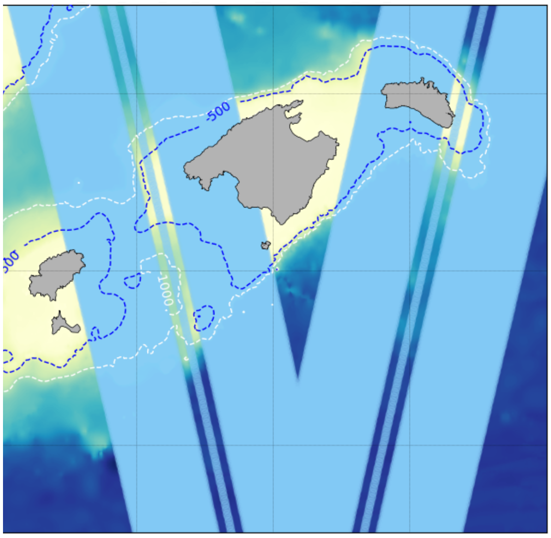
CRUISE PLAN

Fine-Scale ocean currents from integrated multi-platform experiments and numerical simulations: contribution to the new SWOT satellite mission (FaSt-SWOT, PID2021-122417NB-I00)



4 MAY 2023

A. Pascual, B. Mourre, P. Balaguer, B. Barceló-Llull, N. Calafat, B. Casas, V. Combes, E. Cutolo, L. Díaz-Barroso, J. G. Fernández, L. Gómez-Navarro, M. Juza, I. Lizarán, A. Miralles, E. Reyes, P. Rivera, D. Rodríguez-Tarry, P. Rosselló, M. Rubio, A. Sánchez-Román, J. Tintoré, E.Verger-Miralles, J. M. Villoria N. Wirth, N. Zarokanellos

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EXCELENCIA MARÍA DE MAEZTU 2023-2027
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CHANGE RECORD

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23	2023-04-24	Experimental Drifters Sub-section	E. Cutolo	AP
22	2023-04-24	Update satellite images	E. Verger	AP
23	2023-05-04	Add FaSt-SWOT2 tentative sampling strategy and update cruise participants	B. Barceló-Llull	BM
24	2023-05-04	Review of document.	E. Reyes, L. Gómez-Navarro	AP

INDEX

1. BACKGROUND AND MOTIVATION

Horizontal and vertical motions associated with fine-scale ocean features (10-100 km), such as mesoscale and submesoscale fronts, meanders, eddies and filaments, are of fundamental importance for the distribution of heat, salt, gasses, carbon and nutrients in the ocean (e.g., Lévy et al., 2001; Thomas et al., 2008; Mahadevan, 2016; Su et al., 2018; Klein et al., 2019; Siegelman et al., 2020), thus impacting the way the ocean regulates the changing Earth's climate. Understanding the three-dimensional (3D) dynamics associated with fine-scale features and its impact on the large scale ocean circulation and climate system is one of the major international challenges for the next decade in oceanography (e.g., Young and Sikora, 2003; Kwon et al., 2010; Ma et al., 2016; Su et al., 2018; Bishop et al., 2020; Small et al., 2020). Integrated approaches combining multi-platform in-situ data with remote sensing observations and high-resolution model simulations constitute the innovative methodology proposed to evaluate and understand the 3D pathways associated with these structures (Mahadevan et al., 2020a, Pascual et al., 2017, Barceló-Llull et al., 2021, Cutolo et al., 2022).

During the last decades, remote sensing observations of sea surface height (SSH) have significantly increased our understanding of the global ocean large and mesoscale circulation (e.g. Chelton et al., 2011a, e.g. Le Traon et al., 2013); eddy identification and tracking (e.g. Chelton et al., 2011b; Mason et al., 2014; Escudier et al., 2016a; Escudier et al., 2016b), and quantification of eddy kinetic energy (Pascual et al., 2006). Satellite altimetry observations have the advantage of covering the global ocean in short periods of time. However, the effective resolution of present gridded SSH maps is limited, i.e. ~130 km in the Mediterranean Sea (Ballarotta et al., 2019), which is still insufficient to resolve the entire range of mesoscale dynamics which develop over shorter temporal and spatial scales in this basin compared to the open ocean (e.g. Escudier, et al., 2016a; Gómez-Navarro et al., 2018, Barceló-Llull et al., 2019).

The new Surface Water and Ocean Topography (SWOT) satellite mission (Morrow et al., 2019) was launched in December 2022 and it is expected to provide observations of SSH with a spatial resolution one order of magnitude higher than present altimeters, and thus representing the next big breakthrough in Earth observation. The SWOT mission aims to provide SSH measurements in two dimensions along a 120km-wide-swath altimeter with an expected effective resolution between 15 and 30 km, hence, allowing in some regions the observation of the full range of mesoscale dynamics (Fu and Ubelmann, 2014; Morrow et al., 2019, d'Ovidio et al., 2019). This will likely open a new era for the understanding of ocean dynamics at these fine-scales (Pascual and Macías, 2021).

During the fast-sampling phase, SWOT will provide observations of SSH on a daily basis in specific areas of the world ocean for instrumental calibration/validation (d'Ovidio et al., 2019). The region around the Balearic Islands in the Western

Mediterranean Sea is one of the selected areas for SWOT validation. The study of this region is of special interest given that the Mediterranean Sea is recognized as an ideal laboratory for studying ocean processes of global relevance, such as water mass formation, overturning circulation, boundary currents, meso/submesoscale eddies and instabilities, carbon export and associated ecosystem responses (Malanotte-Rizzoli et al., 2014; Tintoré et al., 2019, Mason et al., 2023).

The FaSt-SWOT (Fine-Scale ocean currents from integrated multi-platform experiments and numerical simulations: contribution to the new SWOT satellite mission) experiments will take place in the Balearic Sea during the SWOT fast-sampling phase. The general objective of these experiments is to improve the characterization of oceanic fine scales through the combined use of in-situ multi-platform and satellite data in synergy with numerical models and innovative computational techniques. Gathering a unique multidisciplinary expertise in physical oceanography, satellite remote sensing, in situ monitoring and computational science, the campaigns will assess the actual capability to map SSH variability over a range of scales (30-100 km) traditionally not resolved by conventional altimeters.

A unique aspect of the FaSt-SWOT experiments is the combination of concurrent multi-scale ship-based instruments, autonomous platforms, and satellite observations with *ad hoc* modeling simulations, enabling the evaluation of underlying mechanisms. Taking advantage of the unique observing and high-resolution data-assimilative modeling capacities developed by IMEDEA and SOCIB teams over the recent years, FaSt-SWOT aims to take a step further supporting the analysis and exploitation of the first SWOT high-resolution measurements. The FaSt-SWOT project federates two multiplatform in situ experiments, combining glider, drifter, ship and High-Frequency (HF) radar observations together with satellite observations and high-resolution data-assimilative numerical simulations. Advanced Observing System Simulation Experiments (OSSEs) have been performed to optimize the sampling strategies (Barceló-Llull and Pascual, 2023). New tools of artificial intelligence will be developed and applied to enhance the synergy of in-situ and SWOT data (Cutolo et al., 2023). Moreover, SWOT data assimilation will be implemented to integrate this new data set into operational ocean prediction systems. Overall, these different tools will be combined to retrieve and analyze fine-scale horizontal and vertical currents.

2. PROPOSED RESEARCH

2.1. AREA OF STUDY

To anticipate the 2D SSH fields that will be provided by SWOT and to monitor and understand the vertical exchanges associated with mesoscale and sub-mesoscale structures and their contribution to upper-ocean interior exchanges, multi-sensor synoptic observations need to be collected. In situ systems, including R/V (MVP, CTD, Thermosalinograph, water samples, ADCP), gliders and drifters will be coordinated with satellite data. The observational approach will be integrated with numerical simulations. Within the FaSt-SWOT project we propose to design, conduct and analyze two multi-platform high-resolution experiments in a zone of the Western Mediterranean sampled by SWOT during the 90-day fast phase after launch, in which the satellite is providing daily high resolution SSH measurements in selected areas of the global ocean (see Figure 1).

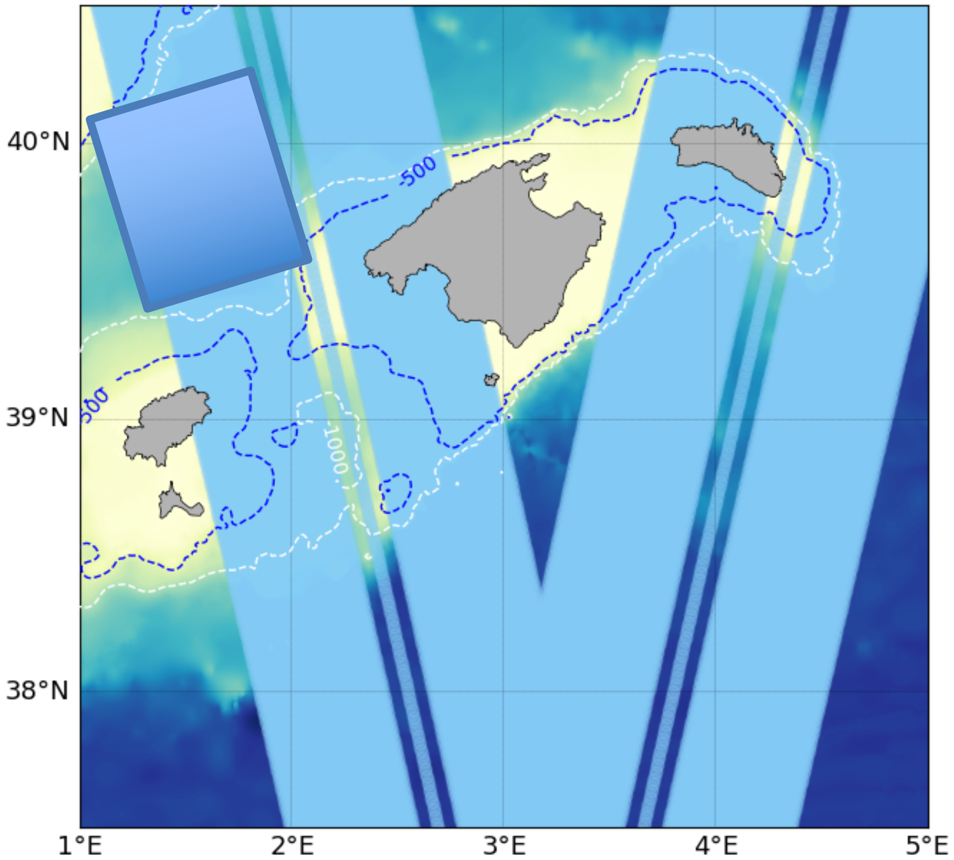


Figure 1. Tentative area of study (rectangle in the inset panel) in the Western Mediterranean showing the SWOT mission swaths during the fast phase after launch.

2.2. OVERALL TIMELINE

There will be two FaSt-SWOT campaigns using the R/V SOCIB during 4 days each. The first phase will take place between 25 and 29 April, the second phase between 7 and 10 May.

Gliders will be deployed during the first phase and will stay in the water until the end of the second phase.

2.3. MULTI-PLATFORM OBSERVATIONS IN FAST-SWOT

Research Vessel

Data from thermosalinograph (TSG), Moving Vessel Profiler (MVP), CTD and Vessel Mounted Acoustic Doppler Profiler (VM-ADCP) will be gathered from the R/V SOCIB. The exact location of the multi-platform experiment will be fixed based on the presence of a front or a remarkable small-scale feature detected in satellite imagery (SSH, sea surface temperature, ocean color) and in real-time model predictions a few days before the cruise. The area of study sampled from the surface to 200 m depth with the MVP at a constant speed of 4 knots. Simultaneously, the TSG and ADCP will be continuously sampling the water column. In addition, the CTD rosette will be released in selected stations down to ~500 m depth; to do this sampling the R/V will stop during ~30 min. The exact sampling strategy will be fixed after performing the OSSEs as detailed below.

Gliders

Two gliders will be deployed at the beginning of the first sampling phase. Both gliders will be sampling the same transect one after the other, separated by ~25-30 km (which is equivalent to a temporal separation of about 1 day, i.e. same temporal resolution of SWOT data during the fast sampling phase). Gliders will collect high-resolution temperature, salinity, oxygen, chlorophyll fluorescence (CHL), backscatter at 700 nm (bbp), turbidity (NTU), colored dissolved organic matter (CDOM) and photosynthetically available radiation (PAR). During the experiment duration, we expect that each glider repeats the transect sampling two times with a navigation speed of 20-22 km/day. The sampling will then be adapted to the oceanographic conditions, until the recovery of the platforms at the end of the second phase of the experiment on 8th of May. For the glider sampling strategy check the glider section 5.3.

Drifters

During the experiment, 45 surface drifters will be deployed within the domain. Surface currents derived from drifters will be used to study the temporal and spatial variability of fronts and filaments, and ideally to detect convergence and divergence. In addition, drifter observations will be useful for validation of altimetry, glider, models and MVP -derived geostrophic velocities. The deployment strategy will address the goal to sample frontal areas and try to detect convergence/divergence areas. For that purpose, the drifters will be deployed over a uniform initial array across the frontal areas with a drifter separation of a few km. The exact deployment location will be fixed based on the position of frontal areas detected in satellite imagery (Figure 2). Kinematic properties of convergence/divergence will be estimated following the methods implemented by the team in Tarry et al., (2021). CARTHE (20 units) (Novelli et al., 2017), HEREON (20 units) (Horstmann, et al.,2022): and SVP-B (5 units) (Niiler, 2001; Maximenko et al., 2013; Centurioni et al., 2017; Horányi et al., 2017) drifters will be used in this experiment.

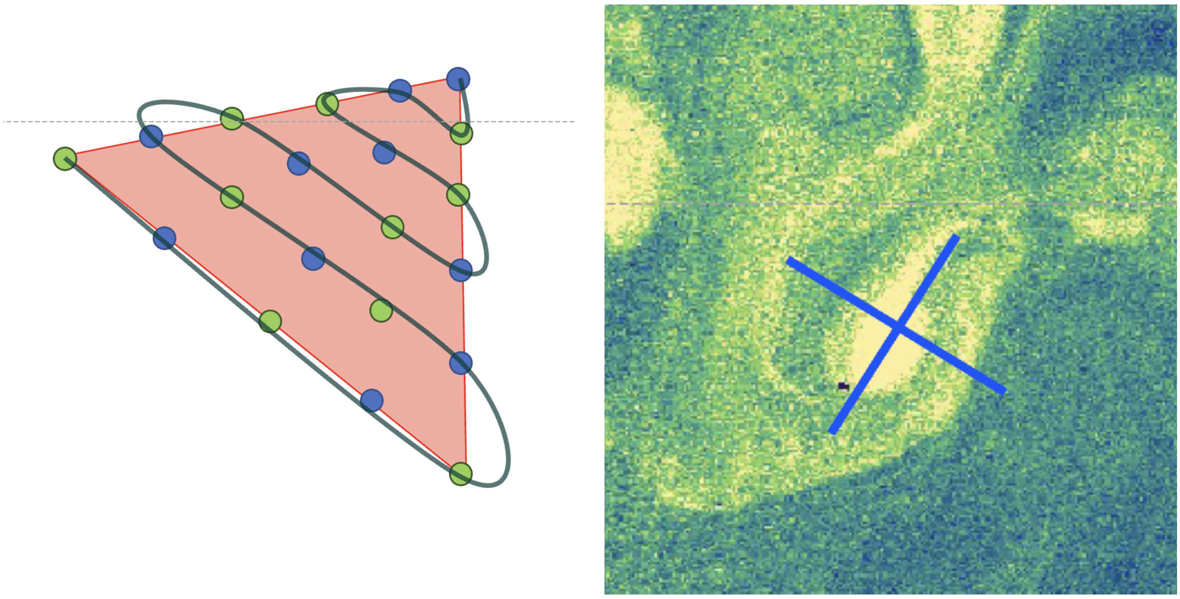
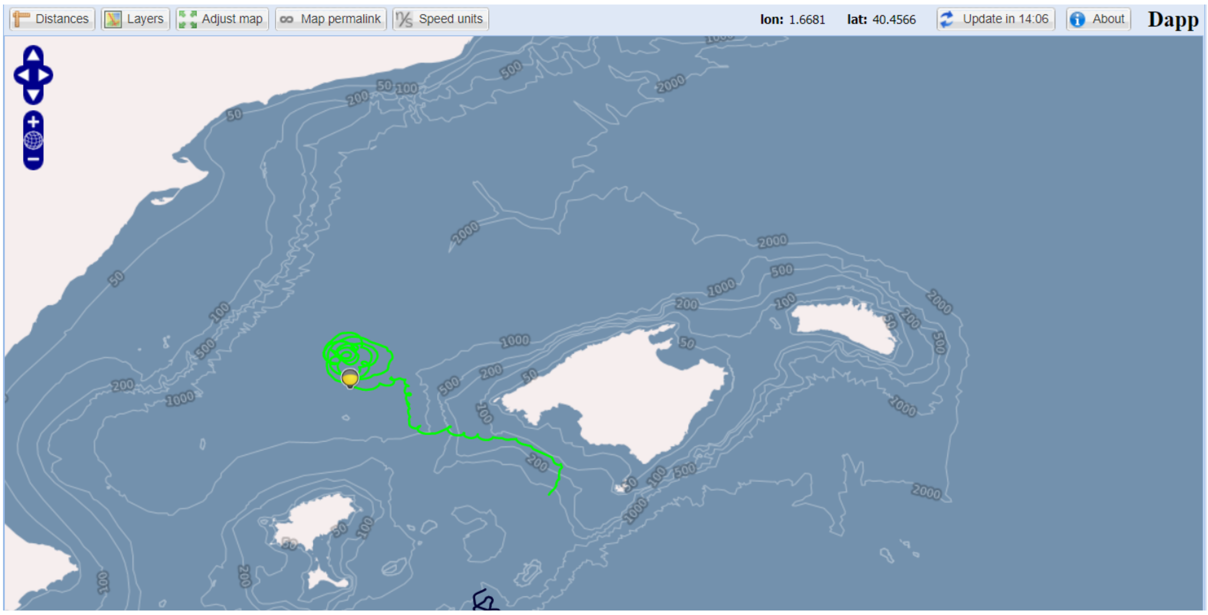


Figure 2. Tentative drifter deployment schemes depending on the structure to sample.

Drifter data available in the area is also useful to determine the sampling area. The sampling area for FaSt-SWOT1 was chosen based on the trajectory of a drifter trapped in a submesoscale eddy (Figure 3).



a. Trajectory since deployment till 24/04/2023.

b. Drifter trajectory of the last 4 days (since 24/04/2023).

Figure 3. SVP-B drifter (SCB-SVPB035 (wmo 6102812)) trajectory trapped in submesoscale eddy (http://apps.socib.es/dapp/?deployments=2142-30-0).

HF radar

Analysis of hourly HF radar (HFR) surface currents from the Ibiza Channel and the Ebro Delta, operated by SOCIB and Puertos del Estado, respectively, will allow investigation of the dominant temporal and spatial scales in the region that are associated with the spatial scales that SWOT will resolve. Both systems consist of two and three, respectively, CODAR SeaSonde HF radar stations transmitting at a central frequency of 13.5 MHz and a bandwidth of 90 kHz. They continuously monitor the surface currents (~ 0.9 m deep) of wide coastal regions (as far offshore as 88 km in the case of radials and 65 km in the case of totals) of the Ibiza Channel and the Ebro Delta at high spatial resolution (3 km), as described in Lana et al., (2015 and 2016) for the HFR-Ibiza and in Lorente et al., (2016) for the HFR-Ebro. Two types of data can be obtained from the HFRs: i) Radial currents moving toward or away from the receiver antenna and ii) total current vectors, which are derived from a geometrical combination of radial current estimations in regions of overlapping coverage from two or more sites. Wavelet and spectral analysis in combination with some filtering techniques will be applied to investigate temporal and spatial scales.

Satellite remote sensing

Satellite remote sensing imagery will be essential for the design of the experiment. The exact position of the oceanic features to be sampled will be determined during the days preceding the experiments from conventional altimetry and high-resolution sea surface temperature and ocean color maps (obtained from the Copernicus Marine Service Catalogue https://marine.copernicus.eu/). Moreover, both along track and gridded near-real-time altimetry products will be then compared against in-situ data and SWOT measurements. We will benefit from the availability of multiple altimeter missions (presently: Cryosat-2, SARAL/AltiKa, Haiyang-2B, Jason-3, Sentinel-3A, Sentinel-3B, Sentinel-6A).

Satellite images (e.g. Figures 4 and 5) will be updated in these google drive folders:

- SST - SSH- CHL:

https://drive.google.com/drive/folders/1BoMyXxMhw9Qw9ZEyLf80AOEqpSg4GrZ2?usp=share_link

- Also including along-track altimetry:

https://drive.google.com/drive/folders/1klf-FQEdS1aKoZhXeFN81zMVuQfWnNWn?usp=share_link

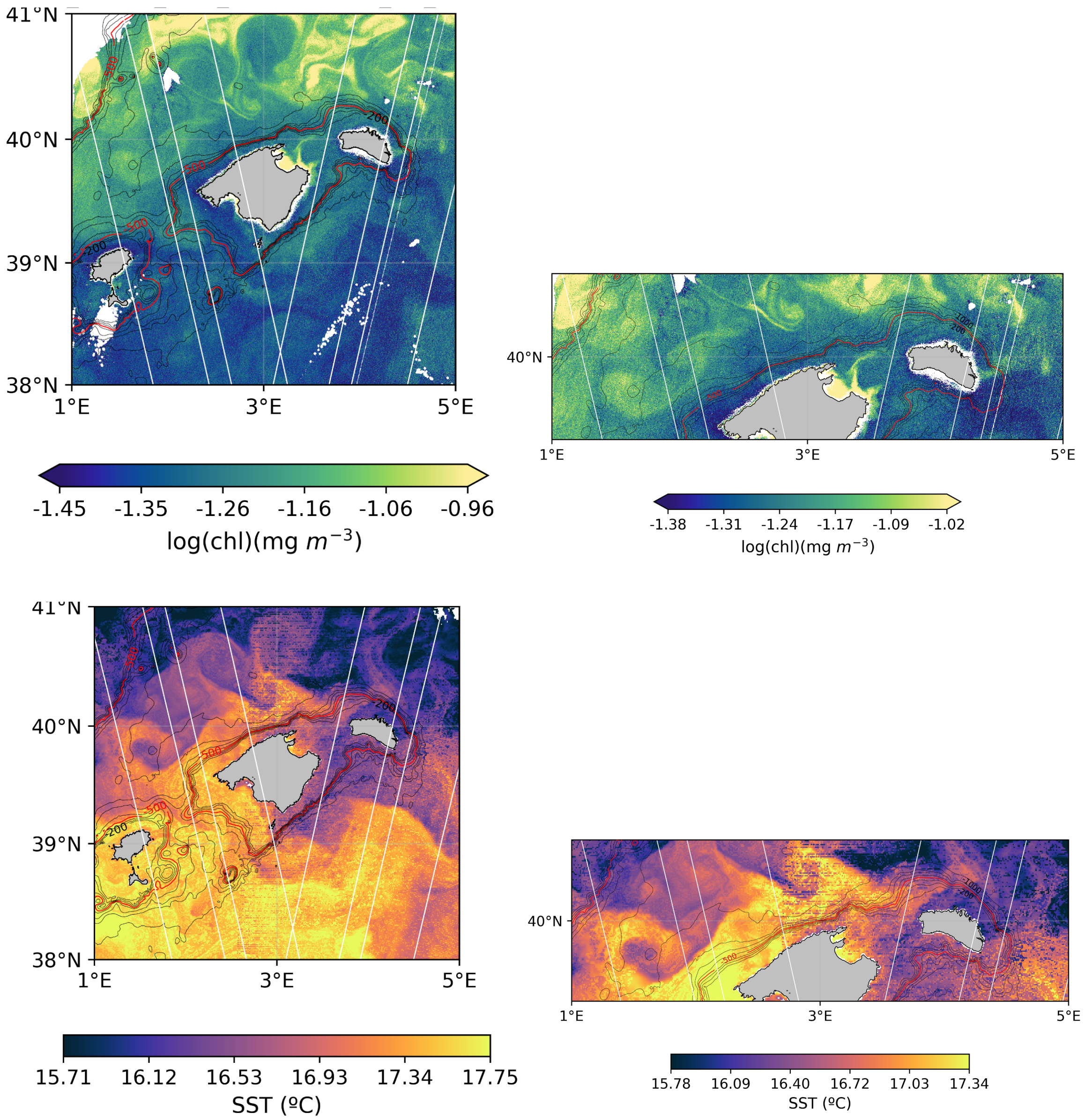


Figure 4. Ocean color (top) and SST (bottom) satellite images in the region of interest on 21/04/2023.

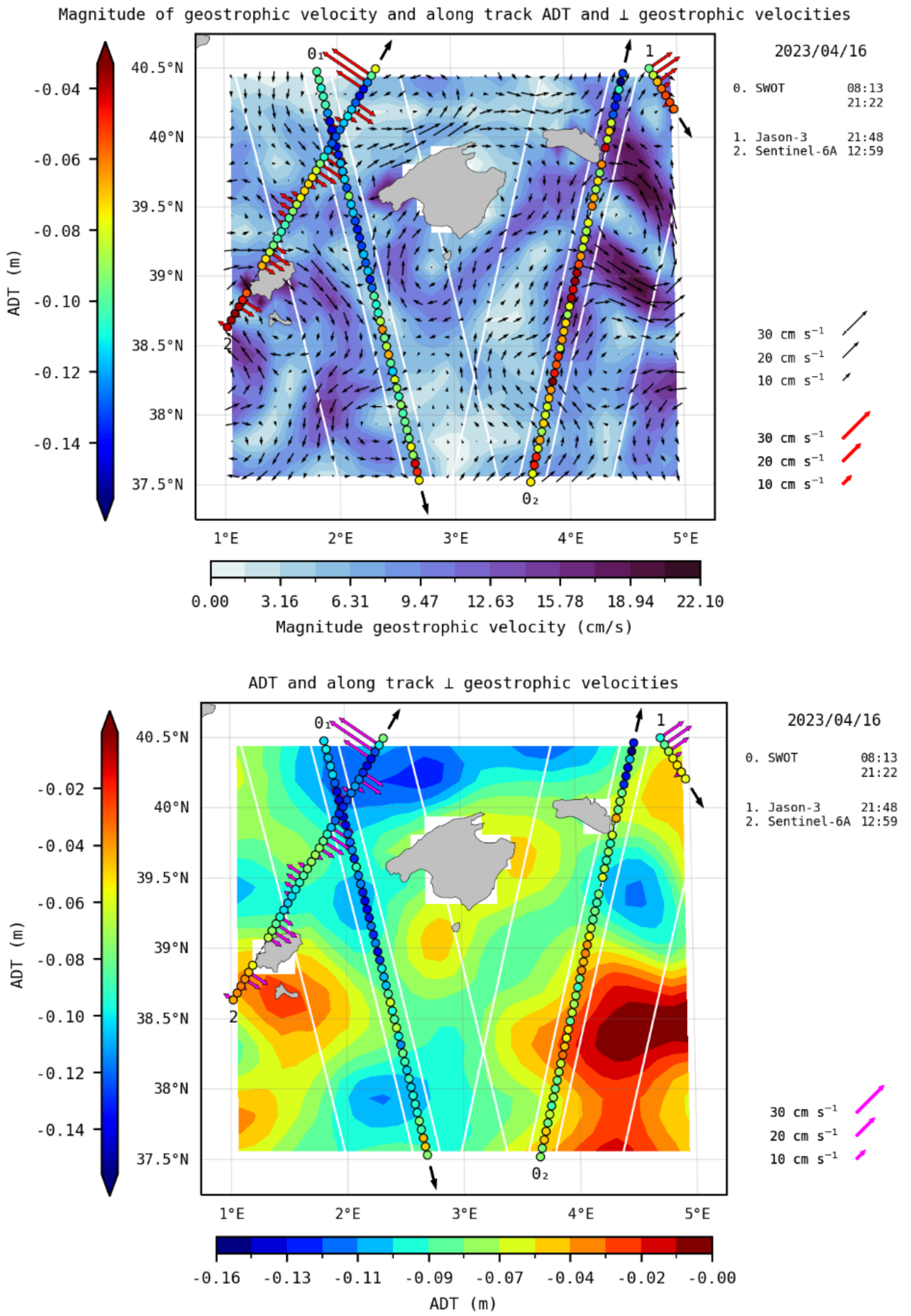


Figure 5a. Examples of plots of along-track satellite altimetry data and SWOT-Nadir along track data for 16/04/20 in the region of interest represented on top of interpolated satellite data (Geostrophic Velocity and ADT in these examples).

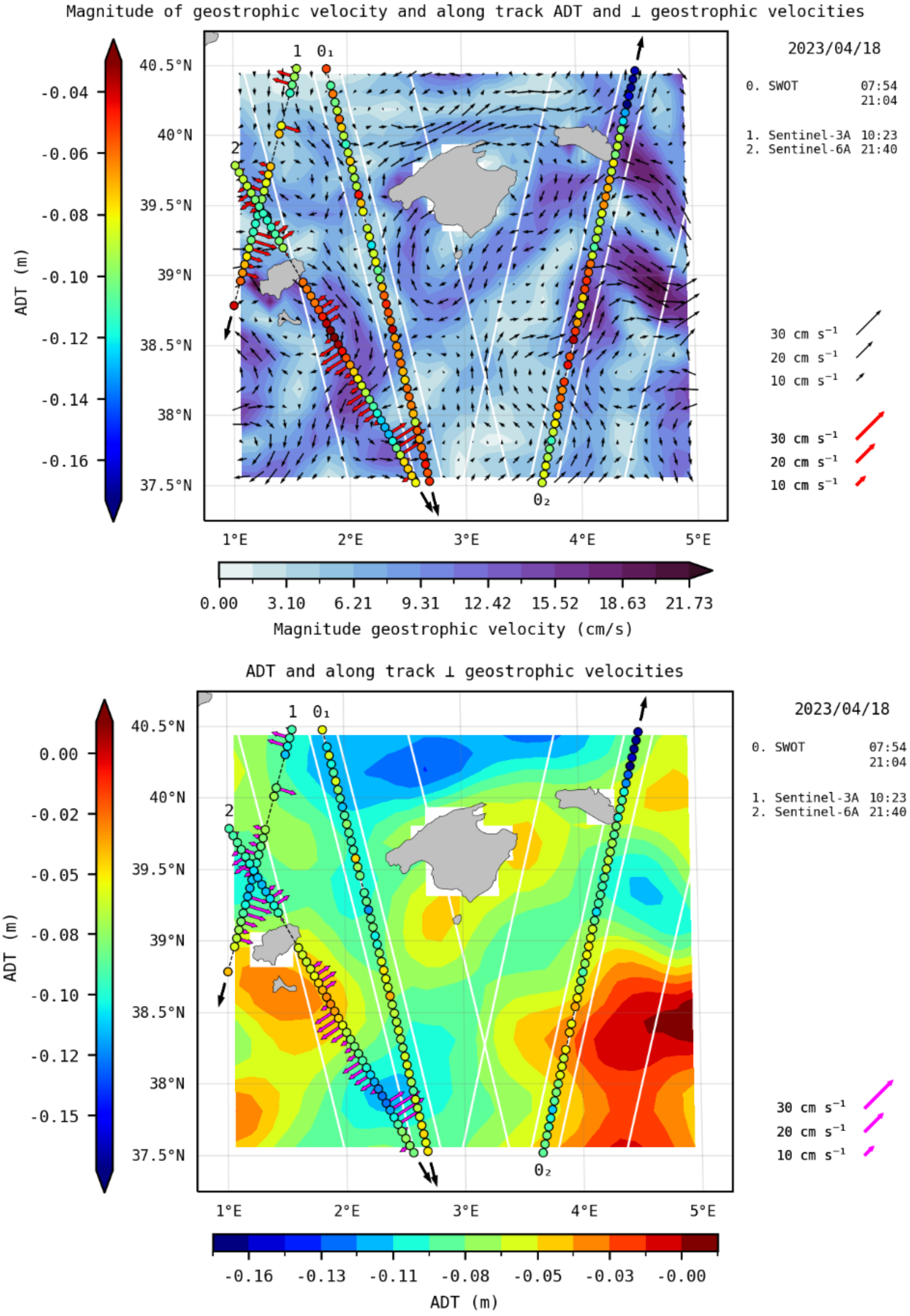


Figure 5b. Examples of plots of along-track satellite altimetry data and SWOT-Nadir along track data for 18/04/20 represented on top of interpolated satellite data (Geostrophic Velocity and ADT in these examples).

Other satellite images are also generated and provided by the AdAc consortium through email. More details in (password protected):
https://www.swot-adac.org/resources/swot-adac-products-access/

Satellite images (ocean temperature, ocean color, ocean currents, ocean surface stress) focused on the FaSt-SWOT sampling region will also be made available through the Satellite imagery SOCIB application and the dedicated WMOP model and satellite visualization webpage. Associated kmz files are also uploaded on the Google Drive (see example in Figure 6):

https://drive.google.com/drive/folders/142QIzxSFriStCU-87_hzXJdRteQuQJbZ?usp=share_link

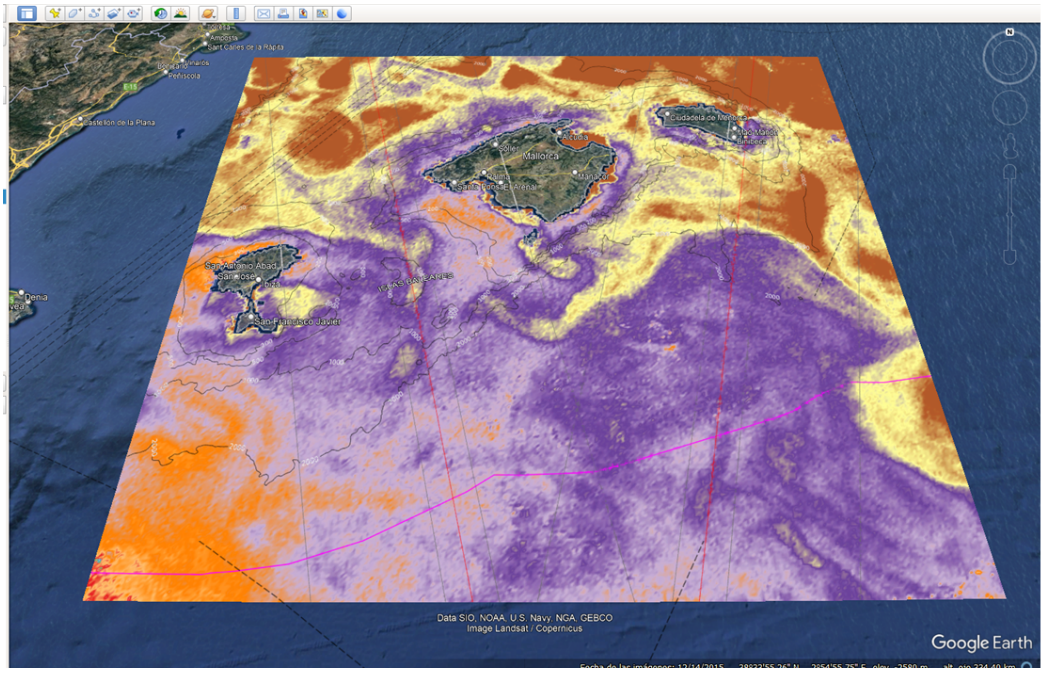


Figure 6. Ocean color image (18 April 2023) visualized through Google Earth kmz files

Quality control and data management

FaST-SWOT will provide world leading data QC through SOCIB Data Centre Facility. Data will be made available and disseminated according to open access and data policy (see Data Management Plan section below).

3. INVOLVED PERSONNEL

Ship crew

List of required ship-crew for the cruise:

- 1 Captain
- 2 Bridge Officer
- 1 Chief Engine
- 1 Engine Officer
- 3 Deck crew
- 1 Chef

Scientific team

NAME	INSTITUTION	ROLE/TASK
Benjamín Casas	SOCIB	Head of campaign, technical coordination
Daniel Rodríguez-Tarry	IMEDEA	Drifter deployment strategy, MVP, GoPros, data processing
Eugenio Cutolo	Atalaia	ADCP, CTD, optimal sampling, data processing and analysis
Irene Lizarán	SOCIB	Drifters, CTD, MVP, salinity samples and analysis
Laura Gómez-Navarro	IMEDEA	GoPros, drifters
Elisabet Verger-Miralles	IMEDEA	MVP, CTD, satellite data, salinity samples, sampling strategy
Nathan Siegel	Ona Agency	Camera/interviews

Table 1. FaSt-SWOT1: cruise participants, institutions and role in the cruise

NAME	INSTITUTION	ROLE/TASK
Baptiste Mourre	SOCIB	Co-principal investigator, Chief Scientist
Niko Wirth	SOCIB	Technical coordination
Emma Reyes	SOCIB	Drifters
Daniel Rodríguez-Tarry	IMEDEA	Drifter deployment strategy, satellite data, CTD, MVP, ADCP, GoPros, salinity samples, data processing and analysis
Noemí Calafat	SOCIB	Drifters, salinity samples, CTD, MVP
Laura Gómez-Navarro	IMEDEA	GoPros, drifter deployment strategy, satellite data, CTD, MVP, ADCP, salinity samples, data processing and analysis
Nathan Siegel	Ona Agency	Camera/interviews

Table 2. FaSt-SWOT2: cruise participants, institutions, and role in the cruise

NAME	INSTITUTION	ROLE/TASK
Ananda Pascual	IMEDEA	Principal investigator, science lead FaSt-SWOT1
Bàrbara Barceló-Llull	IMEDEA	Sampling strategy, data analysis
Albert Miralles	SOCIB	Glider preparation and piloting
Nikolao Zarokanellos	SOCIB	Scientific glider support
Manuel Rubio	SOCIB	Glider preparation and piloting
Patricia Rivera	SOCIB	Glider preparation and piloting
Juan Gabriel Fernández	SOCIB	Data management
Lara Díaz Barroso	SOCIB	Drifter data manager
Juan Miguel Villoria	SOCIB	Data processing
Melanie Juza	SOCIB	Satellite imagery
Pablo Balaguer	SOCIB	Ship logistics
Pere Rosselló	IMEDEA	Satellite imagery/Biogeochemistry
Antonio Sánchez-Román	IMEDEA	Sampling strategy, data analysis
Joaquín Tintoré	IMEDEA & SOCIB	Scientific & Operational support
Vincent Combes	IMEDEA	Data processing

Table 3. Land participants.

4. WORK PLAN

DATE	OVERVIEW
19-24 APRIL 2023	Mobilization
25 APRIL 2023	Start of FaSt-SWOT1 Transit to position of glider deployments MVP, CTD, ADCP, GoPros and water samples Transit to position of drifter deployments
29 APRIL 2023	End of FaSt-SWOT1 Back to Palma harbor
8 MAY 2023	Mobilization Start of FaSt-SWOT2 Transit to position of drifter deployments MVP, CTD, ADCP, GoPros and water samples
12 MAY 2023	Recovery of gliders End of FaSt-SWOT2 Back to Palma harbor
12 MAY 2023	Demobilization

Table 4. Tentative work plan

5. PLANNED ACTIVITIES

- Gliders (2 Slocum gliders)
- Shipboard CTD, Thermosalinograph, ADCP, MVP, 24-hour ops, rosette CTD casts to 500 m depth
- Water samples
- Drifter deployments
- GoPros cameras for macro-plastic detection.

5.1. MVP, CTD, VM-ADCP AND WATER SAMPLES

Observations from the MVP, CTD and VM-ADCP, and water samples will be gathered from the R/V SOCIB. The exact location of the experiment will be fixed based on the presence of fine-scale features within the swath of SWOT located east of Mallorca Island, in a bathymetry deeper than 500 m depth (Figure 1). The strategy will consist of a radiator grid sampled by the MVP down to 200 m depth at 4 knots, with a total of 5 transects 50 km long and separated by 10 km (to capture SWOT scales, Gómez-Navarro et al., 2018) (Figures 7 and 8), with the additional sampling of one of these transects one more time, if possible. Water samples for salinity calibration will be collected at different depths of the CTD profiles, trying to cover the whole range of salinities measured (approx. 4 rosette CTD casts in total). ADCP data will be continuously recorded down to 300 m. The exact position of the grid will be decided based on satellite images, but we will always stay within the Spanish Economic Exclusive Zone (EEZ) and in a bathymetry deeper than 500 m.

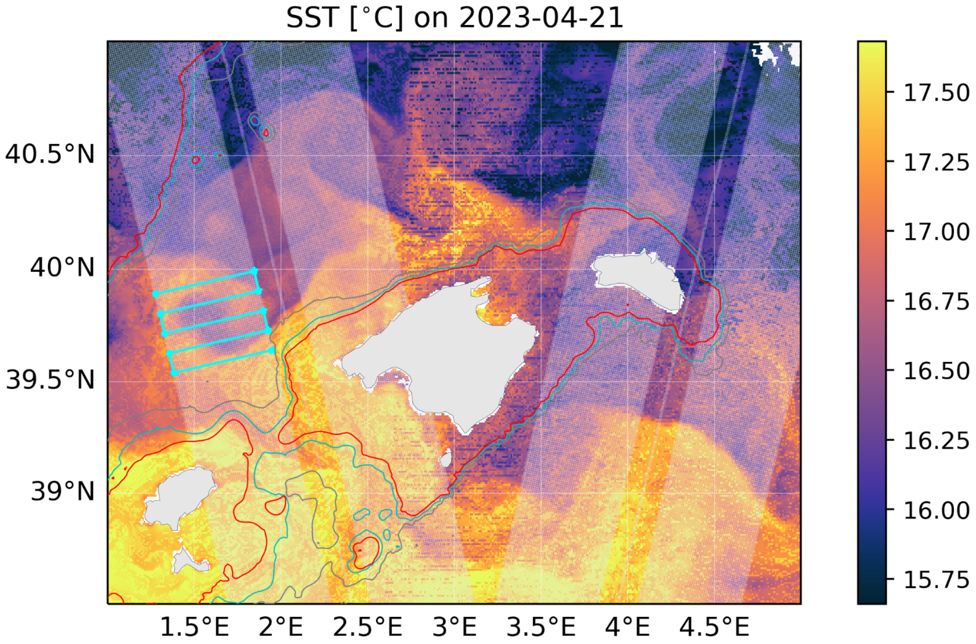


Figure 7. Tentative sampling strategy with the MVP (radiator grid) during FaSt-SWOT1. In the background, satellite observations of SST on 21 April 2023. See fig. 18 for FaSt-SWOT2.

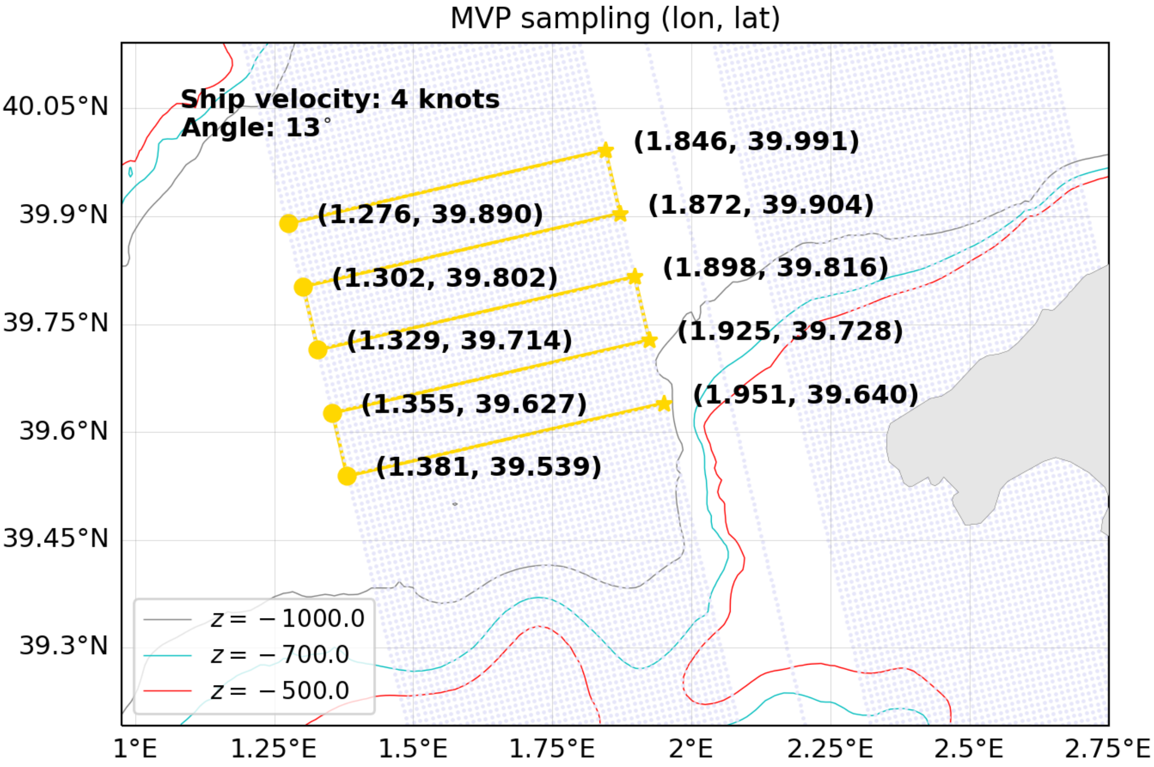


Figure 8. Tentative sampling strategy with the MVP (radiator grid) during FaSt-SWOT1 and the coordinates of the extremes of each transect.

5.2. DEEP-LEARNING ADAPTIVE SAMPLING

A part of the cruise will be targeted to test an adaptive sampling methodology driven by a deep-learning scheme. From a given set of high-resolution remote-sensing images (SST, CHL), the software suggests the most relevant sampling points and, thus, the optimal route. The underlying neural network is called CLuster enhanced Optimal Interpolation Network (CLOINet), developed to achieve a 3D reconstruction of the ocean state by combining in-situ observations with remote-sensing data (Cutolo et al., 2023). In particular, we will use the first part of this network that classifies the spatial domain points into fuzzy clusters according to their values and positions in the remote-sensing images. Once computed how much a specific point belongs to different clusters, we can estimate how much it represents a bigger area and is thus relevant for the sampling. Finally, given the domain's points relevance, the algorithm solves the traveling salesperson problem to compute the optimal sampling route (Figure 9).

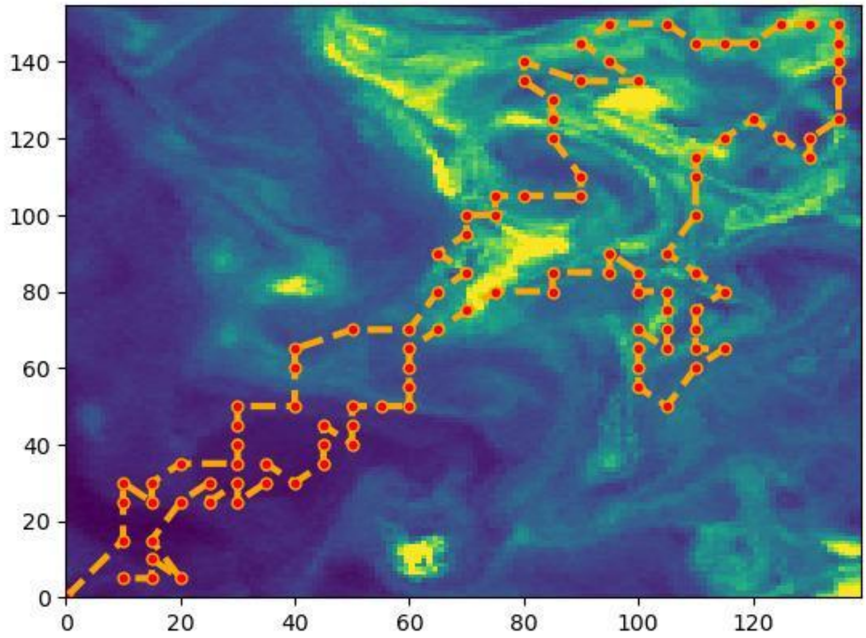


Figure 9. Example of an adaptive sampling based on a CHL image of a submesoscale structures (axes are in kilometers)

5.3. GLIDERS

Two Slocum gliders (owned and operated by SOCIB) will be deployed during the campaign to sample the study area. Both slocum gliders are equipped with CTD and Oxygen sensors. In addition, the one G3 slocum (sdeep09) will carry an FL3 (to measure chlorophyll fluorescence (CHL), Colored dissolved organic matter (CDOM) and backscatter (bbp at 700 nm) and a PAR sensor (Figure 9). The other slocum glider is a G2 (sdeep01) equipped with a FLNTU sensor (to measure turbidity (NTU) and chlorophyll fluorescence). The running operation costs of the glider unit from the SOCIB glider facility are covered by the SWOT project through the External Users Access.

The two gliders have been programmed to profile from the surface up to 700 m at a nominal vertical speed of 0.18 ± 0.02 m/s, and will move horizontally at approximately 20–24 km per/day. One glider will be released 50 km south of the MVP radiator grid and the second glider 25 km from the first glider and 25 km from the MVP radiator grid. Each glider will follow the same trajectory along the SWOT swath, each one 25-30 km apart from the other (which is equivalent to a temporal separation of about 1 day, i.e. same temporal resolution of SWOT data during the fast sampling phase). They will sample a 130-km-long transect, which will be completed in about 5-6 days.The gliders are planned to be deployed the first day of the cruise and operate for a period of 18 days. During this period each glider expects to perform 3 complete transects.

Working plan:

All aspects related to the Launching, Survey and Recovery of the SLOCUM gliders will be covered by SOCIB's Glider Facility. The gliders will be prepared by the SOCIB specialists in the Glider Lab. They will manage all the laboratory operations (ballasting, calibration, informatics, data management and other required operations) and deployment of the instrument.

In a second phase, the gliders will be deployed on 24th of April from the SOCIB R/V to the south of the Mallorca Island with a distance of 25 km apart. The SOCIB gliders will follow the swath of the SWOT satellite. This survey will last for 17 days and will end up on 8th of May with the glider's recovery in the study area.

Glider behavior (Figure 10):

- Yoing
    - Dive to 700m
    - Climb to 10m
    - Surfaces: 10am, 18pm & 2am
    - Infinite yoing
- Goto (Figure 11)
    - Deployment wpt S9 (N39.54939 E1.67221) S1(N39.44668 E1.70114)
    - NW limit of glider track wpt: N40.02792 E1.53692
    - Infinite loop
    - SE limit of glider track wpt: N39.50483 E1.68512
    - Recovery wpt**: tbd**
    - Virtual mooring - 12 hours will be performed on the deployments waypoints

Sampling strategy (Figure 10):

- CTD:
    - climb, dive, overing, surface
    - 0-700m
    - 1/4Hz
- OXY:
    - climb, dive, overing, surface
    - 0-700m
    - 1/4Hz
- FLNTU:
    - climb, dive, overing, surface
    - 0-150m, 150-300m
    - 1/8Hz, 1/16Hz
- FL3
    - climb, dive, overing, surface
    - 0-150m, 150-300m
    - 1/8Hz, 1/16Hz
- PAR
    - dive
    - 0-200m
    - 1/16Hz

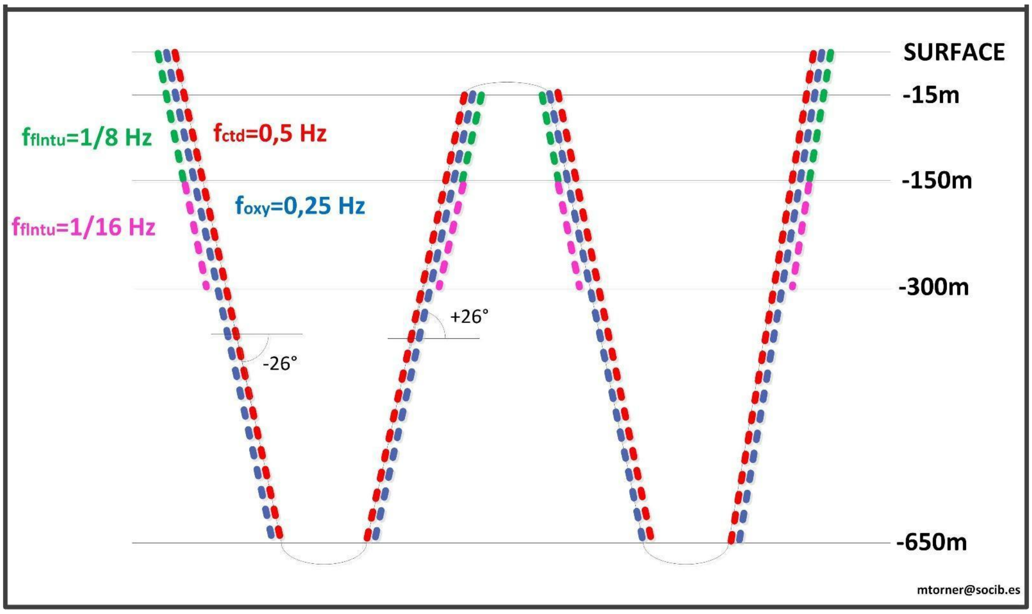


Figure 10. The SOCIB gliders will have the following sampling strategy: For the CTD and oxygen sensor the measurements will performed to ¼ Hz up to 700m depths, for the FL3 and FLNTU sensor will be at ⅛ Hz for the first 0-150m and 1/16 Hz for 150-300m depth and for the PAR at 1/16 Hz for the upper 200m.

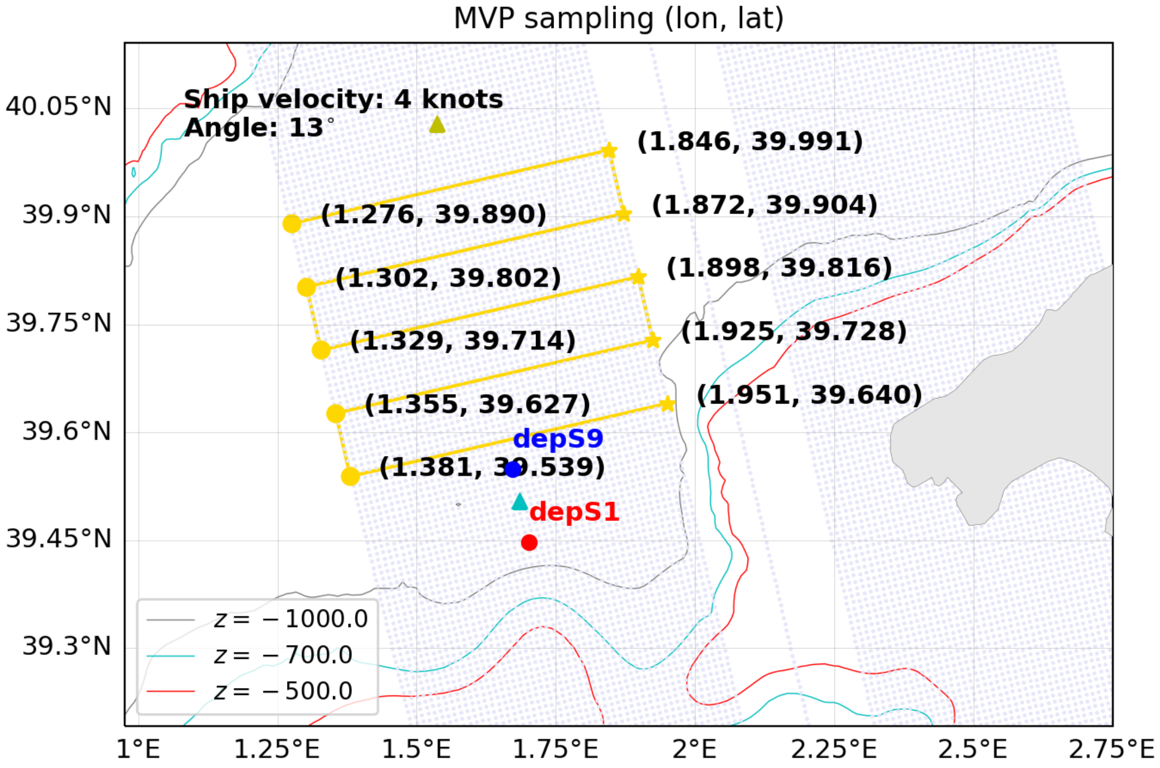


Figure 11. Region of study during FaSt-SWOT1. The blue (red) point is the deployment location for glider S9 (S1), while triangles limit the 60-km-long glider track. The yellow line represents the MVP radiator grid.

5.4. GoPros

Two GoPros from The Ocean CleanUp (https://theoceancleanup.com) will be continuously recording during the daylight time. They will be set-up on the main deck, one portship and one starship on the vessel railing (Figure 12). Plastic items will be detected from the timelapse photos recorded, and drift velocities will be derived for each object if a series is observed. This will provide data on the total surface velocities and give insights into surface accumulation patterns, in combination with other datasets (namely TSG, ADCP and satellite data). At sunrise the time-lapse recording will be started and at sunset stopped. Every day after sunset the external batteries will be charged, and the data transferred to two different external disks. During the day (daylight time) it is important to verify that the GoPro lens did not get dirty or splashed, and that it is recording correctly.

This is done in collaboration with The Ocean CleanUp. The GoPro data saved in external disks will be sent back to The Netherlands to be processed by Robin de Vries (robin.devries@theoceancleanup.com). Support with the instrumentation was also provided by Helen Wolter from The Ocean Cleanup (h.wolter@theoceancleanup.com).

Further details can be found here, and in the official protocol.

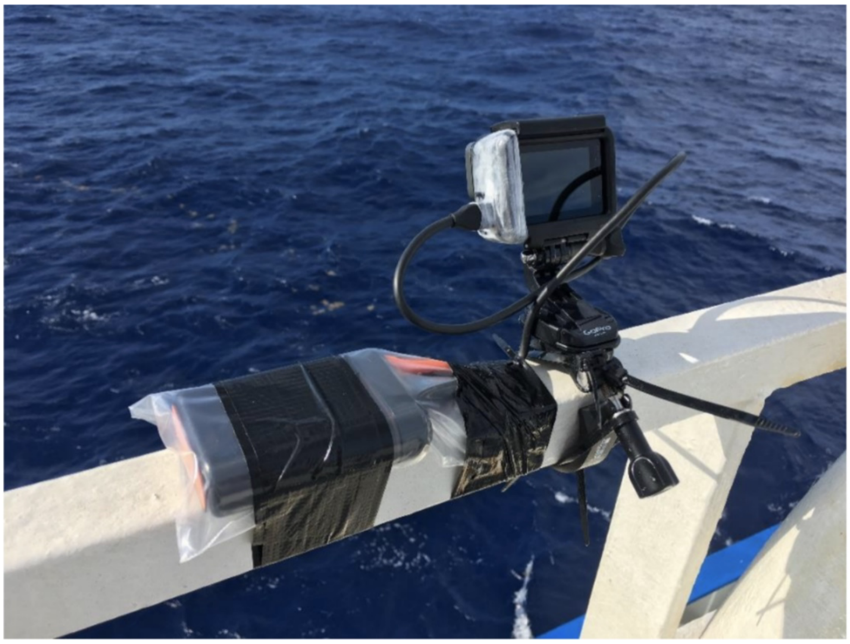


Figure 12. GoPro installation on a vessel railing. The GoPro in its clamp can be seen at the right, the powerbank can be seen to the left. Cables and connections are waterproofed as much as possible using plastic bags and tape. This installation needs to be done every day (from the GoPro protocol from The Ocean CleanUp).

5.5. DRIFTERS

40 surface (20 Carthe and 20 Hereon) + 5 SVP-B drifters will be deployed within the domain. Surface currents derived from drifters will be used to study the temporal and spatial variability of fronts and filaments and ideally to study the kinematic properties of the flow such as divergence, vorticity or strain. In addition, drifter observations will be useful for validation of altimetry, glider, models and CTD derived geostrophic velocities. The deployment strategy will address the goal to sample submesoscale structures (fronts or eddies), to try and detect fine-scale structures that present along-track altimetry does not resolve. For that purpose, the drifters will be deployed in an array adapted to the structure observed (Figure 2). If the structure of interest is:

- a jet or front : triangle (5-10 km side length).
- eddy : line (or repeated transects, depending on eddy diameter and campaign limitations) going through the structure.

The triangle or transect length will not be smaller than the lowest expected resolved wavelength by SWOT, 15 km (structures of 7.5 km).

The exact position of deployment will be determined based on the position of frontal areas determined from satellite imagery. The 5 SVP-Bs will be deployed with the surface drifter array, together with another surface drifter. During leg 1, the 5 SVP-B drifters will be deployed, tentatively in areas as far away from the coast as possible, and half of the surface drifters (10 HEREON and 10 CARTHE, figure 13). During leg

2, 10 HEREON and 10 CARTHE surface drifters will be deployed. The deployment of the SVP-B drifters will make using the FaSt-SWOT1 cruise as ship-of-opportunity.

Figure 13. Surface drifters to be deployed. Left: CARTHE drifter (source: https://www.pacificgyre.com/carthe-drifter.aspx). Middle: HEREON drifter. Right: SVP-B drifter.

The drifters will be followed and tracked at http://apps.socib.es/dapp/. Further details on the drifters and their details can be found here.

Tasks	Responsible	Time	Procedure
1. 1) Deploy drifters	Drifter WG O/B	Deployment	Drop with cape/sea level
1. 2) Send confirmation to DCF (see details below)	ETD/Drifter WG	Deployment	Communicate deployment time and location by Slack (see below, table 6)
1. 3) Send confirmation to NOAA and OceanOPS (only SVP-B)	Lara	Deployment	By Email
1. 4) Start deployment	DCF data steward	Deployment	SOCIB Instrumentation App + download script

Table 5. List of tasks to be done for the Drifter WG during the cruise.

Drifter	SN/ ID	Date	Time (UTC)	Latitude	Longitude
IME-CARTHE00X	XXXXXX	dd/mm/yyyy	hh:mm	xx° xx.xx N	xx° xx.xx E
IME-HEREON00X	XXXXXX	dd/mm/yyyy	hh:mm	xx° xx.xx N	xx° xx.xx E

Table 6. Deployment information to be provided via Slack (Task 2 Table 5).

- Slack channel: fast-swot.slack.com
- Slack messages:
    - IME-CARTHE00X || SN XXXXXX
      Date: yyyy-mm-dd
      Time (UTC): hh:mm
      Location: xx° xx.xx N xx° xx.xx E

    - IME-HEREON00X || ID XXXXXX
      Date: yyyy-mm-dd
      Time (UTC): hh:mm
      Location: xx° xx.xx N xx° xx.xx E

5.5.1. EXPERIMENTAL DRIFTERS DEPLOYMENT

Together with CARTHE and HEREON, some experimental drifters (figure 14) will be deployed to test and compare their capabilities with respect to the firsts. In detail, collaborating with ATALAIA Detection Technologies, three types of drifters were realized: one mainly made with wood and linen canvas and two entirely 3D-printed with biodegradable plastics. Intending to use non-contaminating material, we used filaments of Polyhydroxyalkanoates (PHAs), which are biodegradable polymers produced in nature by numerous microorganisms, including through bacterial fermentation of sugars or lipids. Their positions will be available in real-time through an ATALAIA server and after the campaign for studying their behavior at sea.

Figure 14. One of the experimental drifters made with wood and linen canvas.

5.6. MODELING - WMOP

The prediction of the WMOP high-resolution model will be used to support the experiment. WMOP is based on a 2 km-resolution regional ocean configuration of the ROMS model implemented over the Western Mediterranean Sea. The model is forced by high-resolution winds (5 km, 3 hours) from the Spanish Meteorological Agency (AEMET).

It assimilates observations from satellite along-track altimetry, sea surface temperature, Argo temperature and salinity profiles, surface velocities from the Ibiza Channel HF radar, with a daily cycle. After assimilation of the most recent observations, the model is run every morning, producing a 3-day forecast of ocean temperature, salinity, sea level and currents. Daily predictions are made available around 08h15 UTC.

WMOP model outputs and validations are displayed on the WMOP general webpage as well as through the interactive lw4nc2 interface.

Moreover, a specific FaSt-SWOT visualization webpage (Figure 15) has been developed to provide easy access to WMOP predictions of density, temperature, salinity, sea level and velocity fields, as well as derived variables such as divergence, vorticity or Finite-Size Lyapunov Exponents over the sampling area. It also provides satellite images (Figure 16) for model validation and a quick view of the latest assimilated altimeter and profile data.

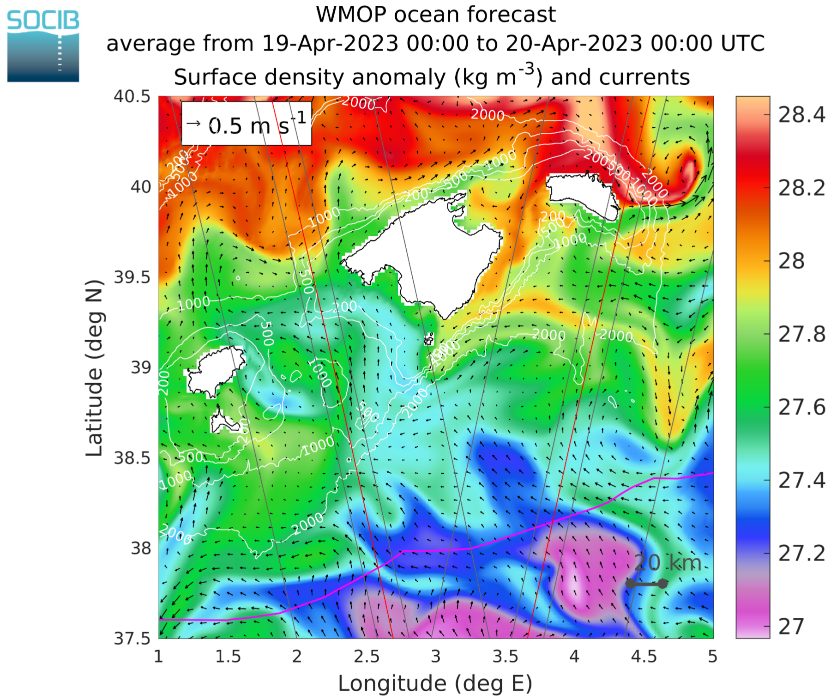


Figure 15. Example of WMOP surface density fields for 19 April 2023, as provided through the FaSt-SWOT WMOP visualization webpage.

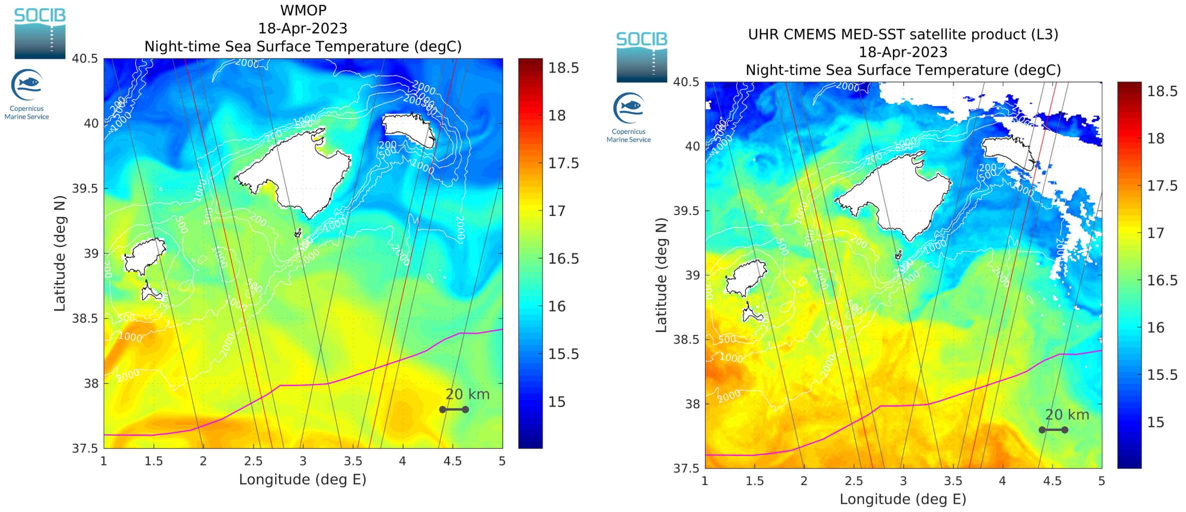


Figure 16. Sea surface temperature on 18 April 2023 from WMOP (left) and satellite L3 product (right). Images available on the FaSt-SWOT WMOP visualization webpage.

5.7. Tentative schedule for FaSt-SWOT1

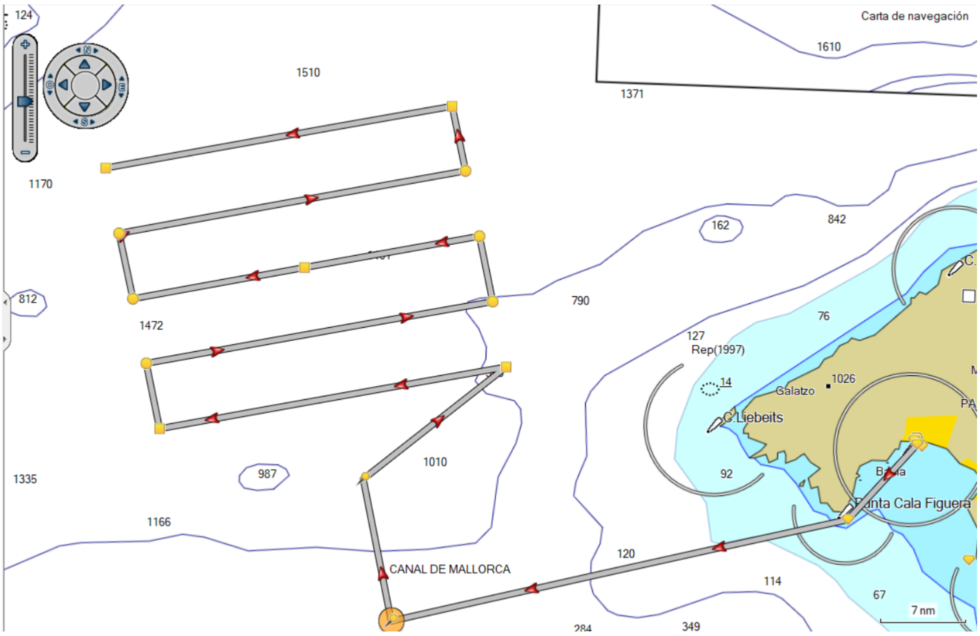
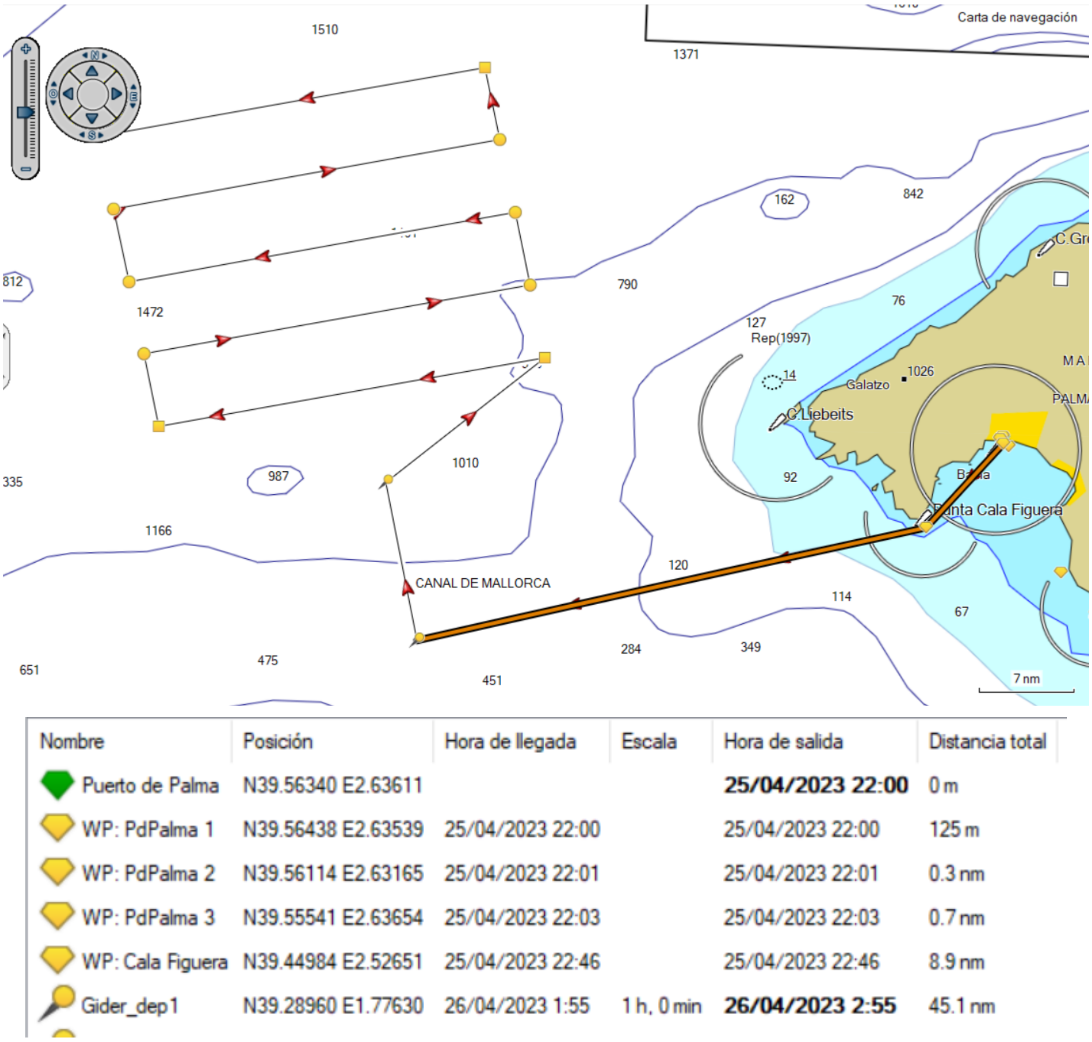


Figure 17a. Tentative working area during FaSt-SWOT1.

- Scheduled activities

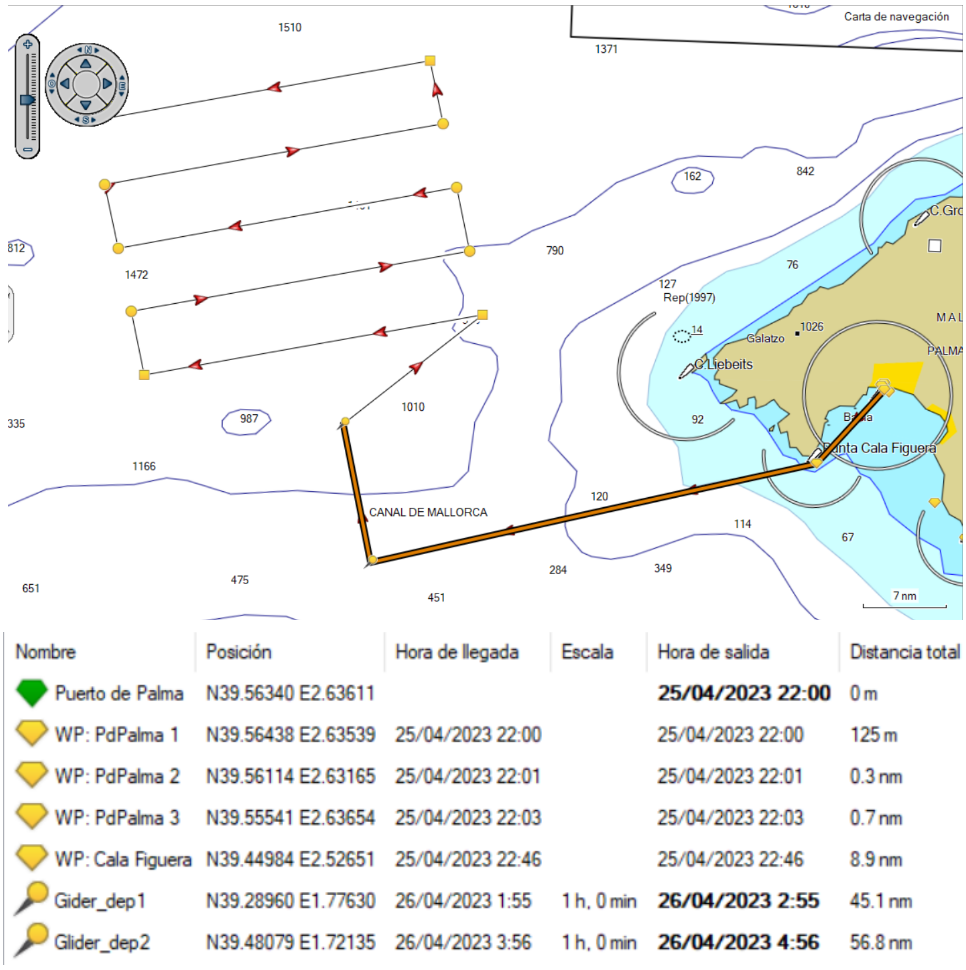
1) Transit Port de Palma - Launch first glider ~15 km south of the radiator grid.



Nombre	Posición	Hora de llegada	Escala	Hora de salida	Distancia total
Puerto de Palma	N39.56340 E2.63611			**25/04/2023 22:00**	0 m
WP: PdPalma 1	N39.56438 E2.63539	25/04/2023 22:00		25/04/2023 22:00	125 m
WP: PdPalma 2	N39.56114 E2.63165	25/04/2023 22:01		25/04/2023 22:01	0.3 nm
WP: PdPalma 3	N39.55541 E2.63654	25/04/2023 22:03		25/04/2023 22:03	0.7 nm
WP: Cala Figuera	N39.44984 E2.52651	25/04/2023 22:46		25/04/2023 22:46	8.9 nm
Gider_dep1	N39.28960 E1.77630	26/04/2023 1:55	1 h, 0 min	**26/04/2023 2:55**	45.1 nm

Figure 17b. Tentative working area and scheduled times.

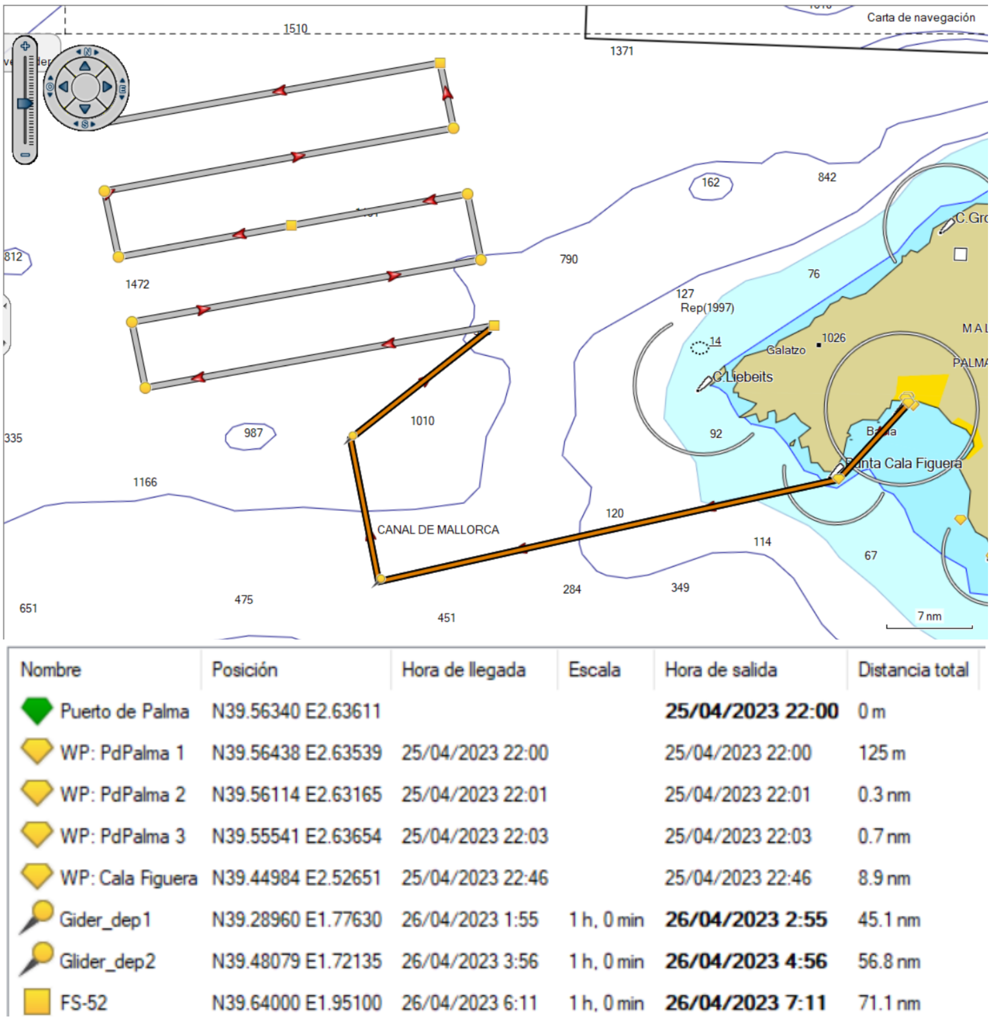
2) Launch of the second glider 10 km from the first glider and ~5 km from the radiator grid. Both gliders will be sampling the water column as virtual moorings during ~12 hours, then they will sample the same 60-km-long track along the SWOT swath.



Nombre	Posición	Hora de llegada	Escala	Hora de salida	Distancia total
Puerto de Palma	N39.56340 E2.63611			**25/04/2023 22:00**	0 m
WP: PdPalma 1	N39.56438 E2.63539	25/04/2023 22:00		25/04/2023 22:00	125 m
WP: PdPalma 2	N39.56114 E2.63165	25/04/2023 22:01		25/04/2023 22:01	0.3 nm
WP: PdPalma 3	N39.55541 E2.63654	25/04/2023 22:03		25/04/2023 22:03	0.7 nm
WP: Cala Figuera	N39.44984 E2.52651	25/04/2023 22:46		25/04/2023 22:46	8.9 nm
Gider_dep1	N39.28960 E1.77630	26/04/2023 1:55	1 h, 0 min	**26/04/2023 2:55**	45.1 nm
Glider_dep2	N39.48079 E1.72135	26/04/2023 3:56	1 h, 0 min	**26/04/2023 4:56**	56.8 nm

Figure 17c. Tentative working area and scheduled times.

3) At the first point of the radiator grid (southeast point), launch CTD at 500 m to calibrate MVP.

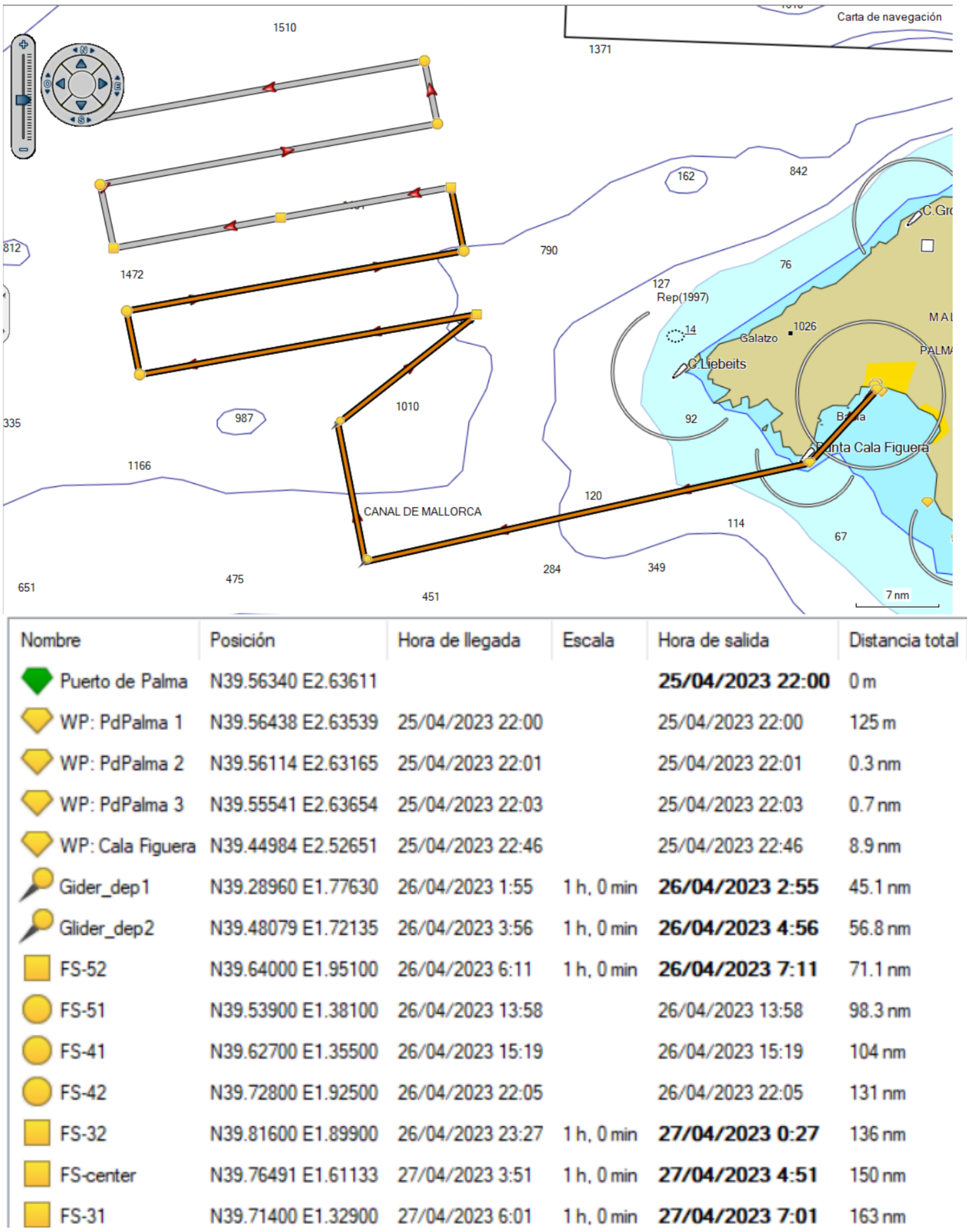


Nombre	Posición	Hora de llegada	Escala	Hora de salida	Distancia total
Puerto de Palma	N39.56340 E2.63611			**25/04/2023 22:00**	0 m
WP: PdPalma 1	N39.56438 E2.63539	25/04/2023 22:00		25/04/2023 22:00	125 m
WP: PdPalma 2	N39.56114 E2.63165	25/04/2023 22:01		25/04/2023 22:01	0.3 nm
WP: PdPalma 3	N39.55541 E2.63654	25/04/2023 22:03		25/04/2023 22:03	0.7 nm
WP: Cala Figuera	N39.44984 E2.52651	25/04/2023 22:46		25/04/2023 22:46	8.9 nm
Gider_dep1	N39.28960 E1.77630	26/04/2023 1:55	1 h, 0 min	**26/04/2023 2:55**	45.1 nm
Glider_dep2	N39.48079 E1.72135	26/04/2023 3:56	1 h, 0 min	**26/04/2023 4:56**	56.8 nm
FS-52	N39.64000 E1.95100	26/04/2023 6:11	1 h, 0 min	**26/04/2023 7:11**	71.1 nm

Figure 17d. Tentative working area.

4) Start the radiator grid with MVP from the southeast point (2 transects).

5) In the 3rd transect with MVP, also release CTD casts at 500 m depth to sample the eddy at its center, middle (r/2) and exterior. The exact position will depend on the eddy location in satellite maps.

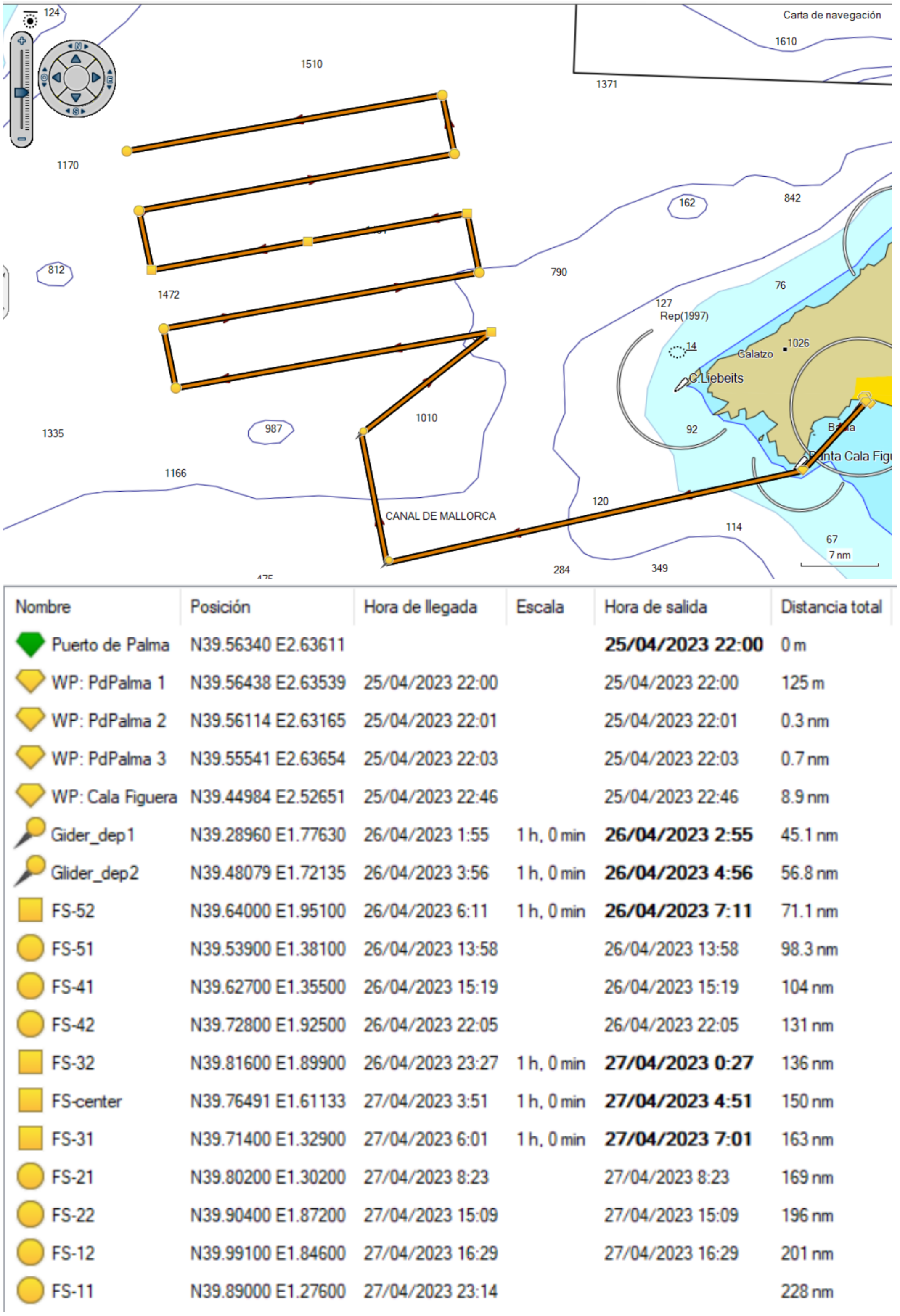


Nombre	Posición	Hora de llegada	Escala	Hora de salida	Distancia total
Puerto de Palma	N39.56340 E2.63611			**25/04/2023 22:00**	0 m
WP: PdPalma 1	N39.56438 E2.63539	25/04/2023 22:00		25/04/2023 22:00	125 m
WP: PdPalma 2	N39.56114 E2.63165	25/04/2023 22:01		25/04/2023 22:01	0.3 nm
WP: PdPalma 3	N39.55541 E2.63654	25/04/2023 22:03		25/04/2023 22:03	0.7 nm
WP: Cala Figuera	N39.44984 E2.52651	25/04/2023 22:46		25/04/2023 22:46	8.9 nm
Gider_dep1	N39.28960 E1.77630	26/04/2023 1:55	1 h, 0 min	**26/04/2023 2:55**	45.1 nm
Glider_dep2	N39.48079 E1.72135	26/04/2023 3:56	1 h, 0 min	**26/04/2023 4:56**	56.8 nm
FS-52	N39.64000 E1.95100	26/04/2023 6:11	1 h, 0 min	**26/04/2023 7:11**	71.1 nm
FS-51	N39.53900 E1.38100	26/04/2023 13:58		26/04/2023 13:58	98.3 nm
FS-41	N39.62700 E1.35500	26/04/2023 15:19		26/04/2023 15:19	104 nm
FS-42	N39.72800 E1.92500	26/04/2023 22:05		26/04/2023 22:05	131 nm
FS-32	N39.81600 E1.89900	26/04/2023 23:27	1 h, 0 min	**27/04/2023 0:27**	136 nm
FS-center	N39.76491 E1.61133	27/04/2023 3:51	1 h, 0 min	**27/04/2023 4:51**	150 nm
FS-31	N39.71400 E1.32900	27/04/2023 6:01	1 h, 0 min	**27/04/2023 7:01**	163 nm

Figure 17e. Tentative working area and scheduled times.

6) Continue with the radiator grid until the last point (2 transects).

7)



Nombre	Posición	Hora de llegada	Escala	Hora de salida	Distancia total
Puerto de Palma	N39.56340 E2.63611			**25/04/2023 22:00**	0 m
WP: PdPalma 1	N39.56438 E2.63539	25/04/2023 22:00		25/04/2023 22:00	125 m
WP: PdPalma 2	N39.56114 E2.63165	25/04/2023 22:01		25/04/2023 22:01	0.3 nm
WP: PdPalma 3	N39.55541 E2.63654	25/04/2023 22:03		25/04/2023 22:03	0.7 nm
WP: Cala Figuera	N39.44984 E2.52651	25/04/2023 22:46		25/04/2023 22:46	8.9 nm
Gider_dep1	N39.28960 E1.77630	26/04/2023 1:55	1 h, 0 min	**26/04/2023 2:55**	45.1 nm
Glider_dep2	N39.48079 E1.72135	26/04/2023 3:56	1 h, 0 min	**26/04/2023 4:56**	56.8 nm
FS-52	N39.64000 E1.95100	26/04/2023 6:11	1 h, 0 min	**26/04/2023 7:11**	71.1 nm
FS-51	N39.53900 E1.38100	26/04/2023 13:58		26/04/2023 13:58	98.3 nm
FS-41	N39.62700 E1.35500	26/04/2023 15:19		26/04/2023 15:19	104 nm
FS-42	N39.72800 E1.92500	26/04/2023 22:05		26/04/2023 22:05	131 nm
FS-32	N39.81600 E1.89900	26/04/2023 23:27	1 h, 0 min	**27/04/2023 0:27**	136 nm
FS-center	N39.76491 E1.61133	27/04/2023 3:51	1 h, 0 min	**27/04/2023 4:51**	150 nm
FS-31	N39.71400 E1.32900	27/04/2023 6:01	1 h, 0 min	**27/04/2023 7:01**	163 nm
FS-21	N39.80200 E1.30200	27/04/2023 8:23		27/04/2023 8:23	169 nm
FS-22	N39.90400 E1.87200	27/04/2023 15:09		27/04/2023 15:09	196 nm
FS-12	N39.99100 E1.84600	27/04/2023 16:29		27/04/2023 16:29	201 nm
FS-11	N39.89000 E1.27600	27/04/2023 23:14			228 nm

Figure 17f. Tentative working area and scheduled times.

8) During the sampling of the radiator grid, 5 SVP buoys will be launched.

9) Launching of buoys: 10 Hereon and 10 Carthe. (depending on the launching location, between 1 and 2 hours) 12 hours.

10) Adaptive sampling.
(12-16 hours)

11) At the end of the adaptive sampling, launch CTD at 500 or 300 m to calibrate MVP.
Approx. 1 hour

12) Transit to Port de Palma.
Approx. 5 hours, 60-70 miles.

Activity	Time
Outbound transit	4 hr
Glider launch	3 hr
1 CTD 500 m to calibrate MVP	1 hr
Radiator grid with MVP + buoy deployment SVP	1 day and 15 hr
3 CTD 500 m to sample the eddy	3 hr
Deployment of Hereon and Carthe buoys (before, after or during adaptive sampling)	12 hr
Adaptive sampling	12 hr
1 CTD 500 m or 300 m to calibrate MVP	1 hr
Return transit	5 hr
Total	81 hr (3 days & 9 hr)

Table 7. Estimated time for each activity.

5.8. TENTATIVE SCHEDULE FOR FAST-SWOT2

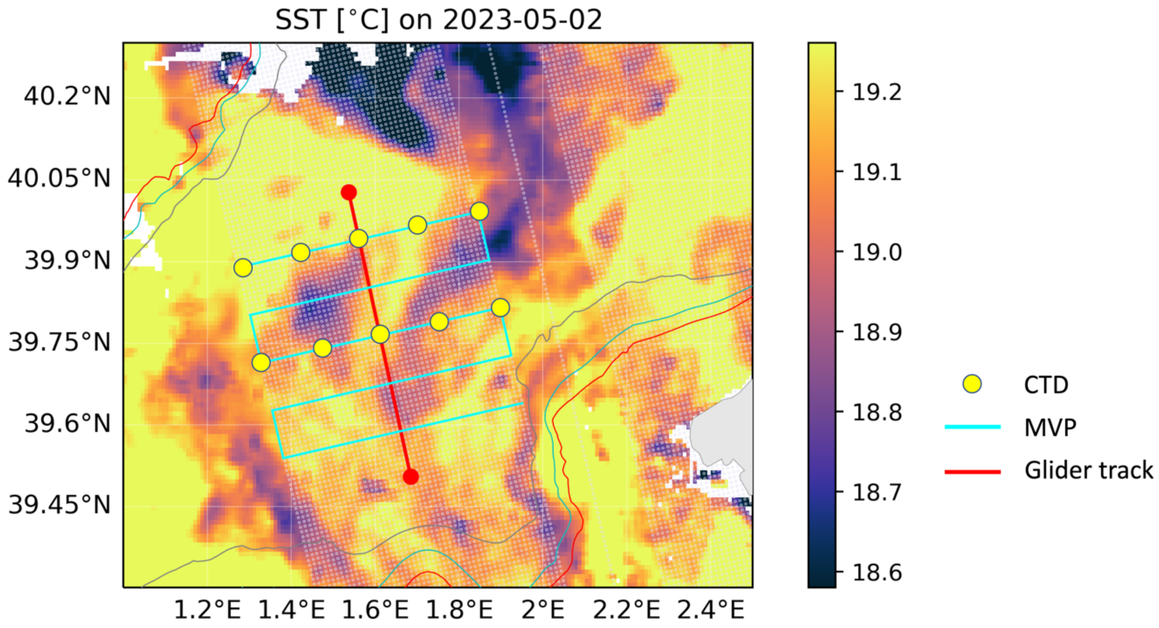


Figure 18. Tentative working area during FaSt-SWOT2. SST map on 2 May 2023 in the background, MVP radiator grid (cyan line), glider track (red line) and rosette CTD casts (yellow dots).

- Scheduled activities

1) Transit Port de Palma - beginning of the radiator grid from the southeast point. 5 hours.

2) Radiator grid with the MVP down to 200 m with a navigation velocity of 4 knots. 40 hours.

3) In the radiator grid, we will release 10 CTD casts down to 700 m depth. The exact location will be determined after checking the last satellite maps of SST. 10 hours.

4) Launching of buoys: 10 Hereon and 10 Carthe. 12 hours.

5) Recovery of gliders. 5 hours.

6) Transit to Port de Palma. 5 hours.

Activity	Time
Outbound transit	5 hr
Radiator grid with MVP	40 hr
10 CTD 700 m depth to sample the eddy	10 hr
Deployment of Hereon and Carthe buoys	12 hr
Glider recovery	5 hr
Return transit	5 hr
Total	77 hr (3 days & 5 hr)

Table 8. Estimated time for each activity.

6. DATA MANAGEMENT PLAN

Overall, the data management plan (DMP) of this project relies on the current data management practices in use in the context of the SOCIB Data Repository. Ranging from long-term preservation to data management standard practices and data services, are guaranteed as of the CoreTrustSeal certification that the SOCIB Data Repository holds.

The specificities of each type of platform that generates data in the context of this project are listed below:

- Research Vessel data: based on the data management practices in the context of the SOCIB Data Repository. The only exception is the management of data generated by the MVP, which will be limited to the archiving of the raw data. The latter implies that the MVP data will not be publicly available (although specific data requests may be managed on demand).
- Glider data: based on the SOCIB Glider Canales Endurance Line Data Management Plan (Marasco, M. et al., 2021a).
- SVPB drifters data: based on the SOCIB - Global Drifter Program Data Management Plan (Marasco, M. et al., 2022).
- Carthe and Hereon drifters data: based on the data management practices in the context of the SOCIB Data Repository. Specific procedures have been implemented to incorporate the Hereon drifter data within the SOCIB Data Management System. The latter includes the provision of raw data in Real Time through the SOCIB web portal during the duration of the 2 campaigns.
- HF radar data: based on the SOCIB - Coastal High Frequency Radar Data Management Plan (Marasco, M. et al., 2021b).

In order to generate the related data product, and only after the 2 campaigns end, a data assessment and curation process will be carried out by the PIs and the SOCIB Data Center data officials. The data product will include the specific data produced in the 2 campaigns and will be published through the SOCIB Data Catalog (including the minting of a DOI by SOCIB).

Finally, it is worth noting that the data will be distributed to the main European data systems (e.g. Coriolis, Copernicus In Situ, EMODnet, Argo Reference DB), as part of the procedures in place in the SOCIB Data Management System.

7. ACKNOWLEDGEMENTS

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Remotely sensed sea level anomaly, sea surface temperature and sea surface chlorophyll concentration came from Copernicus Marine Environment Monitoring Service (CMEMS). European Ocean Gridded L4 Sea Surface Heights and derived variables nrt (https://doi.org/10.48670/moi-00142). European Sea Surface Chlorophyll Concentration from Multi Satellite observations (https://doi.org/10.48670/moi-00095). We thank the Spanish Meteorological Agency (AEMET, Ministerio para la Transición Ecológica y el Reto Demográfico) for providing the HARMONIE-AROME atmospheric fields used to generate WMOP predictions.

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The FaSt-SWOT experiments represent a contribution to CSIC Interdisciplinary Thematic Platform (PTI) Teledetección (PTI-TELEDETECT), the SWOT Science Team (https://swot.jpl.nasa.gov/) and the SWOT Adopt-A-Crossover Consortium (https://www.swot-adac.org/).

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ANNEX 1: LIST OF PERSONAL EQUIPMENT FOR THE CRUISE

Personal equipment:

- Flexible travel/sports bag - NOT a hard suitcase (there's no space)
- Laptop and charger
- If you bring a Mac, adapters to connect USB, etc.
- Hard drive, USB drives
- Notebook
- Pens
- Underwear
- Work clothes (they can get ruined by salt)
- Safety boots (PPE)
- Comfortable shoes
- Flip flops for the shower
- Personal hygiene items
- Headphones, music, movies, and series (I don't know if we'll have a connection, so bring downloaded what we want to watch or listen to. The headphones are because we'll share a cabin and thus not disturb the roommate)
- Mobile phone and charger
- Medicine
- Sunglasses
- Cap
- Raincoat
- Fleece jacket

General:
- PPE (vest, helmets)
- Biodramina (motion sickness medication)
- Sunscreen
- Office supplies: paper, hard drives, USB drives

Note: There are sheets and towels on the boat. It is not necessary to bring them from home.

ANNEX 2: PROVISIONAL PROPOSAL OF WORKING SHIFTS

FaSt-SWOT1
8 am -12 pm / 8 pm -12 am: Benjamín Casas & Eugenio Cutolo
12 pm - 4 pm / 12 12am - 4 am: Elisabet Verger & Daniel R. Tarry
4 am - 8 am / 4 pm - 8 pm: Laura Gómez-Navarro & Irene Lizarán

FaSt-SWOT2
8 am -12 pm / 8 pm -12 am: Baptiste Mourre & Noemí Calafat
12 pm - 4 pm / 12 am - 4 am: Daniel R. Tarry & Emma Reyes
4 am - 8 am / 4 pm - 8 pm: Niko Wirth & Laura Gómez-Navarro

- ANNEX 3: COMMUNICATION, VIDEO, SOCIAL MEDIA

Campaign participants are encouraged to share content on social media (Twitter, Facebook, Instagram) using the hashtag #FaSt_SWOT and contribute to the FaSt-SWOT blog on the SWOT Adopt-a-Crossover webpage: https://www.swot-adac.org/blogs/fast-swot/.

Blog entries (including images) need to be sent to Tosca Ballerini and Laura Secorun (tosca.ballerini@thalassa.one, laura@onaocean.com). Participants may also be interviewed for a short film about the project by the on-board videographer Nathan Siegel (any related questions or requests can be address directly to nathapsiegel@gmail.com)

ANNEX 4: DRIFTERS INVENTORY

FaSt-SWOT1

Inventory	s/n	WMO
IME-CARTHE001	0-4694040	-
IME-CARTHE002	0-4694103	-
IME-CARTHE003	0-4694122	-
IME-CARTHE004	0-4694188	-
IME-CARTHE005	0-4694189	-
IME-CARTHE006	0-4694193	-
IME-CARTHE007	0-4694198	-
IME-CARTHE008	0-4694199	-
IME-CARTHE009	0-4694201	-
IME-CARTHE010	0-4694203	-
IME-HEREON001	D-278	-
IME-HEREON002	D-279	-
IME-HEREON003	D-280	-
IME-HEREON004	D-281	-
IME-HEREON006	D-283	-
IME-HEREON007	D-284	-
IME-HEREON008	D-285	-
IME-HEREON009	D-286	-
IME-HEREON010	D-287	-
IME-HEREON011	D-288	-
SCB-SVPB038	300534061654380	6204604
SCB-SVPB039	300534061654450	6204605
SCB-SVPB040	300534061654460	6204606
SCB-SVPB041	300534061654500	6204607
SCB-SVPB042	300534061654520	6204608

FaSt-SWOT2

Inventory	s/n	WMO
IME-CARTHE011	0-4694206	-
IME-CARTHE012	0-4694223	-
IME-CARTHE013	0-4694458	-
IME-CARTHE014	0-4694461	-
IME-CARTHE015	0-4694462	-
IME-CARTHE016	0-4694473	-
IME-CARTHE017	0-4694474	-
IME-CARTHE018	0-4694475	-
IME-CARTHE019	0-4694476	-
IME-CARTHE020	0-4695850	-
IME-HEREON005	D-282	-
IME-HEREON012	D-289	-
IME-HEREON013	D-290	-
IME-HEREON014	D-291	-
IME-HEREON015	D-292	-
IME-HEREON016	D-293	-
IME-HEREON017	D-294	-
IME-HEREON018	D-295	-
IME-HEREON019	D-296	-
IME-HEREON020	D-297	-

ANNEX 5: R/V SOCIB SCIENTIFIC EQUIPMENT REQUIREMENTS

Scientific equipment required from R/V SOCIB is detailed in the following list:

- CTD Rosette SBE32 + SBE9plus.
- Thermosalinograph
- *VM-ADCP*
- Navigation data (position, echosounder, AIS y gyroscopic).
- Ship Attitude data (GPS-3D).
- Communications coverage (phone + internet).
- CTD SBE11 plus (spare deck unit)

Equipment required on board:

- 7 Personal protective equipment (incl. helmet and lifejacket)
- Safety lines