OCE-408 Final Project

Dylan Morano, Rebecca Cressman, Arielle De Souza, Scott Hara

OCE-311

Jason Dahl

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Introduction

Narragansett Town Beach is an important economic resource to the town of Narragansett, providing an average net income of $270,000 each season and increasing seasonal business for surrounding restaurants, shops, and rentals. It is important to understand the natural forces which contribute to beach erosion for expensive re-nourishment project in order to keep the beach healthy for vacationers. In order to understand these processes, a study was conducted utilizing data from the Wave Informations Studies (WIS) program. 20, and 50 year return storm waves projected towards the beach were analyzed in order to determine incident wave rays and breaking characteristics. This information can then be used in order to determine the littoral processes present at Narragansett Beach.

Task 1

2.1 Statement of Problem

The purpose of this assignment was to investigate the natural forces contributing to littoral transport and beach erosion for re-nourishment purposes. Using 20 years of hind-cast wave height data, 20 and 50 year return period extremes for three dominant wave directions were to be determined. The wave height extrema were also to be determined and fitted with a Gumbel probability distribution function. The results were to be plotted and tabulated.

2.2 Hypotheses and Theories

The Wave Information Studies (WIS) program is an Army Corps of Engineers project which consistently monitors hours, long term wave climatologies along all US coastlines. Wave predictions can be made based off this hind cast data in order to determine future wave characteristics and their effects on the coastline. For this study, weather station 63079 from the WIS program was selected for its close proximity to the Narragansett Town Beach in order to conduct the investigations. A map containing the location of weather station 63079 (outlined in red) can be seen below in Figure **??**

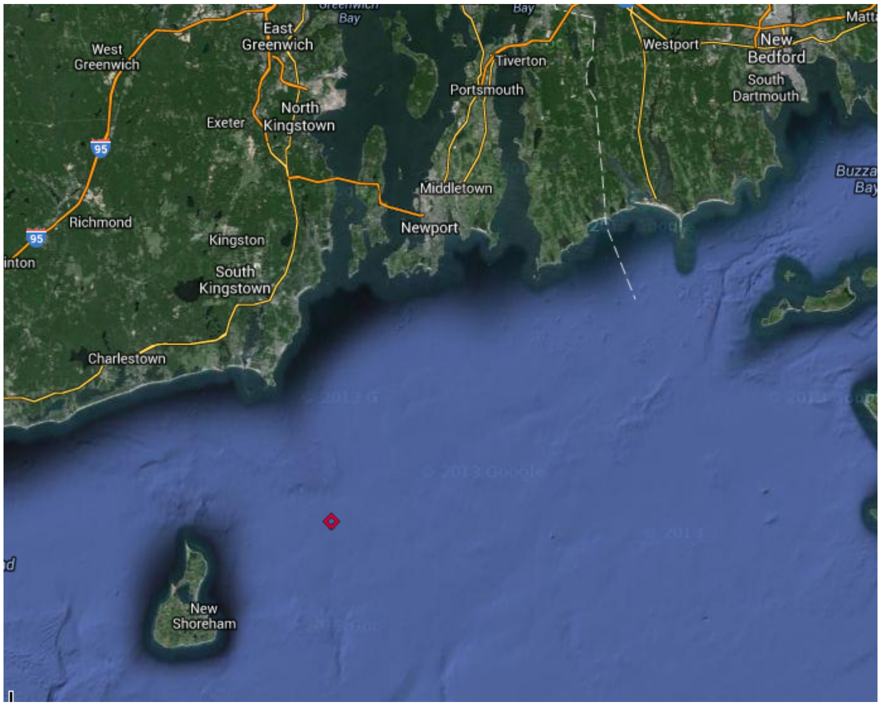

Figure 2.1: Location of WIS station 63079

A collection of functions were provided for the purpose of this study in order to extrapolate information from this weather station. This included the *wavedir.m* function which would extract the predominant wave directions from the hind-cast data. The *monthlyextrema.m* function could be used according to these dominant directions in order to determine the maximum wave height per each month in a 20 year hind-cast interval. These maximums could be processed in using a Gumbel distribution in the $extremeDist2_new.m$.

A Gumbel distribution can be used in order to model the distribution of the maximums in a number of samples of various length. It can be used in order to model the distribution of maximum wave heights throughout a serious of sample periods. A Gumbel distribution can also be used in order to make predictions of certain wave heights occurring in the future.

2.3 Solution of the Problem

20 years of hind-cast wave height data from the Rhode Island coastline was downloaded from the U.S. Army Core of Engineers Wave Information Studies (WIS) project. Due to the functions provided for this study being outdated, a parsing function was developed in order to convert the data from the WIS station in to a form which could be interpreted. This function would parse the date vector from the station data and arrange the array data in a way which interfaced with the provided functions.

Using the *wavedir.m* function, a rose plot consisting of 30 degree intervals was generated which displayed the concentrations of wave direction present at the studied location. This rose can be seen in Figure 1.2.

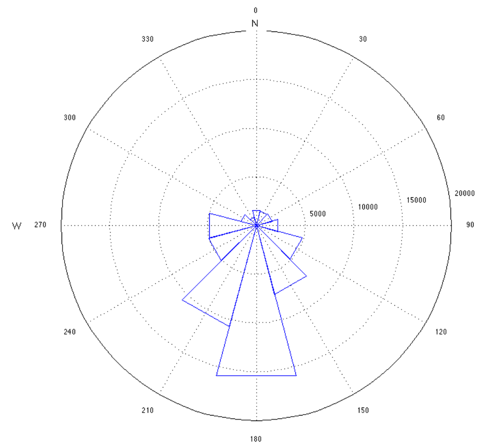

Figure 2.2: Wave Directions at Station 63079

From this rose plot it can be seen that the predominate wave directions were 150°, 180°, and 210°. The monthly maximums were then calculated for each of these three directions. This was done using the *monthlyExtrema_new.m*, which would output the extrema data for each month to a text file for each direction. An example of this output can be seen in Appendix B.1.

Using the *extremeDist2_new.m* function it was possible to render Gumbel distributions based off the calculated monthly extrema data. The distributions for angles 150°, 180°, and 210° respectively can be seen below in Figures 2.3 through 2.8.

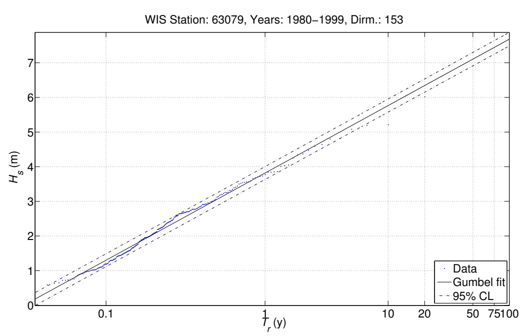

Figure 2.3: Gumbel distribution for Height at 150°

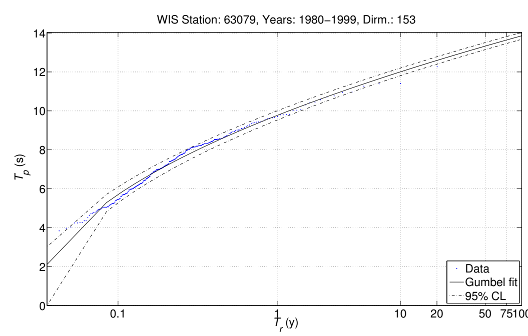

Figure 2.4: Gumbel distribution for Period at 150°

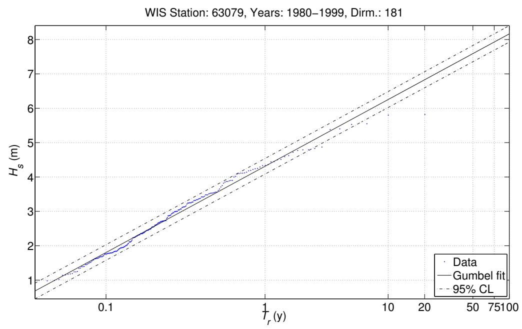

Figure 2.5: Gumbel distribution for Height at 180°

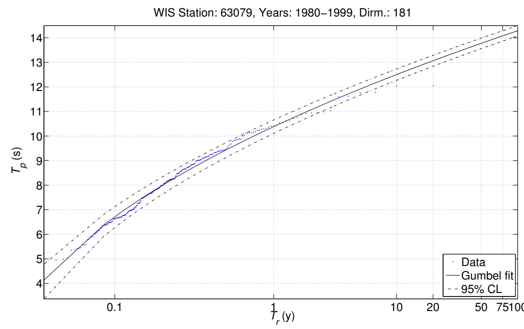

Figure 2.6: Gumbel distribution for Period at 180°

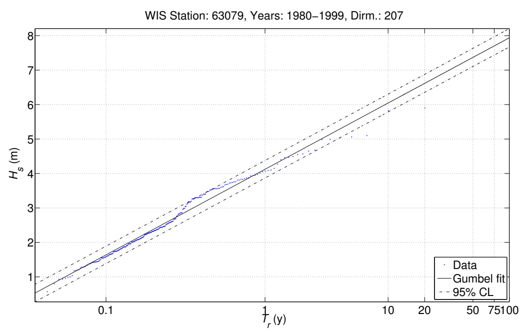

Figure 2.7: Gumbel distribution for Height at 210°

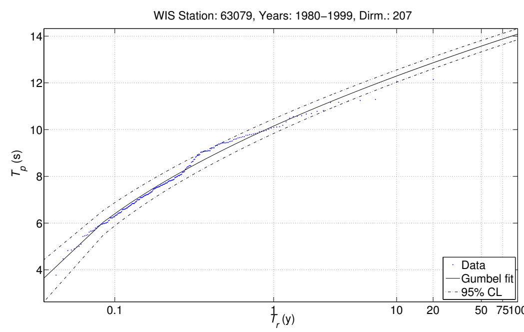

Figure 2.8: Gumbel distribution for Period at 210°

The 20 - 100 year return parameters were also generated using the Gumbel distribution function. Tables containing this information for each dominant incident angle can be seen below in Tables 2.1 through 2.3.

Tr (y)	Hs (m)	Tp (s)	CL95 Hs(m)	CL95 Tp (s)
100.0	7.7	13.9	7.9	14.0
75.0	7.4	13.6	7.6	13.8
50.0	7.1	13.3	7.3	13.5
20.0	6.3	12.6	6.5	12.8

Table 2.1: 150 degree return characteristics

As can be seen in the above table, the function would compile maximum return characteristics for period intervals of 20, 50, 75, and 100 years. The function would return the maximum wave heights as well as the maximum periods. The following tables exhibited the same information for the other angles.

Tr (y)	Hs (m)	Tp (s)	CL95 Hs(m)	CL95 Tp (s)
100.0	8.2	14.3	8.4	14.5
75.0	7.9	14.1	8.2	14.3
50.0	7.6	13.8	7.8	14.0
20.0	6.8	13.1	7.1	13.3

Table 2.2: 180 degree return characteristics

Tr (y)	Hs (m)	Tp (s)	CL95 Hs(m)	CL95 Tp (s)
100.0	7.9	14.1	8.2	14.3
75.0	7.7	13.9	8.0	14.1
50.0	7.4	13.6	7.6	13.8
20.0	6.6	12.9	6.9	13.1

Table 2.3: 210 degree return characteristics

2.4 Conclusion

The results from this task were used in order to generate projected wave rays towards Narragansett Town beach in Task 2. It was found that the dominant wave directions were accurately determined for later use. The resulting Gumbel distributions were also feasible. The data for the monthly extrema fit within the 90% confidence interval for the Gumbel for each direction.

Task 2

3.1 Statement of Problem

Using wave ray tracing and local bathymetry information provided for Narragansett Bay, simulate storm wave propagation from parameters found in Task 1. Conduct simulations for the 20 and 50 year storms parameters, and generate enough wave rays that intersect the shoreline of Narragansett Beach. Use the ray spacing on the beach to calculate a refraction coefficient for each section of beach. Using bathymetry data from a chart near the beach, estimate the beach slope. Find the breaking wave characteristics and shoaling coefficient along each wave ray using the estimated beach slope and refraction coefficient.

3.2 Hypotheses and Theories

When waves propagate over a non uniform sea floor, they refract depending on how the sea floor depth changes along the wavefront. As water depth decreases wave fronts can focus or de-focus along the coastline. Seen in 3.1, the refraction coefficient can be determined with the distance between wave rays initially, and in the target location. A refraction coefficient less than one indicates de-focusing.

$$K_r = \sqrt{\frac{b_o}{b}} \tag{3.1}$$

In shallow water, waves slow down and experience an increase in wave height due to shoaling. The degree of wave refraction, and the shoaling coefficient dictate breaking wave height and water depth. Seen in 3.4, the ratio of phase speed and group celerity changes as water depth approaches the shallow water condition. With the deep water characteristics, and angle of incidence, breaker depth and wave height can be found iteratively.

$$[H]c = c_o * \tanh(kh); \tag{3.2}$$

$$c_g = \frac{c}{2} * \left(1 + \frac{2kh}{\sinh(2kh)}\right) \tag{3.3}$$

$$K_s = \sqrt{c/2c_g} \tag{3.4}$$

$$H_b = H_o K_{sb} K_{rb} = \kappa h_b \tag{3.5}$$

$$K_{sb} = F(L, h) \tag{3.6}$$

$$K_{rb} = F(L, h, \theta_o) \tag{3.7}$$

The programs supplied for the problem simulate waves propagating into a region of supplied bathymetry information. Waveray.m utilized an overlay of latitude and longitude coordinates on bathymetric data. Water depths along each wave ray were evaluated, and the path-line that each ray followed was calculated using the Fast Marching Method.

3.3 Solution of the Problem

Using the supplied C functions and waveray.m, wave rays were simulated propagated into Narragansett Beach under the conditions determined in Task 1. Twenty and fifty year predicted wave parameters were used to simulate the path lines extreme waves followed. Seen in Figure 1.2, three predominant angles of incidence were determined from the supplied data. Waveray.m didn't allow for significant manipulation of the rendered area without ruining the data. None of the simulations intersected the coastline with more than two or three renders.

Seen below, the wave rays in all three simulations indicated that wavefronts de-focus slightly as they propagate into the bay. Figure 3.1 displayed a low degree of focusing or de-focusing along the shoreline. Waves propagating at that angle of incidence didn't experience a large reduction in wave energy before they hit the beach. Figures 3.2 and 3.3 displayed significant de-focusing as they approached the coastline. Waves that impacted the beach from those angles of incidence did so at a lower energy. The 50 year wave ray simulations can be observed in the Appendix. The simulated rays displayed identical wave propagation patterns at each angle of incidence when compared to the 20 year simulations.

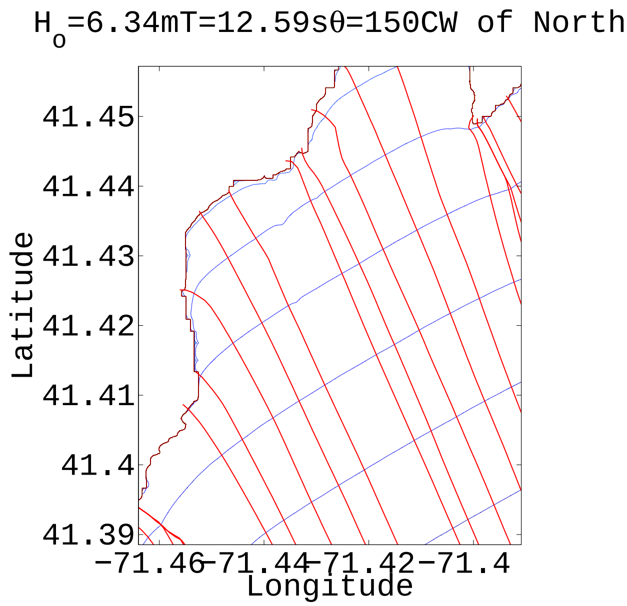

Figure 3.1: 20y Predicted Wave Rays at 150° angle of incidence

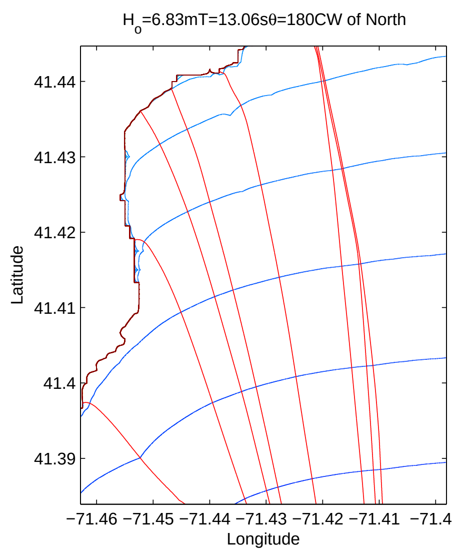

Figure 3.2: 20y Predicted Wave Rays at 180° angle of incidence

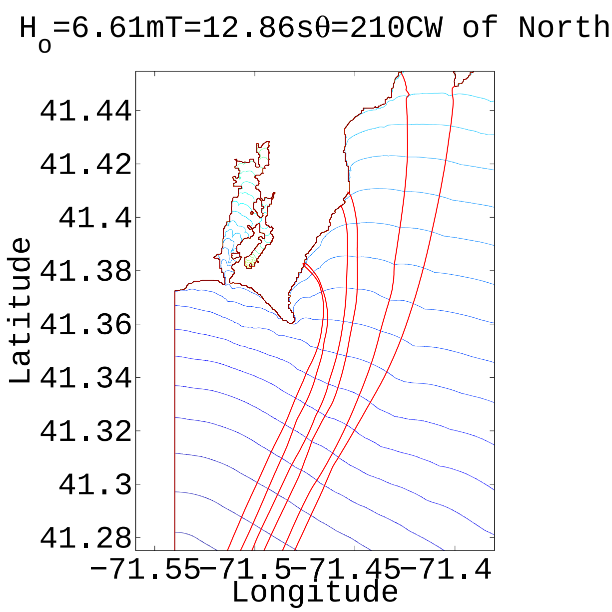

Figure 3.3: Breaking Wave Characteristics for 20 Year extreme wave at 210° angle of incidence

Seen below, breaking wave characteristics were estimated using the simulated wave rays. The local slope of the beach was estimated to be 1/50 in the near shore region. The low number of data points impacted the breaking wave analysis by reducing its accuracy significantly. No calculations were possible for the 20 and 50 year wave ray simulations at a 210° because they did not have any rays intersecting the beach. Seen in 3.4, one data point for each wave ray was taken, and the breaking wave characteristics were evaluated based on the location. The estimated locations were not accurate seen in Tables 3.1, 3.2, 3.3, and 3.4.

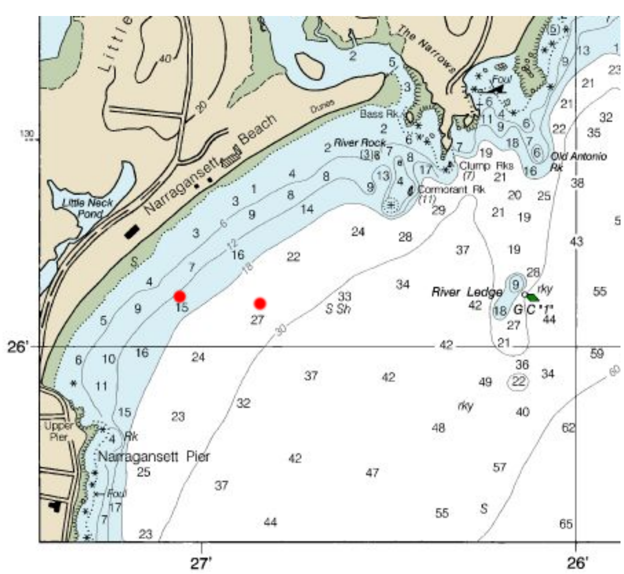

Figure 3.4: 20y, 150° Breaking Wave Predicted Location

Ray:	K_r	K_s	H_b	h_b	$\frac{H_b}{h_b}$
1	1.0	0.1	5.2	7.6	0.7
2	1.0	0.0	3.4	7.5	0.5

Table 3.1: Breaking Wave Characteristics for 20 Year extreme wave at 150° angle of incidence

Ray:	K_r	K_s	H_b	h_b	$\frac{H_b}{h_b}$
1	1.0	0.1	5.8	8.2	0.7
2	1.0	0.1	4.9	8.2	0.6

Table 3.2: Breaking Wave Characteristics for 20 Year extreme wave at 180° angle of incidence

Ray:	K_r	K_s	H_b	h_b	$\frac{H_b}{h_b}$
1	1.0	0.1	6.2	8.6	0.7
2	1.0	0.0	4.0	8.5	0.5

Table 3.3: Breaking Wave Characteristics for 50 Year extreme wave at 150° angle of incidence

Ray:	K_r	K_s	H_b	h_b	$\frac{H_b}{h_b}$
1	1.0	0.1	6.8	9.2	0.7
2	1.0	0.0	4.2	9.0	0.5

Table 3.4: Breaking Wave Characteristics for 50 Year extreme wave at 180° angle of incidence

3.4 Discussion

The results of this study would prove very useful for the estimation of sediment transport at Narragansett Beach. The wave ray analysis provides good incite as to the interaction waves may have with the beach. Areas of high wave activity can be easily spotted with the high resolution wave ray analysis used in this study. The direction of incident wave fronts can also be determined. However, in able to do a proper sediment transport analysis for this beach, further information would be necessary. In order to determine the extent to which the ocean interacts with the beach, wave energy analysis would need to be conducted. The properties of the sediment present at Narragansett Beach would also need to be investigated in order to produce an accurate model.

Placement of a wave energy facility within Narragansett Bay can be determined with the help of the data analysis used for this project. Just as it was used here, hind casting can determine yearly wave characteristics, and major angles of incidence. Wave ray simulations can identify regions of wave focusing within the bay. However, the data used in this project would not be suitable for use in evaluating average conditions of the bay. The supplied 20 and 50 year predictions were based off of the extreme conditions from each sample range. An energy spectra of waves in the region would be required instead of a Gumbel distribution. Average wave parameters can be found using the energy spectra, providing more reasonable characteristics for simulation.

In terms of the specific wave directions determined from task 1, the inclusion of diffraction models would alter the direction of the wave rays in the ray tracing analysis.Wave diffraction involves a change in direction of waves as they pass through an opening or around a barrier in their path. The amount of diffraction (the sharpness of the bending) increases with increasing wavelength and decreases with decreasing wavelength. As waves propagate in the wave directions determined from task 1, the wave from one direction might travel a different distance than the wave from another direction. When the difference in distance is significant, the waves from each direction might be in a different phase. Therefore the waves would look more realistic and accurate.

3.5 Conclusion

Wave ray simulations and breaking wave characteristics were performed to determine a breaker line along Narragansett Beach. From the data in Task 1, the simulated wave rays for the 20 and 50 year extreme wave conditions exhibited similar refraction trends. The degree of de-focusing was observed as increasing as the angle of incidence approached 210°. They indicated that waves with the highest average energy level propagated in at 150° because they experienced the least ray distortion due to refraction. The calculated breaking characteristics were incorrect. The points that were estimated to be along the breaker line were too far offshore, which produced errors in all the results.

References

US Army Corps of Engineers (2002). *Coastal Engineering Manual*

US Army Corps of Engineers (2002). *Wave Information Studies Program*

`http://wis.usace.army.mil/`

NOAA (2014). *Narragansett bay including newport harbor chart: 13223.*

`http://www.charts.noaa.gov/OnLineViewer/13223.shtml`

Appendices

MATLAB Calculations

A.1 Parser Function

```
function parser(fileout,filein)
disp 'Parsing Data...'

[DATE, STATION, LAT, LONG, WNDSPD, WNDDIR, USTAR, CD, WAVSTRS, Hmo, TPD, TP, TM, TM1, TM2, WAVD, SPRD, ~, ~, ~, ~,
    ~, ~, ~, ~, ~, ~, ~, ~, ~, ~, ~, ~]...
    = textread(filein,'%f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f
        %f %f','headerlines',0);

% Date parsing
DATEstring = num2str(DATE);
[YY,MM,DD,HH,mm,ss] = datevec(DATEstring,'yyyymmddHHMMSS');
ID = STATION;
YEAR = YY;
DPTH = 33;  %Depth not record, arbitrarily used YY so matrix agrees
DTp = TPD;
Atp = TP;
tmean = TM1;
wdvmn = WAVD;
wv = WAVD;
wsp = WNDSPD;
wdir = WNDDIR;

parsed = [ID YEAR MM DD HH LONG LAT DPTH Hmo DTp Atp tmean wdvmn wv wsp wdir];
dlmwrite(fileout,parsed);
disp 'Output File Produced'
end
```

A.2 Task 1 Script

```
% Task 1: Determine design deep water wave heights
% and periods for dominant directions relative to
% Narragansett Beach.


```

```
%% Determine wave directions (wavedir used as reference)

% Parse data in to useable format

parser('ST63079.txt','ST63079_v01.onlns')

%% Plot wave direction concentrations
wavedir('ST63079.txt');

%% Monthly Extrema

for deg = [150 180 210]
   monthextrema_new('ST63079.txt',deg,30);
end

%% Gumble Distrobution

% Automatic latex table integration
tableout = extremeDist2_new('monthlyExtreme63079_150.txt')
tableizer(tableout,'name','extrema150.tex')

tableout = extremeDist2_new('monthlyExtreme63079_180.txt')
tableizer(tableout,'name','extrema180.tex')

tableout = extremeDist2_new('monthlyExtreme63079_210.txt')
tableizer(tableout,'name','extrema210.tex')

%% Yearly Maximums

tableout = yearlyDist('ST63079.txt',150,30)
tableizer(tableout,'name','yearly150.tex')

tableout = yearlyDist('ST63079.txt',180,30)
tableizer(tableout,'name','yearly180.tex')

tableout = yearlyDist('ST63079.txt',210,30)
tableizer(tableout,'name','yearly210.tex')
```

A.3 Task 2 Waveray Script

```
T = [10.2 9.58];
HO = [4.16 3.67];
ang = [150 180 210];

waveray(T(1),HO(1),ang(2),2)
%
% for i = 1:1:length(T)
%     for j = 1:1:length(ang)
%         waveray(T(i),HO(i),ang(j))
%     end
% end
```

A.4 Task 2 Breaker Script

```
clear all;
clc;

T_150 = [12.59 13.33];
T_180 = [13.06 13.77];
T_210 = [12.86 13.87];
HO_150 = [6.34 7.10];
HO_180 = [6.83 7.59];
HO_210 = [6.61 7.36];
ang = [150 180 210];

lat20y_150 = [41.4385 41.4357];
lon20y_150 = [-71.452  -71.446];
lat20y_180 = [41.4361 41.4375];
lon20y_180 = [-71.45 -71.4463];

lat50y_150 = [41.4385 41.4357];
lon50y_150 = [-71.452  -71.4463];
lat50y_180 = [41.4325 41.437];
lon50y_180 = [-71.4534 -71.448];

lon = lon50y_180;
lat = lat50y_180;

m = 1/50;


b = [];
refra = [];
shoaling = [];
H_breaker = [];
h_breaker = [];
Ks = [];

% b(1) = ginput(1);
% [lon, lat] = ginput;

for n = 1
    b(1) = 250;
    refra(1) = 0;
    londiff = (lon(1,n+1) - lon(1,n))*(3600)*30.89*cosd(lat(1,n));
    latdiff = (lat(1,n+1) - lat(1,n))*(3600)*30.89;
    b(n + 1) = sqrt(londiff^2 + latdiff^2);
    refra(n+1) = REFRA(b(n),b(1));
end

for n = 1:length(lon)
    [H_breaker(n), h_breaker(n), Ks(n)] = BREAK(T_180(2), ang(2), HO_180(2), m, b(n), b(1));
end

tableize = [refra', Ks', H_breaker', h_breaker', H_breaker'./h_breaker'];
tableizer(tableize)
```

Task 1 Appendicies

B.1 Monthly Maximum output example

```
63079 1980  1 14  9 -71.42000 41.25000 33.00000 1.29000  5.00000  4.78000 4.35000  25.00000 138.00000
            7.80000 136.00000
63079 1980  2 23  6 -71.42000 41.25000 33.00000 1.57000  6.25000  5.90000 4.89000  62.00000 148.00000
            6.70000 198.00000
63079 1980  3 14 15 -71.42000 41.25000 33.00000 3.26000 11.11000 11.36000 7.47000 356.00000 161.00000
            9.60000 219.00000
63079 1980  4 10  6 -71.42000 41.25000 33.00000 2.77000  7.69000  7.95000 6.02000   6.00000 143.00000
           11.70000 144.00000
63079 1980  5 19  0 -71.42000 41.25000 33.00000 1.95000  5.56000  5.79000 5.01000 134.00000 159.00000
           10.00000 160.00000
```

Listing B.1: Example output from monethextrema_new.m

B.2 Yearly Average Wave Conditions

Year	Avg Hs(m)	Avg Ts (m)
1980.0	0.8	6.5
1981.0	0.8	6.5
1982.0	0.6	6.3
1983.0	0.9	6.5
1984.0	0.9	6.7
1985.0	0.7	6.5
1986.0	0.9	6.4
1987.0	0.9	6.3
1988.0	0.8	6.1
1989.0	0.8	6.4
1990.0	0.9	7.0
1991.0	0.9	6.5
1992.0	0.9	7.0
1993.0	0.8	6.7
1994.0	0.9	6.7
1995.0	1.0	8.6
1996.0	1.2	7.3
1997.0	0.9	6.9
1998.0	1.0	7.4
1999.0	0.9	6.9

Table B.1: 150° Yearly Averages

Year	Avg Hs(m)	Avg Ts (m)
1980.0	1.0	6.4
1981.0	1.0	6.6
1982.0	1.0	6.1
1983.0	1.0	6.3
1984.0	1.1	6.6
1985.0	0.9	6.2
1986.0	0.9	6.2
1987.0	0.9	6.1
1988.0	0.9	6.4
1989.0	1.1	6.5
1990.0	1.0	6.8
1991.0	1.0	6.4
1992.0	0.9	6.5
1993.0	1.0	6.5
1994.0	1.1	6.6
1995.0	1.1	7.3
1996.0	1.1	7.2
1997.0	1.0	7.0
1998.0	1.0	7.2
1999.0	1.0	6.8

Table B.2: 180° Yearly Averages

Year	Avg Hs(m)	Avg Ts (m)
1980.0	1.1	6.4
1981.0	1.1	6.5
1982.0	1.1	6.1
1983.0	1.0	6.0
1984.0	0.9	5.9
1985.0	1.0	6.3
1986.0	1.0	6.3
1987.0	0.9	6.1
1988.0	1.2	6.3
1989.0	1.1	6.4
1990.0	1.2	6.4
1991.0	0.9	5.8
1992.0	1.0	6.1
1993.0	1.1	6.2
1994.0	1.0	6.2
1995.0	1.1	6.3
1996.0	1.1	6.7
1997.0	1.1	6.2
1998.0	1.0	6.2
1999.0	1.1	6.3

Table B.3: 210° Yearly Averages