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QUALITATIVE NUMERICAL STATISTICAL ANALYSIS OF THE EXTREME WAVE CHARACTERISTICS FOR DUBAI MARITIME CITY

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ABSTRACT
One of the main reason for creating qualitative statistical and numerical analysis of the extreme wave characteristics for Dubai Maritime city located in Dubai, UAE is to calcutalting extreme wave characteristics in order to facilitate the calculations of waves propagation near and inside Dubai Maritime city located in Dubai, UAE. Qualitative and quantitative statistical analysis for wave characteristics have been widely used during the past decades. This paper is discussing the statistical analysis for the extreme waves for several return periods. The calculations of the extreme wave characteristics can felicitate and validate the design of different coastal elements near and inside Dubai Maritime city located in Dubai, UAE [1] [2].

KEYWORD: Qualitative Analysis, Statistical Analysis, Spectral Waves, Dubai Maritime city.

INTRODUCTION
The objective of this study is to create qualitative statistical and numerical analysis of the extreme wave characteristics for Dubai Maritime city located in Dubai, UAE.
The qualitative statistical analysis has been done using Weibull distribution analysis method to calculate the extreme values for the wave height (H_s) and peak wave period (T_p) for different return periods and for each direction at offshore point near Dubai Maritime city [2].

QUANTITATIVE DATA OF THE STATISTICAL ANALYSIS
The statistical analysis has been done for an offshore point near Dubai Maritime city. The below table summarizes the point's geometry and characteristics.

Table 1. Geometry and Characteristics of the Point.

Latitude	25.30N
Longitude	51.10E
Depth at Point Location	-22.0 m
Datum	World Geodetic System 1984, EPSG:4326
Depth at Point Location	-22.0 m

The Point location considered for the study is shown below.

Figure 1: Point Location, an Extracted Image Using Google Earth software from National Oceanic and Atmospheric Administration (NOAA)

The quantitative met-ocean data for the selected point has been extracted from a multi-year wave hind-cast model of CMEMS (global multi-year reanalysis database).

The CMEMS is a validated global multi-year reanalysis database includes the integrated parameters computed from the total wave spectrum from the significant wave height, period, direction, Stokes drift, the wind wave, the primary swell wave, the secondary swell wave and other parameters [3].

The format of the extracted met-ocean variables are NetCDF (network Common Data Form file format) [3].

The extracted met-ocean variables contain aggregated analyses from dates of 01/01/1993 until 31/12/2019 as per the Gregorian calendar. Two years example of the available data extracted from is shown below.

GLOBAL_REANALYSIS_WAV_001_032	
global-reanalysis-wav-001-032	contains all the variables.
	VHM0 [m] Spectral significant wave height (Hm0) sea_surface_wave_significant_height
	VTM10 [s] Spectral moments (-1,0) wave period (Tm-10) sea_surface_wave_mean_period_from_variance_spectral_density_inverse_frequency_moment
	VTM02 [s] Spectral moments (0,2) wave period (Tm02) sea_surface_wave_mean_period_from_variance_spectral_density_second_frequency_moment
	VTPK [s] Wave period at spectral peak / peak period (Tp) sea_surface_wave_period_at_variance_spectral_density_maximum
	VMDR [degree] Mean wave direction from (Mdir) sea_surface_wave_from_direction
	VPED [degree] Wave principal direction at spectral peak sea_surface_wave_from_direction_at_variance_spectral_density_maximum
	VSDX [m s-1] Stokes drift U sea_surface_wave_stokes_drift_x_velocity
	VSDY [m s-1] Stokes drift V sea_surface_wave_stokes_drift_y_velocity
	VHM0_WW [m] Spectral significant wind wave height sea_surface_wind_wave_significant_height
	VTM01_WW [s] Spectral moments (0,1) wind wave period sea_surface_wind_wave_mean_period
	VMDR_WW [degree] Mean wind wave direction from sea_surface_wind_wave_from_direction
	VHM0_SW1 [m] Spectral significant primary swell wave height sea_surface_primary_swell_wave_significant_height
	VTM01_SW1 [s] Spectral moments (0,1) primary swell wave period sea_surface_primary_swell_wave_mean_period
	VMDR_SW1 [degree] Mean primary swell wave direction from sea_surface_primary_swell_wave_from_direction
	VHM0_SW2 [m] Spectral significant secondary swell wave height sea_surface_secondary_swell_wave_significant_height
	VTM01_SW2 [s] Spectral moments (0,1) secondary swell wave period sea_surface_secondary_swell_wave_mean_period
	VMDR_SW2 [degree] Mean secondary swell wave direction from sea_surface_secondary_swell_wave_from_direction

Figure 2: Extracted Met-ocean Variables

The wave lengths can be expected using the linear wave theory [4]. The below figure shows the used values for cardinal directions together with the corresponding degrees.

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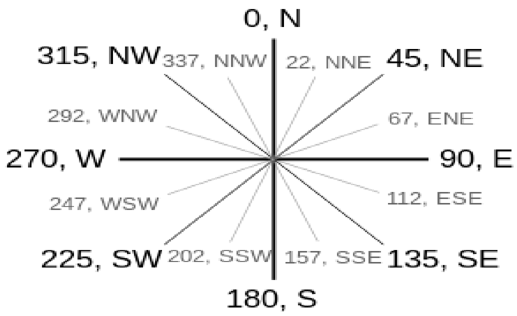

Figure 3: Cardinal Directions and the Corresponding Degrees

Integrated Data Viewer software from UCAR/Unidata and Panoply Data Viewer from National Aeronautics and Space Administration (NASA) have been used in the analysis and visualization of the data [5].

The extracted daily fields are 3-hourly instantaneous at times of 00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00 and 21:00 (Coordinated Universal Time). The below figure shows an example for the extracted variables for the selected boundary point.

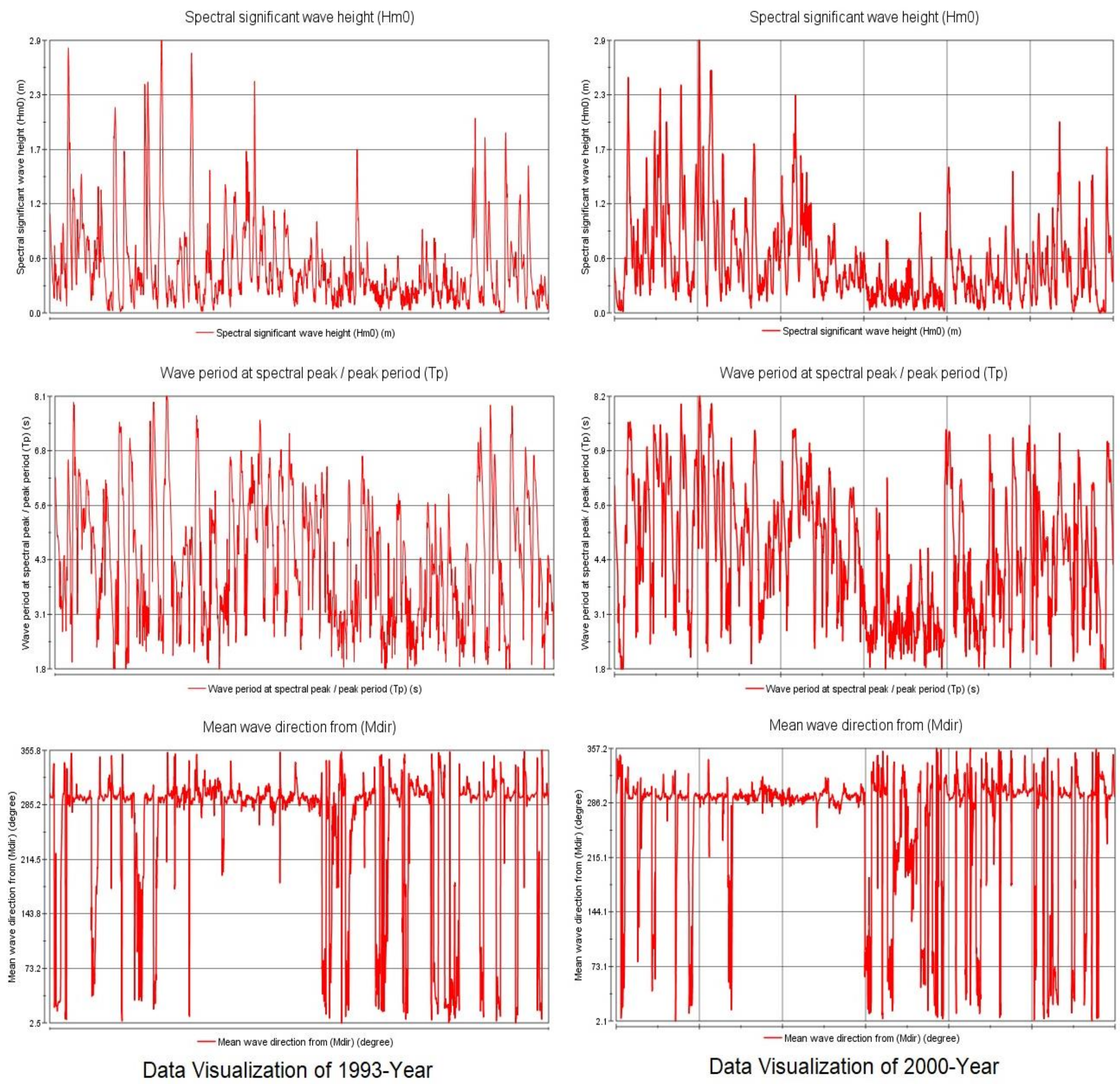

Figure 4: Data Visualization of the 1993 and 2000 years.

QUALITATIVE STATISTICAL ANALYSIS OF THE EXTREME WAVE CHARACTERISTICS

To evaluate the wave characteristics of extreme events, a parametric frequency analysis has been used in accordance to DHI Mike-Zero Extreme Value Analysis Module [6].

This implies that the extreme value model is formulated based on fitting a theoretical probability distribution to the observed extreme value series.

The defining method used for the Extreme Value Analysis Module is the partial duration series (PDS) method, the Weibull distribution has been used for the probability distribution [6], the probability plot correlation coefficient (PPCC) has been used for the module [7] and the Monte Carlo simulation has been used for the uncertainty calculation of rhe module.

The below figures show the frequency plots and probability plots for each direction.

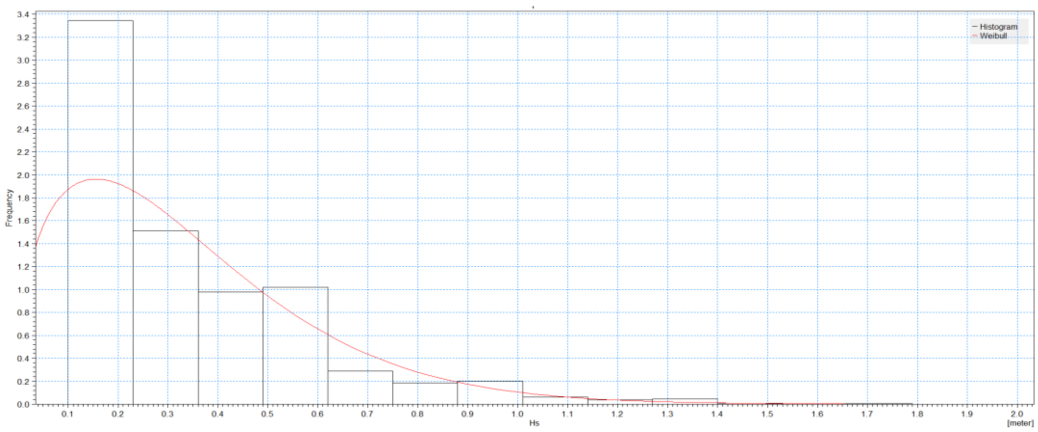

Figure 5: Frequency Plot for Direction Angle 22.5° (0°-45°)

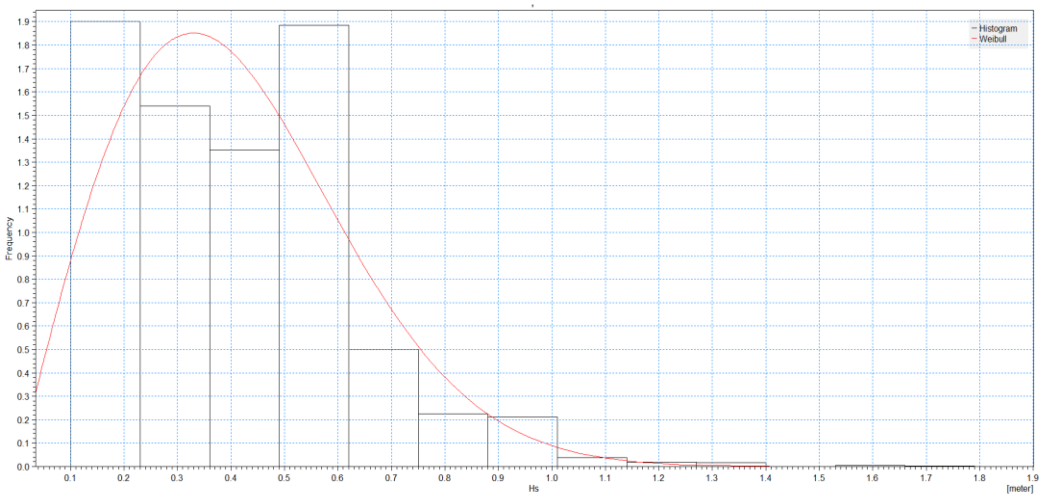

Figure 6: Frequency Plot for Direction Angle 67.5° (45°-90°)

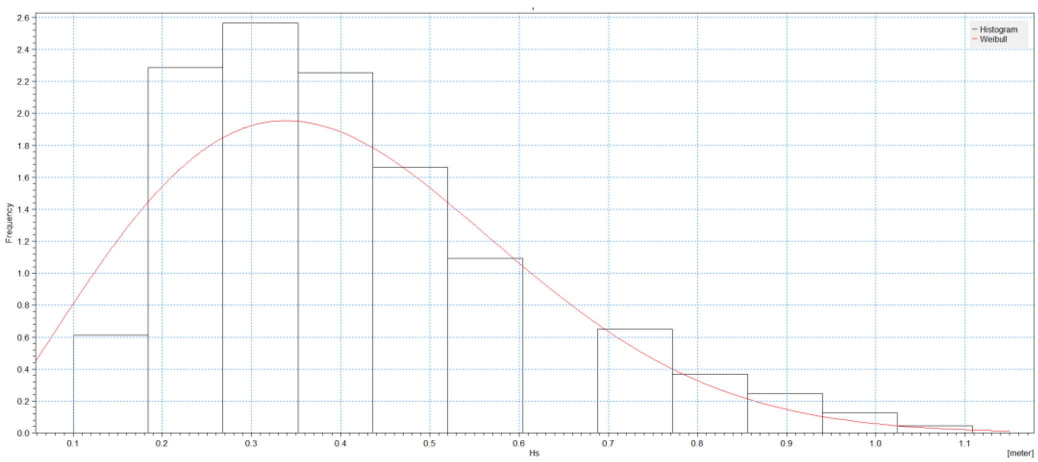

Figure 7: Frequency Plot for Direction Angle 112.5° (90°-135°)

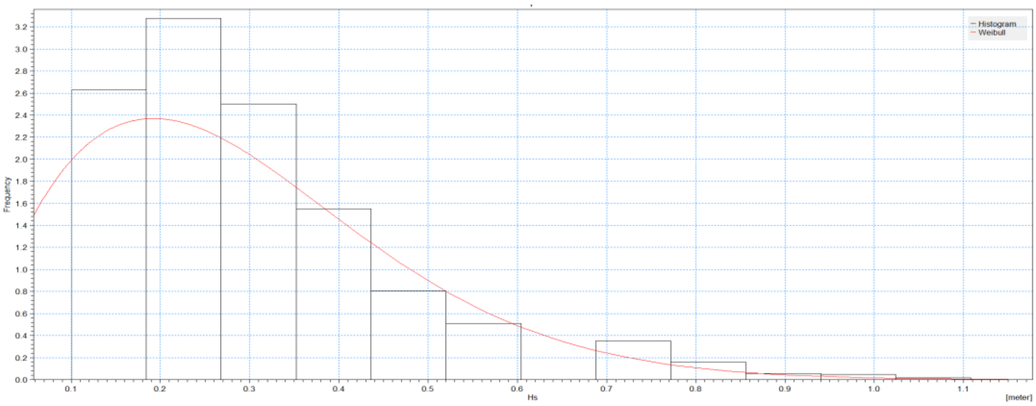

Figure 8: Frequency Plot for Direction Angle 157.5° (135°-180°)

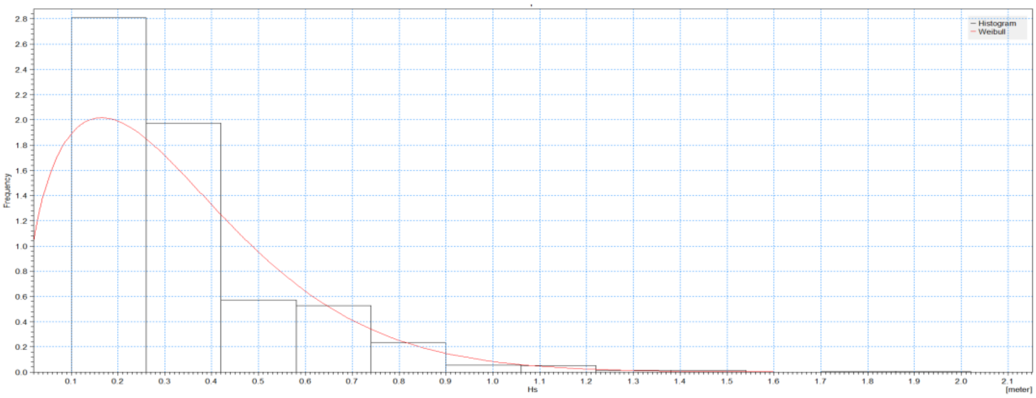

Figure 9: Frequency Plot for Direction Angle 202.5° (180°-225°)

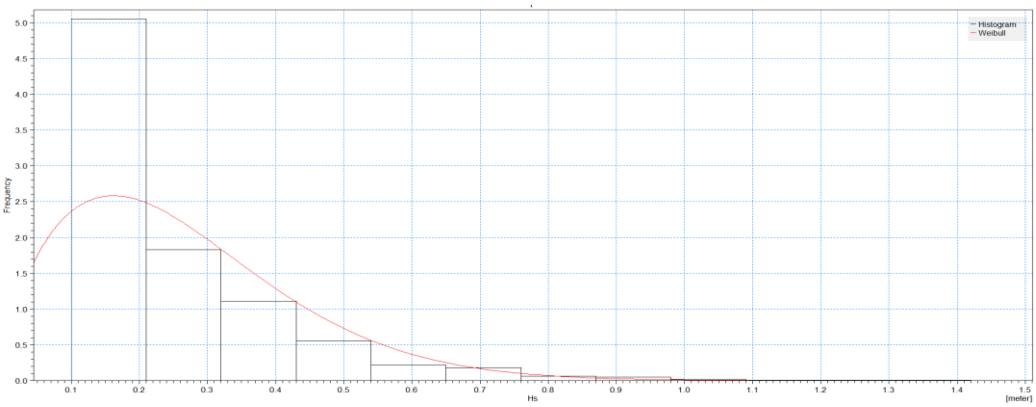

Figure 10: Frequency Plot for Direction Angle 247.5° (225°-270°)

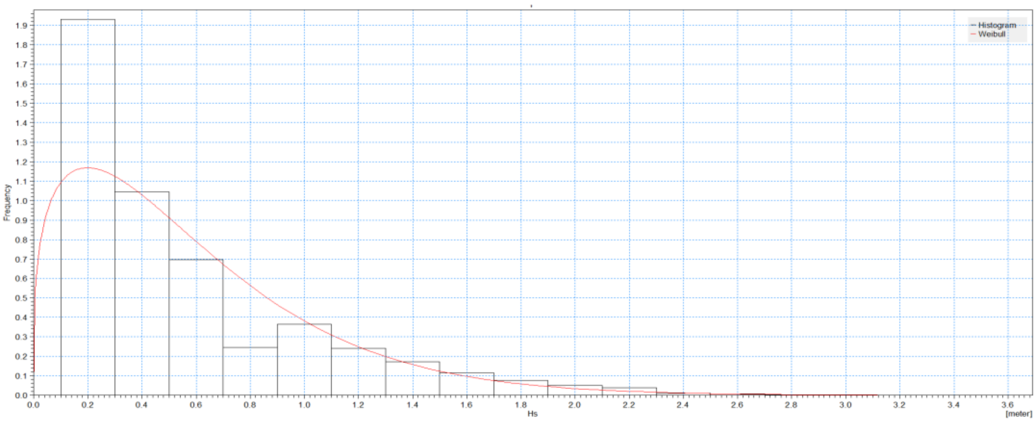

Figure 11: Frequency Plot for Direction Angle 292.5° (270°-315°)

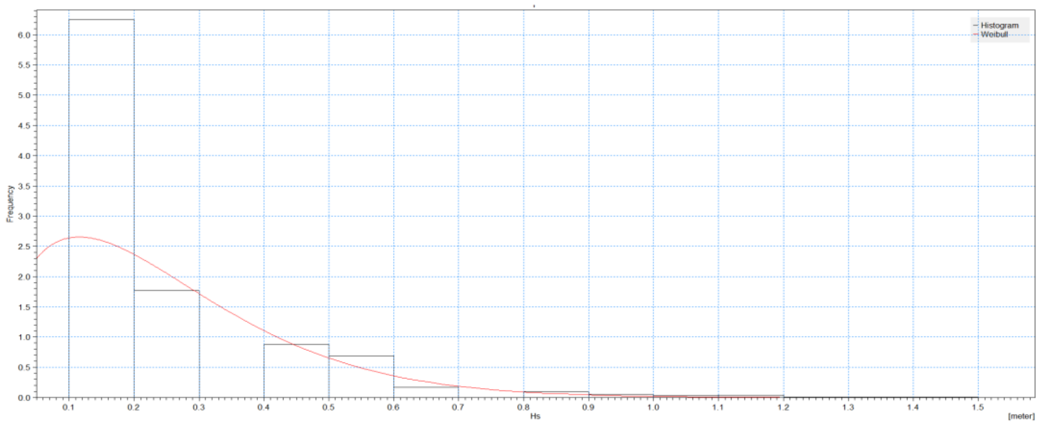

Figure 12: Frequency Plot for Direction Angle 337.5° (315°-0°)

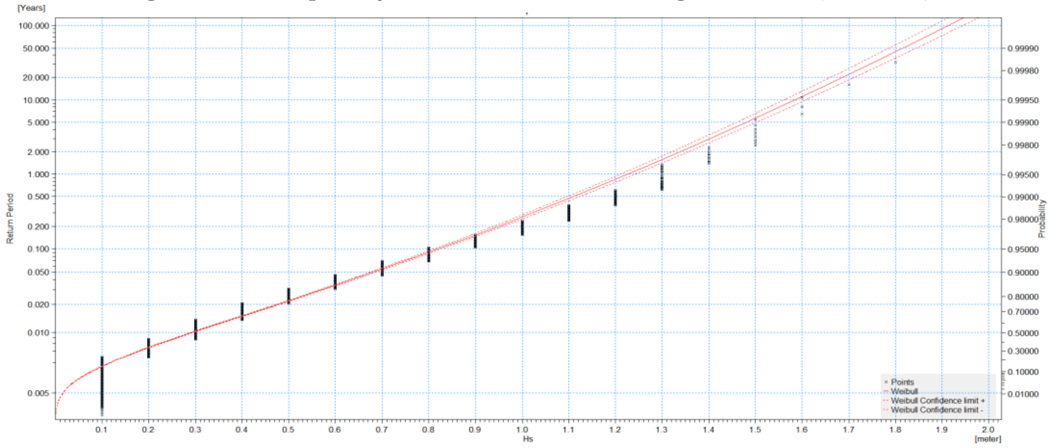

Figure 13: Probability Plot for Direction Angle 22.5° (0°-45°)

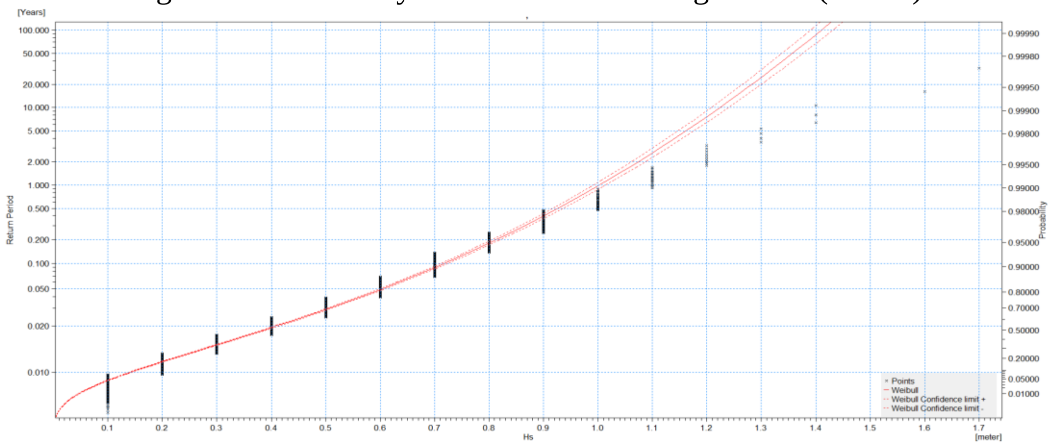

Figure 14: Probability Plot for Direction Angle 67.5° (45°-90°)

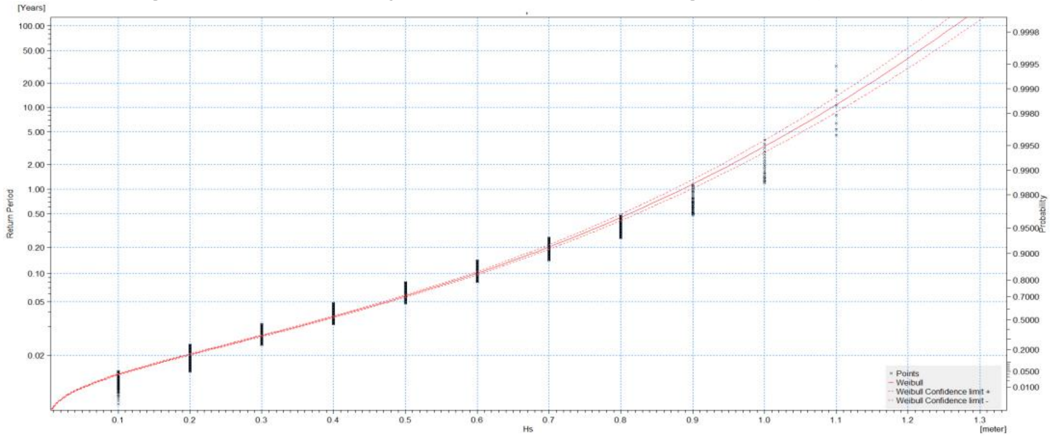

Figure 15: Probability Plot for Direction Angle 112.5° (90°-135°)

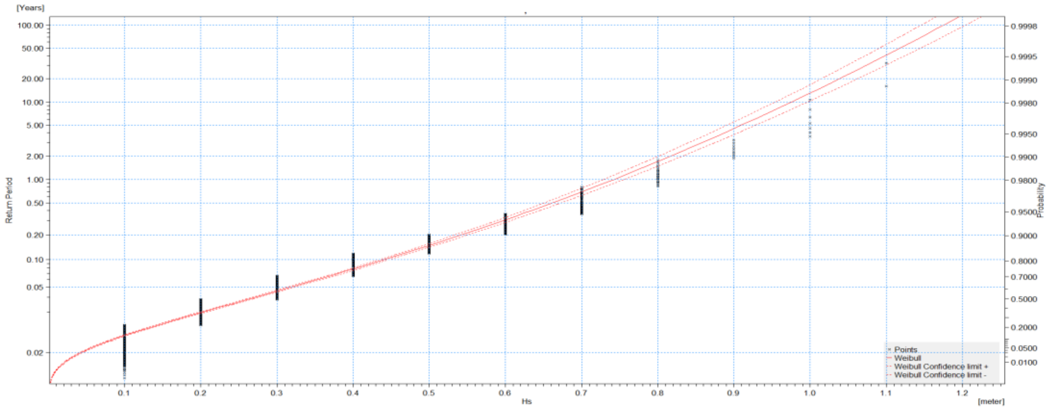

Figure 16: Probability Plot for Direction Angle 157.5° (135°-180°)

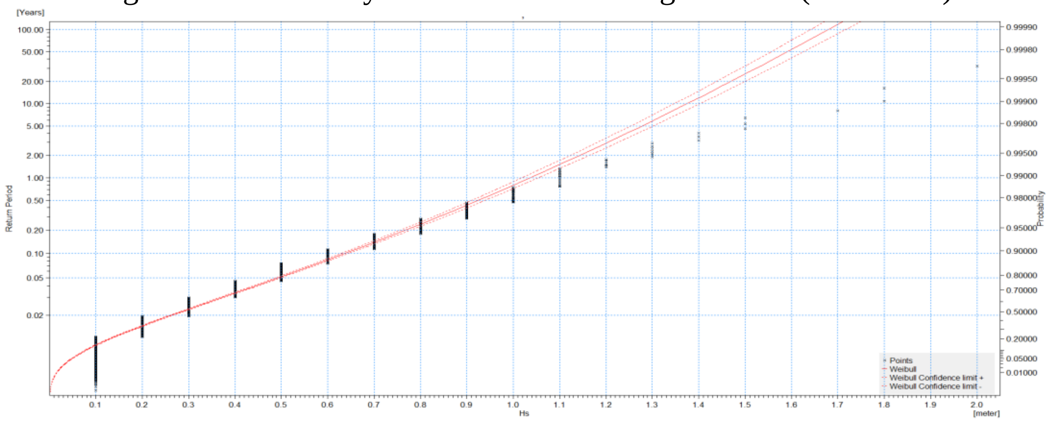

Figure 17: Probability Plot for Direction Angle 202.5° (180°-225°)

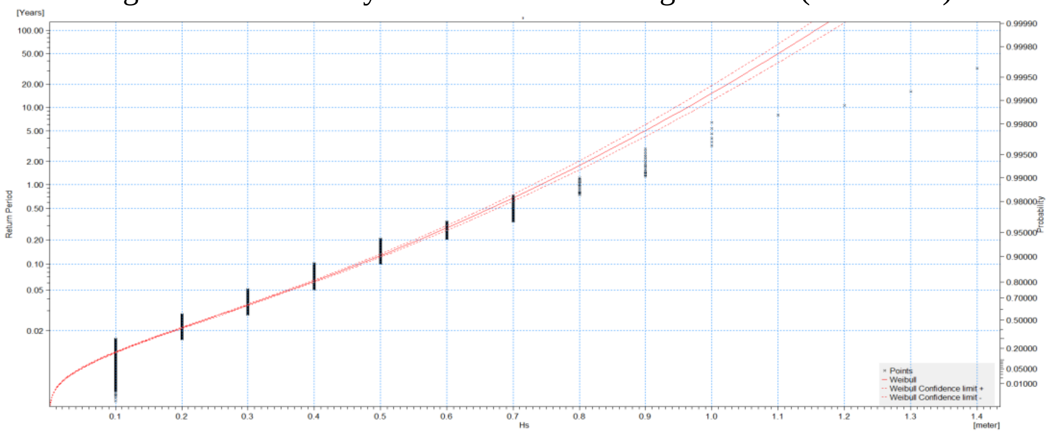

Figure 18: Probability Plot for Direction Angle 247.5° (225°-270°)

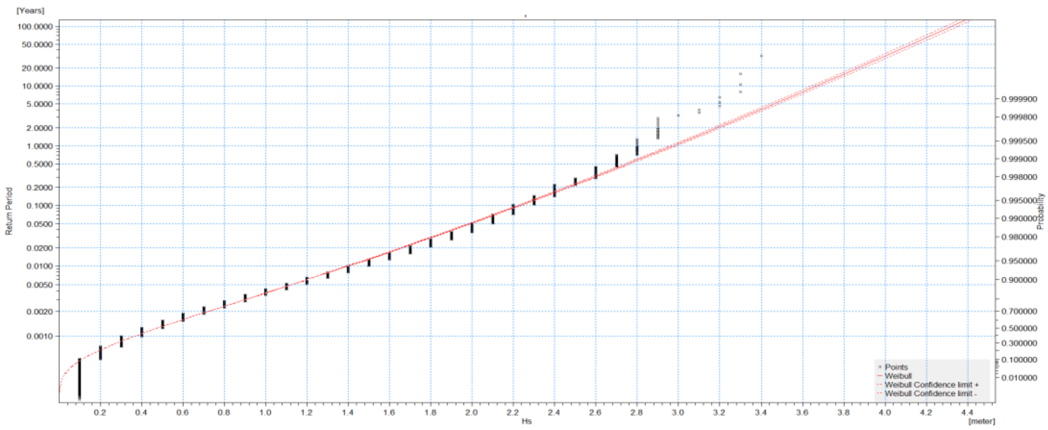

Figure 19: Probability Plot for Direction Angle 292.5° (270°-315°)

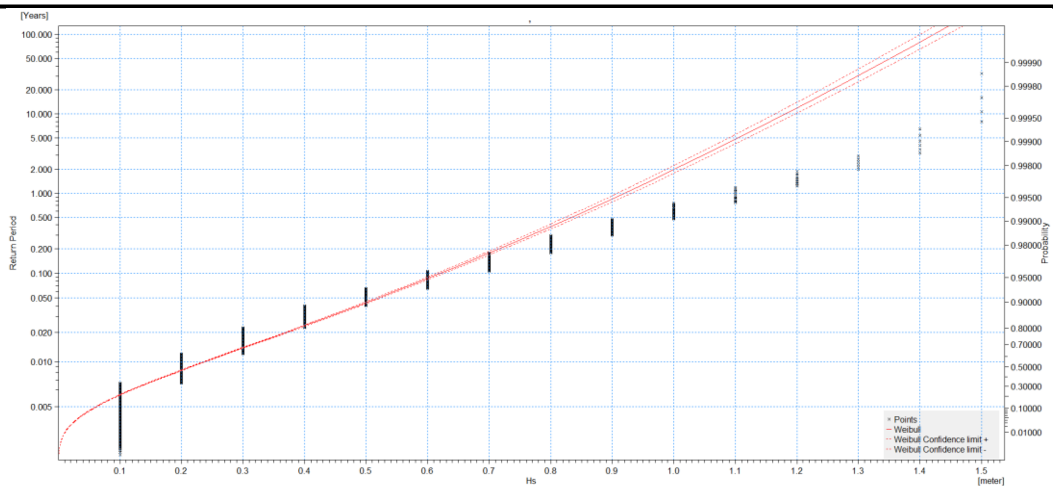

Figure 20: Probability Plot for Direction Angle 337.5° (315°-0°)

The peak wave period (T_p) is estimated from the relation Tp = 5.7378× (H_s) $^{0.3218}$ based on all the significant wave height H_s obtained from statistical analysis. The below figure shows the trend equation and the scatter plot for the peak wave period (T_p) and significant wave height (H_s).

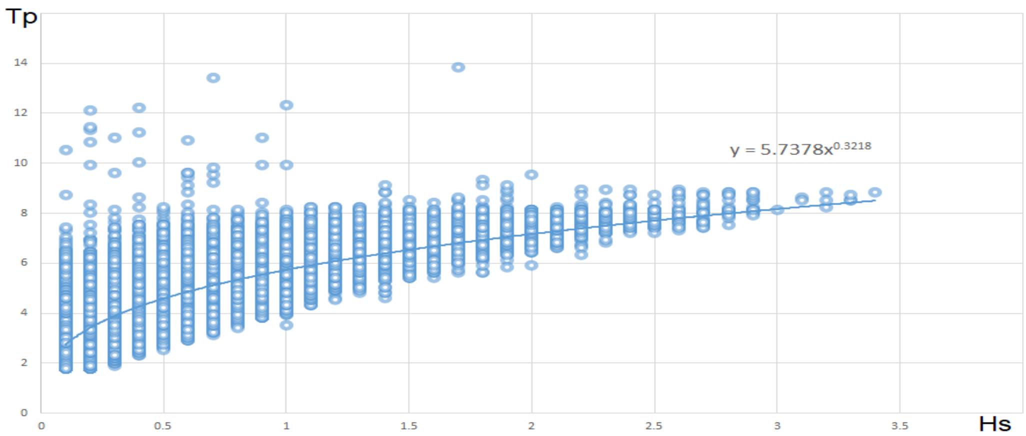

Figure 21: Trend Equation and the Scatter Plot for T_p and H_s

The below tables summarizes the extreme Significant wave height and the peak wave period for each direction.

Table 2. Significant Wave Heights.

Significant wave height (m) (coming from different directions -angle measured clockwise from north)									
Parameters		22.5° (0°-45°)	67.5° (45°-90°)	112.5° (90°-135°)	157.5° (135°-180°)	202.5° (180°-225°)	247.5° (225°-270°)	292.5° (270°-315°)	337.5° (315°-0°)
Return Period (years)	1	1.18	1.010	0.870	0.730	1.040	0.730	2.860	0.920
	10	1.620	1.240	1.090	0.970	1.380	0.970	3.610	1.180
	20	1.680	1.280	1.140	1.040	1.460	1.030	3.840	1.250
	50	1.810	1.350	1.240	1.130	1.580	1.110	4.120	1.340
	100	1.920	1.420	1.270	1.170	1.680	1.160	4.310	1.420
Weibull Parameters	R^2	0.990	0.982	0.988	0.986	0.984	0.977	0.996	0.970
	shape parameter	1.408	2.008	2.125	1.682	1.454	1.610	1.291	1.410
	Scale parameter	0.375	0.465	0.457	0.328	0.367	0.295	0.630	0.277

Table 3. Peak Wave Periods.

Peak Wave Periods (Sec) (coming from different directions -angle measured clockwise from north)									
Parameters		22.5° (0°-45°)	67.5° (45°-90°)	112.5° (90°-135°)	157.5° (135°-180°)	202.5° (180°-225°)	247.5° (225°-270°)	292.5° (270°-315°)	337.5° (315°-0°)
Return Period (years)	1	6.05	5.76	5.49	5.19	5.81	5.19	8.05	5.59
	10	6.70	6.15	5.9	5.68	6.36	5.68	8.67	6.05
	20	6.78	6.21	5.98	5.81	6.48	5.79	8.85	6.16
	50	6.94	6.32	6.15	5.97	6.65	5.93	9.05	6.3
	100	7.08	6.42	6.2	6.04	6.78	6.02	9.18	6.42

CONCLUSION

The statistical analysis considered of the study for the different directions shows that prevailing wave direction range is 270°:315° (angle measured clockwise from north).

The study shows that minimum 100-year return period significant wave height equals to 1.16 meter and maximum 100-year return period significate wave height equals to 4.31 meter, while the minimum 100-year return period peak wave period equals to 6.02 second and maximum 100-year return period peak wave period equals to 9.18 second.

The paper recommends to investigate the probability of exceedance of the significate wave height 95 % for the wave propagation numerical studies for the Dubai Maritime City.

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