CRUISE REPORT

PASSAGE

B/O Ramón Margalef, Cruise **PASSAGE23**,

16/11/2023 – 23/11/2023, Cádiz Port (Spain) – Cádiz Port (Spain)

Project Logo / Picture etc.

PASSAGE
ERC Starting Grant

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PASSAGE23 Shipboard Scientific Party and R/V Ramón Margalef Crew

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1 Summary

Cruise PASSAGE23 started on the 17th of November from Cádiz Port (Spain) and ended on the 23rd of November at Cádiz Port. The cruise took place aboard the R/V Ramón Margalef.

During the cruise, two mooring lines were deployed on the southwestern Portuguese margin (Fig. 1). Each mooring line was equipped with two sediment traps and three different types of hydrographic sensors to measure turbidity, current speed, temperature, and salinity. The mooring lines were deployed at 2625 and 1515 meters water depth (mwd) using train wheels as anchors.

CTD profiles and seawater samples were collected at 21 stations along the southwestern Iberian margin with a 12-bottle rosette. Sea water was filtered with a filtration ramp at selected water depths on cellulose filters for ecological studies and on glass fiber filters for carbon cycle studies.

Surface sediment samples were collected whenever possible by two types of corers: a brand-new monocorer from *Unidad de Tecnología Marina* (UTM-CSIC) that descends attached to the rosette and a small box-corer loaned by the *Instituto Español de Oceanografía* (IEO). Monocorer and box-corer tubes were sampled aboard at 1-cm intervals using a handcrafted core extruder.

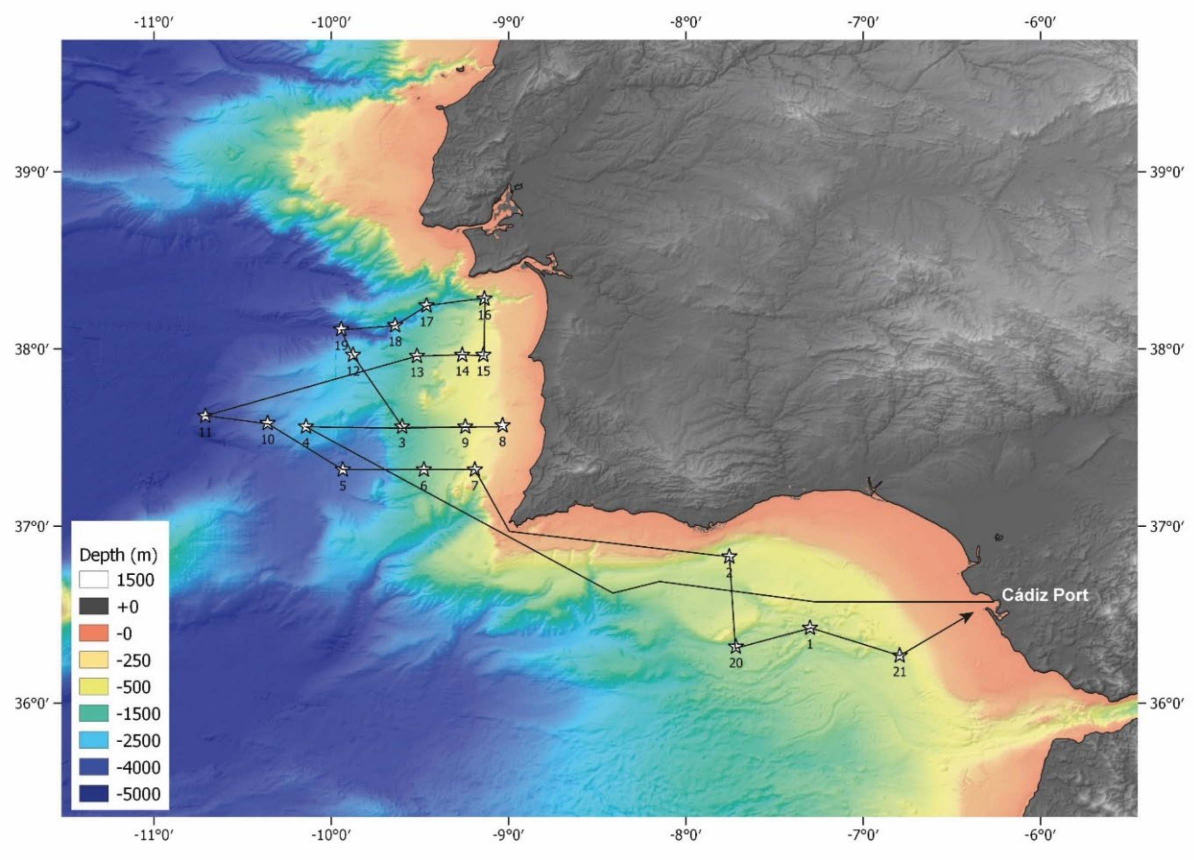

Fig. 1. Working area in the SW Iberian margin, sampling stations (white starts), and track chart of R/V Ramón Margalef during Cruise PASSAGE23. Bathymetry from GEBCO Compilation Group (2023).

2 Research Programme/Objectives

Most paleoclimate research from marine sediments is based on the assumption that the climate signal encapsulated in marine sedimentary components (microfossils, organic matter, etc.) reflects that of the underlying water column at the time of their synthesis. However, a large body of literature indicates that a large part of these components might have originated previously in distant locations, being subsequently transported and deposited on the seabed, which implies the introduction of asynchronous and allochthonous climatic signals (Ausín et al., 2022; Mollenhauer et al., 2003; Ohkouchi et al., 2002). This evidence calls into question the fidelity of paleoclimate records (Ausín et al., 2019). Furthermore, the magnitude of spatiotemporal biases in paleoclimate records is likely to vary as a function of past hydrodynamic changes (Ausín et al., 2021; Magill et al., 2018). This project aims to directly assess the impact of hydrodynamic processes on marine particles and explore their implications for paleoceanographic studies. Specifically, this research aims to: (i) estimate the contribution of allochthonous/asynchronous material; (ii) determine the scope and nature of the specific modes of particle transport; (iii) quantify the potential of this transport to bias derived climate signals such as temperature or productivity; (iv) generate a proxy for hydrodynamic changes with the potential to bias climate signals; and (v) correct for spatiotemporal biases of proxy records. This work will provide a crucial advance in our ability to robustly interpret climate signals on a sub-millennial scale. To achieve these objectives, we intend to deploy two mooring lines with 2 sediment traps each in the southwestern Iberian margin (Fig. 1) and collect them after a 1 year sampling period. One mooring line will be deployed at a station on the *Promontório dos Principes de Avis*, near the location of IODP Site U1385 (Expedition 339 Scientists, 2013) and SHAK06-5K (Ausín et al., 2019) marine core. The second mooring line will be deployed at the same latitude, but on the middle of the slope, at approximately 1520 mwd. A turbidimeter, a current meter, and a temperature and salinity sensor will also be placed next to each trap. A second cruise must be carried out 12 months after this first cruise to collect the samples from the traps and the data recorded by all the sensors. During the two cruises, CTD profiles, water sampling, and surface sediment sampling at various locations in the region will be performed to provide additional information on the provenance and transport pathways of the sedimentary particles that encapsulate climate information.

3 Narrative of the Cruise

The Scientific Party from Salamanca arrived at Cádiz Port on the 16th of November of 2023 at 13:00. Members from other institutions would arrive sequentially along the evening. The Scientific Party is composed of 7 scientists, 3 members from the *Unidad de Tecnología Marina* (UTM), and 1 scientific outreach illustrator. Upon arrival, B. Ausín and N. Schamuells went to IEO Cádiz to pick up the monocorer that was sent there by the UTM and to borrow the boxcorer to be used during the cruise. The truck from Salamanca with all the components and instruments for the two moorings arrived at the port at 15:30. One hour later, we loaded the scientific instrumentation for the mooring lines with the help of a crane that was hired for that purpose and distributed on deck. We unpacked the boxes and cases, organized the laboratory, and started to organize the small components of the moorings. During the evening, we also loaded the ropes for the moorings on the windlass. The ropes for Mooring PA-I were loaded on the starboard windlass and the ropes for Mooring PA-II were loaded on the port windlass. We also began to assemble the small components: buoys, chains, shackles, etc., till nightfall (Fig. 2). During dinner, we celebrated Gervaise Barre's birthday.

Fig. 2. Mooring components organized on deck on the evening of the 16th of November 2023.

At 9:00 on the 17th of November, the Scientific Party attended a briefing on general rules and safety given by the First Official. We also tried on the safety suits and received a guided tour of the vessel. Limited food supplies arrived at Cádiz Port at 11:30 and were immediately loaded aboard. We initially planned to sail for four days based on these limited food provisions to pursue the critical objectives of the cruise: deployment of the mooring lines and seawater and sediment sampling at stations PA23-St4 and PA23-St3. We then initiated the transit to the first mooring station, PA23-St4. The Scientific Party continued assembling the components of the moorings. The temperature was around 20°C and the sea was calm under 9 knots of wind. We also started testing and programming all the instruments for deployment (4 current meters, 4 turbidimeters, 4 CTs, 2 conical and 2 cylindrical sediment traps, and two acoustic releasers). Tasks on deck continued till nightfall whereas instrument programming lasted until midnight.

The transit to the first station lasted all night and we arrived at **PA23-St4** on the 18th of November at approximately 9:00. From then, the Scientific Party would work divided into two groups: the day shift (working from 8 am to 8 pm) and the night shift (working from 8 pm to 8 am). Weather conditions in the first station were good: calm seas and 21°C air temperature. We deployed a rosette-CTD with a monocorer. The majority of the Scientific Party had no previous experience in seawater subsampling and filtering and corer slicing, so we spent some time explaining and learning how to perform these tasks. Nevertheless, a manual with the sampling protocol and labeling procedure had been handed out several days before the cruise to all the scientists. The latter sped up the learning process onboard, which was fairly quick. At our first station, the seawater from seven water depths was filtered on two types of filters (cellulose and glass fiber filters) and the monocorer was sliced at 1 cm onboard. This would be the general procedure followed at all stations at which seawater, monocorer, and/or boxcorer were collected. While part of the day shift handled these samples, the others prepared the mooring for its deployment. Several liters of seawater were used to fill the cups of the sediment trap with a mixture of seawater, formaldehyde, and sodium borate as buffer. A blank of each batch of solution was kept to be stored at Salamanca University. The pH of the cups was measured with a pH-meter. The mixing was performed within the fume hood of the vessel and the cups were filled on deck while wearing special protective gear (laboratory overall with hood, goggles, and gloves) (Fig.3). Deployment of **Mooring PA-I** started at 14:05 and ended successfully at 15:37. Details on the maneuver and the components of the mooring are given in section 4.1. More than half an hour after deployment, the anchor was assumed to reach the bottom and, after switching off the echosounder to avoid interferences, we successfully communicated with the acoustic releaser, which was at 2638 mwd. Because PA23-St4 is less than 0.75 nautical miles away from one of the alternate sites proposed to be drilled during the International Ocean Discovery Program (IODP) Expedition 401 (Flecker et al., 2023), which would take place from the 10th December 2023 to the 9th February 2024, an information email with the coordinates of the mooring was sent to the co-chief scientists of IODP Exp. 401 on the 22nd of November. We calculated that a safety radius of 0.86-1.08 nautical miles around the mooring would be desirable if IODP alternate site U1385 SHACK-4C was finally drilled. The estimate was based on the uncertainty associated with the mooring position and the estimate of the possible tilt of the mooring under strong currents and tidal waves.

Station PA23-St4 was abandoned at 17:05 and we arrived at the second mooring station, **PA23-St3**, at 19:40. At our arrival, we deployed a rosette-CTD, a monocorer, and a boxcorer. The night shift took over but the day shift helped in the beginning to ensure everyone knew the sampling procedures and labelling protocols and to facilitate a smooth transition. The sampling of seawater and sediments continued as usual while other members of the day shift worked on deck to assemble and review the components of Mooring PA-II. Part of the water sampled with the rosette was used to fill the cups of the sediment traps like for Mooring PA-I.

R/V Ramón Margalef arrived at **PA23-St8** on the 19th of November at 1:00 to deploy a rosette-CTD, a monocorer, and a boxcorer. The monocorer was lost and only the topmost cm was recovered. The boxcorer allowed the recovery of a 13-cm core. The sea remained calm with winds of 8 knots and high air temperature. Station **PA23-St9** was sampled at 2:50 and left at 3:50 after successfully deploying a rosetta-CTD, a monocorer, and a boxcorer. We then transited back to **PA23-St3**, which was reached at 8:35 with clear skies, high air temperature, and calm sea. The day shift filled the cups of the tubular sediment traps. The traps were hung from the ship's crane to facilitate the engagement of the rotary disk with the cups (Fig. 3).

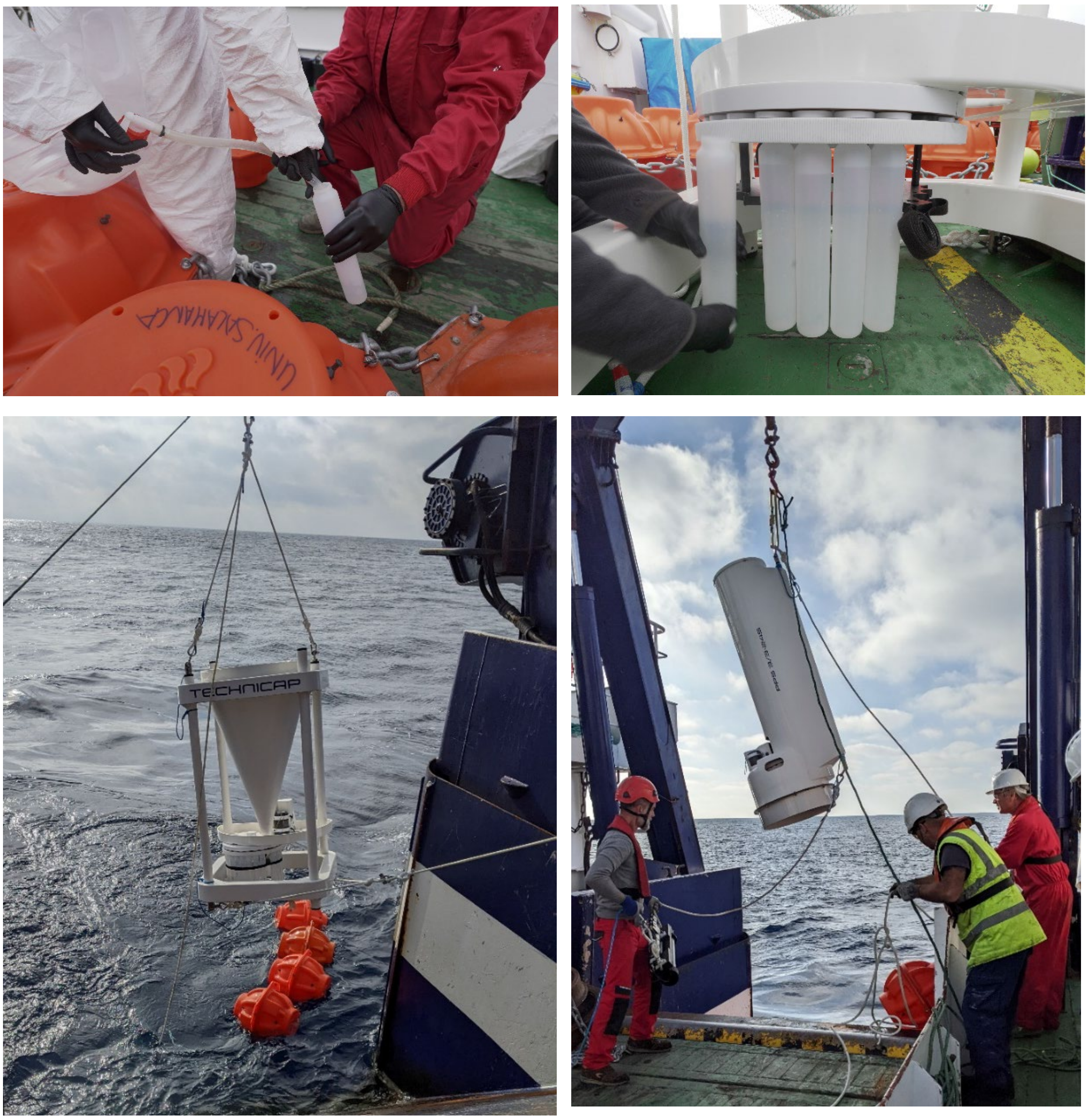

Fig. 3. Mooring deployment. Cup filling (upper left) and rotary disk (upper right). Deployment of the Technicap PPS 6/2 sediment trap "*Lisístrata*" from Mooring PA-I at PA23-St4 (bottom left) and Technicap PPS 3/3 "*Esbarzers*" (bottom right) from Mooring PA-II at PA23-St3.

The maneuver was carried out without difficulty and **Mooring PA-II** was fully deployed in approximately 45 minutes. Details on the maneuver and the components of the mooring are given in section 4.1. Dolphins were spotted around the furthest buoys. We waited until the anchor reached the bottom and successfully communicated with the acoustic releaser at 1487.3 m water depth. We continued to **PA23-St12** and deployed a rosette-CTD, a monocorer, and a boxcorer. Seawater and sediments were sampled as usual. Station **PA23-St19** was reached at 18:25. Because this is a deep station (4343 mwd) and the wires of the rosette and the boxcorer were shorter than the station depth, only the top 1000 m were sampled for seawater at six water depths, and no sediments were retrieved at this station. Weather conditions remained calm with little wind and high air temperature. Station **PA23-St18** is also deep (3319 mwd) but we tried a rosette-CTD with a monocorer. Seawater from 5 depths was sampled, but the monocorer only retrieved 3 cm of surface sediment. We believe the monocorer hit the bottom on the wall of the canyon because there was sediment on the top part of the monocorer and the isobaths were very close to each other. This station was left at 23:00.

We then headed to station **PA23-St17**, which was reached on the 20th of November at 00:15. We performed a rosette-CTD with a monocorer and a boxcorer. At the next station, **PA23-St16**, we performed a rosette-CTD with a monocorer. A school of dolphins accompanied us during seawater sampling swimming around the wire. The first boxcorer event failed (the box did not close) and a second successful event was performed immediately after. A similar situation occurred at the next station, **PA23-St15**, where two boxcorer events were performed because the box did not close during the first attempt. Monocorer and boxcorer recovery in this station was low (11 and 12 cm, respectively).

Some more provisions were supposed to arrive at Cádiz Port on the 20th of November. The plan was to transit to Cádiz Port to pick up these provisions and transit back to continue our work plan. However, because more provisions were never sent to the port, the PI and the Captain, in agreement with the Scientific Party and the R/V Ramón Margalef Crew, decided to continue with the limited provisions we had left and achieve as much work as possible. Operations for the two following stations (**PA23-St14**, and **PA23-St13**) were very successful (rosette-CTD with monocorer and boxcorer) and performed during the day with calm sea, warm and dry weather, and clear skies. Station **PA23-St11** was reached at 20:23. Because of its depth (4651 mwd), only a rosette-CTD was performed down to 1000 mwd for CTD logging and seawater sampling. Similarly, no boxcorer was performed at the next station, **PA23-St10** (3451 mwd), but the monocorer attached to the rosette allowed the recovery of a sediment core of 15 cm in length.

At 01:35 on November 21st, we headed to the next station, **PA23-St5**, while the sea progressed from smooth to slight. After finishing seawater filtering and sediment slicing for this station, no night shift would be ever required. Thus, for the following days, members of the day shift would only work from 07:00 to 16:00, whereas members of the night shift would only work from 16:00 to 23:00. The transit to station PA23-St5 was performed slowly overnight and the station was reached on the 21st of November at 08:10. PA23-St5 is a deep station (3626 mwd) and thus the boxcorer was not deployed. Nevertheless, the monocorer attached to the rosette allowed the recovery of an 18-cm core of muddy sediment. Station **PA23-St6** was reached at midday under moderate sea and a wind of 26 knots. The vessel was bouncing up and down but a rosette-CTD with a monocorer was performed without trouble, which allowed the recovery of a 26-cm sediment core. However, the boxcorer failed three times. It came empty every time because the cable would reach the bottom turning around the pin, preventing the box from closing due to the movement of the vessel. After trying for 1.5 h, we moved on to the next station without a successful boxcorer event. Transit to **PA23-St7** took approximately 2h under moderate sea. A rosette-CTD with a monocorer was performed at arrival, but the monocorer came up empty, probably due to the type of seabed. The boxcorer brought no sediment, but some broken pieces of dead coral and small pebbles.

The transit to the station **PA23-St2** was performed slowly overnight. A rosette-CTD was deployed at 07:00 on the 22nd of November under slight sea and 14°C of air temperature. The NMEA positioning did not work in the beginning but it was fixed 10 minutes later. Both a monocorer and a boxcorer were recovered without trouble. Station PA23-St2 was followed by **PA23-St20** (equivalent to IODP Site U1390), where rosette-CTD, monocorer, and boxcorer were successfully performed and sampled. Similar weather conditions allowed the same successful sampling in the next station, **PA23-St1**. Here, the monocorer and the boxcorer were sliced at 0.5 cm resolution due to the high sedimentation rate that characterizes this site. At station **PA23-St21** (equivalent to IODP Site U1388), a rosette-CTD with a monocorer was performed, but the monocorer came up empty. The boxcorer, nevertheless, came up full and allowed the retrieval of a 17-cm sediment core. Operations ended at 21:00.

A list with the information on all the stations is given in Table 1.

The Scientific Party finished filtering the seawater and sampling the last boxcorer. Immediately after, the Scientific Party started to pack the laboratory tools and materials and organize the remaining buoys, chains, shackles, and tools into three pallets. Two pallets would be shipped the day after to the University of Salamanca and one pallet would be shipped to the University of Barcelona.

The transit back to Cádiz Port was done very slowly overnight, as the R/V Ramón Margalef was not assigned a dock until the next morning. The vessel docked at Cádiz Port early in the morning on November 23rd. At 7:00 the whole Scientific Party met in the dining room to celebrate the 29th birthday of Javier Pérez-Tarruella. Afterward, we cleaned our cabins and the laboratory and finished packing samples and mooring materials. The Scientific Party from Salamanca disembarked in the morning, while the other members left later that evening or the day after.

Table 1. List of mobilization/demobilisation date and station information. DP stands for dynamic positioning.

17/11/2023	Departure from Cádiz Port

Date	Station	Latitude	Longitud	Depth (m)	Start DP	End DP	Total DP
18/11/2023	PA23-ST04	37º 33,680 N	010º 08,530 W	2625	09:15	14:15	05:00
18/11/2023	Mooring PA-I [PA23-St04]	37º 33,680 N	010º 08,530 W	2625	15:05	17:05	02:00
18/11/2023	PA23-ST03	37º 33,673 N	009º35,999 W	1515	19:45	22:12	02:27
DAY 01							09:27
19/11/2023	PAS23-ST08	37º 34,090 N	009º 02,020 W	216	01:00	01:50	00:50
19/11/2023	PAS23-ST09	37º 33,610 N	009º 14,650 W	581	02:50	03:50	01:00
19/11/2023	Mooring PA-II [PA23-St03]	37º 33,673 N	009º35,999 W	1515	08:35	11:30	02:55
19/11/2023	PAS23-ST12	37º 57.970 N	009º 52,510 W	2497	14:15	17:25	03:10
19/11/2023	PAS23-ST19	38º06,662 N	009º56,626 W	4343	18:25	19:15	00:50
19/11/2023	PAS23-ST18	38º 08,03 N	009º 38,39 W	3319	20:35	23:00	02:25
DAY 02							11:10
20/11/2023	PAS23-ST17	38º 14,701 N	009º 127,717 W	2420	00:10	03:15	03:05
20/11/2023	PAS16-ST16	38º17,018 N	009º08,194 W	790	05:00	06:30	01:30
20/11/2023	PAS23-ST15	37º 57,950 N	009º 08.580 W	366	08:25	09:35	01:10
20/11/2023	PAS23-ST14	37º 57,970 N	009º 15,650 W	572	10:10	11:20	01:10
20/11/2023	PAS23-ST13	37º 57,57 N	009º 30,99 W	1335	12:35	14:25	01:50
20/11/2023	PAS23-ST11	37º 37,331 N	010º 42,565 W	4566	20:20	21:10	00:50
20/11/2023	PAS23-ST10	37º 34,889 N	010º 21,534 W	3450	23:00	01:35	02:35
DAY 03							12:10
21/11/2023	PAS23-ST05	37º 19,023 N	009º 56,202 W	3627	07:50	10:50	03:00
21/11/2023	PAS23-ST06	37º 19,120 N	009º 28,650 W	1209	13:30	16:15	02:45
21/11/2023	PAS23-ST07	37º19,114 N	009º11,383 W	344	18:20	19:00	00:40
DAY 04							06:25
22/11/2023	PAS23-ST02	36º 49,690 N	007º 45,323 W	563	07:50	09:05	01:15
22/11/2023	PAS23-ST20	36º 19,031 N	007º 43,150 W	1100	12:15	13:45	01:30
22/11/2023	PAS23-ST01	36º25,478 N	007º17,995 W	652	15:55	17:00	01:05
22/11/2023	PAS23-ST21	36º16,123 N	006º47,654 W	665	19:55	21:00	01:05
DAY 05							04:55

23/11/2023	Arrival at Cádiz Port

4 Preliminary Results

4.1 Mooring deployment

Figure 4 shows the schematic representation of the two mooring lines deployed during the cruise, and the specific composition of each mooring is detailed in Table 2. Mooring PA-II was deployed at station PA23-St4 on the *Promontório dos Principes de Avis*, an undersea hill southwest of Lisbon, at 2625 mwd. Mooring PA-II was deployed at station PA23-St3 at the same latitude as Mooring PA-I, on the mid-slope at 1515 mwd.

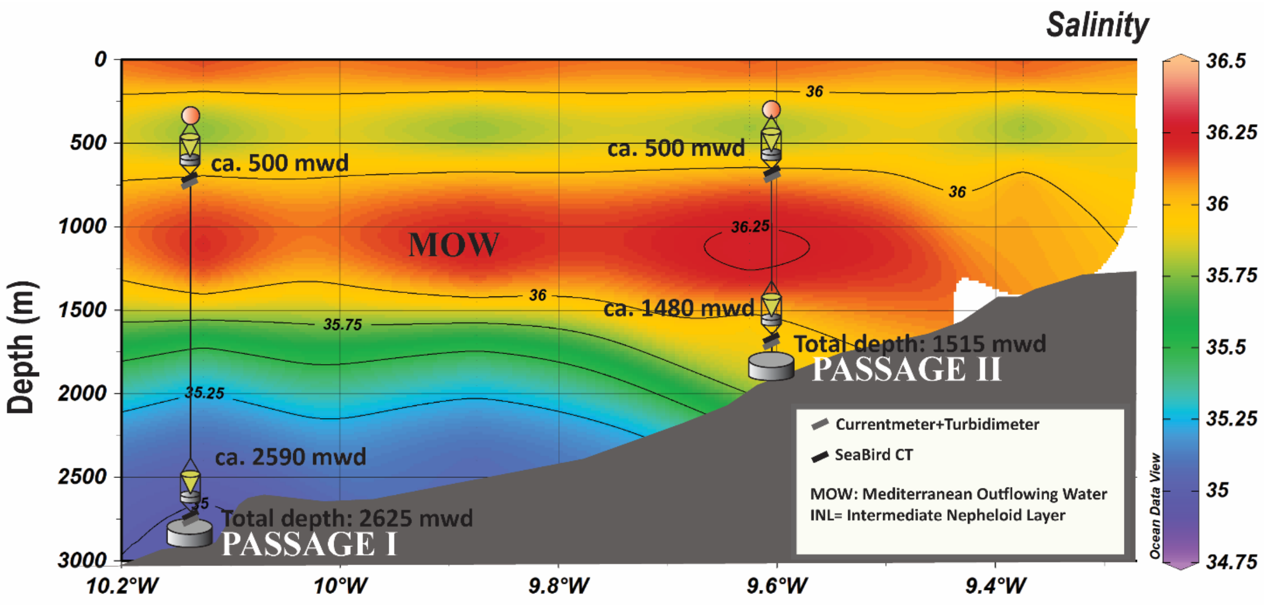

Fig. 4. Schematic representation of the mooring lines Mooring PA-I and Moorin PA-II and salinity section from the World Ocean Atlas (Zweng et al., 2018) plotted with Ocean Data View (Schlitzer and Reiner, 2023).

Table 1. List of mooring line components.

Component	Mooring PA-I	Mooring PA-II
Sediment trap [Technicap PPS6/2]	2	
Sediment trap [Technicap PPS3/3]		2
Currentmeter [Aquadopp DW 3K]	2	2
Turbidimeter [Seapoint]	2	2
Conductivity and temperature sensor [SBE-37SMP]	2	2
Acoustic releaser [Oceano R5]	1	1
Fishing buoys	4	4
Buoys [Vitrovex 17"]	20	14
Sub-surface buoy [SF35" 1500]	1	
Galvanized chain 14 mm in m	26	20
Dyneema 6 mm in m	2215	1015
Polyester 14 mm in m	70	50
Various thimbles	41	19
Various shackles	89	53

For the deployment of Mooring PA-I (Fig. 5), all 500 m sections of 6 mm dyneema rope were joined together by two high-strength galvanized shackles and a galvanized pear in between to facilitate the maneuver. The rope was then wounded on the windlass.

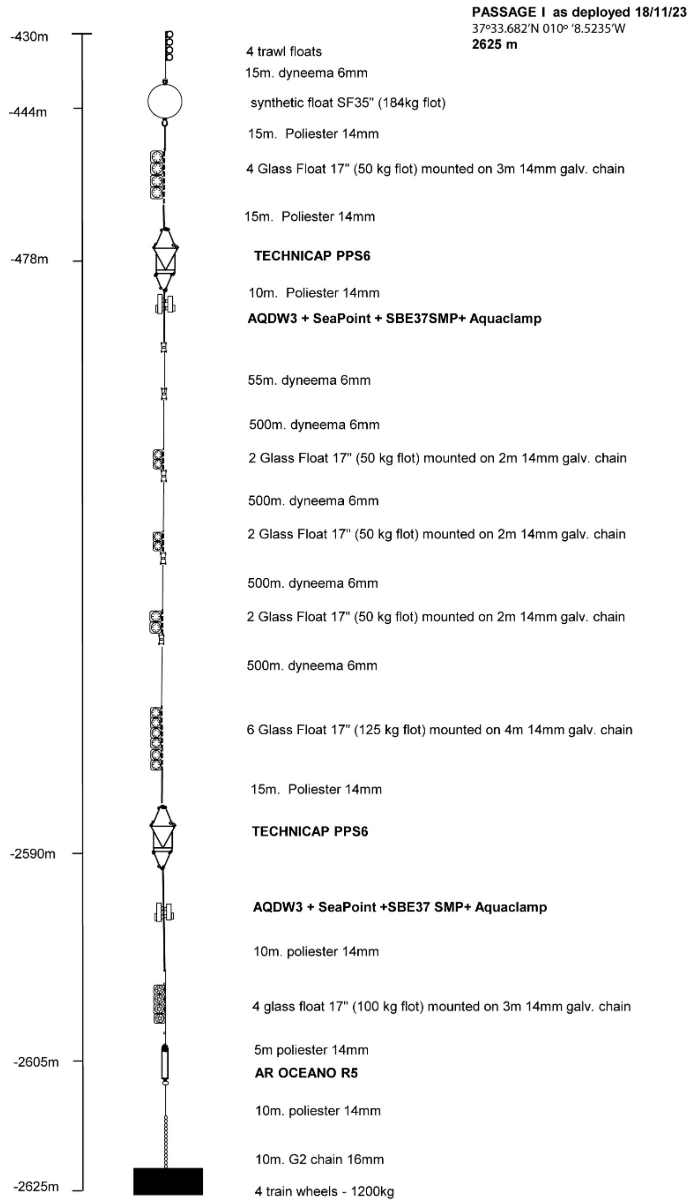

Fig. 5. Schematic design of Mooring PA-I as deployed on the 18/11/2023 at PA23-St4 and estimated depth of each component without current.

The ship approached the station and remained at a distance of 3 miles from the anchoring point. The four fishing buoys at the head of the line were realeased by hand. Immediately afterwards, we released the sub-surface buoy by using a trigger hook. The line was then held below the 4 glass buoys and above the sediment trap. Once the sub-surface buoy was in the water, the trap was hoisted using the gantry, while the instruments were held underneath by hand. When the trap was located above the water, the 4 buoys were released. The latter followed the line and pulled on the upper part of the trap, at which time it was released into the water, dragging the instruments that were below until these were far from the ship. To carry out this maneuver, the 55 meters of dyneema were kept firm so that the instruments did not touch the transom and the line was already attached to the dyneema rope, which was attached to the windlass.

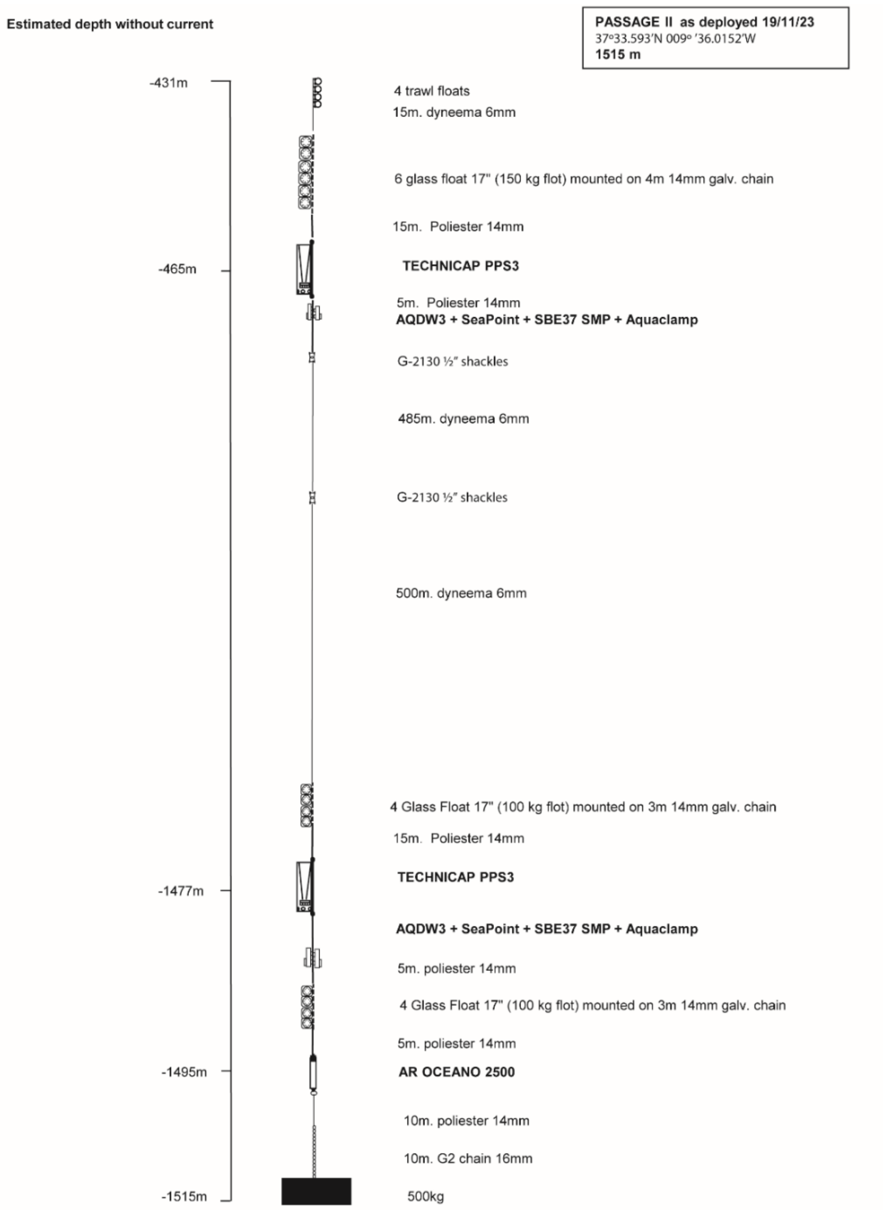

Fig. 6. Schematic design of Mooring PA-II as deployed on the 19/11/2023 at PA23-St3 and estimated depth of each component without current.

From here, the rope wounded on the windlass was sequentially released with care to avoid entanglements, making holds in the pears at each end of the section and inserting 2 glass buoys. When the last section was finished, the 6 glass buoys above the sediment trap were held and the maneuver was carried out in the same way as for the first sediment trap. Once the second sediment trap was in the water along with the instruments below, the 4 following bouys and the acoustic releaser were released. Finally, the four train wheels were released with a hook.

The maneuver to deploy Mooring PA-II was very similar to that of Mooring PA-I with the difference that Mooring PA-II is shorter (ca. 1500), its two sediment trap were cylindrical, it does not need a subsuface buoy, and only two train wheels were neccessary as anchor. Here, the distance between the sediment traps and the sensors was shorter, which complicated the maneuver a little. The acoustic releaser became entangled with the rope that held it. We stopped the maneuver and the releaser was recovered by hand to be able to remove the turn that the rope had made and it was set off again, leaving the line correctly stretched with the two train wheels on the deck that were released afterward with a hook.

4.2 Seawater sampling with rosette-CTD

CTD casts were recorded with a CTD SBE 911 plus (s/n 09P27491-0670) equipped with several sensors (given between brackets) to measure the following variables:

- Conductivity- Max. depth 6.800 m. SBE 4C (s/n 90270-042688).
- Temperature- Max. depth 6.800 m. SBE 3plus (s/n 4169).
- Fluorometer/Turbidimeter- Max. depth 6000m. WETLabs ECO-FL-NTU (s/n FLRTD-034).
- Oxygen- Max. depth 7.000m. SBE 43 (s/n 90419-430270).
- Pressure- Max. depth 6.885m. (s/n 0670).
- Pump- Max. depth. 10.500m. SBE 5T (s/n 90160-053253).

A singlebeam echosounder (SIMRAD EA-600) with a working frequency of 12 kHz and 200 kHz was used to verify depth and seafloor morphology.
The downward and upward casts were performed at a constant velocity of 50 m/min.
The CTD was deployed down to 5 m above the seafloor at all stations except at the two deepest stations, PA23-St11 and PA23-ST19, where we decided to deploy the CTD for the top 1000 m, collect water, and continue to the next station.

Satellite data on sea surface temperature and chlorophyll a for each sampling date (Fig. 4) indicates surface waters cooled moderataly towards the end of the cruise along with an increase in primary productivity, the latter mostly influencing the shallowest stations of the SW Portuguese margin.

Fluorescense peaks coincide with oxygen peaks at most stations and are typically found right below the thermocline, between 25-100 mwd (Figs. 8 to 28). This situation indicates a stable upper water column and the absence of aparent upwelling conditions in most stations (all stations except for PA23-St2, PA23-St7, and PA23-St8), in agreement with satellite SST and Chlorofil data (Fig. 7). Fluorescence peaks are specially minor at PA23-St4, PA23-St5, PA23-St12, PA23-St13, PA23-St17, PA23-St18.

Surface mixing and a weak thermocline is visible at PA23-St7, wereas at PA23-St2 and PA23-St8 there is no thermocline and fluorescence is high for the first top 25 and 50 m, respectively. The latter is in agreement with higher Chlorophyll and lower SST satellite data from the satellite images at these two stations the day of sampling. These three stations (PA23-St7, PA23-St2, and PA23-St8) are located on the upper slope were favourable-upwelling conditions occur.

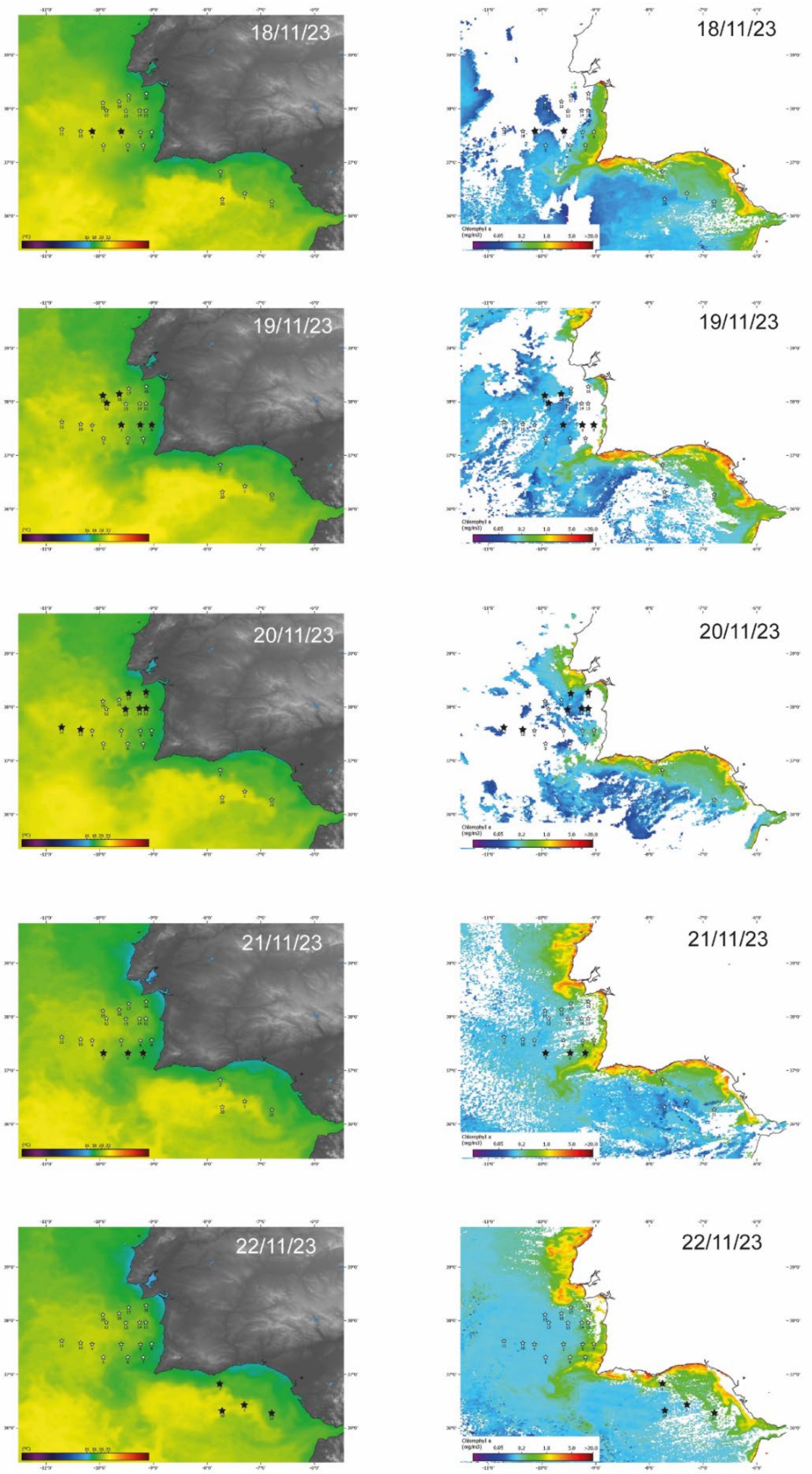

Fig. 7. Images of sea surface temperature (left, from JPL MUR MEaSUREs Project (2015)) and chlorophyll a (right) from combined Terra-Aqua satellites (NASA Ocean Biology Processing Group, 2018) for each day of sampling. Sampled stations on each date are marked with black stars.

The subsurface temperaturae maxima at all stations is related to the North Atlantic Central Water of subtropical origin (NACWst). The NACW of subpolar origin (NACWsp) is marked by an oxygen increase and temperature decrease between 400 and 500 m in some stations (e.g., PA23-St10 and PA23-St20).

The Mediterranean Outflowing Water (MOW) is discernible in CTD profiles and indicated by a salinity and temperature increase, in parallel with a decrease in oxygen concentration. In some stations, both the Upper and the Lower cores of MOW are present (PA23-St5, PA23-St5, PA23-St6, PA23-St10, PA23-St11, PA23-St12, PA23-St13, PA23-St17, PA23-St18, and PA23-St20 and PA23-St21) whereas MOW is not present at stations PA23-St7, PA23-St8, and PA23-St15. Only the upper core of the MOW is present at the very bottom of stations PA23-St9, PA23-St14, PA23-St16, and PA23-St19.

The North Atlantic Deep Water (NADW) is found at the deepest stations (except at PA23-St11 and PA23-St19 because only the top 1000 m were recorded): PA23-St4, PA23-St5, PA23-St10, PA23-St12, PA23-St17, and PA23-St18. This water mass is observed at depth, below MOW, indicated by a temperature and salinity decrease and an oxygen increase.

Turbidity is typically low at all stations, sligtly oscillating around 0.15 NTU. A turbidity peak is observed at around 100-150 mwd of stations PA23-St1, PA23-St2, and PA23-St7 that is not associated to fluorescence maxima. Station PA23-St16 shows a turbidity peak at the top 200 m that becomes thinner but larger at station PA23-St17. These two stations are located on the Setúbal Canyon and such peaks might be related to sediment delivery from the continent chanelled by the canyon. Increased turbidity in association with the MOW is visible at stations PA23-St2 (on the bottom), PA23-St3 from 1100 mwd down to the seafloor with a minimum at around 1350 mwd, PA23-St6 at around 750 mwd, PA23-St9 at ca. 450 mwd, and PA23-St16 towards the bottom.

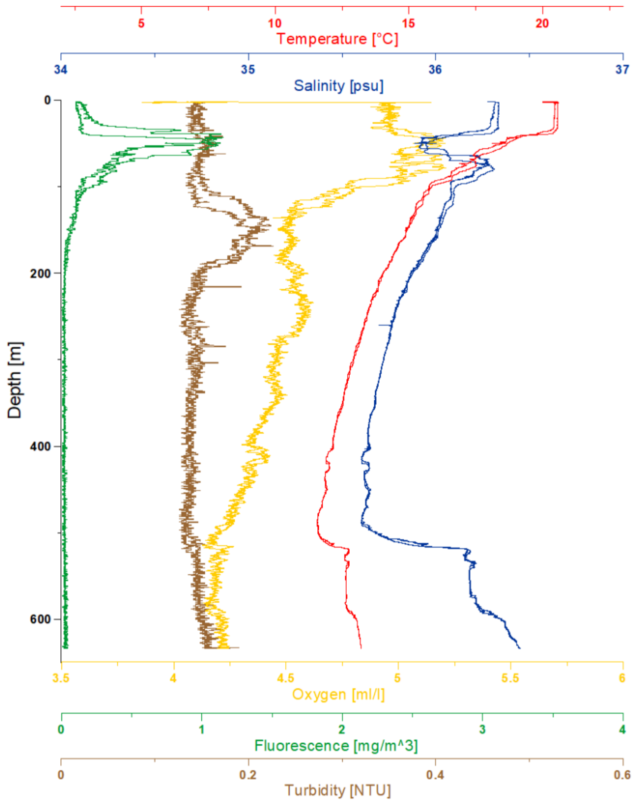

Fig. 8. CTD profile from station PA23-St1. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

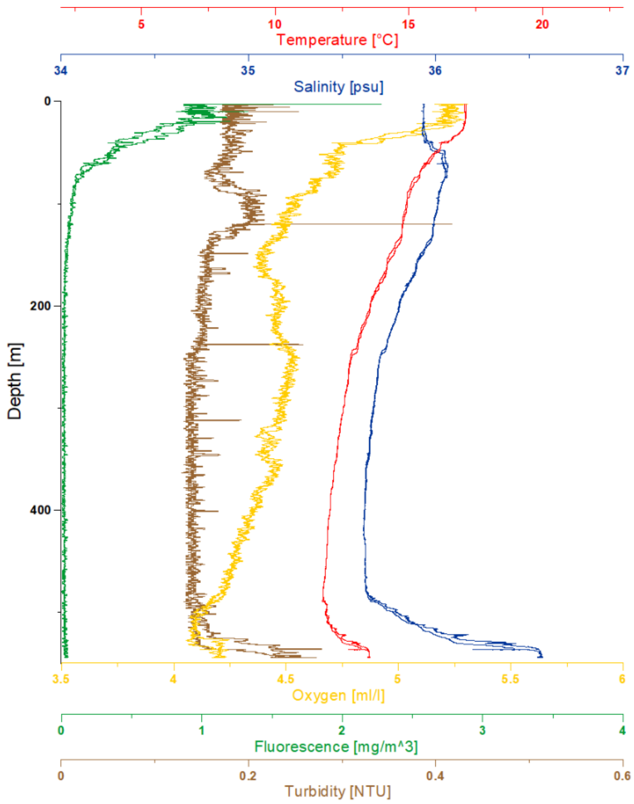

Fig. 9. CTD profile from station PA23-St2. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

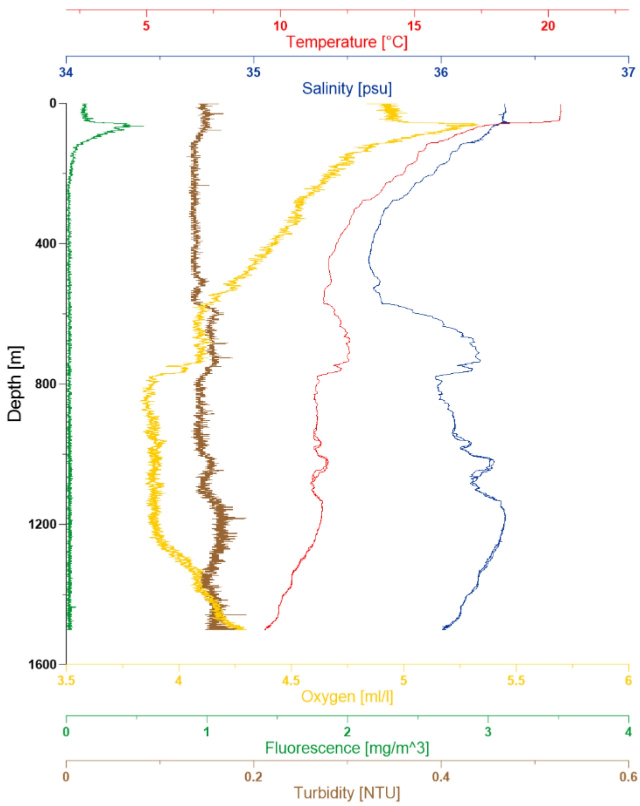

Fig. 10. CTD profile from station PA23-St3. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

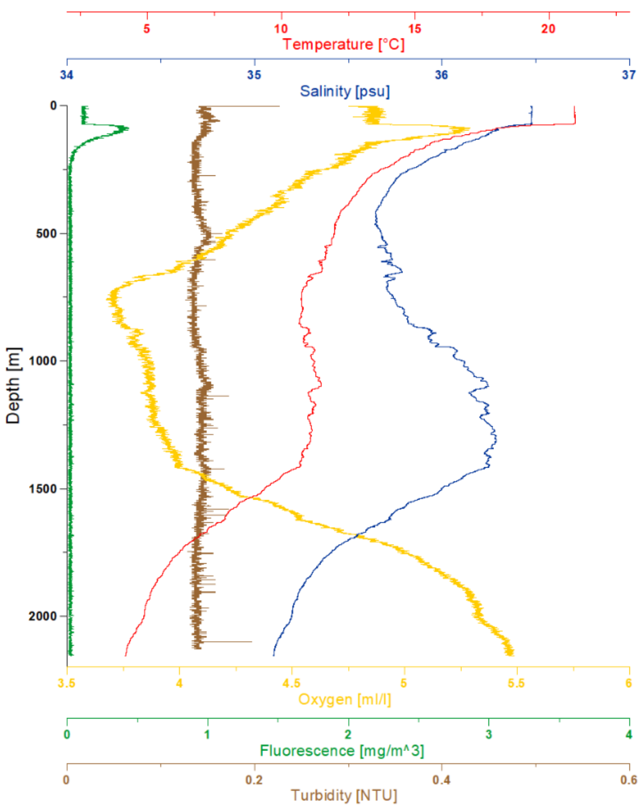

Fig. 11. CTD profile from station PA23-St4. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

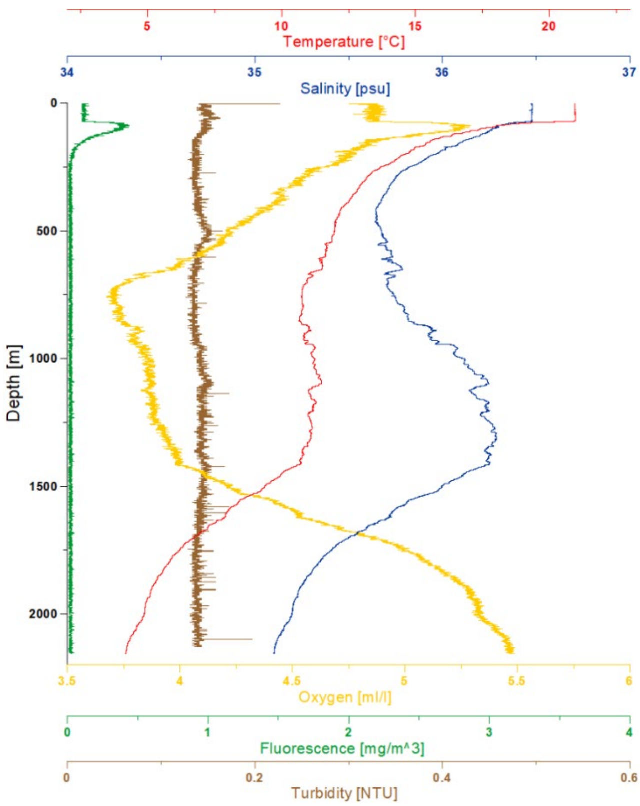

Fig. 12. CTD profile from station PA23-St5. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

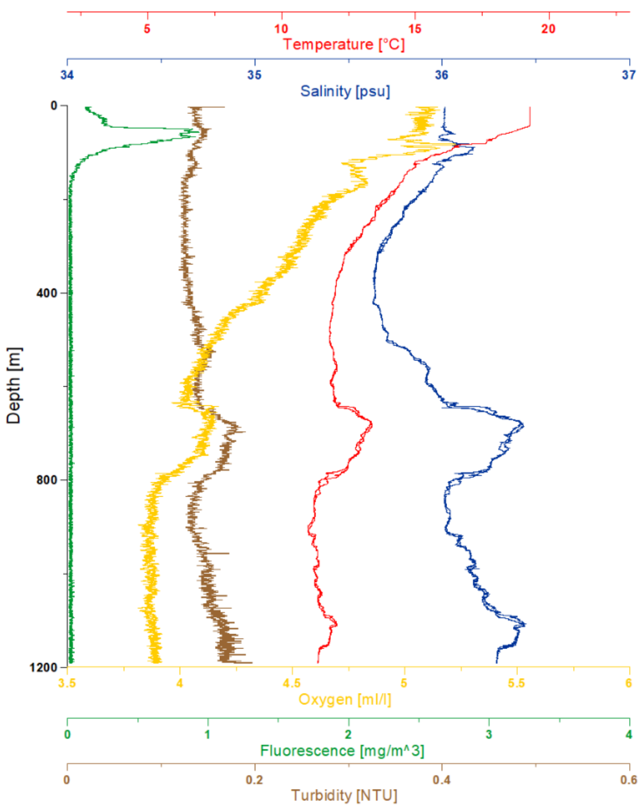

Fig. 13. CTD profile from station PA23-St6. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

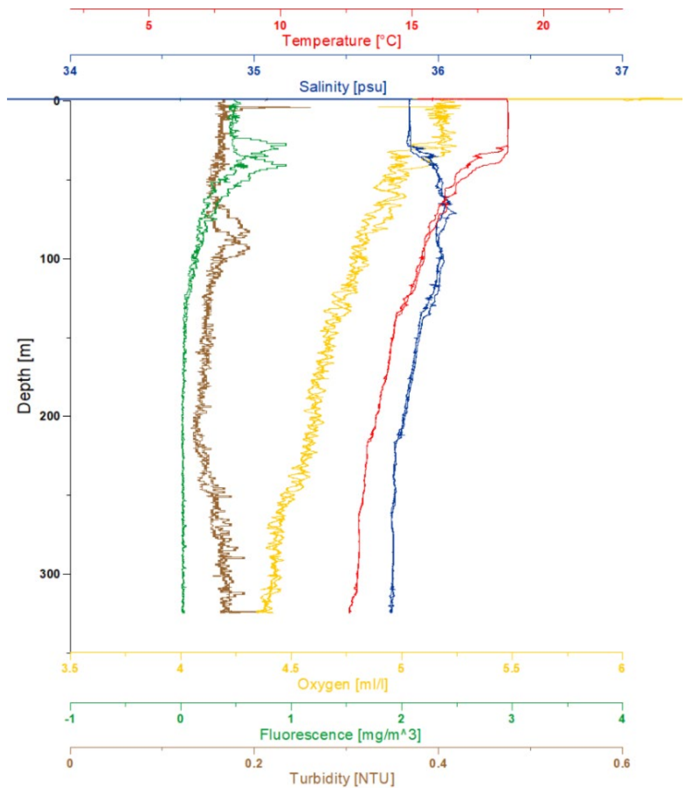

Fig. 14. CTD profile from station PA23-St7. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

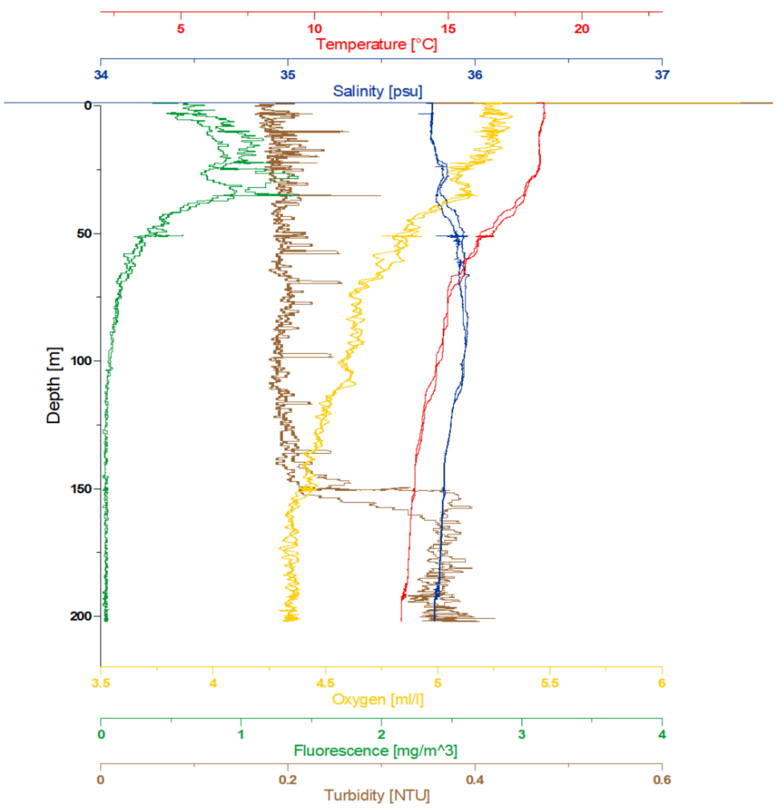

Fig. 15. CTD profile from station PA23-St8. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

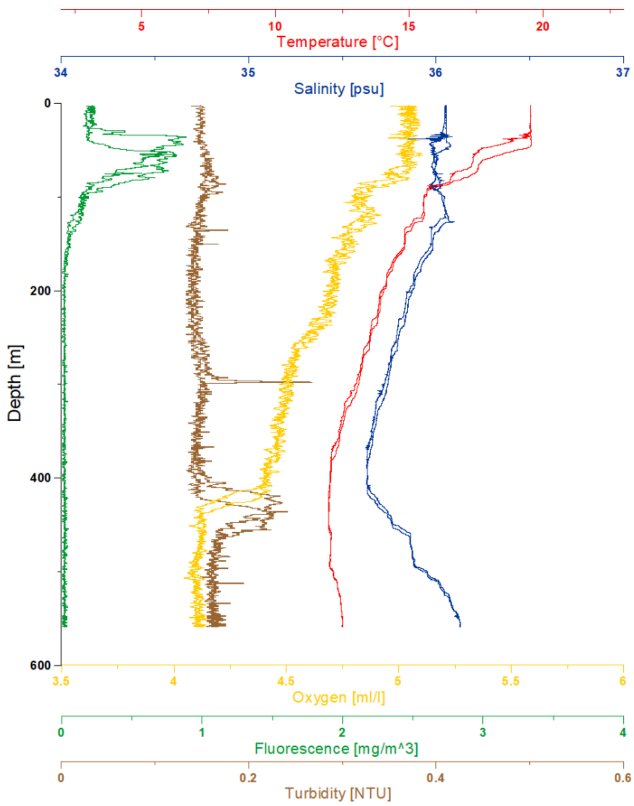

Fig. 16. CTD profile from station PA23-St9. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

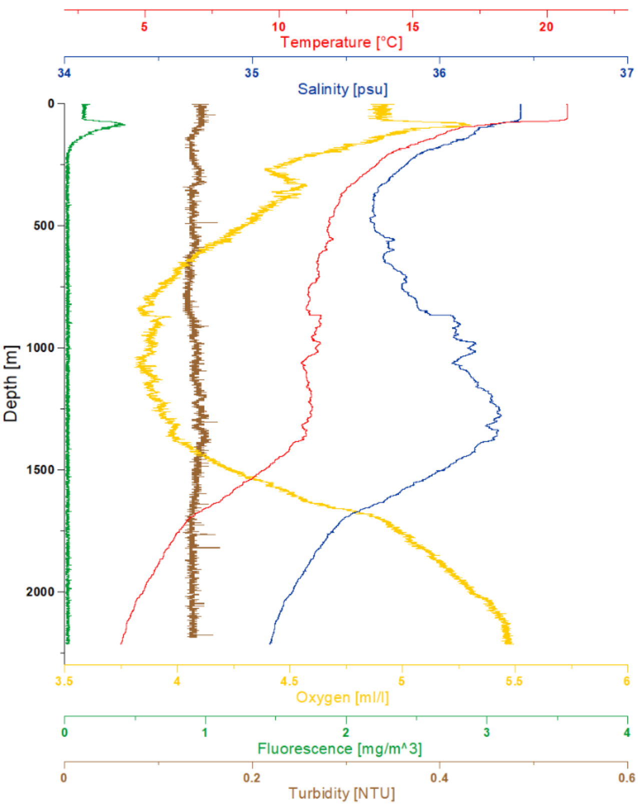

Fig. 17. CTD profile from station PA23-St10. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

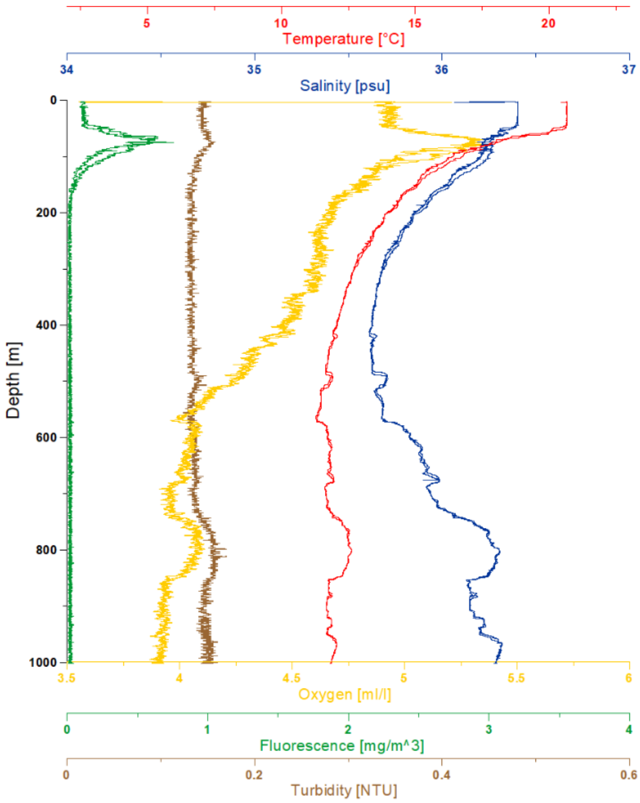

Fig. 18. CTD profile from station PA23-St11. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

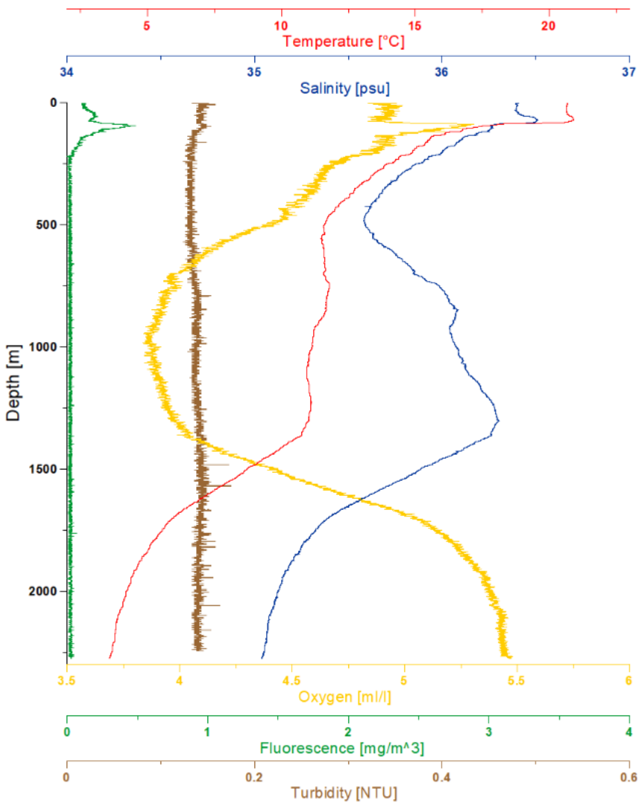

Fig. 19. CTD profile from station PA23-St12. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

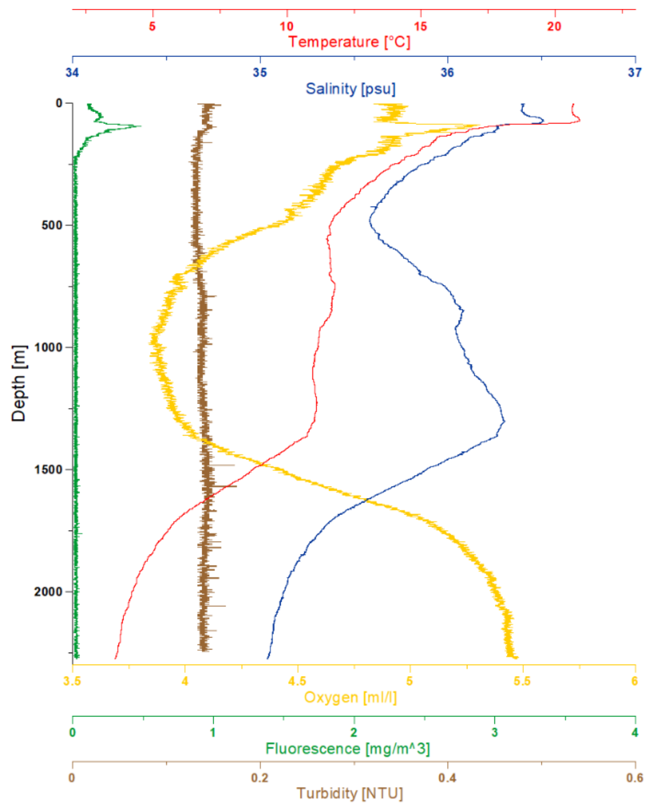

Fig. 20. CTD profile from station PA23-St13. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

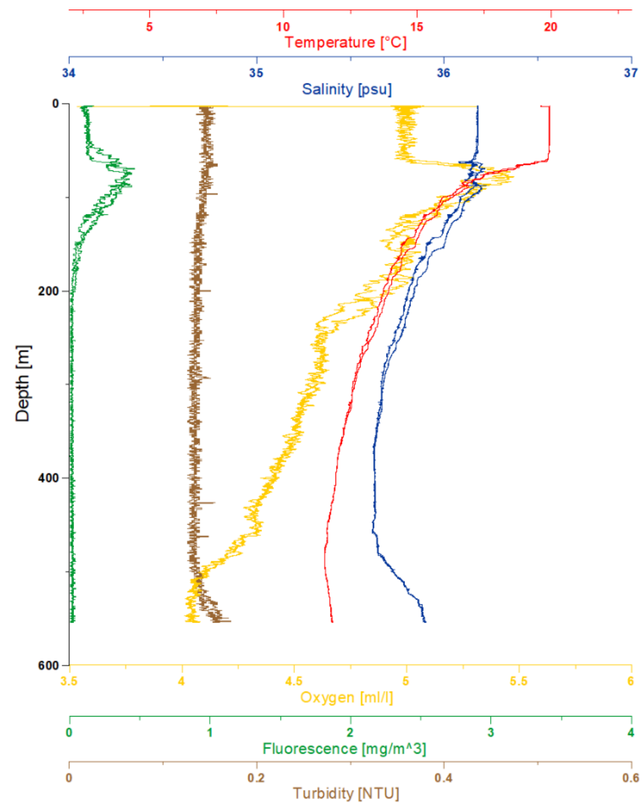

Fig. 21. CTD profile from station PA23-St14. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

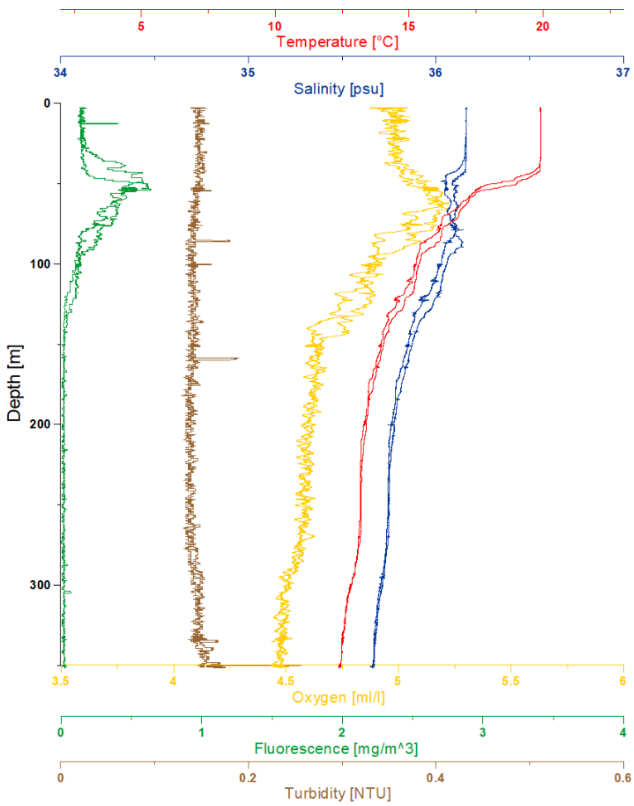

Fig. 22. CTD profile from station PA23-St15. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

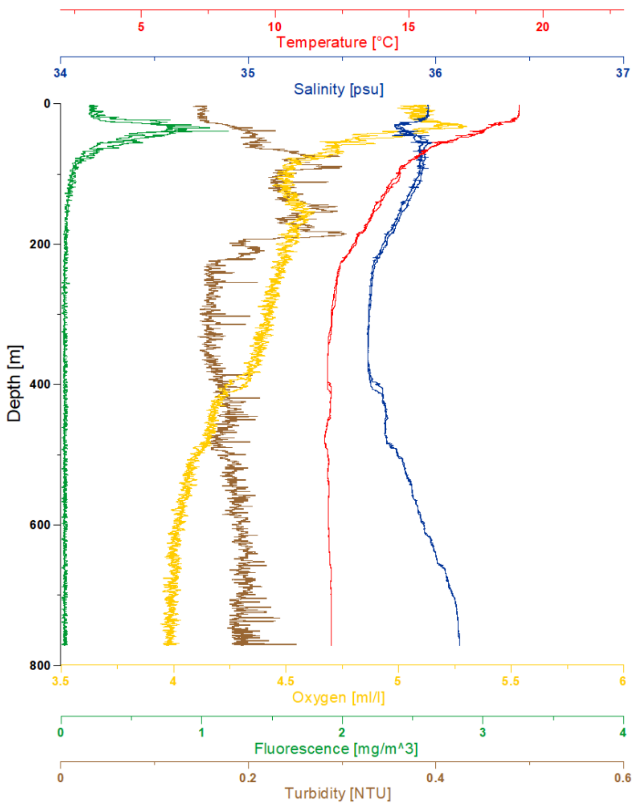

Fig. 23. CTD profile from station PA23-St16. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

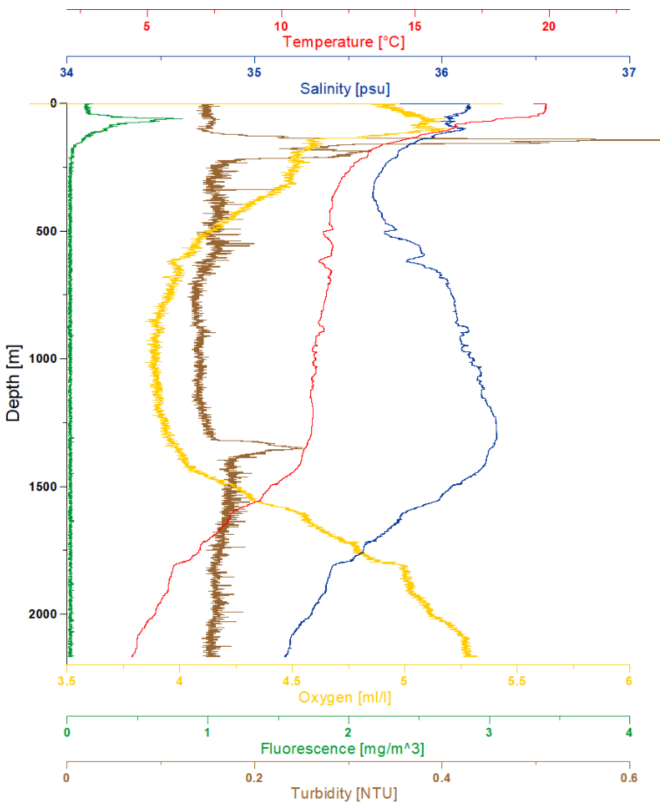

Fig. 24. CTD profile from station PA23-St17. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

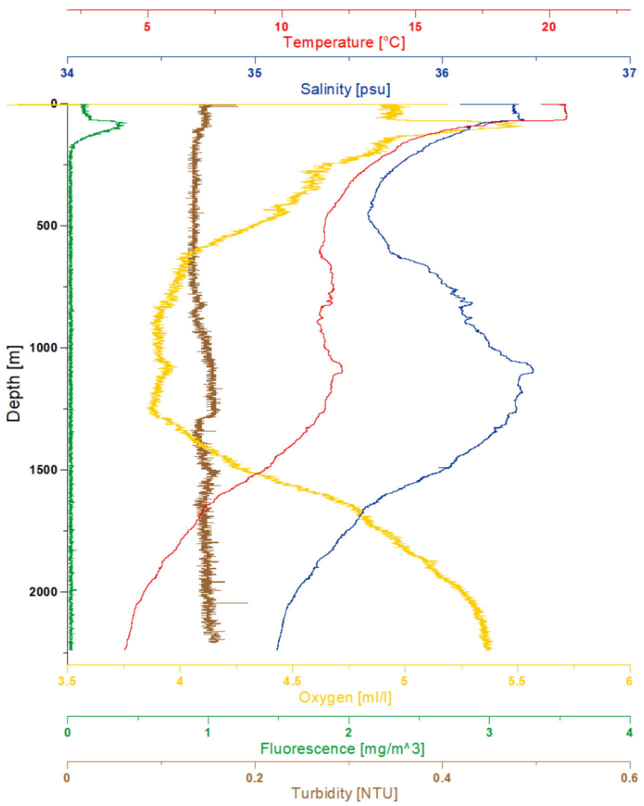

Fig. 25. CTD profile from station PA23-St18. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

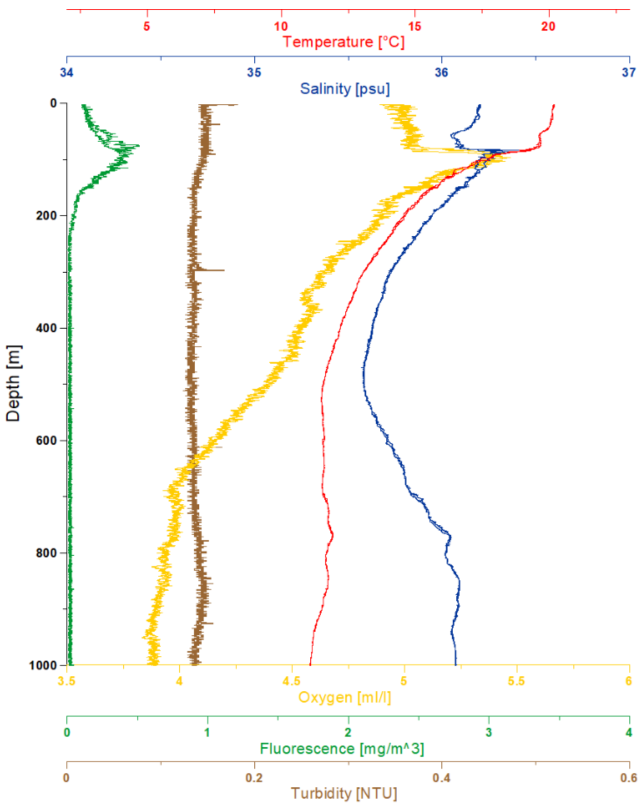

Fig. 26. CTD profile from station PA23-St19. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

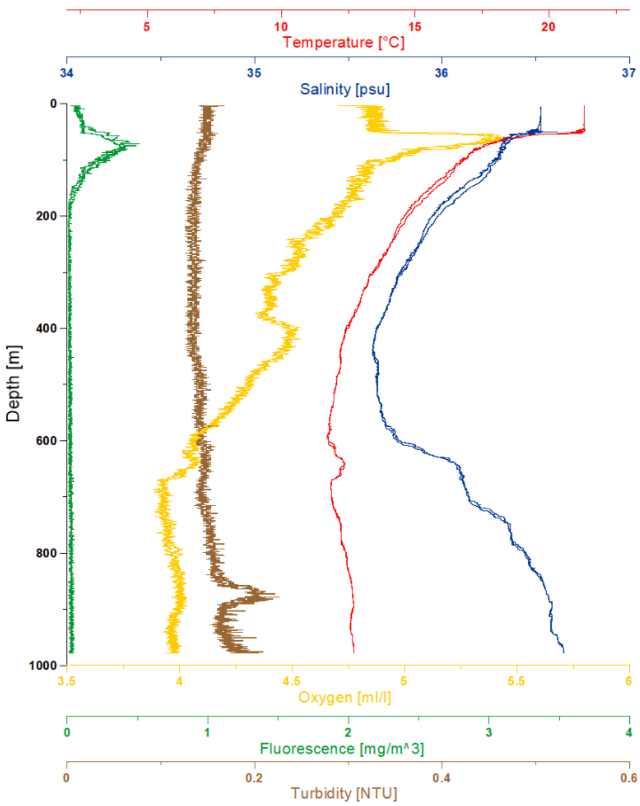

Fig. 27. CTD profile from station PA23-St20. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

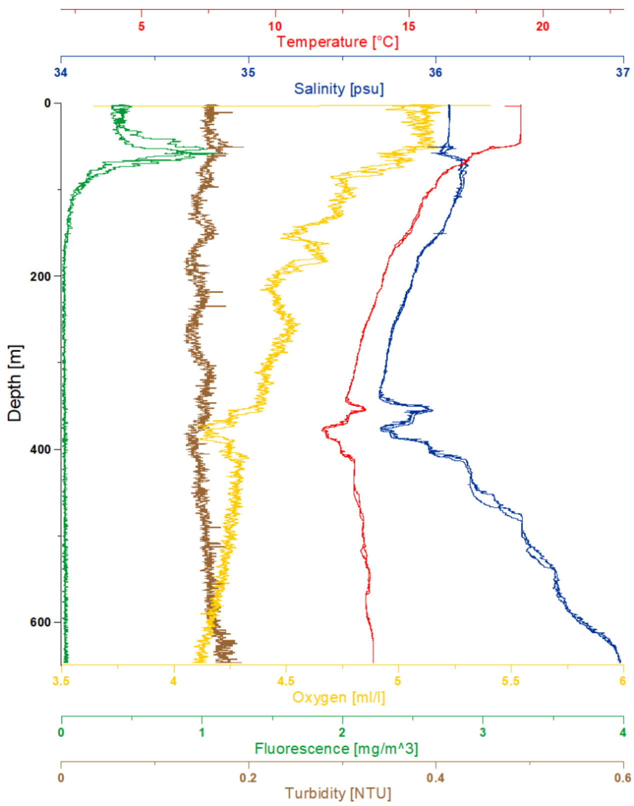

Fig. 28. CTD profile from station PA23-St21. Fluorescence (green), Turbidity (brown), Oxygen (yellow), Temperature (red), and Salinity (blue).

4.2.1 Seawater filtering for ecology studies

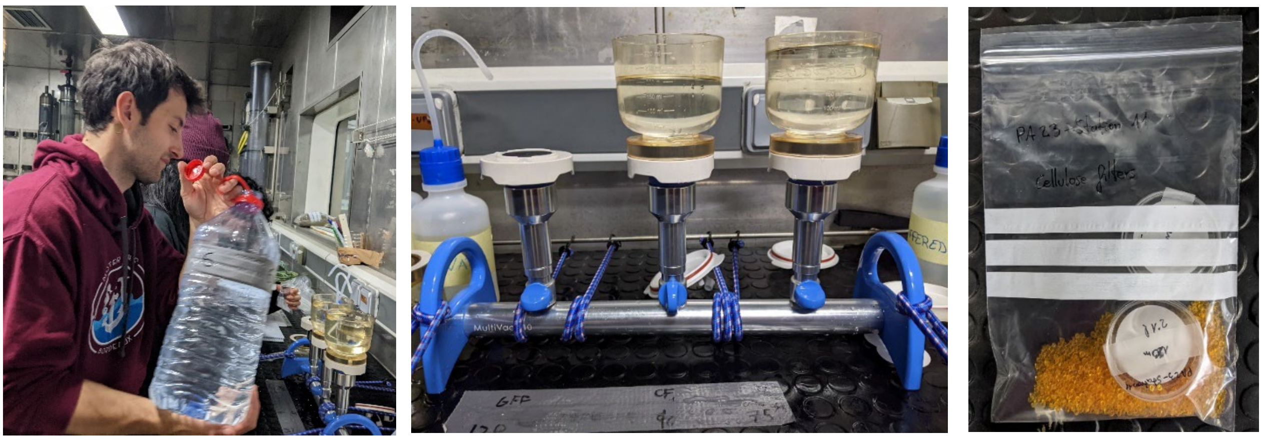

Fig. 29. Sea water filtration for ecological studies. Thibauld M. Béjard from the scientific party filtering seawater for ecologycal studies (left), filtration ramp (middle), and cellulose filters in petri dishes with silica gel (right).

Between 10 (bottles 1-3) and 12 liters (bottles 4-12) of seawater were collected from selective Niskin bottles at discrete depths in the uppermost 300 m of the water column at all stations (Annex I). Between 1.2 and 4.2 liters (until filters became yellowish/brownish) were filtered with a three-cup filtration ramp through mixed cellulose ester membrane filters of 47 mm diameter and with a pore size of 0.45 µm to collect phytoplankton remains (e.g., diatom frustules and coccoliths). A final wash with water buffered with Na_2CO_3 and $NaHCO_3$ was performed to prevent coccolith dissolution and each filter was stored in a labeled plastic petri dish. Petri dishes were put into plastic bags with silica gel to pick humidity and prevent coccolith dissolution with atmospheric CO_2 until filters were dried at 60°C in the oven of the lab.

4.2.2 Seawater filtering for carbon cycle studies

Between 1.2 and 8.1 liters were filtered with a three-cup filtration ramp through glass fiber filters (GFF) of 47 mm diameter and with a pore size of 0.45 µm. Filters had been pre-combusted at 450°C, weighted, and stored in pre-combusted aluminum foil before use. GFF filters were handled with nitrile gloves and metal tweezers, stored in their piece of aluminum foil, and immediately froze at -20°C onboard. Once in the laboratory, GFF filters were freeze-dried and weighed, and sent to ETH Zurich (Switzerland) for radiocarbon (^{14}C) analyses of the organic carbon (OC).

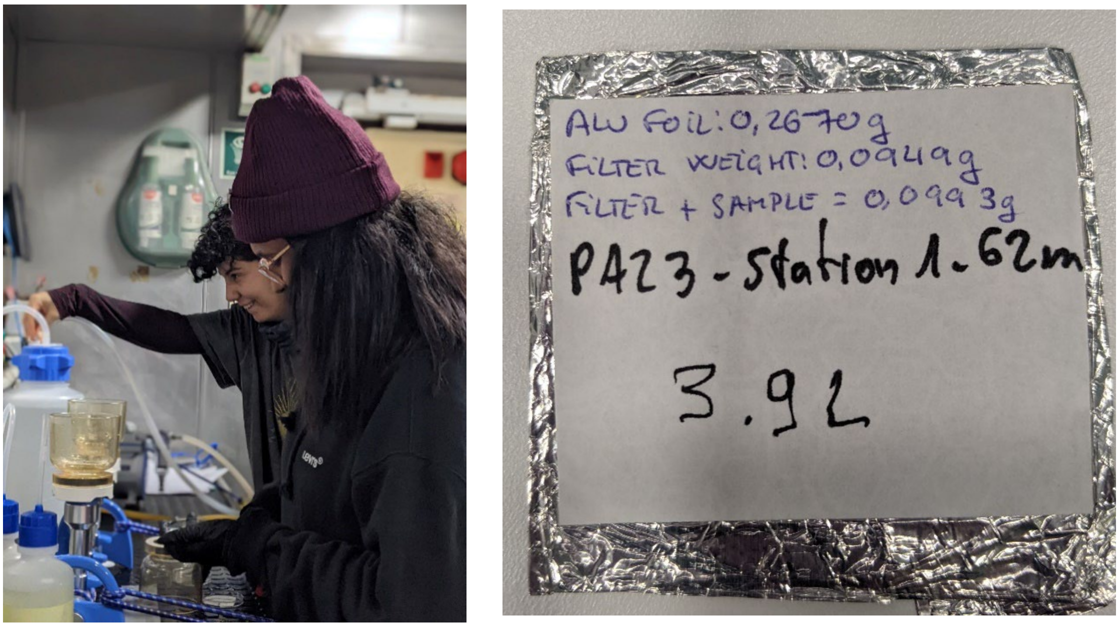

Fig. 30. Sea water filtration for carbon cycle studies. Prabodha Lakrani Hewage and Celia Merchán Gómez filtering seawater on glass fiber filters (left) and glass fiber filter sample stored in pre-combusted aluminum foil (right).

4.3 Sediment sampling with monocorer

The monocorer is mounted with the rosette, by means of a rope and two slings located at the base of the rosette in opposite positions. This way, the monocorer is lowered centered to the rosette at a distance of 25 meters, in the most balanced way possible to not affect the stability of the Rosette. The monocorer (Fig. 31) has an internal diameter of 5.4 cm and a length of 30 cm. It generally provided good sediment recovery, even at depths where the boxcorer was not an option due to the depth of the station. The monocorer allowed us to recover 6 cores where the boxcorer could not be deployed or came up empty.

Once on deck, the length of the sediment core retrieved by the monocorer was measured with a rule. Once the tube was released from the support, the interface water at the uppermost part was carefully removed with a large syringe avoiding sediment resuspension. The core was then sliced at 1 cm resolution using a handcrafted core extruder built for this purpose. Each sediment sample was wrapped into pre-combusted aluminum foil and put into a labeled plastic bag. Sediments were frozen immediately at -20°C in one of the freezers onboard and freeze-dried in the laboratory at the University of Salamanca.

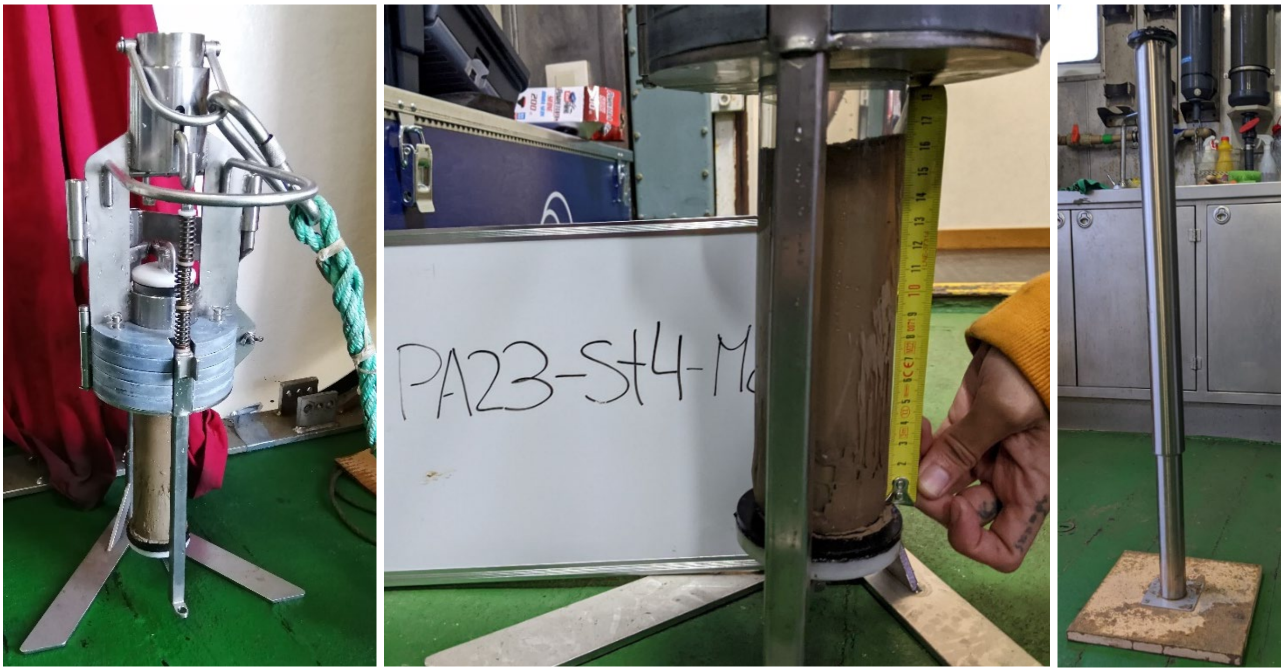

Fig. 31. Sediment sampling with monocorer. Monocorer after retrieval (left), monocorer event recording (middle), and purpose-built extruder for sediment core sampling (right).

4.4 Sediment sampling with boxcorer

The boxcorer descends at a speed of between 20 and 50 m/min. Once it slowly reaches the bottom, it is collected slowly at about 10 meters/minute. After taking off from the bottom it is recovered at 40-60 m/min.

The boxcorer (Fig. 32) had a rectangular box of approximately 20x15 cm and an approximate length of 40 cm. The boxcorer was only deployed at stations shallower than 2500 mwd due to cable length limitations. Once on deck, the box would be released and a PVC tube of ca. 10 cm diameter was inserted into the sediment. The outer sediment would be removed with spoons to free the PVC tube. The core was then sliced at 1 cm resolution with the core extruder and each sediment sample was treated like monocorer sediment samples until they were freeze-dried in the laboratory at the University of Salamanca.

Fig. 32. Sediment sampling with boxcorer. Boxcorer preparation (left) and sub-sampling of pvc tube from boxcorer (right).

5 Data and Sample Storage / Availability

The PI, Blanca Ausín, will store the CTD data following the Data Management Plan stated under the project PASSAGE, until publication.

The echosounder data is stored with, and will be analysed by, Kintxo Salvador Castiella (ICM-CSIC).

The cellulose and GFF filters for ecological and carbon cycle studies are stored at the Biogeosciences laboratory at USAL. GFF filters will be sent to ETH Zurich for analysis in collaboration with Negar Haghipour and Timothy Eglinton, whereas cellulose filters will be studied at USAL.

The sediment samples are stored at -20°C and will be sequentially freeze-dried and studied by PhD student Prabodha Lakrani Hewage (USAL).

6 Participants

No.	Name	Position	Gender	Affiliation	On-board tasks
1	Blanca Ausín González	IP	F	USAL	Assembly of mooring lines Instrument programming Sediment sampling
2	Joan Puigdefàbregas Sagristà	Engineer	M	UPC	Assembly of mooring lines Instrument programming Water filtering
3	Prabodha Lakrani Hewage	PhD student	F	USAL	Assembly of mooring lines Instrument programming Sediment sampling Water filtering
4	Javier Pérez Tarruella	PhD student	M	USAL	Assembly of mooring lines Sediment sampling Water filtering
5	Thibauld Maxime Béjard	PhD student	M	USAL	Assembly of mooring lines Sediment sampling Water filtering
6	Gervaise M. D. Barre	Master student	F	UAlg-CCMAR	Sediment sampling Water filtering
7	Celia Merchán Gómez	Technician	F	USAL	Assembly of mooring lines Sediment sampling Water filtering
8	Stefanía Schamuells Panesso	Outreach Specialist	F	Freelance	Audiovisual material Interviews
9	Kintxo Salvador Castiella	UTM Technician	M	ICM-CSIC	Assembly of mooring lines Rosette-CTD, monocorer and boxcorer deployment
10	Camilo José Gómez López	UTM Technician	M	UTM-CSIC	Rosette-CTD, monocorer and boxcorer deployment
11	Iván Mouzo Bellino	UTM Technician	M	UTM-CSIC	Rosette-CTD, monocorer and boxcorer deployment

USAL: Universidad de Salamanca (Spain)

UPC: Universitat Politècnica de Catalunya (Spain)

UAlg-CCMAR: Universidade do Algarve-Centro de Ciencias do Mar (Portugal)

ICM-CSIC: Instituto de Ciencias del Mar-Consejo Superior de Investigaciones (Spain)

UTM-CSIC: Unidad de Tecnología Marina-Consejo Superior de Investigaciones (Spain)

7 Station List

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear	Remarks/Recovery
		[UTC]	[°N]	[°W]	[m]		
PA23-St4	18/11/ 2023	09:20	37º 33,680 N	010º 08,530 W	2625	ROS/CTD, MoC	Too deep for BC, no attempt
PA23-St4 Mooring	18/11/ 2023	15:05	37º 33,680 N	010º 08,530 W	2625	Mooring deployment	
PA23-St3	18/11/ 2023	19:50	37º 33,673 N	009º35,999 W	1515	ROS/CTD, BC, MoC	
PAS23-St08	19/11/ 2023	01:10	37º 34,090 N	009º 02,020 W	216	ROS/CTD, BC, MoC	MoC of 1 cm only
PAS23-St9	19/11/ 2023	02:55	37º 33,610 N	009º 14,650 W	581	ROS/CTD, BC, MoC	
PA23-St3 Mooring	19/11/ 2023	10:15	37º 33,673 N	009º35,999 W	1515	Mooring deployment	
PAS23-St12	19/11/ 2023	14:15	37º 57.970 N	009º 52,510 W	2497	ROS/CTD, BC, MoC	
PAS23-St19	19/11/ 2023	18:30	38º06,662 N	009º56,626 W	4343	ROS/CTD	CTD till 1000 m only. Too deep for BC or MoC, no attempt
PAS23-St18	19/11/ 2023	20:37	38º 08,03 N	009º 38,39 W	3319	ROS/CTD, MoC	Too deep for BC, no attempt MoC of 3 cm only
PAS23-St17	20/11/ 2023	00:15	38º 14,701 N	009º 127,717 W	2420	ROS/CTD, BC, MoC	
PAS16-St16	20/11/ 2023	05:05	38º17,018 N	009º08,194 W	790	ROS/CTD, BC, MoC	Two BC attempts

PAS23-St15	20/11/2023	08:25	37º 57,950 N	009º 08.580 W	366	ROS/CTD, BC, MoC	Two BC attempts
PAS23-St14	20/11/2023	10:15	37º 57,970 N	009º 15,650 W	572	ROS/CTD, BC, MoC	
PAS23-St13	20/11/2023	12:40	37º 57,57 N	009º 30,99 W	1335	ROS/CTD, BC, MoC	
PAS23-St11	20/11/2023	20:23	37º 37,331 N	010º 42,565 W	4566	ROS/CTD	CTD till 1000 m only. Too deep for BC or MoC, no attempt
PAS23-St10	20/11/2023	23:00	37º 34,889 N	010º 21,534 W	3450	ROS/CTD, MoC	Too deep for BC, no attempt
PAS23-St5	21/11/2023	08:00	37º 19,023 N	009º 56,202 W	3627	ROS/CTD, MoC	Too deep for BC, no attempt
PAS23-St6	21/11/2023	13:30	37º 19,120 N	009º 28,650 W	1209	ROS/CTD, BC, MoC	3 BC attempts
PAS23-St7	21/11/2023	18:25	37º19,114 N	009º11,383 W	344	ROS/CTD, BC, MoC	MoC and BC came up empty
PAS23-St2	22/11/2023	8:00	36º 49,690 N	007º 45,323 W	563	ROS/CTD, BC, MoC	
PAS23-St20	22/11/2023	12:15	36º 19,031 N	007º 43,150 W	1100	ROS/CTD, BC, MoC	
PAS23-St1	22/11/2023	16:00	36º25,478 N	007º17,995 W	652	ROS/CTD, BC, MoC	
PAS23-St21	22/11/2023	19:55	36º16,123 N	006º47,654 W	665	ROS/CTD, BC, MoC	MoC came up empty

8 Acknowledgements

We are infinitely indebted to the Captain and Crew of the R/V Ramon Margalef for making PASSAGE23 possible by agreeing to sail with scarce provisions, and for doing it while creating a pleasant work environment for everyone onboard. A heartfelt thanks goes to the Cook of the R/V Ramon Margalef, for doing so much with so little. We are also deeply thankful to each of the R/V Ramon Margalef Crew members for providing us with all the information and tours within the vessel we needed to create an illustrated story based on this cruise. We are indebted to the Unidad de Tecnología Marina (UTM-CSIC) personnel for their hard work and professionalism before and during the cruise. We are indebted to Anna Sánchez-Vidal, from the University of Barcelona, for lending four buoys, one sediment trap, and the deck unit for our moorings, and for giving us advice whenever we needed it. We are thankful to Pablo Carrera (IEO) and the Grupo de Contaminación Marina (IEO-CSIC) for making available to us the boxcorer used during this cruise. We are also grateful to Jorge Torneo and Carlos Farias from the Instituto Español de Oceanografía (IEO Cádiz), for bringing the boxcorer to the R/V Ramón Margalef. PASSAGE23 was possible thanks to the continuous support of the *Comisión de Coordinación y Seguimiento de las Actividades de los Buques Oceanográficos* (COCSABO), the UTM-CSIC, and the IEO prior the cruise and during the several reschedules. Blanca Ausín acknowledges financial contributions from the PASSAGE project (grant agreement No. 101039348), funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program.

9 References

Ausín, B., Bruni, E., Haghipour, N., Welte, C., Bernasconi, S. M., & Eglinton, T. I. (2021). Controls on the abundance, provenance and age of organic carbon buried in continental margin sediments. *Earth and Planetary Science Letters, 558*, 116759.

Ausín, B., Haghipour, N., Bruni, E., & Eglinton, T. (2022). The influence of lateral transport on sedimentary alkenone paleoproxy signals. *Biogeosciences, 19*, 613-627.

Ausín, B., Magill, C., Haghipour, N., Fernández, Á., Wacker, L., Hodell, D., et al. (2019). (In)coherent multiproxy signals in marine sediments: Implications for high-resolution paleoclimate reconstruction. *Earth and Planetary Science Letters, 515*, 38-46.

Expedition 339 Scientists, 2013. Site U1385. In Stow, D.A.V., Hernández-Molina, F.J., Alvarez Zarikian, C.A., and the Expedition 339 Scientists, Proc. IODP, 339: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.339.103.2013

Flecker, R., Ducassou, E., & Williams, T. (2023). Expedition 401 Scientific Prospectus: Mediterranean–Atlantic Gateway Exchange. *International Ocean Discovery Program.* *https://doi.org/10.14379/iodp.sp.401.2023*.

GEBCO Compilation Group (2023) GEBCO 2023 Grid (doi:10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b)

JPL MUR MEaSUREs Project. 2015. GHRSST Level 4 MUR Global Foundation Sea Surface Temperature Analysis. Ver. 4.1. PO.DAAC, CA, USA. Dataset accessed [2024-01-15] at https://doi.org/10.5067/GHGMR-4FJ04

Magill, C. R., Ausín, B., Wenk, P., McIntyre, C., Skinner, L., Martínez-García, A., et al. (2018). Transient hydrodynamic effects influence organic carbon signatures in marine sediments. *Nature Communications, 9*, 4690.

Mollenhauer, G., Eglinton, T. I., Ohkouchi, N., Schneider, R. R., Müller, P. J., Grootes, P. M., & Rullkötter, J. (2003). Asynchronous alkenone and foraminifera records from the Benguela Upwelling System. *Geochimica et Cosmochimica Acta, 67*, 2157-2171.

NASA Ocean Biology Processing Group. (2018). MODIS-TERRA Level 2 Ocean Color Data Version R2018.0 [Data set]. NASA Ocean Biology Distributed Active Archive Center. Dataset accessed [2024-01-15] at https://commons.datacite.org/doi.org/10.5067/terra/modis/l2/oc/2018

Ohkouchi, N., Eglinton, T. I., Keigwin, L. D., & Hayes, J. M. (2002). Spatial and Temporal Offsets Between Proxy Records in a Sediment Drift. *Science, 298*, 1224-1227.

Schlitzer, Reiner, Ocean Data View, https://odv.awi.de, 2023

Zweng, M. M., J. R. Reagan, D. Seidov, T. P. Boyer, R. A. Locarnini, H. E. García, A. V. Mishonov, O. K. Baranova, K. Weathers, C. R. Paver, and I. Smolyar, 2019. World Ocean Atlas 2018, Volume 2: Salinity. A. Mishonov Technical Ed.; NOAA Atlas NESDIS 82, 50 pp.