Calypso 2022 Pourquoi Pas? Cruise Report

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Contents

1 Summary

This report summarizes activities on the French research vessel Pourquoi Pas? operating as part of the Office of Naval Research CALYPSO project during its main 2022 field program in the northwest Mediterranean. Other components of this field program included the Netherland's research vessel R.V. Pelagia, a fleet of underwater gliders operated by the Scripps Oceanographic Institute and the Balearic Islands Coastal Observing and Forecasting System (SOCIB).

2 Pourquoi Pas? Cruise Log - Feb 16 to Mar 12, 2022

———- Insert LOG PDF HERE ————

Figure 1: Operating the UCTD Winch

3 Underway Profiling

3.0.1 Overview

The primary underway profiling instrument used was an EcoCTD: an RBR Concerto CTD, WETLabs BB2F chlorophyll fluorometer and backscatter meter, and JFE Advantech Rinko Oxygen sensor all mounted in a weighted aluminum housing and tow-yoed manually from the stern with an Oceanscience UCTD winch.

Also aboard, and used sporadically throughout the cruise, was an MVP: a fully automated underway profiling system that provides real-time data. It consisted of a towbody with a CTD, oxygen sensor, and choice of chlorophyll or turbidity sensor, a deck-mounted winch, a cable-counting sheave hung from the A-frame, and a laptop and interface box for system control and data acquisition.

3.0.2 EcoCTD vs. MVP comparison

Typical operation of the EcoCTD was to make one profile to 250 m every 5-6 minutes at a vessel speed of 6 knots. Typical for the MVP was one profile to 200 m every 6-7 minutes at a vessel speed of 3 knots, which used the entire 310 m cable payout available. The dissolved oxygen data provided by the MVP sensor appeared to be of poor quality. These limitations meant that MVP was used sparingly—mostly when there were mechanical issues with the primary system or when transiting drifter-ridden waters—in spite of the benefits of real-time data, fully automated operation, and a rugged, dependable setup. 362 profiles were collected with the MVP during the cruise; 2833 casts were done with the EcoCTD, $\sim$ 98.5% of which returned profile data.

3.0.3 EcoCTD system details

EcoCTD System Details:

- Rutherto: primary probe (2597 casts with data return)

    RBR Concerto S/N 066098

    JFE Advantech Rinko: S/N 0316

    WETLabs BB2F: S/N BB2F-044

Figure 2: MVP Winch and Sheave

- Sedna: secondary probe (201 casts with data return)
  RBR Concerto S/N 203743
  JFE Advantech Rinko: S/N 0319
  WETLabs BB2F: S/N BB2F-6136
- Primary winch (WHOI): S/N WI-1029 (612 casts)
- Backup winch (URI): WI-1030 (2224 casts)
- Shaun yellow box: 121
- Fall rate: 3 m/s

MVP system details:

- MVP winch and sheave
  MVP 30-350 winch: S/N M12469
  Towbody: S/N M12895
  JFE Advantech ARO-FT oxygen sensor :S/N 0BLL008
  CT-Xchange: S/N 451065
  Pressure-Xchange: S/N 307650
  Turner sensor base: S/N A10302

ADCP	Configuration File	Bin Size (m)	# of Bins	Ambiguity Velocity
OS38	pp38gdfdNB_SynchroExterne_V1_6.txt	24	62	3.9 m/s
OS150	pp150gdfdNB_1.8.txt	8	55	3.9 m/s

Table 1: Hull-Mounted ADCP Configurations

Cyclops Turbidity: S/N 900308

Cyclops Chlorophyll: S/N 900382

- Payout from tow position to max out: 310 m
- Fall rate: 2 m/s
- Retrieval rate: 1.0 m/s

3.0.4 Notes on operations

3.0.5 EcoCTD

We had trouble with the power supply boxes for the UCTD winch. The primary unit failed entirely, and exploded parts of electronic components were found inside. The backup unit (S/N PS-1028) began failing intermittently during retrieval, and for a time we switched to running off 4 12V lead acid batteries provided by the ship, which were continually charged. On 3 March, a spare power supply belonging to Shaun Johnston (SIO) was delivered from the Pelagia to the Pourquoi Pas? via small boat. For the remainder of the cruise we ran that box off of regulated 230 V AC, and had no issues. (Previous boxes had run of regular ship's power, and it is possible that spikes in voltage fried them).

The level wind motor failed on the primary winch (S/N WI-1029) after approximately 600 casts. On inspection of the unit, it was found that one of the brushes had worn away. For the remainder of the cruise, we switched to the backup (URI-owned) winch (S/N WI-1030).

Rutherto was the preferred EcoCTD unit (the other units needed to be opened to download). However, the cable for the Rinko occasionally had problems with water intrusion, leading the loss of some oxygen data at various points throughout the cruise.

On 10 March, Rutherto struck the transom with force (winch was not stopped in time). The guard around the Concerto sensors was knocked crooked.

Rutherto was strapped to the CTD rosette for calibration three times during the cruise, and Sedna once.

3.0.6 MVP

There were no incidents of note during MVP operations. Early deployments were done with the turbidity sensor installed, and later ones with the chlorophyll sensor. It appears that the towbody made hard contact with the ship at some point—there are scratches and bottom paint on the tail fin, and the plastic top of the oxygen sensor appears to have been impacted, but it is unclear how or when the contact occurred. The oxygen data looked similarly poor for the entire duration, so that issue does not appear to have been caused by the contact.

3.0.7 ADCP

The CALYPSO 2022 mission gathered ocean current data with three ADCP units. The *Pourquoi Pas?* is equipped with hull-mounted 38 kHz and 150 kHz ADCP units (OS38 and OS150) that are operated by the ship's electronics officers. We additionally installed a 300 kHz unit (WH300) in the deck well for the duration of the cruise. We attempted to synchronize the pinging of the three units, but the WH300 was not able to be run in this setup, causing its data collection to be delayed until Feb 22.

Initial Date (UTC)	Configuration File	Bin Size	# of Bins	Ambiguity Velocity
Feb 17, 17:05	WH300DEF_Calypso_BT	2 m	50	1.1 m/s
Feb 17, 20:41	WH300DEF_Calypso_autonome.txt	1 m	100	1.1 m/s
Feb 21, 16:57	WH300DEF_Calypso_autonome_cellule_4m.txt	4 m	30	1.1 m/s
Feb 26, 06:19	WH300DEF_Calypso_autonome-MODIFIED.txt	2 m	50	1.1 m/s

Table 2: WH300 Configurations

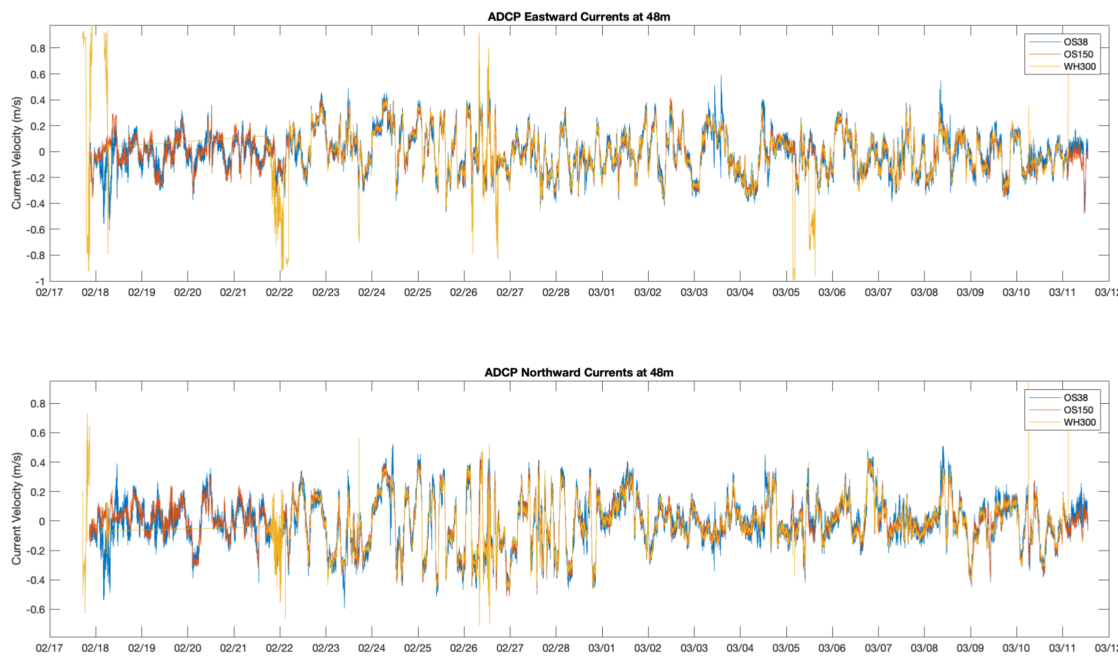

Figure 3: Comparison plot of 48 m velocities measured by the three ADCPs shows generally good agreement.

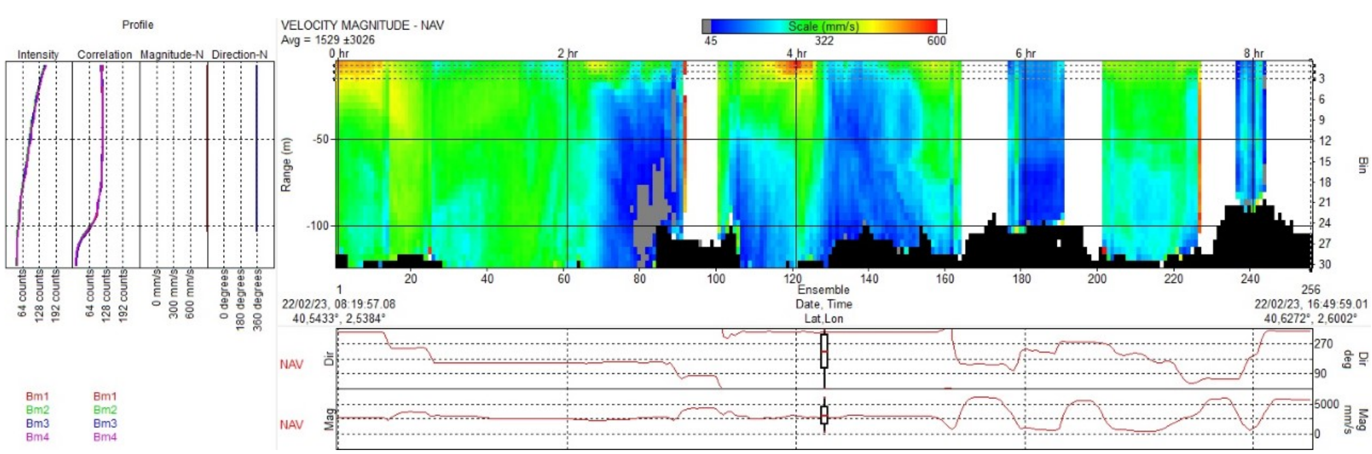

Figure 4: WH300 velocity magnitude and ship navigation showing bad data during fast transit

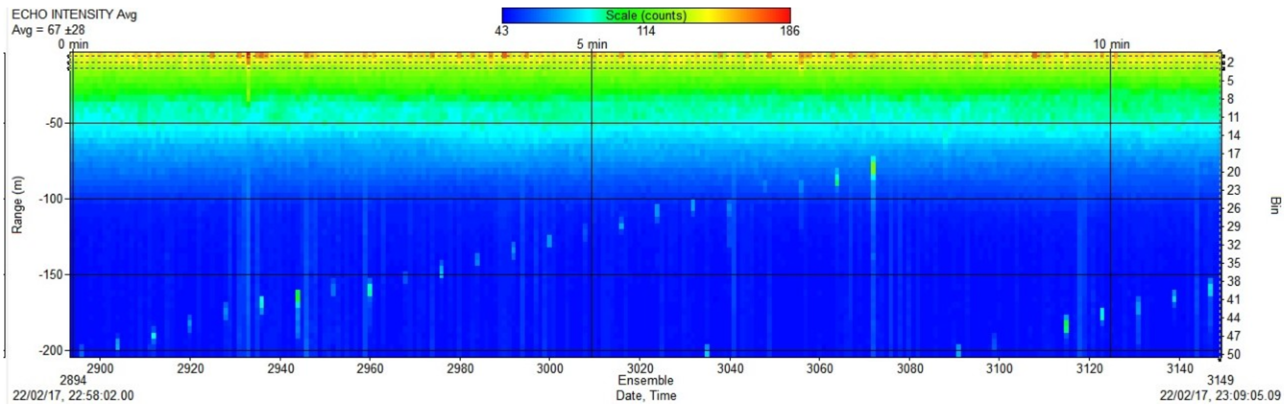

Figure 5: WH300 echo intensity shows weak interference from OS150.

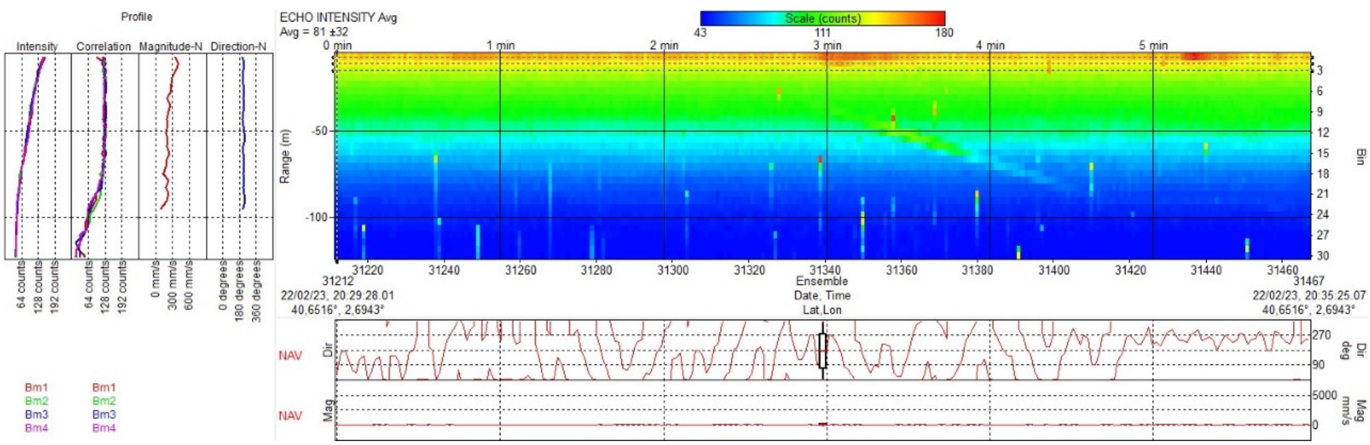

Figure 6: WH300 echo intensity show weak interference from ship bathysonde.

The hull-mounted ADCP units maintained the same narrowband configuration files throughout the cruise. See Table 1 for a summary of the configuration parameters.

The WH300 unit was calibrated with bottom tracking during the initial transit from port. After calibrating, the bottom tracking was turned off for the remainder of the cruise. The WH300 was not able to synchronize with the hull-mounted units and was turned off on Feb 18 until we could verify that the units would not interfere with each other. On Feb 21 it was verified that interference was present but weak, so the unit was turned back on. However, the data only began to look realistic on Feb 22 around 05:45 UTC. See Table 2 for a summary of configurations for the WH300.

The three units agreed well with each other for the periods that they were all operational and the ship track was straight (see Fig. 3). During turns, all units exhibited unrealistic readings, although the WH300 was affected the least.

The WH300 also gave bad readings when the ship was traveling fast, with a cutoff speed around 10 knots (see Fig. 4). Post-processing of the turns and fast transits will be required for quality control of the data.

The WH300 echo intensity was assessed for interference on Feb 21 and 25. There was weak interference of the OS150 unit seen on the WH300 echo intensity (see Fig. 5) and no interference of the WH300 seen on the hull-mounted ADCP echo intensities. Other acoustic instruments caused weak interference on the WH300 as well, such as the bathysonde (see Fig. 6). These interferences are not expected to significantly impact data quality.

3.0.8 Meteorological Measurements

The Pourquoi Pas? has a Mercury weather station installed and maintained by Météo France and consisting of the following instruments:

- Vaisala HMP35DE thermometer/hygrometer
- Vaisala PTB220 barometer
- Young 70721 pyranometer
- Gill Windsonic ultrasonic anemometer

All instruments are installed at 30m above sea surface. There are two Gill anemometers, one to port and one to starboard, that were combined and QCed into a single wind product by an on-board processing algorithm. Flow distortion and stack contamination likely impacted the quality of the meteorological data, particularly for certain relative wind directions.

4 Drifters, Floats and WireWalkers

4.1 Introduction

The main objective of CALYPSO, an ONR DRI project, is to improve our understanding on the 3D dynamics in the upper ocean through which water and properties are transported from the surface to depths below the mixed layer, by exploring the dynamics of the frontal areas in the Alboran Sea (southwest Mediterranean Sea) at scales ranging between 1 and 100 km using data collected by ship-born instruments (CTD, underway-CTD, ADCP, etc.), Lagrangian platforms (drifters and floats), gliders and satellites. As part of CALYPSO, an experiment was carried out in the Balearic Sea on 17 February – 11 March 2022 with the participation of international scientists (from the US, Spain, Italy) on two vessels: the French R/V Pourquoi Pas and the Dutch R/V Pelagia. This report provides information on the deployments of the drifters, floats and Wirewalkers deployed from R/V Pourquoi Pas? and provided by OGS, (Italy), CMRE (Italy), ISMAR (Italy), RSMAS (Florida), SIO (California), WHOI (Massachussetts) and URI (Rhode Island). After a brief description of the Lagrangian instruments (section 2), details on the deployments are given in tables and graphs (section 3). Preliminary results can be found in section 4. Conclusions are in the last section 5.

4.2 Lagrangian instruments

4.2.1 SVP-type drifters

4.2.2 Standard Surface Velocity Program (SVP) drifter

The Surface Velocity Program (SVP) drifter is the standard drifter of the Global Drifter Program (Niiler, 2001; Lumpkin and Pazos, 2006; Centurioni, 2018). It consists of a spherical surface buoy tethered to a weighted nylon drogue that allows it to track the horizontal motion of water at a nominal depth of 15 m (Fig. 1). A tether strain gauge measures the tension of the buoy-drogue connection to monitor the drogue presence. The new design, also called mini-SVP, has a surface buoy of reduced diameter (30.5 cm diameter) which contains alkaline batteries, a satellite Iridium transmitter and a thermistor to measure Sea Surface Temperature (SST). The sampling period was set to 5 min. The 76 SVP drifters used during the CALYPSO 2022 campaign were manufactured by the Lagrangian Drifter Laboratory (LDL) at SIO/UCSD in La Jolla, California.

4.2.3 The Directional Wave Spectra (DWS) drifter

This is essentially the surface buoy of an SVP drifter for which the drogue was replaced by a small (50 cm) stabilizing chain (Fig. 2, Centurioni et al. 2017a,b). It is equipped with a high-performance GPS engine paired with in-house developed software algorithms for onboard computation of the Directional Wave Spectrum (DWS). Location, SST, voltage and wave parameters are transmitted to Iridium satellite at 30 min intervals. The transmission interval is programmable over the air. The 6 DWS drifters used here were designed and produced by the LDL in La Jolla, California.

Figure 7: SVP drifter (surface buoy and folded holey sock drogue)

Figure 8: DWS drifter (surface buoy with ballasting chain)

Figure 9: ADOS drifter (surface buoy with thermistor chain)

4.2.4 The Autonomous Drifting Ocean Station (ADOS) drifter

This drifter is similar to the SVP drifter but a 150 m long tether replaces the drogue (Fig. 3). The surface buoy measures sea surface temperature, while a customizable tether length and set of nodes measure water pressure and temperature. The subsurface nodes use inductive communication technology to send the data through the single-conductor impregnated steel wire rope combined with a seawater contact that closes the electrical circuit. Two ADOS drifters with 10 thermistors each (at 10, 20, 30, 40, 50, 60, 80, 100, 125 and 150 m) were used during the CALYPSO 2022 experiment. SST and subsurface temperature are measured with ± 0.05 °C accuracy. The sampling rate for positionand temperature is 10 min.The drifters were manufactured by LDL. The batteries of all the thermistors were replaced and the 2 drifters were tested by shortening the chain with a resistance. One thermistor of the second ADOS drifter did not work. It was deployed with only 9 working thermistors.

4.2.5 The WHOI drifters

WHOI drifters (Fig. 4) include a surface buoy, a nylon tether and a holey-sock drogue (5m long $\times$ 60 cm diameter) centered at depths of 8 m (yellow buoys), 22 m (orange buoys), 35 m (red buoys), and 50 m (blue buoys). SPOT Trace trackers were attached to the surface buoys to provide positions at 5 min intervals.

4.2.6 CODE-type drifters

The Coastal Ocean Dynamics Experiment (CODE) drifter was designed by Davis (1985) to measure the currents within the top meter of the water column, mostly in coastal areas and marginal seas. It is composed of a slender, vertical, 1-m-long negatively buoyant tube with four drag-producing vanes extending radially from the tube over its entire length and four small spherical surface floats attached to the upper extremities of the vanes to provide buoyancy (Poulain, 1999). The water-following characteristics of the CODE were studied by Davis (1985) and Poulain and Gerin (2019). It was demonstrated that CODE drifters follow the currents with an accuracy of about 3 cm/s, even under strong wind conditions. The wind-induced slippage was estimated to be 0.1% of the local wind speed. The CODE drifter used in the CALYPSO 2022 campaign is similar to the design manufactured by Technocean/DBi (Fig. (5). It was constructed by MAXO, an Italian company, and was equipped with a SPOT/GlobalStar Trace module, which includes a GPS receiver to measure position with high accuracy (¡10 m) and high frequency (every 10 min) (Gerin et al., 2018). Additional external batteries have been fitted to the Trace modules in order to increase the autonomy of the drifters to a few months, using 10 min sampling period. A total of 75 CODE drifters were available for the CALYPSO 2022 experiment.

Figure 10: WHOI drifter: surface buoy (yellow), tether and drogue (blue).

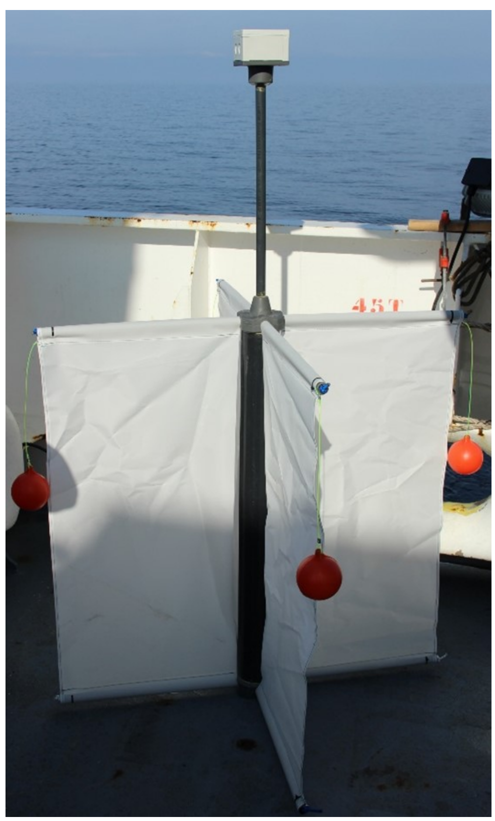

Figure 11: CODE drifter (antenna, vanes and orange balls)

Figure 12: CARTHE drifter

Figure 13: WAVY Ocean drifter

4.2.7 CARTHE drifters

CARTHE drifters were developed to be compact, easy to transport and assemble, and 85% biodegradable (Novelli et al., 2017) so that very large deployments can be attempted in the ocean while being eco-friendly (Fig. 6). About 1000 of these drifters were deployed during a single cruise in the Gulf of Mexico (D'Asaro et al., 2018). A total of 150 of these drifters were used in the CALYPSO 2022 experiment. They were set to transmit their GPS positions every 10 min via the GlobalStar satellite system.

d. WAVY Ocean drifters The WAVY drifters were designed by the MELOA project with financial support from the EU Horizon 2020 Research and Innovation Programme (www.ec-meloa.eu). They are equipped with GNSS, adjustable ballast module, 2 thermistors (near sea-surface temperatures), Argos satellite communications, IMU and solar panels (Fig. 7). Eight Wavy Ocean were kindly made available by the MELOA Consortium. Data are transmitted every 20 min.

e. ARVOR and APEX profiling floats An ARVOR profiling float is an Argo float manufactured by NKE in Hennebont, France. It consists of a tubular body in stainless steel (Fig. 8). A SBE CTD, GPS receiver and Iridium transmitter are fitted near is top. It changes its buoyancy by exchanging oil with and external rubber bladder located at its bottom extremity. Two Arvor-I floats were used, one standard and one with additional Aandeera Optode to measure dissolved oxygen concentration. They were programmed to profile every 3 h down to about 200 m, after their first surfacing. Their parking depth was set up to 350 m and the vertical resolution was 1 m. After the experiment, the floats will be programmed with the standard MedArgo (Poulain et al., 2007) parameters, that is, alternated profiles to 700 and 2000 m with 5-day cycles. One APEX float with SBE CTD manufactured by Teledyne Webb Research in North Falmouth, MA, USA was also deployed. It was tracked by the Argos satellite system and set to cycle down to about 200 m every 6 h. These floats are part of the Argo-Italy program, the Italian contribution to the global Argo array.

Figure 14: Arvor-I (left) and APEX (right) floats.

Figure 15: Wirewalker profilers fitted with RBR CTD and Nortek ADCP: downward-looking (left) and upward-looking (right).

f. Wirewalker profilers Two Wirewalker profilers manufactured by Del Mar Oceanographic in San Diego, CA, USA were used in freely-drifting configuration to monitor the upper water column (down to 200 m depth) with high-frequency sampling (period as little as 15 min). The Wirewalker goes up and down along a wire that is powered by the motion of the surface waves for descent and uses its own positive buoyancy for ascent (Pinkel et al., 2011). One Wirewalker (Fig. 9 left) owned by CMRE was fitted with a RBR Concerto CTD (S/N 203723), and Nortek Signature 1000 AD2CP (S/N: 101670, downward-looking at 22.5°) powered by a RBR Fermata external battery pack. The CTD data were retrieved inductively by a RBR Cervello (S/N: 203724) data controller and transmitted in real time via iridium. The sampling frequency of the CTD was 4 Hz. Positions were monitored with a GlobalStar SPOT Trace (ESN: 0-3184257, sampling every 5 min) and an Iridium Xeos Rover (IMEI 300434063292990, sampling every 30 min). A 200-m cable was attached to the surface buoy (0.9 m diameter) and had a double weight (two $\frac{3}{4}$-inch steel plates with weight 32 kg) at its bottom end. The other Wirewalker (Fig. 9 right), owned by URI was equipped with an RBR Maestro CTD (S/N: 80280) was powered by an RBR Fermata and served as a logger for a Rinko oxygen sensor (S/N: 0322), a WetLABS ECO BBFL2 chlorophyll/CDOM fluorometer and 700-nm backscatter meter (S/N: ECO BBFL2SSC-1309), and a WetLABS 650-nm C-Star beam transmissometer (S/N: CST-1811PR). These sampled continuously at 6 Hz. Internally logging JFE Advantech DEFI2-L PAR sensors were mounted on both the profiler (S/N: 0AAO036) and the buoy (S/N: 0B1C018), and sampled at 1 Hz. A Nortek Signature1000 AD2CP (S/N: 100234), supplied by Andrey Shcherbina (APL/UW), was mounted on the profiler in an upward-looking orientation. It was powered by its own internal battery and logged internally; its sampling configuration was adjusted from deployment to deployment. Positions were supplied at 10-minute intervals by a GPS/Iridium beacon integrated into the buoy (S/N: DMO-GLBCN-0005, IMEI: 300234066300020), and also at 5-minute intervals by SPOT Trace tracker (ESN: 0-3184266). The buoy diameter was 0.75 m, the cable length was 175 m, and weight at the bottom consisted of a single rectangle of $\frac{3}{4}$-inch steel plate (dimensions 8 by 24 inches, weight 16 kg).

4.2.8 Drifter deployments

The drifter and float deployments were conducted between 18 February 2022 and 10 March 2022. They are described hereafter in chronological order. All deployments were conducted from R/V Pourquoi

Figure 16: Deployment of a SVP drifter from the stern of the ship.

Pas?. Fig. 10 shows the deployment of an SVP drifter. Most of them were carried out from the stern starboard side of the ship in between ECO-UCTD casts with typical distance between releases of 1 km (6 min at 6 kts). In total, **328 drifters; 3 floats and 2 Wirewalkers have been deployed**.

4.2.9 a. 18-20 February 2022

On 18-20 February, a total of 41 drifters were deployed to characterize the meso- and sub-mesoscale circulation around 41N 15' and 04E 06' in the Balearic Sea, including 8 SVP and 33 CARTHE drifters. The deployment coordinates are listed in Table 1.

4.2.10 b. 21-22 February 2022

Due to the strong Mistral wind conditions it was decided to move to the southwest and survey the meso- and sub-mesoscale circulation near 40N 36' and 02E 42'. The initial deployments in this area on 21-22 February included 10 SVP, 5 CODE and 5 CARTHE drifters (see their deployment coordinates in Table 2).

4.2.11 c. 23 February 2022

A large number of drifters were then deployed on 23 February in and around a strong northeastward jet, including 14 SVP, 15 CODE and 15 CARTHE drifters (Table 3).

4.2.12 d. 24 February 2022

On 24 February drifters were released across an elongated cyclonic eddy, including 6 CODE and 12 CARTHE drifters (Table 4).

4.2.13 e. 25 February 2022

On 25 February more drifters were released in the northern branch of the eddy (in southwestward current), including 8 CODE, 2 CARTHE, 3 SVP, 2 WAVY and 2 DWS drifters (Table 5).

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CARTHE1, SVP1	18/02/2022 06:59	41N 40.918	4E 39.957	084, 300534061494110
CARTHE2	18/02/2022 08:31	41N 35.790	4E 32.269	064
CARTHE3	18/02/2022 09:07	41N 33.711	4E 28.848	085
CARTHE4, SVP2	18/02/2022 09:44	41N 31.482	4E 25.424	041, 300534061494380
CARTHE5	18/02/2022 11:09	41N 37.539	4E 18.322	144
CARTHE6	18/02/2022 17:25	41N 34.762	4E 13.978	094
CARTHE7, SVP3	18/02/2022 18:02	41N 32.281	4E 10.136	114, 300534061494510
CARTHE8	18/02/2022 19:02	41N 28.090	4E 15.046	074, broken drogue
CARTHE9	18/02/2022 21:52	41N 23.616	4E 20.269	096
CARTHE10, SVP4	18/02/2022 22:38	41N 20.078	4E 24.261	035, 300534061494930
CARTHE11	18/02/2022 23:22	41N 17.463	4E 20.351	068
CARTHE12	19/02/2022 00:03	41N 17.261	4E 20.048	038
CARTHE13	19/02/2022 01:00	41N 18.558	4E 11.377	030
CARTHE14	19/02/2022 03:47	41N 22.608	4E 06.557	150
CARTHE15	19/02/2022 04:54	41N 26.846	4E 01.850	006
CARTHE16	19/02/2022 05:37	41N 24.237	3E 58.233	097
CARTHE17, SVP5	19/02/2022 06:21	41N 21.464	3E 53.922	029, 300534061494960
CARTHE18	19/02/2022 07:17	41N 17.178	3E 58.003	112
CARTHE19	19/02/2022 09:24	41N 17.066	3E 58.158	104
CARTHE20, SVP6	19/02/2022 10:26	41N 09.323	4E 08.071	127, 300534061495030
CARTHE21	19/02/2022 11:13	41N 06.315	4E 03.220	087
CARTHE22	19/02/2022 11:46	41N 04.088	3E 59.769	128
CARTHE23	19/02/2022 12:51	41N 08.029	3E 55.313	113
CARTHE24	19/02/2022 14:46	41N 11.859	3E 50.850	036
CARTHE25	19/02/2022 15:46	41N 15.938	3E 46.059	023
CARTHE26	19/02/2022 16:29	41N 13.953	3E 41.879	110
CARTHE27, SVP7	19/02/2022 17:18	41N 11.098	3E 37.568	095, 300534061495040
CARTHE28	19/02/2022 18:31	41N 06.681	3E 42.081	061
CARTHE29	19/02/2022 20:15	41N 02.686	3E 46.748	109
CARTHE30, SVP8	19/02/2022 21:06	40N 58.857	3E 51.572	137, 300534061495060
CARTHE31	20/02/2022 02:39	40N 44.851	3E 19.923	017
CARTHE32	20/02/2022 03:19	40N 47.442	3E 17.232	124
CARTHE33	20/02/2022 05:42	40N 55.528	3E 30.383	090

Figure 17: Deployment information for the drifters released on 18-20 February (8 SVP +33 CARTHE = 41)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
SVP9	21/02/2022 07:48	41N 25.088	4E 04.854	300234068545440
SVP10	21/02/2022 08:22	41N 25.220	3E 59.779	300234068546010
SVP11	21/02/2022 08:47	41N 22.064	4E 00.731	300234068546020
SVP12	21/02/2022 09:09	41N 21.430	4E 05.071	300234068546030
SVP13	21/02/2022 09:34	41N 24.346	4E 08.332	300234068546110
CODE1	22/02/2022 14:30	40N 40.599	2E 40.308	4439264
CARTHE34, SVP14	22/02/2022 14:53	40N 38.562	2E 38.439	148, 300234068546210
CODE2	22/02/2022 15:06	40N 37.510	2E 37.451	4442203
CARTHE35, SVP15	22/02/2022 15:27	40N 35.830	2E 35.834	079, 300234068546300
CODE3	22/02/2022 15:51	40N 33.772	2E 36.403	4439609
CARTHE36, SVP16	22/02/2022 16:14	40N 31.645	2E 37.274	093, 300234068546400
CODE4	22/02/2022 16:32	40N 30.057	2E 37.753	4438768
CARTHE37, SVP17	22/02/2022 16:55	40N 27.975	2E 38.527	016, 300234068547420
CODE5	22/02/2022 17:19	40N 25.845	2E 39.259	4441899
CARTHE38, SVP18	22/02/2022 17:30	40N 24.823	2E 39.659	126, 300234068547430

Figure 18: Deployment information for the drifters released on 21-22 February (10 SVP +5 CARTHE + 5 CODE = 20)

4.2.14 f. 27 February 2022

On 27 February the eddy got more elongated and formed a ridge. Some CARTHE drifters were released in a zig-zag pattern across the ridge (Table 6).

4.2.15 g. 1 March 2022

On 1 March there was a massive drifter deployment in a tight 2 km x 2 km square in the eastern edge of a small eddy which had formed south of the ridge, including 3 CODE, 9 CARTHE, 9 SVP, 3 WAVY, 2 DWS, 1 ADOS and 36 WHOI drifters (Table 7). More details about this multi-layer drifter experiment can be found in the Appendix.

4.2.16 h. 2-3 March 2022

On 2-3 March we moved to the north to explore another cyclonic vortex feature located near 40N 48' and 02E 50'. In total, 10 CODE, 10 CARTHE and 1 ADOS drifters were deployed (see Table 8).

4.2.17 i. 4 March 2022

More drifters were deployed across the eddy and its western extension into a ridge on 4 March, including 9 CODE, 2 CARTHE, 5 SVP, 3 WAVY, 1 DWS, 1 ADOS and 36 WHOI drifters (see deployment information in Table 9). The ADOS drifter released a day before showed erroneous temperature readings at 5 thermistors. It was successfully recovered at about 17:00 UTC. We discovered that the faulty thermistors had flooded or leaked. Spare thermistors were used and the drifter was tested with a total of 5 sensors on the chain (20, 40, 60, 100 and 150 m).

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CARTHE39, SVP19	23/02/2022 09:09	40N 33.739	2E 28.366	063, 300234068547440
CODE6	23/02/2022 09:19	40N 32.881	2E 28.829	4440070
CARTHE40, SVP20, CARTHE41	23/02/2022 09:30	40N 31.836	2E 29.450	057, 300234068548100, 022; FIRST CARTHE WITHOUT DROGUE
CODE7	23/02/2022 09:43	40N 30.802	2E 30.061	4439262
CARTHE42, SVP21	23/02/2022 09:55	40N 29.878	2E 30.599	053, 300234068548200
CODE8	23/02/2022 10:08	40N 28.897	2E 31.196	4442031
CARTHE43, SVP22	23/02/2022 10:17	40N 28.219	2E 31.646	105, 300234068548220
CODE9	23/02/2022 10:25	40N 27.589	2E 32.037	4442155
CARTHE44, SVP23	23/02/2022 10:31	40N 27.147	2E 32.312	118, 300534068548230
CODE10	23/02/2022 10:39	40N 26.651	2E 32.606	4438796
CARTHE45, SVP24	23/02/2022 10:44	40N 26.270	2E 32.802	054, 300234068548280
CODE11	23/02/2022 10:51	40N 25.783	2E 33.029	4442154
CARTHE46, SVP25	23/02/2022 10:58	40N 25.199	2E 33.274	116, 300234068641070
CODE12	23/02/2022 11:06	40N 24.550	2E 33.638	4441549
CARTHE47, SVP26	23/02/2022 11:14	40N 23.860	2E 34.019	077, 300234068549440
CODE13	23/02/2022 11:25	40N 24.003	2E 35.304	4440073
CODE14	23/02/2022 11:31	40N 24.201	2E 36.472	4439603
CARTHE48, SVP27	23/02/2022 11:37	40N 24.378	2E 37.545	146, 300234068641080
CODE15	23/02/2022 11:46	40N 24.988	2E 37.623	4442201
CARTHE49, SVP28	23/02/2022 11:51	40N 25.549	2E 37.213	103, 300234068549410
CODE16	23/02/2022 11:58	40N 26.161	2E 37.009	4438760
CARTHE50, SVP29	23/02/2022 12:05	40N 26.675	2E 36.811	020, 300234068644080
CODE17	23/02/2022 12:11	40N 27.237	2E 36.626	4442159
CARTHE51, SVP30	23/02/2022 12:17	40N 27.738	2E 36.444	099, 300234068549290
CODE18	23/02/2022 12:23	40N 28.342	2E 36.233	4438522
CARTHE52, SVP31	23/02/2022 12:29	40N 28.872	2E 36.062	091, 300234068549220
CODE19	23/02/2022 12:35	40N 29.393	2E 35.799	4439629
CARTHE53, SVP32	23/02/2022 12:43	40N 30.073	2E 35.533	058, 300234068549230
CODE20	23/02/2022 12:51	40N 30.867	2E 35.261	4439605

Figure 19: Deployment information for the drifters released on 23 February (14 SVP +15 CARTHE + 15 CODE = 44)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CARTHE54	24/02/2022 11:39	40N 34.000	2E 44.092	117
CODE21	24/02/2022 11:45	40N 34.507	2E 43.848	4441016
CARTHE55	24/02/2022 11:50	40N 35.005	2E 43.624	141
CODE22	24/02/2022 11:56	40N 35.508	2E 43.394	4439830
CARTHE56	24/02/2022 12:04	40N 36.196	2E 43.054	011
CODE23	24/02/2022 12:07	40N 36.505	2E 42.871	4440061
CARTHE57	24/02/2022 12:13	40N 37.001	2E 42.610	070
CODE24	24/02/2022 12:19	40N 37.499	2E 42.351	4439090
CARTHE58	24/02/2022 12:24	40N 38.004	2E 42.119	133
CODE25	24/02/2022 12:28	40N 38.514	2E 41.898	4438701
CARTHE59	24/02/2022 12:32	40N 39.001	2E 41.663	033
CODE26	24/02/2022 12:37	40N 39.513	2E 41.396	4439602
CARTHE60	24/02/2022 12:42	40N 39.971	2E 41.152	131, SURFACE SLICKS
CARTHE61	24/02/2022 12:48	40N 40.493	2E 40.910	139, SURFACE SLICKS
CARTHE62	24/02/2022 12:54	40N 41.051	2E 40.651	089, SURFACE SLICKS
CARTHE63	24/02/2022 12:59	40N 41.511	2E 40.436	081, SURFACE SLICKS
CARTHE64	24/02/2022 13:05	40N 41.982	2E 40.204	019, SURFACE SLICKS
CARTHE65	24/02/2022 13:10	40N 42.459	2E 39.974	034, SURFACE SLICKS

Figure 20: Deployment information for the drifters released on 24 February (12 CARTHE + 6 CODE = 18)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CODE27	25/02/2022 10:03	40N 38.493	2E 41.527	4438793
SVP33	25/02/2022 10:09	40N 37.913	2E 41.675	300234068548290
CODE28	25/02/2022 10:14	40N 37.396	2E 41.826	4439611
CODE29, CARTHE66, WAVY1, DWS1	25/02/2022 10:19	40N 37.005	2E 41.998	4436844, 028, 68, 300234068545290
CODE30	25/02/2022 10:25	40N 36.503	2E 42.272	4438792
SVP34	25/02/2022 10:31	40N 36.012	2E 42.534	300234068548430
CODE31	25/02/2022 10:37	40N 35.495	2E 42.812	4441561
CODE32, CARTHE67, WAVY2, DWS2	25/02/2022 10:44	40N 35.000	2E 43.110	4441898, 067, 84, 300234068545300
CODE33	25/02/2022 10:51	40N 34.522	2E 43.508	4438523
SVP35	25/02/2022 10:57	40N 34.010	2E 43.880	300234068548440
CODE34	25/02/2022 11:03	40N 33.499	2E 44.257	4442156

Figure 21: Deployment information for the drifters released on 25 February (3 SVP + 2 CARTHE + 8 CODE + 2 WAVY + 2 DWS= 17)

4.2.18 j. 6 March 2022

More drifter deployments were carried out across the ridge on 6 March, including 7 CARTHE, 8 CODE, 1 DWS and 8 SVP (Table 10). The ADOS drifter was also redeployed.

4.2.19 k. 8 March 2022

Final deployments in the eddy and across the ridge to the west of it were performed on 8 March (see deployment information in Table 11). In total, 19 CARTHE, 11 CODE and 11 SVP drifters were released.

4.2.20 Float deployments

Three Argo floats were deployed during the CALYPSO 2022 campaign, one regular ARVOR with CTD, one ARVOR with CTD and dissolved oxygen sensor and 1 APEX with CTD. The floats were programmed to cycle every 3 h (for the ARVORs) or 6 h (for the APEX). Doing so, they were able to profile between the surface and about 200 m. The floats were released manually with a rope from the stern of the ship. Fig. 11 shows the deployment of the APEX float. Table 12 provides details about the deployments.

4.2.21 Wirewalker deployments

As a test of ballasting and general function, the URI Wirewalker was deployed near 41.619°N, 004.309°E for a 2-hour test at approximately 14:30 UTC on 18 February. PAR sensors were not included. The deployment and recovery were done using a starboard-facing winch just aft of the hanger, with the cable running through a sheave on the squirt boom off the starboard side of the vessel. Wire angle varied during both deployment and recovery risking damage to the cable against the cheeks of the sheave. At one point the cable led under the stern, threatening propeller entanglement. It was decided

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CARTHE68	27/02/2022 10:06	40N 37.175	2E 51.395	060
CARTHE69	27/02/2022 10:22	40N 37.071	2E 49.456	071
CARTHE70	27/02/2022 10:38	40N 36.986	2E 47.342	069
CARTHE71	27/02/2022 11:03	40N 36.964	2E 43.890	100
CARTHE72	27/02/2022 11:20	40N 35.850	2E 43.003	136
CARTHE73	27/02/2022 11:40	40N 33.785	2E 43.276	031
CARTHE74	27/02/2022 11:58	40N 32.009	2E 43.599	007
CARTHE75	27/02/2022 12:15	40N 30.423	2E 43.816	115
CARTHE76	27/02/2022 12:50	40N 28.040	2E 42.437	056
CARTHE77	27/02/2022 13:10			045
CARTHE78	27/02/2022 13:26	40N 26.959	2E 38.28	082
CARTHE79	27/02/2022 13:37	40N 26.565	2E 36.574	083
CARTHE80	27/02/2022 13:44	40N 26.277	2E 35.581	102
CARTHE81	27/02/2022 14:03	40N 26.029	2E 34.678	051
CARTHE82	27/02/2022 14:13	40N 25.854	2E 35.967	055
CARTHE83	27/02/2022 14:18	40N 25.689	2E 36.672	042
CARTHE84	27/02/2022 14:24	40N 25.562	2E 37.360	075
CARTHE85	27/02/2022 14:30	40N 25.407	2E 38.253	080
CARTHE86	27/02/2022 14:35	40N 25.267	2E 38.837	062

Figure 22: Deployment information for the drifters released on 27 February (19 CARTHE)

Date & Time GMT	Latitude	Longitude	IDs and comments
01/03/2022 09:56	40N 20.950	2E 35.044	CARTHE87 (132), CODE35 (4439604), WAVY3 (78), DWS3 (300234068942230), SVP36 (300234068549010), WHOI1 (1), WHOI2 (10), WHOI3 (19), WHOI4 (28)
01/03/2022 10:12	40N 20.610	2E 35.605	CARTHE88 (073), SVP37 (300234068549040), WHOI5 (2), WHOI6 (11), WHOI7 (20), WHOI8 (29)
01/03/2022 10:32	40N 20.247	2E 36.143	CARTHE89 (065), SVP38 (300234068549150), WHOI9 (3), WHOI10 (12), WHOI11 (21), WHOI12 (30)
01/03/2022 10:49	40N 19.847	2E 35.897	CARTHE90 (046), SVP39 (300234068549190), WHOI13 (4), WHOI14 (13), WHOI15 (22), WHOI16 (31)
01/03/2022 11:03	40N 20.249	2E 35.391	CARTHE91 (072), CODE36 (4439614), WAVY4 (79), SVP40 (300234068549200), WHOI17 (5), WHOI18 (14), WHOI19 (23), WHOI20 (32)
01/03/2022 11:07	40N 20.358	2E 35.239	ADOS1 (300234066212310)
01/03/2022 11:16	40N 20.641	2E 34.909	CARTHE92 (138), SVP41 (300234068941600), WHOI21 (6), WHOI22 (15), WHOI23 (24), WHOI24 (33)
01/03/2022 11:33	40N 20.383	2E 34.476	CARTHE93 (052), SVP42 (300234068941670), WHOI25 (7), WHOI26 (16), WHOI27 (25), WHOI28 (34)
01/03/2022 11:46	40N 20.064	2E 34.904	CARTHE94 (130), SVP43 (300234068941760), WHOI29 (8), WHOI30 (17), WHOI31 (26), WHOI32 (35)
01/03/2022 12:01	40N 19.714	2E 35.449	CARTHE95 (013), CODE37 (44440011), WAVY5 (82), DWS4 (300234068942250), SVP44 (300234068941880), WHOI33 (9), WHOI34 (18), WHOI35 (27), WHOI36 (36)

Figure 23: Deployment information for the drifters released on 1 March (9 CARTHE + 9 SVP + 3 CODE + 3 WAVY + 2 DWS + 1 ADOS + 36 WHOI = 63)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CODE38	02/03/2022 10:24	40N 49.775	2E 54.421	4439835
CARTHE96	02/03/2022 10:30	40N 49.363	2E 54.016	106
CODE39	02/03/2022 10:37	40N 48.929	2E 53.493	4440019
CARTHE97	02/03/2022 10:42	40N 48.555	2E 53.030	140
CODE40	02/03/2022 10:48	40N 48.143	2E 52.560	4440074
CARTHE98	02/03/2022 10:54	40N 47.742	2E 52.094	086
CODE41	02/03/2022 11:00	40N 47.322	2E 51.644	4437297
CARTHE99	02/03/2022 11:06	40N 46.937	2E 51.213	119
CODE42	02/03/2022 11:12	40N 46.529	2E 50.783	4440059
CARTHE100	02/03/2022 11:18	40N 46.169	2E 50.358	043
CODE43	02/03/2022 11:23	40N 45.793	2E 49.925	4439608
CARTHE101	02/03/2022 11:29	40N 45.394	2E 49.484	092
CODE44	02/03/2022 11:35	40N 45.016	2E 49.059	4441024
CARTHE102	02/03/2022 11:41	40N 44.644	2E 48.653	121
CODE45	02/03/2022 11:57	40N 44.633	2E 47.045	4438855
CARTHE103	02/03/2022 12:03	40N 44.912	2E 46.430	123
CODE46	02/03/2022 12:09	40N 44.912	2E 45.811	4442027
CARTHE104	02/03/2022 12:15	40N 45.494	2E 45.227	135
CODE47	02/03/2022 12:21	40N 45.776	2E 44.628	4441904
CARTHE105	02/03/2022 12:27	40N 46.070	2E 44.034	021
ADOS2	03/03/2022 09:43	40N 45.638	2E 42.741	300234066212350

Figure 24: Deployment information for the drifters released on 2-3 March (10 CARTHE + 10 CODE + 1 ADOS = 21)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CODE48, SVP45, WAVY6	04/03/2022 09:33	40N 53.291	2E 46.637	4439261, 300234068646070, 61
CODE49	04/03/2022 09:40	40N 53.004	2E 46.916	4441559
CODE50, SVP46	04/03/2022 09:46	40N 52.572	2E 47.366	4439617, 300234068647070
CODE51	04/03/2022 09:52	40N 52.118	2E 47.118	3184008
CODE52, SVP47, WAVY7, DWS5	04/03/2022 09:57	40N 51.658	2E 48.319	3183927, 300234068648070, 76, 300234068942600
CODE53	04/03/2022 10:04	40N 51.157	2E 48.865	3184277
CODE54, SVP48	04/03/2022 10:10	40N 50.691	2E 49.370	3184099, 300234068847820
CODE55	04/03/2022 10:16	40N 50.691	2E 49.370	3184109
CODE56, SVP49, WAVY8, CARTHE106	04/03/2022 10:22	40N 49.741	2E 50.403	3184199, 300234068848820, 83, 037
CARTHE107	04/03/2022 10:29	40N 49.154	2E 51.035	044

Figure 25: Deployment information for the drifters released on 4 March (2 CARTHE + 9 CODE + 3 WAVY + 1 DWS + 5 SVP = 20)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CODE57, SVP50, DWS6	06/03/2022 11:10	40N 52.353	2E 46.343	3184068, 300234068940220, 300234068942610
CARTHE108	06/03/2022 11:17	40N 51.690	2E 46.018	025
CODE58, SVP51	06/03/2022 11:23	40N 51.087	2E 45.729	3184319, 300234068940240
CARTHE109	06/03/2022 11:29	40N 50.506	2E 45.455	142
CODE59, SVP52	06/03/2022 11:35	40N 49.964	2E 45.152	3183891, 300234068940470
CARTHE110	06/03/2022 11:41	40N 49.410	2E 44.852	018
CODE60, SVP53	06/03/2022 11:47	40N 48.979	2E 44.667	3184238, 300234068546420
CARTHE111	06/03/2022 11:51	40N 48.800	2E 44.592	048
CODE61, SVP54, ADOS2	06/03/2022 12:08	40N 48.398	2E 44.478	3183764, 300234068546440, 300234066212350
CARTHE112	06/03/2022 12:17	40N 48.543	2E 43.926	111
CODE62, SVP55	06/03/2022 12:23	40N 48.748	2E 43.236	3194832, 300234068547020
CARTHE113	06/03/2022 12:29	40N 48.943	2E 42.472	122
CODE63, SVP56	06/03/2022 12:35	40N 49.158	2E 41.781	3183834, 300234068547030
CARTHE114	06/03/2022 12:41	40N 49.369	2E 41.052	049
CODE64, SVP57	06/03/2022 12:47	40N 49.565	2E 40.362	3183805, 300234068547130

Figure 26: Deployment information for the drifters released on 6 March (7 CARTHE + 8 CODE + 1 ADOS + 1 DWS + 8 SVP = 25)

Drifters	Date & Time GMT	Latitude	Longitude	IDs and comments
CARTHE115	08/03/2022 10:32	40N 55.105	2E 58.309	050
CODE65, SVP58	08/03/2022 10:37	40N 55.285	2E 57.814	3183838, 300234068547210
CARTHE116	08/03/2022 10:43	40N 55.521	2E 57.117	129
CODE66, SVP59	08/03/2022 10:50	40N 55.792	2E 56.343	3183771, 300234068547230
CARTHE117	08/03/2022 10:56	40N 56.021	2E 55.690	066
CODE67, SVP60	08/03/2022 11:02	40N 56.245	2E 55.084	3196136, 300234068547280
CARTHE118	08/03/2022 11:11	40N 56.658	2E 54.055	032
CODE68, SVP61	08/03/2022 11:25	40N 56.139	2E 54.252	3184204, 300234068940500
CARTHE119	08/03/2022 11:30	40N 55.611	2E 54.494	108
CODE69, SVP62	08/03/2022 11:36	40N 55.075	2E 54.743	3194706, 300234068940510
CARTHE120	08/03/2022 11:43	40N 54.391	2E 55.022	027
CODE70, SVP63	08/03/2022 11:55	40N 54.898	2E 55.475	3197584, 300234068940550
CARTHE121	08/03/2022 12:01	40N 55.425	2E 55.863	098
CARTHE122	08/03/2022 12:12	40N 56.434	2E 56.561	039
CODE71, SVP64	08/03/2022 12:18	40N 56.916	2E 56.899	3197252, 300234068940570
CARTHE123	08/03/2022 12:24	40N 57.369	2E 57.190	047
CARTHE124	08/03/2022 16:55	40N 57.515	2E 57.321	078
CODE72, SVP65	08/03/2022 17:01	40N 51.622	2E 46.375	3197380, 300234068941500
CARTHE125	08/03/2022 17:07	40N 51.026	2E 46.294	076
CODE73, SVP66	08/03/2022 17:13	40N 50.449	2E 46.201	3183630, 300234068941240
CARTHE126	08/03/2022 17:19	40N 49.831	2E 46.158	134
CODE74, SVP67	08/03/2022 17:24	40N 49.317	2E 46.125	3183661, 300234068941550
CARTHE127	08/03/2022 17:32	40N 48.560	2E 46.007	149
CODE75, SVP68	08/03/2022 17:37	40N 48.017	2E 45.929	3183613, 300234068941560
CARTHE128	08/03/2022 17:43	40N 47.395	2E 45.862	143
CARTHE129	08/03/2022 21:31	40N 47.727	2E 40.105	117
CARTHE130	08/03/2022 21:38	40N 48.387	2E 40.018	120
CARTHE131	08/03/2022 21:44	40N 48.990	2E 39.932	088
CARTHE132	08/03/2022 21:50	40N 49.576	2E 39.895	101
CARTHE133	08/03/2022 21:56	40N 50.149	2E 39.869	026
CARTHE134	08/03/2022 22:02	40N 50.771	2E 39.800	125

Figure 27: Deployment information for the drifters released on 8 March (19 CARTHE + 11 CODE + 11 SVP = 41)

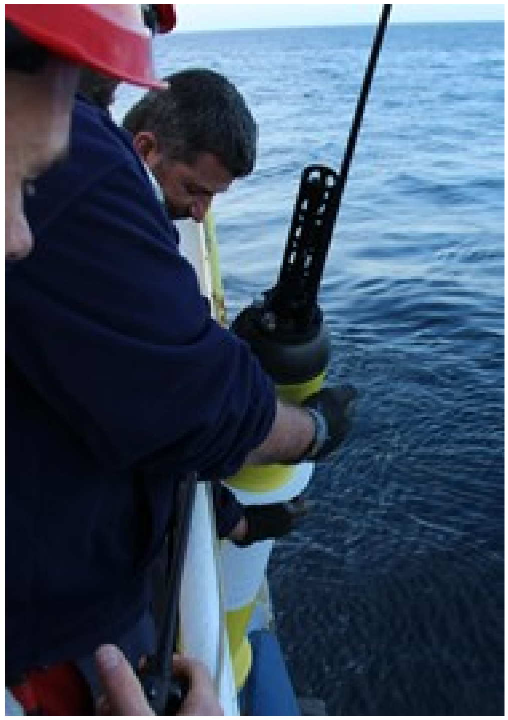

Figure 28: Deployment of the APEX float from the stern of the ship.

Type	S/N	ARGOS/IMEI & WMO numbers	Date & Time UTC	Latitude	Longitude	Water depth Wind
APEX	6842	133513 6903816	23/02/2022 16:20	40N 33.450	2E 37.290	2025 m, 12 kts, 212°
ARVOR DO	AI2632-21EU024	300534060555780 6903818	03/03/2022 13:53	40N 43.655	2E 40.202	1930 m, 3 kts, 225°
ARVOR	AI2600-21EU023	300534060553410 6903817	04/03/2022 09:33	40N 53.291	2E 46.637	1943 m, 2 kts, 45°

Figure 29: Deployment information for the 3 Argo floats released during the CALYPSO 2022 campaign

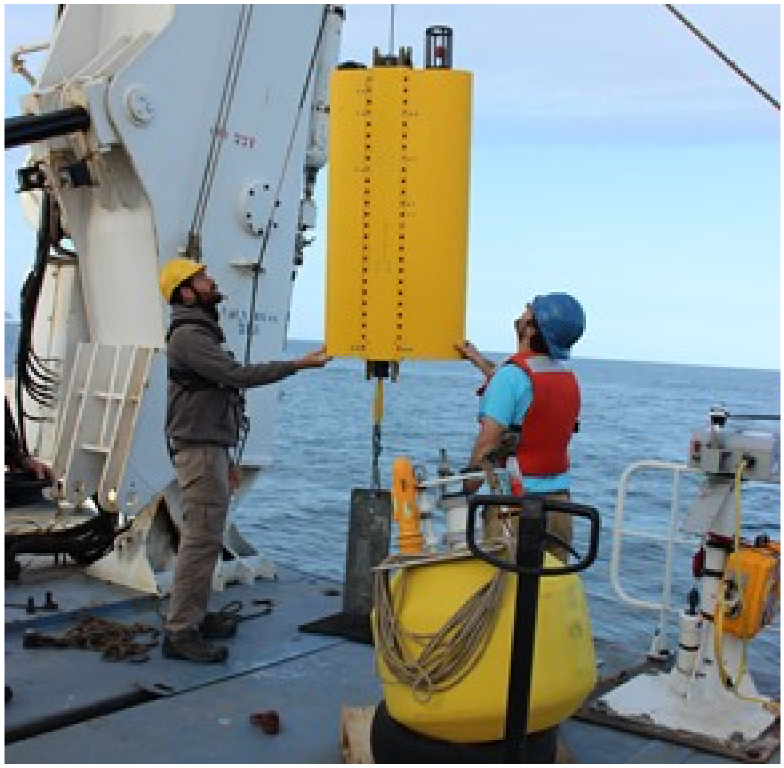

Figure 30: Deployment of the URI Wirewalker.

to do the rest of the Wirewalker operations from the stern, using a sheave suspended from the A-frame. Rather than reposition the winch, a turning block was used to lead the cable aft. For stern recoveries, in order to avoid the risk of transferring the lifting line around the starboard quarter, crew members in a small boat affixed the line to the buoy.

Both Wirewalkers were deployed near 40.51°N, 2.62°E between 14:30 and 15:30 UTC on 23 February and recovered near 40.79°N, 2.88°E between 07:00 and 08:00 UTC on 27 February. PAR sensors were not included on the URI Wirewalker. About half way through the deployment, when the sea state was rougher than usual, the block at the lower end of the pushrod that toggles the walking mechanism of the CMRE Wirewalker jammed, keeping the profiler at the bottom of the cable (near 200 m) until it was recovered.

Both Wirewalkers were re-deployed near 40.44°N, 2.62°E between 16:00 and 17:00 UTC on 27 February and recovered near 40.28°N, 2.48°E between 08:00 and 09:00 UTC on 5 March. The ADCP battery on the URI Wirewalker was not replaced, and expired shortly after deployment. The deployment operation for the URI Wirewalker is illustrqted in Fig. 12.

The two Wirewalkers were deployed near 40N 51.49 02E 57.99 between 08:00 on 09:00 on 6 March and recovered on 10 March. The CMRE Wirewalker was recovered near 41N 02.55 02E 49.87 at about 08:00 UTC, and the URI Wirewalker was retrieved just after (09:00 UTC) near 41N 02.72 03E 00.94.

4.2.22 Real time processing and displaying

The drifter and float data were processed in real time by several systems at OGS, RSMAS/UM and SIO/UCSD. The status of the instruments, along with their trajectories, was monitored using web-based systems reachable with the internet connection onboard R/V Pourquoi Pas?. In addition, all the drifter and float data were inserted into Goggle Earth for display with the measurements of other instruments (ship ADCP and underway, gliders, etc.). Some of the drifter data were also edited and interpolated at 15 min intervals and velocities were computed.

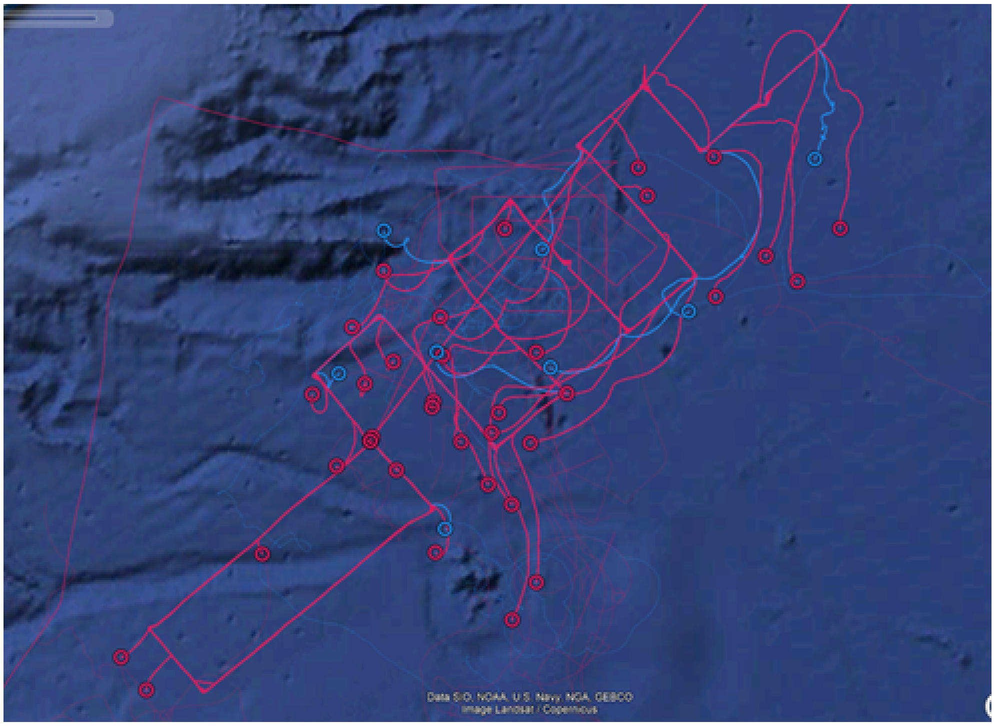

Figure 31: Trajectories and last positions of the SVP (blue) and CARTHE (red) drifters deployed on 18-20 February (last positions at 09:00 UTC on 20 February).

4.2.23 Preliminary results

The following figures (Figs. 13 to 19 show some of the results obtained with the drifters, floats and Wirewalkers.

4.2.24 Conclusions

Overall the drifter, float and Wirewalker operations carried on during the CALYPSO 2022 Experiment on 17 February – 11 March 2022 went well, despite some problems with the thermistor chain on the ADOS drifters. The deployment operations were performed by the various teams onboard R/V POURQUOI PAS? in a coordinated and efficient way. In total more than 350 Lagrangian assets were deployed. The data collected by these instruments during and after the campaign are of good quality and will provide new and interesting results on the dynamics and circulation in the Balearic Sea.

4.2.25 Multi-level drifter experiment

On 1 March 2022 an array of drifters was deployed in the Balearic Sea from the R/V Pourquois Pas? (Fig. A1). The array consisted of nine nodes in a 3-by-3 square with 1-km spacing between nodes. At each node, four purpose-built WHOI drifters with holey-sock drogues (5 m long × 60 cm diameter) centered at depths of 8 m (yellow buoys), 22 m (orange buoys), 35 m (red buoys) and 50 m (blue buoys) respectively were deployed in rapid succession, along with one CARTHE (0.5-m drogue) and one SVP (15-m drogue) drifter. At some nodes, additional assets were deployed: WAVY wave spectrum measuring buoys, DWS surface drifters, and CODE drifters (1-m drogue). Between nodes 5 and 6, near the center of the array at a site denoted by "M" in Table A1, an ADOS drifter with a thermistor chain spanning 0-150 m was deployed. The site selected for the experiment lay on the eastern perimeter of a small cyclonic eddy (see Fig. A2). The URI Wirewalker was located about 1 km to the northwest (40.367° N, 02.550° E at 12:00 UTC). In order to account for the anticipated drift during the deployment of the array, earlier nodes were deployed upstream of their intended locations at the time of array completion. Deployment targets were chosen based on a current estimate of 11 cm/s toward the northeast (bearing 44°), and a deployment schedule of one node every 15 minutes. The array was oriented to align with the direction of the estimated current.

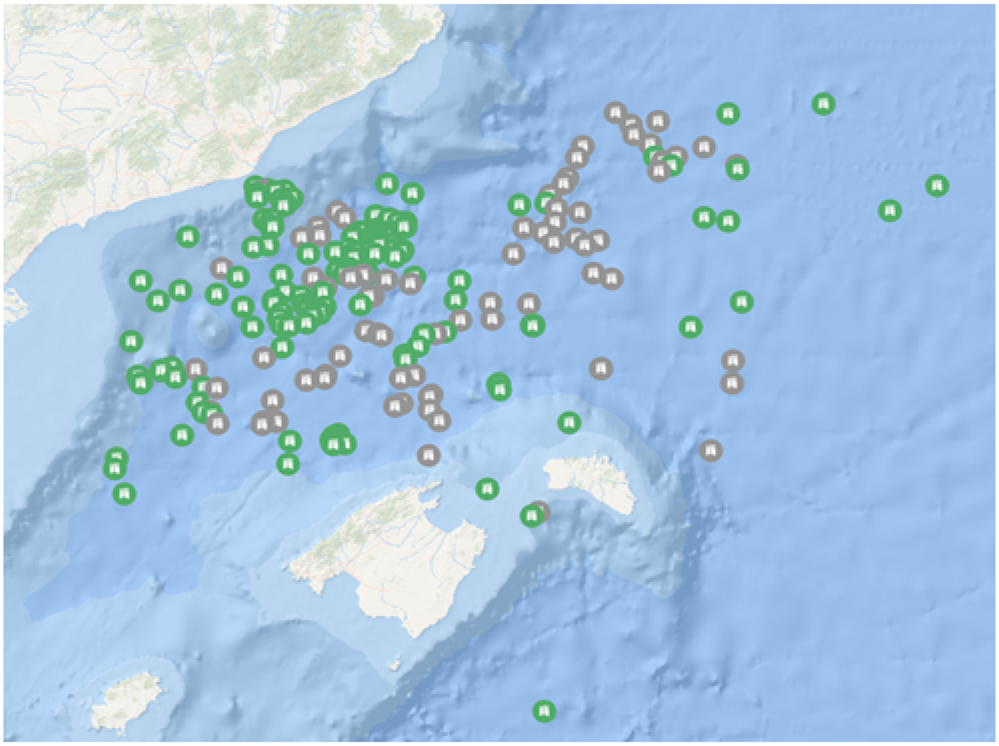

Figure 32: Last positions of all the drifters deployed during the CALYPSO22 cruise: drifters still alive on 11 March (green symbol) and which stopped transmitting before that date (gray symbols).

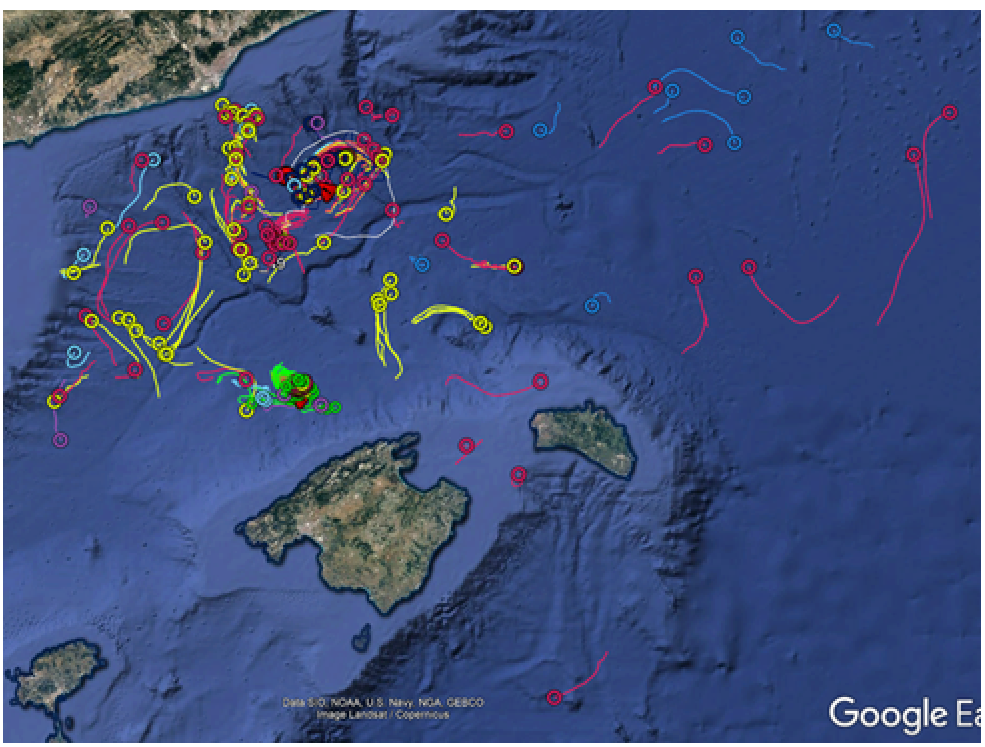

Figure 33: Two-day long tracks of the drifters and floats alive on 9-11 March (circle symbols at the end of the segments on 11 March morning).

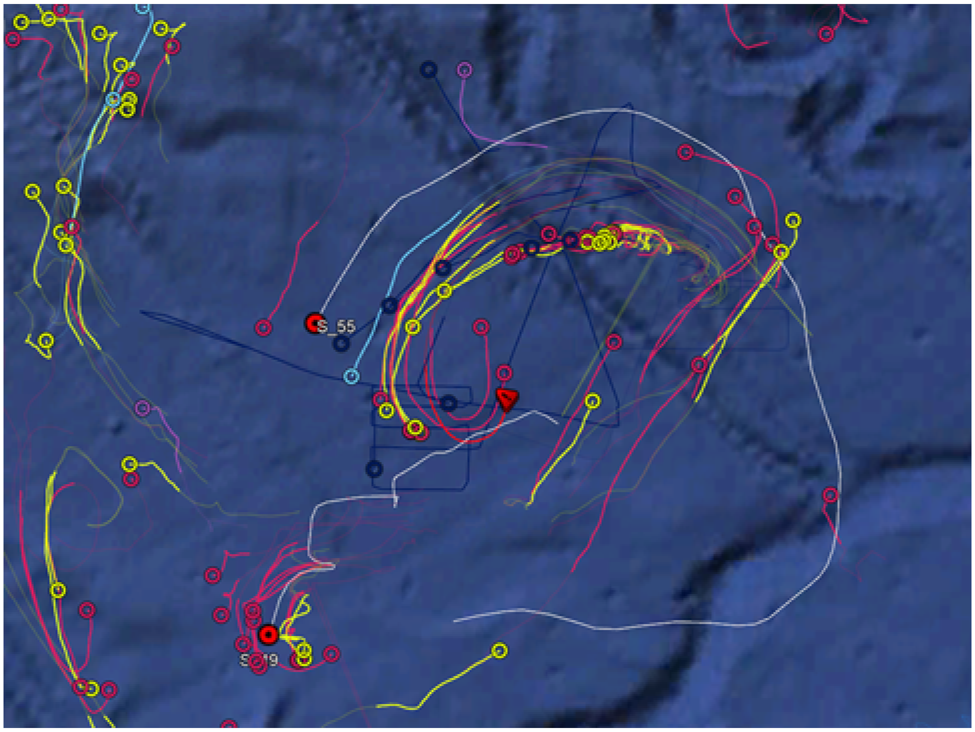

Figure 34: Tracks of the drifters and floats around the last circulation featured studied: entire tracks of the ARVOR floats (white) and one-day segments of the drifter trajectories.

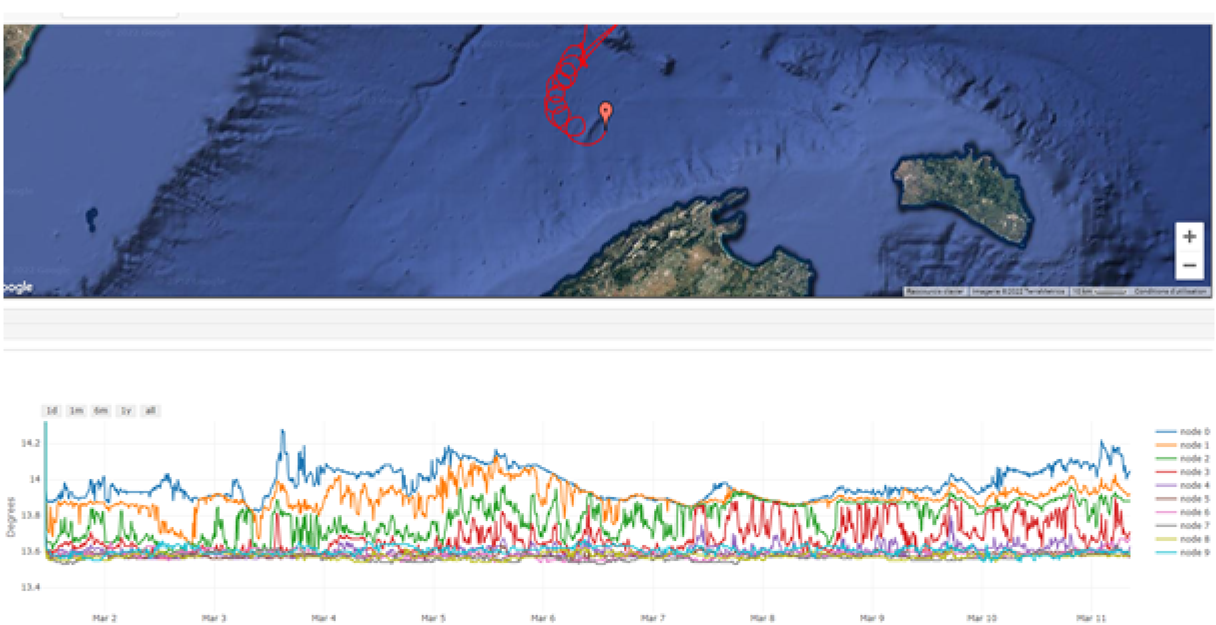

Figure 35: Trajectory and temperature time series (between 10 and 150 m) for ADOS1 drifter (300234066212310) deployed on 1 March.

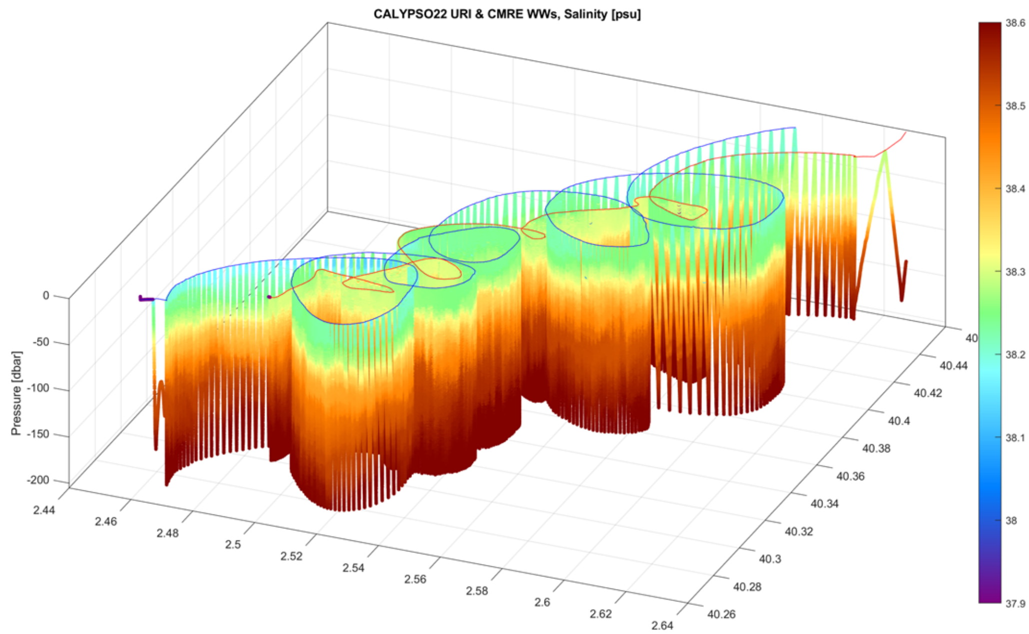

Figure 36: Trajectories and salinity time series for the two Wirewalkers (CMRE - blue track, URI – red track) during the second deployment (27 February – 5 March).

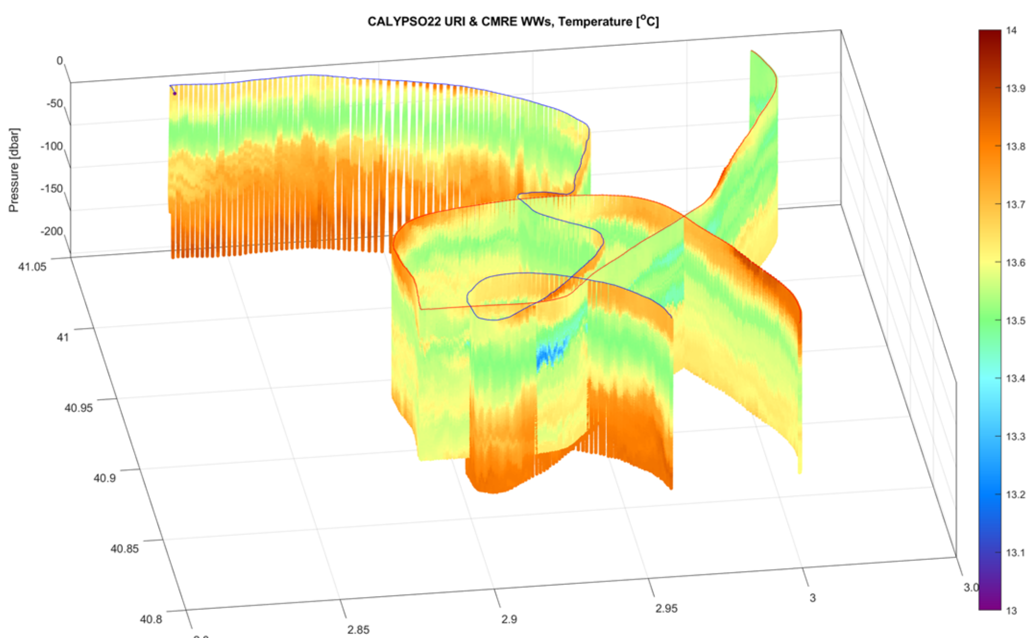

Figure 37: Trajectories and temperature time series for the two Wirewalkers (CMRE - blue track, URI – red track) during the third deployment (6 - 10 March).

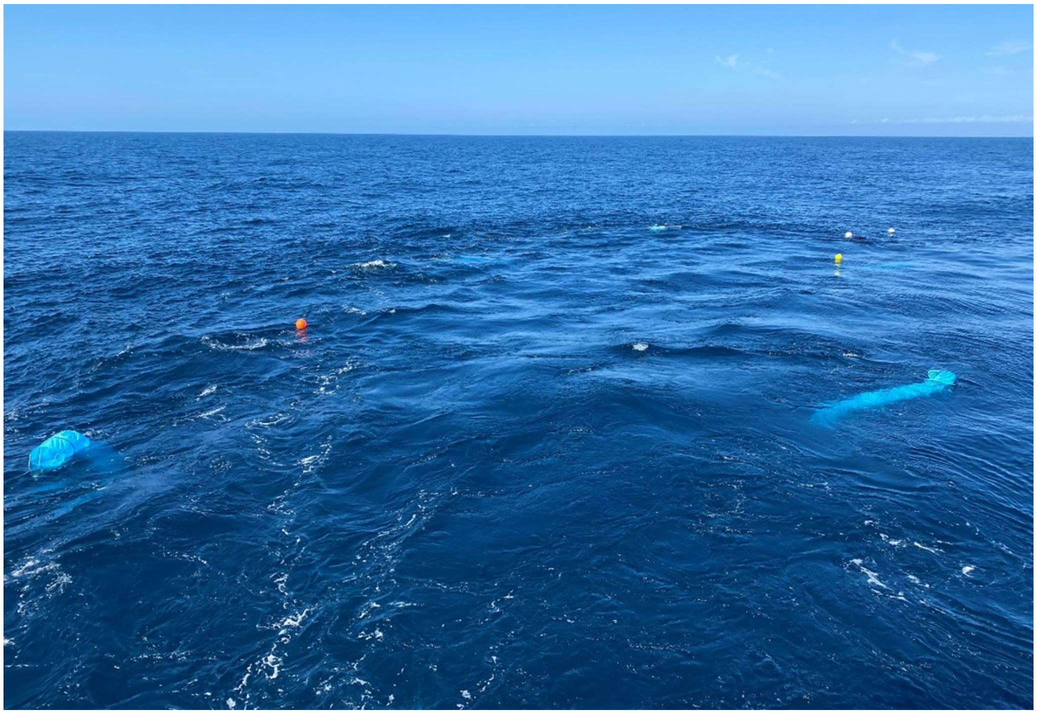

Figure 38: Drifters during deployment as part of the multi-layer array. Colored buoys and blue drogues belong to WHOI drifters. CARTHE and SVP buoys are white and appear at the upper right. The island of Mallorca is visible on the horizon.

4.2.26 Acknowledgements

We are very grateful to all the people who helped us with the drifter preparation, drifter deployments and the real time processing of their data. In particular, thanks to Lance Braasch (SIO/UCSD), Ed Ryan (RSMAS/UM) and Antonio Bussani/Massimo Pacciaroni (OGS) for the real time processing and displaying of the drifter data.

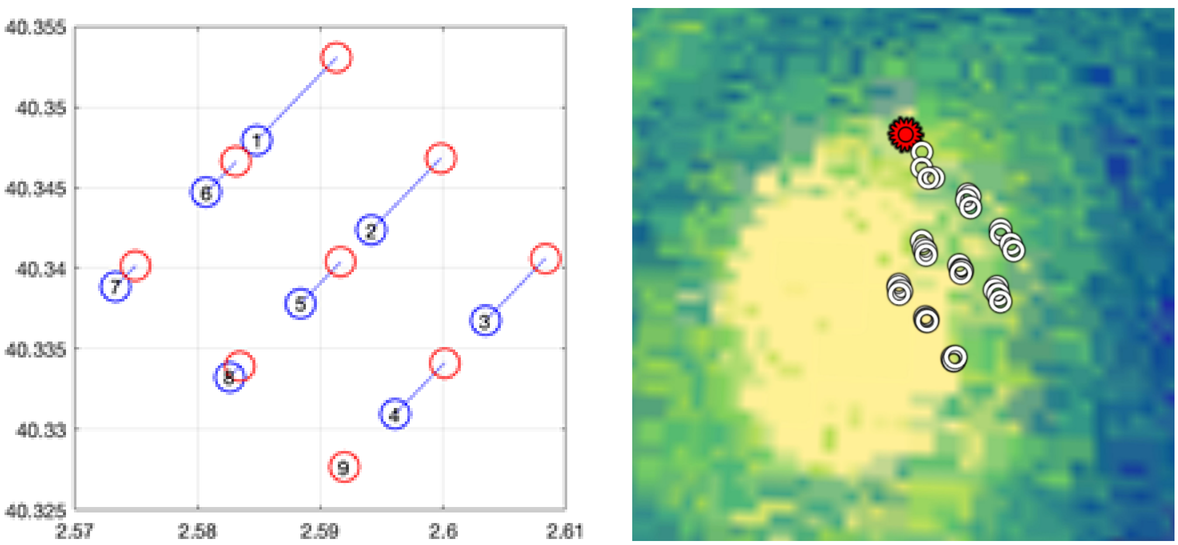

Figure 39: Left: Multi-layer drifter array deployment plan. Deployment targets (blue circles) are labeled by node number. Intended node locations at the time of array completion lie to the northeast of the deployment targets (red circles). Right: Locations of the WHOI drifters at 1200Z (+/- 5 minutes). Initial drift at the western nodes was to the northeast (as anticipated); at the northern nodes it was northward, and at node 9 southeast. The array was positioned on the eastern edge of a cyclonic eddy whose location is roughly indicated by the background daily satellite chlorophyll image. The location (1200Z) of the URI Wirewalker is indicated in red.

Node No.	1	2	3	4	5	M	6	7	8	9
Lat. (N)	40.3531°	40.3468°	40.3406°	40.3341°	40.3404°	-	40.3466°	40.3402°	40.3339°	40.3276°
Long. (E)	2.5913°	2.5998°	2.6083°	2.6001°	2.5916°	-	2.5831°	2.5749°	2.5834°	2.5919°
Lat. (N)	40.3480°	40.3424°	40.3367°	40.3309°	40.3378°	-	40.3447°	40.3389°	40.3333°	40.3276°
Long. (E)	2.5848°	2.5941°	2.6034°	2.5961°	2.5884°	-	2.5807°	2.5733°	2.5826°	2.5919°
Lat. (N)	40.3492°	40.3435°	40.3374°	40.3308°	40.3375°	40.3393°	40.3440°	40.3397°	40.3344°	40.3286°
Long. (E)	2.5840°	2.5934°	2.6024°	2.5982°	2.5899°	2.5873°	2.5818°	2.5746°	2.5817°	2.5908°
UTC	0956	1012	1032	1049	1103	1107	1116	1133	1146	1201
DWS IMEI	942230	-	-	-	-	-	-	-	-	942250
WAVY ID	78	-	-	-	79	-	-	-	-	82
Carthe ID	132	073	065	046	072	-	138	052	130	013
CODE #	35	-	-	-	36	-	-	-	-	37
WHOI 8m ID	1	2	3	4	5	-	6	7	8	9
SVP IMEI	549010	549040	549150	549190	549200	-	941600	941670	941760	941880
WHOI 22m ID	10	11	12	13	14	-	15	16	17	18
WHOI 35m ID	19	20	21	22	23	-	24	25	26	27
WHOI 50m ID	28	29	30	31	32	-	33	34	35	36
WHOI 8m ESN	39665	39645	44149	42613	44322	-	44357	44152	39924	44151
WHOI 22m ESN	43986	38218	43186	42340	40592	-	41839	33694	44335	40698
WHOI 35m ESN	40245	42361	42347	39875	41851	-	41845	44089	38831	39798
WHOI 50m ESN	39631	41673	41849	44341	38086	-	41786	40120	42346	39610

Figure 40: Drifter IDs and location information: Locations given are (top, reddish) intended node position at the time of array completion; (middle, bluish) target deployment location given expected current and schedule; (bottom, greenish) actual location and time on 01-March-2022 at which drifter deployment commenced, as marked by handheld GPS. Only the final 6 digits of the IMEI numbers of DWS and SVP drifters are given—the full IMEI for all drifters are: 300234068******. "WHOI" drifters are listed twice: first by SPOT tracker name, and second by SPOT tracker ESN (final five digits—full ESNs for all trackers are: 0-44*****). Node M denotes the deployment location of the thermistor chain.

MLF	Deployment
88	3/4/2022 08:34, 40° 47.384 N, 2° 46.264 E
89	3/4/2022 08:54, 40 48.579 N, 2 47.134 E
81	3/4/2022 20:00, 40°49.500 N, 2° 53.274 E
82	3/4/2022 20:03, 40 49.436 N, 2 54.039 E
81	3/6/2022 16:43, 40° 51.12'N, 2° 56.58'E
82	3/6/2022 17:00, 40° 51.18'N, 2° 57.16'E

Figure 41: Deployment and recovery times for the four Mixed-Layer Floats

4.2.27 Mixed Layer Floats

During the CALYPSO 2022 cruise aboard R/V Pelagia, the APL team operated four Mixed Layer Lagrangian floats (MLFs). These were standard Lagrangian Floats measuring temperature and salinity at the top and bottom (1.4 m apart) and pressure at the top and center of the float. In addition, each carried a Nortek 1000, 1MHz, 5 beam ADCP mounted on the side of the float and pointing upward. This measured 3 components of velocity using broadband pulses at 1 m resolution to about 20 m range and pulse-coherent pulses at 5 cm resolution to 6 m range. Additionally, two of the floats (88 and 89) measured chlorophyll fluorescence and optical backscatter. The same two floats (88 and 89) were also equipped for acoustic tracking.

Equipment delivery was delayed until March 2nd. Operations started March 4th and continued until March 10th, giving us only 6 days of float operations. This limited time, combined with significant operational problems and the other duties of D'Asaro and Shcherbina resulted in much more limited results than we had hoped for.

The MLFs were deployed in the NE cyclonic eddy in coordination with surface drifter releases and shipboard surveys. The float missions were designed to measure subduction from the surface layer. Floats 81 and 82 were initially clearly too light. They were recovered and the correct ballast weights added. Floats 88 and 89 were designed to be acoustically tracked from R.V. Pelagia, using a Trackpoint II system mounted on an over-the-side pole. However, the pole broke early in the cruise and the tracking could not be conducted as planned. Limited tracking with the ship stopped was still possible. After a further few days of operations, it became apparent that none of the floats behaved in a sufficiently Lagrangian manner to measure accurate 3D Lagrangian trajectories. With only 2 days left, the floats were therefore reprogrammed with the goal of diagnosing the problem. This was successful in eliminating several possible causes. Further work will be required to diagnose the true problem.

Float deployment and recovery dates and positions (all times are UTC):

4.2.28 AUVs

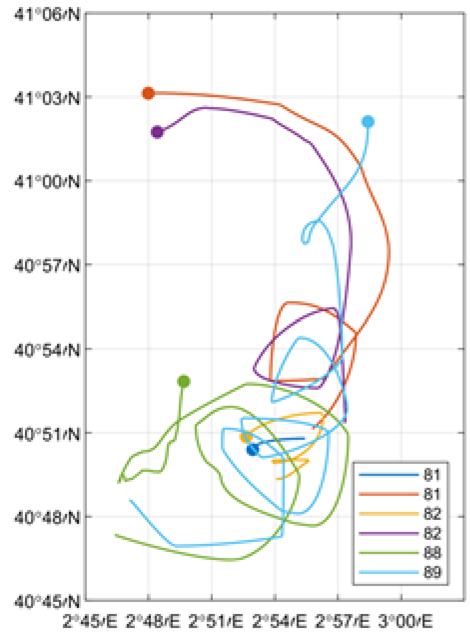

Figure 42: Approximate trajectories of the MLFs during the 6 CALYPSO 2022 deployments. The open/filled circles indicate the deployment recovery locations.

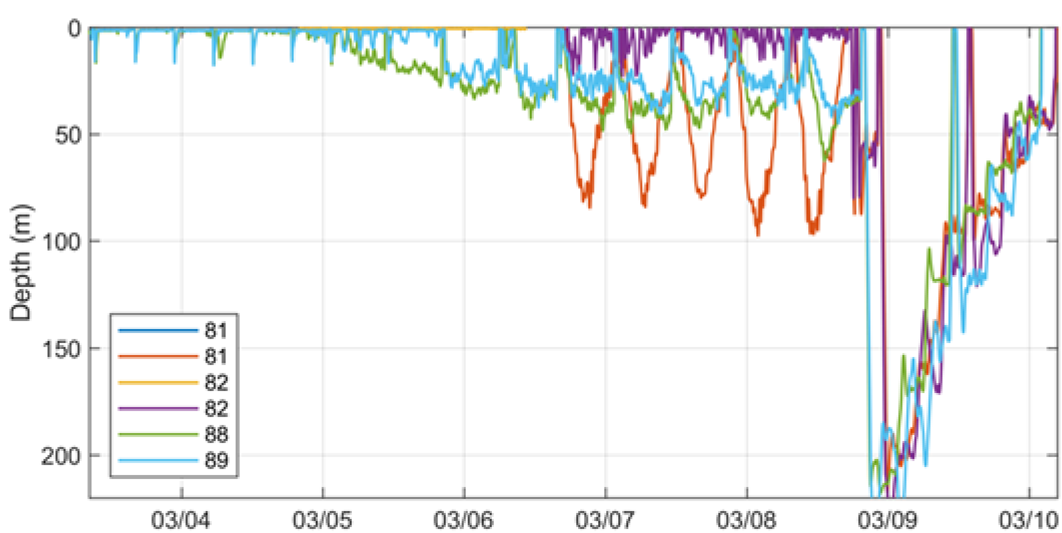

Figure 43: Depth excursions of the MLFs during the 6 CALYPSO 2022 deployments.

Figure 44: CTD SBE rosette

5 CTD and Water Sampling

5.1 Overview

A total of 61 CTD stations were recorded during the cruise. The depths of the profiles ranged from 244 to 611 meters, with the majority of casts falling between 250 and 300 meters in depth. Sensors on the CTD rosette included two Seabird SBE3 temperature sensors (S/Ns 6394 and 5136), two Seabird SBE4 conductivity sensors (S/Ns 3646 and 4855), a Seabird SBE43 Oxygen optode (S/N 3734), a FLNTU turbidity sensor (S/N FLNTURTD-5187), a WetLabs C-Star transmissometer (S/N CST-383PR), a WETStar Chlorophyll-a fluorometer (WS3S-699P), a SUNA V2 Nitrate sensor (S/N 1162), a Seabird SBE18/27 pH sensor (S/N 0504), a Chelsea PAR light sensor (S/N 0491) and an Underway Visual Profiler. Niskin bottles were usually fired at six depths, chosen using an adaptive sampling plan, except in the case of several dilution and SIP experiments, where the water budget was adjusted because more water was needed at a single depth. Bottles were sampled for the following: dissolved oxygen (Winkler titration), flow cytometry, total DNA, nutrients, particular organic carbon, dissolved organic carbon, metatranscriptomics, metagenomics, microplastics, salinity and biological oxygen demand. Not all parameters were sampled on every cast or from every Niskin. More details on the specific measurements collected are described below.

5.2 Details about the CTD and post-processing

The depth of each cast ranged from 250 to 650m, depending on the location and feature of interest. Calibration casts were taken at the beginning and end of the cruise for salinity, chlorophyll, nutrients, POC and oxygen, as well as to calibrate the ecoCTD sensors. These casts are noted in the master cast table. The CTD data is post-processed using the Seabird data processing module. First, the data is converted to .cnv file type, and a low-pass filter is applied to the pressure field. Then the oxygen and PAR data are aligned with the pressure and temperature fields and a cell thermal mass correction is computed for the conductivity to account for the effect of temperature. A loop edit filter is applied to eliminate repeated data, deleting points with a vertical velocity of less than 0.25 meters per second. Dependent variables (dissolved oxygen and PAR from the voltage, salinity from conductivity and density from salinity and temperature) are derived, and then the data is binned into 1-meter bins. Finally, the data is split into the full cast and the downcast and saved on the server in the science/CALYPSO/CTD_Data/DATA folder. Before each cast, the rosette was lowered to 13 meters to soak before being raised back up to the surface to begin the cast at 5 m. Initially, hand-off of the CTD winch control from the bridge to the deck occurred at 100 m, and the upcast speed from

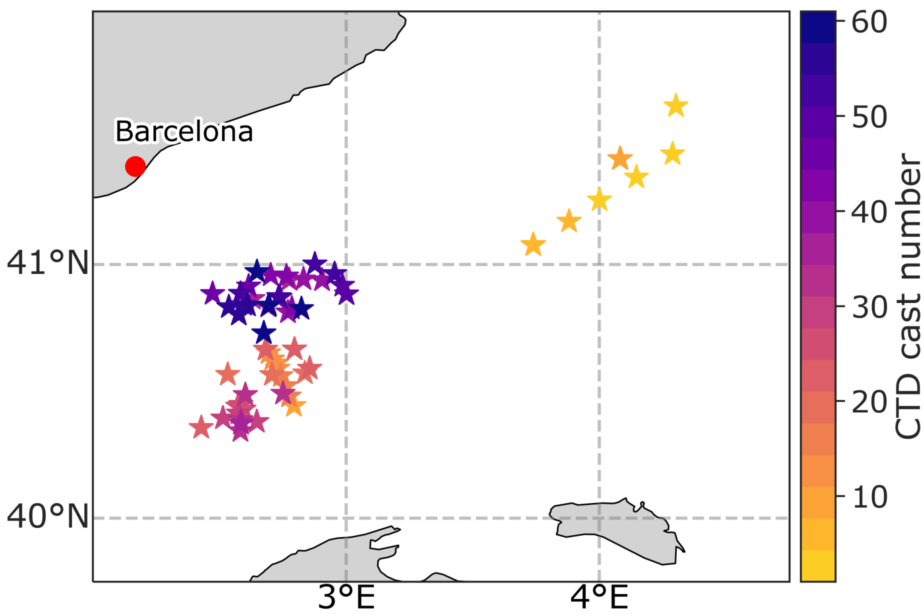

Figure 45: Map of the CTD stations.

Figure 46: List of all CTD stations

100 m to the surface was 0.5 m/s, but starting with cast 26, the hand-off was moved to 50 m from the surface to reduce the spiking that can occur if the rosette is traveling more slowly through the pycnocline. On cast 30, one 5L Niskin bottle imploded under pressure and broke two other 12L bottles on the rosette. Subsequently, the bottles were rewired to a new configuration with more 5L bottles but roughly the same total volume of water. The latch positions and associated bottles are described in the science/CALYPSO/CTD_DATA/MergedCTDcasts/CTD_casts_logs.xlsx. CTD station locations were highly adaptive throughout the cruise, with casts taken in between periods of EcoCTD sampling to include full physicochemical context for water sampling data. One transect was taken across the first submesoscale cyclonic eddy (Fig. 49) on Feb. 23 - 24. Two Lagrangian surveys following a Wirewalker drift were undertaken, although in both cases, the Wirewalker did not follow the projected trajectory and the survey was less informative than expected. Several CTD stations were targeted within an eddy specifically for biological experiments to estimate growth rates or characterize the microbial food web.

Some plots from the CTD data are shown below:

5.3 Dissolved Oxygen

Seawater samples were collected from the Niskin bottles mounted on the CTD- Rosette and the underway system, for comparison and in order to calibrate the oxygen CTD sensor.

5.3.1 Methods

In total 200 samples were collected at different depth levels from 2 to 6 depths at the 45 CTD stations. We chose different depth levels to sample the full range of dissolved oxygen within the water column. We also sampled seawater from the underway system at 3 random stations. The underway system samples were taken at 4-5m depths every minute. Samples were taken back to the onboard lab and processed using the Winkler titration.

Oxygen samples were analyzed using the standard Winkler titration method. The method is based on the Winkler method using reagents up to the level of titration with thiosulfate solution, this is done using a computer controlled potentiometric end-point titration procedure.Dissolved manganese and a

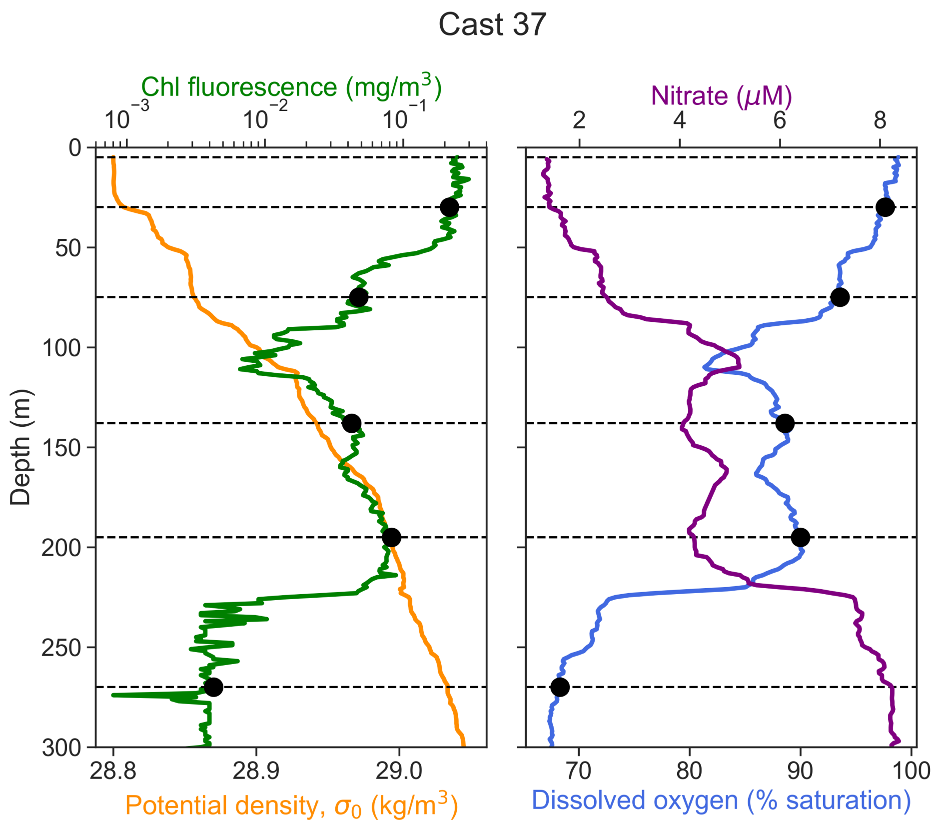

Figure 47: Example of two secondary Chl maxima seen on Cast 37, as well as the correlated relationship with oxygen and anticorrelated relationship with nitrate

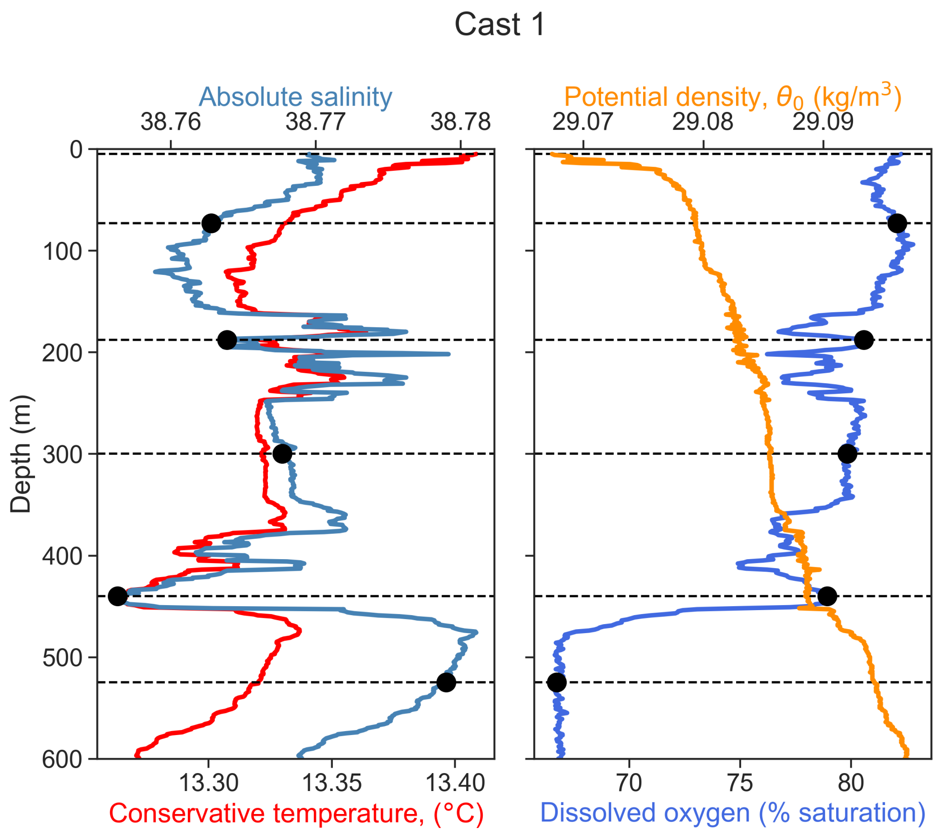

Figure 48: Deep mixed layers seen in the first cast in the Gulf of Lion convective region.

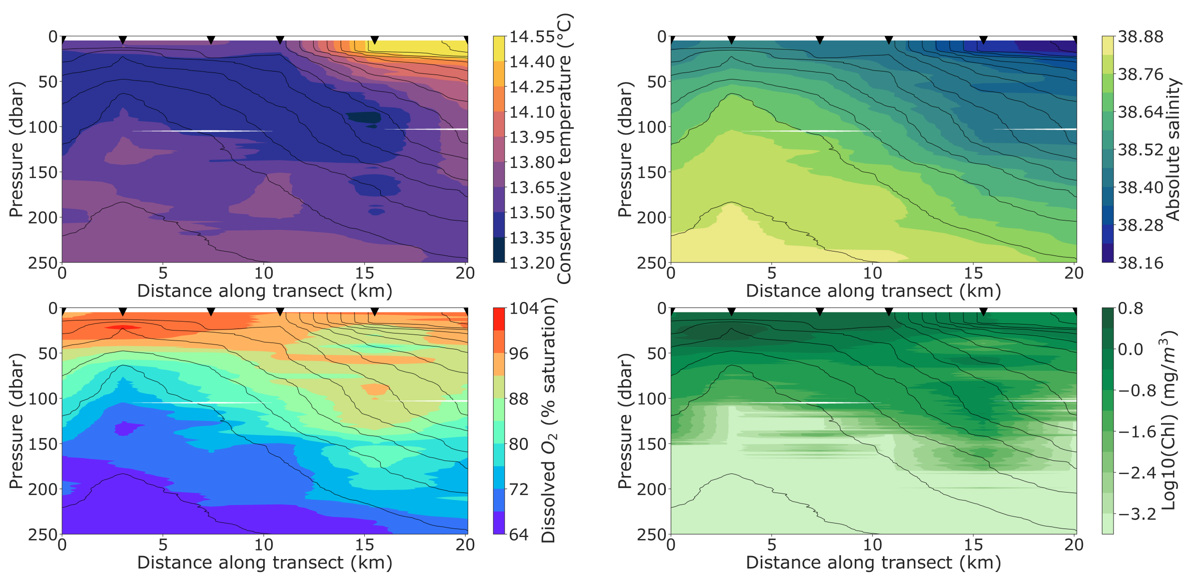

Figure 49: Sections from a cross-front transect during the sampling of a cyclonic eddy, showing temperature, salinity, dissolved oxygen and beam attenuation. The transect ran from northeast to southwest with 6 stations.

Figure 50: Dissolved oxygen samples and the Winkler titration instrument on board.

base of iodide ions are added to the sample, then Mn2+ is oxidized by the molecule of oxygen in the seawater sample, to the point that it precipitates as Mn(OH)2 at the bottom of the bottle. Then an acid solution is added to the sample after some hours to reduce the Manganese into Mn2+.

5.3.2 Preliminary results

The Winkler values of the first 16 samples from cast 1 and cast 2 were lower than the CTD SBE oxygen — the Winkler values are outliers here, so they were flagged as questionable and not used to compute the calibration coefficient.

5.3.3 Dissolved oxygen calibration

We compare the CTD SBE O2 with the Winkler observations for the different cast. After the 1st quality check and flagging, a regression between the Winkler and the CTD will be set to quantify the offset and proceed with the calibration. The calibration is a work in progress and will be be set within a month after the end of the cruise.

5.4 Salinity

Salinity samples were taken on Cast 59 from four depths using 250 ml borosilicate KIMAX-35 bottles provided by the Pourquoi Pas. Samples were taken at 32, 105, 250 and 450 meters depth by filling bottles from the Niskin to the shoulder and capping them using a plastic insert and will be analyzed back on land.

5.5 Nitrate

Nutrient samples were taken from the Niskin bottles after all other water samples were collected. Samples were rinsed three times, filled directly from the bottle without filtration, and stored at -20°C. A SUNA V2 deep (SN 1126) was attached to the CTD rosette with a battery pack and measured optical nitrate on most casts. The SUNA was calibrated before and after the cruise with MilliQ water. The pre-cruise calibration file is SNA1162C.CAL and the post-cruise calibration file is SNA1162C.CAL. For the Level 1 product, the data was postprocessed in the UCI 2.0 software and interpolated to the time stamps of the CTD data, and then a three-point forward-backward running median was applied to smooth the processed field.

5.6 AutoBOD

The WHOI Auto-BOD Mk-II was used to make measurements of whole community respiration rates from sealed incubated bottles of seawater using an oxygen optode system. The AutoBOD (Automatic

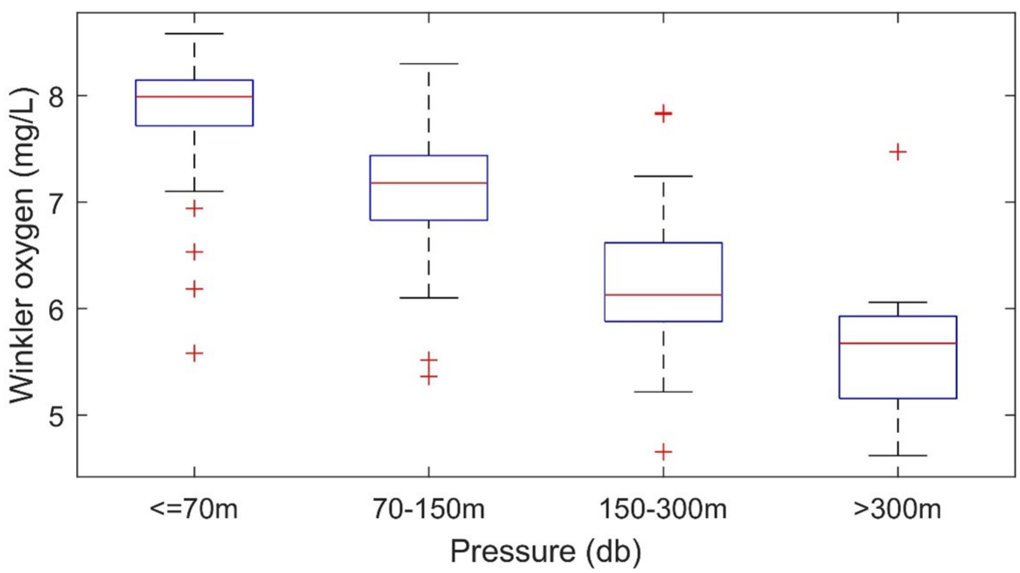

Figure 51: Boxplots by depth range for outlier detection. Data will be quality checked for aberrant observations and will be flagged according the WOCE flags (table 2). A value more than three median absolute deviation will be considered as outlier (ie. Will be flagged as “3”, questionable and not used (Fig. 4), this will be considered as the level 1 product.

WOCE flag value	Interpretation
2	Acceptable/measured
3	Questionable/not used
9	Not measured/ no data

Figure 52: WOCE flags

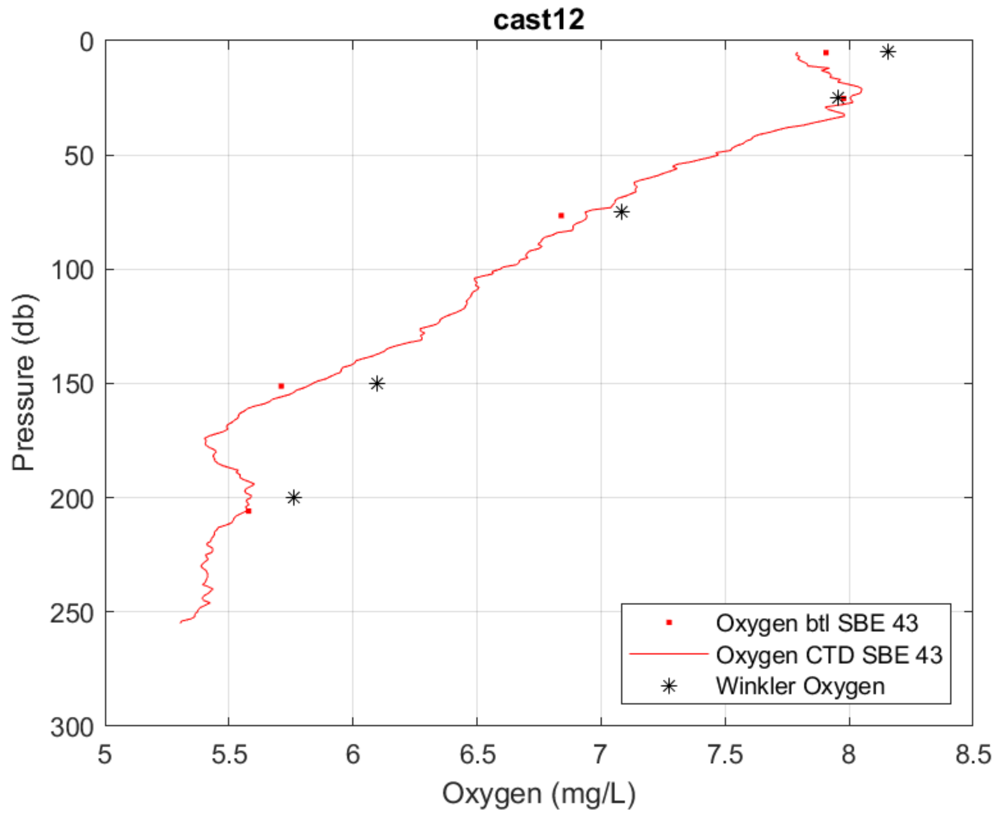

Figure 53: CTD profile of cast 12 vs. pressure with oxygen Niskin bottle values and the Winkler For the calibration, we are following Owens et al. (1985)

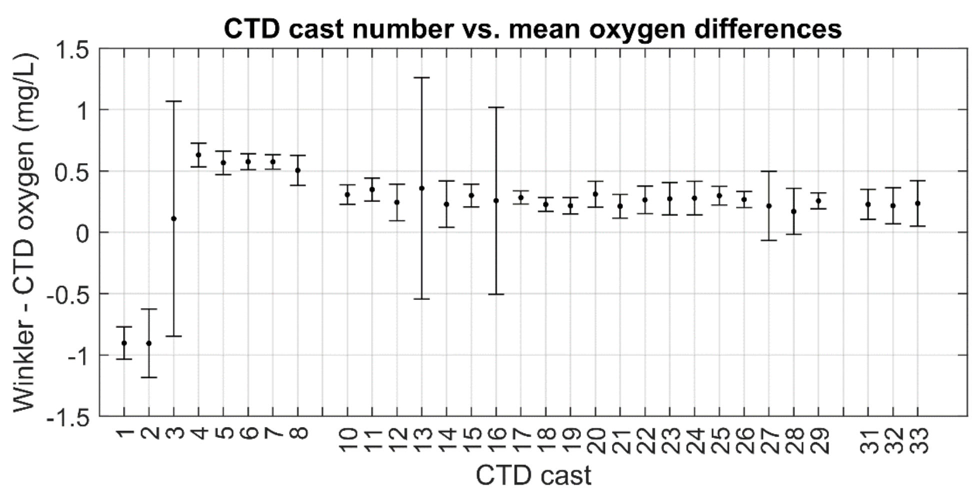

Figure 54: Winkler – CTD oxygen values vs. CTD cast number with standard deviation of the average difference between

Biological Oxygen Demand) can hold 12 bottles at a time on a carousel that rotates the bottles past the spot sensor and generates a set of 10 observations from a sample bottle every 15 minutes. For the first CTD, duplicates were taken at all depths where a bottle was fired. Subsequently, triplicates were taken from each depth. The bottles were incubated in a dark and temperature-controlled room at 14 deg C for 48 hours to track the drawdown of oxygen. Simultaneously, eight to eleven 100 mL glass Winkler bottles were filled with water from the same Niskin and incubated in the dark. At 24 and 48 hours, samples were fixed for flow cytometry (FCM) and filtered for total DNA. For a subset of samples, samples were fixed for FCM at 12 hours and/or 72 hours to extend the timeseries. The exact volume of water used for total DNA varied depending on the number of bottles that could be filled from a Niskin and is documented in the full AutoBOD run logs. Bottles were filled from a dedicated 5L Niskin and care was taken to eliminate bubbles. 46 sets of BOD timeseries measurements were taken during the cruise, sampling communities from a range of depths, density surface, oxygen and chlorophyll concentrations. In many cases, samples were taken in parallel with a dilution or incubation experiment set up by the GEOMAR biological sampling team. 15 samples were taken from secondary chlorophyll maxima that were inferred to represent subduction of surface water.

5.7 Post-cruise calibration

The following sensors will be re-calibrated or adjusted based on analysis of bottle samples taken during the cruise: SUNA nitrate sensor, transmissometer (and calculation of particulate organic carbon from beam c), Chl, dissolved oxygen, salinity. The following individuals plan to be the point of contact for the calibrations: Chlorophyll – Fabian Wittmers (fwittmers@geomar.de) Oxygen – Malek Belgacem (malek.belgacem@ve.ismar.cnr.it) Nutrients, salinity, POC – Kathleen Abbott (keabbott@mit.edu)

6 Flow cytometry at sea

Samples operator = Roxane Tzortzis; Gérald Grégori (installation onboard), Computer analysis = Laurina Oms and Chloé Goret; Collaborators = Andrea Doglioli, Melilotus Thyssen

The data in the "CTD$_{c}ast_{0}228to0310$"and"$surface_{i}ntake_{0}228to0310$"$directoriescomefromtheperiodbetweenFebruar$

To sample phytoplankton communities at high frequency an automated flow cytometer (CytoSense from the CytoBuoy company) was installed on board of the Pourquoi Pas ? and connected to the thermosalinographe (TSG) seawater circuit (surface intake). This cytometer was also used to analyse the samples from the CTD casts (water sampled from the Niskin bottles).

The automated flow cytometry is a technique capable of performing high frequency analysis (typically up to several times pr hour) of seawater to identify different groups of phytoplankton based on their optical properties (scatter and fluorescence intensity). The cytometer contains a sheath fluid composed of 0.1 µm filtered seawater, which stretches the sample to separate, align and drive the cells one by one through a 488nm wavelength laser beam. The cells interact with the photons of the laser beam and several optical signals are recorded for each of them. Light scattered at small angle (FWS: forward scatter) and at 90° to the direction of the light beam (SWS: sideward scatter) are two signals depending on the size, the shape and the granularity of the particles. Then two fluorescence signals induced by the light excitation of photosynthetic pigments are also collected by photomultiplier tubes. In the case of phytoplankton the cytometer measures the red fluorescence (FLR) induced by chlorophyll a and the orange fluorescence (FLO) induced by phycoerythrin. The CytoUSB Software (Cytobuoy) was used to control the instrument and perform the automated sampling and analysis of the seawater.

Two distinct protocols are run sequentially, in order to treat the samples according to the size classes to which the organisms belong : *Protocol FLR2 = dedicated to the analysis of the smallest phytoplankton (Synechococcus, Prochlorochoccus, picoeukaryotes); for whch the FLR threshold is set at 2mV, *Protocol FLR15 = dedicated to the analysis of largest cells (nano- and microphytoplankton); for which FLR threshold is set at 15mV.

The combination of the different optical signals recorded by the cytometer on two-dimensional cytograms makes possible to separate different clusters of dots sharing similar optical properties. The different clusters of phytoplankton are manually gated out and identified. The abundances (cells/cm^{-3})$andaverageintensitiesofthevariousopticalvariablesarerecordedforeachgroupthankstotheCytoCLUSsoftw$
$in-flowcameracapableofphotographingthecellsastheyflowintheinstrument.However, onlythelargestcellsmeasuredbyt$

Up to 9 cytometric groups of phytoplankton have been distinguished from the sea surface intake and CTD cast during the entire focus period : "CTD$_{c}ast_{0}228to0310$"and"$surface_{i}ntake_{0}228to0310$"

FLR2 protocol : *SYNECO = Synechococcus; *SYNECO$_2$ $= othercolonyofSynechococcus; *PROCHLO = Prochlorococcus; *REDPICO = RedfluorescencePicophytoplankton; *PICOHFLR = HighRedfluorescencePicophyt$

FLR15 protocol : *REDNANO = Red fluorescence Nanophytoplankton; *ORGNANO = Orange fluorescence Nanophytoplankton; *HSNANO = High Scatter Nanophytoplankton; *REDMICRO = Red fluorescence Microphytoplankton;

"surface$_{i}ntake_{a}llcruise$" $-Thegroupsarethesamethanbefore, butthenamesaretakenfromstandardizedvocabulary(Th$ $//doi.org/10.3389/fmars.2022.975877)$

FLR2 protocol : *OraPicoProk(=SYNECO) *OraPicoProk$_2$$(= SYNECO_2)*RedPico(= REDPICO)* RedRedPico(= PICOHFLR)$

FLR15 protocol : *RedNano(=REDNANO) *OraNano(=ORGNANO) *HsNano(=HSNANO) *RedMicro(=REDMICRO)

There are 4 different levels of analysis of the flow cytometry data files : L0 = raw data (cyz format) = data analyzed manually with CytoClus; L1 = CytoClus outputs; L2 = Cytoclus outputs+position from CTD and GPS (latitude,longitude,depth); L3 = Map of abundances;

If these data are used in your work, please inform the M.I.O cytometry team by contacting : laurina.oms@mio.osupytheas.fr and gerald.gregori@mio.osupytheas.fr

7 Microplastics

Microplastics were sampled from the rosette sampler at most CTD stations. Sampling depths were chosen together with the water sampling team according to the down-cast CTD profiles. Casts were generally made down to a maximum depth of approximately 200-300 meters, in order to match them with EcoCTD profiles. When selecting sampling depths, efforts were made to sample as many water masses and relevant hydrographic features as possible. In most cases, 6 sampling depths per station were selected and two Niskin bottles were fired at each depth. Of these two bottles, one bottle per depth was entirely dedicated to microplastic sampling. In some cases, water from the remaining bottles was used to collect a duplicate sample or to increase the available sampling volume. To avoid external contamination, all samples were filtered directly on the ship's deck using a closed filtration system preventing air-exposure of seawater samples (Fig. 1). Once the Rosette was retrieved on-board, a 47-mm stainless-steel filter-holder was directly connected to the Niskin's faucets using a silicone tube. Water was then filtered using a diaphragm liquid vacuum pump (Rocker Alligator 200). The filtered volume (mean 10.2 ± 2.6 liters per depth), was measured using graduated cylinders collecting the water outflow from the pump and noted on a log-sheet. The original aim was to collect at least two replicate samples per depth to offset within-site and sample variability, however due to time constraints between stations (i.e., excessive filtration time), after February 24th, sampling was reduced to single replicates per depth. To overcome this limitation, at each CTD station, surface water samples were also collected from the surface microlayer using a 12-L stainless-steel bucket and a natural fiber rope, allowing in this way a comparison with the sub-surface samples collected by the rosette (starting at 5 m below the surface). This activity was not originally planned, but it was added after February 24th, to better highlight the influence of surface processes on microplastics concentration patterns. Surface samples were processed using the same procedure and equipment used for processing water column samples. Contamination control was extensively performed during the cruise and two procedural blanks per station were generally collected. Procedural blanks were performed by connecting the stainless-steel filter holder to a distilled-water outlet in the wet lab and filtered the same volume of water used for sampling. Before reaching the sampling membrane, distilled water was pre-filtered using a filter cartridge (GF/D, 2.7 µm). Distilled water provision was disrupted by the ship on March 4th and so, from this day on, the procedural blanks were performed using freshwater from the ship's tank pre-filtered on GF/C filter membranes (1.2 µm). Processing of surface bucket blanks followed exactly the same procedure and equipment used for surface water sampling. Blanks and seawater samples were all filtered over 47 mm MCE (Mixed Cellulose Ester) filter membranes (5 µm nominal pore size). After being collected, all samples were labeled and stored frozen (-20°C) in 47 mm petri dishes for subsequent laboratory analysis (visual sorting and µ-FTIR analysis). In total, water column sampling was performed at 46 stations and a grand total of 430 samples were collected during the cruise. Of these, 363 samples were collected from the Rosette sampler (including 46 procedural blanks) and 67

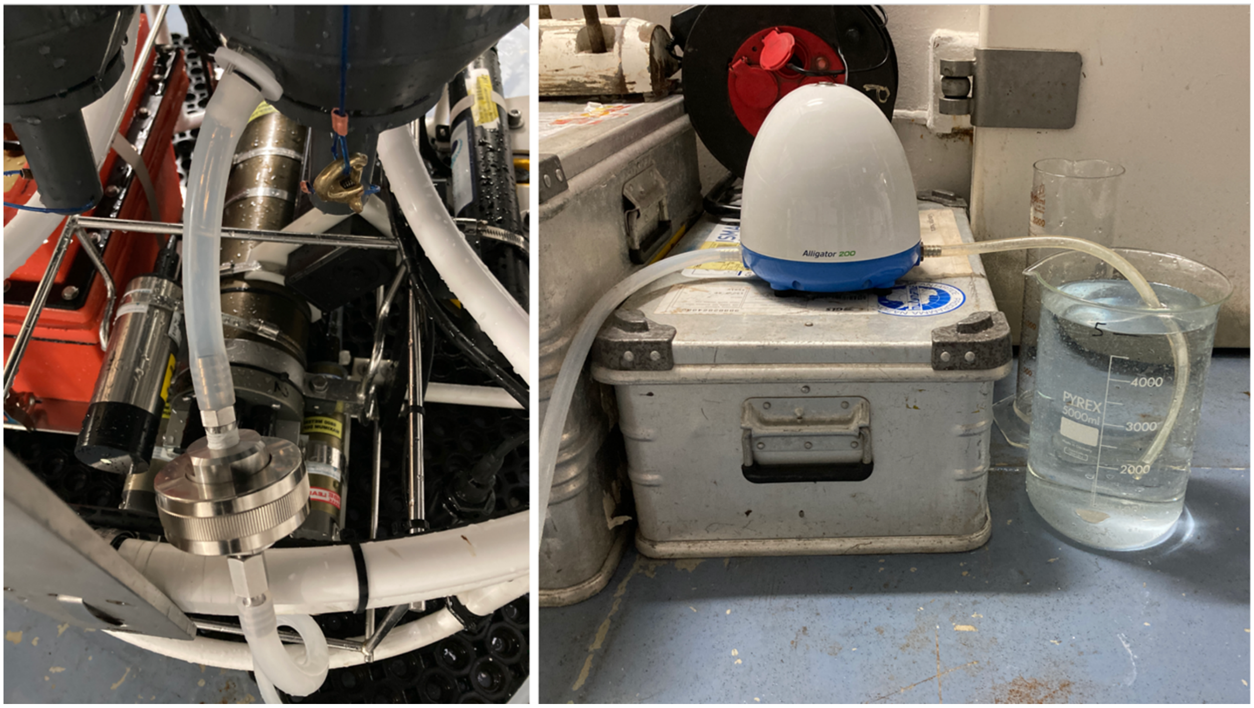

Figure 55: Microplastic sampling set-up at CTD stations. Once on-board the Niskin's bottle faucet is directly connected to a 47mm stainless-steel filter-holder. Seawater is filtered using a diaphragm liquid vacuum pump and the filtered volume is measured using graduated glass cylinders collecting seawater outflow from the pump.

samples were collected from the sea-surface microlayer (including 14 procedural blanks). All the details of the CTD and bucket samples collected during the cruise are reported in Table 1 and 2, respectively. All samples will be transported frozen and stored in the facilities of CNR-ISMAR, Lerici.

Station	Date	Start time (UTC)	End time (UTC)	LAT	LON	Depth 1		Depth 2		Depth 3		Depth 4		Depth 5		Depth 6		Blank (liters)
						Depth (m)	Vol (liters)	Depth (m)	Vol (liters)	Depth (m)	Vol (liters)	Depth (m)	Vol (liters)	Depth (m)	Vol (liters)	Depth (m)	Vol (liters)	
1	18/02/22	13:30	14:00	41,625917	4,302283	5	11,85	73	11,95	188	11,95	300	11,80	440	11,95	525	11,90	12,00
10	22/02/22	19:20	19:50	40,443500	2,794167	350	11,90	206	12,00	103	12,00	78	12,00	40	11,50	6	12,20	12,00
11	22/02/22	22:30	23:00	40,610650	2,725850	278	11,85	183	11,90	104	12,00	52	12,00	27	12,00	5	12,15	12,10
12	23/02/22	20:30	20:48	40,651600	2,694333	205	11,90	150	12,00	75	12,10	25	6,00	5	8,00	/	/	12,10
13	23/02/22	22:50	23:11	40,627000	2,709267	204	12,00	150	12,00	53	12,00	25	9,50	15	5,00	5	5,00	12,10
14	24/02/22	01:45	02:00	40,590900	2,730067	204	11,60	123	12,00	35	9,60	25	9,20	5	5,00	/	/	12,10
15	24/02/22	04:12	04:31	40,561517	2,742800	206	11,90	150	12,00	75	12,00	53	12,00	17	10,00	5	8,30	12,10
16	24/02/22	06:45	06:56	40,521667	2,762500	201	12,00	105	8,10	60	12,00	44	11,90	18	9,20	5	4,00	11,90
17	24/02/22	09:00	09:20	40,481133	2,775183	228	12,00	179	12,00	77	12,00	48	12,00	25	7,10	5	5,00	12,10
19	25/02/22	21:25	21:40	40,566550	2,533117	200	12,00	170	12,00	110	12,00	60	12,00	30	10,20	5	10,00	12,00
20	26/02/22	00:03	00:15	40,566017	2,707333	190	12,00	98	12,00	62	12,00	50	10,00	25	5,00	5	8,00	12,10
21	26/02/22	02:20	02:35	40,591167	2,856950	200	12,00	145	12,00	100	12,00	70	12,00	27	8,00	5	7,20	12,20
22	26/02/22	04:50	05:15	40,665633	2,682033	270	12,00	190	12,00	125	12,00	60	12,00	25	12,00	5	12,00	12,00
23	26/02/22	07:05	07:23	40,666483	2,796400	200	12,00	100	12,00	72	12,00	30	12,20	5	12,00	/	/	12,00
24	26/02/22	19:15	19:30	40,356917	2,428333	200	12,00	175	12,00	120	12,00	62	12,00	25	10,00	5	10,00	12,00
25	26/02/22	22:05	22:30	40,441183	2,572933	230	12,00	150	12,00	103	12,00	53	12,00	25	12,00	6	12,00	12,00
26	27/02/22	20:30	20:45	40,429717	2,596950	198	19,00	134	12,00	49	11,00	32	6,00	5	6,00	/	/	12,00
27	27/02/22	23:10	23:23	40,447267	2,584000	250	12,00	175	12,00	87	12,00	69	12,00	40	6,00	5	6,00	12,00
28	28/02/22	00:45	01:00	40,413400	2,575917	203	12,00	125	12,00	85	12,00	50	10,00	25	6,00	5	7,00	12,00
29	28/02/22	02:50	03:09	40,381000	2,647550	196	12,00	168	12,00	131	12,00	112	12,00	52	12,00	5	9,00	12,00
31	28/02/22	21:10	21:25	40,344117	2,583050	200	12,00	175	12,00	105	12,00	70	12,00	27	10,00	5	5,00	12,00
32	28/02/22	23:00	23:10	40,387567	2,583517	200	12,00	150	12,00	105	12,00	55	12,00	25	10,00	5	8,00	12,00
33	01/03/22	01:05	01:23	40,486883	2,602333	200	12,00	113	12,00	72	12,00	50	10,00	33	7,00	5	6,00	12,00
34	01/03/22	04:00	04:18	40,492033	2,750533	250	12,00	200	12,00	160	12,00	90	12,00	50	9,00	5	6,00	12,00
36	02/03/22	20:25	20:49	40,865917	2,632183	206	12,10	165	12,00	115	12,10	45	12,10	25	8,00	5	6,00	12,50
37	02/03/22	23:30	23:50	40,940317	2,775700	270	12,00	195	12,10	138	12,10	75	12,00	30	9,00	5	8,00	12,00
38	03/03/22	04:50	05:15	40,813083	2,770467	200	12,00	150	12,20	105	12,20	40	10,00	25	8,00	6	5,50	12,10
39	03/03/22	22:15	22:31	40,939183	2,905300	245	12,00	185	12,00	140	12,00	110	12,00	25	6,10	5	6,00	12,00
40	04/03/22	01:20	01:40	40,942650	2,831833	275	12,20	190	12,20	98	12,20	56	12,10	33	8,00	5	5,00	12,00
41	04/03/22	04:15	04:37	40,954250	2,764867	303	12,00	180	12,10	130	12,20	80	12,10	45	10,00	5	6,00	12,00
42	04/03/22	07:45	08:05	40,958483	2,703517	304	12,00	260	12,10	177	12,10	105	12,20	25	7,00	5	6,00	12,00
43	04/03/22	20:05	20:25	40,827583	2,785817	300	12,20	175	12,00	130	12,30	80	12,00	35	12,30	5	7,00	12,00
44	04/03/22	21:50	22:07	40,835433	2,692733	230	12,10	175	12,00	105	12,20	70	12,00	35	10,00	5	6,00	12,00
45	04/03/22	23:30	23:50	40,840633	2,597817	240	12,00	180	12,10	120	12,00	86	12,20	28	9,00	5	6,00	12,00
46	05/03/22	19:10	19:30	40,885383	2,472950	250	12,20	200	12,20	125	12,00	70	12,00	20	9,00	5	6,00	12,10
47	05/03/22	21:15	21:32	40,914850	2,615500	250	11,00	189	12,10	135	12,00	47	12,00	35	7,00	5	6,00	12,10
48	05/03/22	23:45	00:00	40,870683	2,739083	250	12,20	168	12,10	135	12,10	110	12,20	30	12,20	5	6,00	12,00
49	06/03/22	20:30	20:46	40,885433	2,999317	250	12,00	125	12,10	110	12,00	70	12,00	30	6,00	5	6,00	12,20
50	06/03/22	22:45	23:05	40,917817	2,985717	250	12,00	170	12,00	110	12,10	70	12,20	38	6,00	5	6,00	12,00
51	07/03/22	00:30	00:46	40,964033	2,954667	250	12,10	165	12,00	100	12,10	70	12,20	30	6,00	5	6,00	12,10
52	07/03/22	03:00	03:18	41,001683	2,876983	218	12,20	150	12,30	117	12,20	67	12,00	25	6,00	5	6,00	12,10
54	07/03/22	19:40	19:59	40,886217	2,583317	230	12,10	188	12,20	140	12,20	115	12,00	45	10,00	5	7,00	12,00
55	07/03/22	21:12	21:33	40,833317	2,537533	235	12,00	174	12,00	115	12,00	70	12,00	30	6,00	5	6,00	12,00
56	07/03/22	23:00	23:20	40,803333	2,576950	248	12,20	180	12,10	140	12,20	70	12,10	42	12,10	5	6,00	12,20
57	08/03/22	00:55	01:21	40,839383	2,612517	600	12,20	240	12,10	167	12,10	120	12,20	30	10,00	5	6,00	12,10
58	08/03/22	03:30	03:55	40,839200	2,695100	224	12,20	180	12,10	135	12,10	69	12,20	37	8,00	5	7,00	12,00

Figure 56: Station number, date (UTC), time (UTC), GPS coordinates, sampling depth (meters) and volume of filtered water for each sampling depth during CTD casts. At each station, 6 depths were sampled for microplastics and one procedural blank was also performed.

Seq. No.	CTD cast	Date (UTC)	Time (UTC)	LAT	LON	Filtered volume (liters)	Blank Volume (liters)
1	/	24/02/22	22:10	40,472933	3,008833	5,0	/
2	/	24/02/22	23:47	40,560033	2,848383	7,2	/
3	/	25/02/22	00:15	40,574200	2,839800	6,1	6,6
4	/	25/02/22	02:18	40,659167	2,745667	6,2	/
5	/	25/02/22	02:29	40,673083	2,732033	8,8	6,5
6	/	25/02/22	03:08	40,721083	2,684433	7,3	/
7	/	25/02/22	03:42	40,754300	2,685067	7,4	/
8	/	25/02/22	09:50	40,659933	2,715600	7,5	/
9	/	25/02/22	10:01	40,644300	2,691567	7,4	6,5
10	19	25/02/22	21:10	40,559033	2,539100	6,1	/
11	20	26/02/22	00:03	40,566017	2,707333	6,0	/
12	21	26/02/22	02:05	40,592883	2,856383	6,3	/
13	22	26/02/22	04:50	40,665633	2,682033	6,3	/
14	23	26/02/22	07:00	40,666450	2,796400	9,2	9,5
15	24	26/02/22	19:15	40,356917	2,428333	7,5	/
16	25	26/02/22	22:02	40,441167	2,573000	5,6	6,9
17	/	27/02/22	15:35	40,452750	2,591633	7,4	/
18	26	27/02/22	19:46	40,431017	2,607900	6,0	6,8
19	27	27/02/22	23:00	40,447267	2,584000	6,0	/
20	28	28/02/22	00:45	40,413467	2,575850	6,4	7,6
21	29	28/02/22	02:48	40,379900	2,647733	7,7	/
22	31	28/02/22	21:10	40,344117	2,582817	6,1	/
23	32	28/02/22	23:00	40,386950	2,585333	5,1	/
24	33	01/03/22	01:05	40,486800	2,602333	7,0	6,6
25	34	01/03/22	03:48	40,492917	2,751500	8,0	/
26	36	02/03/22	20:18	40,865917	2,632183	7,6	/
27	37	02/03/22	23:25	40,939500	2,777583	11,2	7,2
28	38	03/03/22	04:50	40,813083	2,770467	6,5	/
29	39	03/03/22	22:10	40,939383	2,905617	7,0	/
30	40	04/03/22	01:20	40,942733	2,831817	6,0	6,0
31	41	04/03/22	04:15	40,954250	2,764867	8,0	/
32	42	04/03/22	07:45	40,958467	2,703683	6,0	/
33	43	04/03/22	20:05	40,827550	2,785750	7,1	/
34	44	04/03/22	21:45	40,835400	2,692700	7,2	6,0
35	45	04/03/22	23:30	40,840733	2,597700	6,0	/
36	46	05/03/22	19:05	40,885633	2,473017	6,0	6,2
37	47	05/03/22	21:15	40,914850	2,615700	7,0	/
38	48	05/03/22	23:45	40,870683	2,739083	6,0	/
39	49	06/03/22	20:30	40,883600	3,002417	6,1	/
40	50	06/03/22	22:40	40,917583	2,986150	6,0	/
41	51	07/03/22	00:30	40,963833	2,954817	6,2	6,0
42	52	07/03/22	02:55	41,001267	2,876783	7,0	/
43	54	07/03/22	19:37	40,886133	2,583267	7,0	7,0
44	55	07/03/22	21:10	40,833817	2,538483	6,0	/
45	56	07/03/22	22:46	40,803217	2,576833	8,0	/
46	57	08/03/22	00:45	40,839417	2,611417	7,0	/
47	58	08/03/22	03:30	40,839100	2,695017	8,0	/

Figure 57: Sequential numbering ID, CTD cast, Date (UTC), Time (UTC), GPS coordinates and filtered volume for all surface bucket samples collected during the CALYPSO 2022 cruise. For bucket sampling, only one procedural blank per day was performed and its volume is shown in the last column.

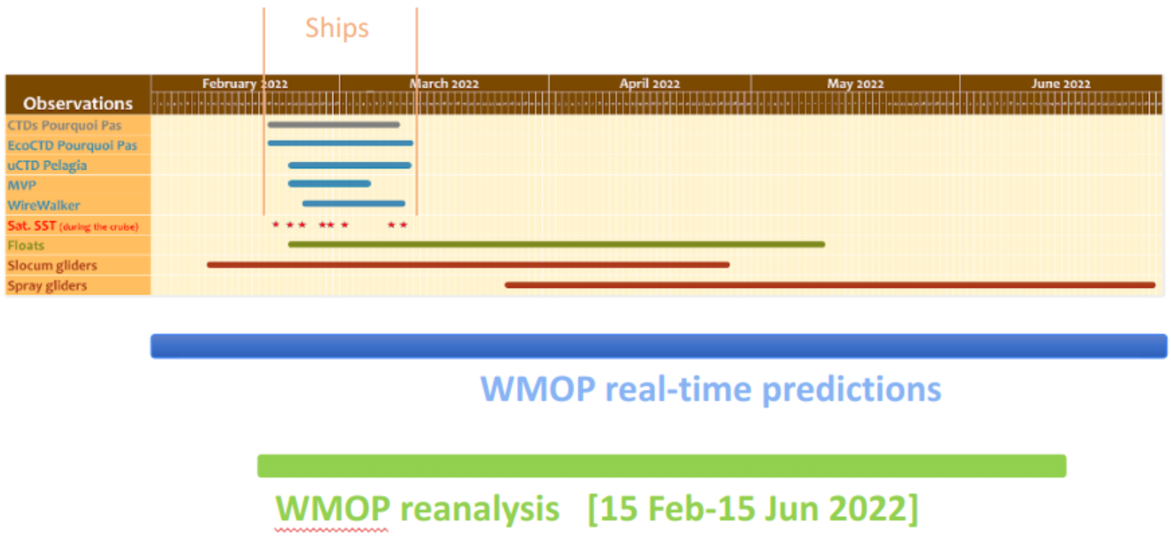

Figure 58: Timeline of the WMOP simulations produced during the CALYPSO sea trial experiment in 2022.

8 Real-Time modeling support

High-resolution data-assimilative forecasting systems and refined simulations (2km to 500m horizontal resolution) were developed by SOCIB and MIT-MSEAS teams to support the intensive field experiment.

8.1 WMOP prediction system

The 2-km resolution Western Mediterranean OPerational modelling system (WMOP; Juza et al., 2016; Mourre et al., 2018) covering the Western Mediterranean basin was used to produce real-time forecasts, as well as retrospective hindcasts and reanalysis simulations including data assimilation over the whole sampling period (Figure 58). The WMOP model data were made available as hourly surface and daily-averaged three-dimensional outputs. The model was forced at the surface by the hourly and 2.5 km spatial resolution Harmonie-Arome atmospheric model (Bengtsson et al., 2017) provided by the Spanish National Meteorological Agency (AEMET). WMOP forecasts product use initial state and boundary conditions from the coarser grid Mediterranean model of the Copernicus Marine Environment Monitoring Service (CMEMS MED-MFC; Clementi al., 2021). WMOP includes data-assimilation obtained with an Ensemble Optimal Interpolation method (Hernandez-Lasheras and Mourre, 2018; Hernandez-Lasheras et al., 2021) with 1 day cycles, assimilating data from satellites (along-track sea level anomalies and SST from the CMEMS-Med ultra-high resolution L4 product), Ibiza Channel HF radar currents, moorings, and Argo profiles (temperature and salinity).

WMOP-FORECAST provided daily predictions of ocean properties including small-scale density gradients, relative vorticity, horizontal convergence, or vertical velocities, as well as Lagrangian metrics such as finite-time Lyapunov exponents, path-integrated divergence or 3-dimensional trajectories. Specific plots were provided on a dedicated web-based visualization WMOP-CALYPSO. Moreover, the SOCIB website offered dynamic visualization tools and WMOP netcdf files were available on SOCIB thredds server. Finally, customized WMOP model netcdf files were also created and distributed through ftp to provide initial and boundary conditions to the MIT-MSEAS very high-resolution predictions MIT-MSEAS Real-Time Balearic Sea Experiment 2022.

Free-run simulations suitable to analyze the processes involved in the vertical displacements associated with the fronts, topography and other forcings were also generated retrospectively, including 650m-resolution simulations nested in WMOP over specific periods of interest to evaluate the submesoscale cyclonic eddies generation and evolution. These tools are used to characterize the variability of vertical velocities in the Balearic Sea, investigate the scale-dependency of associated 3-D pathways and identify the governing physical processes. The simulations of the data-assimilative model were specifically used to guide the glider fleet sampling and support the spatio-temporal reconstruction of oceanic fields from the collected glider data in the frontal areas.

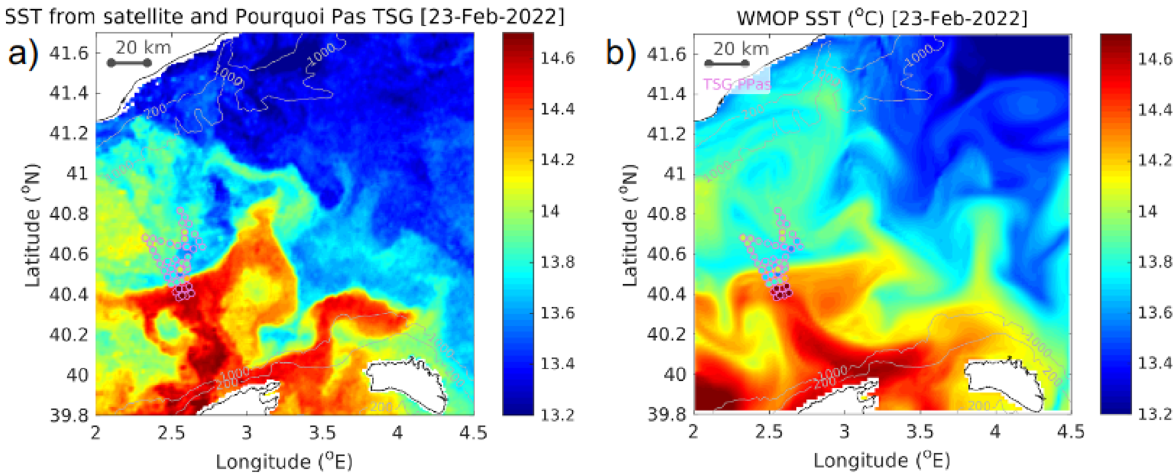

Figure 59: Sea surface temperature from (a) satellite and ship thermosalinograph data (circle markers in a,b) and (b) WMOP real-time predictions on 23 February in the Balearic Sea region.

Fig 59 compares the satellite and modelled SST on 23 Feb 2022. Both depict the presence of the density front associated with a mesoscale vortex dipole which was intensively sampled during the experiment.

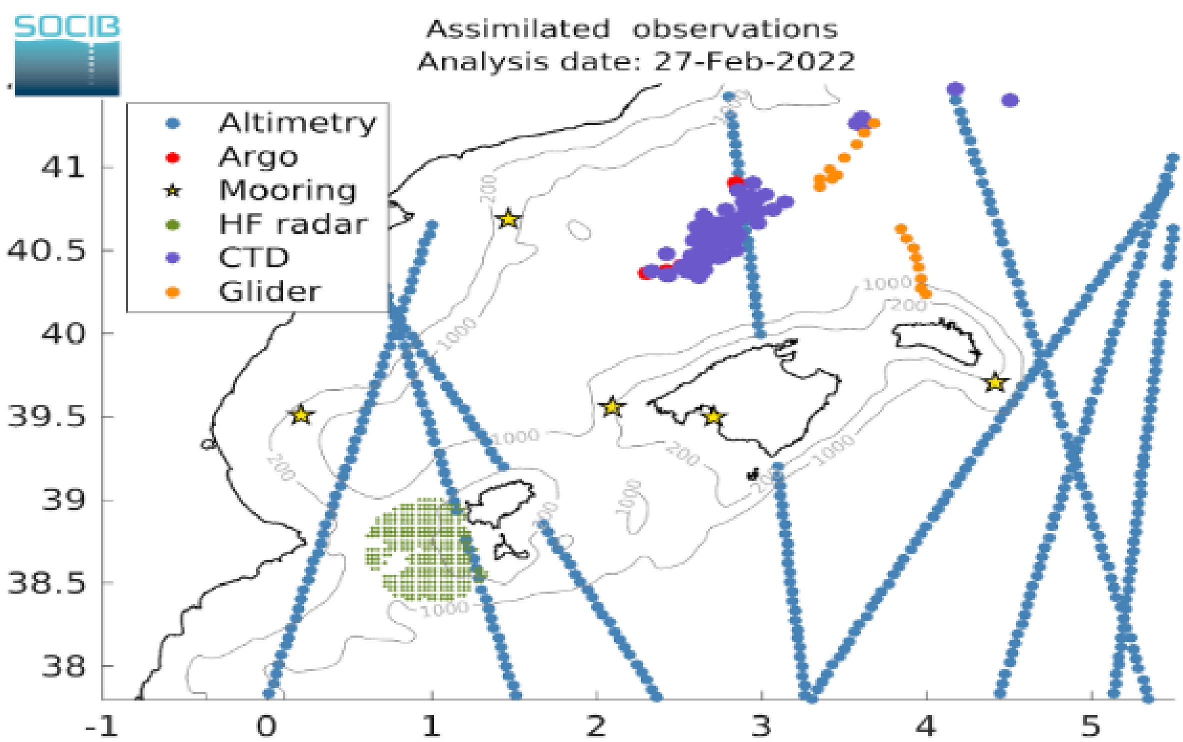

Figure 60: Position of SLA, Argo, moorings, HF radar, CTD and glider data assimilated in WMOP reanalysis on 27 Feb 2022.

In addition, high-resolution reanalysis simulations were developed to incorporate the measurements provided by underwater gliders and ship-based CTDs into the model (notice that satellite and Argo observations as well as some glider measurements were already included in the model forecast product). The assimilated data are illustrated in Figure 60. Data assimilation was performed in the WMOP 2km-resolution model over a period spanning the whole observational phase (15 Feb to 15 June 2022), thus providing a realistic 4D representation of the oceanic fields during 4-month period. The WMOP reanalysis was used to complement the analysis of mesoscale processes from glider, float and uCTD data.

8.2 MIT-MSEAS prediction system

For the two-part Balearic Sea experiment in February-March and April-June 2022, we employed the MIT-MSEAS modeling system Haley and Lermusiaux, OM-2010; Haley et al., 2015; Lermusiaux et al., The Sea-2017). Our multi-resolution CALYPSO domains span approximately 517 km by 382 km at a horizontal resolution of 900 m, with a 2-way nested subdomain at 300 m resolution, see MIT-MSEAS Real-Time Balearic Sea Experiment 2022. We used 70 optimized terrain-following vertical levels, with a bathymetry based on the 15 arcsec SRTM15+ bathymetry from Scripps. Our simulations were forced with atmospheric fluxes from the 1/4° NCEP GFS product and tidal forcing from the TPXO8-Atlas from OSU. These tides were reprocessed for our higher-resolution bathymetry/coastline and quadratic bottom drag formulation. Initial conditions were downscaled from 1/50 deg WMOP (see above) and corrected using available data provided in real-time. The velocities were optimized for our high-resolution coasts and bathymetry. Our simulations were used in real-time to forecast physics, Lagrangian flow maps, 2D and 3D LCS maps, 2D dilation maps, 2D drifter trajectories at several deployment depths, and 3D subduction. We assimilated data of opportunity as well as cruise data. We provided specialized products on web pages designed for access from ships, see Figure 61 and MIT-MSEAS shore support for Calpyso 2022 ships and sea aperations.

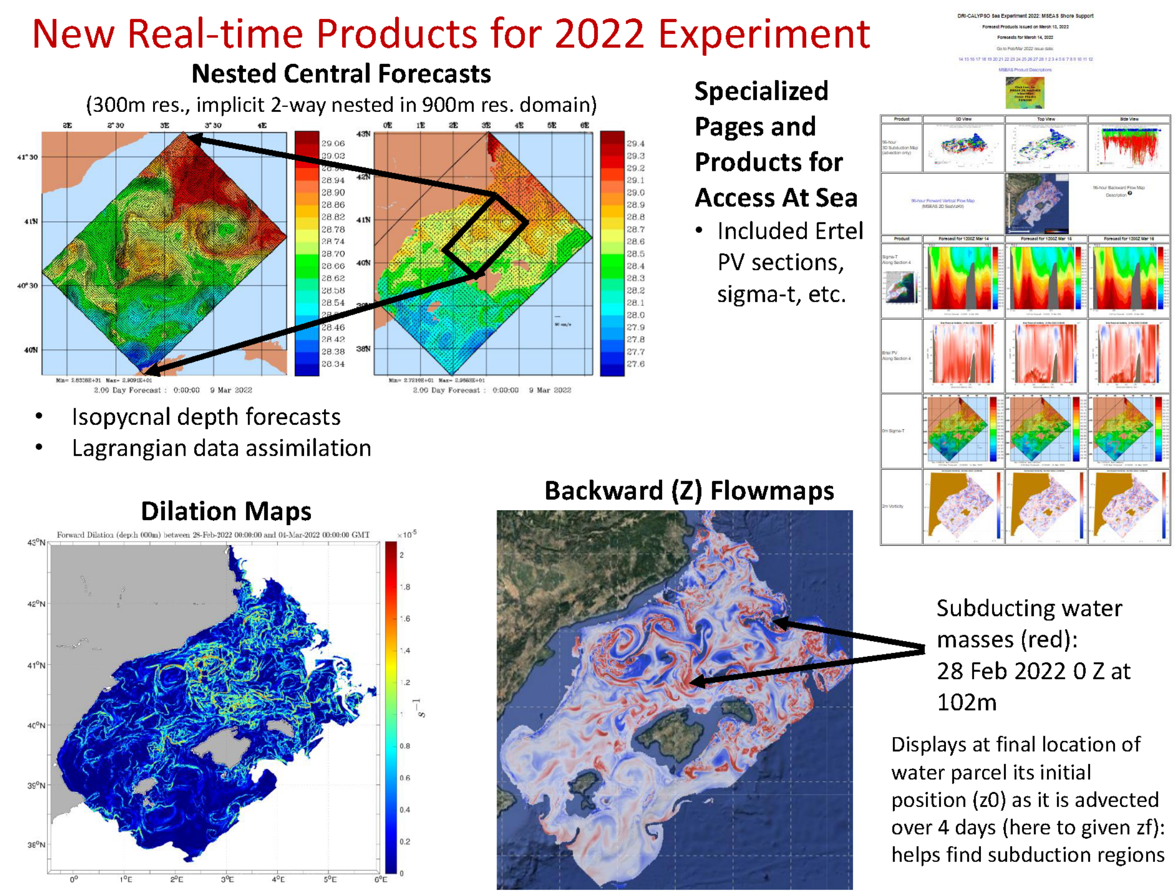

Figure 61: Overview of the new MMIT-MSEAS real-time products issued during the Calypso 2022 Balearic Sea experiment. These include large-ensemble nested forecasts, dilation maps, backward flow maps, and specialized web pages and products intended for at-sea access from ships.

Our downscaled forecasts also served as the central simulations in our large-ensemble forecasts using ESSE. The initial 3D perturbations were constructed starting from vertical EOFs of historical

February and March CTD profile data, segregated in two water masses. The profiles and their joint T/S EOFs were combined with an eigendecomposition of a horizontal correlation matrix. Perturbations from each water mass were melded to cover the domain and preserve variability. A 3D geostrophic and PE balance was applied to obtain the perturbed velocities.

Wind Analysis. Prevailing winds were highly variable in our experiment area. Several mistrals (February 19-20, February 22-23, and March 5) in the Gulf of Lions occurred, with strong winds toward the south-southeast, advecting heavier waters into the Balearic region through Ekman transport processes. During the post-cruise glider survey in April-June, similar processes took place in May due to several near-gales with winds toward the southwest (e.g. May 5 and 25).

Evaluation of Real-Time Forecasts and Reanalyses. For the February-March simulations, we assessed forecast skill (i) qualitatively in terms of how major flow features were captured, and (ii) quantitatively in terms of how well profile-based data, ADCP, SST, and drifter tracks were matched. Major flow features suggested by the drifter track data were present in the model-predicted tracks: anticyclonic eddies by the Spanish coast and north of Mallorca, and southeast-then-northeast flow east of Menorca. The forecasts also capture mistral-driven deep convection and southwesterly Ekman transport in the northeast Balearic Sea, a pair of cyclonic eddies on February 22-23 suggested by satellite SST data, and a cyclone/anticyclone pair on March 1 suggested by SOLO-II tracks. Similar feature skill was exhibited when the forecasts captured cyclonic eddies, an anticyclonic eddy, and an SST mushroom structure (March 7), a submesoscale cyclonic vortex (February 26-March 11), a dense cyclonic eddy (February 21-24), and a dense cyclonic ridge (February 24-25). Our forecast RMSE remains low well after assimilation ends, and it is lower than that from persistence by up to 25%. A similar skill was seen for all other profile types. Compared with ADCP data, the reanalysis RMSE was about 10% lower on average than that of the real-time forecasts.

For the second part of the experiment, the 2-way nested real-time forecasts were compared to Spray glider data and ARGO data of opportunity. Excellent agreement on the location and 28.9 isopycnal depth of major features, such as a very deep valley suggesting the presence of subduction, and an anticyclonic eddy, is seen (June 18 12Z). The anticyclone is forming 3 branches and moving southeast. Anticyclonic flow is present off Mallorca, as forecast for some time. This agreement is maintained for as long as 7 days after assimilation ends. Our forecast maintains skill against non-assimilated ARGO and Spray data through 6 days.

Lagrangian Flow Maps and Coherent Structures for Subduction. Lagrangian flow maps were computed from our reanalyses using our advection-based composition method to eliminate numerical diffusion. We also use the flow maps to obtain various Lagrangian products including subduction maps, Lagrangian coherent structures, and dilation maps. We also computed trajectories using high-order methods in real time around regions with significant subduction.

We continued to develop our new visualization toolkit (SeaVizKit) for multidisciplinary data to create cohesive, portable, and interactive web-based 2D and 3D visualizations of the ocean. The upgraded software was utilized during the second part of the experiment to diagnose the dynamics using the 3D velocity streamtubes and the 28.85 isopycnal isosurface.

Real-time Bayesian Lagrangian data assimilation. For the first time, we successfully assimilated real-time near-surface drifter data using Bayesian multivariate estimation. We used ESSE ensemble forecasts to obtain prior probabilistic forecasts for the augmented states (both Eulerian variables and drifter trajectories). We then used the GMM-DO filter to assimilate the drifter trajectory data and to compute the posterior augmented state and probability density function (PDF). The posterior PDF of the augmented state was then used to initialize the ensemble forecast run for the next issue. We demonstrated improved skill using forecasts initialized with fields assimilated using Lagrangian data.

9 Glider survey

Mesoscale and submesoscale structures significantly influence the vertical transport of carbon and biogeochemical tracers from the surface to the ocean interior. During the ONR CALYPSO 2022 experiment in the Balearic Sea, SOCIB and SCRIPPS deployed eight (6 SPRAY underwater gliders (SIO) + 2 SLOCUM underwater gliders (SOCIB/IMEDEA)) gliders to dive up to 700 m from March 25 to June 21, 2022 (Figure 62), collecting temperature, salinity, velocity, chlorophyll fluorescence, oxygen, and acoustic backscatter data (Table 3). The glider data was mapped using objective mapping of the across-front, along-front, and time on 10 m vertical levels. We estimate the vertical and ageostrophic horizontal velocities using the omega equation. The glider survey provided a comprehensive description of eddy field evolution. The analysis of the uplifted 28.9 isopycnals showed a consistent response to the movement of the dynamic and biogeochemical tracers. The glider observation reveals the evolution of the cyclonic eddy (20-30 km) within the study area. Upwelling and downwelling were also detected by chlorophyll fluorescence, oxygen, and acoustic backscatter near the frontal interface. On the other hand, glider observations were integrated with remote sensing and real-time data-assimilative multi-resolution forecasting. Data and numerical simulations were used to evaluate the evolution of the eddy field and their impact on biological carbon storage in the Balearic Sea. In addition, the assimilation of the glider observations allowed us to validate the model outputs against observed data robustly. The comparison highlighted the model's strength in replicating the mesoscale and submesoscale features. These comprehensive validations confirm that integrating autonomous platform data with advanced modeling techniques significantly enhances our understanding and predictive capabilities of oceanographic processes, facilitating more accurate and reliable ocean forecasts.

9.1 Large-scale survey in support of ship operations

During the large-scale survey, two SLOCUM gliders (SOCIB/IMEDEA) were deployed along and across the channel (9 February to 28 March) to support ship operations. The glider trajectories of the large-scale survey are displayed in lines in Figure 62. The SLOCUM glider was equipped with a suite of sensors (CTD, FLNTU/FL3, and O_2 optode). They covered 3530 km during their survey and performed 1433 dives to 700m. The analysis of the SLOCUM glider observations was combined with remote sensing SST and absolute dynamic observations to provide broader spatial coverage of the eddy and frontal field and help us identify the study area's circulation patterns.

9.2 Small-scale survey (3.5 days)

During the small-scale survey, six more SPRAY gliders were deployed from March 25 to June 29, 2022, covering a ground distance of 12448 km and conducting 3404 dives to 700m. The fleet of 8 gliders focused on a cyclonic eddy observed by a SOLO float and the ship survey during the Calypso campaign. The small-scale survey allowed us to characterize the evolution of the eddy field and how it contributed to the development of the vertical velocities and re-stratification of the upper layer. The glider fleet was deployed to conduct a grid of 4X4 glider lines. The small-scale survey has the following characteristics:

- 8 Gliders (6 Sprays + 2 Slocums)
- Grid 15 km separation between lines
- 4 km and 4 h separation between profiles
- Initial focus on cyclonic eddy observed by float and ship survey
- Combined glider fleet 8 surveys at 2 m/s (equivalent to 3.8 knots)

In the small-scale survey, the glider fleet provided observations that covered the phase space in terms of distance and time. Objective maps created gridded data fields with the methodology followed by Rudnick et al., 2022 and characterized by:

- Horizontal objective maps with scales 15 km across-front, 15 km along-front, time scale 7 days, on 10m levels
- Interpolated to potential density surfaces (isopycnal step 0.1)

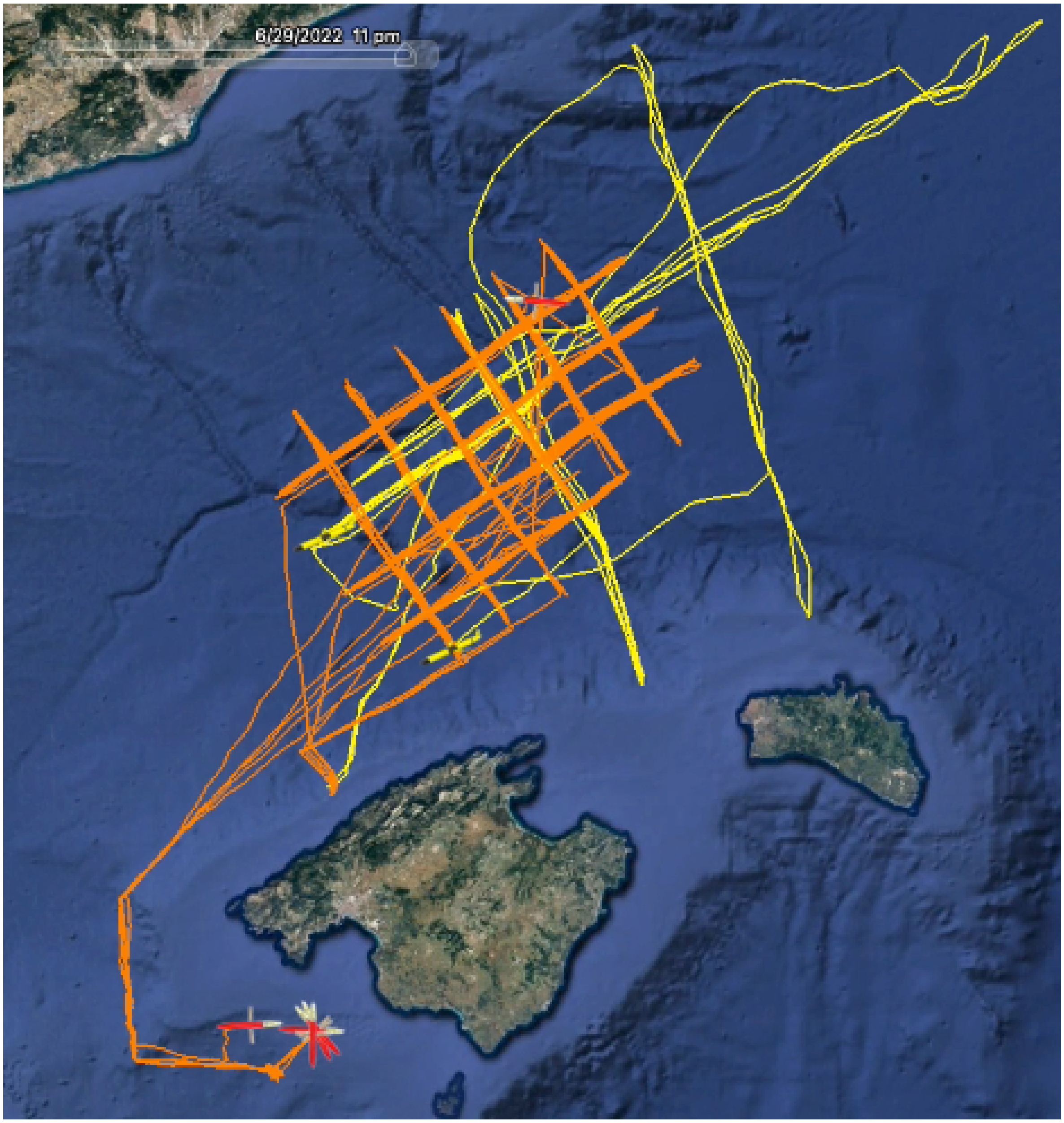

Figure 62: Spatial coverage of the glider large-scale (yellow lines) and small-scale surveys (orange lines) in the Balearic Sea.

Glider Sensor	Measured Variable	Spray	Slocum	Parameters that objective map
CTD	p,t,s	x	x	Temperature, Salinity, Density
ADCP	u and v (depth –dependent), abs	x		U and V velocity, Acoustic backscatter
FLNTU/FL3	Chl and NTU/ Chl, bbp700 and CDOM	x	x	Chl
O_2 Optode	Dissolved oxygen		x	

Table 3: Summary of the sensors that were carried out from Spray and Slocum glider

10 Satellites

10.1 Introduction

During the CALYPSO 2022 experiment, daily images and data from different remote sensing variables were provided. The goal was to give support in near-real time to the science team and provide context on the spatial and temporal variability of the surface signatures of mesoscale (10-100 km) and submesoscale (1-10 km) structures in the Balearic Sea. This analysis was not only done during the experiment but also before to assess in the decision on which would be the best sampling region and also after the cruise as several observing platforms will still provide data in the region (Lagrangian platforms and gliders).

The variables included in the analysis were sea surface height (SSH), sea surface temperature (SST) and sea surface chlorophyll concentration (Chl). SST and Chl were particularly useful to characterise the submesoscale frontal regions while the SSH provided the mesoscale context of the general circulation in the basin. For SST and Chl, data from different sensors were used to maximise the info provided per day.

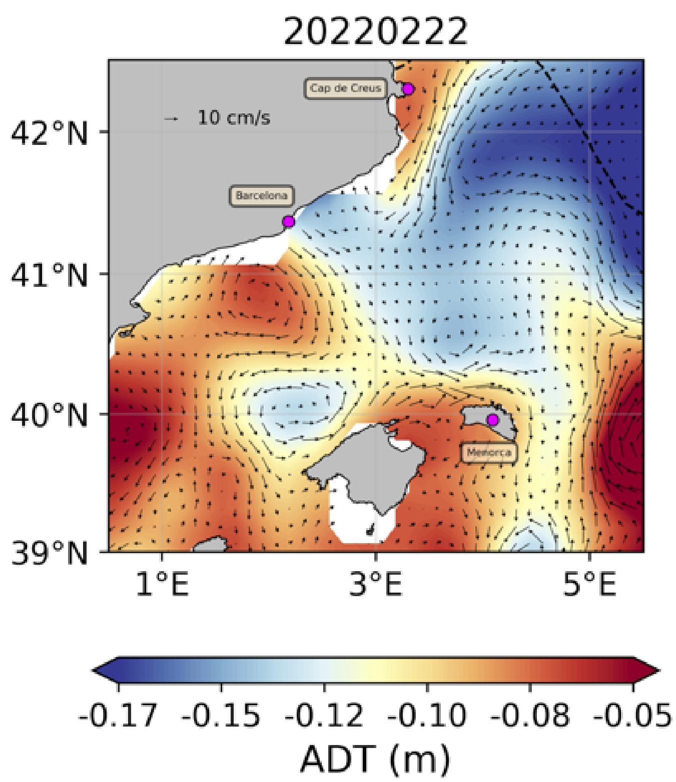

Figure 63: ADT and vector field of the geostrophic current for the 2022/02/22.

10.2 Sea Surface Height

Near-real time gridded Sea Level Anomalies (SLA) computed with respect to a twenty-year 2012 mean and Absolute Dynamic Topography (ADT). The SLA and ADT fields (Figure 63) are estimated by Optimal Interpolation, merging the measurement from the different along-track altimeter missions. This product is processed by the DUACS multimission altimeter data processing system. It processes data from all altimeter missions: Jason-3, Sentinel-3A, HY-2A, Saral/AltiKa, Cryosat-2, Jason-2, Jason-1, T/P, ENVISAT, GFO, ERS1/2. This product also provides derived geostrophic currents from SLA and ADT. The fields have a spatial resolution of 0.125^ox0.125^o. More info available at https://doi.org/10.48670/moi-00142.

10.3 Sea Surface Temperature

10.3.1 Sea and Land Surface Temperature Radiometer

We use the SST provided in the SL_2_WST product from the Sea and Land Surface Temperature Radiometer (SLSTR) on Sentinel-3A (S3A) (Figure 64) and Sentinel-3B (S3B). S3A passed during local daytime while S3B passed during nighttime, having two SST fields per day. More info available at https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-3-slstr.

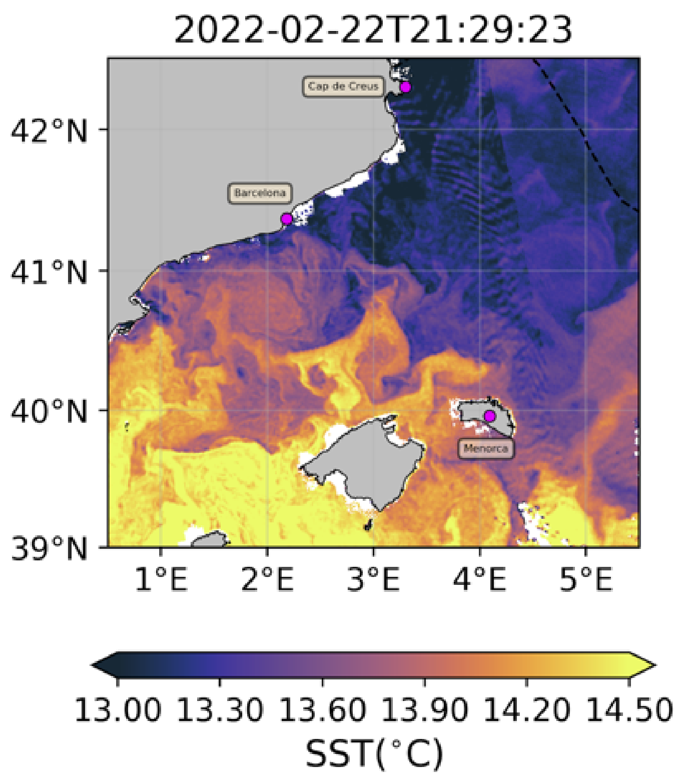

Figure 64: SST from Sentinel3A-SLSTR for the 2022/02/22.

10.3.2 Merged Sea Surface Temperature

The merged SST (Figure 65) product provided by CMEMS uses the highest quality input data from different SST sensors: NOAA20-VIIRS, NPP-VIIRS, MODIS-AQUA, Sentinel3A-SLSTR and Sentinel3B-SLSTR. Only data within a strict temporal window (local nighttime), to avoid diurnal cycle and cloud contamination. Consequently, we only obtain one field per day. It has a lower horizontal resolution compared to the monosensor products as all the inputs are interpolated into a coarser 0.01^ox0.01^o grid. The advantage of this product with respect to the monosensor products shows on days with patches of clouds; as it uses data from passes at different times, if the cloudy patches are not too large, it can fill some of the gaps. More info at https://doi.org/10.48670/moi-00171.

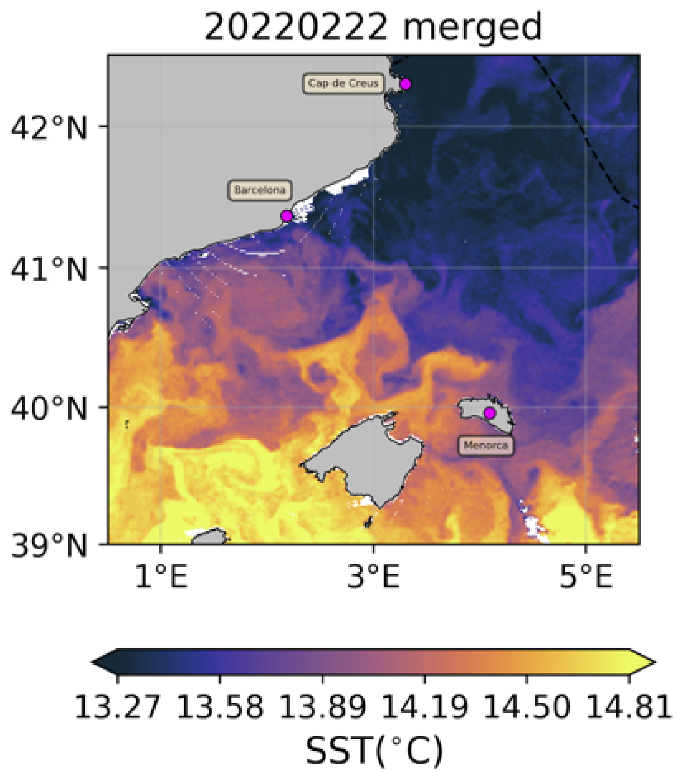

Figure 65: Merged SST from CMEMS for the 2022/02/22.

10.4 Sea Surface Chlorophyll Concentration

Ocean colour technique exploits the emerging electromagnetic radiation from the sea surface in different wavelengths. The spectral variability of this signal defines the so-called ocean colour, which is affected by the presence of phytoplankton. As ocean colour uses the visible spectra, data is only obtained at local daytime.

10.4.1 Ocean and Land Colour Instrument

The Ocean and Land Colour Instrument (OLCI) is an imaging spectrometer that measures solar radiation reflected by the Earth, at a ground spatial resolution of 300 m, in 21 spectral bands (Figure 66). Ocean colour sensors are designed to retrieve the spectral distribution of up-welling radiance just above the sea surface (the water-leaving radiance) that is used to estimate a number of geophysical parameters through the application of specific bio-optical algorithms. One overpass per day. More info available at https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-3-olci.

10.4.2 Merged Sea Surface Chlorophyll Concentration

The merged Chl product provided by CMEMS uses data obtained from the sensors MODIS-AQUA, NOAA20-VIIRS, NPP-VIIRS and Sentinel3A-OLCI at local daytime daily. All the data is remapped at 1km spatial resolution (Figure 67). Afterwards, single sensor Rrs fields are band-shifted, over the SeaWiFS native bands (using the QAAv6 model) and merged with a technique aimed at smoothing the differences among different sensors. More info available at https://doi.org/10.48670/moi-00111. As in the SST, this product was used on cloudy pathy days.

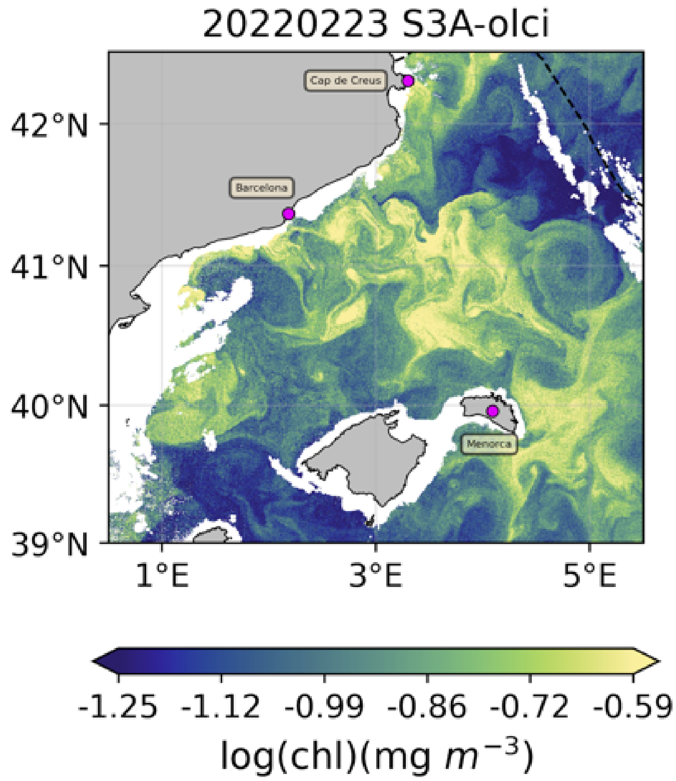

Figure 66: Chl from Sentinel3A-OLCI for the 2022/02/23.

10.4.3 Visible Infrared Imaging Radiometer Suite

The Visible Infrared Imaging Radiometer Suite mounted on NOAA20 and Sumoi NPP provided two additional sources of information for ocean colour. Due to the relative early pass of the Sentinel3A-OLCI (9:00 UTC), on occasions, there were some morning clouds/fog, which later cleared because of the sun heating. The delay between the overpasses of NOAA20/SUMOI NPP (∼12:00-13:00 UTC) and Sentinel3A-OLCI allowed us to obtain better images for the region of interest with these sensors. VIIRS (Figure 68) has a spatial resolution of 750, slightly better than the merged product and also avoids the smoothing produced by the interpolation/remapping. More info available at https://earthdata.nasa.gov/earth-observation-data/near-real-time/download-nrt-data/viirs-nrt.

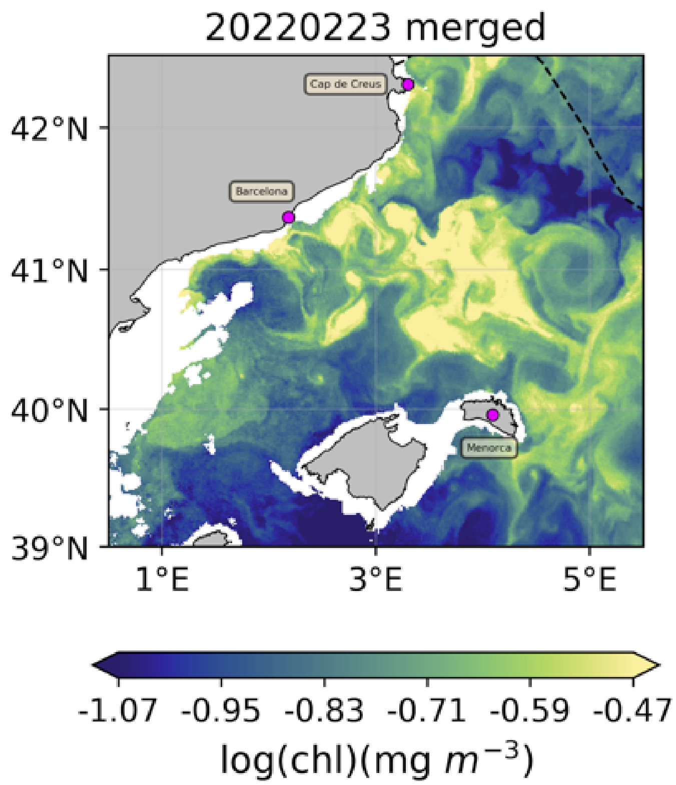

Figure 67: Merged Chl from CMEMS for the 2022/02/23.

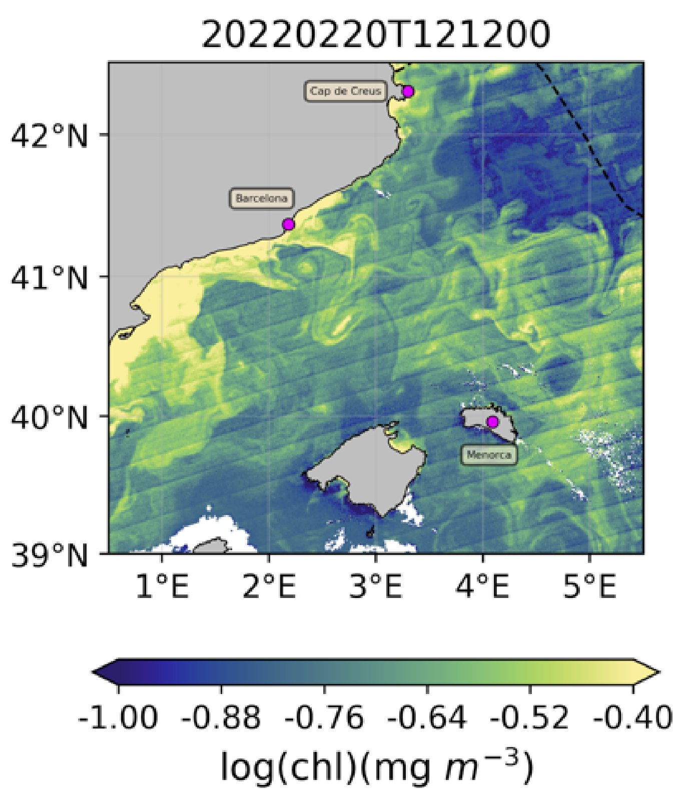

Figure 68: Chl from VIIRS for the 2022/02/22.

10.5 Image quality

Figure 69 provides a database with the info about the quality of the daily images of SST and CHL during the cruise. The quality index goes from 0 to 3 depending on the cloud coverage: 0, totally cloudy; 1, small amount of data; 2, large gaps due to clouds; 3, small gaps due to clouds and 4, complete coverage. SSH is not included as it is not affected by clouds.

	SST		Chl		
Date	SLSTR (day/night)	Merged	OLCI	Merged	Comments
2022/02/16	-	-	-	-	Techincal Issues
2022/02/17	-	-	2	3	
2022/02/18	4/3	4	4	4	
2022/02/19	-	3	0	-	
2022/02/20	3/2	3	3	4	VIIRS
2022/02/21	3/4	4	4	0	
2022/02/22	3/4	4	3	4	
2022/02/23	3/-	0	4	4	
2022/02/24	-	0	2	1	
2022/02/25	-/1	2	0	0	
2022/02/26	-/3	4	2	3	
2022/02/27	-	0	2		
2022/02/28	2/3	3	2	2	VIIRS
2022/03/01	2/-	1	2	3	
2022/03/02	-	0	0	1	
2022/03/03	-	1	1	2	VIIRS
2022/03/04	-	0	2	0	
2022/03/05	-	1	1	1	
2022/03/06	-	1	1	1	
2022/03/07	-/3	3	0	1	
2022/03/08	-	0	2	0	
2022/03/09	1/2	2	1	2	
2022/03/10	-	0	1	1	
2022/03/11	-	-	1	0	

Figure 69: Quality index for the SST and CHL images. 0, totally cloudy; 1, small amount of data; 2, large gaps due to clouds; 3, small gaps due to clouds and 4, complete coverage. Images not produced are marked with a script.

10.6 Evolution of a submesoscale cyclonic eddy

Thanks to the good weather conditions, not specially cloudy, we were able to observe the evolution of the SST and Chl fields of a submesoscale eddy in the Balearic Sea. On February 22, a cold filament of water coming from the Gulf of Lion encountered the warm waters coming from the south of the Balearic Sea in the middle of the basin (Figure 70). The eddy's core is formed by the cold waters with high values of Chl. In Figure 71 we can see the time evolution of the Chl field. It can be seen how the cyclonic eddy gets stretched until it forms an extreme elongated circulation of just 2 km of diameter in the shorter axis. Then, the structure breaks into 3 smaller cyclonic eddies of a few kilometres of diameter.

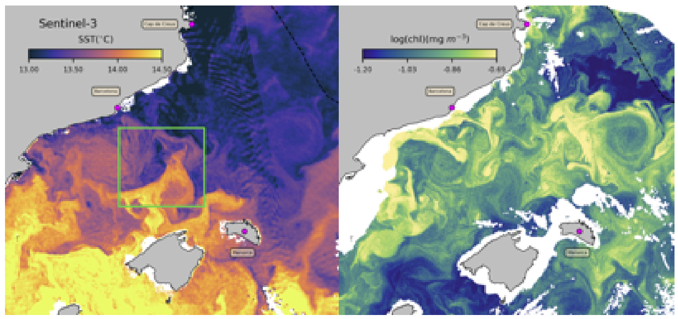

Figure 70: Night SST field for February 21 and Chl field for February 22. Green box shows the eddy's location.

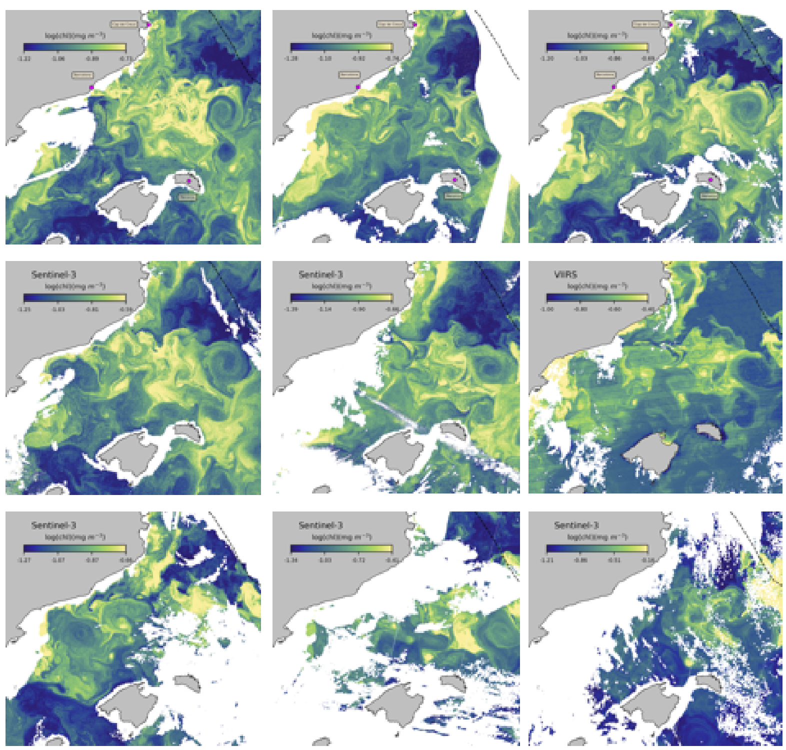

Figure 71: Time evolution of the Chl field. From left to right the dates are: top row, February 18, February 20 and February 21; middle row, February 23, February 26 and February 28; bottom row, March 1, March 4 and March 8.

10.7 Data availability

The satellite data and images can be found at the CALYPSO google drive at the following folders:
Data:
CalypsoShare/2022_Experiment/2022_Data_and_Products/Satellite_Data/raw/
Images:
CalypsoShare/2022_Experiment/2022_Data_and_Products/Satellite_Maps/bal_sea/