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Title:

ClubStead Preliminary Analysis:
Metocean Conditions

Client:
The SeaStead Institute

Project#:
MI&T040-08_R2

Revision:
0

Page 1 of 10

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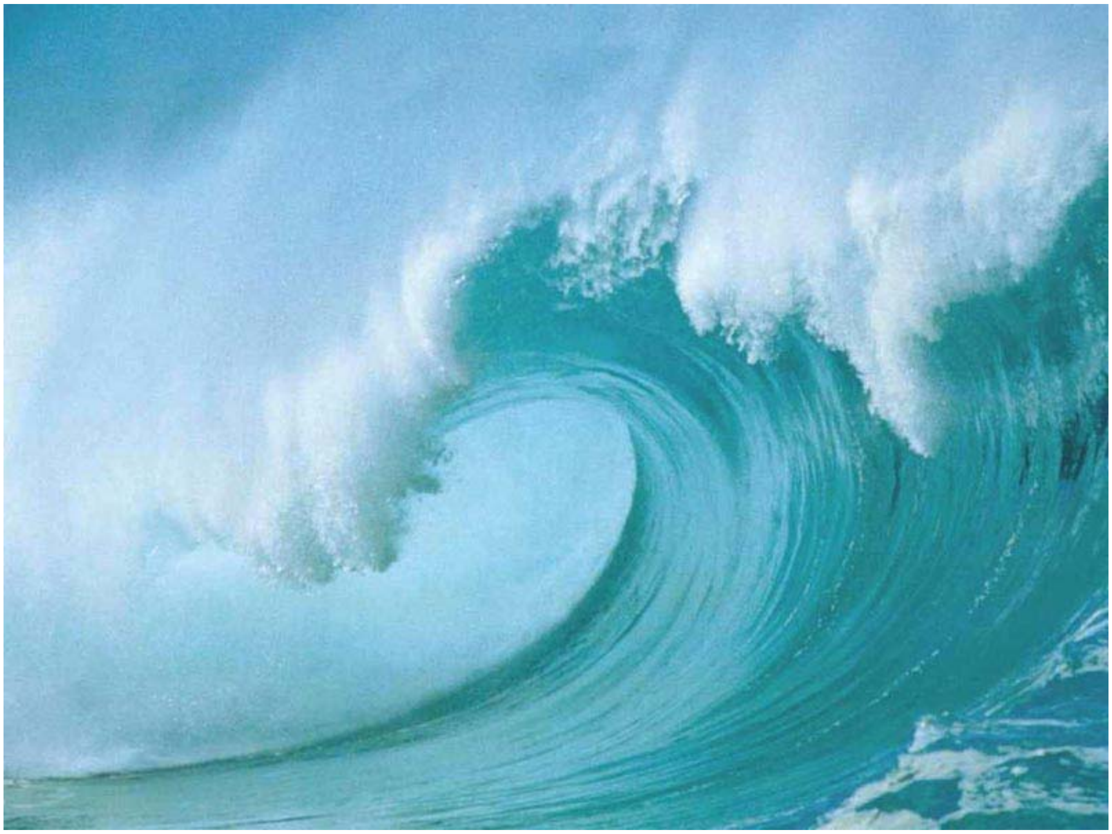
ClubStead Preliminary Analysis: Metocean Conditions



04.01.09	*0*	*AA*	*DGR*	*For Review doc*
Date	Rev.	Written by	Checked by	Status/Comments

Contents

Table of Figures

Table of Tables

1. Summary and Conclusions

The ClubStead must be designed to meet survival and operational requirements. It must survive extreme weather conditions at sea and its motions in operational sea-states need to be limited to ensure the comfort of passengers. To study these aspects of the design, it is important to know the characteristics of the relevant sea-states in operational and extreme conditions.

The environmental conditions are derived from 10 years of archived NOAA data at a location 100 miles off the coast of San Diego, California.

The *wave scatter diagram* provides the probabilities of occurrence of waves with peak period Tp ranging from 4 sec to 20 sec and significant wave height Hs between 1 and 9m. Each wave height is combined with the most probable wind speed at the given Hs.

A Weibull fit on the historical data provides the following *most probable extreme sea-states* at the location:

Return Period		**1 year**	**10 year**	**100 year**
Hs	*m*	7.0	7.7	8.3
Tp	*s*	14.3	14.3	14.3
Wind Speed	*m/s*	16.0	17.5	18.9
Current Speed	*m/s*	0.48	0.53	0.57

2. Introduction

This report discusses the environmental conditions derived for the design of the ClubStead floating facility. It describes the wind and wave conditions at a site 100 miles off the coast of San Diego. The location was selected based on business necessities, including distance to the Californian seashore and mildness of the weather.

Knowledge of the environmental conditions the floater will encounter is a critical component of the design. The metocean analysis aims at gathering wave and wind conditions for both operational sea-states and extreme weather. A sea-state may be defined by the following parameters:

- Wind speed (m/s) averaged over a defined period of time.
- Significant wave height (m) calculated as the average of the highest one-third of all the wave heights during a defined sampling period.
- Dominant wave period (sec) is the period with maximum wave energy
- Mean current velocity (m/s)
- Wind and wave direction of propagation, provided as an angle clock-wise from North.

This information is used to calculate the environmental loads on the platform and study the response of the ClubStead in realistic environmental conditions.

3. Location

Several locations have been investigated for the ClubStead, depending on its economic orientation, ownership and residential organization.

In the present studies, the platform is expected to be dynamically positioned off the Southern West Coast of the United States, far enough from the coast line to be out of US territorial waters. It may be allowed to drift in a delimited zone but will remain in the same region all year round. The waters off the city of San Diego, in California are chosen as a likely position for the ClubStead floater.

Environmental data is obtained at the intended site based on wind and wave measurements downloaded from the NOAA web site[1]. The National Data Buoy Center centralizes statistics and raw data of metocean information over the past decades at given locations along the US coast line, where buoys are dispatched (Figure 1).

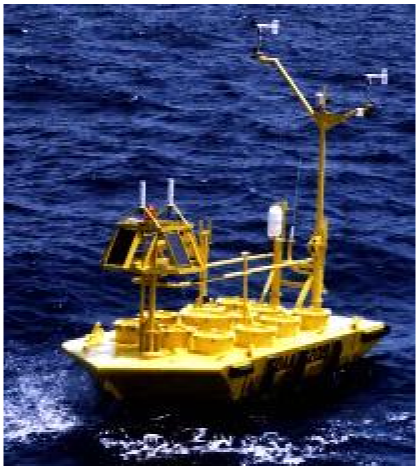


Figure 1: National Data Buoy Center buoy

The environmental conditions are derived from historical data available for the NOAA buoy 46047[2], located at 32°26’0”N and 119°31’59”W, 121 miles West of San Diego, as shown in Figure 2. Wind and wave data covering a 10 year period throughout December 2008 are used to determine the design environmental sea-state for the ClubStead.

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[1] http://www.ndbc.noaa.gov/

[2] http://www.ndbc.noaa.gov/station_page.php?station=46047

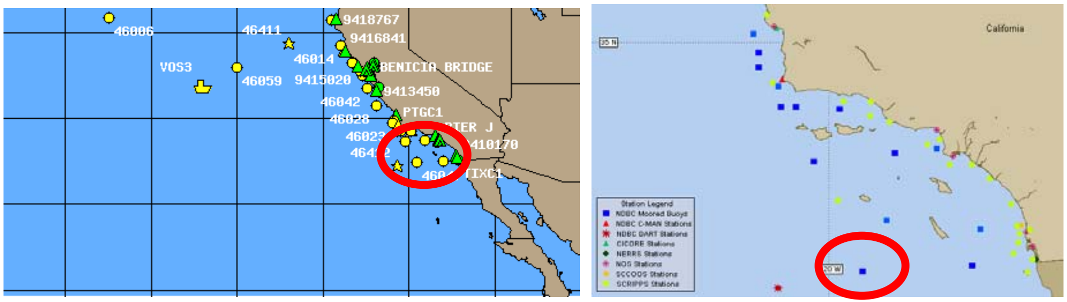

Figure 2: Location of NDBC buoy #46047, off the coast of California

The wave scatter diagram, based on the statistical distribution of seas-states defines the environmental conditions encountered by the ClubStead.

Extreme conditions are derived with a Weibull fit of the available data to obtain the 1 year, 10 year and 100 year sea-state. The associated wind speeds are obtained through a joined analysis.

4. Theoretical Background

The metocean analysis aims to define the following information:

- The **wave scatter diagram** is a table of significant wave height, Hs versus dominant period, Tp which defines the operational sea-state according to a defined sea spectrum such as the Jonswap spectrum. A probability of occurrence is attached to each combination of Hs and Tp. In the present analysis, it is obtained by counting the number of occurrences of the sea-state measured over a number of years at an NOAA buoy. Associated wind speed of most probable occurrence can be jointly tabulated.

- An **extreme sea-state** is defined as the combination of maximum wave height Hs and maximum wind speed Ws likely to occur over a given return period. Return periods that are usually relevant to the design are 1 year, 10 year and 100 year.

To be able to extract, from 10 years of sporadic data, a sea-state of distinct return period , a Weibull distribution is fitted to the right tail (largest) of the extreme values by minimizing the least squares relative error over the ordered statistics. Theoretical justification for the use of the Weibull distribution to describe extreme values of wind and wave data is clearly outside the scope of this document, but the Weibull distribution has been used very frequently and has been shown to be an excellent fit to extreme metocean events.
When concatenating data runs of various lengths (multiple years, with sometimes missing data), assuming that the peak distribution follows a Poisson distribution, one can show that the probability of exceedence / unit time is defined as:

$\varepsilon_{\text{scaled}} = 1 - e^{(-\lambda\varepsilon)}$,
where λ = Number of peaks per unit time.
The center probability of exceedence is given by $\varepsilon = 1 - (i - .5)/N$.

5. Results

5.1. Operational Conditions

The 10 years of data from NOAA buoy #46047 are analyzed and probabilities of occurrence are computed for wave characteristics. The probabilities of occurrence are summarized in the wave scatter diagram in Table 1 based on more than 75,000 data points.

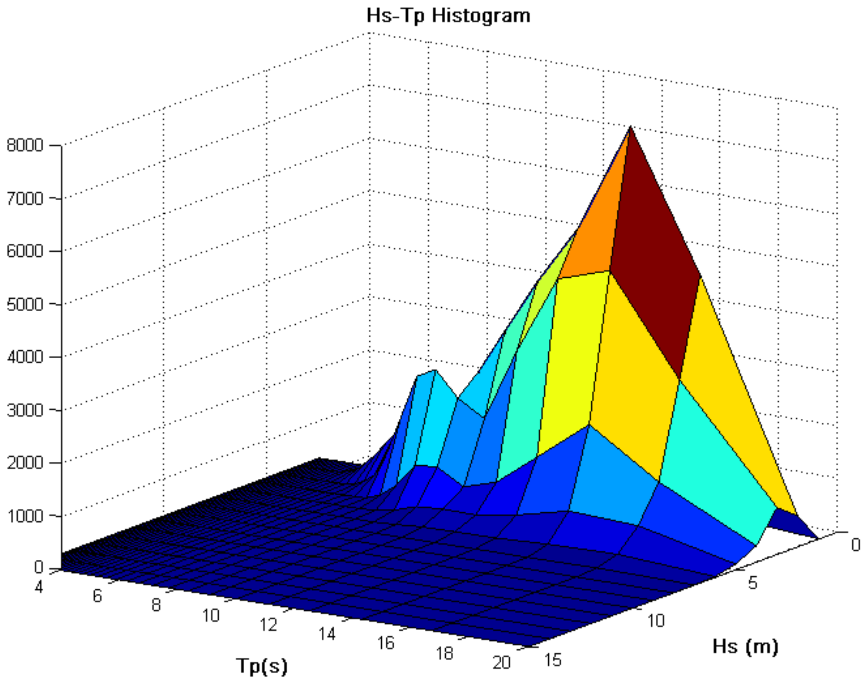

Figure 3: Histogram of Wave Characteristics (Hs/Tp)

5.2. Extreme Conditions

Unlike fixed offshore platforms which are designed for the 100-year storm, the ClubStead is not to be anchored and may be able to take cover behind islands and in naturally shielded areas during large storms. Nevertheless, since it is to remain in the same region over time and it will likely be transporting passengers, and facing tight safety requirements, the 100-year storm is taken as the extreme survivability event of the design basis.

Table 1: Probability of Occurrence of Sea-States at Location #46059 based on 14 years of data
(* indicates that the probability of occurrence is below 0.1%)

Frequency (sec)		**0.25**	**0.24**	**0.23**	**0.22**	**0.21**	**0.20**	**0.19**	**0.18**	**0.17**	**0.16**	**0.15**	**0.14**	**0.13**	**0.12**	**0.11**	**0.10**	**0.09**	**0.08**	**0.07**	**0.06**	**0.05**	
Tp (sec)		**4**	**4.17**	**4.35**	**4.55**	**4.76**	**5**	**5.26**	**5.56**	**5.88**	**6.25**	**6.67**	**7.14**	**7.69**	**8.33**	**9.09**	**10**	**11.11**	**12.5**	**14.29**	**16.67**	**20**	*Total*
Hs (m)	**1**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.10	0.16	0.14	0.22	0.46	0.71	0.21	0.01	*2.1*
	2	0.01	0.01	0.01	0.05	0.09	0.19	0.38	0.58	0.89	1.21	1.43	1.40	1.54	2.02	3.10	4.24	5.61	7.11	9.87	6.42	0.77	*46.9*
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.16	0.36	0.95	1.90	3.00	3.24	2.62	2.21	4.05	6.01	6.43	3.98	1.18	*36.2*
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.15	0.46	1.04	1.09	0.70	0.94	1.74	2.77	1.61	0.41	*10.9*
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	0.29	0.33	0.32	0.48	0.79	0.71	0.14	*3.2*
	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.09	0.10	0.15	0.18	0.03	*0.7*
	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.01	*0.1*
	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	*0.0*
	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.0*
Total		***0.0***	***0.0***	***0.0***	***0.0***	***0.1***	***0.2***	***0.4***	***0.6***	***1.0***	***1.6***	***2.4***	***3.5***	***5.1***	***6.5***	***7.3***	***7.7***	***11.2***	***15.9***	***20.7***	***13.1***	***2.5***	*100*

It is important to estimate accurately the largest sea-states the platform could encounter. The floater will then be designed to withstand the loads induced by these large waves. Herein, the most probable sea-state is obtained for return periods of 1, 10 and 100 years. The maximum significant wave height which will most probably occur over these return periods is derived by extrapolation of the available data using a Weibull fit. It is combined with the most probable dominant wave period at large wave height, Tp=14.29sec. The same method of extrapolation is used to determine the maximum wind speed.

Figure 4 and Figure 5 represent the probability that the wave height and the wind speed respectively exceed a given value. The red dots materialize the 1 year, 10 year and 100 year maximum value. The abscissa represents the wave height in Figure 4 and the wind speed in Figure 5. The ordinate is the return period in seconds. For example 1 year is 1 / (3600 x 24 x 365) = 3.2 10^{-8} sec^{-1}.

Results are summarized in Table 2. In lieu of scatter data, it is a good approximation to assume a wind-induced current velocity equal to 3% of wind speed.

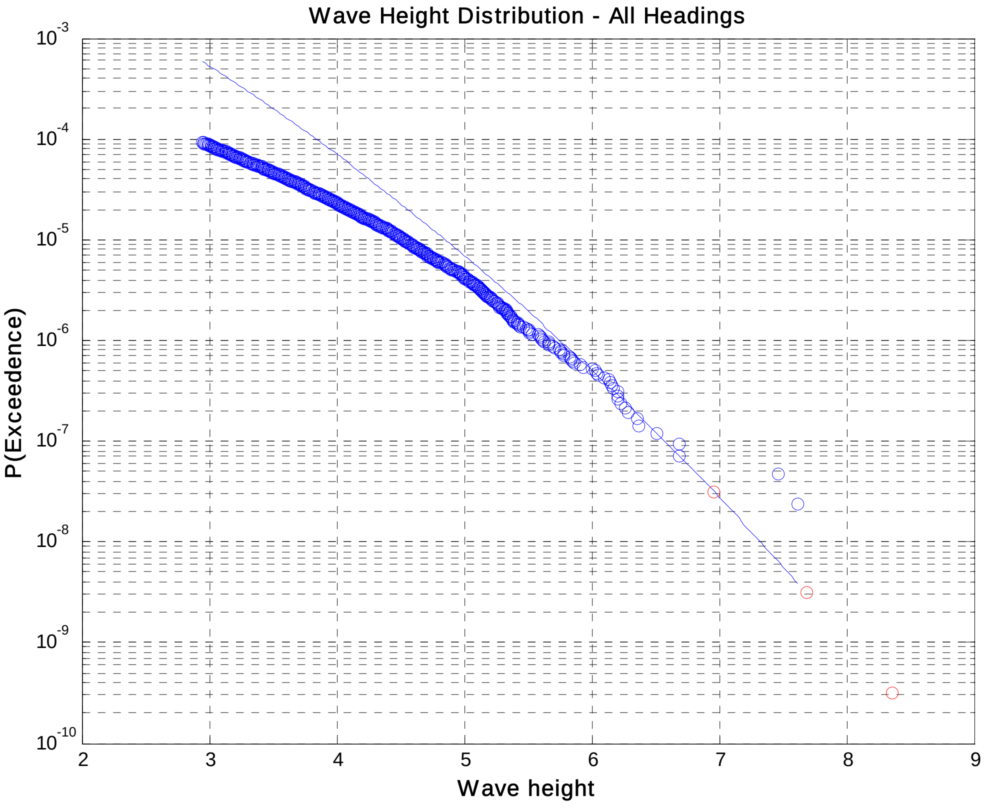

Figure 4: Weibull fit (solid blue line) of the Wave Height Distribution (blue dots)

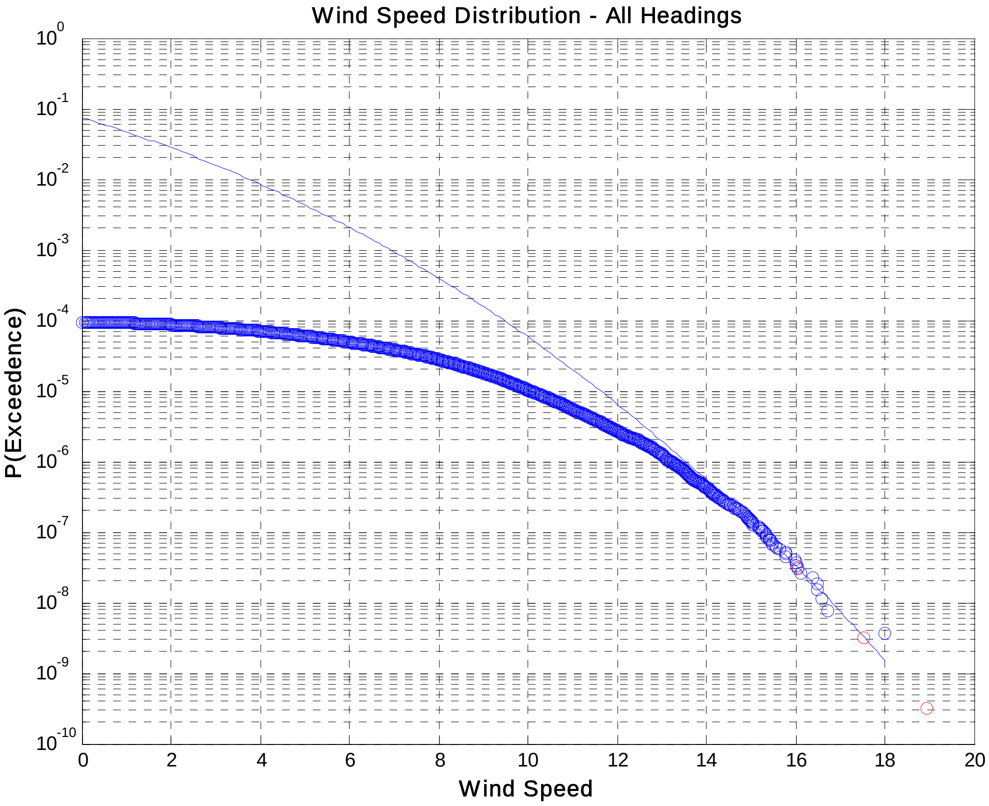

Figure 5: Weibull fit (solid blue line) of the Wind Speed Distribution (blue dots)

Table 2: Extreme Design Sea-States at San Francisco Location

Return Period		1 year	10 year	100 year
Hs	*m*	7.0	7.7	8.3
Tp	*s*	14.3	14.3	14.3
Wind Speed	*m/s*	16.0	17.5	18.9
Current Speed	*m/s*	0.48	0.53	0.57

If the ClubStead angular orientation is predetermined, the directionality of the wind should be considered, since it may affect the design. In the case of the North Pacific Ocean, the wind seas mainly come from the West - North West, as shown in Figure 6. In Figure 7, a secondary direction appears with waves coming from the West. It corresponds to the swell coming from the central Pacific Ocean.

Such directional seas may be taken into account for the detail design of the platform.

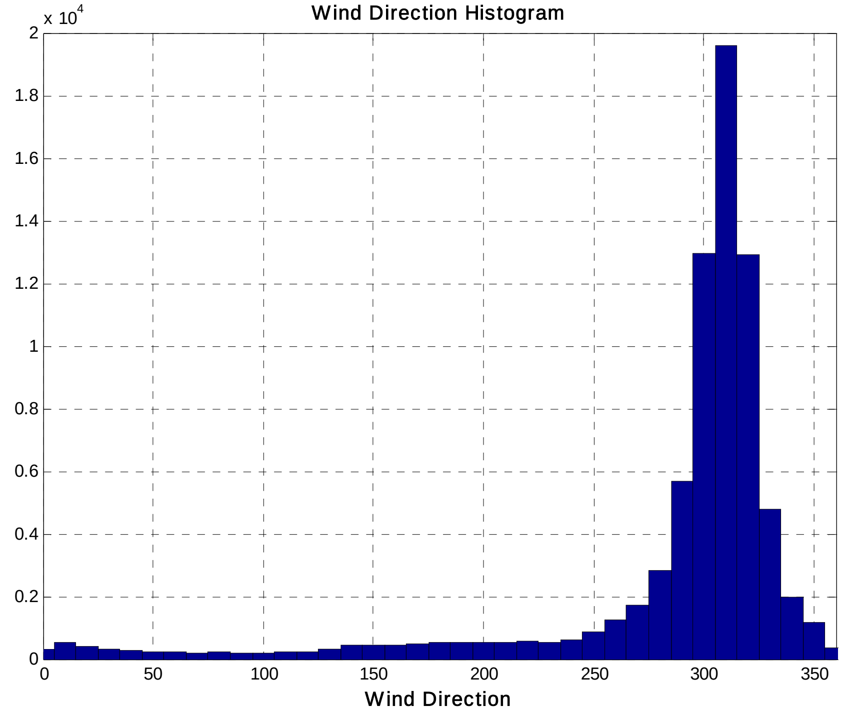

Figure 6: Wind Directionality (origin of the wind, clockwise from North)

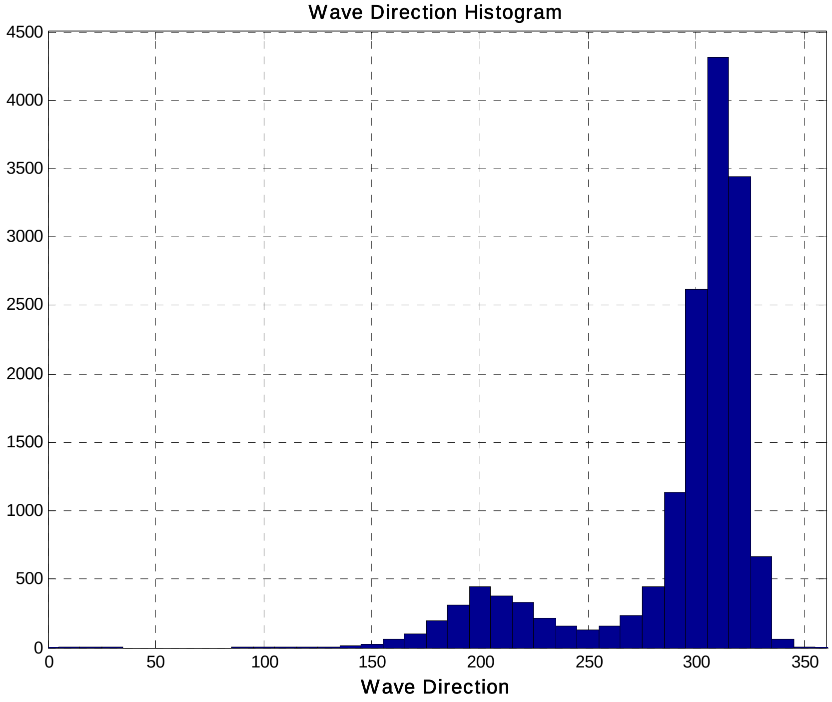

Figure 7: Wave Directionality (origin of the waves, clockwise from North)