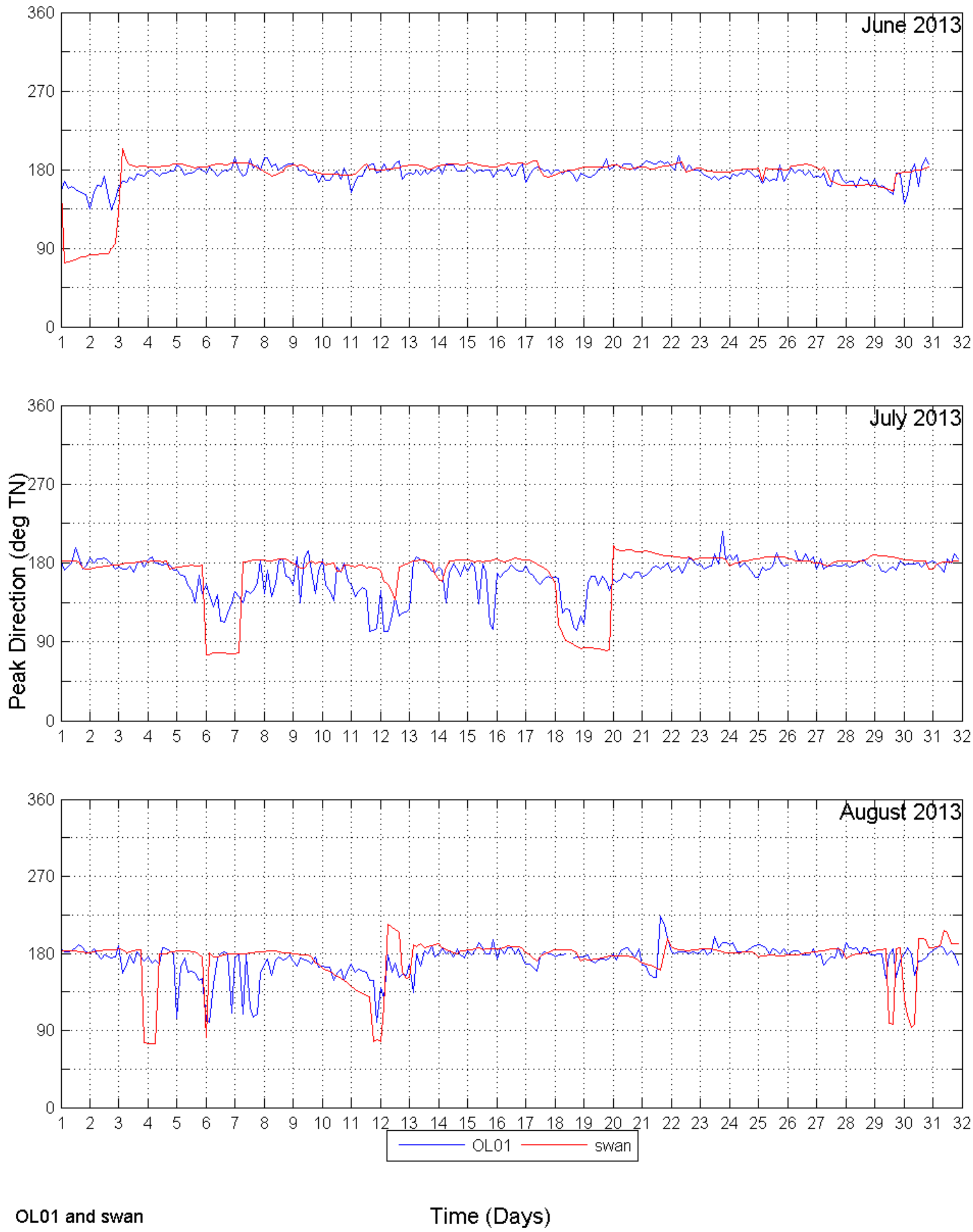


Figure D.3: Peak Direction Validation Time-Series Graph for East London Buoy (EL01) in Blue and the Simulated Data (SWAN) in Red during the months of June to August 2013

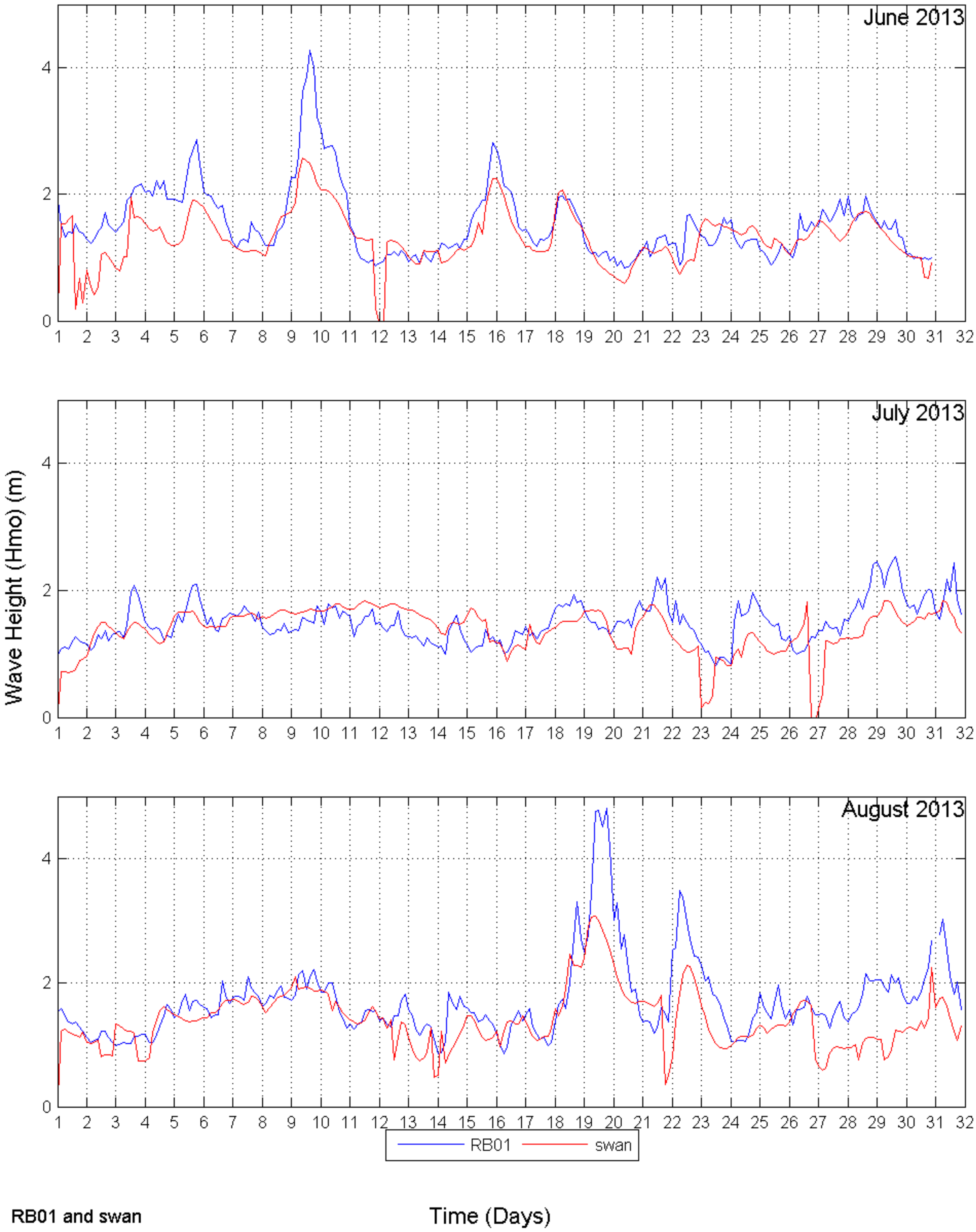


Figure D.4: Wave height Validation Time-Series Graph for Richards Bay Buoy (RB01) in Blue and the Simulated Data (SWAN) in Red during the months of June to August 2013

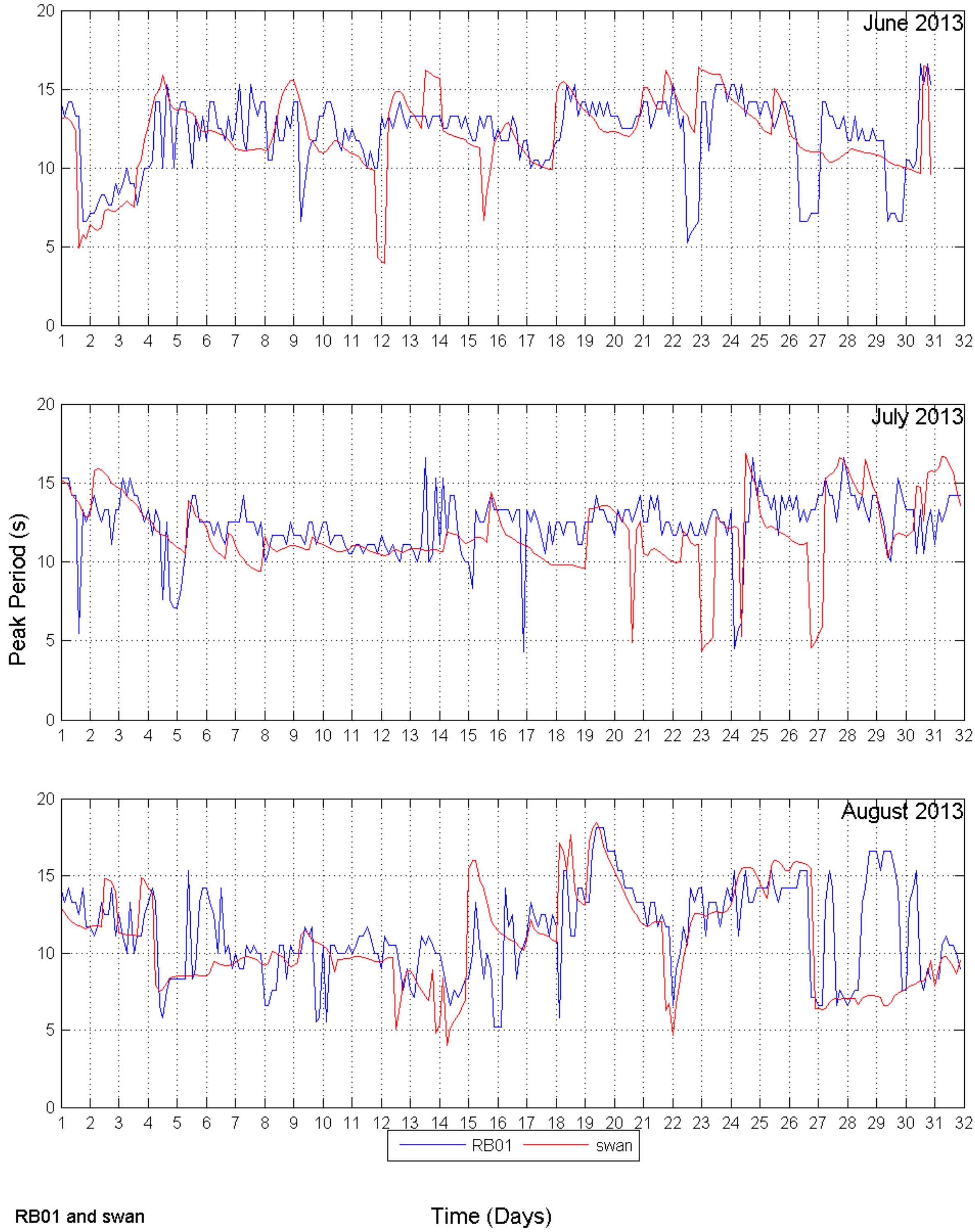


Figure D.5: Peak Period Validation Time-Series Graph for Richards Bay Buoy (RB01) in Blue and the Simulated Data (SWAN) in Red during the months of June to August 2013

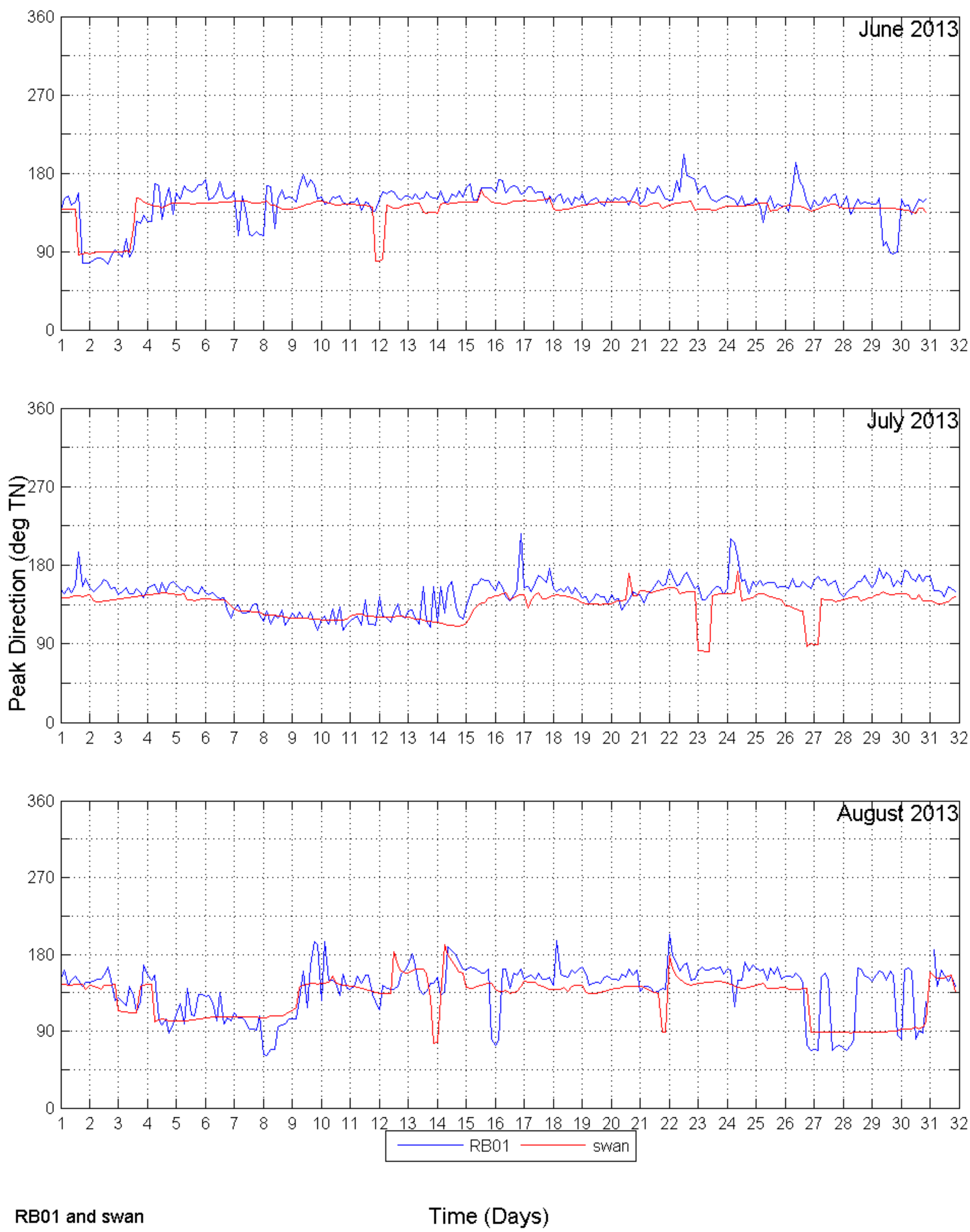
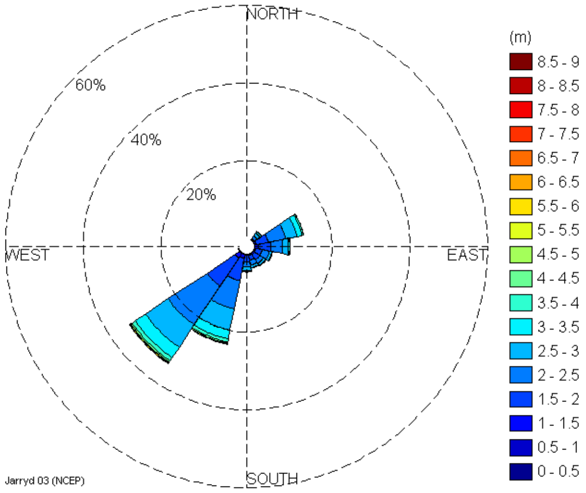


Figure D.6: Peak Direction Validation Time-Series Graph for Richards Bay Buoy (RB01) in Blue and the Simulated Data (SWAN) in Red during the months of June to August 2013

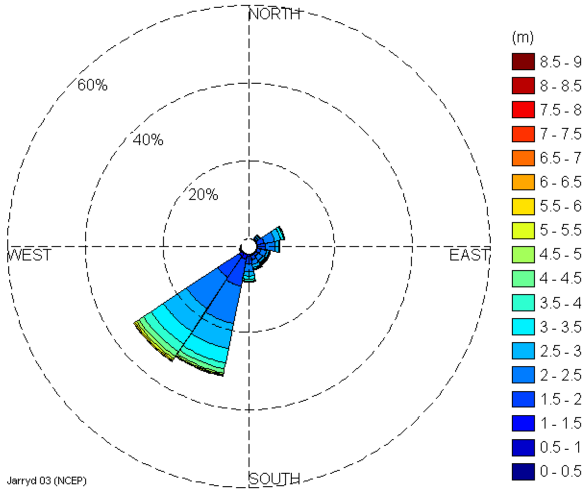
Appendix E

NCEP Data for East London and Richards Bay

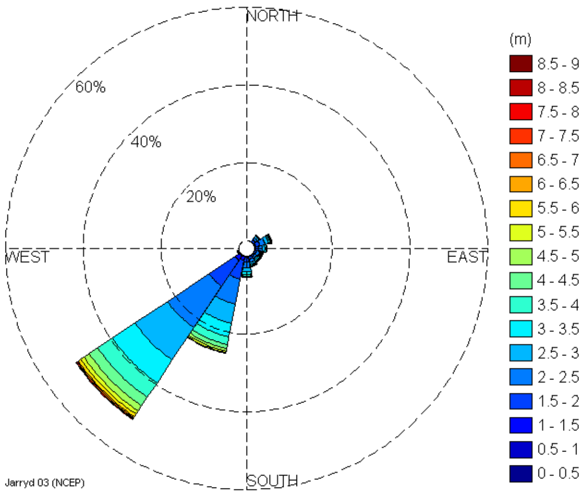
Summer - 14457 Records



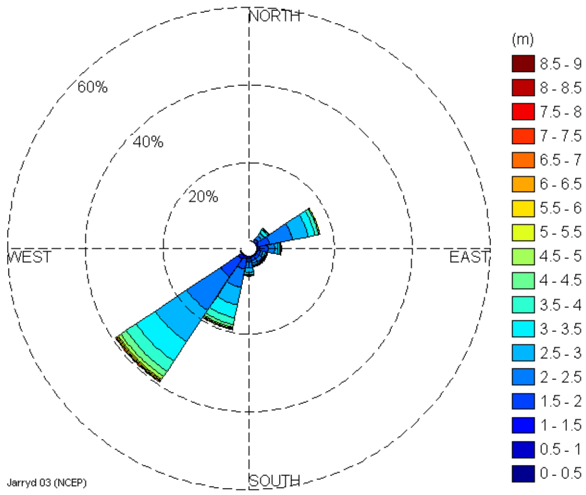
Autumn - 14720 Records



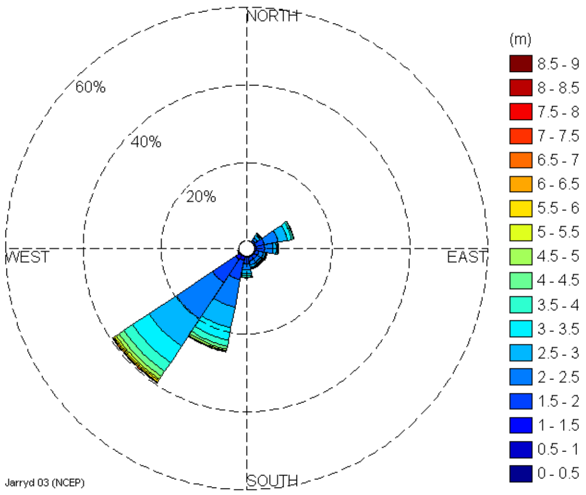
Winter - 14720 Records



Spring - 14560 Records



All Data - 58457 Records



Period	1997-01-30 to 2017-02-01
Station	Jarryd 03 (NCEP)
Position	33.00000 S, 28.75000 E
Instrument Depth	0 m
Water Depth	0.0 m
Instrument Type	WaveWatch III
Records	58457

CSIR

Jarryd 03 (NCEP)
Wave Height (Hmo) vs Wave Direction
1997-01-30 to 2017-02-01

Figure

Table : Percentage Occurrence for Wave height vs Wave Direction - All Data

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 58457

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5			0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.05	0.12						0.23
0.5 - 1.0				0.00	0.01	0.01	0.02	0.01	0.01	0.02	0.01						0.08
1.0 - 1.5		0.01	0.07	0.37	0.55	0.26	0.28	0.29	0.35	1.02	1.31	0.02	0.00	0.00	0.00		4.53
1.5 - 2.0		0.01	0.53	2.31	2.09	0.99	0.89	0.97	1.53	5.22	7.33	0.05	0.01		0.00	0.00	21.94
2.0 - 2.5		0.00	0.75	3.68	2.07	1.20	1.02	1.05	1.58	7.16	11.20	0.10	0.01				29.81
2.5 - 3.0			0.73	2.36	0.93	0.56	0.51	0.62	1.01	5.39	8.39	0.07	0.00				20.58
3.0 - 3.5			0.45	1.06	0.33	0.27	0.26	0.26	0.56	3.22	4.95	0.05	0.00				11.42
3.5 - 4.0			0.12	0.44	0.11	0.08	0.14	0.10	0.32	1.51	2.71	0.03					5.55
4.0 - 4.5			0.02	0.13	0.04	0.04	0.08	0.03	0.10	0.78	1.52	0.01	0.00				2.75
4.5 - 5.0			0.00	0.03	0.02	0.02	0.04	0.02	0.03	0.38	0.85	0.01					1.40
5.0 - 5.5				0.00	0.02	0.01	0.02	0.01	0.03	0.22	0.48	0.02					0.79
5.5 - 6.0				0.01	0.01	0.00	0.00	0.00	0.02	0.08	0.34	0.01					0.47
6.0 - 6.5				0.01		0.00	0.00	0.02	0.01	0.04	0.13	0.00					0.21
6.5 - 7.0						0.00			0.01	0.02	0.10						0.13
7.0 - 7.5						0.00	0.00			0.01	0.05						0.07
7.5 - 8.0						0.01				0.01	0.03						0.04
8.0 - 8.5							0.01			0.01	0.00						0.01
8.5 - 9.0							0.00										0.00
Total	0.00	0.02	2.69	10.41	6.19	3.45	3.28	3.38	5.54	25.13	39.51	0.37	0.03	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Summer

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14457

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5			0.01	0.04	0.01				0.01	0.05	0.12						0.24
0.5 - 1.0				0.01	0.02	0.03	0.07	0.03	0.01	0.03							0.20
1.0 - 1.5			0.03	0.48	0.97	0.37	0.44	0.32	0.21	1.04	1.58	0.01					5.46
1.5 - 2.0			0.43	3.23	3.29	1.67	1.58	1.27	1.68	6.00	8.74	0.06					27.96
2.0 - 2.5			0.77	4.54	3.06	1.87	1.13	1.31	1.40	7.37	11.98	0.06					33.49
2.5 - 3.0			0.94	2.93	1.42	0.70	0.69	0.66	0.92	5.46	6.85	0.04					20.61
3.0 - 3.5			0.41	1.31	0.33	0.13	0.11	0.10	0.28	2.32	3.20	0.01					8.20
3.5 - 4.0			0.06	0.38	0.10	0.01		0.01	0.02	0.80	0.99						2.36
4.0 - 4.5			0.02	0.06	0.03				0.01	0.30	0.35						0.75
4.5 - 5.0										0.13	0.18						0.31
5.0 - 5.5										0.09	0.10						0.19
5.5 - 6.0										0.01	0.10						0.12
6.0 - 6.5										0.01	0.05						0.06
6.5 - 7.0										0.02	0.05						0.07
7.0 - 7.5																	0.00
Total	0.00	0.00	2.66	12.98	9.23	4.79	4.03	3.69	4.54	23.61	34.28	0.17	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Autumn

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5			0.01		0.01			0.02	0.01	0.10	0.08						0.22
0.5 - 1.0							0.01		0.01	0.01	0.04						0.07
1.0 - 1.5			0.03	0.21	0.33	0.26	0.19	0.38	0.43	1.23	1.01	0.02					4.10
1.5 - 2.0		0.01	0.30	1.81	1.96	0.95	0.79	1.09	2.12	7.21	6.73	0.06	0.02			0.01	23.08
2.0 - 2.5			0.58	2.76	2.51	1.49	1.37	1.24	1.92	9.81	9.52	0.10	0.03				31.31
2.5 - 3.0			0.53	1.60	0.91	0.63	0.60	0.79	1.09	6.51	7.07	0.10	0.01				19.83
3.0 - 3.5			0.16	0.75	0.20	0.29	0.26	0.36	0.78	3.72	3.82	0.05					10.39
3.5 - 4.0			0.01	0.24	0.05	0.09	0.25	0.13	0.50	1.47	2.30	0.05					5.11
4.0 - 4.5				0.05	0.01		0.17	0.05	0.13	1.11	1.42	0.02					2.96
4.5 - 5.0					0.02	0.01	0.09	0.05	0.03	0.40	0.76	0.02					1.38
5.0 - 5.5					0.01		0.05		0.04	0.24	0.44	0.04					0.82
5.5 - 6.0							0.01		0.02	0.12	0.32	0.02					0.49
6.0 - 6.5								0.03	0.03	0.03	0.06						0.16
6.5 - 7.0									0.01	0.02	0.03						0.07
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
Total	0.00	0.01	1.62	7.42	6.02	3.71	3.79	4.15	7.12	31.99	33.61	0.49	0.06	0.00	0.00	0.01	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Winter

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5				0.01			0.01		0.02	0.03	0.15						0.22
0.5 - 1.0					0.01				0.01	0.03	0.01						0.06
1.0 - 1.5		0.01	0.16	0.36	0.19	0.10	0.16	0.15	0.26	1.13	1.51	0.03	0.01	0.01	0.01		4.08
1.5 - 2.0		0.03	0.59	1.13	0.98	0.54	0.37	0.65	1.28	4.91	8.18	0.02	0.01		0.01		18.69
2.0 - 2.5		0.01	0.63	1.37	0.97	0.82	0.63	0.90	1.49	6.60	12.86	0.15	0.01				26.45
2.5 - 3.0			0.52	0.98	0.50	0.28	0.36	0.53	0.94	4.99	9.93	0.10					19.14
3.0 - 3.5			0.24	0.41	0.33	0.32	0.38	0.36	0.62	3.49	6.94	0.09	0.01				13.19
3.5 - 4.0			0.06	0.22	0.11	0.09	0.17	0.13	0.47	1.99	4.45	0.05					7.73
4.0 - 4.5			0.02	0.13	0.03	0.10	0.14	0.03	0.14	1.05	2.64	0.03	0.01				4.31
4.5 - 5.0				0.05		0.07	0.05	0.02	0.06	0.68	1.62	0.01					2.57
5.0 - 5.5				0.01	0.03	0.03	0.01	0.02	0.06	0.38	1.00	0.01					1.56
5.5 - 6.0				0.02	0.03	0.01		0.01	0.05	0.10	0.72						0.93
6.0 - 6.5				0.03		0.01	0.01	0.03	0.01	0.03	0.33	0.01					0.45
6.5 - 7.0						0.01			0.01	0.01	0.23						0.25
7.0 - 7.5						0.01	0.01			0.02	0.13						0.16
7.5 - 8.0						0.02				0.04	0.09						0.15
8.0 - 8.5							0.02			0.03	0.01						0.05
8.5 - 9.0							0.01										0.01
Total	0.00	0.05	2.23	4.73	3.17	2.40	2.32	2.83	5.43	25.52	50.78	0.49	0.05	0.01	0.01	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Spring

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14560

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5			0.01	0.03	0.01	0.02		0.01	0.01	0.03	0.12						0.23
0.5 - 1.0																	0.00
1.0 - 1.5		0.01	0.07	0.43	0.73	0.30	0.34	0.31	0.47	0.68	1.13	0.01					4.48
1.5 - 2.0			0.80	3.10	2.16	0.80	0.84	0.86	1.06	2.76	5.66	0.08					18.12
2.0 - 2.5			1.04	6.09	1.74	0.60	0.94	0.77	1.50	4.83	10.44	0.09					28.04
2.5 - 3.0			0.93	3.97	0.91	0.63	0.41	0.49	1.09	4.58	9.71	0.05					22.75
3.0 - 3.5			1.00	1.77	0.47	0.36	0.29	0.23	0.54	3.35	5.82	0.05					13.87
3.5 - 4.0			0.36	0.92	0.19	0.14	0.12	0.14	0.27	1.75	3.07	0.01					6.98
4.0 - 4.5			0.04	0.28	0.07	0.05	0.02	0.05	0.10	0.67	1.66	0.01					2.95
4.5 - 5.0			0.01	0.05	0.05	0.02	0.01		0.02	0.30	0.82	0.01					1.30
5.0 - 5.5					0.03	0.01	0.01		0.01	0.15	0.36	0.01					0.56
5.5 - 6.0					0.01					0.08	0.23						0.32
6.0 - 6.5										0.08	0.08						0.16
6.5 - 7.0										0.02	0.10						0.12
7.0 - 7.5										0.02	0.08						0.10
7.5 - 8.0											0.02						0.02
8.0 - 8.5																	0.00
8.5 - 9.0																	0.00
Total	0.00	0.01	4.27	16.63	6.38	2.92	2.98	2.85	5.06	19.30	39.29	0.31	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Period - All Data
Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 58457

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5						0.00	0.01	0.02	0.01	0.01	0.02	0.04	0.03	0.04	0.03	0.01	0.23
0.5 - 1.0				0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.01					0.08
1.0 - 1.5				0.06	0.13	0.14	0.33	0.55	0.59	0.74	0.86	0.65	0.28	0.13	0.04	0.01	4.52
1.5 - 2.0				0.02	0.64	1.06	1.14	2.09	2.31	2.75	3.99	4.05	2.24	1.05	0.41	0.12	21.86
2.0 - 2.5					0.16	1.19	1.91	2.39	2.25	2.73	4.22	6.02	4.61	2.72	1.08	0.33	29.63
2.5 - 3.0						0.28	1.42	1.71	1.38	1.27	2.32	3.65	3.98	2.72	1.26	0.38	20.37
3.0 - 3.5						0.03	0.46	1.11	0.85	0.66	1.00	1.60	2.32	1.86	1.04	0.34	11.26
3.5 - 4.0						0.00	0.07	0.37	0.46	0.41	0.45	0.69	0.99	1.06	0.68	0.25	5.43
4.0 - 4.5							0.01	0.09	0.23	0.27	0.25	0.31	0.45	0.48	0.40	0.19	2.68
4.5 - 5.0							0.00	0.02	0.07	0.16	0.14	0.22	0.20	0.23	0.22	0.09	1.35
5.0 - 5.5								0.01	0.03	0.07	0.12	0.10	0.12	0.13	0.13	0.05	0.76
5.5 - 6.0									0.01	0.04	0.04	0.09	0.08	0.08	0.07	0.05	0.44
6.0 - 6.5									0.00	0.01	0.02	0.04	0.06	0.02	0.02	0.02	0.20
6.5 - 7.0									0.00		0.00	0.02	0.02	0.03	0.03	0.02	0.12
7.0 - 7.5										0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.06
7.5 - 8.0													0.01	0.02	0.01	0.01	0.04
8.0 - 8.5													0.01		0.01	0.00	0.01
8.5 - 9.0													0.00				0.00
Total	0.00	0.00	0.00	0.09	0.93	2.71	5.37	8.37	8.20	9.13	13.45	17.51	15.40	10.58	5.45	1.86	100.

Table : Percentage Occurrence for Wave height vs Period - Summer
Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14457

	Period (Tp) (s)																
Hmo (m)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5							0.03	0.03	0.01	0.01	0.01	0.05	0.01	0.04	0.03	0.01	0.24
0.5 - 1.0				0.01	0.03	0.04	0.03	0.03	0.06								0.20
1.0 - 1.5				0.06	0.27	0.18	0.59	0.74	0.81	1.16	0.95	0.46	0.15	0.08	0.01		5.46
1.5 - 2.0				0.01	0.85	2.03	2.41	3.24	3.09	3.98	5.06	4.32	1.79	0.74	0.24	0.08	27.83
2.0 - 2.5					0.15	1.58	2.76	3.08	2.74	2.88	5.79	6.74	4.14	2.19	0.91	0.29	33.26
2.5 - 3.0						0.21	1.97	2.38	1.38	1.10	2.27	4.00	3.65	2.12	1.04	0.32	20.43
3.0 - 3.5							0.55	1.24	0.68	0.31	0.57	1.05	1.59	1.02	0.91	0.16	8.07
3.5 - 4.0							0.02	0.37	0.31	0.12	0.14	0.24	0.42	0.33	0.17	0.16	2.28
4.0 - 4.5							0.01	0.04	0.16	0.03	0.08	0.05	0.17	0.06	0.10	0.01	0.71
4.5 - 5.0										0.03	0.03	0.05	0.06	0.06	0.04	0.02	0.30
5.0 - 5.5									0.01	0.01	0.02	0.03	0.02	0.05	0.03		0.17
5.5 - 6.0									0.01	0.01	0.02	0.03	0.02	0.02		0.01	0.12
6.0 - 6.5												0.02	0.03			0.01	0.06
6.5 - 7.0												0.03	0.01		0.01	0.01	0.07
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
8.0 - 8.5																	0.00
8.5 - 9.0																	0.00
Total	0.00	0.00	0.00	0.08	1.31	4.05	8.36	11.16	9.23	9.65	14.93	17.07	12.07	6.70	3.49	1.08	100.

Table : Percentage Occurrence for Wave height vs Period - Autumn

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5						0.01	0.01		0.01	0.01	0.05	0.07	0.02	0.01	0.04		0.22
0.5 - 1.0										0.07							0.07
1.0 - 1.5				0.02	0.05	0.05	0.24	0.43	0.34	0.60	1.01	0.77	0.37	0.13	0.09		4.10
1.5 - 2.0				0.02	0.48	0.86	0.87	1.82	1.63	2.70	4.80	5.12	2.96	1.11	0.49	0.16	23.01
2.0 - 2.5					0.13	0.96	1.82	2.18	1.56	2.71	4.50	7.20	5.29	3.19	1.28	0.33	31.14
2.5 - 3.0						0.25	1.20	1.28	0.95	1.13	2.25	3.78	4.18	2.59	1.46	0.50	19.57
3.0 - 3.5						0.01	0.32	0.86	0.58	0.69	0.99	1.45	2.30	1.62	0.96	0.46	10.24
3.5 - 4.0							0.06	0.26	0.31	0.39	0.54	0.69	0.97	0.92	0.65	0.21	5.01
4.0 - 4.5							0.01	0.06	0.19	0.27	0.29	0.41	0.55	0.52	0.38	0.22	2.90
4.5 - 5.0								0.03	0.09	0.15	0.15	0.22	0.20	0.20	0.20	0.07	1.32
5.0 - 5.5									0.04	0.10	0.10	0.13	0.14	0.14	0.07	0.06	0.77
5.5 - 6.0										0.04	0.04	0.07	0.07	0.09	0.07	0.04	0.43
6.0 - 6.5											0.01	0.05	0.06	0.01		0.02	0.16
6.5 - 7.0												0.03	0.01	0.01		0.01	0.06
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
8.0 - 8.5																	0.00
8.5 - 9.0																	0.00
Total	0.00	0.00	0.00	0.04	0.66	2.14	4.52	6.93	5.71	8.87	14.72	19.99	17.13	10.52	5.70	2.09	100.

Table : Percentage Occurrence for Wave height vs Period - Winter

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Period (Tp) (s)															
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5								0.02	0.01	0.01	0.01	0.03	0.03	0.05	0.04	0.01	0.22
0.5 - 1.0								0.01			0.01	0.04					0.06
1.0 - 1.5				0.08	0.10	0.09	0.17	0.20	0.43	0.39	0.96	0.99	0.37	0.18	0.05	0.02	4.05
1.5 - 2.0				0.03	0.32	0.26	0.43	0.77	1.45	1.57	3.46	4.45	3.09	1.76	0.75	0.20	18.55
2.0 - 2.5					0.08	0.56	0.76	0.92	1.37	2.04	3.11	5.64	5.71	3.87	1.63	0.50	26.21
2.5 - 3.0						0.27	0.75	0.79	0.96	0.88	2.16	3.08	4.28	3.91	1.49	0.38	18.95
3.0 - 3.5						0.03	0.31	0.72	0.61	0.58	1.41	2.00	2.99	2.55	1.35	0.46	13.00
3.5 - 4.0							0.07	0.28	0.30	0.46	0.65	0.98	1.53	1.77	1.07	0.46	7.57
4.0 - 4.5							0.02	0.11	0.21	0.35	0.40	0.50	0.73	0.91	0.67	0.34	4.24
4.5 - 5.0								0.03	0.08	0.26	0.25	0.45	0.37	0.50	0.43	0.12	2.50
5.0 - 5.5								0.03	0.04	0.12	0.24	0.18	0.19	0.26	0.39	0.08	1.53
5.5 - 6.0									0.01	0.06	0.10	0.19	0.18	0.12	0.16	0.09	0.91
6.0 - 6.5									0.01	0.03	0.05	0.07	0.12	0.05	0.07	0.03	0.44
6.5 - 7.0											0.01	0.01	0.04	0.09	0.07	0.02	0.24
7.0 - 7.5											0.01	0.02	0.02	0.05	0.04	0.02	0.16
7.5 - 8.0													0.05	0.05	0.03	0.02	0.15
8.0 - 8.5													0.02		0.02	0.01	0.05
8.5 - 9.0													0.01				0.01
Total	0.00	0.00	0.00	0.12	0.50	1.21	2.51	3.90	5.50	6.77	12.83	18.63	19.73	16.11	8.27	2.75	100.

Table : Percentage Occurrence for Wave height vs Period - Spring
Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14560

Hmo (m)	Period (Tp) (s)															
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5							0.01	0.01	0.01	0.03	0.02	0.01	0.05	0.05	0.01	0.01	0.23
0.5 - 1.0																	0.00
1.0 - 1.5				0.09	0.08	0.22	0.34	0.84	0.78	0.80	0.52	0.38	0.25	0.12	0.02	0.03	4.48
1.5 - 2.0				0.03	0.91	1.11	0.87	2.53	3.08	2.76	2.65	2.30	1.09	0.56	0.17	0.03	18.10
2.0 - 2.5					0.26	1.68	2.32	3.41	3.37	3.30	3.50	4.52	3.28	1.61	0.49	0.19	27.94
2.5 - 3.0						0.39	1.77	2.39	2.24	1.98	2.61	3.74	3.78	2.27	1.04	0.32	22.53
3.0 - 3.5						0.06	0.68	1.62	1.53	1.06	1.04	1.88	2.38	2.24	0.94	0.27	13.71
3.5 - 4.0						0.01	0.14	0.58	0.93	0.66	0.47	0.87	1.02	1.20	0.81	0.17	6.84
4.0 - 4.5							0.01	0.15	0.38	0.40	0.23	0.29	0.34	0.42	0.42	0.19	2.82
4.5 - 5.0							0.01	0.02	0.09	0.18	0.12	0.17	0.17	0.16	0.21	0.14	1.27
5.0 - 5.5									0.02	0.05	0.11	0.05	0.11	0.09	0.05	0.08	0.55
5.5 - 6.0										0.03	0.01	0.05	0.05	0.08	0.03	0.05	0.30
6.0 - 6.5										0.01	0.01	0.02	0.03	0.01	0.02	0.02	0.12
6.5 - 7.0									0.01			0.01	0.02	0.02	0.03	0.02	0.11
7.0 - 7.5										0.01			0.02	0.03	0.03	0.01	0.10
7.5 - 8.0														0.01	0.01		0.02
8.0 - 8.5																	0.00
8.5 - 9.0																	0.00
Total	0.00	0.00	0.00	0.12	1.26	3.46	6.16	11.57	12.43	11.26	11.30	14.29	12.59	8.89	4.29	1.52	100.

Table : Percentage Occurrence for Period vs Wave Direction - All Data

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 58457

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4		0.01	0.01	0.03	0.01	0.00				0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.09
4 - 6		0.01	0.50	1.46	0.33	0.05	0.03	0.06	0.07	0.17	0.78	0.17	0.02		0.00		3.66
6 - 8			1.68	6.11	1.96	0.57	0.49	0.48	0.41	0.41	1.52	0.13	0.00				13.77
8 - 10			0.49	2.64	2.70	1.85	1.50	1.46	1.85	2.73	2.13	0.04					17.39
10 - 12			0.00	0.15	1.06	0.89	1.10	1.19	2.53	11.87	12.27	0.02					31.07
12 - 14				0.01	0.11	0.09	0.15	0.16	0.53	7.74	17.02						25.81
14 - 16				0.01	0.02	0.00	0.02	0.03	0.15	1.96	5.08						7.26
16 - 18									0.01	0.24	0.63						0.88
18 - 20										0.01	0.05						0.06
20 - 22											0.01						0.01
Total	0.00	0.02	2.69	10.41	6.19	3.45	3.28	3.38	5.54	25.13	39.51	0.37	0.03	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Summer

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14457

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4			0.01	0.04	0.01	0.01				0.01		0.01					0.08
4 - 6			0.46	2.32	0.75	0.11	0.03	0.08	0.17	0.28	1.04	0.13					5.38
6 - 8			1.88	8.81	4.22	0.66	0.82	0.72	0.62	0.56	1.26	0.03					19.58
8 - 10			0.32	1.74	3.05	2.77	1.97	1.58	1.70	3.82	1.97	0.01					18.93
10 - 12				0.07	0.95	1.20	1.07	1.11	1.65	11.75	14.30						32.10
12 - 14					0.20	0.05	0.12	0.15	0.34	5.74	11.98						18.58
14 - 16					0.05	0.01	0.03	0.03	0.06	1.25	3.12						4.55
16 - 18										0.19	0.53						0.72
18 - 20										0.02	0.04						0.06
20 - 22											0.03						0.03
Total	0.00	0.00	2.66	12.98	9.23	4.79	4.03	3.69	4.54	23.61	34.28	0.17	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Autumn

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4		0.01									0.01	0.02				0.01	0.04
4 - 6		0.01	0.34	1.18	0.13		0.03	0.05	0.07	0.14	0.64	0.18	0.06				2.81
6 - 8			1.21	4.73	1.61	0.67	0.48	0.44	0.46	0.38	1.37	0.13					11.47
8 - 10			0.07	1.35	2.71	1.93	1.51	1.62	1.72	2.04	1.66	0.12					14.71
10 - 12				0.06	1.41	0.98	1.52	1.72	3.76	15.60	9.70	0.05					34.80
12 - 14				0.05	0.14	0.13	0.24	0.25	0.82	10.96	14.85						27.44
14 - 16				0.05	0.01		0.02	0.07	0.25	2.60	4.72						7.73
16 - 18									0.04	0.27	0.61						0.92
18 - 20										0.01	0.04						0.05
20 - 22											0.02						0.02
Total	0.00	0.01	1.62	7.42	6.02	3.71	3.79	4.15	7.12	31.99	33.61	0.49	0.06	0.00	0.00	0.01	100.

Table : Percentage Occurrence for Period vs Wave Direction - Winter

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

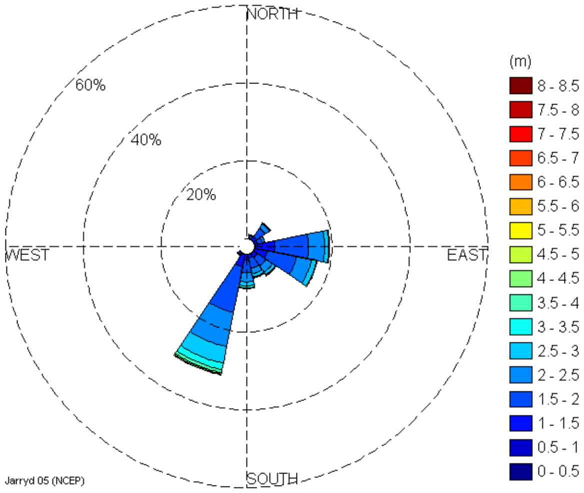
Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4		0.01	0.03	0.02	0.01					0.01	0.02		0.01	0.01	0.01		0.12
4 - 6		0.03	0.60	0.47	0.01	0.04		0.01		0.02	0.30	0.20	0.02		0.01		1.71
6 - 8			1.35	2.16	0.38	0.18	0.18	0.24	0.14	0.14	1.39	0.25	0.01				6.43
8 - 10			0.25	1.77	1.54	1.54	0.79	0.90	1.42	1.94	2.12	0.02					12.30
10 - 12				0.31	1.21	0.50	1.11	1.43	2.89	11.91	12.26	0.02					31.65
12 - 14					0.02	0.13	0.21	0.23	0.76	8.61	25.74						35.71
14 - 16							0.01	0.01	0.21	2.57	8.12						10.93
16 - 18										0.31	0.78						1.09
18 - 20											0.05						0.05
20 - 22																	0.00
Total	0.00	0.05	2.23	4.73	3.17	2.40	2.32	2.83	5.43	25.52	50.78	0.49	0.05	0.01	0.01	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Spring

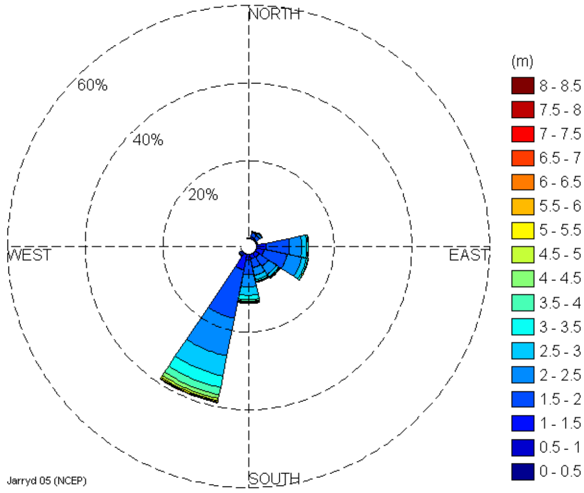
Period : 1997-01-30 to 2017-02-01
Station : Jarryd 03 (NCEP)
Position : 33.00000 S, 28.75000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14560

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4		0.01	0.01	0.04	0.01					0.01	0.03	0.01					0.12
4 - 6			0.60	1.91	0.44	0.06	0.05	0.10	0.03	0.25	1.15	0.18					4.77
6 - 8			2.31	8.83	1.66	0.77	0.49	0.52	0.43	0.57	2.06	0.10					17.74
8 - 10			1.34	5.71	3.52	1.17	1.72	1.74	2.56	3.15	2.78	0.01					23.72
10 - 12			0.01	0.14	0.66	0.87	0.69	0.49	1.80	8.18	12.85	0.01					25.69
12 - 14					0.09	0.04	0.03	0.01	0.18	5.58	15.40						21.33
14 - 16									0.06	1.37	4.33						5.77
16 - 18										0.18	0.61						0.79
18 - 20										0.01	0.06						0.07
20 - 22											0.01						0.01
Total	0.00	0.01	4.27	16.63	6.38	2.92	2.98	2.85	5.06	19.30	39.29	0.31	0.00	0.00	0.00	0.00	100.

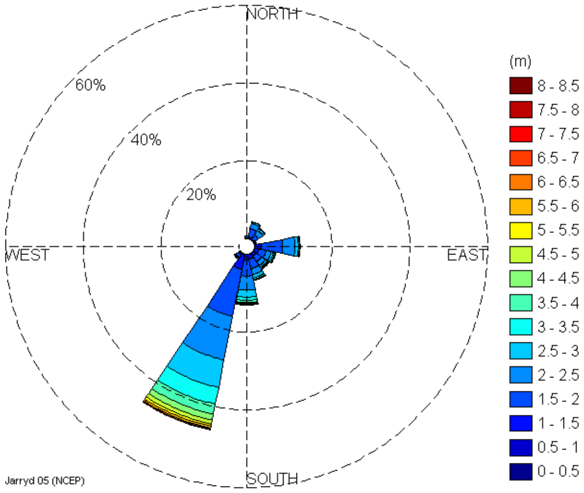
Summer - 14457 Records



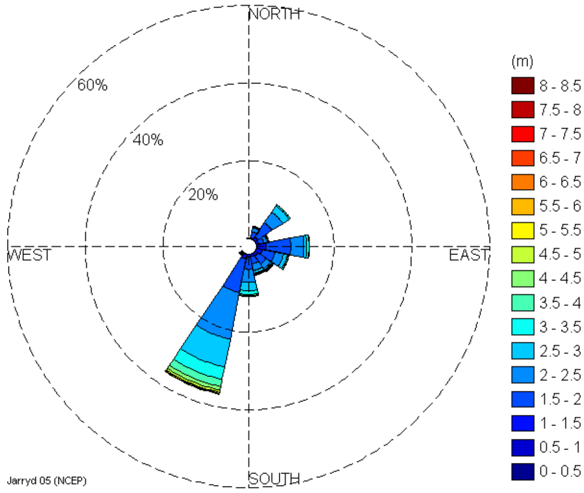
Autumn - 14720 Records



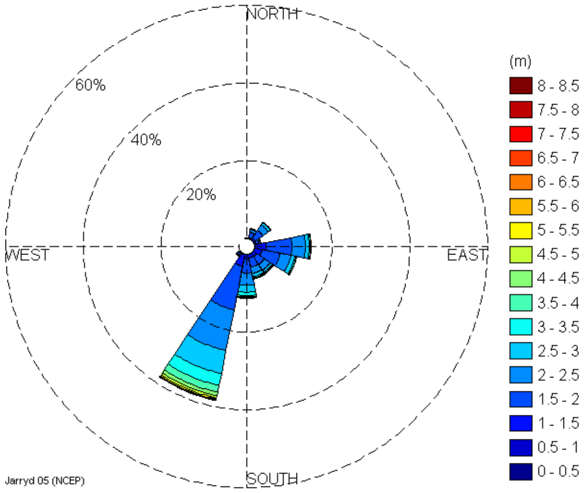
Winter - 14720 Records



Spring - 14560 Records



All Data - 58457 Records



Period	1997-01-30 to 2017-02-01
Station	Jarryd 05 (NCEP)
Position	29.00000 S, 32.50000 E
Instrument Depth	0 m
Water Depth	0.0 m
Instrument Type	WaveWatch III
Records	58457

CSIR	Jarryd 05 (NCEP) Wave Height (Hmo) vs Wave Direction 1997-01-30 to 2017-02-01	Figure

Table : Percentage Occurrence for Wave height vs Wave Direction - All Data

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 58457

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5		0.00	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.11	0.00						0.23
0.5 - 1.0	0.00	0.00	0.00	0.02	0.05	0.06	0.03	0.04	0.02	0.05	0.02						0.31
1.0 - 1.5	0.11	0.42	0.69	0.48	3.10	2.05	1.06	0.99	1.26	3.11	0.30	0.00	0.00				13.56
1.5 - 2.0	0.17	1.37	2.37	0.72	6.56	4.76	2.50	2.39	3.60	11.60	0.55						36.58
2.0 - 2.5	0.03	0.72	1.67	0.41	3.38	2.79	1.75	1.71	3.11	10.56	0.19						26.32
2.5 - 3.0	0.01	0.19	0.70	0.11	0.95	1.00	0.63	0.86	1.77	5.93	0.08						12.23
3.0 - 3.5		0.04	0.14	0.02	0.34	0.31	0.25	0.30	0.83	3.02	0.02						5.25
3.5 - 4.0			0.00	0.01	0.11	0.09	0.15	0.15	0.35	1.79	0.01						2.67
4.0 - 4.5				0.00	0.01	0.03	0.05	0.07	0.14	0.95	0.00						1.26
4.5 - 5.0					0.02	0.01	0.01	0.02	0.13	0.59	0.00						0.78
5.0 - 5.5					0.01	0.01	0.00	0.00	0.06	0.30							0.38
5.5 - 6.0					0.01	0.00	0.00	0.01	0.04	0.21							0.27
6.0 - 6.5					0.00		0.00	0.00	0.01	0.09							0.11
6.5 - 7.0								0.00	0.00	0.04							0.04
7.0 - 7.5									0.00	0.01							0.01
7.5 - 8.0										0.01							0.01
8.0 - 8.5									0.00	0.00							0.01
Total	0.31	2.75	5.57	1.78	14.55	11.12	6.46	6.55	11.36	38.36	1.18	0.00	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Summer
Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14457

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5				0.02	0.03	0.03	0.03	0.03	0.02	0.07							0.24
0.5 - 1.0			0.01	0.03	0.16	0.10	0.02	0.05	0.01	0.03							0.42
1.0 - 1.5		0.25	1.07	0.83	5.29	3.42	1.24	0.93	1.46	3.33	0.14						17.94
1.5 - 2.0	0.05	0.66	2.73	1.22	8.58	7.66	2.77	2.72	3.29	12.04	0.50						42.23
2.0 - 2.5		0.19	1.27	0.64	4.01	3.88	1.94	1.47	2.31	8.94	0.20						24.85
2.5 - 3.0		0.05	0.23	0.06	1.06	1.25	0.79	0.80	1.02	4.23	0.10						9.58
3.0 - 3.5			0.04	0.02	0.16	0.20	0.20	0.15	0.46	1.67							2.91
3.5 - 4.0					0.05	0.01	0.08	0.08	0.15	0.77							1.14
4.0 - 4.5							0.01	0.03	0.01	0.30							0.35
4.5 - 5.0								0.01	0.07	0.19							0.26
5.0 - 5.5										0.06							0.06
5.5 - 6.0										0.03							0.03
6.0 - 6.5																	0.00
6.5 - 7.0																	0.00
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
8.0 - 8.5																	0.00
Total	0.05	1.16	5.35	2.82	19.34	16.55	7.08	6.25	8.81	31.67	0.94	0.00	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Autumn

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5					0.02	0.01	0.02	0.02	0.03	0.11	0.01						0.22
0.5 - 1.0				0.01		0.07	0.03	0.02	0.04	0.03							0.20
1.0 - 1.5	0.08	0.63	0.36	0.23	2.51	2.07	1.22	1.17	1.42	4.10	0.43	0.01					14.22
1.5 - 2.0	0.14	0.99	1.12	0.10	6.02	6.04	2.93	2.38	3.78	12.85	0.43						36.78
2.0 - 2.5		0.31	0.72	0.03	3.15	3.80	2.45	2.02	3.14	9.71	0.12						25.44
2.5 - 3.0		0.07	0.07	0.01	1.27	1.16	0.75	1.11	2.15	5.20	0.02						11.80
3.0 - 3.5					0.31	0.38	0.23	0.39	1.12	2.96	0.01						5.40
3.5 - 4.0					0.06	0.14	0.15	0.22	0.39	1.90							2.87
4.0 - 4.5					0.02		0.07	0.13	0.22	1.01							1.45
4.5 - 5.0					0.03	0.01	0.01	0.03	0.18	0.56							0.82
5.0 - 5.5					0.02	0.01	0.01		0.08	0.26							0.39
5.5 - 6.0					0.03	0.01	0.01		0.04	0.14							0.23
6.0 - 6.5					0.01		0.01		0.02	0.05							0.09
6.5 - 7.0									0.01	0.04							0.05
7.0 - 7.5									0.01	0.01							0.02
7.5 - 8.0										0.01							0.01
8.0 - 8.5									0.01	0.01							0.02
Total	0.22	1.99	2.27	0.38	13.44	13.71	7.87	7.49	12.64	38.95	1.02	0.01	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Winter

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5		0.01		0.01	0.01		0.01	0.01	0.04	0.14	0.01						0.22
0.5 - 1.0	0.01	0.01		0.04		0.04	0.05	0.10	0.04	0.12	0.08						0.50
1.0 - 1.5	0.33	0.50	0.33	0.21	1.95	1.13	0.82	1.19	1.39	3.82	0.47		0.01				12.13
1.5 - 2.0	0.36	2.18	1.26	0.20	5.49	1.97	1.81	2.53	4.21	12.51	0.86						33.39
2.0 - 2.5	0.07	1.37	1.45	0.11	3.04	1.30	1.22	1.58	3.56	11.39	0.24						25.33
2.5 - 3.0		0.38	0.58	0.03	0.82	0.63	0.56	0.84	1.80	7.09	0.13						12.85
3.0 - 3.5		0.03	0.16		0.26	0.35	0.35	0.39	0.77	4.27	0.05						6.64
3.5 - 4.0					0.16	0.13	0.20	0.14	0.56	2.57	0.03						3.80
4.0 - 4.5				0.01	0.02	0.07	0.03	0.03	0.26	1.54	0.01						1.98
4.5 - 5.0					0.03	0.02	0.01	0.03	0.18	1.03							1.29
5.0 - 5.5						0.01		0.01	0.14	0.65							0.82
5.5 - 6.0								0.03	0.10	0.49							0.61
6.0 - 6.5								0.01	0.01	0.27							0.30
6.5 - 7.0								0.01		0.10							0.10
7.0 - 7.5										0.01							0.01
7.5 - 8.0										0.01							0.01
8.0 - 8.5																	0.00
Total	0.77	4.48	3.78	0.60	11.77	5.65	5.06	6.90	13.08	46.03	1.88	0.00	0.01	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Wave Direction - Spring

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14560

Hmo (m)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0 - 0.5		0.01	0.03	0.01	0.03	0.01	0.01	0.01	0.01	0.11							0.23
0.5 - 1.0				0.01	0.03	0.01	0.02			0.03	0.01						0.11
1.0 - 1.5	0.01	0.30	1.00	0.66	2.70	1.59	0.95	0.65	0.76	1.18	0.15						9.97
1.5 - 2.0	0.11	1.63	4.40	1.36	6.18	3.41	2.52	1.92	3.10	8.97	0.41						34.01
2.0 - 2.5	0.05	1.00	3.25	0.89	3.34	2.21	1.39	1.77	3.41	12.19	0.20						29.69
2.5 - 3.0	0.02	0.27	1.92	0.36	0.65	0.98	0.41	0.67	2.12	7.20	0.07						14.66
3.0 - 3.5		0.12	0.34	0.05	0.62	0.31	0.21	0.26	0.95	3.13	0.03						6.02
3.5 - 4.0			0.01	0.03	0.16	0.08	0.18	0.17	0.29	1.90	0.01						2.82
4.0 - 4.5				0.01	0.01	0.05	0.11	0.08	0.07	0.93							1.24
4.5 - 5.0					0.01	0.01	0.03	0.02	0.11	0.56	0.01						0.76
5.0 - 5.5									0.03	0.23							0.25
5.5 - 6.0									0.01	0.19							0.19
6.0 - 6.5										0.04							0.04
6.5 - 7.0										0.01							0.01
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
8.0 - 8.5																	0.00
Total	0.20	3.33	10.94	3.37	13.72	8.66	5.84	5.56	10.84	36.67	0.88	0.00	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Wave height vs Period - All Data

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 58457

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5						0.00	0.02	0.02	0.03	0.03	0.03	0.01	0.03	0.02	0.01	0.01	0.22
0.5 - 1.0				0.01	0.01	0.03	0.01	0.05	0.04	0.05	0.05	0.02	0.02	0.02	0.00		0.31
1.0 - 1.5				0.20	0.71	0.60	1.05	2.49	2.29	1.56	1.62	1.22	0.84	0.56	0.29	0.11	13.51
1.5 - 2.0				0.05	1.76	2.94	2.15	3.43	6.05	4.61	3.68	3.81	3.38	2.50	1.51	0.46	36.32
2.0 - 2.5					0.20	1.82	2.69	2.09	2.62	3.71	3.00	2.66	2.54	2.33	1.61	0.67	25.95
2.5 - 3.0					0.01	0.31	1.52	1.46	1.03	1.38	1.46	1.28	1.12	1.08	0.94	0.40	12.00
3.0 - 3.5					0.00	0.04	0.30	0.97	0.66	0.50	0.65	0.54	0.44	0.41	0.39	0.22	5.12
3.5 - 4.0						0.02	0.07	0.28	0.53	0.41	0.34	0.33	0.20	0.19	0.13	0.10	2.59
4.0 - 4.5							0.02	0.08	0.17	0.29	0.18	0.17	0.11	0.07	0.11	0.04	1.23
4.5 - 5.0							0.01	0.03	0.09	0.20	0.15	0.12	0.05	0.05	0.03	0.02	0.76
5.0 - 5.5							0.00		0.02	0.09	0.10	0.08	0.02	0.02	0.02	0.02	0.37
5.5 - 6.0								0.00	0.01	0.03	0.06	0.08	0.05	0.01	0.01	0.01	0.26
6.0 - 6.5									0.00	0.01	0.02	0.05	0.02	0.01	0.01	0.00	0.10
6.5 - 7.0											0.01	0.01	0.01	0.00		0.00	0.03
7.0 - 7.5												0.00	0.00	0.00			0.01
7.5 - 8.0													0.01				0.01
8.0 - 8.5													0.00	0.00			0.01
Total	0.00	0.00	0.00	0.26	2.70	5.76	7.84	10.90	13.54	12.85	11.36	10.38	8.81	7.28	5.05	2.06	100.

Table : Percentage Occurrence for Wave height vs Period - Summer

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14457

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5						0.01	0.02	0.02	0.06	0.04	0.03		0.03	0.02	0.01		0.24
0.5 - 1.0				0.03	0.04	0.08	0.01	0.12	0.08	0.02	0.01	0.01		0.01	0.01		0.42
1.0 - 1.5				0.20	0.88	1.00	2.26	4.56	3.07	2.14	1.54	1.20	0.64	0.31	0.10	0.03	17.92
1.5 - 2.0				0.01	1.69	3.63	2.99	5.62	7.77	5.12	3.83	4.15	3.39	2.23	1.09	0.40	41.92
2.0 - 2.5					0.14	1.52	3.20	2.43	2.77	4.09	2.63	2.14	2.20	1.80	1.18	0.42	24.52
2.5 - 3.0					0.02	0.22	1.45	1.34	1.01	1.40	1.15	1.04	0.77	0.59	0.37	0.11	9.48
3.0 - 3.5						0.03	0.19	0.74	0.55	0.28	0.25	0.21	0.22	0.18	0.19	0.06	2.90
3.5 - 4.0						0.01	0.03	0.25	0.43	0.11	0.09	0.06	0.06	0.06	0.01	0.03	1.14
4.0 - 4.5								0.03	0.03	0.08	0.03	0.02	0.04	0.06	0.01	0.01	0.32
4.5 - 5.0									0.02	0.07	0.04	0.06	0.04	0.02		0.01	0.26
5.0 - 5.5										0.01	0.01	0.01	0.02				0.06
5.5 - 6.0													0.03				0.03
6.0 - 6.5																	0.00
6.5 - 7.0																	0.00
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
8.0 - 8.5																	0.00
Total	0.00	0.00	0.00	0.24	2.77	6.50	10.15	15.13	15.80	13.37	9.61	8.90	7.44	5.27	2.95	1.07	100.

Table : Percentage Occurrence for Wave height vs Period - Autumn

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5							0.01	0.01	0.01	0.02	0.06	0.03	0.04	0.01	0.01	0.01	0.21
0.5 - 1.0						0.01	0.01	0.03	0.01	0.09	0.05						0.20
1.0 - 1.5				0.15	0.75	0.35	0.50	2.04	2.47	1.60	1.96	1.62	1.24	0.94	0.43	0.16	14.21
1.5 - 2.0				0.03	1.13	1.63	1.19	2.91	6.43	4.67	4.46	4.67	4.21	2.83	1.77	0.50	36.41
2.0 - 2.5					0.07	0.99	1.55	1.58	2.83	3.98	3.50	2.91	2.74	2.41	1.74	0.69	24.99
2.5 - 3.0					0.01	0.18	0.93	0.86	0.89	1.62	1.95	1.41	1.16	1.07	0.95	0.50	11.52
3.0 - 3.5						0.03	0.24	0.94	0.56	0.46	0.77	0.77	0.37	0.42	0.38	0.27	5.22
3.5 - 4.0						0.02	0.09	0.22	0.55	0.49	0.44	0.36	0.26	0.15	0.14	0.09	2.82
4.0 - 4.5							0.01	0.10	0.20	0.43	0.18	0.29	0.07	0.02	0.10	0.04	1.43
4.5 - 5.0							0.01	0.04	0.11	0.21	0.12	0.15	0.01	0.09	0.02	0.03	0.79
5.0 - 5.5									0.04	0.14	0.08	0.08	0.01	0.03			0.39
5.5 - 6.0									0.02	0.05	0.06	0.03	0.05	0.01			0.23
6.0 - 6.5										0.01	0.03		0.03	0.01			0.09
6.5 - 7.0											0.01	0.01	0.01	0.01			0.05
7.0 - 7.5												0.01	0.01	0.01			0.02
7.5 - 8.0													0.01				0.01
8.0 - 8.5													0.01	0.01			0.02
Total	0.00	0.00	0.00	0.18	1.95	3.21	4.54	8.72	14.12	13.76	13.68	12.34	10.24	8.03	5.54	2.28	100.

Table : Percentage Occurrence for Wave height vs Period - Winter

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5							0.01	0.01	0.02	0.01	0.03	0.01	0.03	0.04	0.02	0.03	0.21
0.5 - 1.0				0.01		0.01	0.02	0.01	0.05	0.07	0.14	0.05	0.06	0.07			0.50
1.0 - 1.5				0.25	0.60	0.25	0.32	1.15	1.50	1.34	2.17	1.62	1.21	0.81	0.57	0.22	12.00
1.5 - 2.0				0.10	1.73	2.19	1.08	1.24	4.09	4.40	4.19	4.04	3.72	3.48	2.11	0.76	33.12
2.0 - 2.5					0.21	1.60	2.04	1.11	1.83	3.32	3.16	2.93	2.59	2.97	2.13	1.03	24.93
2.5 - 3.0					0.01	0.27	1.22	0.89	0.77	1.30	1.82	1.52	1.35	1.44	1.32	0.63	12.54
3.0 - 3.5					0.01	0.04	0.33	0.94	0.71	0.62	0.85	0.76	0.72	0.57	0.52	0.35	6.41
3.5 - 4.0						0.03	0.07	0.27	0.50	0.63	0.48	0.57	0.29	0.37	0.26	0.14	3.63
4.0 - 4.5							0.04	0.10	0.20	0.38	0.35	0.24	0.23	0.14	0.24	0.05	1.96
4.5 - 5.0							0.02	0.05	0.14	0.31	0.30	0.16	0.13	0.04	0.07	0.04	1.27
5.0 - 5.5							0.01		0.03	0.13	0.28	0.18	0.05	0.03	0.05	0.06	0.82
5.5 - 6.0								0.01	0.01	0.03	0.13	0.22	0.09	0.02	0.05	0.03	0.60
6.0 - 6.5									0.01	0.01	0.03	0.16	0.03	0.02	0.01	0.01	0.28
6.5 - 7.0											0.03	0.02	0.01	0.01		0.01	0.07
7.0 - 7.5												0.01		0.01			0.01
7.5 - 8.0													0.01				0.01
8.0 - 8.5																	0.00
Total	0.00	0.00	0.00	0.35	2.56	4.40	5.16	5.79	9.88	12.54	13.95	12.50	10.53	10.02	7.34	3.36	100.

Table : Percentage Occurrence for Wave height vs Period - Spring

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14560

Hmo (m)	Period (Tp) (s)																
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Total
0.0 - 0.5						0.01	0.03	0.03	0.03	0.03	0.01	0.01	0.03	0.03	0.01		0.22
0.5 - 1.0				0.01			0.01	0.03	0.03		0.01	0.02					0.11
1.0 - 1.5				0.19	0.62	0.79	1.13	2.23	2.12	1.15	0.82	0.43	0.26	0.15	0.05	0.03	9.97
1.5 - 2.0				0.07	2.51	4.34	3.35	4.00	5.91	4.27	2.24	2.38	2.17	1.44	1.03	0.18	33.88
2.0 - 2.5					0.40	3.18	4.00	3.26	3.06	3.46	2.69	2.66	2.60	2.14	1.39	0.55	29.38
2.5 - 3.0					0.01	0.59	2.51	2.77	1.44	1.19	0.91	1.13	1.19	1.22	1.10	0.37	14.44
3.0 - 3.5						0.06	0.45	1.26	0.82	0.65	0.71	0.40	0.43	0.45	0.47	0.21	5.91
3.5 - 4.0						0.01	0.09	0.36	0.63	0.40	0.34	0.31	0.17	0.18	0.12	0.12	2.73
4.0 - 4.5							0.02	0.08	0.25	0.27	0.16	0.14	0.08	0.05	0.08	0.05	1.20
4.5 - 5.0								0.04	0.08	0.20	0.15	0.11	0.03	0.04	0.03	0.02	0.70
5.0 - 5.5									0.02	0.08	0.04	0.04	0.01	0.02	0.01	0.01	0.23
5.5 - 6.0									0.01	0.03	0.04	0.07	0.02	0.01	0.01		0.19
6.0 - 6.5												0.03			0.01		0.04
6.5 - 7.0											0.01	0.01					0.01
7.0 - 7.5																	0.00
7.5 - 8.0																	0.00
8.0 - 8.5																	0.00
Total	0.00	0.00	0.00	0.27	3.54	8.98	11.60	14.06	14.41	11.73	8.14	7.73	6.99	5.73	4.31	1.53	100.

Table : Percentage Occurrence for Period vs Wave Direction - All Data

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 58457

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4	0.05	0.09	0.06	0.02		0.00			0.01	0.03	0.01	0.00	0.00				0.26
4 - 6	0.25	2.07	2.94	0.59	0.13	0.05	0.06	0.12	0.69	1.47	0.13						8.49
6 - 8	0.01	0.59	2.53	0.99	3.23	2.38	1.48	1.32	2.12	4.12	0.05						18.82
8 - 10			0.04	0.17	9.11	6.10	2.81	2.50	2.61	3.07	0.00						26.41
10 - 12			0.00	0.01	1.87	2.41	1.87	2.23	4.21	9.09	0.03						21.72
12 - 14			0.01	0.00	0.16	0.16	0.21	0.32	1.29	13.46	0.41						16.02
14 - 16			0.00	0.00	0.03	0.02	0.02	0.07	0.39	6.10	0.45						7.08
16 - 18					0.01	0.00	0.01		0.05	0.96	0.08						1.10
18 - 20										0.07	0.02						0.09
20 - 22										0.00	0.00						0.01
Total	0.31	2.75	5.57	1.78	14.55	11.12	6.46	6.55	11.36	38.36	1.18	0.00	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Summer

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14457

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4	0.01	0.06	0.12	0.03						0.03							0.24
4 - 6	0.04	0.98	3.71	1.25	0.28	0.11	0.10	0.24	0.84	1.60	0.15						9.30
6 - 8		0.12	1.45	1.30	6.19	4.43	2.61	1.87	2.67	4.71	0.05						25.41
8 - 10			0.01	0.20	10.18	9.26	2.74	2.45	2.30	1.97							29.10
10 - 12			0.01	0.01	2.12	2.42	1.35	1.36	2.34	8.86	0.02						18.51
12 - 14			0.03	0.01	0.44	0.25	0.21	0.31	0.59	10.45	0.35						12.64
14 - 16			0.01	0.01	0.08	0.08	0.06	0.02	0.06	3.40	0.28						4.00
16 - 18					0.05	0.01				0.59	0.04						0.69
18 - 20										0.06	0.05						0.10
20 - 22										0.01							0.01
Total	0.05	1.16	5.35	2.82	19.34	16.55	7.08	6.25	8.81	31.67	0.94	0.00	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Autumn

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4	0.03	0.10	0.02			0.01			0.01	0.01		0.01					0.18
4 - 6	0.20	1.72	1.47	0.10	0.09	0.05	0.03	0.04	0.40	1.05	0.03						5.18
6 - 8		0.17	0.77	0.26	2.19	2.27	1.35	1.39	2.02	2.91	0.05						13.38
8 - 10				0.02	8.68	7.23	3.98	2.95	2.28	2.77							27.91
10 - 12					2.24	3.91	2.39	2.48	5.16	9.81	0.03						26.03
12 - 14					0.21	0.24	0.12	0.50	2.07	14.58	0.40						18.11
14 - 16					0.03			0.14	0.63	6.63	0.41						7.83
16 - 18									0.09	1.13	0.08						1.30
18 - 20										0.07							0.07
20 - 22											0.01						0.01
Total	0.22	1.99	2.27	0.38	13.44	13.71	7.87	7.49	12.64	38.95	1.02	0.01	0.00	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Winter

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14720

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4	0.18	0.09	0.02	0.01						0.04	0.02		0.01				0.36
4 - 6	0.59	2.97	1.47	0.04			0.01	0.05	0.60	1.11	0.13						6.98
6 - 8		1.43	2.24	0.36	1.16	0.72	0.31	0.48	0.87	3.33	0.07						10.96
8 - 10			0.06	0.18	8.63	2.77	1.75	2.33	2.79	4.04							22.54
10 - 12				0.01	1.98	2.11	2.53	3.55	6.27	9.94	0.03						26.41
12 - 14					0.01	0.05	0.41	0.40	1.82	17.11	0.69						20.50
14 - 16							0.03	0.09	0.63	9.14	0.76						10.65
16 - 18							0.02		0.10	1.30	0.15						1.56
18 - 20										0.03	0.01						0.04
20 - 22																	0.00
Total	0.77	4.48	3.78	0.60	11.77	5.65	5.06	6.90	13.08	46.03	1.87	0.00	0.01	0.00	0.00	0.00	100.

Table : Percentage Occurrence for Period vs Wave Direction - Spring

Period : 1997-01-30 to 2017-02-01
Station : Jarryd 05 (NCEP)
Position : 29.00000 S, 32.50000 E
Instrument Depth : 0 m
Water Depth : 0.0 m
Instrument Type : WaveWatch III
Records : 14560

Tp (s)	Wave Direction (degrees TN)																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 2																	0.00
2 - 4		0.10	0.08	0.03					0.01	0.05	0.01						0.27
4 - 6	0.17	2.58	5.14	1.00	0.17	0.03	0.10	0.14	0.91	2.14	0.19						12.58
6 - 8	0.03	0.65	5.66	2.06	3.43	2.14	1.67	1.55	2.94	5.56	0.03						25.71
8 - 10			0.07	0.28	8.97	5.19	2.77	2.27	3.09	3.48	0.01						26.13
10 - 12					1.15	1.20	1.21	1.50	3.01	7.75	0.03						15.83
12 - 14						0.12	0.08	0.06	0.64	11.61	0.21						12.72
14 - 16								0.03	0.24	5.17	0.34						5.78
16 - 18										0.80	0.03						0.84
18 - 20										0.12	0.03						0.14
20 - 22																	0.00
Total	0.20	3.33	10.94	3.37	13.72	8.66	5.84	5.56	10.84	36.67	0.88	0.00	0.00	0.00	0.00	0.00	100.

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