LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

UBEST FIELD CAMPAIGNS

6th Campaign: Tagus Estuary, November 6, 2018

UBEST – Understanding the biogeochemical buffering capacity of estuaries relative to climate change and anthropogenic inputs

FCT – Fundação para a Ciência e a Tecnologia

Lisbon ● January 2019

R & D HYDRAULICS AND ENVIRONMENT

REPORT 000/**2018 – DHA/NEC**

The UBEST project (PTDC/AAG-MAA/6899/2014) has received funding from the Fundação para a Ciência e a Tecnologia.

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Title

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Relatório xxx/2018

Proc. 0604/111/19764

UBEST FIELD CAMPAIGNS

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Abstract

The present report summarizes the 6th field campaign of the project UBEST, performed in the Tagus estuary on November 6, 2018. This campaign was the third in the Tagus estuary and was representative of autumn conditions. Seven stations were chosen along the estuary. *In situ* measurements of temperature, salinity, pH and dissolved oxygen were carried out and water samples were collected to determine in laboratory the concentration of nutrients, chlorophyll *a*, total suspended solids, and confirm dissolved oxygen and pH on samples where pH sensors were not available.

The data acquired will contribute to a better understanding of the biogeochemical functioning of the Tagus estuary and to calibrate and validate numerical models (hydrodynamic and biogeochemical), that will attempt to predict the response of the estuary to future scenarios of climate change and anthropogenic inputs.

Keywords: Tagus estuary / Field campaign / Water samples / Physico-chemical parameters

CAMPANHAS UBEST

6ª Campanha: Estuário do Tejo, 6 de novembro de 2018

Resumo

O presente relatório sumariza a sexta campanha do projeto UBEST, realizada a 6 de novembro de 2018 no estuário do Tejo. Esta campanha foi a terceira a ser realizada neste estuário e é representativa das condições de outono. Foram selecionadas sete estações ao longo do estuário, onde se realizaram medições *in situ* de temperatura, salinidade, pH e oxigénio dissolvido, e se recolheram amostras de água, que foram posteriormente tratadas em laboratório para determinar a concentração de nutrientes, clorofila *a*, e sólidos suspensos totais, o pH em amostras de estações onde os sensores de pH não se encontravam funcionais e para confirmar os valores de oxigénio dissolvido.

Os resultados obtidos irão contribuir para a melhor compreensão do funcionamento biogeoquímico do estuário do Tejo e para calibrar e validar modelos numéricos (hidrodinâmico e biogeoquímico), que tentarão prever a resposta do estuário a futuros cenários relacionados com as alterações climáticas e pressões antropogénicas.

Palavras-chave: Estuário do Tejo / Campanha / Amostras de água / Parâmetros físico-químicos

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List of Acronyms

APA – Agência Portuguesa do Ambiente

CWB – Coastal Water Body

DO – Dissolved Oxygen

FCT – Fundação para a Ciência e a Tecnologia

HMWB – Heavily Modified Water Bodies

LNEC – Laboratório Nacional de Engenharia Civil

MARE – Marine and Environmental Sciences Centre

UAlg – University of Algarve

UBEST – Understanding the biogeochemical buffering capacity of estuaries relative to climate change and anthropogenic inputs

WB – Water Body

1 | Introduction

This report describes the 6th field campaign of the project UBEST- Understanding the biogeochemical buffering capacity of estuaries relative to climate change and anthropogenic inputs (PTDC/AAG-MAA/6899/2014), performed in the Tagus estuary. The project UBEST is funded by the *Fundação para a Ciência e a Tecnologia (FCT)* and aims at improving the understanding of the biogeochemical buffering capacity of the estuaries and their susceptibility to future scenarios of anthropogenic inputs and climate change, that will support the short and long term management of these systems. This goal will be achieved by the deploying of «observatories» in two Portuguese coastal systems, the Ria Formosa lagoon and the Tagus estuary. These two systems were chosen due to their distinct characteristics, allowing a generalization of the project conclusions.

This campaign was the third campaign in the Tagus estuary, UBEST 6, and was performed on November 6, 2018, aiming to be representative of autumn conditions. To assure the coverage of the entire estuary, seven stations throughout the system were chosen. In each station, physical, chemical and biological data were collected during almost one semidiurnal tidal cycle (~12 hours).

This report is divided into two sections, besides the introduction. Chapter 2 presents the location of the sampling stations and the weather conditions, and describes the field and laboratorial work. Chapter 3 presents a brief evaluation of this campaign and of the previous ones.

2 | Description of the field campaign

2.1 Objective of the field campaign

This campaign aimed to characterise the autumn biogeochemical conditions of the Tagus estuary, through the collection of water samples and *in situ* measurements of physical and chemical parameters. This data will also support the modelling of the estuary, through hydrodynamic and biogeochemical models.

2.2 Sampling stations

The seven sampling stations were chosen to allow the best coverage of the entire estuary, including the different water bodies (WB) described by *APA (Agência Portuguesa do Ambiente)* (Figure 2.1). Table 2.1 presents the coordinates of each station and Figure 2.2 presents the satellite image of each station, referring the water body where each station is situated. P1 is situated in the water body Tagus river (HMWB – *Jusante Bs. Castelo do Bode e Belver*).

The sampling stations P1 (*Muge/Valada*) and P7 (*Cascais*) are representative of the river and oceanic boundary conditions, respectively. The other five stations are distributed longitudinally through the estuary. P2 is situated in *Vila Franca de Xira*, in the south margin of the estuary, and the water samples were collected from a floating platform. P3 is located in *Santa Iria* at a fixed platform of the VALORSUL facilities, situated on the north margin. The two next stations (P4 and P5) are located in channels of the estuary, near the *Vasco da Gama* Bridge and *Barreiro*, respectively. The sampling at these two stations was performed by boat, supported by Azimuth Globe. P6 is located near the mouth of the estuary, in *Algés*.

Figure 2.1 – Location of the sampling stations (source: ArcMap). Legend: Green – Tagus water bodies (WB); Light Blue – Coastal water bodies (CWB); Dark Blue – Heavily modified water bodies (HMWB)

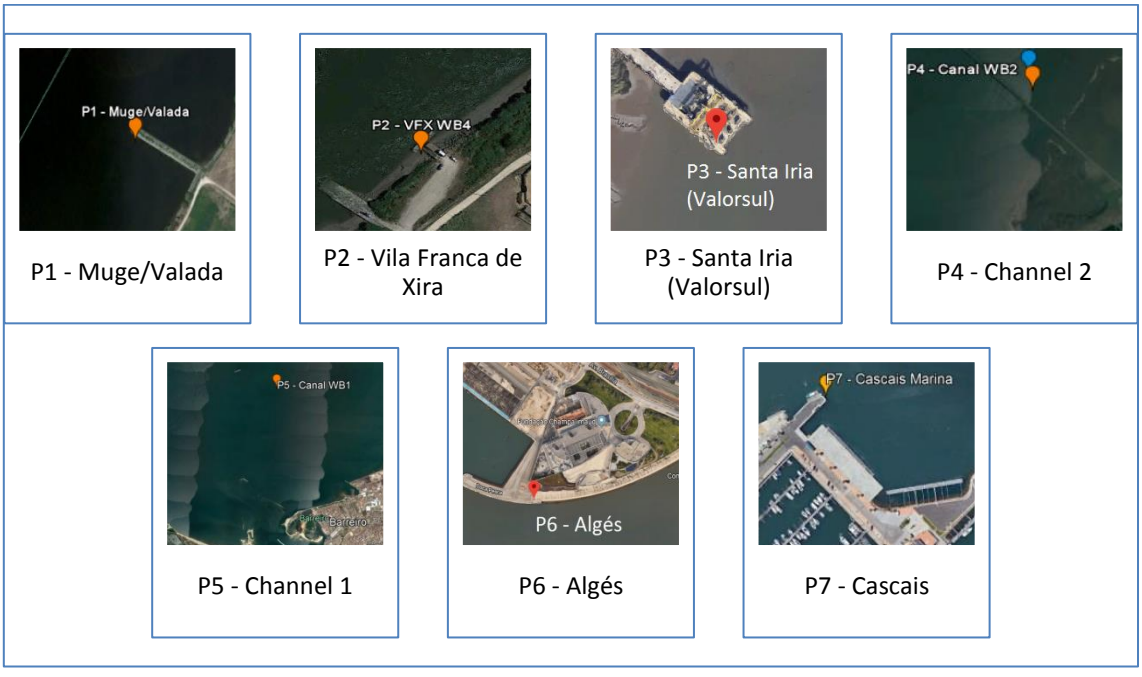

Figure 2.2 – Satellite image of each station (source: Google Earth)

Table 2-1 – Coordinates of the sampling stations

Station	Location	Latitude	Longitude
P1	Muge/Valada	39°5'27.66" N	8°44'46.17" W
P2	Vila Franca de Xira	38°57'13.97" N	8°58'41.55" W
P3	Santa Iria	38°49'40.00" N	9°4'45.64" W
P4	Channel WB2	38°45'19.52" N *	9°1'42.09" W *
P5	Channel WB1	38°41'39.43" N *	9°6'0.10" W *
P6	Algés	38°41'32.2" N	9°13'23.1" W
P7	Cascais	38°41'40.77" N	9°24'59.56" W

Obs: *Expected coordinates, real coordinates in Appendix I

2.3 Weather conditions

Table 2.2 presents mean values and range of the air temperature, humidity, pressure and wind speed, and the wind direction in locations near the sampling stations. The data were retrieved from Weather Underground (source: https://www.wunderground.com/, November 13, 2018) and were recorded in *Parede (Oeiras), Cais do Sodré (Lisboa)*, *Montijo* Air Base and *Vila Franca de Xira.*

Table 2-2 – Mean (minimum and maximum) temperature (°C), relative humidity (%), pressure (hPa), wind speed (km/h) and wind direction in *Parede*, *Cais do Sodré*, *Montijo* Air Base and *Vila Franca de Xira* on November 6, 2018 (source: Weather Underground)

Location	Temperature (°C)	Humidity (%)	Pressure (hPa)	Wind Speed (km/h)	Wind Direction
Parede	**14.2** (12.1-16.2)	**81** (73-90)	1011-1016	-	North
Cais do Sodré	**14.6** (12.3-16.9)	**83** (71-89)	1011-1016	**15** (High – 29)	SSW
Montijo	**14** (11-18)	**83** (62-99)	1011-1014	**17** (High – 36)	NNW
Vila Franca de Xira	**15.7** (10.1-21.4)	**81** (59-91)	1008-1013	-	North

In contrast to the previous campaigns, there was some rainfall during the afternoon, which made difficult the collection of the samples, especially at the stations sampled by boat. P1 was the only station where rain did not fall during the sampling, while at station P7 some rainfall occurred by the end of the second sampling hour (between 1:30 and 2:30 pm). At stations P2, P3 and P6 some weak showers occurred after 5 pm, but all the samplings were performed. The daily variability of the air temperature, relative humidity, sea level pressure and wind velocity recorded in the Lisbon airport during the day of the campaign is presented in Appendix II. These data were obtained in *tempo.pt*

website (source: https://www.tempo.pt/lisboa.htm, November 21, 2018). Figures retrieved from Weather Underground are also presented in Appendix II.

Regarding the tide, the prediction at *Cascais* tide table for the low tide was at 7:13 am (0.7 m) and the high tide was at 1:28 pm (3.5 m) (source: http://www.hidrografico.pt/ , October 23, 2018), so the sampling hours were chosen around these hours.

2.4 Field work

The field campaign UBEST 6 took place on November 6, 2018, during approximately one semidiurnal tidal cycle (~12 hours). The sampling was supported by five vehicles: three cars from LNEC, one van with a driver from LNEC, and one car from the University of Algarve. The teams in each vehicle were responsible for the transport of the team members and all the material and equipment. During the day, the teams from P1, P7 and Paula Freire (transported by the van) were responsible for the delivery of the samples to the laboratory located in LNEC.

The *in situ* measurements of temperature, salinity, pH and dissolved oxygen (DO) (concentration in mg/L and saturation %) were performed with YSI multiparameter probes, one in each station. Their calibration was performed previously to the field survey with the adequate calibration solutions in the laboratory. The exception was the DO sensors that were calibrated before each sampling moment, in the field. The distribution of the equipment in each station is presented in Table 2.3. Each station also had a specific device to collect water samples (a Niskin bottle, a Van Dorn bottle or a sampling cup). The water samples were collected for the determination of dissolved oxygen (Winkler flasks of about 120 mL), nutrients and total suspended solids compounds (1 L), chlorophyll *a* (2 L) and to quantify photosynthetic pigments[1] (1.5 L). In the stations with the Niskin or Van Dorn bottles water was collected at two levels of the water column: surface and bottom. In order to preserve the quality of the water samples, these were preserved in thermal containers.

The sampling intervals were as follows:

- Stations P2, P3 and P6 – sampling was performed mostly with intervals of two hours;
- Stations P1 and P7 – sampling was performed during the low and high tide;
- Stations P4 and P5 – sampling was performed by boat at four moments (around the peaks of the tide – high and low water, and mid flood and mid ebb periods).

All the information related to the sampling is presented in Table 2.4. Aspects of the sampling stations are presented in Figure 2.3 to Figure 2.8. In station P2 water levels were also measured along the sampling period. The multiparameter probes used in the stations P1, P2 and P3 did not have the pH sensor working properly, so the pH measurement was performed at the laboratory.

[1] The list of the photosynthetic pigments is presented in the Appendix.

Table 2-3 – Multiparameter probes and samplers distribution

Station	Location	Multiparameter Probe	Parameters	Samplers
P1	Muge/Valada	YSI	Cond, T	Sampling Cup
P2	Vila Franca de Xira	YSI 660 XL	T, DO, Sal	Sampling Cup
P3	Santa Iria	YSI 556 MPS	T, DO, pH, Sal	Niskin Bottle
P4	Channel WB2	YSI EXO2	T, DO, pH, Sal	Niskin Bottle
P5	Channel WB1			
P6	Algés	YSI 6820	T, DO, pH, Sal	Van Dorn Bottle
P7	Cascais	YSI 556 MPS	Cond, T, DO, pH, Sal	Van Dorn Bottle

Table 2-4 – Sampling specifications (parameters, depths and hours). Legend: T – temperature; DO – dissolved oxygen; Cond – conductivity; Sal – salinity; Winkler – water collection for laboratorial confirmation of dissolved oxygen concentration acquired by the probes

Station	Intervals of Sampling	Depths	Measurements	Sampling
P1	7:30 am, 1:30 pm	Surface	T , Sal, pH, Cond, Dissolved Oxygen (DO)	Water, Winkler
P2	7:30 am, 9:30 am, 11:30 am 1:30 pm, 3:30 pm, 5:00 pm, 7:30 pm	Surface	T, Sal, pH, Dissolved Oxygen (DO)	Water, Winkler*
P3	7:30 am, 9:30 am, 11:30 am 1:30 pm, 3:30 pm, 5:00 pm, 7:30 pm	Surface and Bottom	T, Sal, pH, Dissolved Oxygen (DO)	Water, Winkler*
P4	7:30 am, 10:30 am, 1:30 pm, 5:00 pm	Surface and Bottom	T, Sal, pH, Dissolved Oxygen (DO)	Water, Winkler
P5	7:30 am, 10:30 am, 1:30 pm, 5:00 pm	Surface and Bottom	T, Sal, pH, Dissolved Oxygen (DO)	Water, Winkler
P6	7:30 am, 9:30 am, 11:30 am 1:30 pm, 3:30 pm, 5:00 pm, 7:30 pm	Surface and Bottom	T, Sal, pH, Dissolved Oxygen (DO)	Water, Winkler*
P7	7:30 am, 1:30 pm	Surface and Bottom	T, Sal, pH, Dissolved Oxygen (DO)	Water, Winkler

Obs: * 7:30am, 1:30pm, 5:00pm, 7:30 pm

Figure 2.3 – Sampling station P1: Muge/Valada

Figure 2.4 – Sampling station P2: Vila Franca de Xira

Figure 2.5 – Sampling station P3: Santa Iria

Figure 2.6 – Sampling station P4/P5: Channels

Figure 2.7 – Sampling station P6: Algés

Figure 2.8 – Sampling station P7: Cascais

2.5 Team

Table 2.5 presents the team that participated in the campaign, both in the sampling stations and in the laboratory. The team included persons from the *Laboratório Nacional de Engenharia Civil* (LNEC), the University of Algarve (UAlg) and *Faculdade de Ciências da Universidade de Lisboa* (FCUL).

Table 2-5 –Team of the field campaign UBEST 6

Station/Laboratory work/ Car	Name	Institution
Co-coordination of the campaign and delivery of samples to the laboratory (Car 3)	Paula Freire	LNEC
P1 and delivery of samples to the laboratory (Car 1)	Pedro Lopes	LNEC
	Simões Pedro	LNEC
P2 (Car 2)	André Fortunato	LNEC
	Joana Teixeira	LNEC
P3 (Car 2)	Fernando Brito	LNEC
	João Rogeiro	LNEC
	Ricardo Martins	LNEC
P4/P5 (Car 3)	Alberto Azevedo	LNEC
	Daniela Santos	LNEC
	Joana Cruz	FCUL
	Rui Cereja	FCUL
	Teresa Camelo	FCUL
P6 (Car UAlg)	Diogo Mendes	LNEC
	José Jacob	UAlg
P7 and delivery of samples to the laboratory (Car 4)	Anabela Oliveira	LNEC
	Marta Rodrigues	LNEC
Co-coordination of the campaign and laboratory work	Alexandra Cravo	UAlg
Laboratory work	Cátia Correia	UAlg
	Alexandra Rosa	UAlg

2.6 Laboratorial procedures

The processing of the water samples was performed in the laboratory of the *Estação Experimental de Sedimentos Coesivos* of LNEC by the team members of the University of Algarve. The water samples were filtered according to specific protocol and type of filters: Gellman-Pall filters of mixed esters of cellulose with 0.45 µm porosity for suspended solids, and 0.7 µm porosity Whatman GF/F filters for chlorophyll *a*.

The water samples filtered through 0.45 µm filters were used for subsequent determination of the nutrients concentration (nitrate, nitrite, ammonium, phosphate and silicate) by specific spectrophotometric methods described in Grasshoff *et al*. (1983).The 0.7 µm Whatman GF/F filters were used to determine the chlorophyll *a*, through the spectrophotometric method described by Lorenzen (1967). To determine the total suspended solids concentrations the gravimetric method described in APHA (1992) was used. The chemical analyses for the determination of the nutrients and chlorophyll *a* concentration will be performed at the University of Algarve, by the UAlg team of the UBEST project.

In order to confirm the DO concentrations measured *in situ*, the Winkler method was performed in the laboratory at LNEC. Figures 2.9 and 2.10 show some of the equipment used to process the water samples in the laboratory.

Figure 2.9 – Aspects of the laboratorial procedures: laboratorial analyses for the determination of oxygen concentration (left); filtration system used to determine the concentration of chlorophyll *a* (right)

Figure 2.10 – Aspects of laboratorial procedures: filtration system used to determine suspended solids and further nutrient concentrations

3 | Conclusions

The last campaign of the project UBEST in the Tagus estuary was mainly successful, allowing accomplishing most of the proposed objectives. Due to the weather conditions felt in the day of the campaign, especially during the afternoon, it was not possible to follow the sampling plan in the stations sampled by boat. Consequently, the last sample of station P4 was not performed.

Regardless of the difficulties, a considerable amount of physical, chemical and biological data was acquired. This will allow the characterization of the autumn conditions of the estuary, which was the main purpose of the campaign.

This campaign completes the planned field campaigns to characterize and identify the biogeochemical variations in the Tagus estuary. In general, the main objectives of these field campaigns were accomplished, and data that cover distinct environmental conditions, in particular at the seasonal level, were obtained. These data will help understanding the estuary and its response to climatic variability, climate change and anthropogenic inputs.

Acknowledgments

This work was funded by *Fundação para a Ciência e a Tecnologia* project UBEST - Understanding the biogeochemical buffering capacity of estuaries relative to climate change and anthropogenic inputs (PTDC/AAG-MAA/6899/2014). This project also funds the grants of Alexandra Rosa (UALG) and Daniela Santos (LNEC).

The authors would like to thank: the volunteers Teresa Camelo and Joana Cruz from the *Faculdade de Ciências da Universidade de Lisboa* (FCUL), Diogo Mendes[2] from LNEC/FCT, and Rui Cereja[3] from *Instituto Dom Luiz* (IDL – FCUL) and Marine and Environmental Science Centre (MARE – FCUL), for their support in the sampling, and Cátia Correia from CIMA – University of Algarve for their support in the campaign and on the laboratorial work; the Marine and Environmental Science Centre (MARE – FCUL) for the equipment availability; and *VALORSUL*, *Administração do Porto de Lisboa* and *Marina de Cascais* for the authorization to use their facilities for sampling.

[2] PhD research grant (PD/BD/114463/2016) attributed by *Fundação para a Ciência e a Tecnologia*.

[3] PhD research grant (PD/BD/135064/2017) attributed by *Fundação para a Ciência e a Tecnologia* with financing from *Programa Operacional Capital Humano* (POCH) by the Portugal2020 program.

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Lisbon, LNEC, January 2019

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Annexes

ANNEX I
Coordinates of P4 and P5

Table I.3-1 – Coordinates of P4 during the hours of the campaign

Time	Depths (m)	Latitude	Longitude
08:42	0.20	38°45'18.8''N	9°01'43.6''W
08:55	6.40	38°45'18.8''N	9°01'43.6''W
12:18	0.35	38°45'20.8''N	9°01'42.7''W
12:28	6.40	38°45'20.8''N	9°01'42.7''W
16:15	0.20	38º45’17.3”N	9º01’43.8”W
16:18	11.07	38º45’17.3N	9º01’43.8”W

Table I.3-2 – Coordinates of P5 during the hours of the campaign

Time	Depths (m)	Latitude	Longitude
07:27	0.20	38°41'31.2''N	9°06'5.8''W
07:47	8.20	38°41'31.2''N	9°06'5.8''W
10:50	0.00	38°41'32.9''N	9°05'5.2''W
11:19	8.00	38°41'32.9''N	9°05'5.2''W
15:00	0.20	38º41’31.3”N	9º05’58.1”W
15:04	10.90	38º41’31.3”N	9º05’58.1”W
18:44	0.20	38º41’32.0”N	9º07’9.8”W
18:46	7.97	38º41’32.0”N	9º07’9.8”W

ANNEX II
Weather Conditions

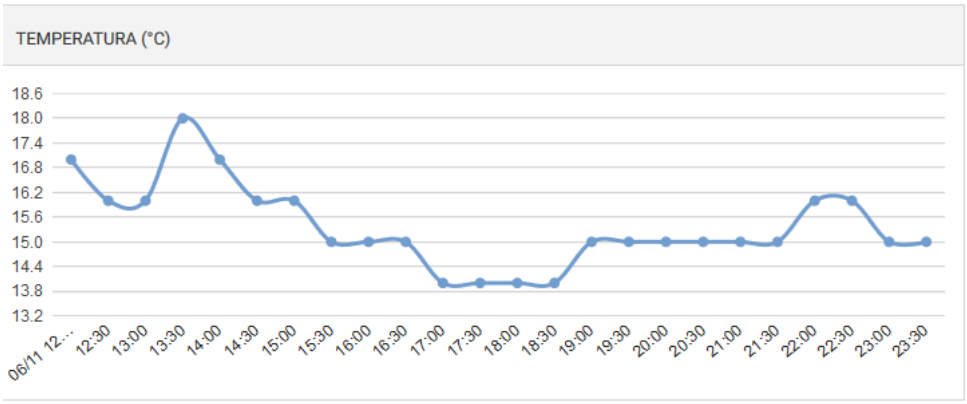

Figure II.1 – Temperature (°C) variation during November 6, 2018 (source: https://www.tempo.pt/, November 21, 2018)

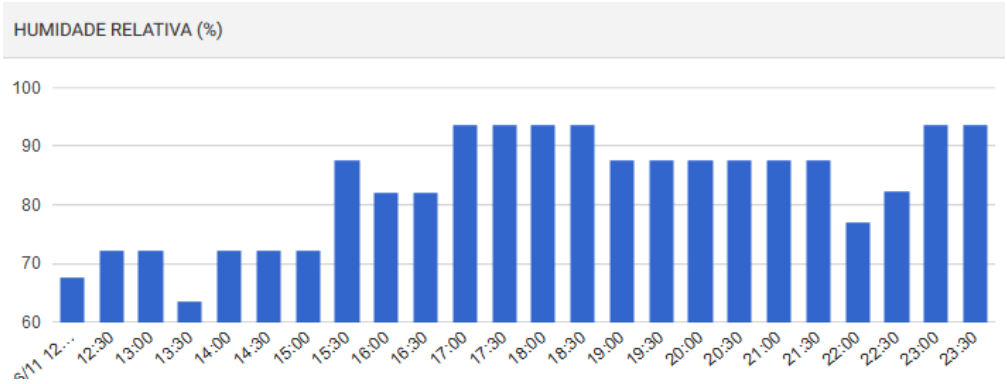

Figure II.2 – Relative humidity (%) variation during November 6, 2018 (source: https://www.tempo.pt/, November 21, 2018)

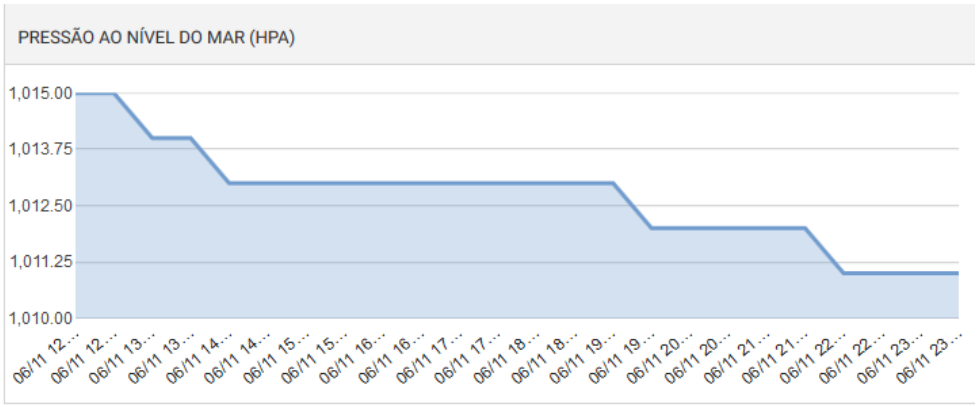

Figure II.3 – Pressure at sea level (hPa) variation during November 6, 2018 (source: https://www.tempo.pt/, November 21, 2018)

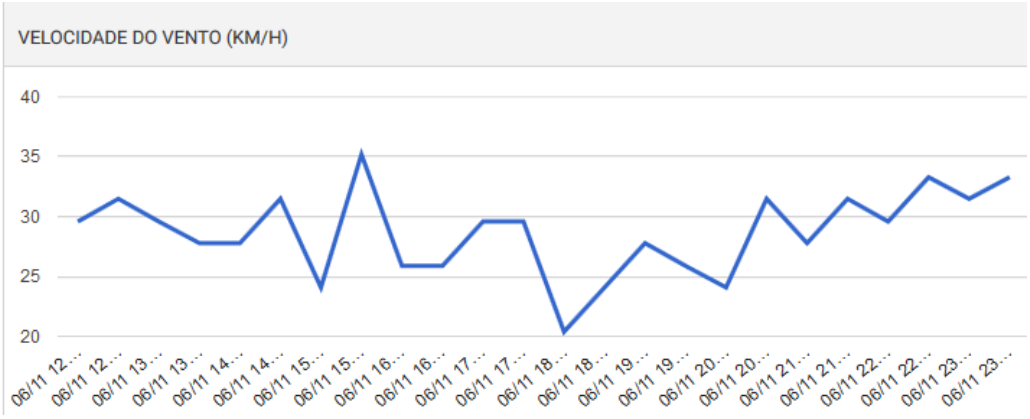

Figure II.4 – Wind velocity (km/h) variation during November 6, 2018 (source: https://www.tempo.pt/, November 21, 2018)

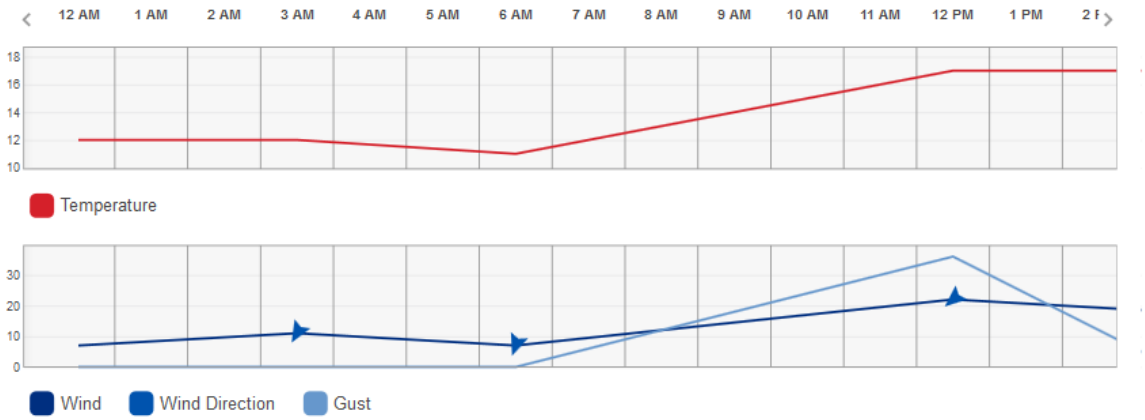

Figure II.5 – Temperature (°C) and wind (km/h) variation during November 6, 2018 (source: https://www.wunderground.com/history/daily/po/montijo/LPMT/date/2018-11-6, November 13, 2018)

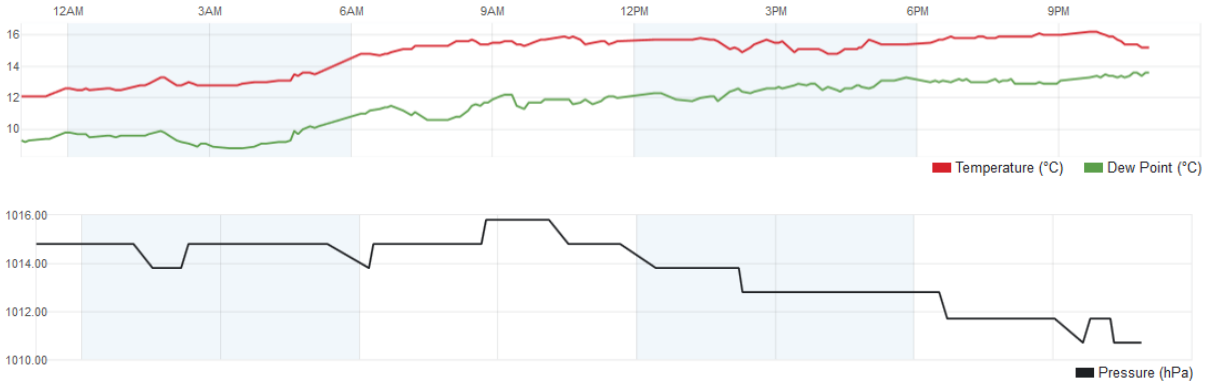

Figure II.6 – Temperature (°C), dew point (°C) and pressure (hPa) variation during November 6, 2018 in Parede, Oeiras (source: https://www.wunderground.com/personal-weather-station/dashboard?ID=ILISBOAP3#history/tgraphs/s20181106/e20181106/mdaily, November 13, 2018)

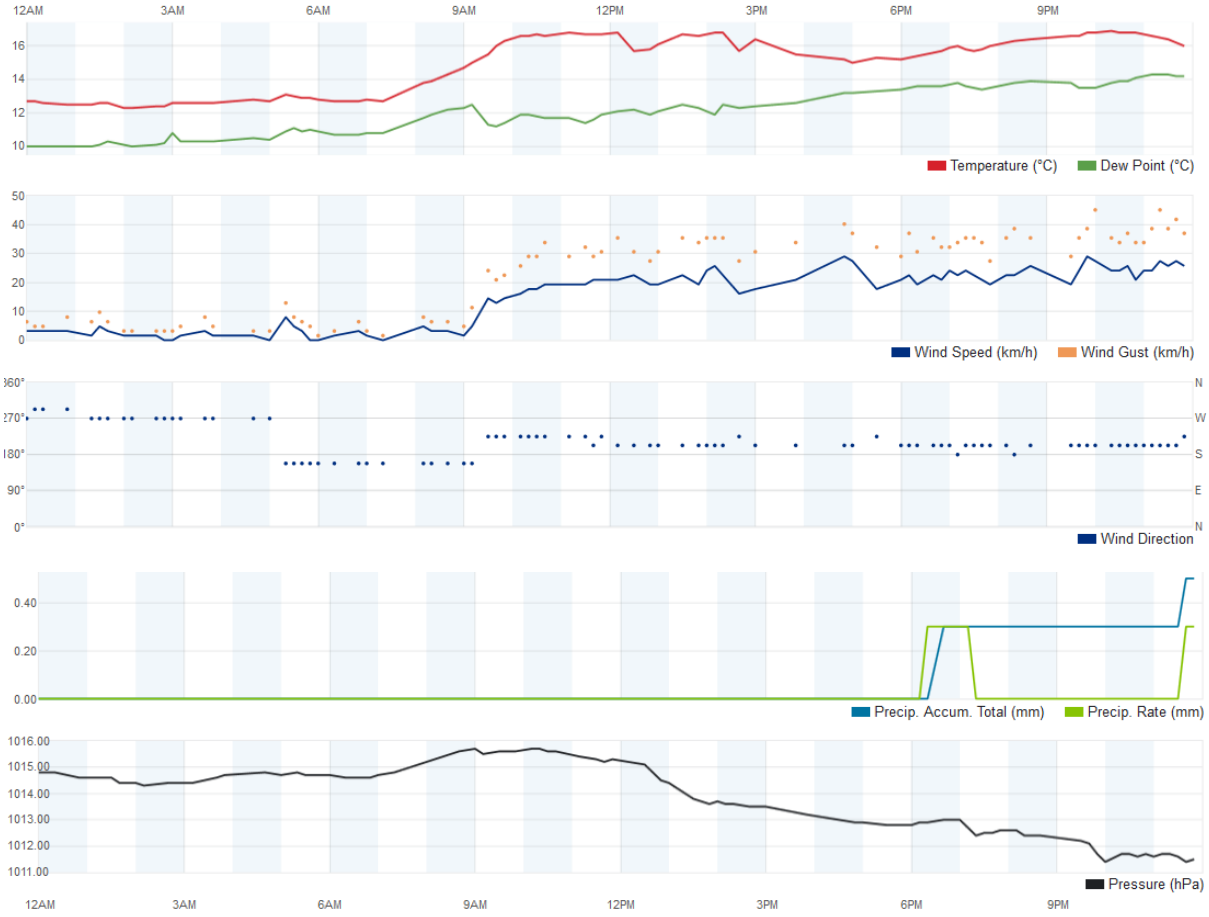

Figure II.7 – Temperature (°C), dew point (°C), wind speed (km/h), wind gust (km/h), wind direction, precipitation rate(mm) and pressure (hPa) variation during November 6, 2018 in Cais do Sodré, Lisbon (source: https://www.wunderground.com/personal-weather-station/dashboard?ID=IPORTUGA25#history/s20181106/e20181106/mdaily, November 13, 2018)

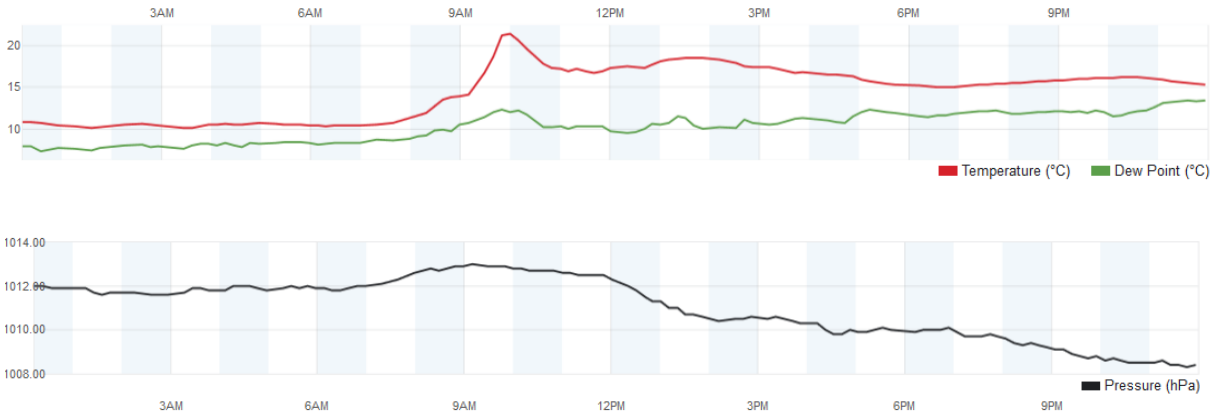

Figure II.8 – Temperature (°C), dew point (°C) and pressure (hPa) variation during November 6, 2018 in Vila Franca de Xira (source: https://www.wunderground.com/personal-weather-station/dashboard?ID=IVILAFRA15#history/s20181106/e20181106/mdaily, November 13, 2018)

ANNEX III
Photosynthetic Pigments list

Photosynthetic pigments read by HPLC:

- Zeaxanthin
- Prasinoxanthin
- Violaxanthin
- Feofitin a
- Feoforbide a
- Peridinin
- Neoxanthin
- Lutein
- Fucoxanthin
- Mg DVP
- Divinil chl a
- Diatoxanthin
- Diadinoxanthin
- Chlorophyll *a*
- Chlorophyll c3
- Chlorophyll c1 + c2 (does not separate)
- Chlorophyll b
- β-carotene
- Anteraxanthin
- Aloxanthin
- α-carotene
- 19-hexa-fucoxanthine
- 19-buta-fucoxanthin