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STARESO experiment

Short range acoustic propagation and backscatter

Data report

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Abstract	This report describes the short range acoustic propagation and backscatter data gathered in summer of 2018 in the Mediterranean sea near the Station de Recherche Océanographiques et sous-marines (STARESO) in Calvi, Corsica (France), during a period of approximately one week.
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Abstract

This report describes the acoustic and other complementary data gathered during an experiment carried from September 24th to September 29th of 2018 in the Mediterranean sea near the Station de Recherche Océanographiques et sous-marines (STARESO) in Calvi, Corsica (France), during a period of approximately 5 days, in the framework of the SEAOX project (PTDC/EEIPRO/2598/2014). The sea bottom is covered by seagrass, particularly *Posidonia oceanica*. The objective of this experiment was to study the effect of oxygen bubbles released by marina plants on acoustic propagation and correlate this effect to monitor the photosynthetic production of marine plants in the meadow. This experiment was divided into two parts, local measurements (plant level, i.e. short range acoustic propagation and acoustic backscatter) and meadow level measurements, and this report describes only data from the first part. Simultaneously with acoustic data, temperature, salinity and dissolved O2 data were measured by a CTD and optode. This report also includes data recorded by the atmospheric station installed at the Station. The report presents the experimental setup, the acoustic and complementary environmental data.

Acknowledgments

The authors thank the technical and scientific staff at STARESO for the logistics and their help and support during the experiment, to *Fred Zabel* for help with Red Pitaya network setup and to *CCMAR* people for the loan of the optode and their help to anchor the equipment.

This work was funded by National Funds through FCT-Foundation for Science and Technology under project SEAOX (PTDC/EEIPRO/2598/2014).

Chapter 1

Introduction

The project SEAOX (Using acoustics for monitoring the metabolism of marine ecosystems) aims at using the properties of sound propagation in seagrass beds as a proxy of the amount of oxygen bubbles released by photosynthesis and therefore to monitor the photosynthetic production of marine plants.

Previous experiments have shown that photosynthesis of seagrass has an acoustic signature ([1] and references therein). The acoustic signature is ascribed to

- O2 bubbles released to the water column,
- pressurization of the aerenchyma,
- O2 released to roots and sediments.

The occurrence and strength of the acoustic signature may vary among seagrass species anmd environmental conditions. The signature is also frequency dependent.

In an experiment conducted in a *Posidonia oceanica* meadow, it has been shown the (anti) correlation between the attenuation of low frequency signals transmitted through the meadow (100m between source and receiver) and the dissolved O2 measured by an array of optodes. However, in order to propose an acoustic method to quantify the O2 released as bubbles, it is necessary to understand the various contributions for the acoustic signature. Several experiments were made at EPPO-IPMA in Olhão ([2] and [3]) to verify the acoustic signature of the marine plants and to study and measure environmental parameters to support acoustic signal analysis.

After all the tests and experiments have been performed and the measurement system has been developed, an integration experiment was carried out in STARESO station (Corsica, France). This experiment was divided into two parts:

- **local measurements** - short range acoustic transmissions and high frequency acoustic backscattering;
- **meadow level measurements** - transmissions of the acoustic signal through the meadow.

The area of this station is covered by Posidonia oceania, which can be an excellent indicator of the health of the environment, because they produce a large amounts of oxygen and store CO_2. This experiments supports the task T3 (Calibration and validation) and the main objective is to calibrate and validate the measurement node and the developed processing methods in the field.

This report describes only the *local measurements* part presented above, and is organized as follows: in the next chapter the experimental setup is presented. The 3rd chapter is devoted to present environmental data, in particular, the CTD, meteo and the dissolved O_2 data. The acoustic data of short range propagation measurements are in chapter 4. The high frequency acoustic backscatter data is discussed in chapter 5. The conclusions are drawn in a final chapter.

Chapter 2

Experimental setup

Next, we describe the site and the measurement setup of the experiment carried out from midday of September 24th until morning of September 29th. All the timestamps in this report are in GMT.

2.1 Site description

As already mentioned, this experiment was carried out at the STARESO station (see Figure 2.1). This station is a scientific station dedicated to marine research and is located in Calvi Bay on the North-Western coast of Corsica (France) in the Mediterranean Sea. Calvi Bay is characterized by very rich ecosystems associated with a large biodiversity, in particular, the marine plant *Posidonia oceanica*.

The location of the anchoring of the equipment is shown in Figure 2.2 with the red cross. In this area the water depth is 5.5 meters being practically null the variation of the tide in this zone of the Mediterranean Sea. However, there was some sea turmoil, which causes small oscillations of the water depth.

Posidonia oceanica covers almost completely the bottom of the place where the equipment was placed, as shown in Figure 2.3. Visual inspection of the plants shows long leaves and short roots. The bottom parameters are unknown, but visual inspection shows that it appears to be sandy. Another curiosity is that the plants have a white coloration, which, according to biologists, is due to limestone (see Figure 2.3 on the right).

Figure 2.1: STARESO station with one of the boats that supports the experiments.

Figure 2.2: Satellite view of STARESO station location and the red cross represents the area where equipment has placed. On the right, the different types of bottom in the Calvi Bay (the yellow is sand, the green is marine plants and the pink is rocks).

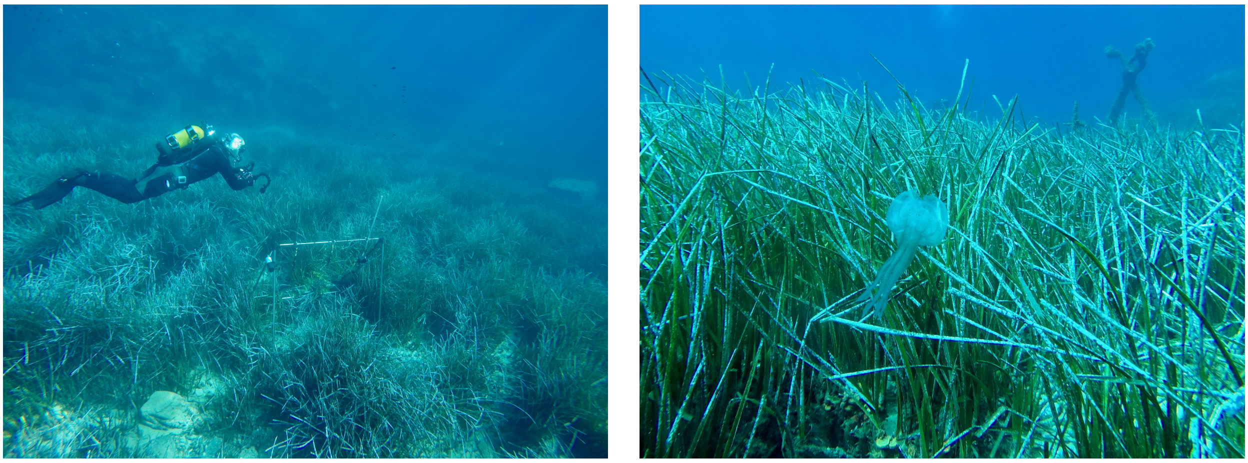


Figure 2.3: Structure with equipment installed in an area with high density Posidonia oceanica meadow.

2.2 Equipment and mooring

The equipment used in this experiment was:

- CCMAR optode to measure dissolved O2,
- the multiparameter CTD RBRconcerto, that in addition to temperature, conductivity and pressure, also measures oxygen concentration,
- measurement system developed in master thesis [4], fixed at an anchoring structure, which was deployed in the area shown with the red cross in Figure 2.2,
- the buoy with electronic devices (red pitaya, amplifiers) and batteries to power and control the system through a wireless connection, installed near the structure as shown in Figure 2.5,
- the Acoustic Backscatter System (ABS) AQUAscat 1000S from AQUATEC operating in the 0.5-4MHz band with the external battery pack, attached to a structure near the same area of the measurement system with the device pointed to the top.

During the experiment, the weather conditions were not the best, so we only managed to put the equipament on the morning of September 27th. Only the ABS was possible to place the previous day. The equipment was anchored on morning of September 27th with the precious help of expert diver of station. The structure was placed above the marina plants, as shown in Figure 2.5, with the transducers about 90cm from the bottom. The source was placed approximately 40 cm from the first receiver, and the distance between the receivers was about 50 cm (see Figure 2.4). As already mentioned, the water depth in this area is about 5.50 meters.

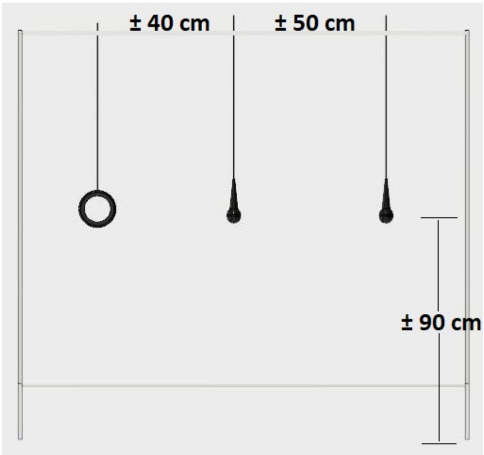


Figure 2.4: Setup with the transducers fixed in the stainless steel structure. The black ring represents the source (transducer ITC2044) and the two black circle represents the two receivers (transducers RESON TC4033).

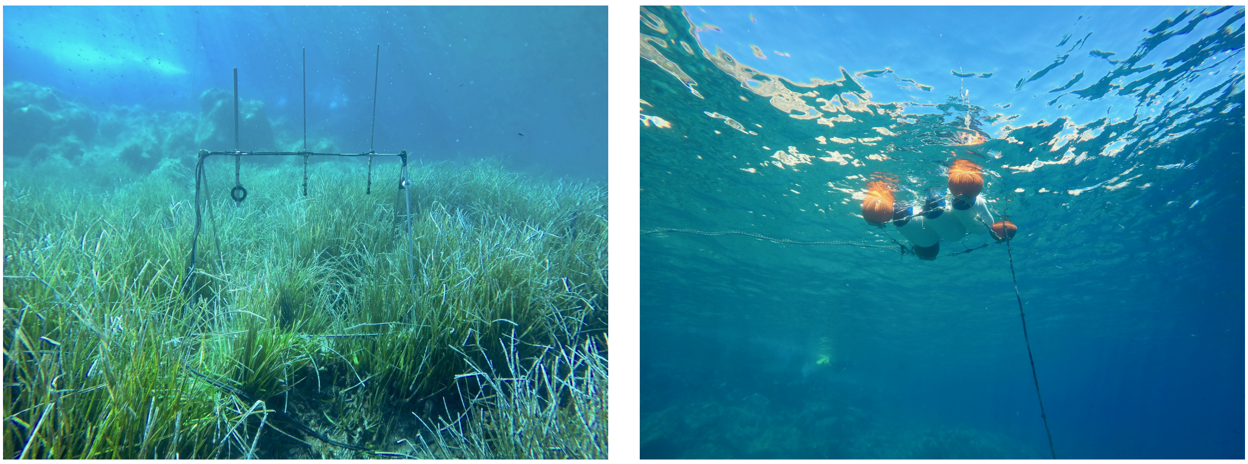


Figure 2.5: Equipment moored during the experiment. On the left the structure with the transducers placed above the marine plants; on the right the buoy with electronic devices and batteries floating near the anchored structure area.

Chapter 3

Environmental data

This chapter presents the meteorological data, CTD data and CCMAR dissolved O2 data gathered during the experiment period. The meteorological data presents the data of the complete week, including the main days of the experiment.

3.1 Meteorological data

The meteorological data, provided by STARESO station people, were recorded by a meteo station installed in the station building. The mean values of wind speed, wind direction, air temperature, atmospheric pressure, relative humidity and solar radiation collected every 20 minute are presented in the figures below.

The data measured by the station are typical values for the time of the year in which the experiment was performed. Usually this season, the days are quite sunny, a few days of rain and the maximum air temperature around 25°C and the minimum around 16°C, as shown in figures below.

During the beginning of the week, the station was affected by very strong winds from the East side (see Figure 3.1(a) and (b)), the worst side for the station location, which cause big waves that affect the station. Due to these weather conditions, we had to delay the start of the experiments because there were no conditions to put the equipment in the sea. Therefore, as shown in the following figures, it was only possible to place the equipment on September 27th.

As we previously saw, the solar radiation is one of the most relevant parameters for the photosynthetic activity of the marine plants because it measures light availability, however, the wavelength is not known. The solar irradiance has practically the same peak values during the days of the experiment, and these daily peaks values (around $800\,\mathrm{kW/m^2}$) occurred in the middle of the day, as shown in Figure 3.2(f).

These meteorological data are in agreement with the logs presented in the *LOG* file (see appendices), accomplished through direct observation of the weather conditions.

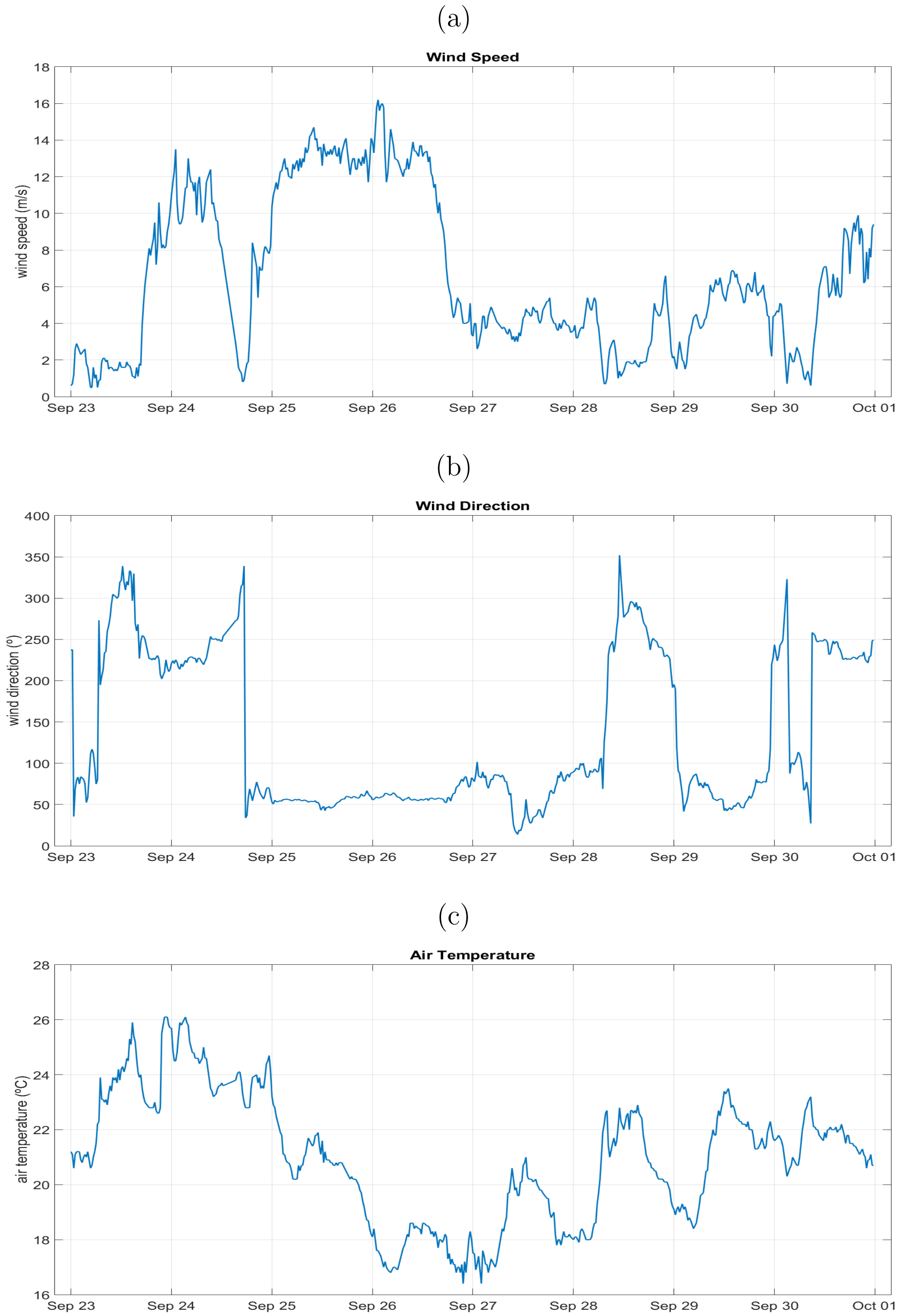
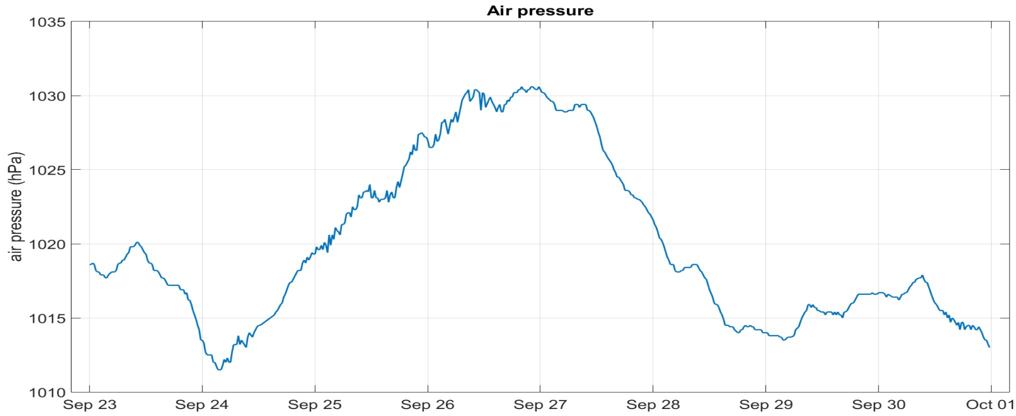
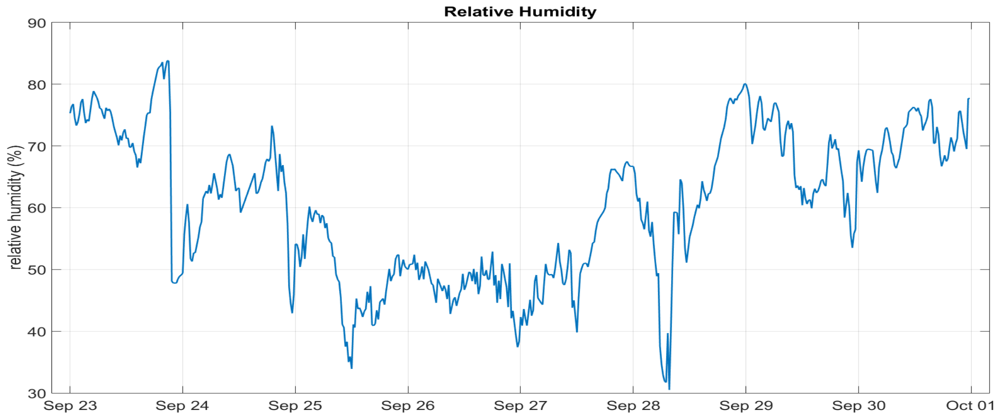


Figure 3.1: Meteorological data : wind speed (a), wind direction (b), air temperature (c).

(d)



(e)



(f)

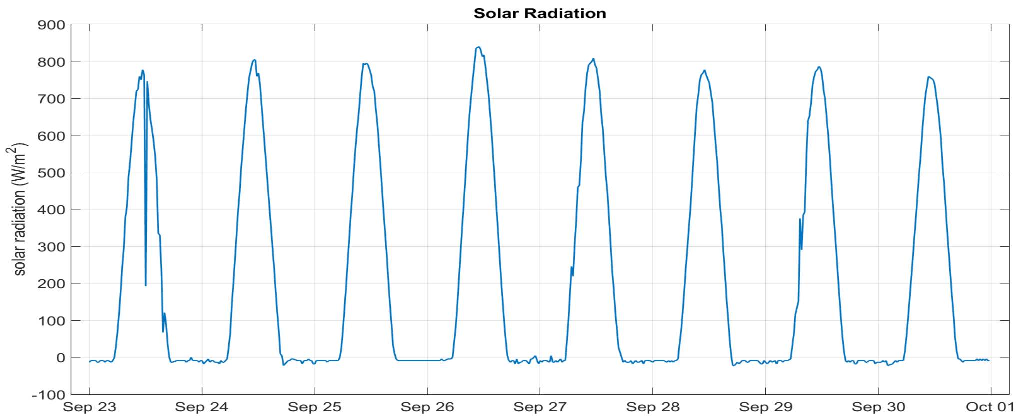


Figure 3.2: Meteorological data : air pressure (d), relative humidity (e), solar radiation (f).

3.2 CTD data

The CTD collected pressure (depth), conductivity, temperature and dissolved O2 data at sampling frequency of 6 samples per minute. Several data collections periods were performed, one of them performed by placing the CTD suspended on the pier at approximately 2 m depth and only one of the samples was performed a CTD profile near the experiment zone through the use of a boat.

The first CTD data recording period was approximately 1 hour on the morning of September 27th at the pier. These data are presented in Figure 3.3 and 3.4. The water temperature varied about 0.15 °C between 21.2 and 21.35 °C during this hour. The salinity is practically constant, about 38.2 ppm and the sound speed increases slightly during this hour. The dissolved O2 is about 130% which was to be expected the presence of bubbles.

The second CTD data recording period was approximately 2 hours on the morning of September 28th at the pier. These data are presented in Figure 3.5 and 3.6. In this period, the salinity is practically the same of the previous period. Only the water temperature and the sound speed are slightly higher. The dissolved O2 increase along the time, always presenting values above 100% which represents supersaturation of the water column.

The CTD profile was performed at the exit of the port bay, near the experiment zone. These profile data were taken on the afternoon of September 27th and are shown in Figure 3.7 and 3.8. The dissolved O2 has values below what was expected, therefore, the formation of oxygen bubbles didn't occur. In relation to the other parameters (temperature, salinity and sound speed), the variation is very small along the water column, see Figure 3.7.

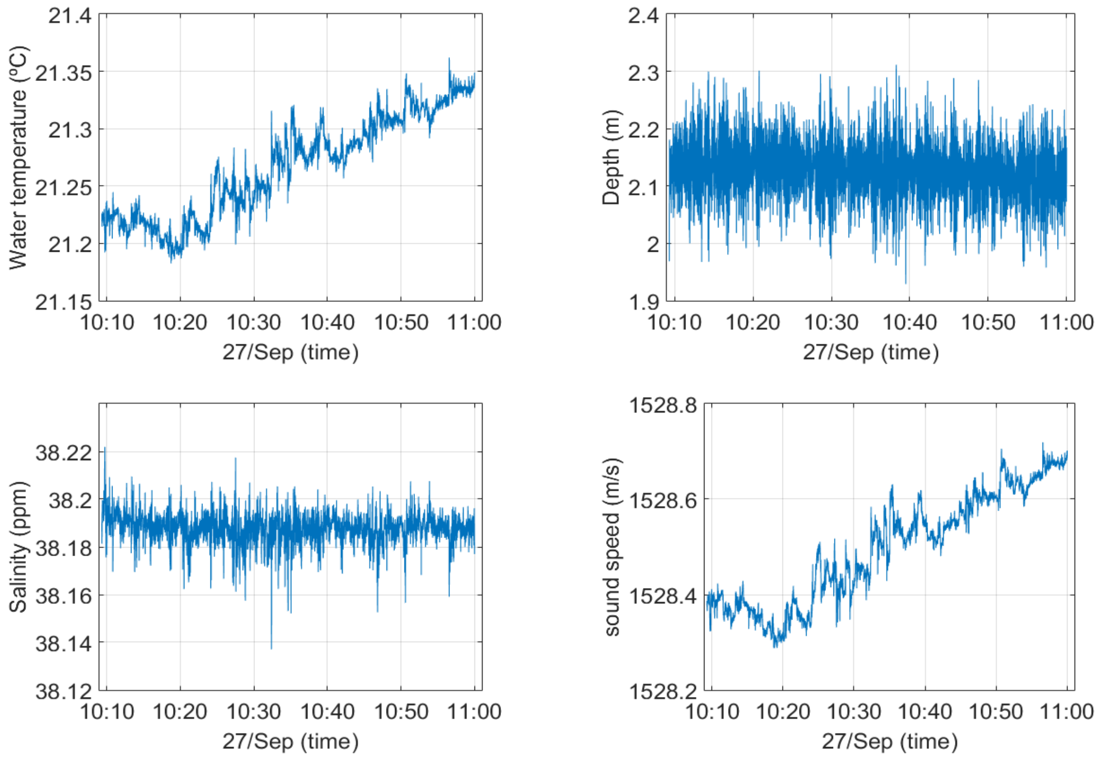


Figure 3.3: CTD data 1st period at the pier: water temperature (top left), depth (top right), salinity (bottom left), sound speed (bottom right).

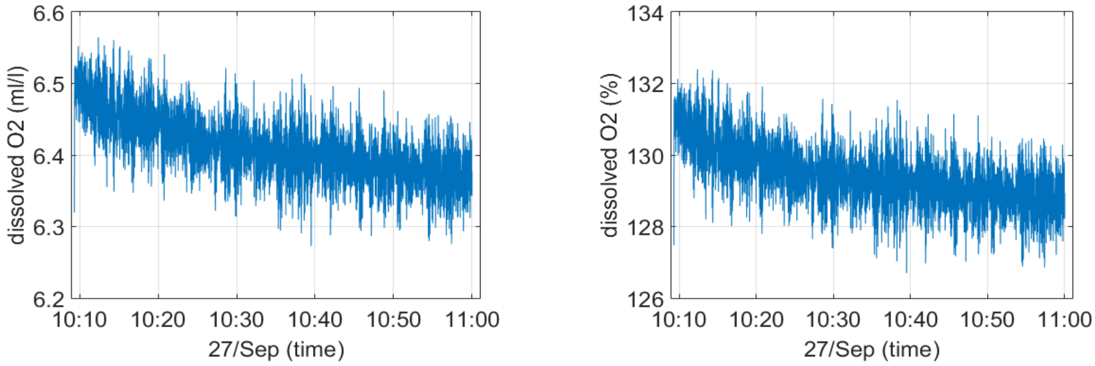


Figure 3.4: CTD data 1st period at the pier: dissolved O2 in percentage of saturation (left) and concentration (right) .

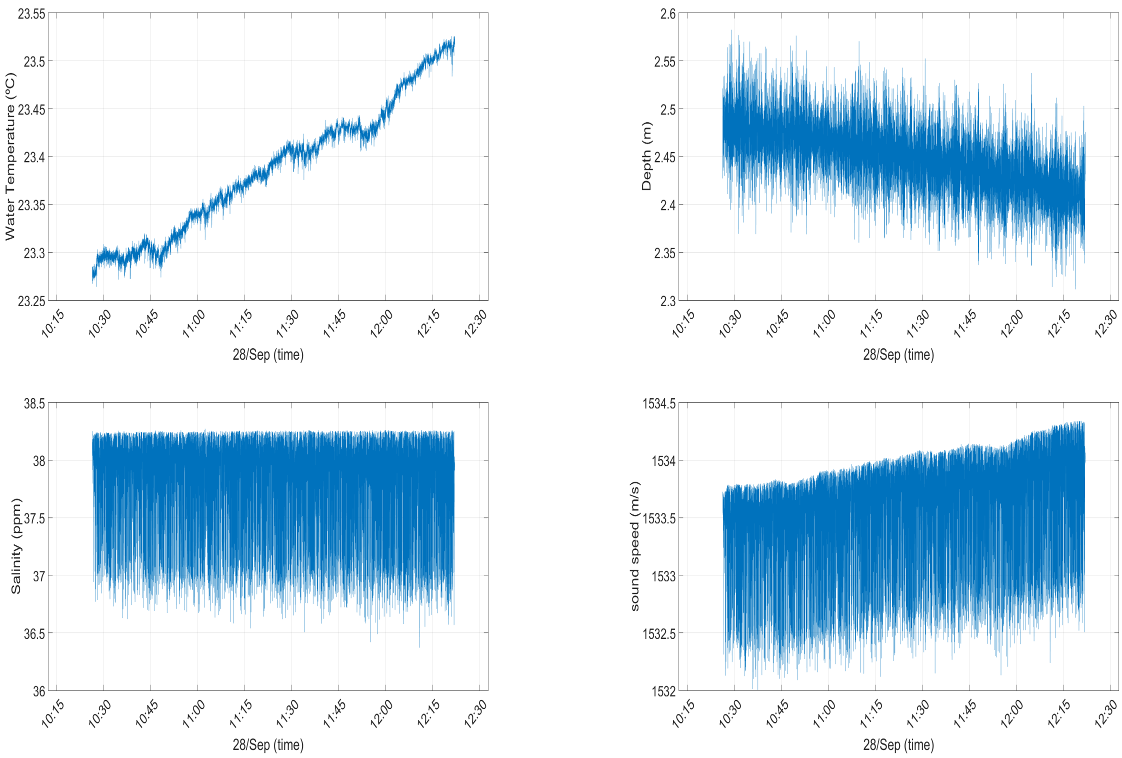


Figure 3.5: CTD data 2nd period at the pier: water temperature (top left), depth (top right), salinity (bottom left), sound speed (bottom right).

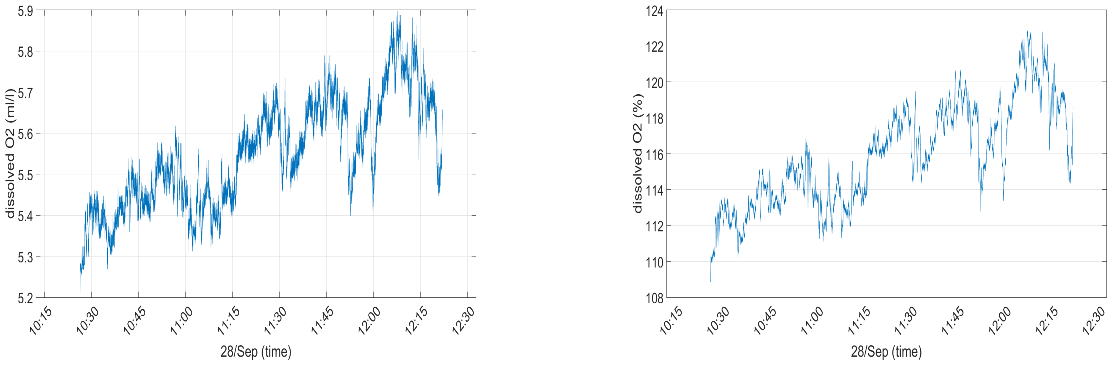


Figure 3.6: CTD data 2nd period at the pier: dissolved O2 in percentage of saturation (left) and concentration (right).

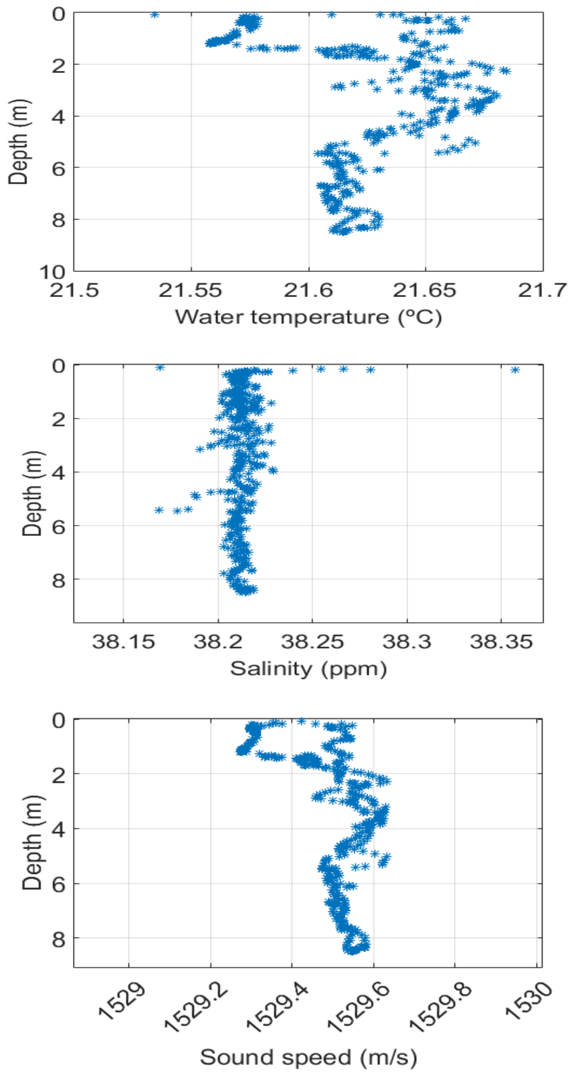


Figure 3.7: CTD profile data close to the backscatter and short range measurements: water temperature (top), salinity (middle) and sound speed (bottom)

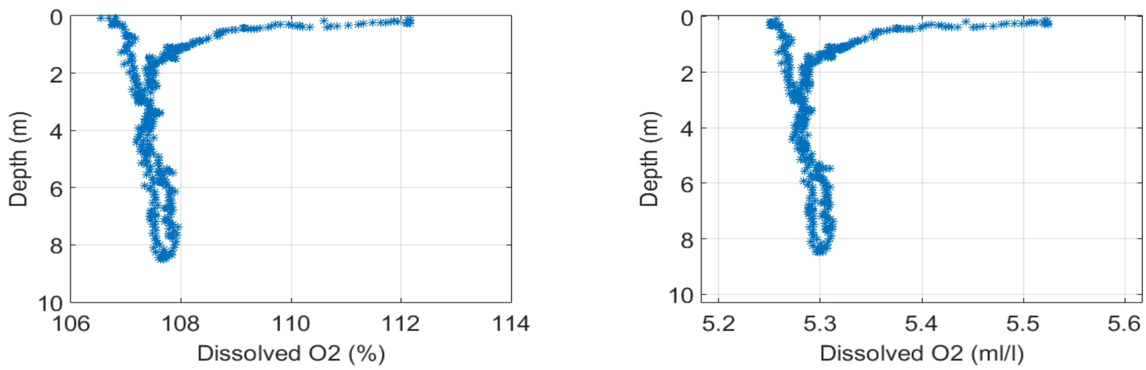


Figure 3.8: CTD profile data close to the backscatter and short range measurements: dissolved O2 in percentage of saturation (left) and concentration (right) .

3.3 CCMAR optode

The optode acquired temperature and dissolved oxygen data at a sampling frequency of 1 sample every 2 minutes. This recording started on the morning of September 27th until noon of September 29th. The sensor was placed in the structure shown in Figure 2.5 (left), approximately one meter from the bottom.

The water temperature is presented in Figure 3.9 (black line). This parameter varies about 4°C during the period, and increases steadily throughout the experiment. It doesn't present any diurnal pattern or any correlation with sunlight. This may be due to weather conditions, the air temperature (shown in Figure 3.1(c)) was lower in the previous days and was also increasing gradually until September 29th.

The dissolved O2 is presented in Figure 3.9 (blue line in % and red line in mg/l), showing a diurnal pattern with a minimum during the night, afterwards rapidly increases until noon (approximately 14:00h). The saturation level reaches a maximum of approximately 105% in the 1st daily cycle and 110% in the 2nd. These results suggest that there is bubble production in the water column because there is supersaturation (above ± 100%). However, as we will see in the next chapters, this doesn't happen, or the bubble production is much lower than expected.

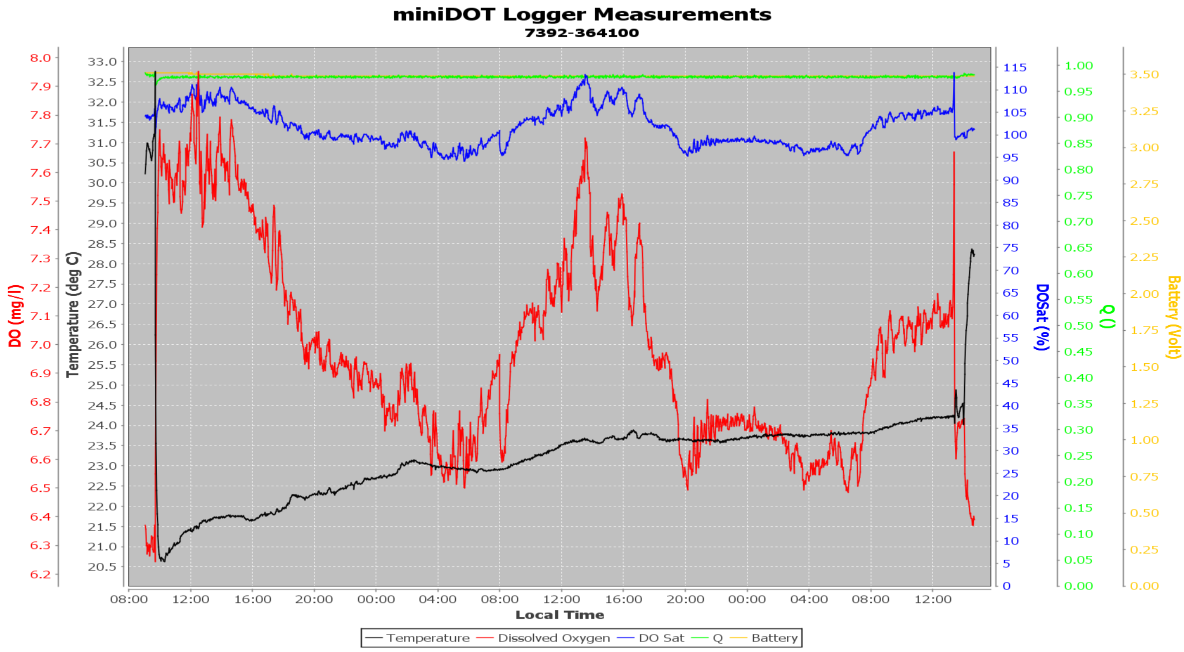


Figure 3.9: Optode data from morning of September 27th to afternoon of September 29th.

Chapter 4

Short range (plant level) acoustic propagation measurements

This chapter presents the experiment with the measurement system developed [4]. This system is controlled by the Red Pitaya system board, which hardware and software were initially conceived as a tool to replace expensive laboratory measurement instruments. The assembly of this system is shown in figure 2.4 and 2.5.

This experiment was performed from the morning of September 27th until the afternoon of September 29th. However, there were some problems in the wireless connection with the red pitaya that caused periods without data.

Were transmitted various sequences of burst signals from 4 to 25 kHz. These sequences were transmitted and acquired during the experiment period with a pause interval of approximately 1 minutes between each sequence. In each sequence, are acquired one signal per each frequency, continuously (i.e. one of 4 kHz followed by 5 kHz, and so on up to 25 kHz). Afterward, was performed the peak detection of all data using the envelope of the match filter, and then were calculated the sound speed and attenuation of the signal.

In figures 4.1 and 4.2 is possible to verify the estimation of the sound speed and attenuation, respectively. The sound speed doesn't show any diurnal pattern, as expected. It was expected that the sound speed would decrease when there was an increase in oxygen production (during the day, due to bubbles). It was also expected that attenuation of the signal would increase during these periods, but this doesn't happen, there is no pattern correlating with dissolved oxygen.

In an attempt to further investigate the problem, the amplitudes of the signals received at both receivers and the travel times of the first arrival were verified (see figures below).

Figures 4.3 and 4.4 show the amplitudes of the first arrival (direct arrival) and second arrival (bottom reflected arrival), respectively, in both receivers. On the first arrival, there is no pattern correlated with dissolved oxygen. The only point is that the amplitude at the first receiver is practically twice the amplitude of the signal at the second receiver. This fact is also observed on the second arrival (reflection in the bottom) , however, this ratio of the amplitudes is not verified (figure 4.4).

In figure 4.5 it is possible to verify the travel time of the first arrival in both receivers. As shown in the figure, in both frequencies, the travel time is practically constant along the day, for both receivers. There are no changes or any patterns on travel times during the diurnal period, as expected. There is only a constant difference of 0.3 ms, approximately, between direct arrival on both receivers, which corresponds to the distance between them.

The travel time of the second arrival is a little more complicated to find through the analysis the peaks. However, in figure 4.6 it is possible to verify the time difference between the first and second receivers, approximately 0.1 ms.

Figures 4.7, 4.8 and 4.9 show all arrivals at the first receiver (left image) and the second receiver (right image). The direct arrival is easily detected as it has a very strong signal amplitude. It is also possible to check both the second arrival (bottom reflection) and the third arrival (surface reflection), being this one easily correlated with the water depth pattern.

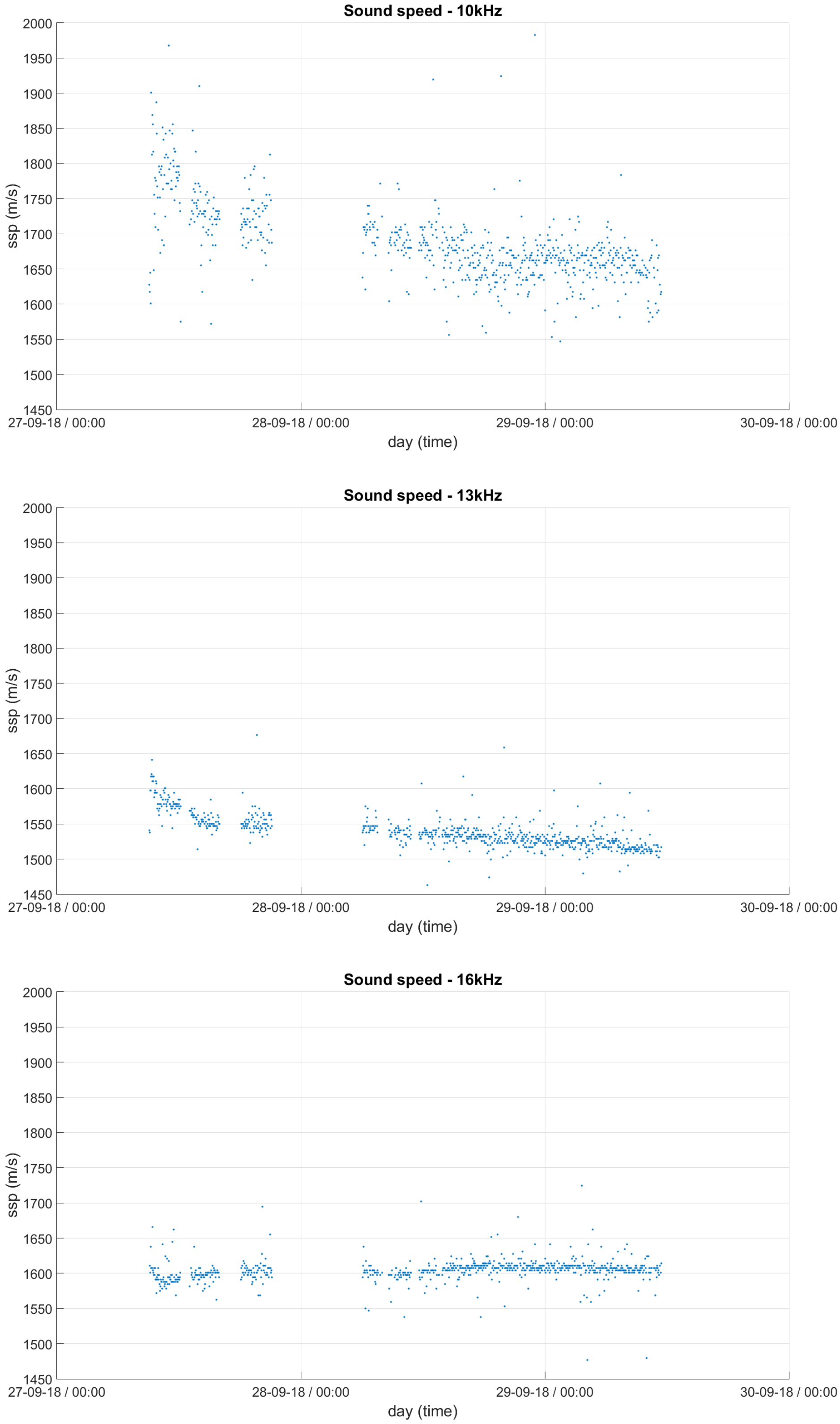


Figure 4.1: The sound speed for signals transmitted at 10 kHz (on the top), 13 kHz (on the middle) and 16 kHz (on the bottom).

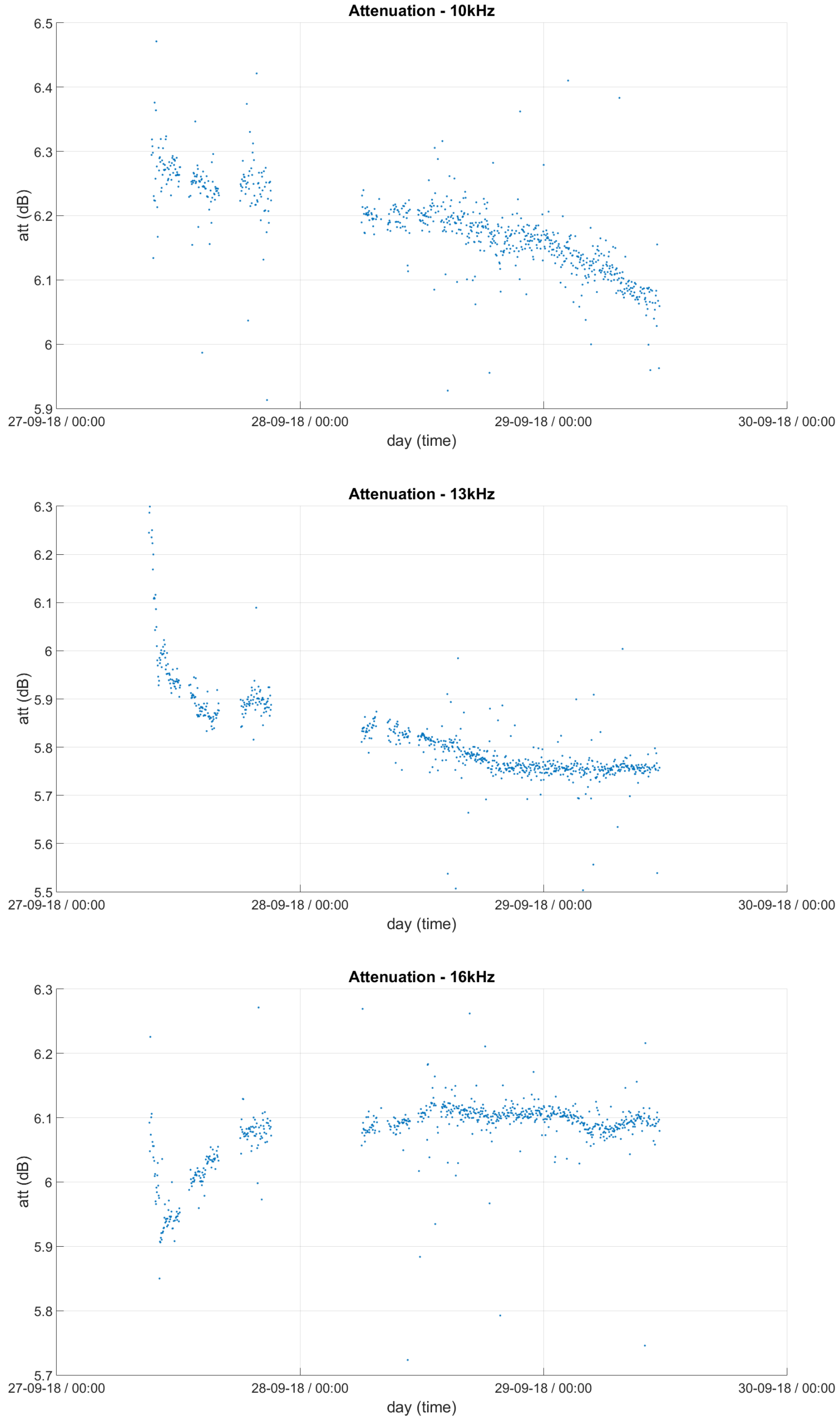


Figure 4.2: The attenuation for signals transmitted at 10 kHz (on the top), 13 kHz (on the middle) and 16 kHz (on the bottom).

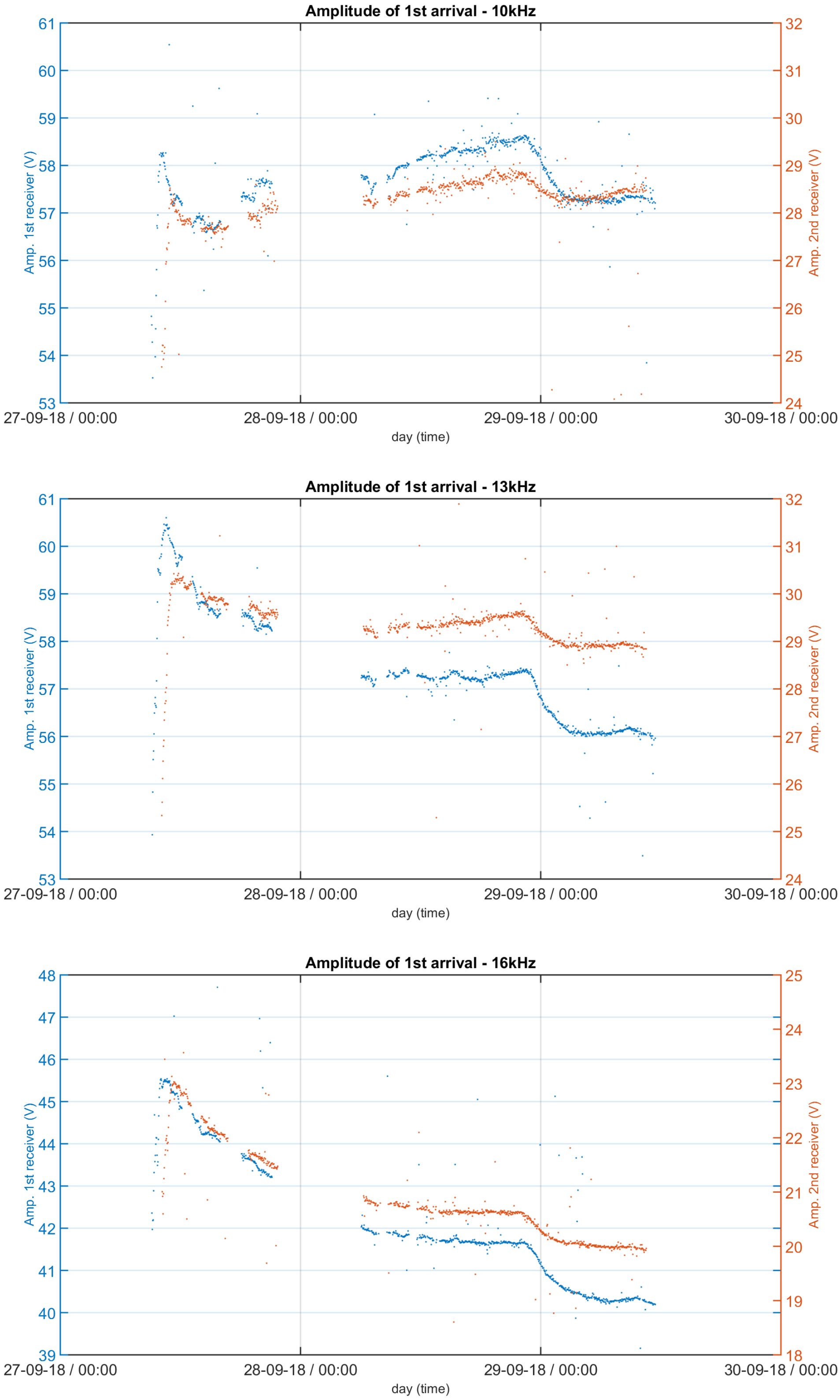


Figure 4.3: The comparison between the amplitude of 1st arrival in both receivers (1st receiver in blue and 2nd receiver in red), for signals transmitted at 10 kHz (on the top), 13 kHz (on the middle) and 16 kHz (on the bottom).

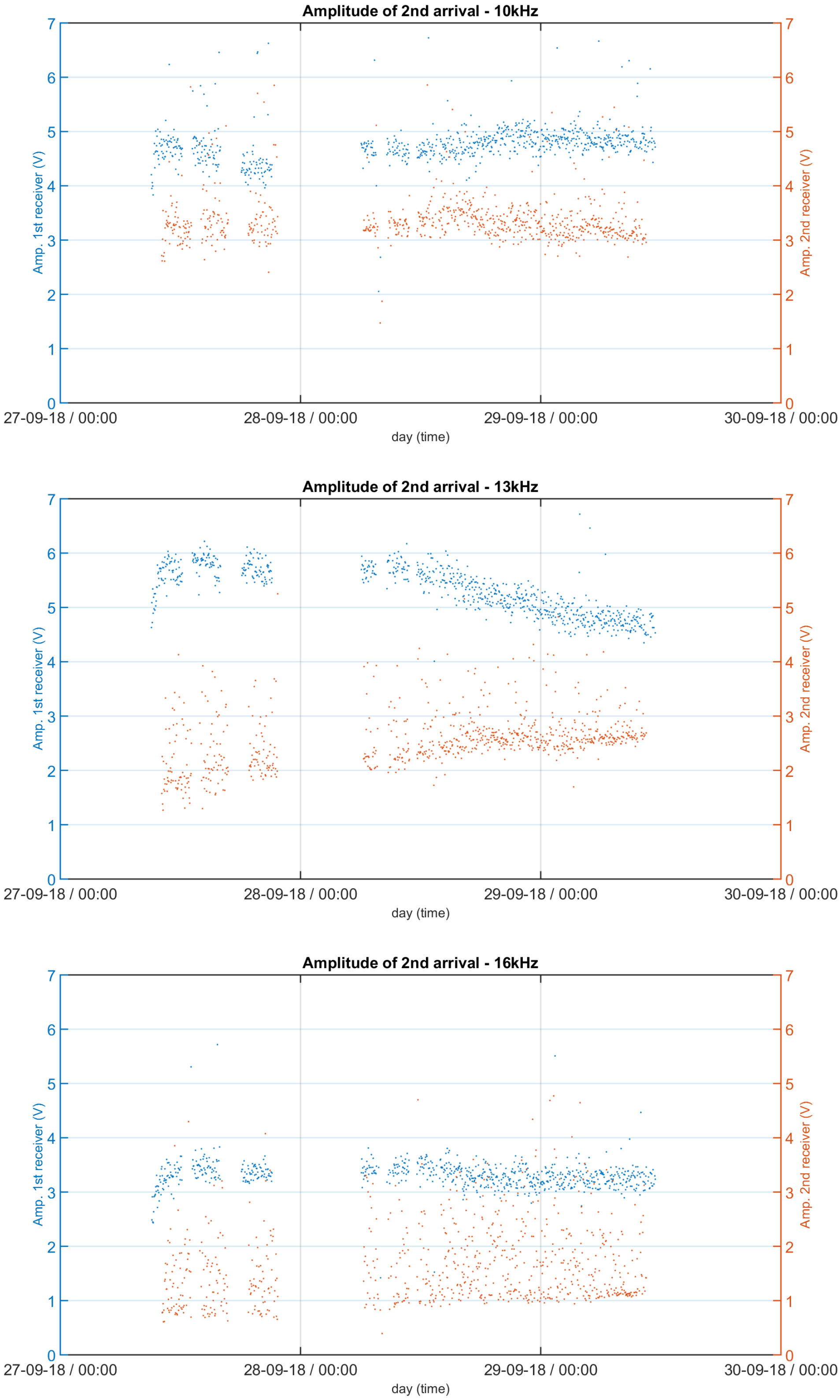


Figure 4.4: The comparison between the amplitude of 2nd arrival in both receivers (1st receiver in blue and 2nd receiver in red), for signals transmitted at 10 kHz (on the top), 13 kHz (on the middle) and 16 kHz (on the bottom).

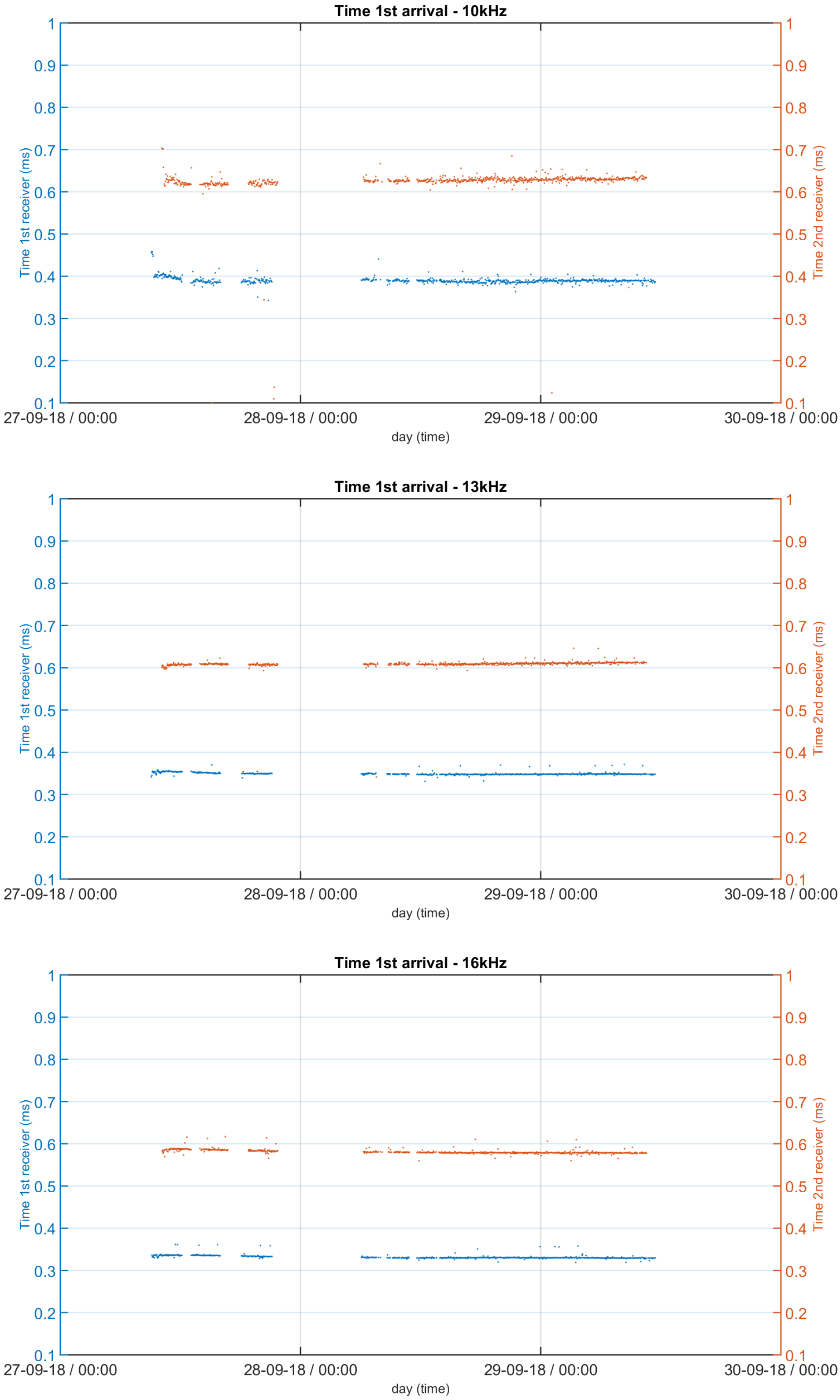


Figure 4.5: The comparison between the time of 1st arrival in both receivers (1st receiver in blue and 2nd receiver in red), for signals transmitted at 10 kHz (on the top), 13 kHz (on the middle) and 16 kHz (on the bottom).

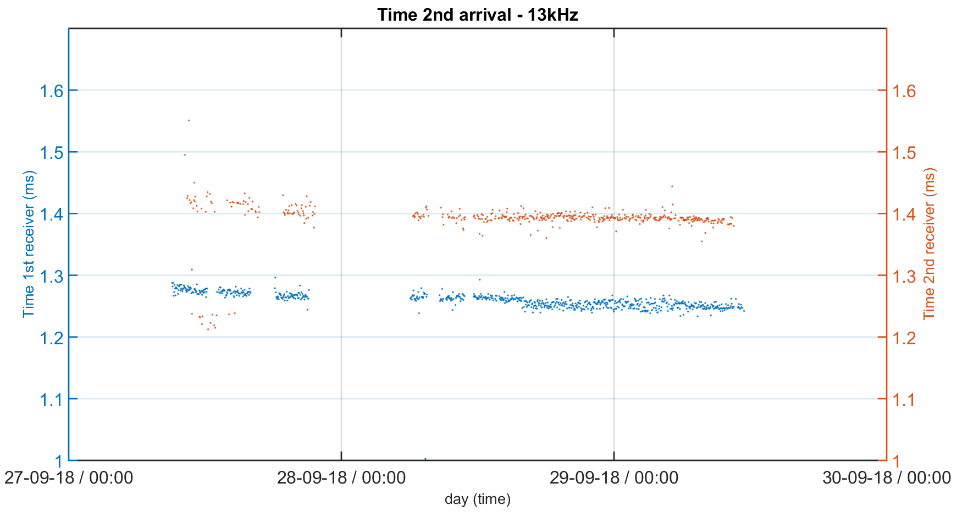


Figure 4.6: The comparison between the time of 2nd arrival in both receivers (1st receiver in blue and 2nd receiver in red), for signals transmitted at 13 kHz.

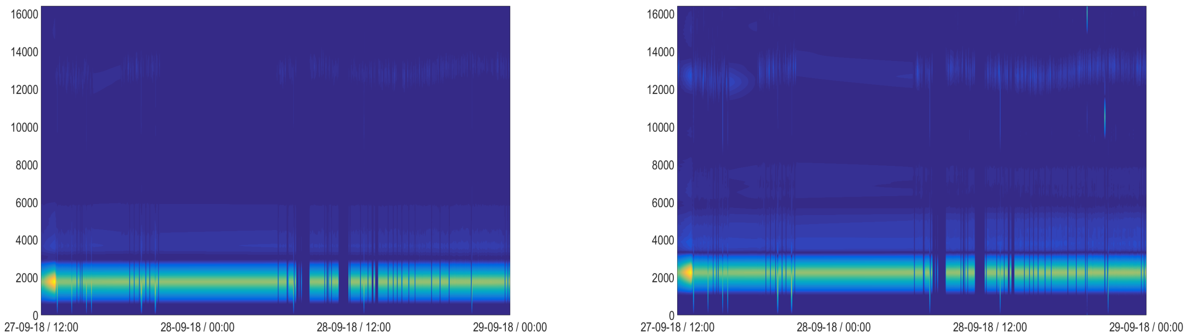


Figure 4.7: The various arrivals at 10 kHz in both receivers: first receiver (oh the left) and second receiver (on the right).

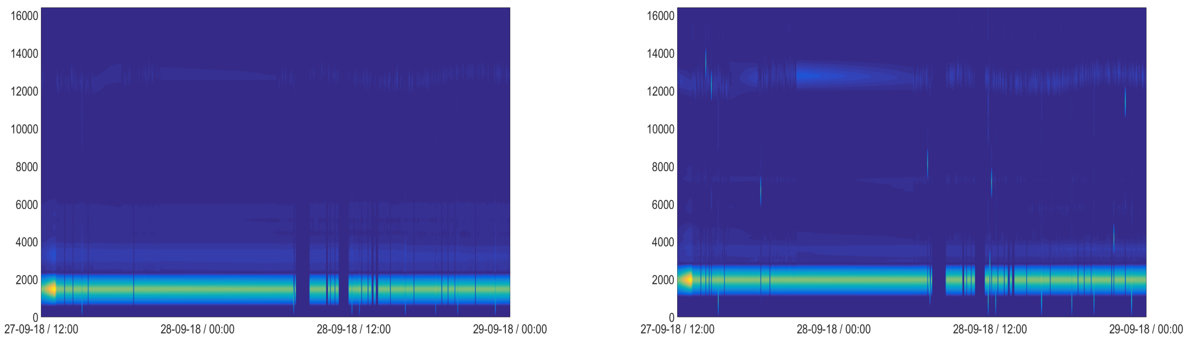


Figure 4.8: The various arrivals at 13 kHz in both receivers: first receiver (oh the left) and second receiver (on the right).

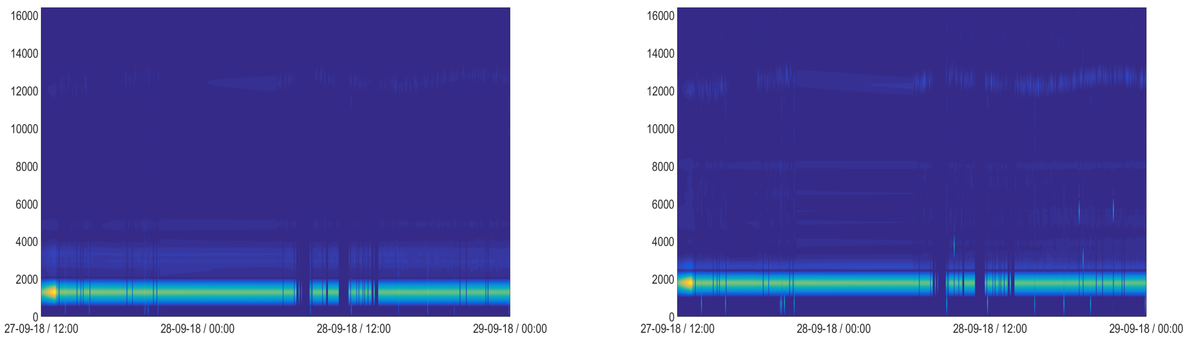


Figure 4.9: The various arrivals at 16 kHz in both receivers: first receiver (oh the left) and second receiver (on the right).

Chapter 5

Acoustic Backscatter System

The ABS was only used to check for the occurrence of bubbles produced by *Posidonia oceanica*. Sequences of backscatter data were acquired every 10 minutes during the experiment period (in the case of ABS, began at noon from September 26th until noon on September 29th) and the system was operated at 0.5 MHz, 1 MHz, 2 MHz and 4 MHz. The transducers were pointed upward to measure the backscatter along the water column. This chapter describes the acquired data and presents preliminary data analysis.

The figure 5.1 and 5.2 shows the backscatter level measured by the various sensors. During the first day of this ABS experiment, the weather conditions is not good enough (1.5m wave entrance of the port and strong wind), so its possible to verify the surface in all the frequencies due to the oscillations of the water depth. Another note is the fact that due to state of the weather, there was some turbidity in the water, which causes the appearance of sands and leaves in the water column.

It was expected that when the O2 saturation level is high, the level of the scattered signal for to all frequencies is also high. However, as can be seen in the following figures, this doesn't happen, there is no increase in the backscatter level during these periods. Therefore, during these days there was no release of bubbles. We believe it was due to the storm that affected the area on the days of the experiment. In the days of the storm, the divers noticed that there was some turbidity in the water, due to the leaves of plants that were previously deposited in the bottom. This may be a possible explanation for non-existent bubble production.

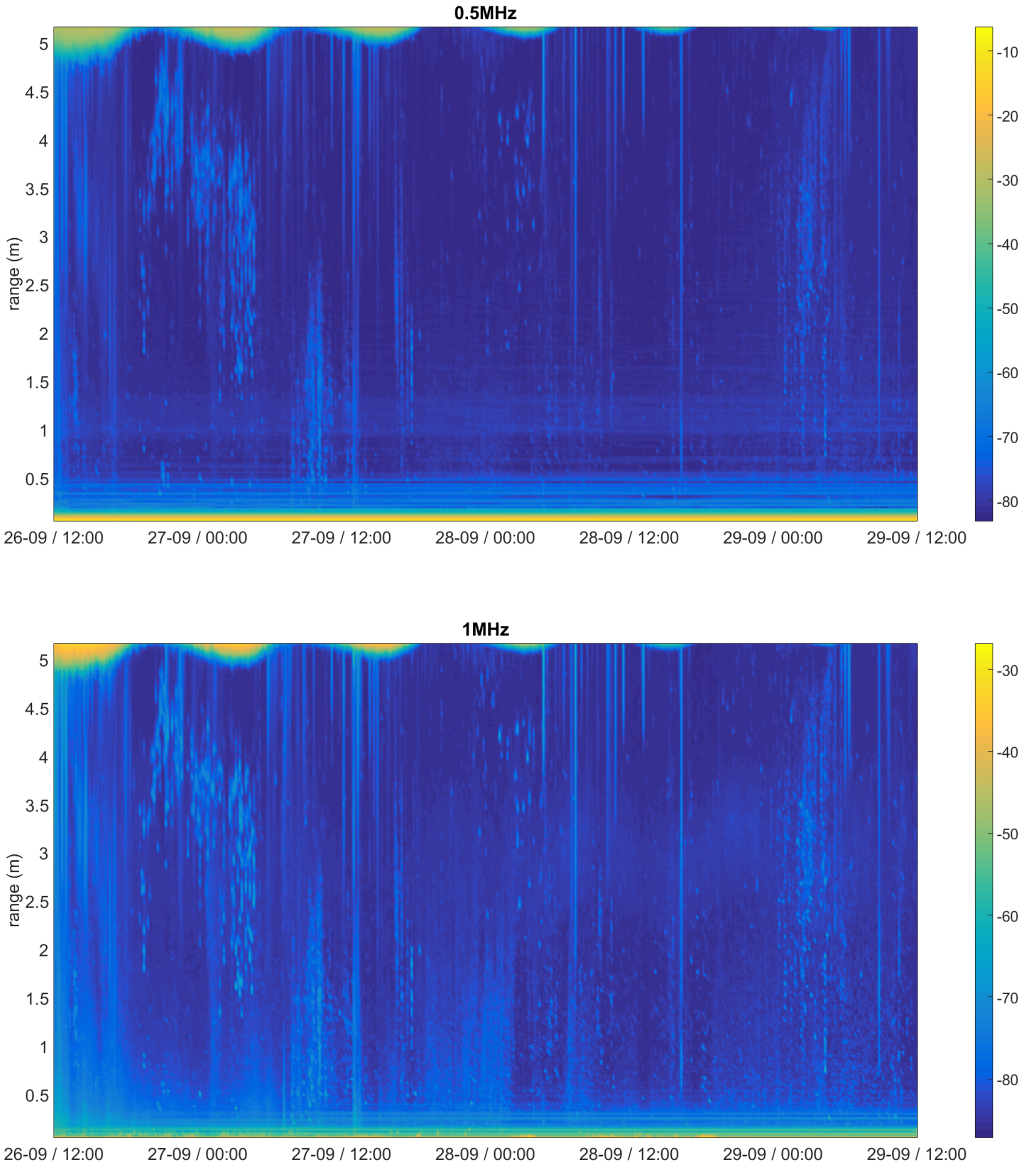


Figure 5.1: Backscatter level measured by the ABS at 0.5 MHz (upper) and 1 MHz (bottom) sensors during the experiment period.

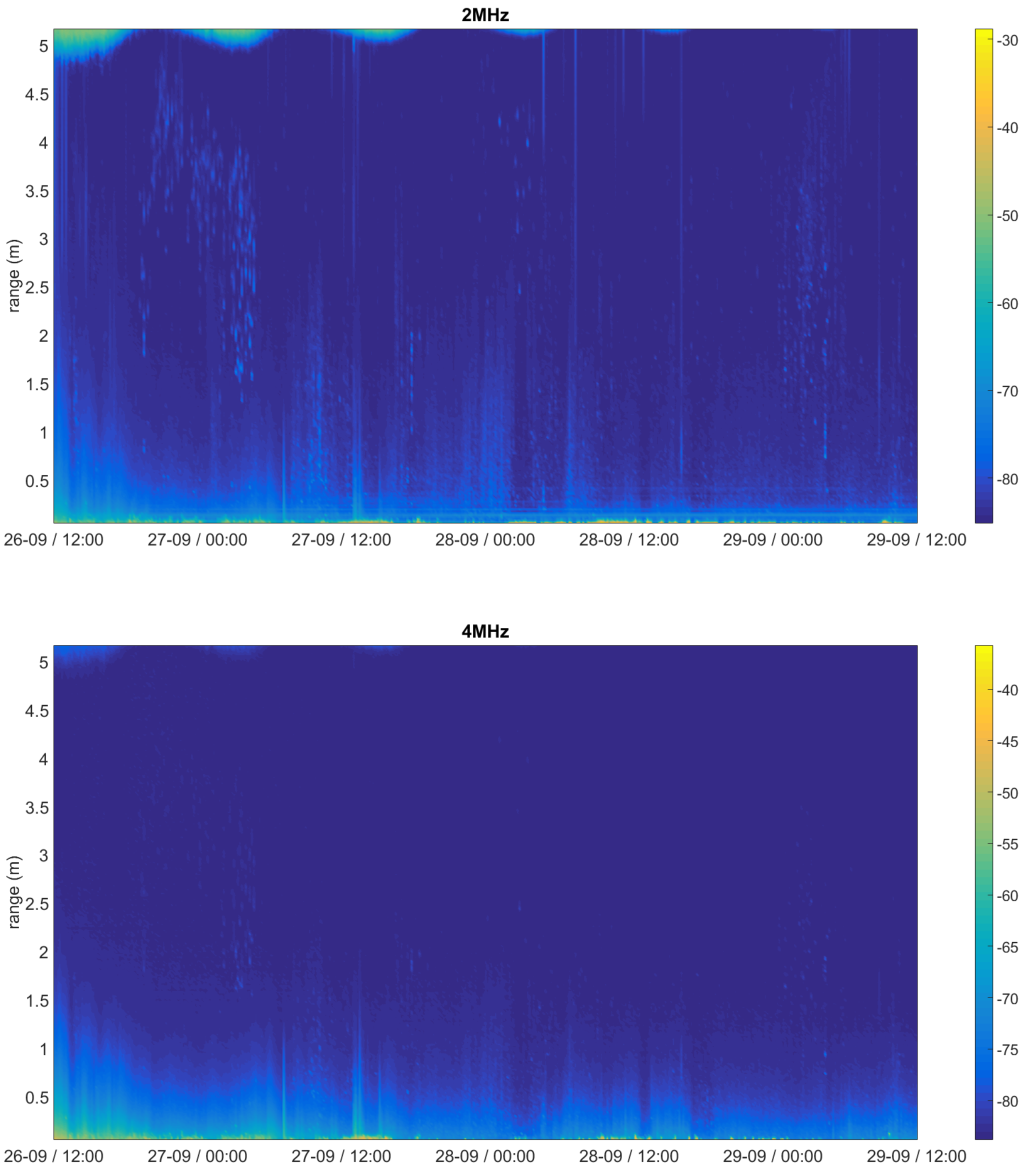


Figure 5.2: Backscatter level measured by the ABS at 2 MHz (upper) and 4 MHz (bottom) sensors during the experiment period.

Chapter 6

Conclusion

This report presents the environmental and acoustic data acquired at the STARESO station during the experiment performed. The objective of this experiment was to assess the acoustic signature of photosynthesis in seagrass meadows (in this case, *Posidonia oceanica*) at frequencies below 20kHz (in particular, 10, 13 and 16 kHz) and high frequencies (ABS). The high O2 saturation levels measured during daylight periods suggests that part of the O2 is released as bubbles.

At frequencies below 20kHz, no pattern was observed, as expected. The variation of the sound speed and the attenuation was practically null over the day. Therefore, there is no correlation, in this particular experiment, with the dissolved oxygen. This can be due to the fact that the production of oxygen by the marine plants was not high enough in the experiment area. As was said in the previous chapter, we believe that the storm that affected the area on the days of the experiment causes a non-existent of bubbles production, because, the water was very choppy, causing a lot of turbidity and pieces of plant leaves suspended in the water column. Considering that the bubbles are formed when there is supersaturation of water column (above 100%), this may have been the problem, because, according to the CCMAR optode data, the dissolved oxygen had peak values of approximately 105% and 110%, therefore may not have been sufficient to produce bubbles.

The acoustic signature of bubbles released during over saturation conditions was not observed in signal acquired by an acoustic backscatter device operating at frequencies 0.5MHz, 1MHz, 2MHz and 4MHz. In short, this experiment was inconclusive and more studies of these will be explored in the future.

Bibliography

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Appendices

.1 Log of the experiment

STARESO - 2018 experiment

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1. Objectives

- engineering test DAVS

- measure particle motion in the vicinity of Stareso pier and compare particle velocity field with pressure field

- same comparison for source transmitted signals (so DAVS should not be far from source)

2. Questions

- how to set gain to cope with both source signal amplitude and biological SPL ?

- DAVS in vertical position: how to handle VS outputs and atitude sensor outputs ?

3. Preparation

- session with Fred on how to setup DAVS for streaming

- instructions on how to configure for autonomous operation and back to streaming (open DAVS, connect programmer box, flashing firmware, etc, Pfelis was doing it from windows computer with an app)

- everything was loaded on box, I took DAVS in my laguge

4. Stareso log

Day 24-9 (good weather, calm sea)

- setting up streaming box with RPi and HD + 110m long cable + DAVS in streaming mode. Not working. Stream data does not appears on web page running on RPi through address 192.168.200.254:7681

- change to TP-1, same problem

- looking for solutions

- deploying Lubell source on position A (8m depth, in wd 10m, cabled to shore - pier)

- deploying two SR-1 on existing optode mooring about 60 m from pier (JoÃ£o Parente made movie)

- 19:30 (?) start transmitting with source

Day 25-9 (20 knot wind from NE, 1.5m wave at the entrance of the port, water with visibility in the port)

- gave up looking for streaming problem, start programming for autonomous setup of DAVS

- flash firmware, etc

- made acquisition and have seen: date was not setup and hydrophone had only negative signals. Signals appeared ok on VS1 and VS2.

- setup time synchro by installing ntp server on my computer and synchronizing DAVS with magnet and through ethernet cable (complex procedure, see Fred's email); this was performed with success and tested with new acquisition; date holds with backup system battery;

- found holding PCB out of place and attempted to put it back in the connector to solve the hydrohone power supply shift problem. Success with the connection of the board but the signal on the hydrophone was still biased.

- a suggestion from Fred to replace streaming box AC - 24V DC transformer by a pair of 12V batteries (borrowed from the ITC system) and the streaming now works with no problem, using the 110 m ethernet cable and the TP-1.

DAY 26-9 (10h-wind 20kn, 1.5m waves)

- deploy aquascat in the port, 6m water depth, start recording @12h local;

- test flashing DAVS back to streaming mode

- test streaming with new streaming box setup (using batteries, instead power supply)

- close DAVS and test streaming again

- 19h wind and sea decreased significantely

DAY 27-9 (calm weather)

- 09:45 local time, DAVS deployed on streaming mode, attached to STARESO mooring @ 5.5m depth

- 09:53 start recording (RPi is in PT time = FR-1 = 08h53 start time)

- 10:00 local time, deploy ITC

- 11:00 doing CTD on pier

- 13:30 mooring of Cedric's receivers with Julie

- doing three CTDs + GPS location of Lubell source CTD near optode mooring = N42 34.796 E008 43.515

Lubell source position SRC18(Garmin) = N42 34.790 E008 43.495

CTD near 3rd buoy (Cedric) = N42 34.566 E008 43.751

CTD near 1st buoy (Cedric) = N42 34 E008 43

- signals checked at 21h: 60GB filled

DAY 28-9 (calm weather)

- 09:00 local check DAVS OK (106GB), copy files for test

- 10:45 local, change batteries of DAVS streaming

- exchange with Fred about reading of atitude sensors

- went to beach after lunch

- 19h - check DAVS, OK, copied some files

DAY 29-9 (forecast: calm weather)

- check DAVS

- start processing of DAVS signals

* meteo data (low station - Alberto Borges)

* bathymetry

* GPS location of string

* sea data (optodes - Alberto Borges)

* CTD data

* biological data ?

* readers for data + atitude sensors

- stop energy on DAVS and Lubell @13:30

- start recover @ 13:45 - end @ 15:00, in order: aquascat, ITC,

source, DAVS, SR1s

- backup data

SR-1 5m No.1-SDcard

SR-1 7m No.2-SDcard

- pack boxes

Posicoes tiradas pelo Rui Santos

Fonte: N42 34.794 - E008 43.495

SR1+DAVS: N42 34.807 - E008 43.505

===Silvie information

Loic Kever - carapus acus

Eric Parmentier - sound by specie

Pinnegar - Chromis chromis abundance, review

DAY 30-9

- depart from STARESO

Comments for improvement

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DAVS electronics:

- improve mechanics so PCBs do not move

- improve operation with everything should be done through the connector without opening the box: streaming, change from streaming to autonomous, fixed card, configure, download data, charge batteries.

- improve attachment: take example on the CTD, where two rings go around the body and fix a rope or wire; this fixing should be with a mobile piece and a large screw (porca de orelhas) so it can be done by a diver; at the end of the plastic part another metallic eye should make it possible to pass a rope or a plastic stripe to attach to a wider structure (not a rope) either by a diver underwater or on land before deployment on a specific mooring.

- memoria SSD em vez de cartÃ£o SD ?

Streaming box:

- fix transformer noise

- attach all components

- buy a suitable box

- should it be operable with a battery / mains ?

- swapable disks

- WiFi and wired ?

DAVS report

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- missing figures or pages

- DeviceDetect information

- WAV reader ?