INSTITUTO SUPERIOR TECNICO

MODELLING OF SEA WAVES

PROJECT 2

Davide Melozzi

Ist1102230

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PART I

EX.1

The first problem is to analyze a set of wave data in terms of their significant height (H), period (T), and direction (Dp) across years. The goal is to find the scatter tables showing the distribution of the number of elements for different combinations of H and T, H and Dp, and T and Dp in the region of Figure 1. Using the histcounts2 function in Matlab and using the appropriate size of the bins, Figures 2 to 4 could be produced.

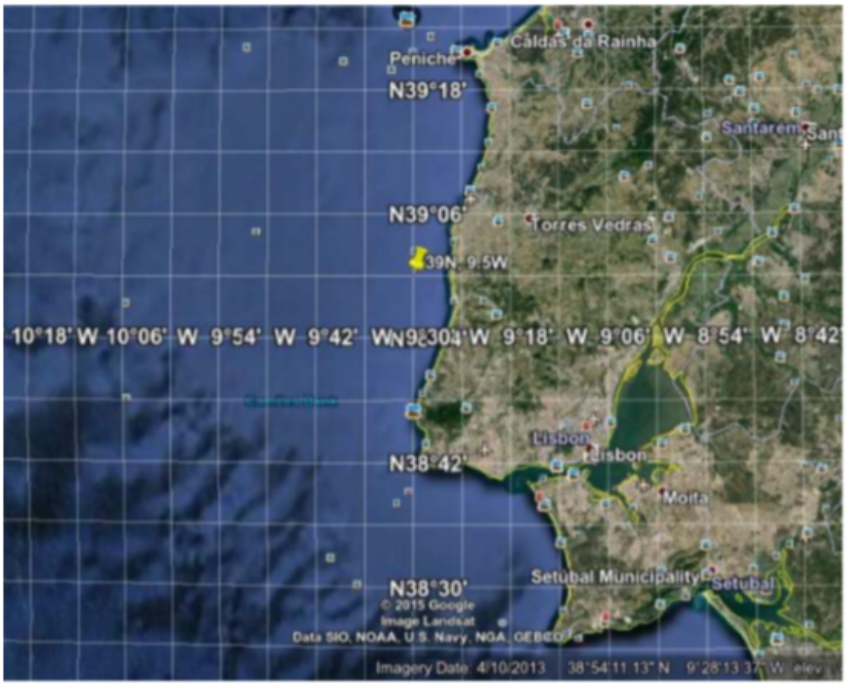


Fig.1 region to be analyzed

Figure 2 shows that the most common wave has a period between 10 and 11 seconds and a wave height between 1.5 and 2 meters. It can also be observed that the waves with a period between 7 and 14 seconds and a height of 0.5 to 3.5 meters are the most frequent.

Figures 3 and 4 must be analyzed together with Figure 1. Figure 3 shows that the predominant direction and height is between 260-360° with 0.5 to 3.5 meters, while Figure 4 shows that the predominant direction and period is between 260-360° with 7 to 14 seconds. This is in line with expectations as Figure 1 shows that this angular range is associated with the Atlantic Ocean. Figure 1 also explains that a small number of waves have a peak direction of 0 to 160 degrees as the land impedes wave development.

		Tp (s)																					
		0-1	1.0-2	2.0-3	3.0-4	4.0-5	5.0-6	6.0-7	7.0-8	8.0-9	9.0-10	10.0-11	11.0-12	12.0-13	13.0-14	14.0-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22
Hs (m)	0-0.5	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
	0.5-1	0	0	0	1	3	5	13	44	102	94	75	48	26	15	9	5	2	1	0	0	0	0
	1-1.5	0	0	0	0	7	30	72	163	394	444	430	337	184	107	55	23	12	5	3	0	0	0
	1.5-2	0	0	0	0	1	30	159	262	469	718	900	774	514	296	154	74	43	19	7	3	0	0
	2-2,5	0	0	0	0	0	3	70	255	309	493	852	1082	937	548	290	153	74	24	10	3	1	0
	2.5-3	0	0	0	0	0	0	8	133	243	258	616	1055	1150	908	501	225	102	34	10	5	3	0
	3-3.5	0	0	0	0	0	0	0	28	127	165	327	746	1072	1033	736	310	99	37	13	3	0	0
	3.5-4	0	0	0	0	0	0	0	3	34	113	220	459	797	951	768	331	141	51	15	3	0	0
	4-4.5	0	0	0	0	0	0	0	1	12	58	140	272	551	780	769	568	188	49	12	0	0	0
	4.5-5	0	0	0	0	0	0	0	0	0	24	100	154	382	493	611	543	276	110	28	14	3	0
	5-5.5	0	0	0	0	0	0	0	0	0	7	38	102	153	215	395	406	289	85	31	3	0	0
	5.5-6	0	0	0	0	0	0	0	0	0	0	13	51	117	199	304	368	275	112	30	4	0	0
	6-6.5	0	0	0	0	0	0	0	0	0	2	5	22	48	163	206	271	264	107	26	14	0	0
	6.5-7	0	0	0	0	0	0	0	0	0	0	0	6	34	56	167	178	104	43	10	0	0	0
	7-7.5	0	0	0	0	0	0	0	0	0	0	0	0	24	38	110	112	114	38	0	0	0	0
	7.5-8	0	0	0	0	0	0	0	0	0	0	0	0	5	15	68	127	100	56	0	0	0	0
	8-8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	11	23	94	47	14	15	0	0	0
	8.5-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	21	45	63	8	9	0	0
	9-9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	16	8	26	9	10	0	0
	9.5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	18	0	0	0	0	0
	10-10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
	10.5-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0
	11-11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0

Fig.2 scatter table H_sxT_p

		Dp (°)																	
		0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200	200-220	220-240	240-260	260-280	280-300	300-320	320-340	340-360
	0-0.5	0	0	0	0	0	0	0	0	0	0	7	1	0	40	121	62	30	13
	0.5-1	0	0	0	1	0	0	0	0	0	6	44	16	158	1258	3057	2173	1026	526
	1-1.5	0	0	0	2	7	6	1	0	8	33	71	76	228	2515	6015	5074	2979	1121
	1.5-2	0	0	0	1	2	3	0	0	9	31	63	92	214	2566	5835	5279	3671	1198
	2-2,5	0	0	0	0	0	0	0	0	2	11	61	97	194	1907	4664	3602	1897	573
	2.5-3	0	0	0	0	0	0	0	0	0	9	44	75	137	1369	3643	2419	754	255
	3-3.5	0	0	0	0	0	0	0	0	0	6	29	56	116	774	2530	1544	321	45
	3.5-4	0	0	0	0	0	0	0	0	0	1	4	31	60	563	1641	883	123	8
	4-4.5	0	0	0	0	0	0	0	0	0	0	5	16	32	380	1088	626	61	0
	4.5-5	0	0	0	0	0	0	0	0	0	0	0	9	17	257	670	407	31	0
	5-5.5	0	0	0	0	0	0	0	0	0	0	0	3	16	139	351	192	2	0
Hs (m)	5.5-6	0	0	0	0	0	0	0	0	0	0	0	0	4	99	260	130	0	0
	6-6.5	0	0	0	0	0	0	0	0	0	0	0	0	2	58	188	67	0	0
	6.5-7	0	0	0	0	0	0	0	0	0	0	0	0	0	32	87	26	0	0
	7-7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	19	54	18	0	0
	7.5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	15	29	22	0	0
	8-8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	13	11	8	0	0
	8.5-9	0	0	0	0	0	0	0	0	0	0	0	0	0	9	11	4	0	0
	9-9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	0	0	0
	9.5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
	10-10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	10.5-11	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	11-11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0

Fig.3 scatter table $H_s x D_p$

		Dp (°)																
		0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200	200-220	220-240	240-260	260-280	280-300	300-320	320-340	340-360
Hs (m)	0-0.5	0	0	0	0	0	0	0	0	0	0	7	1	0	40	121	62	30	13
	0.5-1	0	0	0	1	0	0	0	0	0	6	44	16	158	1258	3057	2173	1026	526
	1-1.5	0	0	0	2	7	6	1	0	8	33	71	76	228	2515	6015	5074	2979	1121
	1.5-2	0	0	0	1	2	3	0	0	9	31	63	92	214	2566	5835	5279	3671	1198
	2-2,5	0	0	0	0	0	0	0	0	2	11	61	97	194	1907	4664	3602	1897	573
	2.5-3	0	0	0	0	0	0	0	0	0	9	44	75	137	1369	3643	2419	754	255
	3-3.5	0	0	0	0	0	0	0	0	0	6	29	56	116	774	2530	1544	321	45
	3.5-4	0	0	0	0	0	0	0	0	0	1	4	31	60	563	1641	883	123	8
	4-4.5	0	0	0	0	0	0	0	0	0	0	5	16	32	380	1088	626	61	0
	4.5-5	0	0	0	0	0	0	0	0	0	0	0	9	17	257	670	407	31	0
	5-5.5	0	0	0	0	0	0	0	0	0	0	0	3	16	139	351	192	2	0
	5.5-6	0	0	0	0	0	0	0	0	0	0	0	0	4	99	260	130	0	0
	6-6.5	0	0	0	0	0	0	0	0	0	0	0	0	2	58	188	67	0	0
	6.5-7	0	0	0	0	0	0	0	0	0	0	0	0	0	32	87	26	0	0
	7-7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	19	54	18	0	0
	7.5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	15	29	22	0	0
	8-8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	13	11	8	0	0
	8.5-9	0	0	0	0	0	0	0	0	0	0	0	0	0	9	11	4	0	0
	9-9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	0	0	0
	9.5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
	10-10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	10.5-11	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	11-11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0

Fig.4 scatter table H_sxD_p

EX.2

The first point is to calculate the average power for the whole series. It can be calculated using the equation below.

$$\overline{P_w} = \frac{\rho * g^2}{64 * \pi} * \overline{H_s}^2 * 0.9 * \overline{T_p}$$

Where ro is 1025 kg/m3, Hs is the mean of the significant height, and Tp is the mean of the period of the waves. This gives an average power of 21.45 MW /m.

The same process was repeated to calculate the mean power for different seasons to find out which one has more power for the whole series. It was assumed that winter consists of December, January and February, spring consists of March, April and May, summer consists of June, July and August and autumn consists of September, October and November. The average performance for each season can be seen in the table below. The table shows that winter is the best season because waves with a greater height are created during this stormier period. It is also one of the most energetic periods, which also helps to increase the power capacity.

ELECTRICITY PRODUCTION	
SEASON	POWER(MW/m)
WINTER	42.580
SPRING	21.787
SUMMER	9.10
AUTUMN	20.873
AVERAGE	21.777

Fig.5 power generated for different season

The third point is to obtain the power scatter table. To do this, we must first obtain the normalized scatter table of Hs x Tp, because it gives the probability that a given sea state will occur. Then, the power scatter table as a function of Hs and Tp is obtained from the following equation.

$$P_{ij} = \frac{\rho * g^2}{64 * \pi} * H_{ij}{}^2 * 0.9 * T_{ij} * p_{ij}$$

Where Pij is the power of row i and column j of the scatter table, and pij is the probability that this swell will occur.

The normalized scatter plot and power table can be seen below. As you can see from both figures, the maximum power (1150 kW/m) has a probability of 3.27% (H = 2.5-3 m and T = 12-13 s) to occur. The more likely power (900 kW/m) has a probability of 4.63% (H = 1.5-2 m and T = 10-11 s). The range of heights and time periods in which the highest power occurs is between 9 and 15 seconds and 1.5 to 4.5 meters, corresponding to a probability of 49%.

	Tp (s)																					
Hs (m)	0-1	1.0-2	2.0-3	3.0-4	4.0-5	5.0-6	6.0-7	7.0-8	8.0-9	9.0-10	10.0-11	11.0-12	12.0-13	13.0-14	14.0-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22
0-0.5	0,000%	0,000%	0,004%	0,002%	0,007%	0,000%	0,006%	0,071%	0,056%	0,043%	0,054%	0,039%	0,021%	0,017%	0,011%	0,004%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
0.5-1	0,000%	0,000%	0,000%	0,037%	0,126%	0,181%	0,432%	1,233%	2,563%	2,135%	1,554%	0,906%	0,456%	0,249%	0,136%	0,066%	0,031%	0,018%	0,005%	0,001%	0,000%	0,001%
1-1.5	0,000%	0,000%	0,000%	0,011%	0,150%	0,509%	1,038%	2,057%	4,402%	4,472%	3,934%	2,826%	1,422%	0,772%	0,370%	0,147%	0,074%	0,028%	0,016%	0,002%	0,001%	0,001%
1.5-2	0,000%	0,000%	0,000%	0,000%	0,009%	0,286%	1,290%	1,856%	2,951%	4,065%	4,630%	3,651%	2,238%	1,199%	0,582%	0,262%	0,142%	0,059%	0,020%	0,009%	0,000%	0,000%
2-2,.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,016%	0,362%	1,156%	1,243%	1,786%	2,807%	3,267%	2,612%	1,418%	0,701%	0,347%	0,157%	0,048%	0,020%	0,005%	0,001%	0,000%
2.5-3	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,029%	0,417%	0,680%	0,648%	1,409%	2,213%	2,226%	1,632%	0,841%	0,354%	0,151%	0,048%	0,013%	0,006%	0,004%	0,000%
3-3.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,064%	0,261%	0,305%	0,550%	1,149%	1,525%	1,364%	0,907%	0,358%	0,108%	0,038%	0,012%	0,002%	0,000%	0,000%
3.5-4	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,006%	0,053%	0,161%	0,283%	0,542%	0,868%	0,961%	0,724%	0,293%	0,118%	0,040%	0,011%	0,002%	0,000%	0,000%
4-4.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,015%	0,065%	0,142%	0,254%	0,474%	0,623%	0,574%	0,397%	0,124%	0,031%	0,007%	0,000%	0,000%	0,000%
4.5-5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,022%	0,082%	0,116%	0,266%	0,319%	0,369%	0,308%	0,147%	0,055%	0,013%	0,006%	0,001%	0,000%
5-5.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,005%	0,026%	0,064%	0,088%	0,115%	0,197%	0,190%	0,127%	0,036%	0,012%	0,001%	0,000%	0,000%
5.5-6	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,007%	0,027%	0,056%	0,089%	0,127%	0,145%	0,102%	0,039%	0,010%	0,001%	0,000%	0,000%
6-6.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,002%	0,010%	0,020%	0,063%	0,074%	0,091%	0,083%	0,032%	0,007%	0,004%	0,000%	0,000%
6.5-7	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,012%	0,018%	0,051%	0,051%	0,028%	0,011%	0,002%	0,000%	0,000%	0,000%
7-7.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,007%	0,011%	0,029%	0,028%	0,027%	0,009%	0,000%	0,000%	0,000%	0,000%
7.5-8	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,004%	0,016%	0,028%	0,021%	0,011%	0,000%	0,000%	0,000%	0,000%
8-8.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,005%	0,018%	0,009%	0,002%	0,002%	0,000%	0,000%	0,000%
8.5-9	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,006%	0,004%	0,007%	0,010%	0,001%	0,001%	0,000%	0,000%
9-9.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,002%	0,001%	0,004%	0,001%	0,001%	0,000%	0,000%
9.5-10	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,002%	0,000%	0,000%	0,000%	0,000%	0,000%
10-10.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%
10.5-11	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,000%	0,000%	0,000%	0,000%	0,000%
11-11.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,004%	0,000%	0,000%	0,000%	0,000%	0,000%

	Dp (°)																	
Hs (m)	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200	200-220	220-240	240-260	260-280	280-300	300-320	320-340	340-360
0-0.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,009%	0,001%	0,000%	0,049%	0,148%	0,076%	0,037%	0,016%
0.5-1	0,000%	0,000%	0,000%	0,001%	0,000%	0,000%	0,000%	0,000%	0,000%	0,007%	0,054%	0,020%	0,194%	1,542%	3,747%	2,664%	1,258%	0,645%
1-1.5	0,000%	0,000%	0,000%	0,002%	0,009%	0,007%	0,001%	0,000%	0,010%	0,040%	0,087%	0,093%	0,279%	3,083%	7,374%	6,220%	3,652%	1,374%
1.5-2	0,000%	0,000%	0,000%	0,001%	0,002%	0,004%	0,000%	0,000%	0,011%	0,038%	0,077%	0,113%	0,262%	3,146%	7,153%	6,471%	4,500%	1,469%
2-2,.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,013%	0,075%	0,119%	0,238%	2,338%	5,717%	4,416%	2,325%	0,702%
2.5-3	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,011%	0,054%	0,092%	0,168%	1,678%	4,466%	2,965%	0,924%	0,313%
3-3.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,007%	0,036%	0,069%	0,142%	0,949%	3,101%	1,893%	0,394%	0,055%
3.5-4	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,005%	0,038%	0,074%	0,690%	2,012%	1,082%	0,151%	0,010%
4-4.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,006%	0,020%	0,039%	0,466%	1,334%	0,767%	0,075%	0,000%
4.5-5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,011%	0,021%	0,315%	0,821%	0,499%	0,038%	0,000%
5-5.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,004%	0,020%	0,170%	0,430%	0,235%	0,002%	0,000%
5.5-6	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,005%	0,121%	0,319%	0,159%	0,000%	0,000%
6-6.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,071%	0,230%	0,082%	0,000%	0,000%
6.5-7	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,039%	0,107%	0,032%	0,000%	0,000%
7-7.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,023%	0,066%	0,022%	0,000%	0,000%
7.5-8	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,018%	0,036%	0,027%	0,000%	0,000%
8-8.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,016%	0,013%	0,010%	0,000%	0,000%
8.5-9	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,011%	0,013%	0,005%	0,000%	0,000%
9-9.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,005%	0,007%	0,000%	0,000%	0,000%
9.5-10	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,002%	0,000%	0,000%	0,000%
10-10.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,000%	0,000%	0,000%	0,000%

	10.5-11	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,000%	0,000%	0,000%	0,000%
	11-11.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,004%	0,000%	0,000%	0,000%	0,000%

	Dp (°)																	
Hs (m)	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200	200-220	220-240	240-260	260-280	280-300	300-320	320-340	340-360
0-0.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,009%	0,001%	0,000%	0,049%	0,148%	0,076%	0,037%	0,016%
0.5-1	0,000%	0,000%	0,000%	0,001%	0,000%	0,000%	0,000%	0,000%	0,000%	0,007%	0,054%	0,020%	0,194%	1,542%	3,747%	2,664%	1,258%	0,645%
1-1.5	0,000%	0,000%	0,000%	0,002%	0,009%	0,007%	0,001%	0,000%	0,010%	0,040%	0,087%	0,093%	0,279%	3,083%	7,374%	6,220%	3,652%	1,374%
1.5-2	0,000%	0,000%	0,000%	0,001%	0,002%	0,004%	0,000%	0,000%	0,011%	0,038%	0,077%	0,113%	0,262%	3,146%	7,153%	6,471%	4,500%	1,469%
2-2,.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,013%	0,075%	0,119%	0,238%	2,338%	5,717%	4,416%	2,325%	0,702%
2.5-3	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,011%	0,054%	0,092%	0,168%	1,678%	4,466%	2,965%	0,924%	0,313%
3-3.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,007%	0,036%	0,069%	0,142%	0,949%	3,101%	1,893%	0,394%	0,055%
3.5-4	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,005%	0,038%	0,074%	0,690%	2,012%	1,082%	0,151%	0,010%
4-4.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,006%	0,020%	0,039%	0,466%	1,334%	0,767%	0,075%	0,000%
4.5-5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,011%	0,021%	0,315%	0,821%	0,499%	0,038%	0,000%
5-5.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,004%	0,020%	0,170%	0,430%	0,235%	0,002%	0,000%
5.5-6	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,005%	0,121%	0,319%	0,159%	0,000%	0,000%
6-6.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,071%	0,230%	0,082%	0,000%	0,000%
6.5-7	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,039%	0,107%	0,032%	0,000%	0,000%
7-7.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,023%	0,066%	0,022%	0,000%	0,000%
7.5-8	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,018%	0,036%	0,027%	0,000%	0,000%
8-8.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,016%	0,013%	0,010%	0,000%	0,000%
8.5-9	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,011%	0,013%	0,005%	0,000%	0,000%
9-9.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,005%	0,007%	0,000%	0,000%	0,000%
9.5-10	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,002%	0,000%	0,000%	0,000%
10-10.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,001%	0,000%	0,000%	0,000%	0,000%
10.5-11	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,002%	0,000%	0,000%	0,000%	0,000%
11-11.5	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,004%	0,000%	0,000%	0,000%	0,000%

Fig.6 normalized scatter table for $H_s x T_p$

	Tp (s)																					
Hs (m)	0-1	1.0-2	2.0-3	3.0-4	4.0-5	5.0-6	6.0-7	7.0-8	8.0-9	9.0-10	10.0-11	11.0-12	12.0-13	13.0-14	14.0-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22
0-0.5	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
0.5-1	0	0	0	1	3	5	13	44	102	94	75	48	26	15	9	5	2	1	0	0	0	0
1-1.5	0	0	0	0	7	30	72	163	394	444	430	337	184	107	55	23	12	5	3	0	0	0
1.5-2	0	0	0	0	1	30	159	262	469	718	900	774	514	296	154	74	43	19	7	3	0	0
2-2,.5	0	0	0	0	0	3	70	255	309	493	852	1082	937	548	290	153	74	24	10	3	1	0
2.5-3	0	0	0	0	0	0	8	133	243	258	616	1055	1150	908	501	225	102	34	10	5	3	0
3-3.5	0	0	0	0	0	0	0	28	127	165	327	746	1072	1033	736	310	99	37	13	3	0	0
3.5-4	0	0	0	0	0	0	0	3	34	113	220	459	797	951	768	331	141	51	15	3	0	0
4-4.5	0	0	0	0	0	0	0	1	12	58	140	272	551	780	769	568	188	49	12	0	0	0
4.5-5	0	0	0	0	0	0	0	0	0	24	100	154	382	493	611	543	276	110	28	14	3	0
5-5.5	0	0	0	0	0	0	0	0	0	7	38	102	153	215	395	406	289	85	31	3	0	0
5.5-6	0	0	0	0	0	0	0	0	0	0	13	51	117	199	304	368	275	112	30	4	0	0
6-6.5	0	0	0	0	0	0	0	0	0	2	5	22	48	163	206	271	264	107	26	14	0	0
6.5-7	0	0	0	0	0	0	0	0	0	0	0	6	34	56	167	178	104	43	10	0	0	0
7-7.5	0	0	0	0	0	0	0	0	0	0	0	0	24	38	110	112	114	38	0	0	0	0
7.5-8	0	0	0	0	0	0	0	0	0	0	0	0	5	15	68	127	100	56	0	0	0	0
8-8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	11	23	94	47	14	15	0	0	0
8.5-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	21	45	63	8	9	0	0
9-9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	16	8	26	9	10	0	0
9.5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	18	0	0	0	0	0
10-10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
10.5-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0
11-11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0

Fig.7 Power matrix in function of H_s e T_p

EX.3

The third problem compares different wave energy converters (WEC) based on the power they produce. This power can be calculated using the following equation, where pij is the probability of this sea state occurring and Pij is the value from the power matrix.

$$P_E = \sum_{i=1}^{N}\sum_{j=1}^{M} p_{ij} * P_{ij}$$

Using this equation along with the power matrix of each WEC and the scatter table normalized to Hs x Tp, the following table could be produced. This represents the average power generated for each WEC in the analyzed region from Figure 1.

ELECTRICITY PRODUCTION	
WEC	POWER(KW)
PELAMIS	95.27
AQUA BUOUY	33.67
WAVE DRAGON	991.12

Fig.8 Electricity production for different WEC

From Table 3, it can be concluded that the Wave Dragon generates the most energy at the given location. This can be explained by the fact that it has higher power values for the range of altitude and period that produces the most power at this location. However, it should be noted that further research is required to determine the optimum energy converter. This is because a Wave Dragon has larger dimensions compared to the Aquabuoy, so it may be more efficient to place multiple Aquabuoys than one Wave Dragon.

PART 2 Project 2

DAVIDE MELOZZI
IST 1102230

$D_0 = 2{,}5\ m$

$W = 800\ N/m$

$\rho = 1025\ kg/m^3$

$C_D = 0{,}9$

$V = 3\ m/s$

$D = 10\ m$

a) $D_{FD} = \frac{1}{2} \cdot \rho \cdot C_D \cdot D_0 \cdot V^2 \Rightarrow D_{FD} = \frac{1}{2} \cdot 1025 \cdot 0{,}9 \cdot 2{,}5 \cdot 3^2$

$= 10378.13\ N/m$

b) $F_H = D_{FD} \cdot D = 10378.13 \cdot 10 = 103781{,}3\ N = 103{,}8\ kN$

c) $T_H \leftarrow \boxed{\cdot} \rightarrow F_H$ $\quad T_H = F_H \quad$ Because $\theta = 45° \rightarrow T_Z = T_H$

$$L_s = \frac{T_H}{w} \operatorname{senh}\left(\frac{xw}{T_H}\right) \Leftrightarrow x = \frac{T_H}{w} \operatorname{senh}^{-1}\left(\frac{L_s w}{T_H}\right) \Leftrightarrow$$

$$= \frac{103781.3}{800} \operatorname{senh}^{-1}\left(\frac{129{,}7 \cdot 800}{103781{,}3}\right)$$

$$= 114{,}3\ m$$

$$T = \sqrt{T_H^2 + T_Z^2} \Rightarrow T = \sqrt{103781{,}9^2 \cdot 2} = 196768{,}5\ N$$

d) $L_D = \frac{1}{w} \cdot \sqrt{T^2 - 4H^2} \Leftrightarrow L_D = \frac{T_Z}{w} \Rightarrow L_D = \frac{103781.3}{800}$

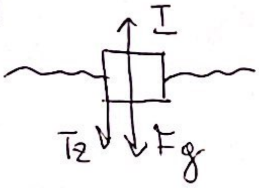
$= 129{,}7\ m$

$$x' = \frac{T_H}{w} \operatorname{senh}^{-1}\left(\frac{w L_s}{T_H}\right) + \left(\frac{L_s T_H}{EA}\right) \Leftrightarrow x' = x + \frac{L_s \cdot T_H}{EA}$$

$$= 114{,}3 + \frac{129{,}7 \cdot 103781{,}3}{3240000}$$

$$= 118{,}45\ m$$

e)



$$I = T_z + F_g \Rightarrow F_g = I - T_z \Rightarrow M = \frac{I - T_z}{g}$$

$$M = \frac{\rho \cdot g \cdot V - T_z}{g} \quad *$$

$$* = M = \frac{1025 \cdot 9{,}81 \cdot \pi \cdot 1{,}25^2 \cdot 10 - 103\,781{,}3}{9{,}81}$$

$\pi \cdot r^2 \cdot l$

$$= M = 39735{,}5 \text{ kg}$$

$$r = \frac{2{,}5}{2} = 1{,}25 \text{ m}$$