PivotBuoy

PivotBuoy

An Advanced System for Cost-effective and Reliable Mooring, Connection, Installation & Operation of Floating Wind

Call identifier: H2020-LC-SC3-RES-11-2018

D4.1: Test site environmental conditions

Due Date of Deliverable: 30/04/2019
Completion Date of Deliverable: 30/04/2019

Start date of project: 1 April 2019 Duration: 36 months

Lead partner for deliverable: PLOCAN

Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including Commission Services)	
CO	Confidential, only for members of the consortium (including Commission Services)	

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

Document History

Issue Date	Version	Changes Made / Reason for this Issue
23/04/2019	0.1	First draft prepared by PLOCAN
25/04/2019	0.2	Reviewed by X1 Wind
29/04/2019	0.4	New version prepared by PLOCAN
30/04/2019	1.0	Final version for submission reviewed by X1 Wind

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

INDEX

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

1 INTRODUCTION

The Oceanic Platform of the Canary Islands (PLOCAN) is a multipurpose technical-scientific service infrastructure that provides support for research, technological development and innovation in the marine and maritime sectors, available to public and private users. PLOCAN offers both onshore and offshore experimental facilities and laboratories, operational throughout the whole year thanks to the Canary Islands excellent climatic conditions. PLOCAN also brings a broad experience in large national and EU marine/maritime projects.

PLOCAN is, thus, a Public consortium aimed to promote research, development and innovation in the field of marine sciences and technology, supporting the industry to test and demonstrate the feasibility of emerging technologies. PLOCAN has a marine test site at the North-East coast of Gran Canaria island (Canary Islands, Spain), occupying a marine area of 23 km2 with a range of depths among 20 m and 600 m, shown in Figure 1. The test site includes an underwater electrical and communication grid directly connected to an onshore electrical substation.

This marine test site will be the place where the PivotBuoy prototype will be tested, and this deliverable will ensure that the environmental conditions where the system will be deployed are well fed into the design process in WP2.

Figure 1. PLOCAN test site – Canary Islands

The Canary Islands, surrounded by the waters of the Atlantic Ocean, on the edge of the sub-tropical band, form an archipelago situated close to the North West coast of Africa, which gives it characteristic climate traits. The climate of the Islands is consequence of the atmospheric dynamics typical of sub-tropical latitudes, its proximity to the African mainland and its rugged relief (especially in Gran Canaria, which reaches an altitude of 1949m at the highest point), and the cold ocean currents.

Due to its sub-tropical latitude and the proximity of the Azores Anticyclone, the Canary Islands are affected permanently by the Trade Winds, blowing from the high-pressure area. The intensity of the Trade Winds varies throughout the year, depending on the distance between the archipelago and the Azores Anticyclone. In winter, the Anticyclone is usually situated close to the islands and it is less intense. In summer, the Anticyclone settles in the Azores, far from Canaries, causing the Trade Winds to blow more intensely. The rotation of the Earth diverts the Trade Winds to the West.

The Archipelago receives the southern branch of the cold ocean current from The Gulf (Central America), which descends parallel to the coasts of Portugal and Morocco. The water temperature is

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

lower than it should be at that latitude. The Trade Winds facilitate the upwelling that causes deeper, colder waters to come up to the surface.

The proximity of the African mainland occasionally gives rise to the arrival of masses of hot, dry air, responsible for days of intense heat. The continental winds from the South South East, usually bring dust from the desert, known locally as “calima”.

The following chapters describe the waves, wind, currents, bathymetry, seabed conditions, water quality and submarine noise present in the area, and the last section identifies the selected area for the deployment of the PivotBuoy prototype.

This project has received funding from the European Union’s Horizon H2020 research and innovation programme under grant agreement No 815159

2 WAVES

The wave action data shown in this chapter comes from Las Palmas East wave buoy (scalar instrumental data) and from SWAN numerical modelling [1]. These latter, from modelling at a spatial resolution of 1km, have been bi-linearly interpolated to some points of interest, defined from P1 to P6. In Figure 2, SWAN grid points and wave buoy locations are shown.

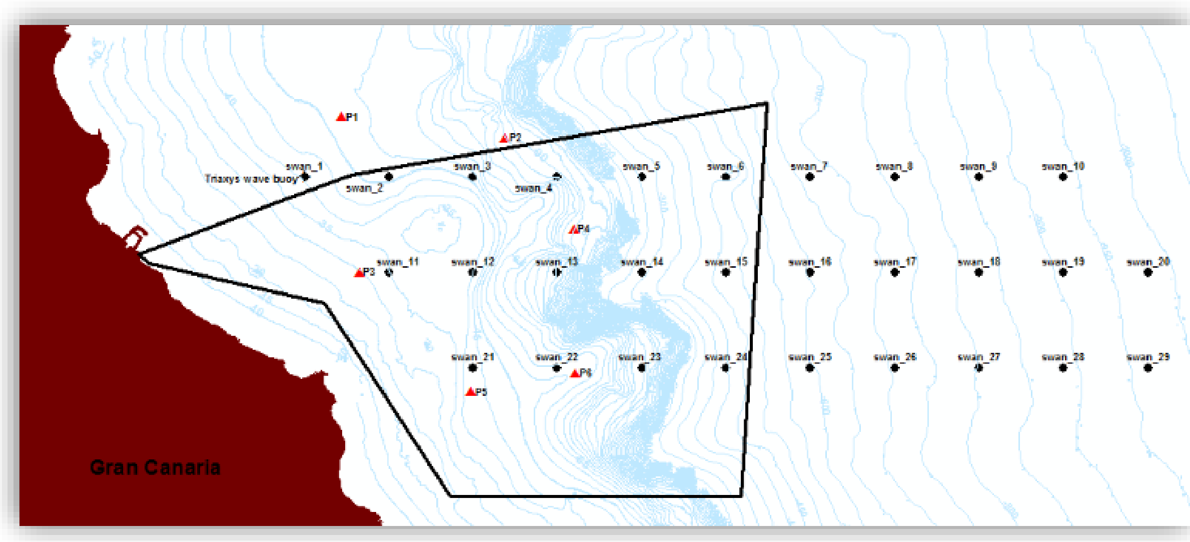


Figure 2: SWAN grid points inside PLOCAN Test site and wave buoy location

Below are the most representative results of the mean and extreme climate analysis.

2.1 Mean climate

According to the wave roses for points P3 and P4 shown in Figure 3, the predominant components of the wave action are NNW, N, NNE and NE, with the NNE component as the most energetic, with an approximate frequency of between 60 and 70%.

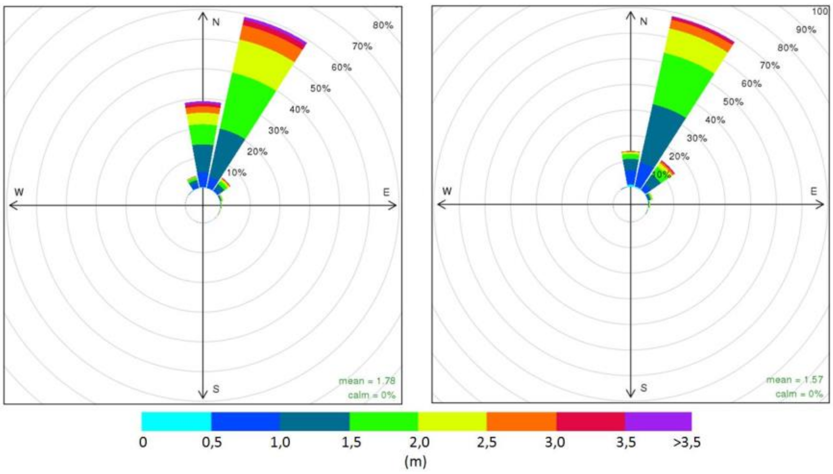


Figure 3: Mean climate. Wave rose for P4 (left) and P3 (right)

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

For the deeper locations, the N component is more important than in the locations with less depth, where it loses energy that is dissipated with the interaction of the wave action and the bathymetry.

Figure 4 shows an annual profile of mean monthly significant wave height and monthly maximum for point 1 and 2. Throughout an average year, the wave height as a monthly average is between 1.5 and 2.0 m. The maximum wave heights modelled in the study period occurred between December and April. The maximum value occurred in January 1994, reaching a significant wave height of 6.0 m for point 1 and 6.4 m for point 2.

The mean monthly direction of the wave action, calculated as the direction of the vector sum of the wave height, fluctuates slightly over the course of the year. This fluctuation is even less significant for the shallower locations. At greater depths, like point P2, the incident waves come from 30 degrees in the winter, they back around slightly to 20 degrees in spring, veering to 25 degrees in summer and come back to 20 degrees in autumn. The seasonal pattern to wave direction fits with the seasonal pattern of the mean monthly direction of the wind. Furthermore, an inter-annual profile has been drawn up with mean annual significant wave height, which shows no significant trend over the last 30 years.

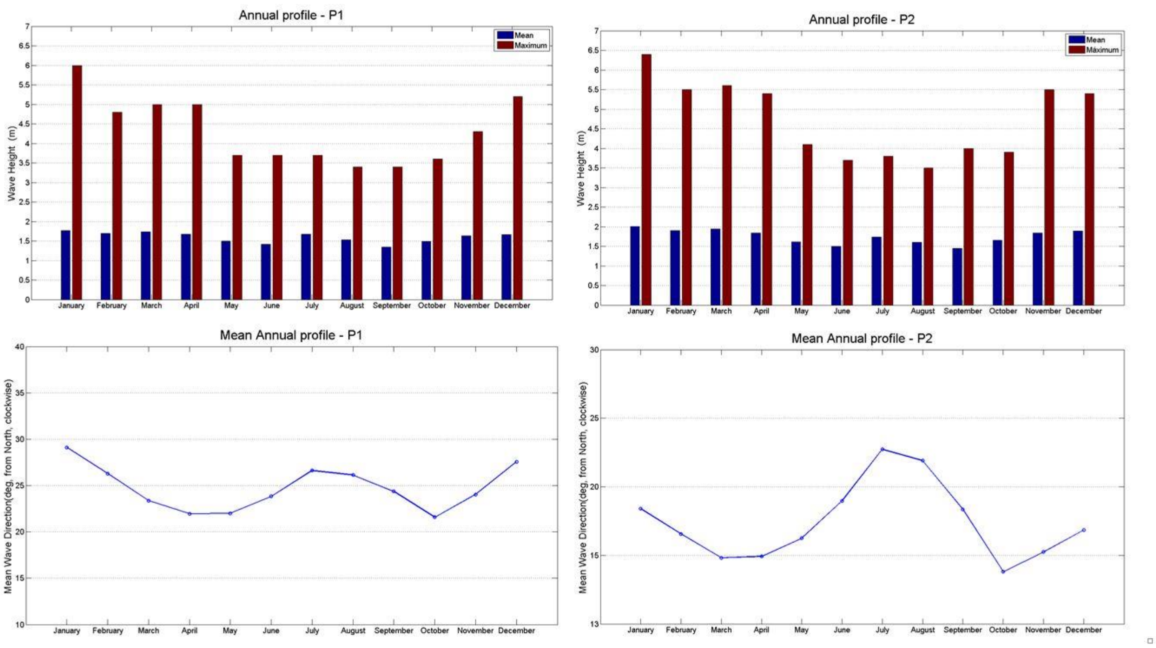


Figure 4: Annual wave height and mean direction profile for P1 (left) and P2 (right)

The following tables show the scatter diagrams Hs vs Tp, with data measured by Las Palmas East buoy from Puertos del Estado (1990-2001). That buoy is moored inside the test site, on its North Western side.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

	Tp (s)											Total
H_S(m)	≤2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	>20,0	
≤0,5	0,000	0,371	0,716	1,484	1,903	1,829	1,046	0,516	0,033	0,004	0,000	7,902
1,0	0,000	0,705	9,876	10,295	5,966	3,981	3,484	2,326	0,200	0,059	0,000	36,892
1,5	0,000	0,000	6,099	17,137	6,151	2,026	1,373	1,046	0,093	0,004	0,004	33,936
2,0	0,000	0,000	0,312	8,563	5,606	0,790	0,571	0,234	0,52	0,000	0,000	16,127
2,5	0,000	0,000	0,019	0,820	2,690	0,256	0,152	0,089	0,041	0,000	0,000	4,066
3,0	0,000	0,000	0,000	0,037	0,534	0,130	0,030	0,011	0,033	0,007	0,000	0,783
3,5	0,000	0,000	0,000	0,000	0,093	0,108	0,011	0,000	0,000	0,000	0,000	0,211
4,0	0,000	0,000	0,000	0,004	0,007	0,026	0,019	0,000	0,000	0,000	0,000	0,056
4,5	0,000	0,000	0,000	0,000	0,000	0,007	0,015	0,004	0,000	0,000	0,000	0,026
5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
>5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Total	0,000	1,076	17,022	38,339	22,950	9,153	6,700	4,226	0,456	0,074	0,004	100

Figure 5: Annual joint distribution: Hs-Tp (Buoy LP East, period 1990-2001)

The most frequent wave combination is considered to be a significant wave height (H_s) of 1.5 meters with a period (T_p) of 8 seconds. During the summer, this wave component gets specially remarkable, as can be seen on Figure 6. The following tables show the same data but filtered as seasonal average distribution.

Spring

	Tp (s)											Total
H_S(m)	≤2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	>20,0	
≤0,5	0,000	0,308	1,091	1,931	3,176	2,630	1,077	0,322	0,042	0,000	0,000	10,578
1,0	0,000	0,686	7,975	10,788	6,408	4,981	2,477	1,651	0,350	0,000	0,000	35,316
1,5	0,000	0,000	4,673	14,985	6,618	2,602	0,728	0,630	0,070	0,000	0,000	30,306
2,0	0,000	0,000	0,210	9,598	5,821	1,007	0,616	0,252	0,042	0,000	0,000	17,546
2,5	0,000	0,000	0,000	0,854	3,372	0,420	0,350	0,084	0,028	0,000	0,000	5,107
3,0	0,000	0,000	0,000	0,014	0,574	0,294	0,098	0,000	0,000	0,000	0,000	0,979
3,5	0,000	0,000	0,000	0,000	0,056	0,070	0,000	0,000	0,000	0,000	0,000	0,126
4,0	0,000	0,000	0,000	0,000	0,014	0,028	0,000	0,000	0,000	0,000	0,000	0,042
4,5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
>5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Total	0,000	0,993	13,950	38,170	26,039	12,033	5,345	2,938	0,532	0,000	0,000	100

Summer

	Tp (s)											Total
H_S(m)	≤2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	>20,0	
≤0,5	0,000	0,564	0,423	0,987	0,830	0,251	0,016	0,000	0,000	0,000	0,000	3,070
1,0	0,000	0,517	9,085	10,479	4,746	0,345	0,110	0,078	0,016	0,000	0,000	25,376
1,5	0,000	0,000	6,501	28,916	8,678	0,642	0,094	0,047	0,000	0,000	0,000	44,878
2,0	0,000	0,000	0,047	12,876	9,539	0,172	0,000	0,000	0,000	0,000	0,000	22,635
2,5	0,000	0,000	0,000	0,454	3,430	0,016	0,000	0,000	0,000	0,000	0,000	3,900
3,0	0,000	0,000	0,000	0,000	0,110	0,031	0,000	0,000	0,000	0,000	0,000	0,141
3,5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4,5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
>5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Total	0,000	1,081	16,056	53,712	27,334	1,457	0,219	0,125	0,016	0,000	0,000	100

Autumn

	Tp (s)											Total
H_S(m)	≤2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	>20,0	
≤0,5	0,000	0,493	0,911	2,151	2,166	1,882	0,986	0,612	0,060	0,015	0,000	9,276
1,0	0,000	0,926	13,204	12,502	6,841	4,511	4,152	1,509	0,060	0,134	0,000	43,839
1,5	0,000	0,000	5,736	15,161	4,765	2,061	2,166	0,508	0,015	0,000	0,000	30,411
2,0	0,000	0,000	0,418	6,154	3,898	0,762	1,060	0,149	0,000	0,000	0,000	12,442
2,5	0,000	0,000	0,045	0,762	2,091	0,164	0,105	0,149	0,000	0,000	0,000	3,316
3,0	0,000	0,000	0,000	0,045	0,403	0,000	0,000	0,045	0,000	0,000	0,000	0,493
3,5	0,000	0,000	0,000	0,000	0,134	0,090	0,000	0,000	0,000	0,000	0,000	0,224
4,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4,5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
>5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Total	0,000	1,419	20,314	36,774	20,299	9,470	8,469	2,972	0,134	0,149	0,000	100

Winter

	Tp (s)											Total
H_S(m)	≤2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	>20,0	
≤0,5	0,000	0,134	0,401	0,817	1,308	2,423	2,051	1,115	0,030	0,000	0,000	8,279
1,0	0,000	0,684	9,334	7,402	5,782	5,841	7,090	5,990	0,357	0,104	0,000	42,583
1,5	0,000	0,000	7,595	10,211	4,637	2,690	2,482	2,973	0,297	0,015	0,015	30,916
2,0	0,000	0,000	0,565	5,767	3,344	1,174	0,580	0,520	0,163	0,000	0,000	12,114
2,5	0,000	0,000	0,030	1,189	1,858	0,401	0,134	0,119	0,134	0,000	0,000	3,864
3,0	0,000	0,000	0,000	0,089	1,026	0,178	0,015	0,000	0,134	0,030	0,000	1,471
3,5	0,000	0,000	0,000	0,000	0,178	0,268	0,045	0,000	0,000	0,000	0,000	0,490
4,0	0,000	0,000	0,000	0,015	0,015	0,074	0,074	0,000	0,000	0,000	0,000	0,178
4,5	0,000	0,000	0,000	0,000	0,000	0,030	0,059	0,015	0,000	0,000	0,000	0,104
5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
>5,0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Total	0,000	0,817	17,925	25,490	18,148	13,080	12,530	10,731	1,115	0,149	0,15	100

Figure 6: Seasonal joint distribution: Hs-Tp (Buoy LP East, period 1990-2001)

2.2 Extreme climate

An extreme value analysis has been conducted to assess the extreme climate, by adjusting a GEV (Generalized Extreme Value) distribution function to the extreme values of the significant wave height data set. MA (Annual Maxima) and POT (Peak Over Threshold) methodologies were used [2]. For selecting the peaks, a 2m wave height threshold was set and a minimum distance between peaks of 7 days.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

The results of the fit for P3 are presented in the figures below, where maxH are the maximum annual wave height peaks and VmaxD are the independent wave height peaks over 2m.

Figure 7 shows the estimated parameters from adjusting them with a GEV (Generalised Extreme Value) function using the Maximum Likelihood Method, where *k* is the shape parameter, *μ* the position parameter and *σ* the scale parameter.

	MA (GEV)			POT (GPD)			
	k	σ (m)	μ (m)	k	σ (m)	μ (m)	Storms /year
P1	*-0.118*	*0.478*	*4.124*	-0.238	1.025	2	22.1
P2	-0.171	0.509	4.651	-0.276	1.292	2	24.3
P3	-0.117	0.473	4.057	*-0.231*	*0.979*	2	21.77
P4	-0.168	0.506	4.746	-0.282	1.338	2	24.63
P5	-0.127	0.488	4.304	*-0.253*	1.130	2	22.73
P6	-0.162	0.505	4.602	-0.272	1.268	2	24.20
wave buoy	0.0627	*0.410*	*3.212*	-0.143	0.616	2	12.10

Figure 7: Seasonal joint distribution Hs-Tp (Buoy LP East, period 1990-2001)

The differences observed between the parameters coming from the buoy time series and the points of the model may be caused by the fact that the numerical models of wave propagation do not adequately simulate the extreme values of the waves, so the results of an extreme value analysis from modeled time series has lower reliability. To assess the results from the buoy, Puertos del Estado specific extreme value report corresponding to that same buoy is used for the time series between 1992 and 2017 [3]. These results are shown in Figure 11, observing a wave height of 5,11 m associated with the return period of 50 years, and an average value of storms per year of 16,58 (available in the report [3]). The differences between the results shown in Figure 7 and Figure 11 are due to the way in which the storms have been selected in the POT method, as well as to the length of the time series analyzed.

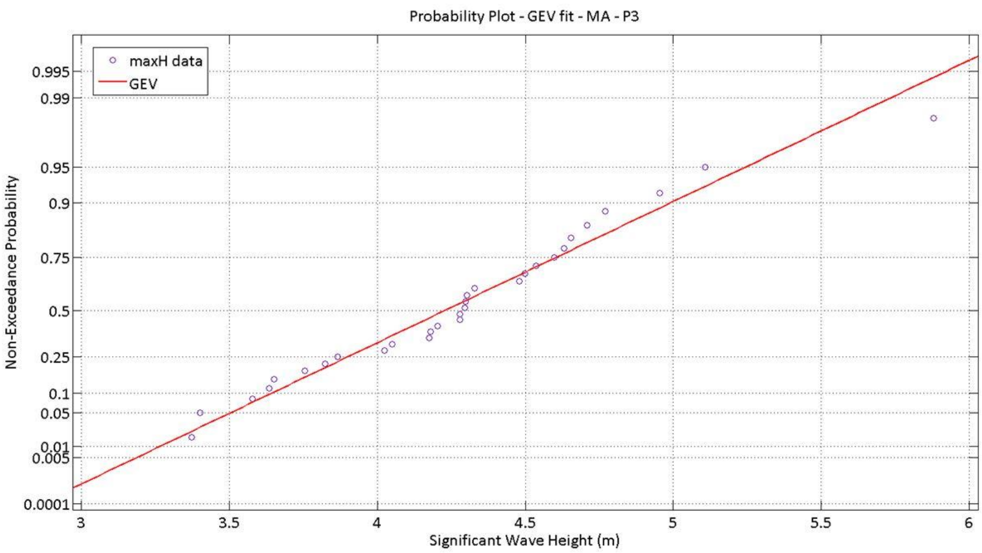


Figure 8: GEV (Generalized Extreme Value) fit to Hs by MA

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

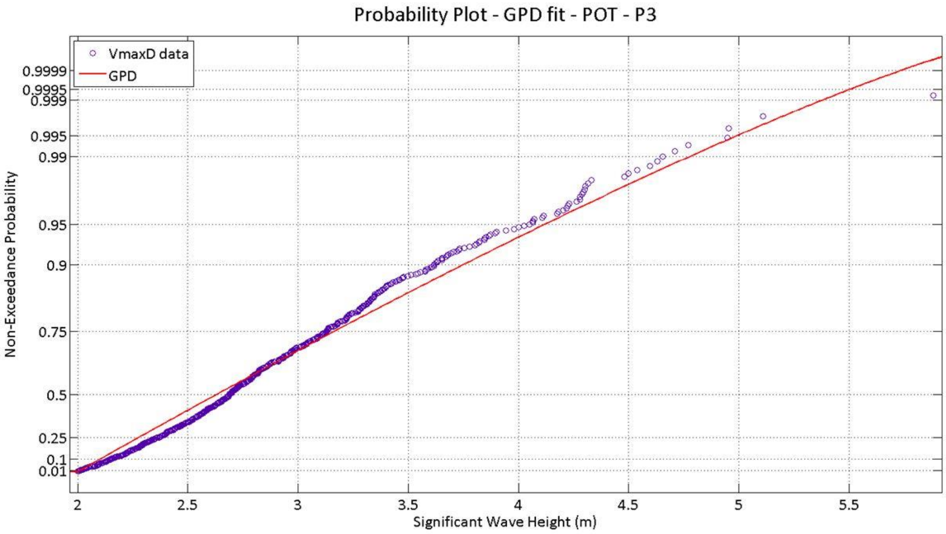


Figure 9: GDP (generalized Pareto distribution) fit to VmaxD by POT

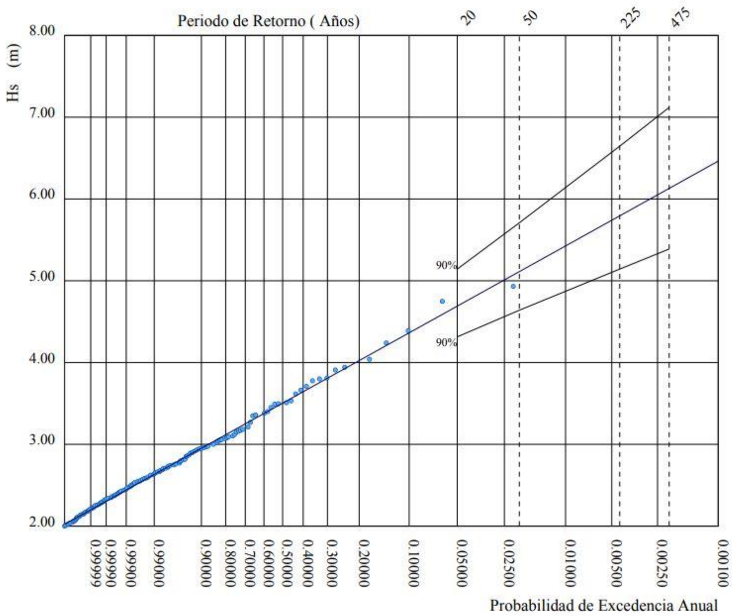


Figure 10: Extreme climate. Las Palmas East buoy. Hs vs Annual exceedance probability

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

	MA (GEV)			POT (GPD)		
	P_{10} (m)	P_{20} (m)	P_{50} (m)	P_{10} (m)	P_{20} (m)	P_{50} (m)
P1	5.06	5.32	5.61	5.11	5.29	5.38
P2	5.60	5.84	6.10	5.63	5.83	6.02
P3	4.99	5.24	5.53	5.01	5.20	5.40
P4	5.69	5.93	6.19	5.74	5.92	6.11
P5	5.26	5.51	5.80	5.34	5.52	5.71
P6	5.56	5.79	6.06	5.62	5.80	5.99
wave buoy	4.20	4.55	5.02	4.13	4.34	4.45

Figure 11: Extreme climate. Hs for return periods according to MA or POT

Individual maximum wave height data (Hmax) is also available for Las Palmas East Buoy, so an extreme climate study can be conducted for individual maximum wave action. The MA and POT methods have been used to select the extreme values. The GEV function has been chosen for the MA method and Log-Normal for the POT method. A 2m threshold and a minimum distance between peaks of 7 days have been set for selecting the peaks by the POT method. The results are shown in Figure 12.

	MA (GEV)			POT (Log-Normal)		
	k	σ (m)	μ (m)	σ (m)	μ (m)	Storms /year
wave buoy	0.0658	0.805	5.913	0.271	1.290	18.7

Figure 12: Extreme climate. Log-normal fit to Hmax by POT

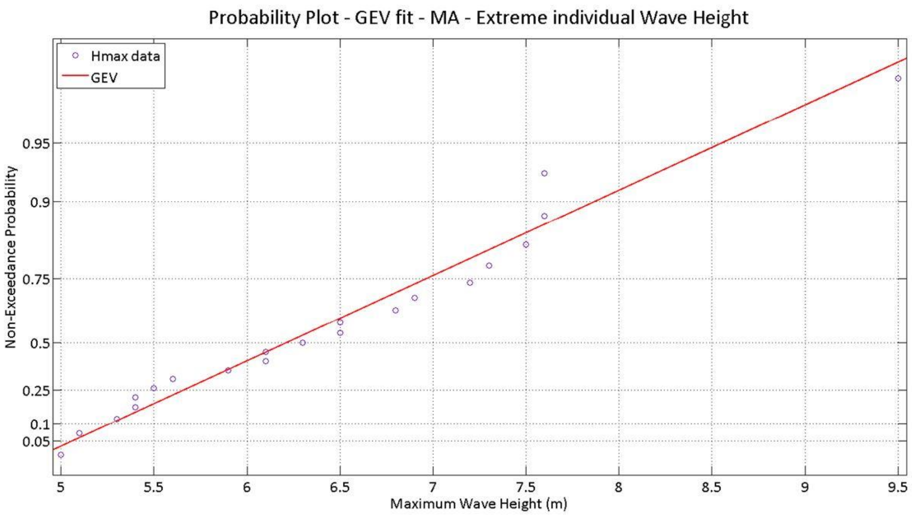


Figure 13: Extreme climate. Hmax for return periods according to MA

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

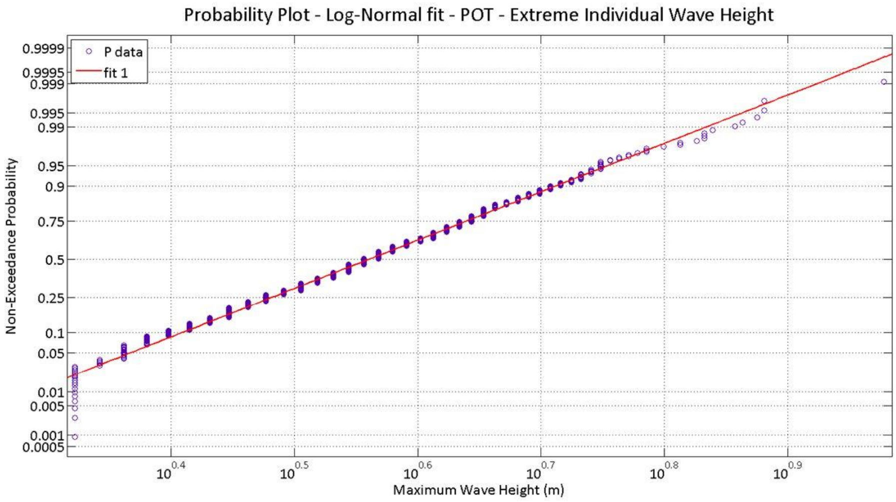


Figure 14: Extreme climate. Log normal fit to Hmax by POT

2.3 Time series

In addition, in order to run more detailed analysis and simulations for the design phase, the following time series of data have been made available to the project partners:

- Wave height, period and direction from Swan model: 29 points (1958 – 2001)
- Wave height, period and direction from interpolated points: P1 – P6 (1958 – 2001)
- Wave height, period and direction from wave buoy *Las Palmas Este* (1992 – 2015)

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

3 WIND

Wind data shown in this chapter is chosen at a height of 10m and at a standard hub height, set at 100m in this case. The 10m wind data comes from the CFSR (Climate Forecast System Reanalysis) global numeric modelling with low spatial resolution (1/3^{o}) [4]. The bilinear interpolation applied to extract sets for specific points, especially among points between land and sea, could add significant errors to the resulting set.

For this reason, the sets in the calculation points will be used for the wind climate analysis in this first stage, without applying interpolation, even though these are further away from the PLOCAN area of interest. It is also worth mentioning that a meteorological station will be installed at PLOCAN platform rooftop at around 25 m height, which will offer more realistic data of what the hub of the part-scale will see at around 31.5m

The hub-height wind data comes from global numeric modelling by the ERA-Interim at a spatial resolution of 3/4^{o} [5] . As with the CFSR, given the low resolution of the data, interpolation could add significant errors. In this case, the model grid points are a long way from the area of interest and cannot be considered representative of this project.

Below is an analysis of the mean climate and the extreme climate for the wind at a height of 10m. Then a wind shear model is estimated for the available data at hub height to transfer the data calculated at 10m to the desired height.

3.1 Mean climate

Table 1 shows the annual average and maximum wind speed profile and mean wind direction profile. In the course of an average year, the mean monthly wind speed is around 7m/s, reaching maximum mean values between June and August. The mean monthly wind direction has a markedly annual pattern: during the winter, the wind comes from around 45 degrees from N and in summer, it comes from around 10 degrees from north. The monthly maximum wind on the other hand, was greater in winter than in summer. The direction regime varies between NE for winter and NNE for summer. Figure 17 shows the wind rose, where N, NNE and NE stand out against the rest. Furthermore, an inter-annual mean annual speed profile has been drawn up (not shown in the report) that shows no major trend over the last 30 years. Despite the fact that no trend was found in the annual means, there is a well-known inter-annual trend approximately every 6 years in line with the NAO index (North Atlantic Oscillation) with alternate periods of greater or lesser wind intensity from the North.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

Table 1: Mean monthly wind profile

	Mean speed (m/s)	Maximum speed (m/s)	Mean direction (°)
Average	*6.6*	*16.1*	*23*
January	6.8	18.4	46
February	6.6	16.6	33
March	6.7	17.7	19
April	6.9	16.8	13
May	6.6	13.6	12
June	6.9	14.3	13
July	7.9	14.4	14
August	7.2	13.8	15
September	5.9	12.7	17
October	5.6	16.2	21
November	6.1	18.9	32
December	6.5	20.4	46

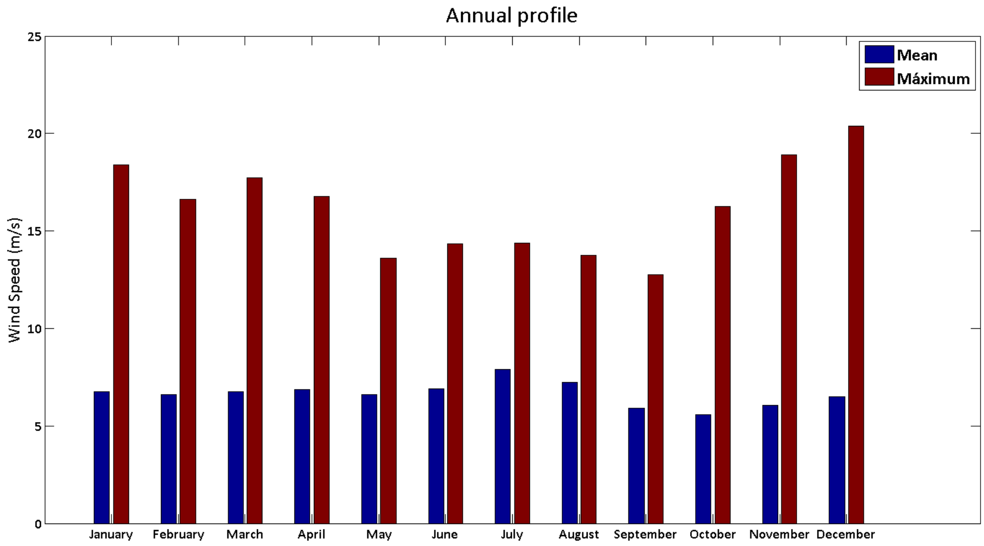


Figure 15: Wind speed annual profile

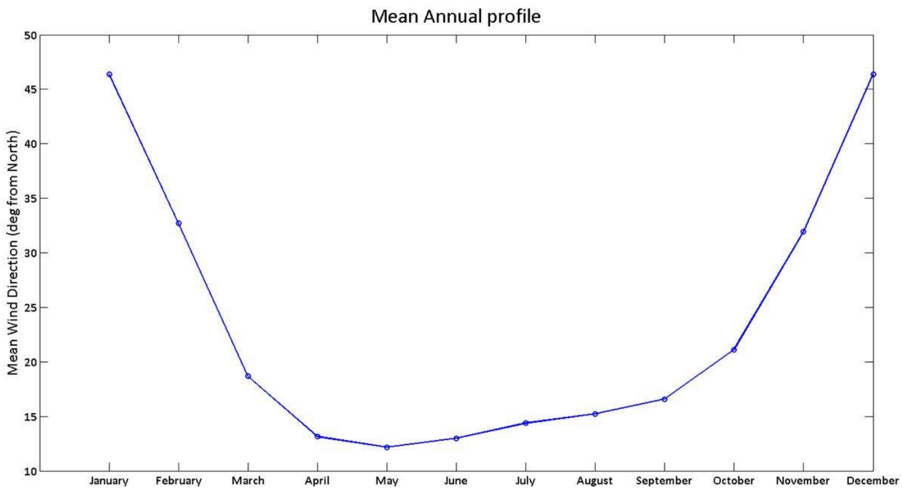


Figure 16: Mean climate. Annual mean monthly wind speed profile

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

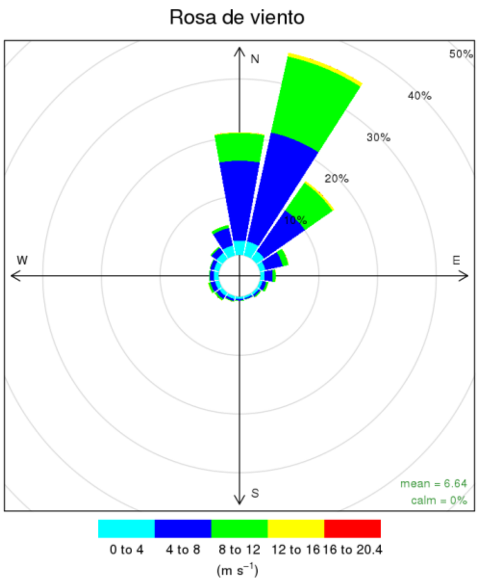


Figure 17: Mean climate wind rose

3.2 Extreme climate

An EVA analysis (Extreme Value Analysis) was conducted to assess the extreme wind climate. A GEV (Generalised) distribution function will be fitted combining the Gumbel, Frechet and Weibull family, also known as extreme value distributions I, II and III. These are defined according to the following expression [2]:

$$F(x;\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

where μ is the position parameter, σ the scale coefficient and ξ the shape coefficient.

The extreme values of the available data set must be selected for the adjustment. Two methodologies have been followed for this :

- MA (Annual Maxima): Selection of the annual maximum extreme.
- POT (Peak Over Threshold): Selection of the independent maximum values over the previously set threshold. The threshold is the position parameter of the GEV distribution function, in this case, called the Generalised Pareto Distribution (GPD).

As there are no data on the maximum gust of wind, the adjustment described with the wind speed modelled has been made. Wind speed usually correlates well with values measured every 10 minutes.

The GEV distribution function adjusted for MA and POT is shown in Figure 18 and Figure 19 respectively.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

As in the previous chapter, k is the shape parameter, μ the position parameter and σ the scale parameter, estimated with a GEV (Generalised Extreme Value) function using the Maximum Likelihood Method

Distribution: GEV
Log likelihood: -618633
K: -0.0699964
σ: 1.3182
μ: 15.4546

Values for 10, 20 and 50-year return periods:
P_{10} = 18.19 m/s
P_{20} = 18.99 m/s
P_{50} = 19.95 m/s

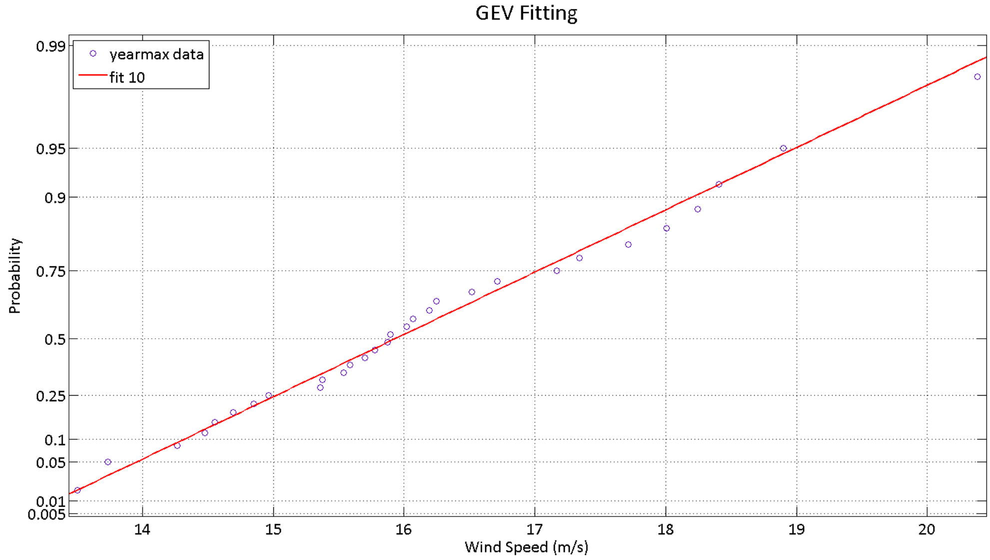


Figure 18: Extreme climate. GEV adjustment according to MA

Distribution: GPD
Log likelihood: -425.041
K (shape): -0.0493162
σ (scale): 1.45873
μ (threshold): 12

Values from 10, 20 and 50-year return periods:
P10 = 18.08 m/s
P20 = 18.87 m/s
P50 = 19.88 m/s

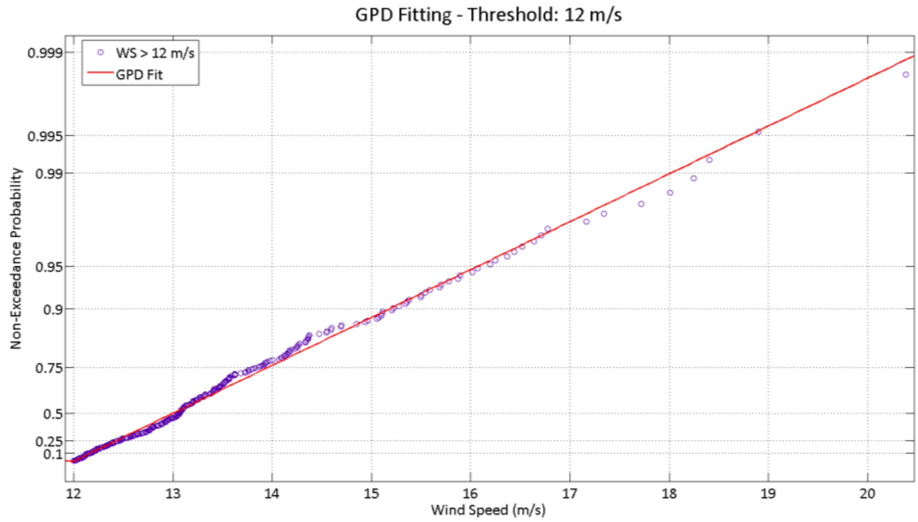


Figure 19: Extreme climate. GDP adjustment according to POT

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

3.3 Wind shear model

The vertical wind profile is adjusted normally to a potential-type curve with the following expression:

$$\left(\frac{V_{h_1}}{V_{h_2}}\right) = \left(\frac{h_1}{h_2}\right)^{\alpha}$$

Where V_{h1} is the wind speed at height h_i and α is the *wind shear.*

Table 2 shows the mean annual speed for the PLOCAN platform location points according to the Institute for the Energy Diversification and Energy wind map (*Instituto para la Diversificación y Ahorro de la Energía* - IDAE) developed by AWST. *Wind shear* (α) is the result of adjusting the potential function using minimum squares.

Table 2 shows the mean annual speed for the PLOCAN platform location points according to the Institute for the Energy Diversification and Energy wind map (Instituto para la Diversificación y Ahorro de la Energía - IDAE) developed by AWS TruePower [6]. Wind shear (α) is the result of adjusting the potential function using minimum squares.

Table 2: Wind Shear and mean annual wind speeds for the location points of the platform and different hub heights

	30 m	60 m	80 m	100 m	α
P1	5.79	6.04	6.15	6.21	0.0591
P2	6.14	6.35	6.44	6.5	0.0477
P3	6.07	6.34	6.46	6.53	0.0615
P4	6.32	6.53	6.62	6.68	0.0464
P5	6.52	6.79	6.9	6.97	0.0561
P6	6.53	6.77	6.88	6.95	0.0522

3.4 Time series

In addition, in order to run more detailed analysis and simulations for the design phase, the following time series of data have been made available to the project partners:

- Time series from model ERA Interim at 7 locations (P1 – P7)
Period: 1979 - 2013
Vertical interpolation: bilinear at 100m
Parameters: wind speed, wind direction, temperature, pressure, density

- Time series from model CFSR model at 7 locations (P1 – P7)
Period: 1980 - 2010
Interpolation: bilinear at 10m
Parameters: wind speed, wind direction

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

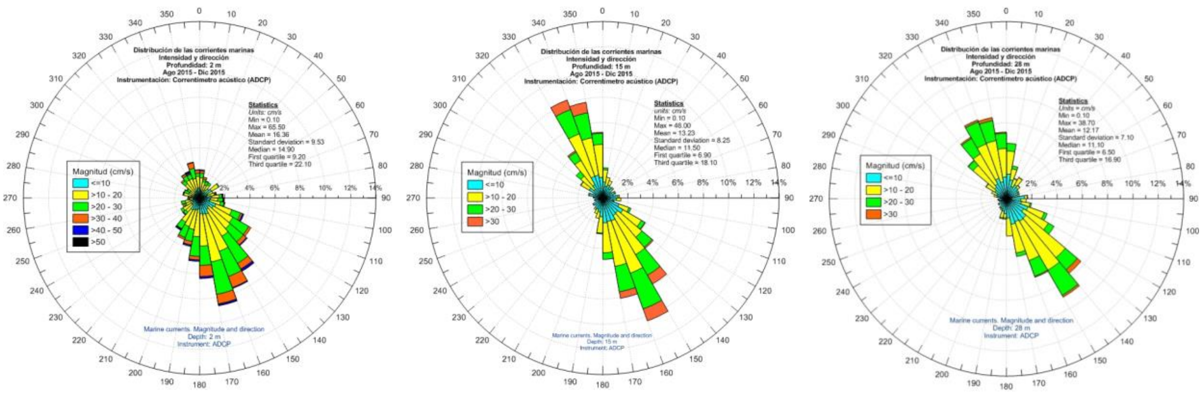
4 CURRENTS

4.1 Mean climate

Canary Islands archipelago is under influence of the Canary Current as part of the Subtropical Gyre and a semi-diurnal tide. Marine currents and associated water transport are mainly generated by these two factors, being in surface also significantly influenced by trade-winds effect.

Continuous monitoring in the test site area is conducted with an upward-looking Acoustic Doppler Current Profiler, installed at different locations inside the area of interest.

Typical measured values of currents vary between 0 and 0.5 m/s, with maximums reaching 1 m/s at the surface. Direction is usually aligned with the NW-SE axis, as can be seen in the sample current roses that are shown below (Figure 20). A rough correlation between direction and magnitude is: highest marine currents values are Southward direction, what is in line with the main ocean dynamics in the area motivated as previously mentioned by the influence of the Canary Current as part of the Subtropical Gyre. “Channel effect” between islands is also an issue to consider concerning marine currents magnitude. The semidiurnal tide behavior is also usually clearly seen on the plots.



2 m depth | 15 m depth | 28 m depth

Figure 20: Current rose at different depths (Ago-Dec 2015)

As a sample, in Figure 20, Figure 21 and Figure 22 some magnitude and direction values are shown from a deployment which took place at the central western area of the test site (X: 462730, Y: 3100638).

This project has received funding from the European Union’s Horizon H2020 research and innovation programme under grant agreement No 815159

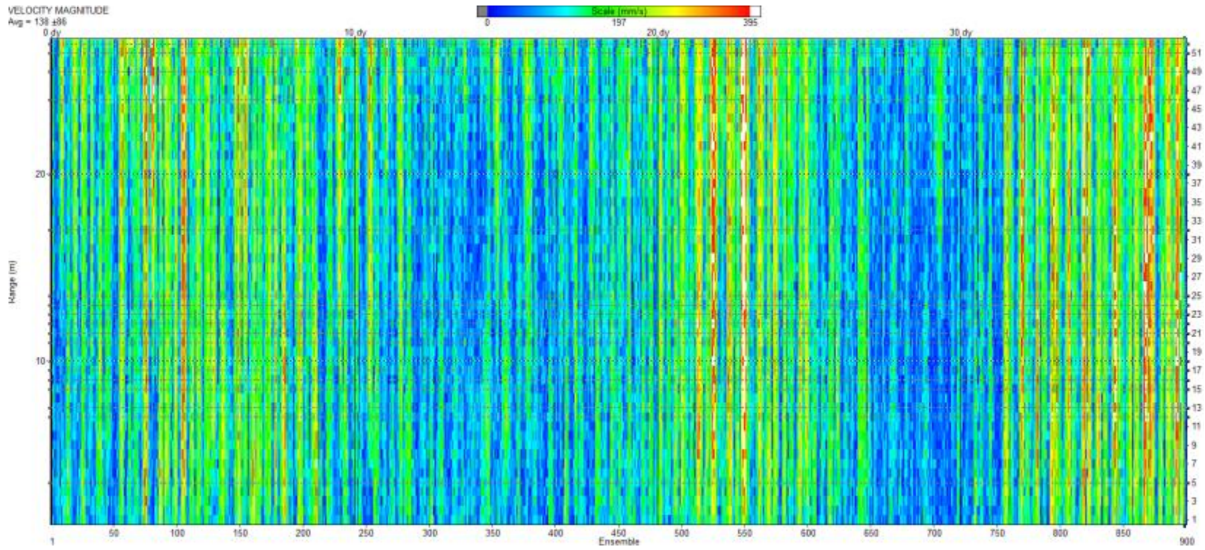


Figure 21: Current velocity magnitude (Ago-Dec 2015)

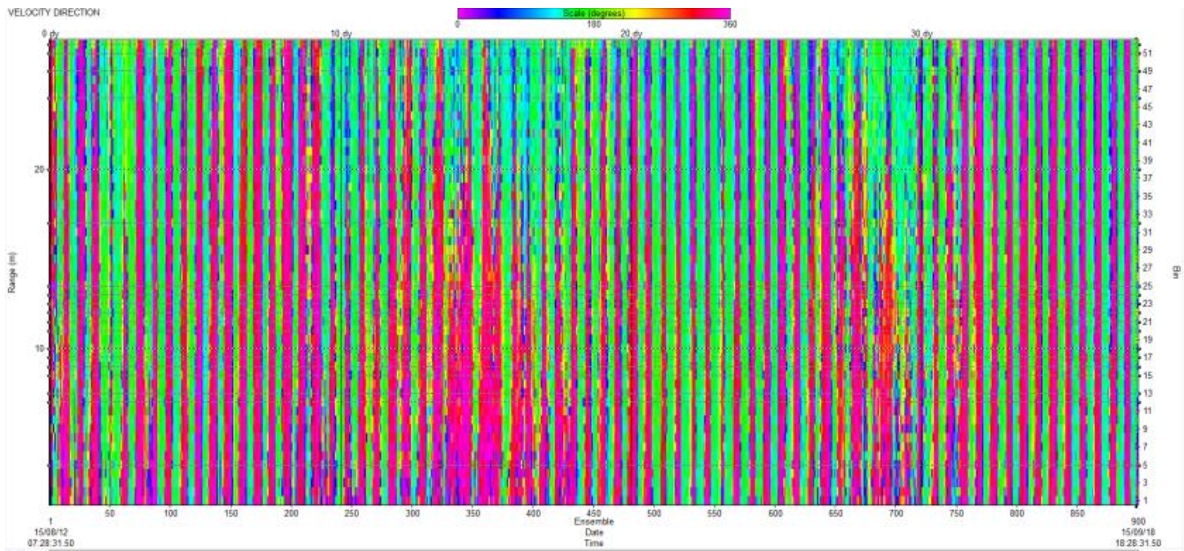


Figure 22: Current velocity direction (Ago-Dec 2015)

4.2 Time series

In addition, in order to run more detailed analysis and simulations for the design phase, the following time series of data have been made available to the project partners:

- Several vertical profiles of marine currents from ADCP measurements
Parameters: speed and direction
Period: several months between 2012 – 2015

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

5 SEA LEVEL

Sea level values, obtained from Puertos del Estado, are summarized on the following charts. Data comes from the Redmar network [7], which has a measuring station at Las Palmas harbor, around 6 nautical miles from PLOCAN test site. This information is relevant for the TLP design.

Table 3: Sea level (cm) from Redmar network

	Sea Level (cm)				Astronomical tide (cm)			
Mean: 158 cm	Max	Min	Average	Std. dev	Max	Min	Average	Std. dev
High tide	319	169	239	27	311	173	238	26
Low tide	146	0	77	26	141	13	78	25
Spring high tide	319	244	278	16	311	246	276	15
Spring low tide	112	0	43	17	73	13	45	14
Neap high tide	258	169	199	12	223	173	198	11
Neap low tide	146	82	116	12	141	95	116	10

Table 4: Sea level extreme values with Weibull distribution

Sea Level (cm). Extreme values. Weibull distribution				
	Return period (years)			
	20	**50**	**100**	**300**
Sea level (cm)	332	336	338	341
Sea level upper bound (90%)	338	342	345	350

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

6 BATHYMETRY

Several bathymetry surveys of the test site are made available for the consortium, in order to characterize properly de desired deployment area. The depths vary greatly, from the coast to a maximum depth of 600 meters on the NE corner of the test site.

As a first approach, depths of around 50 meters are being targeted, since simulations have shown that the X30 platform system dynamics improve when depths is equal or more than 50m [8]. As the prototype would be as close as possible to the platform to minimize the connection cable length, the NW sector of the test site seems to be the ideal choice.

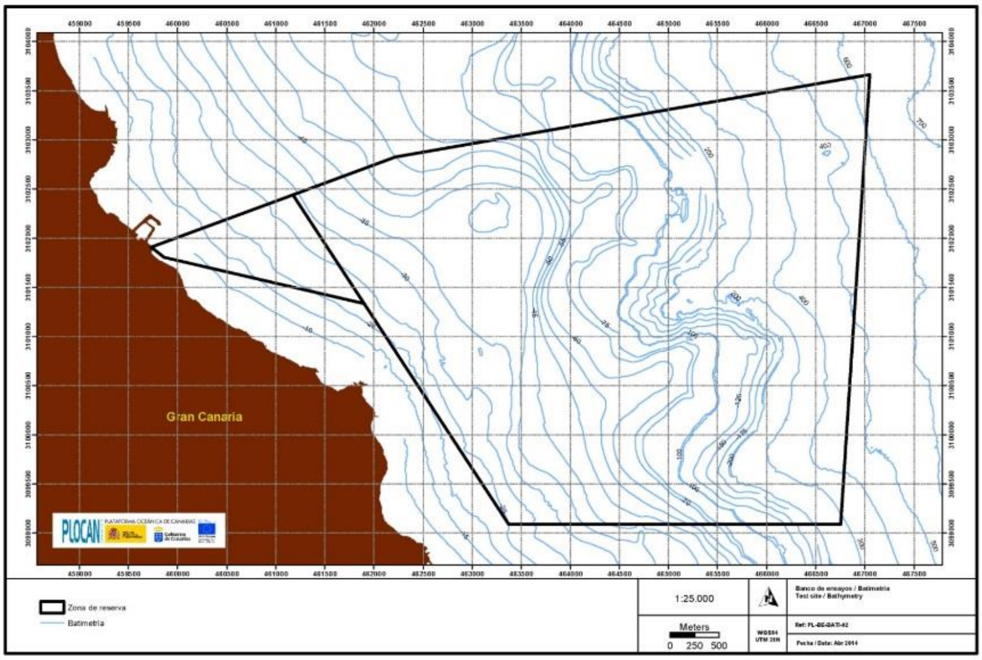


Figure 23: Test site bathymetry

The slopes present at the seafloor vary between 0º and 15º (0 - 27%), being more intense on the Eastern side of the test site. This is another parameter which needs to be considered carefully, as gravity-based anchors need as flat as possible areas to work properly. In the selected area for deployment, the slope would be between 0º and 5º.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

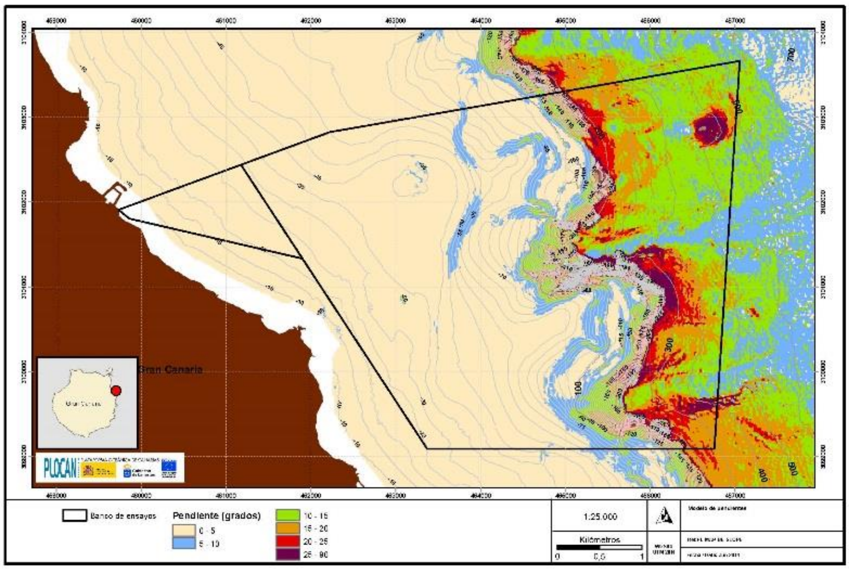


Figure 24: Seafloor slope

On Figure 25, a visual representation of the bathymetry can be found, which clearly presents the differences in depths and slope between the NE and the SW sectors of the test site.

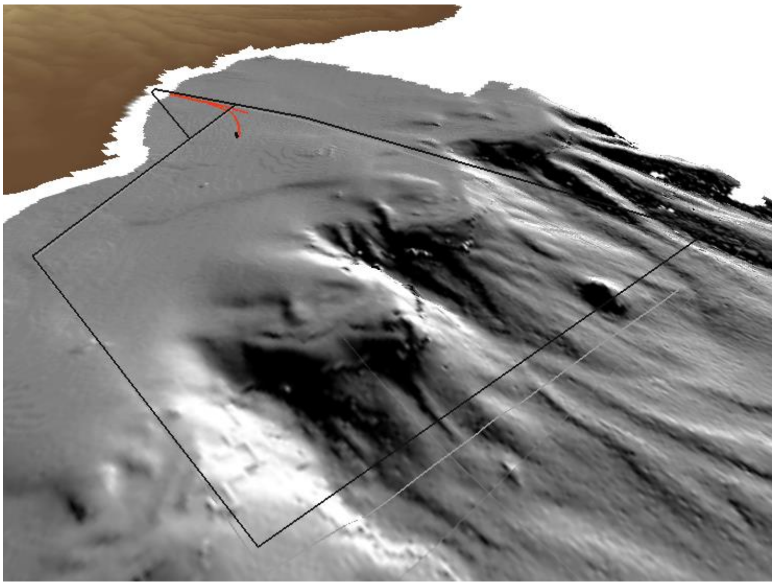


Figure 25: Bathymetry visual representation

The oceanic and volcanic nature of the Canary Islands has shaped the underwater topography of the area, resulting in a very narrow island (a.k.a. continental) platform and very pronounced slope. This particular configuration of the subsea relief of the Canary Islands makes access to deep-waters possible at a relatively short distance from shore, further reducing the cost of operations and installations. One of the key features of the location of PLOCAN test site facility is that it is placed in the edge of the slope that leads to the deep ocean, as can be seen in the figures above. This way, PLOCAN, by means of the test site, provides the possibility of accessing the deep ocean effectively, realistically and operatively either permanently, in the environment of the platform, or sporadically, using the set of underwater vehicles and machines available.

7 SEABED CONDITIONS

The sea bottom of the test site has a diverse geology that has been widely studied by PLOCAN in order to locate the platform and additional equipment on the most convenient area. The geology information has been taken from grab samples and video survey coming from different missions using different types of underwater vehicles. The parameters available for the test site area comprises: size, plasticity, humidity, density, porosity and organic matter. As can be seen in Figure 26, the sea bottom of the test site is composed mainly by different types of sand and some scattered rocky sectors.

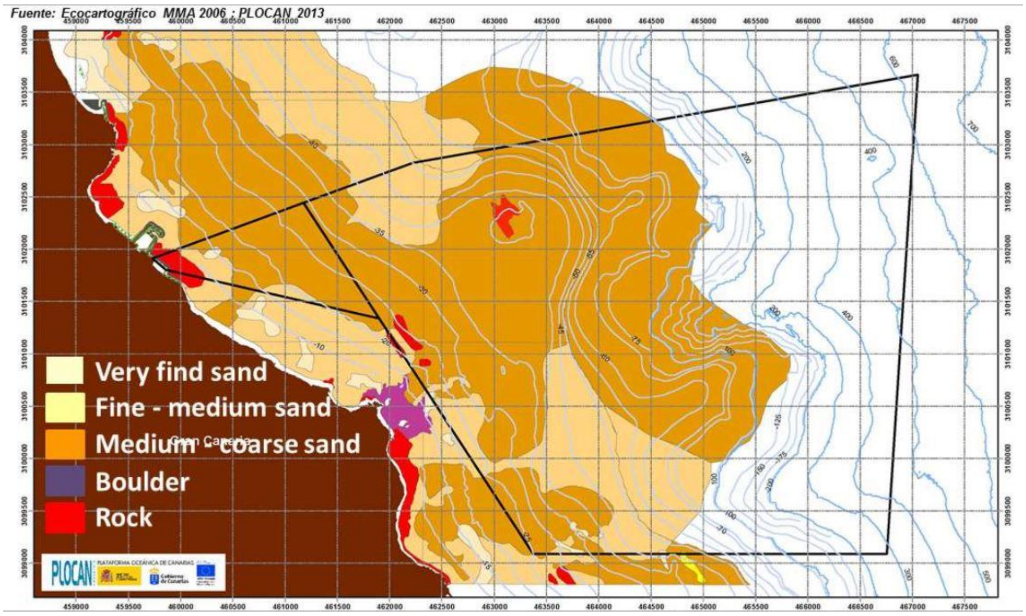


Figure 26: Geology of the Test site

The NW sector of the Test site, preselected for the installation of the prototype, presents fine to medium coarse sand conditions.

8 OTHER RELEVANT DATA

8.1 Water quality

Despite Canary Islands archipelago is clearly located in an open-ocean region (closest point to Africa is at 100 kilometers distance), PLOCAN test site waters have to be considered coastal waters in general terms due to the closeness to shore. However, its volcanic nature provides deep waters very few miles from shore. This particular geomorphology entails having specific oceanographic conditions regarding the physical and biochemical seawater parameters, with oligotrophic waters.

The PLOCAN test site area has continuous monitoring of seawater-parameters through fix and mobile autonomous platforms (buoys, moorings, gliders, etc.) and ship-based technologies (CTD-Rosette, XBT, etc.) in selected reference-stations. The temperature in surface ranges along the year mean values between 18ºC and 24ºC, being the salinity range between 36.60 and 36.95 PSU.

Figure 27 shows seawater-column temperature distribution in several stations where continuous monitoring is performed. Stratification (seasonal thermocline) ranges from less than 20 m in summer and more that 150 m in winter season. Similar conditions are shown in Figure 28 for the seawater salinity in the control stations along the test-site area.

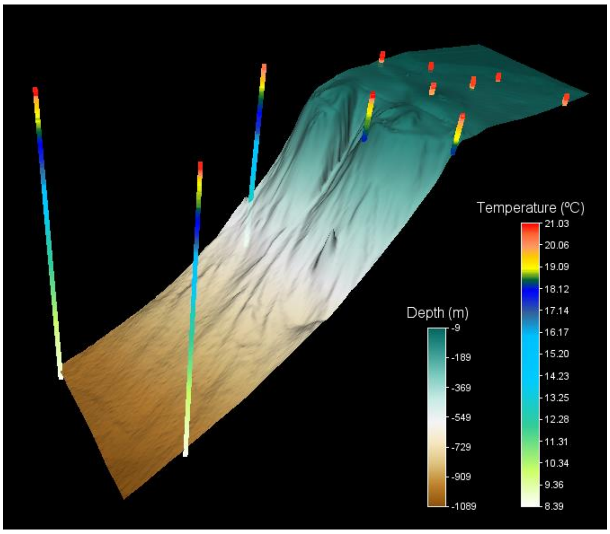


Figure 27: Sea water temperature profile at certain points of the Test site

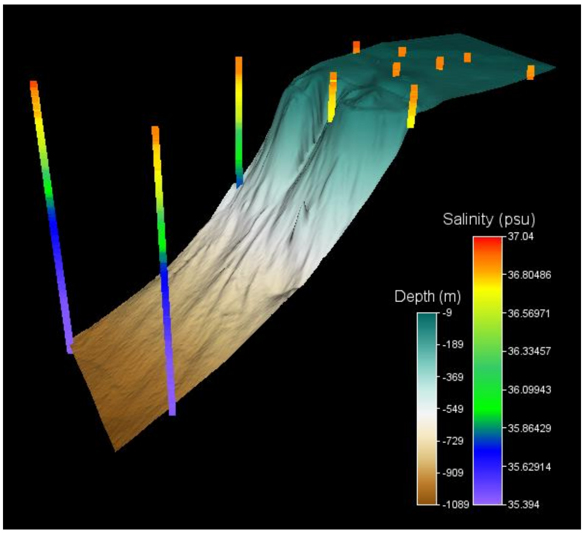


Figure 28: Sea water salinity profile at certain points of the Test site

In general terms, coastal waters in Canary Islands are oversaturated with oxygen due to Canary Current temperature and salinity values. Since they are oligotrophic waters, no large concentrations of nutrients are present. Turbidity has also low values. However, in some coastal areas, turbidity increases when significant rainy events arise.

Despite the closeness to Las Palmas harbor with its high ship-traffic density and associated activity, water quality of the PLOCAN test site area in terms of pollutants (PAHs) is considered appropriate according to experimental values, gathered by water sampling techniques as part of the continuous monitoring of the test site and analyzed in lab through reference international methodologies and based on EU-rules and standards.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

8.2 Submarine noise

As part of the environmental monitoring program carried out at PLOCAN, several noise measurements have been made along the test site. These records of underwater noise show some alterations in different noise bands, mainly associated with vessel movements through the area.

They can be considered as reference measurements for future acoustic data to be gathered once the PivotBuoy prototype is deployed.

As a sample, a heat map representation of sound pressure level (SPL) at 125Hz for several days is shown on Figure 29.

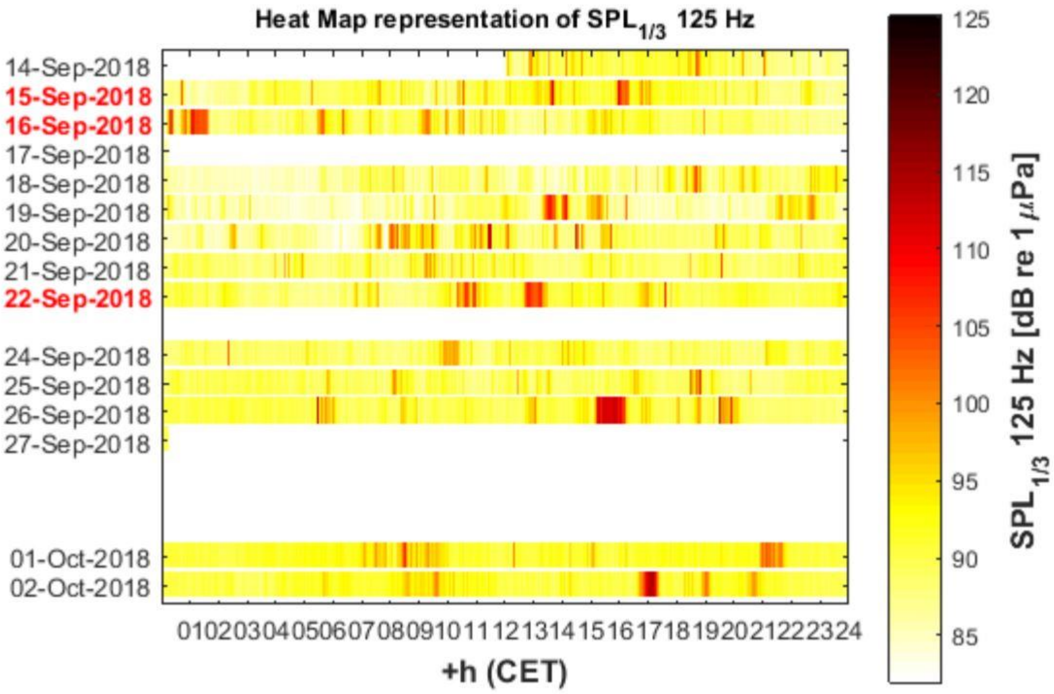


Figure 29: Heat map representation of $SPL_{1/3}$ 125 Hz

8.3 Environmental assessment

The scope of this initial deliverable is to characterize the test site environmental conditions including metocean data (wave, wind and currents) as well as bathymetry, seabed conditions and other relevant information for the preliminary design phase.

A separate task (task 6.3 Environmental assessment) will ensure environmental considerations are followed throughout the design and execution phases. The work will assess the environmental risks and mitigation plans in the design phase, which will give input to the planning of the testing phase.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

Prior to the deployment of the system, PLOCAN will characterize the baseline environmental conditions, for comparison with the data gathered in task 4.5 during the testing phase and after the testing. The experience and environmental data gathered will be analysed and compared to the baseline environmental conditions. A final report will include an assessment on the impact on:

- Environmental data: baseline information for the environmental monitoring
- Passive acoustics, obtained before, during and after the project including acoustic monitoring
- Footprint and Visual inspection for seabed monitoring with ROV

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

9 SELECTED SITE OF DEPLOYMENT

As a first proposal, and taking into account the prototype requirements (around 50 meter depth, as flat as possible sea bed, minimum distance to the platform), the location of the selected deployment area is shown in Figure 30, and some of its specifications have been detailed in Table 5.

Table 5: Selected site specification details

	Selected site specifications
Coordinates	*UTM X:462461 / Y:3102619*
Depth	≈ 50 m
Slope	0 to 4º
Type of seabed / sediments	Fine sand
Distance to platform	≈ 900 m

The selected site is at around 50m water depth, which is a depth providing an adequate behavior for the TLP mooring system [8], with a mild slope of 0 to 4º and fine sand which is adequate for a gravity base anchor. The distance to the PLOCAN platform, where the electric cable will be connected, is around 900m.

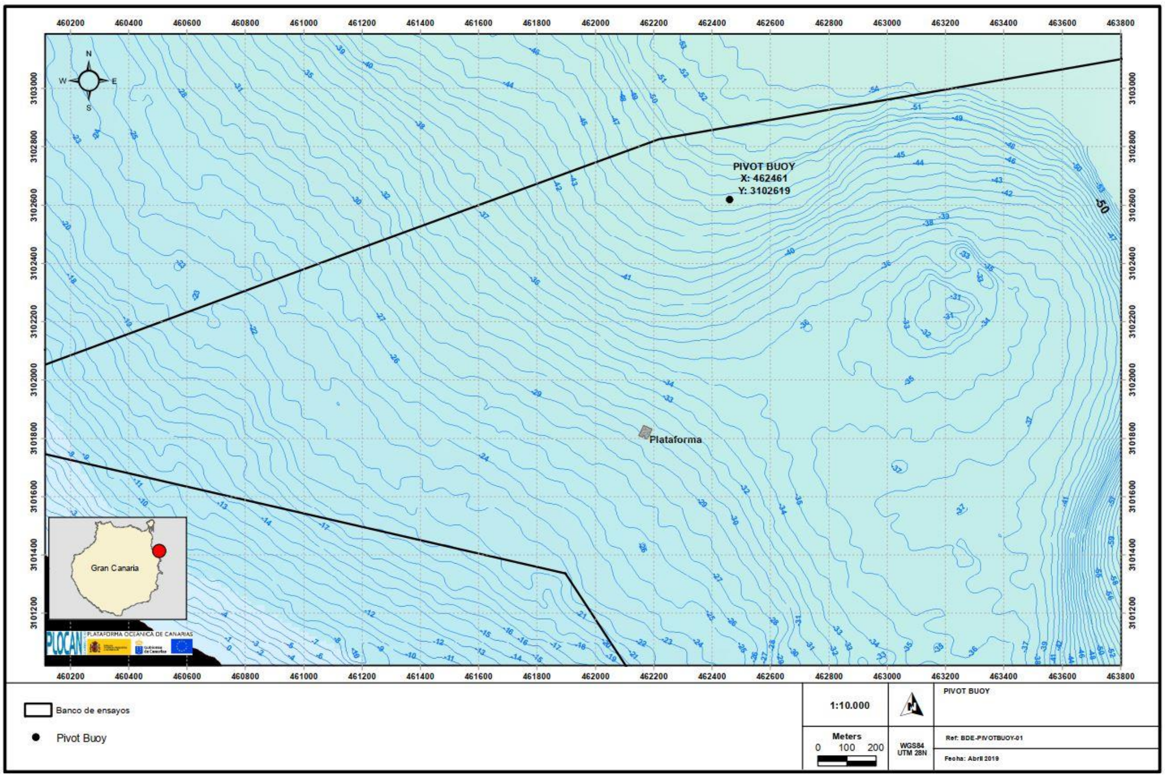


Figure 30: Selected site map, showing also bathymetry and platform location

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

10 CONCLUSIONS

Several environmental base line studies are being conducted aiming to characterize PLOCAN test site and are being used to set a permanent environmental monitoring programme.

This document summarizes, based on those studies, the environmental conditions of PLOCAN test site, as expected for Task 4.1. This task ensures that those conditions of the location where the system will be deployed and tested are well fed into the design process of WP2, and thus guaranteeing that the prototype and its mooring system are properly dimensioned and arranged. Detailed data including time series of wave, wind and currents have been already fed into WP2.

After analyzing the PLOCAN test site characteristics, the NW area of the test site has been identified as an ideal location for the installation of the prototype and the following position is proposed: UTM X:462461 / Y:3102619. Depths of 50m can be found in the area, as required by the floating platform, and the seabed conditions are optimal for the anchoring system.

This project has received funding from the European Union's Horizon H2020 research and innovation programme under grant agreement No 815159

11 REFERENCES

[1] N. Booij, L. Holthuijsen and R. C. Ris, “The "SWAN" wave model for swallow water,” *Coastal Engineering,* vol. 1, 1996.

[2] J. P. Palutikof, B. B. Brabson, D. H. Lister y S. T. Adcock, «A review of methods to calculate extreme wind speeds,» *Meteorol. Appl.,* vol. 6, pp. 119-132, 1999.

[3] Puertos del Estado, «Extremos máximos de oleaje. Boyas Las Palmas Este.,» 2017. [En línea]. Available: https://bancodatos.puertos.es/BD/informes/extremales/EXT_1_1_1414.pdf.

[4] S. Saha et al., «The NCEP Climate Forecast System Reanalysis,» *BAMS, American Meteorological Society,* vol. 91, nº 8, pp. 1015 - 1057, 2010.

[5] ECMWF, «ERA-Interim,» [En línea]. Available: https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era-interim.

[6] Instituto para la Diversificación y Ahorro de la Energía, «Análisis del recurso. Atlas eólico de España,» IDAE, 2011.

[7] Puertos del Estado, «portus.puertos.es,» 2015. [En línea]. Available: https://bancodatos.puertos.es//BD/informes/INT_3.pdf. [Último acceso: 26 04 2019].

[8] C. Casanovas, «X30 225 kW Concept Design Report,» X1 Wind, Barcelona, 2018.

This project has received funding from the European Union’s Horizon H2020 research and innovation programme under grant agreement No 815159